A Bug's Life

All sorts of creepy crawlies preserved in perspex blocks or jars. - All sorts of creepy crawlies preserved in perspex blocks or jars.

Last initially checked on 2023-01-22 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-02-10 by Margaret Johncock (mllyj2@cam.ac.uk).

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Various insects inside perspex blocks or in jars.
- A magnifying glass
- Key with descriptions of each insect (below)
- Jam jar lid
- Hair comb

Experiment Explanation

*** OVERVIEW ***

Children will look at lots of jars and blocks of interesting creatures, try to identify them, and learn a few things are each one. This is one of those experiments where you'll often get kids who are very interested or not really interested at all, so feel free to vary how long you keep them with you depending on how interested they seem. Don't worry if they only look at one thing then leave!

Tips for demonstrating:

1. Make sure that none of your bugs disappear during the day! I would recommend having a smaller selection out at a time so you can keep an eye on them all (and can remember interesting facts about them all).
2. If they're young ask them to look at their fingernail or a hair under the magnifying glass â€“ this will give them a better concept of scale and show them how much more detail you can see under the magnifying glass!

*** BASIC PROCEDURE AND EXPLANATION ***

1. Ask the child to choose a sample on display that looks interesting to them. Then go through the following questions with them:
2. What do you think this is?
3. Do they know anything about the type of bug? (if they recognise it they will often start splurging everything they know about it - just let them talk to you about it!)
4. If they look using the magnifying glass can they see anything interesting (hairs on legs, joints of exoskeleton etc. - talk about the purposes of these things if you know!)
5. For older/very keen kids you can talk about taxonomy (a good website to flick through if you have time before you start: http://www.earthlife.net/insects/classtax.html)

KEY DESCRIPTIONS FOR JARS

10. White Cabbage Butterfly Eggs
11. White Cabbage Butterfly Larvae/Caterpillar
12. White Cabbage Butterfly Pupae
13. White Cabbage Butterfly Adults

- Cocoons=chrysalis
- In the chrysalis the caterpillar is 'digested' by enzymes, like with food in your stomach, and then rebuilt into a butterfly.

3. Cockroach nymph

4. Cockroach 2nd stage
5. Cockroach 3rd stage
6. Cockroach fully grown

- Nymphs hatch from eggs. As they grow, they must also grow their exoskeleton and so they undergo a series of molts until they are fully grown.
- Cockroaches are nocturnal.
- Cockroaches can survive without their heads for over a week - they breath through spiracles (holes in their exoskeleton) so don't suffocate without heads, but die of dehydration. They also don't bleed to death as they have open circulatory systems (unlike our high pressure systems).

4. Mealworm

- Actually the larvae of the Darkling Beetle

5. Blowfly

- Also called a bluebottle
- The flies that lands on uncovered food in your house
- Their larvae (maggots) can be used to eat dead tissue to promote healing

6. Tick

- Eat blood
- Might have seen them on pets, can also be on humans too
- Transmit Lymes disease as well as many other diseases
- Can spend 200 days without food and water
- Mouth has a part for squirting saliva into the bite (prevents blood clotting which would close the wound) and one for sucking blood

7. Flea

- Eats blood - make you itchy when they bite
- Might have seen them on pets/know pets had them
- Carry diseases - the oriental Rat Flea carried the bubonic plague/black death to England
- Mouth has a part for squirting saliva into the bite (prevents blood clotting which would close the wound) and one for sucking blood
- Can jump very long distances so can travel from one pet to another (can you see their long hind legs?) - up to 35cm horizontally and 18cm vertically!

8. Locust

- When lots of them get together they form swarms which can destroy fields and fields of crops causing famines.

13. Roundworm

- Live in intestines (depending on kid's age, explain what this is!) of animals including people
- Lifecycle involves animal eating food contaminated with eggs, hatching of eggs in intestines, babies are too small to live in intestines yet so leave through gut wall into veins, travel to lungs, cause tickling feeling leading to coughing, cough phlegm and (unless you spit it out) swallow, now big enough to survive in intestines, lay eggs in intestine which come out in poo, gets onto other people's hands/food through poor hygiene (wash your hands after going to the toilet!) and so get ingested.
- They eat the food you are digesting and so cause people to lose weight and be very hungry as they are not getting the nutrients from the food they eat

14. Tapeworm

- Infect animals especially pigs, cows and humans
- Similar lifecycle to roundworm
- Can grow up to 16m (work out how many yous that would be when put end to end to help them visualise)

16. Lungworm

- Infects animals especially cats and dogs
- Dogs/cats eat slugs/snails/frogs which are infected with larvae (can be really small slugs on their fur that they ingest when grooming), larvae migrate to lungs as in roundworm but then stay there until adults, adults can stay in lungs or migrate through blood vessels into the heart

15. Slug

- Slime prevents the slugs drying out (we have a layer of dry keratin which protects our wet insides)

- Leave trails which are use to find each other, to repel predators, and in the case of carnivorous slugs, to find smaller slugs to eat

KEY DESCRIPTIONS FOR PERSPEX BLOCKS

1. Giant Planthopper

- Walks very slowly as pretends to be a leaf then if it needs to escape predators/catch prey can do big leaps like a grasshopper

2. American Cockroach

- (see 3/11/12/9 in jars)

3. Blue Weevils

- Weevils are a type of beetle - often pests
- Colour warns predators that they are not tasty - they eat yam leaves which are toxic to most animals and eating enough blue weevils can be toxic as the chemicals from the yam leaves build up in them

4. Water Beetle

- Some species carry an air bubble under its abdomen to prevent water getting into its spiracles
- Other species have a modified exoskeleton which can carry out gas exchange with the water

5. Flower Mantis

- Aggressive mimicry = camouflage that attracts prey
- Climbs a plant that has flowers matching it's pattern (different species have different patterns specific to the area they live in and what flowers are there) and sits very still, waiting for pollinators to come up to it then strikes out with it's long forearms.

6. Giant Stag Beetle

- Can grow to over 12cm in length
- Males use large jaws to wrestle over females (similar to how stags fight over hinds)
- Females' jaws are smaller but much more powerful

7. Long-Nose Jungle Beetle

- Long nose is for eating pollen out of flowers
- Used to think they were pests as they prefer to eat dead flowers and so were always found when there were lots of dying plants - correlation not causation!

8. Cicada

- Use tymbals (modified exoskeleton walls on abdomen sides) to produce their loud noise - works by buckling (demonstrate using jam jar lid) (compare with grasshopper, 11)
- Nymphs live underground for up to 13 years before emerging as adults

10. Devil Spider

11. Shield Bug

- Also called stink bugs as they produce a smelly secretion from glands at the top of their legs to deter predators

11. Field Grasshopper

- Can jump up to a metre horizontally and 25cm vertically from standing
- Make their song using stridulation (scraping) - have a comb-like structure and a ridge on each wing and rub the comb of one wing against the ridge of the other (demonstrate using comb) (compare with cicada, 8) - they have a thick membrane on their wing which resonates to amplify the sound

12. Unicorn Beetle

- Also known as rhinoceros beetle
- Named because of their large horn - used to fight in males (similar to jaws in stag beetle, 6)

13. Giant Wasp

- It's sting can kill a mouse

14. Emerald Beetle

15. Manchurian Scorpion

- A chemical in its venom has analgesic properties so it's prey doesn't notice being stung
- It has hairs on it's tail which can sense the movement of nearby prey

Risk Assessment

Hazard: Breaking the blocks/jar/magnifying glass

Description: Smashing a specimen block/jar or magnifying glass could cause cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: It is very unlikely that the perspex blocks would break, even with a significant amount of force. However, demonstrators should keep a careful eye on the blocks and jars and magnifying glass, account for all specimen tubes every time a demonstration is completed. Call first aider in case of injury (cut). Clear up perspex (using the dustpan and brush from Set Up and Clear Up), wrapping up in paper or similar so that it won't rip through the bin bag. Place in broken glass box if available at a school. In case of injury, call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Tripping over blocks

Description: Blocks are quite small and their transparency means that it might be difficult to see them, creating a potential tripping hazard.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Demonstrators should make sure that blocks are not played with by young children without supervision. If a block is dropped, it should be picked back up as soon as the area is safe to do so. In case of a child (or adult) tripping over, call first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Perspex blocks

Description: Kids may throw them or drop them on feet

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Take away from kids if they are being silly with them. Keep all perspex blocks in sight during the demonstration.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Magnifying Glass

Description: Kids (or demonstrators!) may set fire to paper or dry grass if very sunny day.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Take away from kids (and scold demonstrators) if they are deliberately trying to set fire to things

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Preservative

Description: Could escape if jars are broken/opened. Preservative is 1% Propylene phenoxetol, which should not be irritant to eyes or skin at that concentration, but which may be harmful if ingested. (If asked about the toxicity of propylene phenoxetol, mention that it is used as a preservative in personal care products and it is chemically inert).

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Keep a careful eye on the jars and do not let anyone open them. They should all be taped up around the top - if the tape is coming off redo it. If any liquid leaks, clear it up straight away, preferably wearing gloves, then wash your hands immediately. Advise any children to wash their hands immediately if any liquid goes on their skin.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

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Air Rockets

Launching lemonade bottle air rockets along a rope - 5, 4, 3, 2, 1, Lift Off! With a lemonade bottle and a bike pump, we'll show you how to make a rocket! How high can you get it to fly?

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-12 Jessica Trevelyan (jet81@cam.ac.uk)

Tags

Missiles

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **This experiment can take place outdoors**
- Pump
- Bung with hole or with valve
- Rope
- Lemonade (or other fizzy drink) bottle with tube attached for the rope to run through (something with low friction so that the bottle will come back down again and fly further)
- Launch stand

Experiment Explanation

Launching lemonade bottle air rockets along a rope (going up at an angle of 20-30 degrees) - this is a less messy version of the water rockets experiment which can be done inside in a suitably large hall.

Setup Set up the rope running from the launch area to a higher point (raising the launch area, e.g. blocks, can keep the rope above head height) - run the rope through the tube attached to the bottle. Jam the bung in the bottle and get kids to pump until the rocket launches up the rope. Hopefully it should come back down to somewhere you can grab it. Keep people out of the area where the rope is so that they don't get hit by the rocket or walk into the rope!

As a further point - it can very occasionally be done without the guide rope pointing vertically upwards, or without a guide rope at all. This is suitable in large sports halls or outside only. Here care needs to be taken that a large enough area is cordoned off so that it does not hit anyone when it returns to Earth. If a guide rope is not being used, it can still be helpful to attach a rope to the rocket, in order to limit its range (such as to avoid hitting people if you can't cordon off a large enough area) - however, care must be taken to ensure the rope itself does not pose a hazard in such cases.

Explanation and Demonstrating

Like the water rockets, everyone likes to play with the air rockets... and they can't fail to notice the experiment since it makes a bang every time the rocket goes off!

If you want to explain the experiment, you'll probably find it best not to let the kids get onto the launch platform until you've talked to them a bit. It's generally best to ask a question first to see what they know already.

There's quite a lot of physics you can explain with the experiment. Firstly the idea of pressure - you can talk about the pump - put your finger over the valve and get them to push down on the pump - they'll find it gets harder as they push down and increase the pressure. So we have the idea that as we pump the bottle up, we increase the pressure and this pushes the bung out. If they understand (ask them to explain it again!) you can talk about molecules. The molecules move at about 500 ms-1, so even though they are light give a good push on the walls of the bottle when they hit (plus obviously there are > 10^23 of them!). So, as you pump up the bottle, adding more molecules, there is a harder push against the wall and the bottle gets harder.

So what happens when the rocket launches? We've said that the bung gets forced out by the pressure in the bottle (what pressure it reaches depends on how hard you jam the bung in each time, and varies, and thus does the height the rocket gets to). You probably don't want to talk about conservation of momentum with the kids - the bung flies out backwards with a certain momentum, and thus to give the overall system zero momentum the bottle gets equal and opposite momentum, sending it up the rope. You can talk about equal and opposite reactions, though. Think about leaning on a wall - does it push back on you? Most kids probably think not. However, if you get one of them to push on your hand, and you push back, you both stay where you are. If you ask them to stop pushing, then you fall forwards (or at least pretend to!) - so leaning against the wall, the wall must be pushing against you! Going back to the rocket - when you pump up the bottle the air is pushing against the bung - when the bung pops out it's like stopping pushing against your hand, so the rocket flies forward. You can show this with throwing a bag of rice; as you throw it it pushes you back. Another example that kids might know about is cannon/ gun recoil which is essentially the same physics as this. The cannon moves backwards and fires the shot forwards and in the same way the bung moves backwards and fires the bottle forwards.

You can also talk about energy - where does the energy for launching the rocket come from, and where is it stored? The more pumping you do, the higher the rocket goes (all else being equal).

Kids will keep coming back to have another go, so each time ask them something about it to see what they've remembered!

N.B. A good trick with families or other groups is to challenge them to get the rocket as far as possible along the string (maybe with only one attempt!) little do they know that the distance pretty much only depends on how tightly you put in the bung, and thus the meekest among them can be the mightiest!

Risk Assessment

Hazard: Bottle

Description: Projectile may hit people

Affected People: All

Before Mitigation: Likelihood: 5, Severity: 2, Overall: 10

Mitigation: Keep people away from the rope (which the rocket travels on) by blocking off any area where the rope is below head height with chairs, hazard tape or similar. Make sure the person launching the rocket doesn't lean into its path (try to keep the pump as far away from the rocket as the hose will allow - we have lengthened the hose to make this job easier). Also locate the experiment sensibly, bearing in mind walkways that people will want to use in the venue, roads etc and wind direction.

If done without a guide rope, cordon off sufficiently large area to ensure it lands within it. Check prevalent wind direction as well by test firing the rocket before people come.

If using the rope to limit range, the areas in which the rocket might land (accounting for prevalent wind direction and lean of the launch stand) must still be cordoned off as there are two hazards - both from the rocket falling on someone and the trip hazard due to the rope.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Bottle (pressurised)

Description: Bottle exploding; debris might cause small cuts or fall on people. Debris may fall into eyes damaging cornea.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Check bottle for cracks and other damage before use. Any damaged bottles should be cut or marked to show they cannot be used if they cannot be disposed of immediately. Only use 2L "fizzy drink" bottles (Coke, Fanta, etc.) with thick walls, not bottles for still drinks which are not (always) suitable for pressurising. If possible, wear safety goggles.

In the event of an accident call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Rope

Description: Walking into/tripping on rope.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: The provisions for ensuring people arenâ€™t hit by the bottle keep visitors away from the rope. Try using thick/bright-coloured rope so it is easily visible. Keep rope ends tucked away and off the ground if possible. If the ends are on the ground, tape it firmly.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-01-14 - Aaron Barker (arb78@cam.ac.uk)

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Air Streams

Balancing balls on upward streams of air, and looking at aerodynamics. - Can you make something float on thin air? Find out how to levitate ping pong balls and why planes can fly in this entertaining experiment.

PLUS experiment includes: Newton's laws, stable equilibria, drag, lift and the Magnus Effect.

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-12 by Jessica Trevelyan (jet81@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Electricity needed**
- Electrical stuff:
- Big Blower (too big for box, needs 2 people to lift)
- Stream stabiliser for the big blower (a hollow box open on one end and with a grid on the opposite end)
- 'Small' blower (in box)
- 2 x variable power switches for blowers.
- Floating Objects:
- Beach Balls
- Ping-pong balls
- Aeroplane wing
- Plastic cups and elastic bands
- Also Useful:
- Screwdriver with haztape streamer (for showing streamlines)
- Paper
- CHaOS only:
- Bendy straws (consumable), must have reasonably wide holes.
- Small wooden rocket puzzle
- Anti-bacteria wipes (consumable)
- CHaOS+ only:
- Diagrams of wing cross sections / streamlines around an aerofoil

Experiment Explanation

In a nutshell

Show how flowing air acts on object in or next to it.

How to set up the experiment

Note: The big blower is not necessary but makes a nice show. It may cause the circuit breakers to go off, so check first so that you don't cause a power outage a the beginning of the session.

Place the blowers on the ground. Make sure they are not in anyone's way, and also check above them to make sure nothing will be disturbed by the fan (such as lightweight ceiling tiles). Put the stream stabiliser on top of the big blower. Plug the cables to the power switches and to the grid.

Note: The switch for the big blower gives full power for a few seconds after switched on. Afterwards you will be able to regulate it.

Blow up the beach balls and have the straws pingpong balls and aeroplane wing handy.

How to proceed

This is a suggestion on how to proceed with the demonstration. The demonstrator should encourage the kids to try and figure parts of explanation out by themselves by asking the right questions, so that they stay focused. There's a lot in here: you may not explain all of it!

Straws and pingpong balls

Take a straw and bend it in right angle. You can start by asking the kids if they can think of a way to balance the ball on top of the short end (not holding it by hand). Two ways are quite good: sucking and blowing. (Simple balancing it is possible but very hard.)

If you suck the air from under the ball, the air pressure from the outside will hold it in place. You can tell them about the air pressure and that we are constantly pressed everywhere and that suction occurs when we reduce the pressure in an area (eg the inside of the straw). (The concept might be hard to grasp so consider the age of the children.) They might already have some knowledge of it if they have seen the Vacuums experiment.

If you blow into the long end and hold the short end upwards, you are able to balance a pingpong ball on the stream. (The straw end needs to be vertical and you have to blow quite hard.) It requires a bit of practice. Let the kids have a go at it. Give each a new straw and dispose of them afterwards to avoid spread of infection. Demonstrating what goes on is easier with the blowers. It's the same on a larger scale.

A bit of theory - what are forces

Hold a ball in mid air and ask them what is going to happen if you let go. Show them that they are right. Now ask them why the ball falls down. You should get to gravitational force. Explain what a force is. That it is what makes things move, for example pushing, pulling, gravity, magnetic force, friction. Explain that if something isn't moving, the forces must be balanced (they are pulled down by gravity but pushed up by the ground). Tell them about Newton's third law - action and reaction. If you push or pull something, you get pushed/pulled yourself. You can demonstrate by letting them push/pull your hand.

Wooden Rocket 'Puzzle'

Put the rocket on a flat surface with the tip of the orange 'rocket' pointing upwards. Explain that the aim is to get the rocket out of the container without touching the container. (Hopefully they'll come up with blowing on it after doing the ping-pong straw experiment - though it's really not obvious when you first look at it that it's going to work!). You can then demonstrate that indeed the rocket does jump out of it's container (literally!) if you blow on it. I find that it works best if you blow at about 45 degrees to horizontal - have a practice yourself before hand. (I can generally get it to go the highest when I blow straight across the rocket, but this makes it harder to aim and half the time I just end up blowing the whole thing across the desk). The kids can then have a go themselves. There are some anti-bacterial wipes to use on the rocket afterwards. Explain that the air in the container with the rocket is forced out, bringing the rocket with it - another example of air creating a force. (Air pressure decreases over the top of the rocket when you blow over it creating a pressure gradient, the air needs to be replenished from somewhere and part of it comes from inside the container. The explanation inside the rocket box says 'A short, sharp breath of air directed across the top of the puzzle creates a fierce vacuum, causing the wooden rocket to take off' , however I think vacuum is a bit extreme but if that makes more sense to the group you're explaining it to?)

Blowers and beach balls

Preferably use the big blower for this. If you place the ball in the air stream it will balance on it and not fall off. You can demosnstrate that it always balances at the same height. If you hold the ball at the edge of the stream you can feel how it is pulled in. You can let the kids to feel it too. You can use the screwdriver with haztape to demonstrate the direction of the stream.

Explaining why the ball doesn't fall directly down is easy and the kids might tell you that on their own. The tricky part is why is it pulled to the middle of the airstream. There are two ways to go about the explanation. The first is using Newton's third law. When you look at the airstream around the ball when it is at the edge of the stream, you will see that it is bend around the ball. After passing the ball, the stream is not strictly vertical (it is going a bit sideways). That means that the ball effectively pulls the passing air towards itself. The equal and opposite reaction on the ball then is that it is pulled inside. The other way of explaining it is using the Bernoulli's principle - the fact that the pressure is lower where the air has greater speed. (You can demonstrate it by blowing between two parallel sheets of paper hanging vertically next to each other.) So there is atmospheric pressure on one side of the ball and lower on the side of the airstream. The difference in pressure results in a force towards the stream.

This can also be illustrated by tilting the smaller blower, and having it keep the beach ball still, even though it's not blowing from underneath.

A bit on stability

By the time you're reading this we should have a few beach balls of various sizes in the box, if not shout at Zephyr...

Using these we can do a brief discussion on stability of systems and how they will tend to rearrange themselves in the most stable form.

If we put two balls of different sizes into the air stream at once, the most stable configuration is the smallest on the bottom and the largest on top. This is because each ball effectively blocks some of the air hitting it from getting to the ball above (though by no means all, as seen with the bigger at the bottom) and hence there is less upward force on the higher ball.

Thus with the smaller on the bottom, enough air still reaches the second ball to hold it up, whereas the other way up little air makes it to the smaller, higher ball and it is likely to 'fall' off the side of the stream.

Why the quotation marks? Well, if you're lucky (/careful with the settings) the second ball rarely actually escapes the stream, instead the larger ball barges it's way past and then the smaller slots back into place under it. I.e. the system seeks out the most stable configuration.

That said, the smaller ball on top is still an equilibrium state, just less stable, and for more advanced audiences you can talk about the differences between equilibrium and stability.

Note, there is another effect with very small balls, like the ping pongs balls, where they are so light that the force they experience hugely outweighs the difference in amount of air hitting them, so make sure that the balls are of roughly comparable mass, or the lightest will just fly off!

Aeroplane wing

When you tilt the small blower so that the stream of air is horizontal, you can demonstrate the forces acting on the aeroplane wing. Children should be able to feel the air pushing the plane upwards when it is held horizontally. The wings are designed to maximise the upward thrust (which means they push down air significantly) while the backward thrust is minimised (we donâ€™t want the wings to slow down the plane too much). Tilting the wing in the airstream results in greater upward force but also greater backwards force. Let the kids feel it but be careful so that the wing doesnâ€™t fly off and hit them in the face.

Two possible explanations you can use:

One way to think about this is again with Newton's Third Law. The curvature of the wing means that the wing pushes the air blowing at it downwards, and so the air pushes the wing upwards. The size of the force depends on how fast the air is moving, and therefore how much air it is pushing down - you can show this by adjusting how hard the fan is blowing. This means that a plane has to travel VERY fast to get enough lift to keep it in the air (commercial airliners travel around 500mph).

Or using air pressure to explain: When the plane moves forward it pushes air out of the way, over and under the wing. As the top of the wing is curved more than the bottom of the wing, the air has to go further to get over the top and so it has to move faster. Bernoulli's principle says that the pressure is lowered when the air speeds up, so the air pressure above the wing is lower than the pressure below it, and the wing (and plane) is pulled upward (ie the same way things get sucked into a vacuum), opposing the gravity pulling it down. [note: this doesn't explain *why* the air has to move faster over the wing - the air stream moving over the top of the wing has to move through a narrowing space due to the curvature, but with a constant volume per time (like water through a tube that then gets narrower).]

Other things to talk about:

Have you ever noticed your ears going pop as your train goes through a tunnel?

For the train to move forward the air in front of it has to get out of the way, normally there is lots of space for it to do this, but in a tunnel there is just a little gap around the side, which the air has to squeeze through really fast.

This fast moving air sucks some of the air out of the train, which then sucks on your eardrums, making them go pop!

Why do you think they go pop again when you leave the tunnel?

The air isn't going as fast outside so the pressure goes up and the pop back inwards again.

You may notice the ball is spinning sometimes - think about where the air must be flowing to stop the ball falling off.

This happens when the straw is at an angle so the ball drops down a little and the air stream is faster over the top which is what is holding it up.

Try moving your hands across the blower, just above the grill. This will cause the ball to 'dance' as you are changing the air stream so the beach ball adjusts its position to remain in equilibrium.

PLUS Explanation

Aims

- Newton's Laws and Stable Equilibria
- Drag Forces
- Bernoulli's Equation - Lift and Magnus Effect

1 Newton's Laws, Weight and Velocity Profile

What are Newton's Laws? How might they be relevant here?

1 - still or constant velocity if no net force

2 - acceleration proportional to net force

3 - equal and opposite reaction of same type

Here the ball hangs in equilibrium - weight and drag must balance.

How does weight vary with height?

Weight essentially constant over the range of the room compared to the radius of the Earth (if they are familiar with binomial expansions could show this mathematically by expanding F = - GMm/(r+h)^2).

How would we expect the velocity to vary with distance? Can we draw a graph of this (i.e. velocity on y as function of height on x)?

Well collimated at exit - velocity gradient 0 - can show this using streamers. Falls to 0 at large distance - wouldn't feel effect of fan far away. Doesn't keep going negative - no bulk downward motion above the fan caused (there may be turbulence or circulation at the sides). Smoothly interpolate. Full solution very complicated.

2 Drag Forces

What factors will affect the drag?

Relative velocity of wind/object (you feel a force from the air if you run as well as on a windy day, easy to run with wind than into it), size of object, shape (streamlined), also properties of fluid - density, viscosity

In fact the functional form is as follows: At high velocities, inertia effects dominate with constant drag coeffcient:

F = Cpd^2v^2

At low velocities, viscosity dominates. Get Stokes' formula (most likely to have seen this before with Millikan Oil Drop:

F = 6*pi*eta*rv

(Result of drag coeffcient being inverse in velocity i.e.

C = eta/(pdv))

Note in each case - increasing function of velocity.

Therefore, what would you do if you were building something?

Engineers have to design things to minimise drag by size of area, roughness, stability, smoothness of flow to stop vortices (streamlined tail). Very complicated - get things like vortex shedding which leads to vibration (sounds of wind). Also need to consider laminar and turbulent flow - rough surfaces can actually be better eg golf balls!

Try the "plane wing" (in reality a Pringles tube wrapped in card that you can stick your hand into) in the stream - which way round is it easiest to hold (ignoring the fact it wants to turn a lot) and why? What height is easiest? How does this change when fan turned down?

Should be easier to hold pointing into fan as lower area, more streamlined.

Return to our graph from earlier. Let's assume Stoke's law (where F proportional to v) which means we can relabel y as force. Given weight constant, what should line for weight look like? Where should it be?

Needs to be somewhere between maximum and minimum force such that it crosses the force from the air so we can have equilibrium.

3 Stability

Have a closer look at the graph. When the ball moves above the equilibrium, which is greater and thus what happens? What about the other way?

Up - weight greater - falls. Down - drag greater - rises.

This is an example of being stable, when we move away we return. Also described as negative feedback. What other examples of stability are in this problem? Hint: look for other directions that things can move (ball as a whole has 3 directions it can move, with each point having 3 relative to ball):

- The ball doesn't explode or collapse - e.g. the pressure inside goes up if we try to squeeze it. (Accounts for one degree of freedom - distance from centre of mass.)
- The ball often settles a particular way up with nearish the valve at the bottom. Rotational stability familiar from measuring the centre of mass - if we move away we get a moment that moves us back. (A second degree of freedom - azimuthal angle from centre of mass.)
- The ball doesn't fall out sideways - due to Bernoulli effect which we will come onto. (Accounts for two degrees of freedom - x and y position of whole ball.)

Other examples across the sciences of feedback/stability:

- Populations - predator increases lead to prey decreases which starves predators.
- Homeostasis - e.g. if glucose levels too high, then insulin reduces them and vice versa for glucagon.
- Chemical equilibrium - in reversible reaction, if we increase products, then backward rate increases and we return - relates to Le Chatelier.
- Bond lengths in atoms - balance of electron energies from attraction to two protons to repulsion of atoms. Can be modelled with Lennard-Jones Potential.
- Balls can sit in valleys but not on top of hills!
- Mass on a spring SHM experiment.

With a good group you could go through stable equilibria being potential minima more - but might need building up idea of force as gradient of potential etc. If they know about Taylor series, you can also discuss all minima being quadratic like SHM.

4 Bernoulli's Equation - Lift and Magnus Effect

In steady flow (only) the arrows show both the direction of the fluid at any one point and also where a particle will go over time. Where is the flow around the ball? Try sketching this on paper and confirming hypothesis with streamers.

Important to visualise streamlines using streamers at variety of places - note speed and direction at various heights; distances from centre; bottom, side and top of ball with varying proximity.

Bernoulli's Equation

For a unit volume of incompressible fluid (suprisingly good even for gas), energy conservation gives us (derivation not needed here, we are looking at mathematical reasoning):

P + 1/2pv2 + pgh = constant

What do the terms in this equation mean?

P is pressure, p is the density, v is the velocity, gh is gravitational potential

What happens if the velocity at a given height changes?

Pressure must change to balance.

Thus, why does the ball stay in? Try the ping-pong ball. Why does it not stay in?

Pressure difference between side of ball if off-centre. Pressure difference too small on ping-pong ball.

Shows diagram illustrating how the pathlines/streamlines go around a aerofoil (wing). Where are the lines more spread? What does this mean for velocity? Therefore, how does the pressure vary between sides?

Lines spread below and bunch up above. Mass conservation means that lower velocity below meaning higher pressure - net upwards force - lift. Bird Wings also use similar principles - also have narrow tips to minimise vortices - see cross section comparison.

Magnus Effect

Demo - a pair of plastic cups taped back to back. Wrap (chain of) elastic bands around them. Hold off of one finger like slingshot and release. Have a look at this pair of cups. What does it do immediately after firing?

Cups loop up into air.

Why does this happen? Can we draw diagram of flow lines? Cups drag air as they rotate- adds to motion on one side and detracts on the other meaning there is a velocity and hence pressure difference.

This is known as the Magnus effect. One example is rotor ships. Perhaps more common is the spin on a ball in sports e.g. football, golf, table tennis.

Risk Assessment

Hazard: Blower (intakes)

Description: Trapping fingers/long hair in the intakes/gaps.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Keep visitors away from the intakes. There are guards designed specifically to keep fingers out of the danger area.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Blower (weight)

Description: Injuries from lifting/moving the apparatus from place to place. Also the possibility of falling from a height onto people, causing injuries to the public.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Keep air conditioning generator on floor. Make sure that it is stable in the mount. Take care when moving it (refer to lifting advice on CHaOS website).

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Electrical cables/electrical parts

Description: Tripping over cables. Electrical hazards as detailed in Electrical Parts RA.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Tape wires to floor and lay sensibly (not across the middle of the room). If necessary, attach something brightly coloured so that cables are clearly visible. Ask children to put down cups of water before interacting with blower. Follow electrical parts RA.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Ping pong balls

Description: Slip hazard from ping-pong balls. Risk of child injuring mouth from falling over with a straw in his/her mouth. Also, children are liable to run across people s paths after escaped ping pong balls, which can lead to accidents.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Keep track of where the ping pong balls are and do not leave them on the floor. Get the kids to sit down if possible when playing with the ping pong balls so that they don t run around with the straws in their mouths and fall over. Encourage them not to chase balls. Do not allow young children to take straws away with them after experiment.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Saliva on straws/rocket

Description: Transmission of illness through contact with saliva.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Give every child a fresh straw. Wipe the rocket with anti-bacterial wipes, after attempts at making it take off.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Straws/model wing blown out of child or volunteer's hands

Description: Injuries as the result of collisions with flying objects, particularly with eyes/face.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure model wing is held securely - do not let small children hold unassisted and avoid using blower at full power for this part. Discourage dropping of straws into air streams. Call a first aider if there is an accident

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Blowing too hard when making air streams

Description: Dizziness, possible collapse

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Warn before blowing into the straws not to blow too hard and to stop if dizzy. Call a first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Wooden rocket

Description: Rocket may hit child in face when it takes off - It s not very heavy nor does it go that high so will probably only be a problem if it hits their teeth. Splinter from wooden rocket.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure the child isn't too close to the rocket when blowing on it. Demonstrator to check for splinters before use and not use if any are noticed. Children should not need to touch the rocket anyway. Call a first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Objects above the fan

Description: Blower, or objects lifted by the blower, may disturb overhead objects such as lightweight ceiling tiles, causing them to fall down and potentially injure someone.

Affected People: All

Before Mitigation: Likelikhood: 3, Severity: 2, Overall: 6

Mitigation: Be careful to check above the blower for anything that might be disturbed when choosing where to place it. If this is unavoidable, then make sure the power is sufficiently low that nothing will be disturbed.

If an incident occurs, turn off the fans, clean up and call a first aider if necessary

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Plastic cups (PLUS)

Description: They may hit someone when launched.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 1, Overall: 4

Mitigation: Only launch cups in a controlled manner where there is a clear area to do so allowing for things veering off course.

Call a first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Risk Assessment Check History

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Alloys

Investigating the interesting properties of alloys - Using stainless steel as an example of how composition affects magnetic properties and Nitinol as an example of a shape memory alloy

Last initially checked on 2023-01-19 by Toni Renz (ir331@cam.ac.uk) and double-checked on 2023-01-19 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Materials Science

Active (Experiment has working equipment at the time of last update, and is available for events.)

CHaOS+ (More complex explanations suitable for older children are available)

Requires Electricity

Equipment Needed

- **Electricity needed**
- Cutlery, a cheap stainless set and a more expensive stainless set (all spoons)
- Magnet
- NiTinol springs
- NiTinol Magic Tricks (Bending Paperclip and Heart Wire)
- Normal steel spring
- Heat gun and tongs
- Other lumps of metal could be good needs more thought
- (Double check RA) Sandy Plasticine Models (increments of 2g sand to 35g Plasticine)

Experiment Explanation

What is an alloy? A metal which is a metal mixed with something. More rigorously: A metallic solid or liquid that is composed of a mixture of two or more metals, or of metals and nonmetal or metalloid elements, usually for the purpose of imparting or increasing specific characteristics or properties.

Alloys may be homogenous or inhomogenous depending on how the different metals interact. This will have a large effect on the properties of the alloy, so alloying additions need to be carefully chosen to ensure you optimise the properties and don't ruin the stock.

The composition and manufacturing conditions of the alloy will determine which phases are present in the metal. A phase is the specific arrangement of atoms in the unit cell of a crystal lattice. For example in steels, the austenite phase is a face-centred cubic arrangement of iron atoms while the ferrite phase (typically more stable at room temperature) is body-centred cubic.

Say that you can tell how expensive someone's cutlery is from whether it is magnetic. Good stainless steel contains Cr and Ni, the Ni stabilizes austenite phase which is not magnetic. Bad stainless steel contains just Cr, this means the ferrite (magnetic) phase is stable and therefore cheap cutlery is magnetic. The proportions are usually 18:10, 18:8 or 18:0 Cr:Ni - the higher the Ni content the higher the quality. Show that the good John Lewis stainless steel is non-magnetic and the cheap Asda stainless steel is magnetic. The result of this means the Asda cutlery scratches more easily, which makes it look less shiny.

(Look at other properties. Ask if they know the difference between hardness and toughness? Most won't, toughness is a measure of the amount of impact energy it can take before fracturing, whereas hardness is a measure of its how difficult it is to scratch. This is related to strength, which is a measure of how hard it is to permanently plastically deform.)

Finally, demonstrate the shape memory alloys. Ask members of the audience to deform the NiTinol wire sample. After this, tell them you will return it to its original shape. Heat up using the heat gun, holding the wire using a pair of tongs. If the wire has been tangled by an ambitious member of the audience, you may need to untangle it, as this may prevent the wire from uncoiling fully. The ideal geometry is to curl the wire into a spring.

Plasticine Models

I have made some Plasticine alloy models which you can play around with. They're made by taking Plasticine (duh) and varying quantities of sand. Please pack them away in the nice sealed containers so they don't dry out! Get kids to play with some they're body temperature and then roll them into a cylinder (approx 1.5cm diameter x 6cm length, although having the different alloys similar size is more important) then gently pull apart till you get a gentle failure (no arms flying around, that's not gentle). You should get a ductile fracture, small pockets form, these coalesce, then a crack propagates until we reach separation. Compare the forces needed, the fracture surfaces (using a magnifying glass, you could even compare to a tear or snap you make) and make theories about what adding the sand has done.

PLUS Explanation

Background/Intro to alloys

What is an alloy? A metal which is a metal mixed with something. More rigorously: A metallic solid or liquid that is composed of a mixture of two or more metals, or of metals and nonmetal or metalloid elements, usually for the purpose of imparting or increasing specific characteristics or properties.

Alloys may be homogenous or inhomogenous depending on how the different metals interact. This will have a large effect on the properties of the alloy, so alloying additions need to be carefully chosen to ensure you optimise the properties and don't ruin the stock.

The composition and manufacturing conditions of the alloy will determine which phases are present in the metal. A phase is the specific arrangement of atoms in the unit cell of a crystal lattice. For example in steels, the austenite phase is a face-centred cubic arrangement of iron atoms while the ferrite phase (typically more stable at room temperature) is body-centred cubic. Phases can have different compositions, mechanical and magnetic/electrical properties because of the differences in structure. For example, the austenite phase of stainless steel is not magnetic, but the ferrite phase is, whilst martensitic stainless steel is extremely hard - might be a good point to discuss hardness v. toughness.

Ask if they know the difference between hardness and toughness. Most won't: toughness is a measure of the amount of impact energy it can take before fracturing, whereas hardness is a measure of its how difficult it is to scratch. This is related to strength, which is a measure of how hard it is to permanently plastically deform.

If they're (understandably) glazing over, maybe move on to thinking about why we might want specific properties and what we can do to get them - composition, heat treatment, developing a particular microstructure etc.

Microstructures!

There are (or should be) a few phase diagrams in the box, which could do with laminating, that can be used to illustrate the different regions and what phases you'd expect to find in under certain conditions. I think I put a steel one in there (because everyone loves steel) and some nice simple binary eutectic one (?) - all composition-temperature ones. Ask what they expect a material to look like under a microscope - all the same or different regions? Then introduce the micrographs and what they can see in them (also could do to be laminated, I can't remember exactly which ones I left in there...). They should notice the grains, some annealing twins in a brass, the grain boundaries and possibly notice the different appearances of the different phases. You can talk about how different phases form different grains, and discuss solidification (if they're really keen) using the phase diagram.

The point isn't to bore them to tears by discussing alloys at length - just to go beyond the A-level "alloys are a mixture of different metals" idea and show them that they're really complex and cool (if you like that kind of thing).

If we could get hold of some turbine blade, silicon wafers, copper alloys and similar materials stuff, that'd be great for discussing the specific applications of alloys (I am aware that single crystal pure Si isn't an alloy, but it's cool and shiny) and some materials processing methods (Czochralski process, quenching to get martensite, age hardening etc.), which would definitely make this section more engaging.

There's a model of some hcp layers (looks like a Christmas tree kinda) that you can use to illustrate the idea of bcc, hcp and fcc structures. You can use this to explain the twins you see in the brass micrograph - they occur due to a stacking fault. Stacking faults can be illustrated by organising the layers of "atoms" in the model out of sequence to show that they can stack in different ways. The "twin" comes from the symmetry that arises either side of the twin boundary:

Normal stacking ABCABCABCABCABC

Stacking fault ABCABCAB|A|BCABCABC

Note the shape of the twins - they're squarish. Compare to the idea of deformation twins, which are lenticular. Annealing twins arise from growth accidents at high temperatures. Deformation twins need to be lenticular to minimise strain energy, whilst annealing twins don't need to do this because there's no strain energy associated with their formation.

Cutlery

Say that you can tell how expensive someone's cutlery is from whether it is magnetic. Good stainless steel contains Cr and Ni, the Ni stabilizes austenite phase, which is not magnetic. Bad stainless steel contains just Cr, this means the ferrite (magnetic) phase is stable and therefore cheap cutlery is magnetic. The proportions are usually 18:10, 18:8 or 18:0 Cr:Ni - the higher the Ni content the higher the quality. Show that the good John Lewis stainless steel is non-magnetic and the cheap Asda stainless steel is magnetic. The result of this means the Asda cutlery scratches more easily, which makes it look less shiny. They might say that the Asda cutlery is bendy (stop them before they break it) - this is to do with the manufacturing method and not the steel they've used!

Shape memory effect

Finally, demonstrate the shape memory alloys. Ask members of the audience to deform the NiTinol wire sample. After this, tell them you will return it to its original shape. Heat up using the heat gun, holding the wire using a pair of tongs (we will need to get tongs). You could ask an audience member to hold the sample in the tongs - they should wear gloves and the demonstrator should remain in control of the heat gun at all times.

If the wire has been tangled by an ambitious member of the audience, you may need to untangle it, as this may prevent the wire from uncoiling fully. The ideal geometry is to curl the wire into a spring. The heart magic trick is the best at springing back - the paperclip is a bit dead and doesn't look much like a paperclip any more. For curious audience members, there are some (slightly manky) normal springs that you could heat up for comparison. Ask what they expect to happen and then show them that it doesn't return to its original shape like the NiTinol ones do. There are a couple of springs that have been deformed permanently - show them that this isn't recoverable for a normal alloy, which they should ideally recall from work they've done on Hooke's law and elastic limits.

You'll also need to explain why it happens! I've uploaded an image that you could use/copy out. You'll need to know what a phase is for this to make any sense, and that phases can have different crystal structures (the Christmas tree model is useful here). The important thing about shape memory materials is that they can undergo a diffusionless transformation from a parent phase (austenite) into a low-symmetry metastable martensite phase. The names are taken from the phases of steel - shape memory materials are not steels - it's just that materials scientists aren't that inventive. Transformations between the austenite and martensite phases can be induces by temperature or stresses. You can expose the material to a temperature or apply a stress such that the parent phase becomes unstable with respect to the martensite phase, and the material transforms. This also works in reverse, when you remove the stress/temperature driving force, and you can get martensite -> austenite transformations as a result.

The shape memory effect depends on temperature. You can train your alloy in the austenite phase and recover deformation that occurs in the martensite phase.

1. Heat the alloy to above AF (i.e. above the austenite finish temperature, where the sample is entirely austenitic).

2. Rapidly cool the alloy into the martensitic region. The sample will transform such that minimal shape change occurs and the sample will look have approximately the same dimensions as when it was austenitic. This is because the martensite has adopted a twinned structure - you don't really need to worry about what that means for the purposes of the demo, only that it's an easy way for the martensite to deform by detwinning).

3. Shear the martensitic sample (i.e. what your volunteer is v. kindly doing for you). This detwins the martensite, which is important to us because the new detwinned structure is crystallographically related to the original austenite we had to begin with.

4. Heat it back up to above AF again (all austenitic). We said that the detwinned structure is related to the austenite we started off with, which means we can basically recover the original austenite grains we had in the first place - and the same shape! As the sample cools, it will return to the twinned martensite structure, but we can't see that because it will transform in order to generate the smallest dimensional change.

If they're still listening, then ask why you might want this effect at all:

1. Stents - nitinol/iron-platinum alloys. AF ~ 30 degrees (i.e. <37 degrees). Crimped while martensitic, then guided into the body (the heart), where it then expands as it transforms back into the austenite phase. No need for the balloon stuff you have to do with SS stents, and superelasticity means it recovers its shape with the high loads applied to it.

2. Morphing structures in planes - adapting chevrons in turbines. Change shape in response to temperature. Take-off and climb = high temperature, chevrons deployed to reduce noise and improve air mixing. Cruising = lower temperature, chevrons retract to maximise efficiency. I'll admit that this kinda needs a photo to be more interesting.

3. Braces - dental wires. Can be used to pull the teeth when the wire heats up (which I think sounds nasty, but y'know).

4. Fixing broken bones - kinda like the stent stuff but with bones. Plates used to apply a compressive force to bones to help knit them back together, which works because the shape memory alloy is heated when in the body.

5. Glasses - if you squish glasses that have shape-memory frames, you can just heat them back up and they should spring back into shape.

You could also compare this behaviour with a standard paperclip (you'll need one per demo because they're gonna break it). Get them to bend it out of shape and then ask them to bend it back into the original paperclip shape. They definitely shouldn't be able to do that. With an ordinary alloy, like the paperclip, bending introduces dislocations, which are awkward to explain. They are essentially defects that move through the material and allow it to shear - it's a mechanism by which a lot of metals tend to deform (the alternative is by deformation twinning, popular in hexagonal structures where there are very few slip systems). The problem is that you're introducing lots of dislocations in the paperclip that mean it can't just deform straight back into its original shape - the dislocations get in the way. When the shape memory alloy is deformed, you do introduce dislocations, but not as many. It will, eventually, stop cycling through the shape memory cycle, but it takes time. One of the ones we have (I think the paperclip) is kinda getting there now - best to use the heart.

Potential addition

If we need more shape memory samples, the Materials Department gives them away for free on open days and Rob said we could just ask him for them. Would also be nice to get a superelesticity demo if we can, but we'd need to do a Hooke's law F vs. extension style thing at a raised temperature and I'm not sure how feasible that would be - maybe a hairdryer, perspex tube, clamp stand and mass hanger would do the trick. Both shape memory and superelasticity exploit the same martensitic phase transformation, so they'd be good to do together.

Yaron's Rant

I (Yaron) am on tour at the moment but when I get back I will be working on a major overhaul for this experiment.

Also, I really want to take all the knives and forks out of the experiment since a kid threatened to **STAB ME** earlier. And we should replace the spoons with less rusty ones because it's difficult to demonstrate that stainless steel is oxidation resistant when all your SS samples have rusted.

Depending on how much steel is already in the demonstration, one could acquire a pearlite and martensite sample and compare their physical properties (strength, stiffness, hardness). This may have previously been a part of the demonstration but has since been taken out.

Finally, we should get a couple more samples to talk about because the demonstration is a little short. Perhaps an Al-Cu alloy to talk about age hardening? Can anyone convince the Materials Department to donate a single crystal turbine blade? **UPDATE:** Yes, we may be able to get a defective sample from Rolls Royce. I discussed it briefly with Dr Catherine Rae (cr18) and she says it can be arranged. Will need to email at some point.

I've left Yaron's little rant in because he raises some excellent points about this demo, which we should work on when we have time. I've added to the explanation to make this into a PLUS version, but I reckon the experiment could do with more samples to make it more engaging. I've tried to write this in sections so when you, the lovely demonstrator, come to do this you can pick and choose what you'd like to talk about. Ideally not all of it because even I don't think alloys are that interesting. Grace, 17/06/19

Risk Assessment

Hazard: Heat Gun

Description: Fire risk and also the possibility of burns.

Affected People: all

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: Demonstrator to control heat gun. Do not leave on. Keep flammable material away from the heat gun and use with heat proof mat. Use stand instead of lying heat gun on a surface. Do not touch the heat gun. Keep the temperature setting low.

In case of burns, run affected area under tepid water for 10 minutes. Call a first aider.

Follow venue RA protocols in case of fire.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: NiTinol wire and tongs hot when heated

Description: Risk of burns.

Affected People: all

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not let anyone near the heated wire. The wire is thin and should cool within a few seconds, but care should be taken with the tongs. If possible, obtain a heat-resistant mat to lay the tongs/wire on after heating.

In case of burns, run affected area under tepid water for 10 minutes. Call a first aider.

Follow venue RA protocols in case of fire.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Ends of wires

Description: Cuts

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure sharp ends are doubled back.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Cutlery

Description: Stabbing self/others

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Limit cutlery to spoons or make sure that any knives or forks are not sharp. Only give cutlery to responsible children and if they being silly with the cutlery take it off them.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Magnets

Description: Skin getting caught between cutlery and magnet

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Use weak magnet so wonâ€™t cause harm if occurs.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Plasticine Models

Description: Ingestion and risk of accidentally hitting children when arms fly apart from breaking.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Plasticine and sand are both non-toxic, although parents should be informed as eating small quantities may lead to stomach upset. Large quantities may require a stomach pump however there's no need to be giving out large amounts. Don't give plasticine to small children and tell them not to eat it. Ensure children are standing apart while testing models and ensure they pull gently.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2015-02-12 - Tim Morgan Boyd (tmb58@cam.ac.uk), **Check 2**: 2015-02-13 - Joseph Hooton (jh795@cam.ac.uk)

Check 1: 2015-12-30 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2016-01-20 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2017-01-22 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2017-01-23 - James Nicholas (james.nicholas@cantab.net)

Check 1: 2017-02-09 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2018-02-04 - Giedre Sirvinskaite (gs508@cam.ac.uk)

Check 1: 2018-12-13 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-01-05 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2019-01-20 - Yaron Bernstein (yb258@cam.ac.uk), **Check 2**: 2019-01-21 - Grace Exley (gae23@cam.ac.uk)

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Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2022-02-06 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-07 - Peter Methley (pm631@cam.ac.uk)

Check 1: 2023-01-19 - Toni Renz (ir331@cam.ac.uk), **Check 2**: 2023-01-19 - Jamie Barrett (jb2369@cam.ac.uk)

Animal Cognition

A challenge to get people thinking about animal intelligence - Intelligence tests for animals.

Last initially checked on 2023-02-05 by Chiara Delpiano Cordeiro (cd796@cam.ac.uk) and double-checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- 2 Large measuring cylinders
- Jug
- Water
- Gravel/stones
- Balloons
- Twigs/Straws
- Clothes pegs
- [Optional] Bird Skulls (in Animal Skulls)

Experiment Explanation

Set up the challenge:

Partially fill the 2 tubes with water to the same level. Float a partially inflated balloon in the tube. People can fashion very good straw hooks and you'd like them to use the gravel ideally so limit the number of straws they have and consider how high the water is filled. We now have wider tubes which they could just stick their hand in so use tape to mark near the top of the tube and say they can only use their hands once the balloon gets beyond that point.

During the experiment: 1)What is intelligence? 2)How do we test human intelligence? IQ tests (more info below), school exams 3)Obviously we can't give animals these tests so what kind of tests might we use to test their intelligence? Mazes, puzzles, memory tests

This challenge is an example of a puzzle: Split them into 2 teams, one with each tube, to make it a race. They need to get the balloon out of the tube using the objects here (gravel, twigs/straws, pegs). Congratulate for effort and talk about why using gravel worked, or if they managed without ask how it might be possible if they just had the gravel (water displacement).

5)What animals do you think could do this? Monkeys, apes, birds - intelligent enough to understand how the rocks displace the water 6)What challenges are there with testing animal intelligence? Motivation - use food instead of balloon Ambiguity - we think this shows understanding of displacement but can't be certain of what an animal's thought process is so this is a bit of an assumption. Complex patterns of behaviour can also be instinctive rather than require cognition as shown in fixed action patterns e.g. grey geese scoop eggs up into their nest if they roll away but will also scoop up anything egg-like in their vicinity - don't know why they're doing it just doing the action. Also, there can be other underlying reasons for behaviour, for example Clever Hans was a horse who appeared to be able to perform simple addition but was just interpreting subtle unintentional body language cues from a trainer to see what the right answer was 7)How else can we estimate animal intelligence? Cranium size - good to compare magpie and pigeon skulls here and similar sized birds but magpie's cranium is significantly bigger. Magpies are very intelligent, indicated by tool use and good spatial memory. Large brains use up a lot of energy so animals will only have big brains if they need them, making it a fairly useful indicator.

If they seem interested, you can go into more detail about other animal intelligence tests: Physical intelligence - this is the kind of test we have just done. It tests the animal's 'knowledge' of the physical laws of the universe e.g. gravity, water displacement etc. It also tests whether they understand the properties of objects, in particular whether they can use them as tools.

Maze/obstacle tests - penalise visiting areas you've been before (i.e. tests memory of where you've been = spatial memory), might run multiple times starting at different points in the maze to see if they learn and remember the maze layout (if you started at the same place each time they might just be learning muscle memory). Some examples include 8-arm mazes where some arms have food at the end and they have to not visit arms they've been to before, a water maze where they have to swim in a pool to an invisible platform and there are items on the walls which they can use to navigate if they are put in the pool at different positions.

Memory tests - show them a selection of items, take one away/add one when they can't see and ask them to identify which is missing/added. Have an object on one side of the table in front of them, cover it up with a bowl when they aren't looking and put another bowl on the other side, see if they remember which side the item was on (and whether they can understand that the item is still there if they can't see it = object permanence)

Consciousness test - whether animals are conscious is a big question that is very hard to answer. One test that approximates an answer to an approximated version of this question is whether they recognise themselves in their reflection. A red dot is shined on their forehead when they are in front of a mirror and some animals will try and touch their own forehead where the dot is. This implies a sense of 'I-ness' in that they recognise that what is in the mirror is themselves, and therefore must know what 'themself' is. However, failing this test cannot prove that they don't have this sense as there could be many reasons they fail to react.

Risk Assessment

Hazard: Peg/pipe cleaner/gravel

Description: Injury from peg/pipe cleaners/gravel e.g. stabbing or throwing.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Warn children to be sensible and careful and not grab/throw/stab each other with the pegs/pipe cleaners/gravel. Call first aider in event of incident.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Dirty water

Description: Illness from ingesting the dirty water.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure the children don't drink the water or splash it in each other's faces. Tell them to stop if they put things in their mouth. Suggest they wash hands when they leave. If ingested encourage child to spit out water and rinse out mouth with clean water.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Water

Description: Water spilt on the floor, causing a slip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Don't carry out experiment near a thoroughfare and be careful when emptying/refilling the tube (do over a sink if there is one next to you), don't let the children add too much gravel at once or add with too much vigour. Mop up any spilt water as soon as possible. Call first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Gravel

Description: Gravel being choked on.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Don't give gravel to really young children, confiscate if they are getting silly and putting anywhere near mouth. Call a first aider and/or a ambulance in the event of choking. Give Heimlich manoeuvre if confident you know how.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2015-12-27 - Sarah Wiseman (sw628@cam.ac.uk), **Check 2**: 2016-02-11 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2016-12-26 - Sarah Wiseman (sw628@cam.ac.uk), **Check 2**: 2017-02-06 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Check 1: 2019-01-07 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2019-01-16 - Amanda Buckingham (abb53@cam.ac.uk)

Check 1: 2020-01-23 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2020-01-25 - Matt Worssam (mdw47@cam.ac.uk)

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Check 1: 2023-02-05 - Chiara Delpiano Cordeiro (cd796@cam.ac.uk), **Check 2**: 2023-02-10 - Amy Migunda (aom36@cam.ac.uk)

Animal skulls (including primate skulls)

Looking at different animal skulls to compare them and see how they differ. - Why do some animals have really long beaks? Why do others have really big TEETH? With our collection of animal skulls, you can find out how different animals evolved to suit their habitats - and how you are a lot more similar to them than you might think!

Last initially checked on 2023-02-05 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Various different skulls and a pile of laminated photos
- Box 1
- Mammals: sheep, dog, cat, fox, mole, rabbit, roe deer
- Birds: magpie, pigeon, oystercatcher, duck (one complete, one in parts), parrots
- Other: gulper shark jaw, striped snakehead fish, snake (some kind of boa), Siamese Crocodile
- (nb: The magpie and pidgeon skulls are sometimes moved into animal cognition)
- Box 2
- Primates: human, chimp, gorilla, orangutan (all models)
- For CBS, some can also be borrowed from the zoology museum.
- Pictures of the animals

Experiment Explanation

OVERVIEW

We have some skulls of different animals. Each has different adaptations relating to the animalâ€™s lifestyle and environment. Looking at a skullâ€™s characteristics, such as teeth, eye placement and size, scientists can determine whether the animal was an herbivore, carnivore, or omnivore, and if the animal was a predator or prey animal.

SETTING OUT THE EXPERIMENT

In a calm event it can be nice to set out all the skulls on a table, with all the photo cards spread out in front of them so that you can play a matching game. In a busier event or with an excited group of kids it's probably better to have them in the big blue boxes and pull out one skull at a time, or choose a few skulls you like that fit a narrative (e.g. comparing herbivores and carnivores) and have just those out. That makes it easier to control which kids are holding the skull(s) and it makes it easier to control the questions, as you don't have to jump backwards and forwards between lots of different animals!

BASIC PROCEDURE AND EXPLANATION

Unlike some of the other biology experiments, the animal skulls experiment has no fixed story line. This makes it much more flexible, so you can talk about the skulls that you find cool or know more about. (No-one will know which ones you've left in the box!).

Our advice is to start talking about one skull in detail, then compare other skulls to the first one you picked. It's easier to pick one of the bigger/ less fragile skulls first, such as the human (made of plastic!) or the sheep skull. Make sure that you've established what a skull is on the first one- it's not as obvious as you might think that it's the boney stuff that is inside our head/ protects our brain. You might also want to briefly talk about what bones are for/ made of - an explanation of hard stuff that holds our bodies up is probably enough detail for the youngest kids!

- Start by asking the child if they recognise any of the skulls - they will probably recognise the human one at least
- On the human skull - can ask if they know the names of any parts of the skull (can help them out by providing a couple - remember to use simple terms e.g. teeth, eye sockets)
- Point out interesting points on the skull that you might know e.g. foramen magnum where the spine attaches to the skull and through which the spinal cord runs, or the holes on either side of the skull where the inner ear goes
- Once you've established the names of a few of the skull's main features, ask the child if they know what each of these features does or what they're for
- Point out that the jaw isn't fixed to the main part of the skull - apart from anything else we wouldn't be able to open our mouths to eat if it was stuck (fused) to the rest of the skull.
- Holes for nerves, such as at the back of the eye sockets. These allow the brain to connect to send and receive signals from the rest of the body.
- Can then move onto the other skulls - discuss the features of the skulls and how these relate to the demands that the animal has to cope with in its environment. Why might the adaptations help the animal to succeed in its environment/why might the animal have developed these skull features? You might want to discuss each skull in turn, or you may prefer to talk about a particular 'theme' i.e. teeth, brain size across a number of skulls at once
- Make sure you get child involved i.e. get them to (gently!) handle skulls so they can feel how delicate/sturdy they are, ask lots of questions. Remember to use simple language and explain difficult words in simpler terms (e.g. 'animals that come out at night' rather than 'nocturnal animals') Particularly delicate skulls have a small piece of red gaffa on their boxes - only let children handle these if you think they will be careful enough with them!

Interesting features/comparisons include:

TEETH

The type, shape and number of teeth an animal has can help determine its diet.

- Incisors are the front teeth. They are used primarily for cutting and grasping.
- Canines are the teeth next to the incisors. The canine teeth typically are large in a predator and are used for tearing and grasping.
- Premolars are the teeth behind the canines. These teeth have sharp edges for crushing food.
- Molars are the very back teeth. They are broad and flat and are used for grinding.

If a mammal has long, sharp canines, it is most likely a predator. Canines are used for grabbing, holding and killing prey. Some meat-eating mammals (carnivores) have sharp shearing cheek-teeth called carnassials. These teeth act like a scissor to cut through tough flesh and to break it into smaller pieces for swallowing and digestion. The fox is mainly carnivorous, although they also gather a wide variety of other foods like fruit and berries. The European Mole is also carnivorous, and feeds on invertebrates e.g. earthworms, insects. Ask the child if they can think of any other carnivores (cats and dogs are just two familiar carnivores).

Plant eating animals tend to have teeth specialized in chewing various parts of plants. Some plant eaters eat grasses (grazers e.g. sheep, using incisors to nip plants close to their bases), some eat twigs, leaves and berries (browsers e.g. goats/deer) while others eat only specific plant parts (i.e. roots, fruit, etc.). In order to properly digest vegetation, an animal must chew its food to help break down the plant. Most herbivores have cheek teeth called molars. These molars help grind leaves, stems, grasses, fruit and even seeds before the animal swallows them. Examples of herbivores in our skull collection include the hare (hares eat grasses during the summer and twigs/tree bark etc. during the winter, and also commonly re-ingest their faecal pellets...) and the sheep (these mainly feed on grasses, have a large and complex stomach which is able to digest highly fibrous foods that cannot be digested by many other animals). Sheep, cows, llamas and alpacas all don't have top inscisors! Instead they have a thick, hardened gum line (called the dental pad) which they use to pinch off blades of grass against.

Some animals (omnivores) eat both plants and animals, and have both types of teeth. The primates and magpie are omnivores (although obviously the mapgpie doesnâ€™t have any teeth). Interestingly though, recent studies have shown that chickens (and possibly other bird species) still retain the genetic blueprints to produce teeth in the jaws, although these are dormant in living animals. These are a feature from primitive birds such as Archaeopteryx, which were descended from theropod dinosaurs. Other examples of omnivores include pigs and bears.

Fish - some fish have teeth, others don't. They tend to all be small and sharp if they have them and are mostly found in carnivorous species. This fish eats frogs, insects, and smaller fish. It has small and large teeth but they are all the same shape.

Snake - snakes have long sharp teeth. Venomous species have venom teeth which have either a groove or a hole running through the tooth, through which the venom is injected. These are the only specialised teeth in snakes.

Shark - sharks have many sharp teeth. Their teeth often fall out as they grab moving prey and so they have a continuous 'conveyor belt' of teeth growing from their jaw. The new teeth that aren't needed yet lay flat against the jaw until the tooth in front falls out and they they move up into the normal tooth position. You can see the new teeth ready to move up on the inside of the jaw.

Crocodile - the crocodile can also replace it's teeth when it loses them but rather than having a 'conveyor belt' system like the shark, it has permanent teeth buds (which are what your teeth develop from) under each tooth which are stimulated by the tooth falling out, causing another one to grow.

BEAKS

You might want to talk about how birds such as the chicken use their beaks to feed, and talk about how other birds have adapted their beaks to help them eat their chosen food.

The beak of a bird is an extension of its skull and is designed for feeding. Some beaks have evolved to specialize for feeding on specific items.

Duck: wide flattened "bill" used for eating aquatic plants and mosses - specialised for "dredging" type jobs. Dabbling ducks, which feed on the surface of the water (or as deep as they can reach by upending without completely submerging) have a comb like structure along the edge of their beak called a pectin - this strains the water squirting from the side of the beak and traps any food. This can be seen on one of our duck skulls. Also used to preen feathers.

Parrots: seeds are the most important part of their diet, which has led to the evolution of a large and powerful bill which is primarily an adaptation to opening and consuming seeds.

Oystercatcher: bill shape varies between species, according to diet - birds with blade like bill tips pry open or smash mollusc shells, and those with pointed bill tips tend to probe for annelid worms.

Pigeons: homing pigeons have iron containing structures in their beaks which may enable the birds to use the earth's magnetic field for navigation

Other birds (which we don't have, but that you could discuss) include - the hawk, which has a sharp hooked beak used in tearing flesh from its prey or carrion. A hummingbird uses its long narrow beak to lap nectar from flowers and a sparrow has a small powerful beak used for picking berries and cracking seeds.

NOSES

Possibly start by asking what is missing (nose, ears, eyes and other soft tissues) - they are not part of the skeleton, made of either cartilige or muscles and nerves. The kids can think about the differences in nose sizes, do they think that cats have a better sense of smell than dogs? etc (dogs are 10,000 times more sensitive to odors than humans). Apart from food, what else do animals need noses for? (smelling mould, predators, recognising family members, detecting when another animal is in heat). The sheep skull has large nasal cavities, with delicate rolls of (turbinate) bones, which support a large area of nasal epithelium (skin inside the nose) for many, many scent receptors and to reduce heat/moisture loss.

Nose length varies in dog species-

Dolicephalic- long nosed breeds like greyhounds

Brachycephalic- short nosed breeds like pugs

Mesocephalic- medium nosed breeds like terriers

EYE PLACEMENT AND SIZE (particularly relevant to mammals)

Large eye sockets suggest an animal is active at night (nocturnal). In this case, a larger eye has evolved to allow the animal to see better at night. Moles and cats (very obvious large eye sockets) are nocturnal, hunting prey and remaining active at night.

Eyes that face forward on a skull suggest a predator (â€˜an animal that hunts other animals for foodâ€™). Forward facing eyes allow for binocular or stereoscopic vision, which allows an animal to see and judge depth. Predators need this depth perception to track and pursue prey. The fox is an example of a predator in our collection. The orangutan also has forward facing eyes that give it depth perception needed to swing and leap in their tree top habitat. Humans have forward facing eyes as well (you could talk here about us being descended from apes).

Animals with eyes that are located on the side of its head would suggest a prey animal. Side eye placement allows for greater peripheral or side vision. This enables the animal to see predators approaching from the side as well as from behind. This vision is very important for protecting an animal when it is grazing or feeding. The hare is an example of a prey animal in our collection. Other examples include deer and rabbits.

"Eyes in the front, the animal hunts. Eyes on the side, the animal hides."

CRANIUM

The size of an animalâ€™s cranium (relative to its body size) can give you an idea of how well developed its cerebral cortex (the part of the brain that contributes to â€˜intelligenceâ€™) is. The size of an animalâ€™s cerebral cortex can be used as a rough indicator for how 'intelligent' it is as a larger brain gives more processing power. A good way to compare the size of the brain cavity is to look at how big it is relative to the rest of the animalâ€™s skull. Generally, social animals such as monkeys, apes (including humans), dolphins, and elephants have large cerebral cortices. This is because keeping track of social relations within the group requires a great deal of â€˜processing powerâ€™.

Magpies are a member of the corvid family - group of birds including crows, jackdaws etc. - these birds are thought to be the most intelligent of all bird species, and have larger cerebral cortices than would be expected for their body size. This intelligence is demonstrated in several ways e.g. European magpies have shown self awareness (i.e. recognising themselves) in mirror tests, crows and rooks have tool making abilities (e.g. hooks to 'fish' for grubs) - things that people generally associate with higher mammals such as ourselves and other apes. These birds also have highly complex social lives, just like apes (need to have large brains with lots of computational power to keep track of what other animals are doing, understand their relationships with other animals in the group etc.).

Parrots also highly intelligent and have high brain size to body ratio - some have been shown to be able to associate words with their meanings and form simple sentences (e.g. Alex the African Grey), some species of parrots are highly skilled at using tools and solving puzzles.

Pigeons, by contrast, seem to be less "intelligent". If a pigeon is taught that doing something (e.g. pecking at light A) leads to reward, and doing something else (e.g. pecking at light B) doesn't, then they can learn these rules, but if you change the rules around (e.g. pecking at A doesn't lead to a reward, and pecking at B does) they find it difficult to "reverse" their behaviour (whereas corvids and humans manage easily!) As pigeons are a similar size to magpies, comparing the size of these 2 skull's craniums is a good example of how cranial size can indicate intelligence. Another good comparison is the human and the chimpanzee.

NB Unlike most other apes, orangutans are shy, solitary animals. They live alone in large territories. This is probably due to their eating habits; they need a large area in order to get enough food and too many orangutans in one area might lead to starvation. However, they are very intelligent. They have been known to use found objects as tools; for example, they use leaves as umbrellas to keep the rain from getting them wet. They also use leaves as cups to help them drink water.

OTHER THINGS TO TALK ABOUT

Can the child think of any other distinctively-shaped skulls that animals have, and why might they have developed to be like that? E.g. crocodile, hammerhead shark, elephant (tusks)...

Crocodile things - so from the crocodile skull the bones look fairly different (part of this is as the skull is beetle cleaned vs chemical cleaning on other skulls). Crocodiles have spiraled bone fibres to help them resist torsion, allowing them to death roll and resist forces from fleeing pray which could break their skull. Crocodiles are also diapsids. These have two 'temporal fenestra' or holes in each side of the skull, these are positioned above and below the eye. This allows for larger stronger jaw muscles and wider movement than a single hole. On the human skull you can see the single bony arch behind the eye where the ear would be. The original classification was complicated as, other than crocodiles, many diapsids have lost these additional holes since the Pennsylvanian period. Lizards (lost one hole), snakes and turtles (lost both) and birds (heavily restructured skull) are also in this class.

If the child is old enough and seems keen, you might want to touch on the concept of natural selection (survival of the fittest) and how this drives development of the peculiar features that some animals have. For example nocturnal animals will have more success catching food and escaping predators if they have large eyes that let in as much light as possible in low light conditions. Animals with smaller eyes than average will find it more difficult to do this and are less likely to survive than animals with larger than average eyes. The animals with larger eyes will therefore be more likely to survive and have babies, who will in turn also have big eyes like their parents (you will need to briefly touch on genetics here too â€“ has the child noticed that they share the same eye/hair/skin colour/nose shape etc with their parents?)

PLUS Explanation

Animal skulls experiment is flexible and you can talk about the skulls that you find cool or know more about.

You could start talking about one skull in detail and how it is suited to its function. Then you could move on to comparisons with other skulls to the first one you picked. It's easier to pick one of the bigger/ less fragile skulls first, such as the human (made of plastic!) or the sheep skull.

- Start by selecting a skull of a species that you are going to focus on.
- Discuss what the skull is made of- bone. The skull is made up of flat bones. Bone is made of 1/3 organic type 1 collagen and 2/3 hydroxyapatite with adsorbed calcium carbonate. Skull bone is formed from condensed

sheets of fibrous tissue- cancellous bone and marrow sandwiched between two layers of compact bone and periosteum - this is called a diploÃ« (Compare this to long bones which are different. Long bones are made up of osteoblasts and osteoclasts. Osteoblasts are uninucleate cells that live as long as the animal and are responsible for formation of the bone matrix. Osteoclasts are myeloid derived blood cells which are multinucleate, short lived and are in control of bone destruction. Together these types of cells are in charge of bone formation and destruction. This is a feature of bone in general and applies to the skull as well under the control of parathyroid hormone, calcitonin and vitamin D. Another example of a flat bone is the scapula)

- Discuss how the skull bone is formed developmentally- it is formed from pharyngeal arches. The toothed, upper and lower jaws are dermocranium- they form around viscerocranial cartilage templates from pharyngeal arches.
- The skull is made up of lots of different bones: premaxilla, maxilla, vomer, nasal, palatine, lacrimal, frontal, parietal, interparietal and tympanic bones. There are also also teeth.
- On the skull you have taken- can ask if they know the names of any parts of the skull. Key features to notice:

- The cranium contains a cavity that has the main function of containing the brain.
- Eye sockets- supports the eye balls. There is a nasolacrimal fossa for the sac and the duct. There is a hole at the back of the socket through which the optic nerve runs
- Tympanic bullae are the bulges associated with the auditory canal- these have the function of amplifying sounds and particularly low frequencies.
- Nasal conchae are scrolls within the nasal canal and these increase surface area for the olfactory epithelium to cover which
- The foramen magnum is the main cavity at the back of the skull and this is where the spine attaches to the skull. The spinal cord runs through this hole and connects to the hindbrain.
- The mandible is used for creating a hinge join at the temporomandibular joint which allows jaw movement
- The mandibular symphysis is the joint in the chin where the two bones of either side of the mandible are fusedâ€“ note that this is one of the most common â€˜fracturesâ€™ to result from cat/car impacts. The symphysis fuses in horse around two years of age and may also fuse into a â€˜synostosisâ€™ late in life in ruminants.
- Other holes in the skull are for nerves e.g. the supraorbital foramen which you can feel in the middle of your eyebrow and which carries the supraorbital nerve, part of the frontal nerve, in tern part of the opthalmic nerve (1/3 of the trigeminal nerve) which carries sensory information (touch, heat, pain etc) from the eye region (but not the image from the retina, which is transmitted via the optic nerve). This nerve is particularly prominent on the horse skull (see below).

The cranial nerves are:

I- Olfactory nerve II- Optic nerve III- Oculomotor nerve IV- Trochlear nerve V- Trigeminal nerve VI- Abducens nerve VII- Facial nerve VIII- Vestibulocochlear nerve IX- Glossopharyngeal nerve X- Vagus nerve XI- Accessory nerve XII- Hypoglossal nerve

These allow the brain to connect to send and receive signals from the rest of the body.

- Can then move onto the other skulls - discuss the features of the skulls and how these relate to the demands that the animal has to cope with in its environment. Why might the adaptations help the animal to succeed in its environment/why might the animal have developed these skull features? You might want to discuss each skull in turn, or you may prefer to talk about a particular 'theme' i.e. teeth, brain size across a number of skulls at once
- Allow the students to handle skulls so they can feel how delicate/sturdy they are
- Note that delicate skulls have a small piece of red gaffa on their boxes - only let children handle these if you think they will be careful enough with them!

Basic information about the skulls is as in the regular explanation. Extra things to mention for CHaOS+ are:

TEMPOROMANDIBULAR JOINT

This is the 'jaw joint between the cranium and the mandible. In carnivores it is quite limited to a dorsoventral hinge movement (in badgers the lower jaw is so firmly hinged that it cannot be detached). In contrast, in herbivores there is much lateral grinding movement as well. The temporomandibular joints each contain a disk similar to the menisci of the stifle, and like the menisci, the disks may help to partition the movements of the jaw joint into compartments (hinge-like between disk and mandible, translation between disk and skull)

It may also be helpful to draw out these comparative anatomy points from domestic breeds:

1. Cat: Note the domed cranium, huge orbits and short snout.
2. Pig: exhibits dramatic specialisation for rooting It is extremely tall caudally for the attachment of strong neck muscles. Also, in life there is an extra bone in the snout - the os rostri

3. Ruminants: Have distinctively domed crania, although this may be obscured by the horns . The horns are frontal in position in sheep and goats and more temporal in cattle. Also, the ruminant basi-cranial axis appears rather â€˜bentâ€™. There is no alar canal for the maxillary artery in ruminants. The nasal bones often fall off.

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4. Horse: Extremely long and the origin of the jaw muscles is extended cranially from the zygomatic arch by the long facial crest . There is a supraorbital foramen dorsal to the eye through which passes the supraorbital artery (used for arteripuncture) and supraorbital nerve (used for nerve blocks).
5. Rabbit: Extremely delicate skullsâ€“ sometimes the occiput falls off, which is the bones at the back part of the skull

Risk Assessment

Hazard: Teeth or beaks.

Description: Some skulls have sharp teeth or beaks, which can cut/stab children and demonstrators.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Remind children to handle skulls carefully; in particular, be careful not to pinch fingers/hands in the jaw.

Demonstrator should visually inspect skulls before use - any skulls with sharp edges may need to be smoothed off or replaced.

Call first aider in event of incident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Shattered skulls

Description: If dropped, skulls may fall on feet or shatter, causing cuts and other injuries.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrator only have a few skulls present at a time to minimise risk of children picking up or playing with skulls. Demonstrator to keep an eye on anybody holding skulls. If a skull smashes, clear it up immediately with dustpan and brush. Any damaged skulls with sharp edges should be repaired as soon as possible - demonstrator should notify committee if this is needed.

Call first aider in event of injuries.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Unsanitary skulls

Description: Possible infection risk from bone if skin is cut by touching the bone.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: We have boiled the skulls we found in bleach for a few hours to sterilise them. Please note, however, this does not necessarily mean that the skulls are completely sterile now. One could give the skulls a gentle clean with disinfecting wipes if they're on hand.

Call first aider to properly dress and sterilise wounds. Warn parents of the possibility of infection if a child does cut him/herself on the skull. Advise parents to take child to a doctor if the cut looks infected.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

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Anti-bubbles

Make fascinating bubbles which rather than floating on water actually sink.

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Physics

Equipment Needed

- A small transparent tank or a large clear bowl
- Some washing up liquid
- A wash bottle or a washing up liquid bottle
- Salt

Experiment Explanation

Description taken from Dave's Naked Scientist write-up:
http://www.thenakedscientists.com/HTML/content/kitchenscience/exp/bubbles-that-sink-antibubbles/

What to Do

Add 3-4 tsp of salt into the wash bottle, or rather more into a washing up liquid bottle and then top it up with water.

Add some washing up liquid into the tank of water - probably 2-3 times stronger than normal washing up water.

Clear any bubbles from the top of the tank.

Drip the saltwater from the wash bottle onto the top of the tank from 5-10cm above and look at the bubbles being formed on the surface. Are they all the same?

Now do the same thing looking into the side of the tank, for a couple of hundred drops, does anything interesting appear?

What may Happen

On the top mostly you will produce normal drops, but sometimes you will see what look like bubbles but if you look closer they reflect light much better and they have far more momentum skittering across the surface. If you look from the side you sometimes see bubbles which actually sink rather than float.

What is going on?

You are creating what are known as antibubbles. A conventional bubble is air surrounded by a thin film of water in air, an antibubble is the other way around, water surrounded by a thin film of air in water. Both types of bubble are highly unstable in pure water because water molecules attract one another very strongly and try to minimise the surface area of the liquid. Detergent molecules have one end which is very attracted to water and a long oily tail which is repelled by it. so they cover the surface of the bubble stabilising it.

The air in an antibubble will cause it to float gently so they would be hard to tell from conventional bubbles. The salt weighs them down so they sink and you can tell the difference.

The antibubbles seem to form best when they are dropped onto water that is falling so the impact is less violent.

Risk Assessment

Hazard: Liquids

Description: Slips and falls as a result of spillages. Electrical risks if the liquid spills on nearby electrical equipment.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Clear up any spillage immediately. Have mops or paper towels ready. Ensure there are no electric components on ground near the experiment. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Bubble mixture

Description: Damage to eyes as a result of contact with the mixture. Ingestion of the bubble mixture resulting in illness or allergic reaction.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Try to keep children under control. Demonstrator should show effect unless group are very calm and should take bottle away if child shows signs of getting excitable. Do not allow very young children to hold the bottle. Call a first aider in the event of an accident. If the salt mixture from the dropping bottle, or washing up water from tank, gets into an eye, demonstrator must call a first aider and may perform an eye wash if trained and confident to do so. If ingestion occurs, get child to drink a glass of water. If liquid gets on skin, check about allergies.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

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Arch Bridge

Building an arch bridge, and then walking over it. - Can you build a bridge strong enough to walk on?

Last initially checked on 2023-01-14 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2022-01-14 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- Bridge Base (flat board and two triangular pieces, they attach together with wing nuts)
- 5 Blocks (all the same)
- 2 wooden supports (scaffolding to assist the building process) - MISSING SINCE 2019

Experiment Explanation

Overview:

This is an arch bridge built of 5 identical blocks, which the children can then walk over.

Possible activities:

1. Build bridge.
2. Walk over it.

Other things to talk about: Forces on blocks.

Tips for demonstrating: The blocks are quite heavy for small children, so you may need to lift them for them/get parents to help. Don't let them jump on the bridge/too many on at once - jumping off sideways may cause the bridge to fall to the side, too many children on at once may push each other off.

Basic procedure and explanation:

To build the arch bridge, get the children to place the wooden supports between the ends of the bridge (say there like the scaffolding used around the edge of buildings or under bridges), then get them to add the blocks, starting at the ends. If they have trouble working out which way round to put the blocks try showing them the trapezium shaped side of the block. Ask them whether the longer or shorter side needs to go on top to make the arch shape.

Check that the blocks are all lined up straight and that the tops of the blocks all meet. Ask them what will happen when you take the wood away - will the bridge stay up? Why?

Take the wood away - the bridge stays up! Talk about how the shape of the brick means that they are being squashed in from the sides ('in compression') and they can't fall down. Ask if they think the bridge is strong enough for them to walk over (subtly check that the bridge is sturdy first) - take care that they don't fall when they do this.

When the child is standing on the middle of the bridge, ask them what is stopping them from going straight down. Depending on the child's age, could talk about the force of their weight, and explain how it is pushed out sideways and that it is because the ends of the bridge cannot move away from one another that they don't fall down.

Explain that this is how real arch bridges work - the mortar 'gluing' the bricks together isn't very important, all the strength is due to the bricks being squashed together horizontally. Bricks are strong in compression, but no good in tension.

It can be useful to ask the children how the other blocks would have to move to allow one of the blocks to fall, to get them to see the arch as a lot of wedges jammed in between the piers. Very wide stone arches have a tendency to force apart their piers and collapse.

Risk Assessment

Hazard: Blocks

Description: May fall on feet and injure people.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Blocks are designed to be fairly light and covered with rubber. Demonstrators may need to help younger children carry the blocks. When taking apart ensure feet are sufficiently far back.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Bridge Collapse

Description: Bridge may collapse due to instability. Blocks may become smooth over time and slip against each other causing bridge collapse. Could result in people falling off bridge or being hit by falling blocks.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Demonstrators should test the bridge by walking over it before any children do. Children should not be allowed to jump off the bridge sideways, as this may cause the bridge to fall. Blocks should be checked for smoothness at the beginning of the event. Demonstrator should remain vigilant for blocks slipping during the event.

Demonstrator must stop experiment if they suspect that the blocks are getting smooth.

Call first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Blocks

Description: May trap fingers between blocks during construction.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrators may wish to help small humans when placing the blocks. Mention that it is better to hold them across their sides rather than ends.

Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Blocks

Description: Being hit by carried blocks.

Affected people: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Small or overexcited children should be supervised when moving blocks. Demonstrator should volunteer to do it themselves.

Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Built bridge

Description: Children/demonstrator falling off the bridge.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure that the bridge is erected somewhere the floor is flat, with no sharp corners or objects to fall on. Don't let kids jump up and down on the bridge (both because the blocks can slip and the child can fall off). Children should only go on the bridge one at a time. Don't let children crawl under the bridge. Demonstrator to check the bridge is stable before allowing children to stand on it.

Call first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

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Articulated Knee Model and Tendon Hammer

A spare plastic skeleton leg, now with added ligaments. - Come and see the complexity behind how your knee works!

Last initially checked on 2023-01-20 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-01-31 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Plastic skeleton leg with rubber ligaments
- Tendon hammer

Experiment Explanation

Articulated Knee Model

!!!CURRENTLY BROKEN!!!

- See the Skeletons explanation for things to discuss about bones - e.g. why they are needed (support, movement, protection).

Ideas for What to Do:

- As always, first get the kids to tell you what it's a model of (the leg) and work out what the joints are etc.
- Talk about bones and skeletons (see above).
- Perhaps start with looking at the ankle (or even another spare bit of skeleton) and ask the kids what's different about this model compared to their real leg (there are lots of bits missing - you are not held together with screws!)
- Ask them if they know what holds the bones together in the body (ligaments - could compare these to tendons attaching muscle to bone if they've had a look at the giant hand model). Ask them if they have heard about ligaments before (they may have heard of injuries to cruciate ligaments etc. - ACL tear is a common injury to occur to footballers)
- The model shows the patellar ligament, anterior and posterior cruciate ligaments, and medial and lateral collateral ligaments. It also has the quadriceps tendon, which is not attached at the proximal end because it's a tendon not a ligament and attaches to the quadriceps muscle. You could perhaps flex the knee and get the kid to 'be' the quadriceps, pulling on the tendon to straighten the leg. You could talk about the location of the patella (kneecap) and how it is a vital component in how the knee works mechanically.
- Cruciate ligaments - could talk about how 'cruciate' means 'crossed', let them look at how the ligaments cross within the joint. They may well have heard of these being injured in skiing or something.
- Anterior cruciate - limits anterior draw of tibia on femur, tight in extension, tested by pulling the tibia forwards. You could perhaps show how, if it was ruptured, the tibia would move excessively far forwards.
- Posterior cruciate - limits anterior slide of femur on tibia, tested by pushing tibia backwards, used on hills and stairs (so if you've ruptured it, you cannot walk down stairs as the femur will slide too far forwards on the tibia).
- You could also talk about what else is missing from the model - evidently there are lots more tendons and muscle attachments, and also the medial and lateral menisci helping to shape the articulating surfaces (again they may have heard of these in the context of sporting injuries).

Tendon Hammer

ACTIVITIES

- Try to demonstrate some common reflexes

THINGS TO TALK ABOUT:

- What is a reflex? (see below)
- Why do we have reflexes (here you could talk about reflexes in general i.e. blinking) - reflexes are there to protect us
- Why would we want to test reflex action? By testing reflexes, doctors can find out if there is nerve damage etc.
- Do they know what any of the reflex tests are?

TIPS FOR DEMONSTRATING:

- It is often difficult to show the reflexes on the kid. A good idea is to try it out on yourself first. If all else fails, you could try to demonstrate some other reflexes; i.e. demonstrate blinking; demonstrate the pupil reflex (get one kid to close their eyes for a bit and then open them; does the pupil size change?) - you can have one kid doing it whilst the others watch and then swap, so everyone gets to see them

BASIC PROCEDURE AND EXPLANATION:

- Getting the reflexes to work can often be tricky. Try to find them on yourself/one of the other demonstrators first. (Hitting a bit harder often also helps.)
- If in doubt, ask a committee medic to show you how to elicit different reflexes.

These are some of the reflexes you could try:

Arm:

1. Biceps: put your thumb on distal bicep tendon and tap that.
2. Supinator: Put your finger their forearm (distal radius over the supinator muscle) and tap it.
3. Triceps: bend their arm and tap distal tricep tendon.
4. finger: Lay their fingers over your index finger and tap your index finger.

Leg:

1. Knee: get them to cross their legs and tap the patella tendon.
2. Ankle: Sit them on high ledge (if you have one), dorsiflex the foot and tap the achilles tendon.
3. Babinski's: if they've got shoes that are easy to take off, run your finger up the lateral side of their sole.

Most of these won't work in kids, because they don't relax. You could try reinforcement:

- Upper limbs: get them to grit their teeth.
- Lower limbs: Get them to clasp their fingers together and pull.
- NOTE: reinforcement only works for a very short period of time so you must do it at the same time as you bang the reflex.
- If you can't get a reflex there's no point bashing away at the same limb, because your chance of getting decreases each time - try the other limb.

EXPLAIN WHAT A REFLEX IS:

a. Start with nerves: wires that carry messages from body to brain (SENSORY) and brain to body (MOTOR). If the kids are small, you can say it's a bit like a telephone line - messages travel from one phone to another.

b. There are some things we need to do so quickly that we haven't got time to send messages to and from our brain.

- Can they think of any?
- Use the example of blinking when something goes near eye.
- We also have reflexes in our arms. What do we need those for?
- Ask them if they've ever touched anything that's very hot.
- We also need reflexes in our legs, why?
- Ever stepped on something sharp.
- So we have reflexes to protect us
- Balance?
- Posture - what keeps us upright? Lots of muscles! If we sway forwards some of our muscles pull us back without us having to think about it
- (Also note in both cases the reflexes stop the tendons being stretched too far)

OTHER THINGS TO TALK ABOUT:

This usually works better if the kids are a bit older:

- Why does a doctor want to test your reflexes
- Get them to think about nerve damage and how you could assess that
- Usually asking is a good idea (i.e. can someone feel something, see if they can move their arm etc.)
- However, what do you do if someone can't talk and doesn't move (i.e. in an accident when someone is unconscious)

- Can then test if reflexes still work (i.e. doctors have pocket lamps; they can test the pupil reflex in an unconscious patient)**

Risk Assessment

Hazard: Protruding parts

Description: Poking injury from protruding parts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure children do not go too near protruding parts; use tape to cover up the more dangerous parts of the skeleton.

Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Joints

Description: Finger trap between bones (e.g. joints).

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure children do not put fingers between bones, and ensure that leg is in a stable position when they do touch it.

Call a first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Leg

Description: Leg is surprisingly heavy and could cause injury.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Do not leave the leg where it may fall on someone.

Call a first aider in the event of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Tendon hammer and leg

Description: One end of the hammer tapers to a point - risk of getting into eyes. Also these items may generally be used inappropriately as weapons.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not let children use tendon hammer or leg without supervision, don't let them get boisterous and over-excited with these items.

Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Improper hammer use

Description: Risk of bruising if used with excessive force.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Use medics who have been taught how to use the hammer, or someone who has been shown by a committee medic how to use the hammer. Do not use tendon hammer with excessive force.

Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2012-01-05 - Ashley Smith (ashley.smith@cantab.net), **Check 2**: 2012-01-25 - Daniel Obute (rdo23@cam.ac.uk)

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Blood Glucose

Learn about diabetes and try using a handheld blood glucose meter.

Last initially checked on 2023-01-29 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Blood glucose meter
- Test strips (these are expensive, use with care!)
- 100mM stock glucose solution
- Syringes
- 20ml universal tubes
- Water
- Plastic dropper pipettes

Experiment Explanation

In a nutshell:

Use the handheld glucose meter to test the glucose concentration of different solutions (in place of blood). Many children will know someone who has diabetes but may not have had the chance to look at the equipment they use. Use this opportunity to let them investigate, and talk about the different types of diabetes and how it affects lifestyle.

How to set up the experiment:

Make up bottles of a variety of glucose concentrations using the syringes to measure out 100mM stock solution for dilution. Aim for solutions with concentrations of approximately 2 (hypoglycaemic), 5 (normal fasting), 7 (normal post-meal, diabetic fasting), 12 (diabetic post-meal), and 25 (approaching ketoacidosis). I normally only use two different solutions though to conserve the testing strips (a normal one and a diabetic one). You may then wish to hide the numbers on the bottles, depending on how you wish to demonstrate! Talk about diabetes in general. Use the charts to explain how blood glucose varies throughout the day and how this differs in diabetes. You could then get the children to choose one glucose solution and test the concentration, then work out what situation this reading is likely to have arisen in. You could also talk about the pancreas, its role in regulating glucose levels, and the actions of insulin and glucagon (this may also lead on to a discussion about hormones).

USING THE METER - this is very simple. Press the large on button and insert a new single-use test strip. Apply a tiny drop of solution to the end of the strip â€“ not on top of the flat part, but poking the thin end into the droplet so it can be drawn in to the capillary. It may be easiest to do this by placing a small droplet of the solution onto the childâ€™s (clean â€“ this isnâ€™t going to work if theyâ€™re covered in chocolate) finger/back of hand and then poking the test strip in to it as if it were a real drop of blood.

Background information:

Diabetes Mellitus (from Wikipedia)

Diabetes mellitus, or simply diabetes, is a group of metabolic diseases in which a person has high blood sugar, either because the pancreas does not produce enough insulin, or because cells do not respond to the insulin that is produced. This high blood sugar produces the classical symptoms of polyuria (frequent urination), polydipsia (increased thirst) and polyphagia (increased hunger). The cause of the polyuria is simply osmotic diuresis â€“ the glucose content of the blood is so high that it cannot all be reabsorbed by the renal tubules and thus glucose is excreted in the urine. This increases osmotic pressure in the tubule, causing retention of water and thus high volumes of urine. There are three main types of diabetes mellitus (DM).

- Type 1 DM results from the body's failure to produce insulin, and currently requires the person to inject insulin or wear an insulin pump. This form was previously referred to as "insulin-dependent diabetes mellitus" (IDDM) or "juvenile diabetes".
- Type 2 DM results from insulin resistance, a condition in which cells fail to use insulin properly, sometimes combined with an absolute insulin deficiency. This form was previously referred to as non insulin-dependent diabetes mellitus (NIDDM) or "adult-onset diabetes".
- The third main form, gestational diabetes occurs when pregnant women without a previous diagnosis of diabetes develop a high blood glucose level. It may precede development of type 2 DM.

Type 1 diabetes

Type 1 diabetes mellitus is characterized by loss of the insulin-producing beta cells of the islets of Langerhans in the pancreas, leading to insulin deficiency. This type can be further classified as immune-mediated or idiopathic. The majority of type 1 diabetes is of the immune-mediated nature, in which beta cell loss is a T-cell-mediated autoimmune attack. There is no known preventive measure against type 1 diabetes, which causes approximately 10% of diabetes mellitus cases in North America and Europe. Most affected people are otherwise healthy and of a healthy weight when onset occurs. Sensitivity and responsiveness to insulin are usually normal, especially in the early stages. Type 1 diabetes can affect children or adults, but was traditionally termed "juvenile diabetes" because a majority of these diabetes cases were in children.

Type 2 diabetes

Type 2 diabetes mellitus is characterized by insulin resistance, which may be combined with relatively reduced insulin secretion. The defective responsiveness of body tissues to insulin is believed to involve the insulin receptor. However, the specific defects are not known. Diabetes mellitus cases due to a known defect are classified separately. Type 2 diabetes is the most common type. Type 2 diabetes is a risk factor associated with 'lifestyle' problems such as obesity.

Diabetic Emergencies

People (usually with type 1 diabetes) may also present with diabetic ketoacidosis, a state of metabolic dysregulation characterized by the smell of acetone, a rapid, deep breathing known as Kussmaul breathing, nausea, vomiting and abdominal pain, and altered states of consciousness. It occurs when the body breaks down lots of fat to fuel cells as glucose cannot enter them. In ketoacidosis the pH of the blood rapidly drops which affects a variety of bodily functions.

Diagnosis

- Fasting plasma glucose level â‰¥ 7.0 mmol/l (126 mg/dl)
- Plasma glucose â‰¥ 11.1 mmol/l (200 mg/dL) two hours after a 75 g oral glucose load as in a glucose tolerance test
- Symptoms of hyperglycemia and casual plasma glucose â‰¥ 11.1 mmol/l (200 mg/dl)

Pancreas

The pancreas is a glandular organ in the digestive system and endocrine system of vertebrates. It is an endocrine gland producing several important hormones, including insulin and glucagon which circulate in the blood. Insulin is a peptide hormone, produced by beta cells of the pancreas, and is central to regulating carbohydrate and fat metabolism in the body. It causes cells in the liver, skeletal muscles, and fat tissue to absorb glucose from the blood (thus lowering blood glucose levels). Glucagon is a peptide hormone secreted by the pancreas that raises blood glucose levels. Its effect is opposite that of insulin.

Treatment (from diabetes.org.uk)

Insulin is used to treat type 1 diabetes, and only used in type 2 diabetes when other, non insulin based treatments, have failed. There are six main types of insulin:

- Rapid-acting analogues can be injected just before, with or after food and have a peak action at between 0 and three hours. They tend to last between two and five hours and only last long enough for the meal at which they are taken. They are clear in appearance.
- Long-acting analogues tend to be injected once a day to provide background insulin lasting approximately 24 hours. They don't need to be taken with food because they don't have a peak action. They are clear in appearance.
- Short-acting insulins should be injected 15â€“30 minutes before a meal to cover the rise in blood glucose levels that occurs after eating. They have a peak action of twoâ€“six hours and can last for up to eight hours. They are clear in appearance.
- Medium- and long-acting insulins are taken once or twice a day to provide background insulin or in combination with short-acting insulins/rapid-acting analogues. Their peak activity is between four and 12 hours and can last up to 30 hours. They are cloudy in appearance.
- Mixed insulin â€“ a combination of medium- and short-acting insulin.

- Mixed analogue â€“ a combination of medium-acting insulin and rapid-acting analogue. Historically, people would have taken two doses of short-acting insulin and had to tailor their diet around it, eating specific quantities of food at specific times. Now, most people take a long-acting insulin once per day and then rapid acting insulin every time they eat, calculating the dose against the amount of carbohydrate in their food. This means more injections, but much greater freedom in eating.

What about insulin pumps?

These are increasing in popularity. They are small electronic pumps which are clipped to the waistband and have a narrow tube with a small plastic cannula inserted into the subcutaneous tissue in the abdomen (this set is changed every few days). They allow a constant infusion of insulin with â€˜bolusesâ€™ added at the press of a button on eating. They allow freedom in choice and timing of food, but some people find them restrictive because of the tubing and the device clipped to the belt.

Is this the same as an â€˜artificial pancreasâ€™?

Not quite â€“ itâ€™s sort of half of one! The aim of an â€˜artificial pancreasâ€™ is to monitor blood glucose levels and respond to this by alteration of insulin infusion â€“ i.e. a closed unit where the user does not have to have any input themselves and without having to do finger-prick blood glucose tests. One of the major difficulties in this is devising a way of monitoring glucose levels in the body.

Canâ€™t we test real blood?

No! Good opportunity to talk about blood-borne diseases, blood and sharps safety.

Risk Assessment

Hazard: Spillages

Description: Slip hazard.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: All spills should be cleared up immediately. Call first aider in case of injury. Use wet floor sign if necessary.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Fake blood

Description: Feeling faint at sight of fake blood.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Red food dye is used, rather than realistic fake blood. Remind people that the blood isn't real and ask them to tell you if they feel faint. Chair nearby for light-headed-feeling people (although asking them to sit on the floor is better - fainted people fall off chairs). In case of faintness, ask person to sit or lie down and remove fake blood from line of sight. In case of injury call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2014-01-06 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-22 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-06 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2015-01-21 - Jessica Gorman (jrg63@cam.ac.uk)

Check 1: 2016-01-05 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2015-01-14 - Jessica Gorman

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Blood Groups

Why are blood groups important? - What are 'blood groups'? Why is it important to match blood groups for transfusion? Find out with our colourful demonstration.

Last initially checked on 2023-01-29 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Red and blue food colouring
- Plastic droppers
- 20ml Universal containers
- 4 well plates
- Water
- Laminated cells and antibodies â€“ A antigens are red and triangular, B green and semi-circular, RhesusD orange and squarish. The antibodies have corresponding shapes.

Experiment Explanation

In a nutshell:

Talk about different blood groups and why it is important to match blood for transfusion. Demonstrate how different blood groups are compatible using the food colouring, and use the laminated cells and antibodies as props for explanation.

How to set up the experiment:
Make up some A, B, AB and O â€˜bloodâ€™ in the universal containers as follows:

- A: 2 drops red food colouring in 20ml water
- B: 4 drops blue food colouring in 20ml water
- AB: 2 drops red and 4 drops blue colouring in 20ml water
- O: water

Take four 4-well plates and lay them out in a square. Put about 1ml of A blood in each of the 4 wells in the first column, 1ml of B in the second, 1ml of AB in the third and 1ml of O in the fourth column. These represent the recipient blood.
You can then get the children to add about 4 drops of each blood type from the 20ml tubes to each of the types in the plates (so add 4 drops of A to each of the wells in the top row, 4 drops B to each in the second row etc). These represent the donor blood.
It is worth testing this at first to check that your colouring concentrations give the results that you want! The idea is that if the colour of the â€˜bloodâ€™ in the well changes, the blood groups are incompatible. If it doesnâ€™t change, they are compatible. For example, adding B (blue) blood to AB (purple) will not cause a colour change, but adding B to O (clear) will.

The laminated cells and antibodies can be laid out in areas corresponding to each blood group. The contents of one area can then be transferred into another area (a transfusion) and any matches between the antibodies/antigens observed.

Background information:
(From www.blood.co.uk)
The most important blood groups in transfusion are the ABO blood group system and the RhD blood group system. Blood groups are determined by a protein (antigen) on the surface of the red cell. So, the ABO system has A and B antigens and the RhD system has the D antigen.
In all, there are 30 major blood group systems. This means a person may be A RhD positive, and at the same time Kell (Kell system) positive, M and N (MNS system) positive and Lea and Leb (Lewis system) positive.

The ABO blood group system
Blood group A - you have got the A antigen on your red cells
Blood group B - you have the B antigen
Blood group O - you have neither antigen
Blood group AB - you have both A and B antigens
The ABO system has associated anti-A and anti-B antibodies, antibodies being the body's natural defence against foreign antigens. These antibodies are found in the plasma.
Blood group A will recognise the B antigen as foreign and can make anti-B antibodies against the B antigen.
Similarly, blood group B will recognise the A antigen as foreign and can make anti-A antibodies against it.
Group AB has both the A antigen and the B antigen so this group makes no antibodies.
Group O has neither A nor B antigen so blood from this group can be given safely to any other group. This is why Group O donors are known as "universal donors". Group O individuals can make both anti-A and anti-B antibodies if exposed to these antigens so can't receive blood from either.
Giving someone blood from the wrong ABO group could be life-threatening. For instance, the anti-A antibodies in group B attack group A cells and vice versa. This is why group A blood must never be given to a group B person.

For transfuions of packed red blood cells (so no antibodies transferred as these are in plasma):

- AB individuals - RBCs have both A and B antigens and blood plasma does not contain antibodies against A or B. Can therefore receive blood from any group (**universal recipients**), but cannot donate blood to either A or B group
- A individuals - RBCs have A antigen and blood plasma has anti-B IgM antibodies. Can therefore receive blood from group A or group O individuals (A is preferrable), and can donate blood to group A or group AB individuals
- B individuals - RBCs have B antigen and blood plasma has anti-A IgM antibodies. Can therefore receive blood from group B or group O individuals (B is preferrable), and can donate blood to group B or group AB individuals
- O individuals - RBCs don't have A or B, but blood plasma contains both anti-A and anti-B IgM antibodies. Can therefore only receive blood from group O individuals, but can give blood to any ABO group (A, B, O, or AB group) - are **universal donors**
  If a patient in a hospital situation were to need a blood transfusion in an emergency, and if the time taken to process the recipient's blood would cause a detrimental delay, O Negative blood can be issued

What about plasma?
Plasma is the liquid component of blood that doesn't contain any cells. Recipients can receive plasma of the same blood group, but otherwise the donor-recipient compatibility for blood plasma is the converse of that of RBCs - plasma extracted from type AB blood can be transfused to individuals of any blood group because it won't contain any antibodies against A or B antigens; individuals of blood group O can receive plasma from any blood group; and type O plasma can be used only by type O recipients.

The RhD system
Another important blood group system in transfusion is the RhD system.
85% of people have the D antigen on their red blood cells and are RhD positive.
The remaining 15% lack the D antigen and are RhD negative.
Your blood group is defined by your ABO group together with your RhD group. For instance, someone who is group A and RhD negative is known as A negative.

| ABO Blood Group | Rh(D)Type | Percentage of Population with this Group | |---|---|---| | O + | Pos | 37% | | O - | Neg | 7% | | Total Blood Type O | 44% | | A + | Pos | 35% | | A - | Neg | 7% | | Total Blood Type A | 42% | | B + | Pos | 8% | | B - | Neg | 2% | | Total Blood Type B | 10% | | AB + | Pos | 3% | | AB - | Neg | 1% | | Total Blood Type AB | 4% | | Total Pos | 83% | | Total Neg | 17% |

Why is the Rhesus system important for pregnant ladies?
Unlike A and B antibodies, RhesusD antibodies are not found in people who are RhesusD negative. Therefore they wonâ€™t react to RhesusD positive blood unless they have already been sensitised. If a RhD- mother has a RhD+ foetus (only possible if the father is RhD+), feto-maternal transfusion may occur during pregnancy/childbirth, causing the mother to produce anti-RhD antibodies. If the mother subsequently has a second Rh+ pregnancy, the anti-RhD antibodies can cross the placenta and cause agglutination and degradation of the red blood cells in the foetus. This causes â€˜haemolytic disease of the newbornâ€™, features of which include enlarged liver, spleen or heart in the foetus and anaemia, jaundice, enlarged organs and difficulty breathing in the newborn. To prevent this, RhD- mothers can be given IgG anti-D antibodies by intramuscular injection. These antibodies then cause destruction of foetal RhD+ blood cells before the maternal immune system can react to them. These are administered at 28 weeks of pregnancy, sometimes 34 weeks and within 72 hours of birth. This is passive immunity and wears off after 4-6 weeks so treatment is required with each pregnancy.

Why do people have antibodies against the A and B antigens if they donâ€™t have those antigens themselves?
It's thought that blood groups are very similar to some bacterial/food sugars which act as antigens so you get cross reactivity. Because ABO antigens are expressed quite widely in tissues (all endothelium and all epithelial cells, and other cell types express the H antigen which is a precursor and can still react with antibody) your natural tolerance

mechanisms kick in to protect the sugar you do have, but obviously not to the ones you don't.

How can blood group be used to determine paternity?
BE CAREFUL discussing this! **Do not ask the parents for their blood groups!**
From www.transfusion.com.au:

The ABO blood group system is determined by the ABO gene, which is found on chromosome 9. The four ABO blood groups, A, B, AB and O, arise from inheriting one or more of the alternative forms of this gene (or alleles) namely A, B or O.

Blood group Possible genes:

- A - AA or AO
- B - BB or BO
- AB - AB
- O - OO
  The A and B alleles are codominant so both A and B antigens will be expressed on the red cells whenever either allele is present. O alleles do not produce either A or B antigens, thus, are sometimes called â€˜silent' alleles.

ABO Inheritance Patterns

| Parental blood groups | Child's blood group | |---|---| | O and O | O | | O and A | O or A | | O and B | O or B | | O and AB | A or B | | A and A | A or O | | A and B | O or A or B or AB | | A and AB | A or B or AB | | B and B | O or B | | B and AB | B or A or AB | | AB and AB | A or B or AB |

Risk Assessment

Hazard: Spillages

Description: Slip hazard.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: All spills should be cleared up immediately, get children to be careful using pipettes. Call first aider in case of injury. Use wet floor sign if necessary.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Fake blood

Description: Feeling faint at sight of fake blood/ discussion of blood.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Remind people that the blood isn't real and ask them to tell you if they feel faint. Chair nearby for light-headed-feeling people (sitting on the floor may be better as people can still faint off chairs) - ask them to sit down and remove 'blood' from line of site. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

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Brain Model ft. Pipecleaner Neurons

Anatomical model of the brain and making model neurons from coloured pipe cleaners! - Have you ever wondered what the brain looks like and what it's made of? Come and discover the structure of the brain and the different functions each part has, as well as making your own brain cells out of brightly coloured pipecleaners!

Last initially checked on 2023-02-05 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-02-10 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Brain Model
- Pipe cleaners - some full-length, others 1/3 length (cut using wire snips *caution - keep these hidden when demonstrating as they're very sharp!*)

Experiment Explanation

Brain Model:

Anatomical model of the brain split into several parts.
Shows the different parts of the brain.

Take care with age of kids! If they've never heard of nerves... take it easy (and introduce them using pipe cleaner neurons)
If they're the interested get them to ask you questions, its more fun for them...
DO NOT try and cover all of these or you'll only have the parents listening. If even them...

At the end get the kids to put it together again, amazingly they like it. When they get stuck ask them which bit does this? To see if they've remembered anything before telling them what bit they need to put in next.

This is the sort of things you could say/ might come up:

- Brain is made up of nerves - what are nerves? E.g. say they're like telephone systems from the body to the brain and vice versa (often they'll only know they're involved in pain etc so expand on that). Think about the spinal cord and what happens if it gets damaged. If you've used the tendon hammers remind them of that too.
- Cortex - really big, like newspaper scrunched up around an orange or something. Unfolded cortex is about 3 sheets of A4 (think for a lizard it's size of a postage stamp). Different bits control movement, sensation, vision, etc. Get them to guess where senses are on the cortex by relation to the sensing organ (will usually get vision wrong because they won't know that nerves go from front to back of the cortex). Also concept of contralateral control of movement, sensation etc. Neocortex - another name to do with recent evolution.
- Could mention prefrontal cortex and explain it using Phineas Gage - America 100 years ago, blowing up mines, accident with a metal pole shooting into his head embedded in his prefrontal. Perfectly normal after accident except before was nice and kind bloke, after was mean and quick to anger. Hence to do with personality, especially controlling anger.
- Can talk about Wernicke's (understanding language) and Broca's (producing language) areas - could talk about the English pilot who was gunned down sustaining damage to Wernicke's area so that he couldn't understand the English doctors and nurses, leading him to believe he had been captured by the Nazis.
- Also could talk more about visual bits, different areas that are important for different things like seeing colour, motion, peoples faces etc. So what happens if these parts get damaged?
- Corpus callosum - is it on the left, right or middle? What might it do then? In the middle so allows signals to go between hemispheres. Talk about patients who had their corpus callosum split as experimental surgery for epilepsy - they got Alien Hand Syndrome where one hand would act seemingly on its own as it was not 'communicating' with the other side of the body. They would even have times where one hand would suddenly grab the other to stop it doing something.
- Basal ganglia - they're to do with emotion and starting movements. Parts degenerate in Parkinson's Syndrome -

could mention Muhammad Ali or Michael J Fox as examples. Ask them what problems they have. Explain by talking about how one bit increases movement and another dampens/decreases movement. In normal people it is balanced, in Parkinson's decreasing of movement is too strong hence shaking. Opposite is Huntington's Disease. Also mention that if Parkinson's patient was in burning house, he/she would be able to run out of it and if walking across a street and about to be run over would be able to jump out of the way because the brain finds an alternate pathway in an emergency, bypassing basal ganglia, for quicker actions. Parents might ask about treatment, mention L-DOPA and also stem cells for dopamine receptors.

- Insula - pain perception (if they look interested in that sort of thing). Gating theory, i.e. can modulate pain signals released from nerves endings at the level of the brain through opiate nerves from insula that release morphine onto nerve endings. Example is when you play football and cut yourself but don't notice the pain till after the game is finished all due to attention being focused elsewhere on the game. Touch neurons feed into the opiate neurons, inhibiting pain, which is why rubbing a banged elbow makes it hurt less.
- Cerebellum - monitors all our movement and helps correct errors, balance (get them to think about how unstable we are because we stand on only 2 feet - we have a large cerebellum compared to other mammals). Also movement memories - make it relevant to them e.g. what happens if you practice a sport or a musical instrument (you improve). Hand eye coordination when you play computer games or play tennis - don't have to look at your hands but you learn to control them.
- Explain about cerebellar ataxia and overshooting and not being able to touch your nose with your finger when your eyes are closed. Get them to try - normal people can do it, but with a cerebellar injury, you can't touch end of your nose and will just poke yourself in the eye - gets a giggle. Cortex the area of tea towel but some cells have the surface area of a door (purkinje fibres) - make lots of connections to talk to other neurons.
- Hippocampus - makes new memories but not to do with storage - kids always ask where memories are stored - truthfully no one knows for sure but all over the place depending on what kind, eg. episodic, motor, semantic. Mention Dory from Finding Nemo, ask them to explain what is wrong with her and relate that to hippocampal damage. Also can mention HM - damage to an area that included the hippocampus and got mild retrograde amnesia (forgetting things that happened) and severe anterograde amnesia (can't make new memories). One famous story was when a psychologist met him for the first time he attached a pin to his hand so when they shook hands the pin spiked HM. The next day, HM met the psychologist again and couldn't remember meeting him before, but knew that he didn't want to shake his hands. This shows how memories (remembering the event that happened) are different to associations (knowing that shaking this man's hand would be bad)
- Pons, Medulla and Brainstem - things really essential for basic life that we donâ€™t have to think about like breathing, heart beating (heart beats by itself but needs the brain to regulate speed), eye movements, chewing etc? So what happens if this bit gets damaged? Can talk about Mike the headless chicken - had head chopped off below the main part of his brain but above the brain stem and survived for a further 18 months with his owners pouring food and water down his oesophagus.

Other FAQs!

- How does our brain work? (great...)

Having explained about how nerves help your brain to communicate with the rest of the body, explain that the brain itself is made up of lots of little ones all talking to each other. We get all this information in from our senses, then these little nerves have a good chat to each other, bit like what's happening when your computer makes a grrring noise (!), and then they make decisions about what we are going to do, and act on them by controlling our muscles to move us around/speak etc.

- How/why do we dream?

What is a dream? A dream includes any images, thoughts and emotions that are experienced during sleep. No one knows for certain why we dream. Some theories: 1) dreams help us process all the information we have encountered in the day 2) they are involved in how we form memories 3) that they represent your emotions 4) that they are pointless

- What are all the red bits?

On our model it shows the arteries etc. This can be a good talking point - why does our brain need blood? What happens if parts of it do not get blood any more (often they've heard of strokes etc. because of grandparents or something)?

Pipecleaner neurons:
This is a great way to explain the basic concepts of what nerves are and what they do. You'll be getting the kids to make a simple neuron from different coloured pipe cleaners. Each colour will represent a different part of the neuron e.g. cell body, axon, dendrites, myelin sheath!

1. Take one pipe cleaner and roll it into a ball. This is will be the cell body.
2. Take another pipe cleaner and attach it to the new "cell body" by pushing it through the ball so there are two halves sticking out. Take the two halves and twist them together into a single extension. This will be the axon.
3. Take other pipe cleaners and push them through the "cell body" on the side opposite the axon. These are dendrites. These can be shorter than your axon and you can twist more pipe cleaners to make more dendrites.
4. Wrap small individual pipe cleaners along the length of the axon. These will represent the myelin sheath.

5. Wrap another pipe cleaner on the end of the axon. This will be the synaptic terminal.

Background information about neurons:

Our nervous system (which includes the brain and spinal cord, together the central nervous system) is one of the ways we send messages around the body, working alongside hormones (chemicals that travel in our bloodstream). The nervous system uses electricity (but much lower voltages and currents than we use to run lightbulbs!) to transmit these messages.
A major component of the nervous system is the neurons.
Neurons (also called nerve cells) are electrically excitable cells - with information travelling down the axon by shuffling of ions (charged particles).
At synapses (connections with other neurons) chemical transmission is used, with molecules moving between the neurons across the synaptic cleft.

A number of specialized types of neurone exist: sensory neurons respond to touch, sound, light and numerous other stimuli.
They send information from the periphery to the central nervous system.
Motor neurons send signals the other way, from the central nervous system to muscles at the periphery and cause e.g. muscle contractions.

A typical neurone consists of 3 parts: the cell body (soma), dendrites and the axon.
The nucleus ('control centre of the cell' as it's described in schools) is located in the cell body.
Dendrites are lots of branches from the cell body that receive signals from other neurons.
The axon is very thin and conducts electrical impulses away from the cell body, towards the axon termini where the neurone forms synapses with other neurons.
The longest axons in the human body are in the sciatic nerve which runs from the base of the spine to the big toe of each foot! These single cells can be more than a metre long!

In vertebrates, some neurons have axons insulated by a sheath of myelin, formed from Schwann cells.
Along myelinated nerve fibers, gaps (approx a micrometre long) in the sheath known as nodes of Ranvier occur at evenly-spaced intervals (action potentials jump between these sites where ion channels are found in a manner known as saltatory conduction, but this is probably way above the heads of the majority of your audience for this experiment! - essentially myelination makes the messages travel faster by insulating the axons).
Even in vertebrates there are some unmeylinated axons because myelin uses up lots of space and you wouldn't be able to fit enough neurons into our bodies if they all had myelin sheaths - so neurons which need to conduct messages really quickly or that are very long are myelinated.
Loss of myelin from axons is found in people with multiple sclerosis. They get tremors because their axons are not insulated and so impulses move slower than normal and have the potential to 'jump' to nearby neurons within neuron bundles (which make up large nerves such as the sciatic).

Risk Assessment

Hazard: Broken parts of model

Description: If broken, parts could be sharp.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Remove broken models. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Joining sticks

Description: The stick bits that slot into holes on other parts of the model to join it together could cause damage to skin or eyes.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Make sure kids are being sensible with the model. Call a first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Pipe cleaners

Description: Kids getting pipe cleaners in their eyes or swallowing small bits of pipe cleaners. Wire core of pipe cleaner could potentially cause cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Ensure that children are carefully supervised; demonstrator to try to keep all neuron-making activity on the table. Demonstrator should calm down children if they are using the pipe cleaners in an unsafe way.

In case of injury, call first aider. Do not attempt to move anything lodged in the eye.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 4

Hazard: Wire snips

Description: Wire snips are very sharp and could potentially cause cuts.

Affected People: Demonstrator

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Keep wire snips hidden during demonstrating - they're only used to prepare pipe cleaners beforehand so don't need to be out.

In case of injury, call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-05 - Ashley Smith (ashley.smith@cantab.net), **Check 2**: 2012-01-25 - Daniel Obute (rdo23@cam.ac.uk)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

Check 1: 2014-01-06 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-22 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-06 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2015-01-21 - Jessica Gorman (jrg63@cam.ac.uk)

Check 1: 2016-01-05 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2016-01-14 - Jessica Gorman (jrg63@cam.ac.uk)

Check 1: 2017-02-07 - Jessica Gorman (jrg63@cam.ac.uk), **Check 2**: 2017-02-08 - Fiona Coventry (fiona.coventry@cantab.net)

Check 1: 2018-01-27 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2018-02-05 - Esmae Jemima Woods (ejw89@cam.ac.uk)

Check 1: 2019-01-13 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2019-01-24 - Jennifer Simpson (jks61@cam.ac.uk)

Check 1: 2020-01-24 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2020-01-25 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-12 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2021-01-20 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2022-01-14 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2022-02-09 - Margaret Johncock (mllyj2@cam.ac.uk)

Check 1: 2023-02-05 - Emily Wolfenden (elw74@cam.ac.uk), **Check 2**: 2023-02-10 - Jamie Barrett (jb2369@cam.ac.uk)

Bubble Guns

Bubbles - Magical bubbles!!!

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Busking

Floating

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- Bubble Gun (don't keep mix in here)
- Bubble Mix holder (don't throw away)
- Bubble Mix (buy or make and transfer to gun holder)

Experiment Explanation

This experiment is designed to be a quick but attention grabbing experiment for drawing in crowds. There's currently little science involved but it can be linked to other bubble experiments. Firstly ask people what a bubble is? There are lots of things that might be said, however bubbles are a film of water with soap molecules on either side. The hydrophilic head of soap faces into the water and hydrophobic towards air. Whats inside a bubble? In this case air, but can we get other fillings? Co2 bubbles in drinks. What shape is a bubble? Sphere, are they always? What if bubbles meet, you can see this and there's square faces. If they're differently sized then the small one bulges into the big one. Why do bubbles pop? Other than being poked or hitting the floor, do they pop? Try keeping them up by fanning them. Bubbles can also pop through evaporation of the water film. What colour are bubbles? Light reflects on the film, thickness of the water layer affects colour. You can also see reflections in them.

Risk Assessment

Hazard: Bubble mixture

Description: Spillage of bubble liquid is slippery.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Have mops or paper towels ready. Clean up spills immediately, keep lid on any storage containers and stick to small volume storable in the gun. Don't shoot at the floor. Mop up spills and put a wet floor sign up in area if necessary. In case of injury, call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Bubbles

Description: Bubbles can be irritating to eyes, possibly skin irritant.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Use clean water and disinfectant wipes if bubbles touch skin. Don't shoot close to people's faces. Eye wash procedure (call qualified first aider) in the event of contact with eyes.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Bubble gun

Description: Children may mess with gun: playing with the gun, hitting one another etc.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep gun with demonstrator unless confident children will be sensible (maybe OK with older, sensible children). First aider to be summoned in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2018-10-02 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-12-12 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-02-03 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2020-02-03 - Beatrix Huissoon (beh37@cam.ac.uk)

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Bubbly Crystals

Modelling crystals with soap bubbles - Using a raft of tiny bubbles, see how materials are made up of crystals and watch the atoms move when the material is deformed! (Or itâ€™s just fun for little kids to play with the bubbles)

Last initially checked on 2023-01-13 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-01-17 by Jamie Barrett (jb2369@cam.ac.uk)

Frequency of use: 4

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

CHaOS+ (More complex explanations suitable for older children are available)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Materials Science

Requires Water

Equipment Needed

- Black Tray
- Gas Generator (two bottles stuck together with their bottoms chopped off, and a thin tube â€“ made from the insulation of an electrical cable â€“ coming out with some Blu-tack on the end. The upper bottle should be full of rice or something else to weigh it down)
- Base of clear plastic bottle to put gas generator in
- 2 wooden skewers for manipulating bubbles
- Spare tube, rice and Blu-tack
- 7 plastic cups (or other equally-sized round objects)
- Quartz prism (example of a crystal)
- Laminated printouts of figures
- Fairy liquid (consumable) â€“ note that cheap washing up liquid doesn't work very well!
- Kitchen roll (for popping bubbles and cleaning up)
- Requires ~100 ml of water (not included)

Experiment Explanation

This experiment is based on a classic demonstration originally devised (and filmed!) by Sir Lawrence Bragg: Nobel laureate, former director of the Cavendish Laboratory and co-discoverer (along with his dad) of Braggâ€™s Law of Diffraction. His video is available here: https://youtu.be/UEB39-jlmdw; if you have an internet connection then watching this is recommended (though not strictly necessary) before demonstrating this experiment.

The following explanation includes quite a lot of detail: how much of this you include depends on your audience. For younger children, it might be better just to let them play with the raft, and you can point out anything interesting you see.

A CHaOS+ explanation is available for this experiment; see additional details in italics.

Set-up

Set the tray on a flat surface, and, using another container or bottle, fill it with water to about 5 mm depth. Add a small squirt (~1 ml) of liquid soap. Stir with your finger until the soap is mixed in, being careful to avoid making bubbles. Also fill the clear plastic half-a-bottle with water, to between the first and second lines from the bottom. Place the gas generator into this water.

Put the end of the green tube into the tray of soapy water so that it sits flat on the base of the tray â€“ donâ€™t let it poke up to the surface. Move the gas generator around and squash the blu-tack to help it stay down (though note that it wonâ€™t stick properly underwater).

Fig 1: the setup for the experiment.

Making Bubbles

The weight of the gas generator causes it to sink into the water, pressurising the air inside the green bottle.
(CHaOS+: calculate the pressure using $\Delta p = \rho_w g \Delta h = m_\mathrm{gas~gen}g / A$)
This can escape (very slowly) through the small tube and into the water, making bubbles.
Q: What will be the effect on flow of increasing the pressure Δp */ radius of tube* r */ length of tube* L */ fluid viscosity* $Î¼$?
A: Flow rate Q *calculated using Hagen-Poiseuille Equation:* $Q \approx \pi r^4 \Delta p / 8\mu L$ *(Not exact as air is compressible). As the air is used up, the bottle sinks lower, maintaining a constant* Δh *and therefore flow rate, so the bubbles stay the same size.)*

If all is well, small bubbles should now be coming out of the tube and settling on the surface of the water. If not, try pressing down on the gas generator â€“ if this works then you might need to add more weight so it works automatically. Otherwise, try checking the seal of the cap on the green bottle in the gas generator.

This experiment works best if the bubbles are all a uniform size, which they should be if the generator is working properly. If you ever need to take the tube out of the water, wipe the end before putting it back in â€“ otherwise larger bubbles will have built up there. Any spurious large bubbles can be popped by using a small piece of kitchen roll to absorb their water.

The bubbles should be able to stick around for minutes to hours once made â€“ if they are popping too quickly, add more soap to the water. If too many bubbles have built up, empty the tray and refill with fresh water and soap (a quick fix is to push them to the edge and then fish as many of them out as you can).

The experiment uses a single layer of bubbles: if they stick around near the tube for too long, they can start forming a double layer, so waft them away from the tube with a skewer.

Some people might ask why the bubbles stick together: if you look at the water surface around a bubble it dips downwards slightly (surface tension makes it behave a bit like a trampoline with a weight on it) - when two bubbles approach they 'fall into' each others' dips.

Forming Crystals

The bubbles will aggregate to form a regular pattern, analogous to a crystal lattice. **Crystals** have a regular structure or pattern that repeats in space, though made of atoms/ions/molecules rather than bubbles. This particular arrangement is known as **hexagonal close packing** (HCP) â€“ ask children if they can identify the hexagons. HCP is the most space-efficient way to arrange a sheet of spheres, which is why HCP structures occur in nature (e.g. honeycomb, and graphite; Fig 2). *(It is also the lowest energy and therefore most thermodynamically favoured: the tension in the walls of the bubbles creates elastic potential energy, and having an HCP arrangement enables the greatest length of these walls to be shared with adjacent bubbles, minimising the energy per bubble)*

You can use the seven cups to let children work this fact out for themselves. Arrange them randomly on the table, then ask a volunteer to imagine they are all attracting each other like the bubbles are, then to push the cups together so they occupy as small a space as possible. This should have naturally made a HCP arrangement.

Fig 2: naturally-occurring hexagonal close-packed structures: honeycomb and graphite. The bubble raft is most similar to graphene â€“ a single sheet of graphite.

Q: How would you extend this into 3D?
A: By putting the next layer of spheres in the gaps between those in the first layer, then filling the gaps in the second layer, etc. You can demonstrate this by allowing a double layer of bubbles to build up near the tube. There are two options for repeating this tiling in the z direction: ABABâ€¦ (3D HCP, e.g. zinc) or ABCABCâ€¦ (Cubic close packing, aka face-centred cubic, e.g. copper). See Fig 3.

Fig 3 : 3D close-packed structures

Crystal growth can be observed by two methods. Addition of one bubble at a time to an existing crystal is analogous to the â€˜classicalâ€™ view of crystal growth, ion by ion. The addition is favoured at any â€˜kink sitesâ€™ with missing bubbles on the outside of the crystal. Crystals can also grow by the formation of smaller nuclei (made of several bubbles, often with a more irregular structure), followed by their aggregation and alignment with the crystal lattice. This is known as â€˜oriented attachmentâ€™ â€“ such â€˜non-classical crystal growthâ€™ has been the subject of much research in materials science and mineralogy in the last decade.

Polycrystalline Materials

After enough bubbles have accumulated, you should see that the lattice is not going in the same direction throughout the raft. Instead, there will be regions where the lattice is in different orientations â€“ each region is a separate crystal, or **grain**. The **grain boundaries** separating crystals of different orientations are characterised by a series of defects in the lattice. Ask the children to point out some separate grains, and they can attempt to make their own grain by pulling in a new cluster of bubbles with a skewer. Most metals, rocks, etc are made up of multiple crystals in this way.

*A 2D lattice can be described by two **lattice vectors**,* $\mathbf{a}$ *and* $\mathbf{b}$. *Translation by either of these (or a linear combination of their integer multiples) will leave the lattice invariant. Ask the student to point out the lattice vectors, maybe on a scaled-up drawing of the lattice. The misorientation between two grains is the smallest angle between equivalent lattice vectors in each grain.*
Q: What is the maximum misorientation in this HCP lattice?
A: 30Â°. A rotation of 60Â° will bring the lattice back into alignment.

Fig 4: three grains, with the lattice orientations for each drawn. Note the defects on the grain boundaries. Screenshot from the Bragg video.

Deformation and Dislocations

Take the two skewers (or have a child do it) and constrain two edges of the raft with them. This works better once there are a lot of bubbles. Then move one skewer relative to the other to stretch, squash or shear the raft and see how the deformation is accommodated. There are three ways in which a polycrystalline material like this raft can deform:

Elastic deformation: If the skewers are only slightly moved, the whole raft can stretch or squash like a spring. No bubbles move relative to their neighbours. When the force is released, the raft returns to its original shape.

Moving the skewers more results inâ€¦
Grain boundary sliding. As the name suggests, this is when crystals slide past each other along their boundaries. This deformation is now permanent (*plastic deformation*): the grains will not slide back when the force is removed. Grain boundary sliding allows dry sand to be poured like a fluid, *and is the dominant method of deformation in fault zones in the upper crust.*

The grains themselves can also change shape (also permanently/plastically). This is done throughâ€¦
Movement of Dislocations. You might have spotted little defects in the crystal lattice (e.g. a row that stops suddenly), even within a single grain. These defects are known as **dislocations**.

Fig 5: Dislocation within a bubble â€˜crystalâ€™. Note how there is an extra column of bubbles on the top compared to the bottom. This dislocation has a Burgers vector of 1 bubble diameter to the left, and will move to the left to relieve the applied stress. Screenshot from the Bragg video.

When the crystal is deforming, you can see the dislocations zipping from one side of the grain to the other. They are created where the stress on the lattice is greatest (at irregularities on the grain boundaries), and when they reach another grain boundary they get stuck and may contribute to some grain boundary sliding. They leave the grain permanently deformed in a way that reduces the stress that acted on it. When the direction of stress is reversed, the dislocations start moving the other way.

Q: Why do crystals deform in this way?
A: Compared to moving a whole row of bubbles/atoms at once, moving a dislocation has a much lower energy barrier as only a few bonds need to be strained at a time compared to the hundreds (or millions in real crystals) in a row of a crystal lattice. However, once the dislocation has made it to the other side, the net effect is the same.

*The direction a dislocation will move in can be calculated by counting the same number of bubbles horizontally and vertically in a circuit around the dislocation: the offset that is left over is the **Burgers Vector**. Dislocations can combine, adding their Burgers vectors together. The stress field around a dislocation can also influence other dislocations, causing them to attract or repel each other. See the Bragg video (5:35 to 12:07) for more details on this.*

*In addition to elastic deformation, grain boundary sliding and dislocation creep, real crystals can also deform by **diffusion creep**, where individual atoms/ions move from one side of the crystal to the other. However, I have not seen a good analogy for this in the bubble model.*
Q: What conditions would favour diffusion creep?
A: High temperatures (more thermal movement of ions); presence of a solvent (e.g. water) that can dissolve the ions and help them move.

The bubble raft experiment was developed in 1952 to study dislocations, which at the time were only theoretical predictions. Real dislocations were first observed four years later (Hirsch *et al.*, 1956) after the development of high-resolution transmission electron microscopy, and were found to behave almost exactly as the bubble raft experiment predicted!

Fig 6: Electron microscope image of real grain boundaries and dislocations (marked in red) in a crystal of platinum. Scale bar is 2 nm (that is 0.000000002 m!) From Wang et al. (2014).

Vacancies and Impurities

As well as the dislocations and grain boundaries, you may be able to see other types of defects in the crystals.

A **vacancy** is a site where a bubble is missing. They often occur naturally but, if not, you can create one by popping a bubble with kitchen roll. A passing dislocation can fill in a vacancy, jumping over a row in the process.

A bubble of the wrong size resembles an **impurity**, e.g. an atom of carbon in a lattice containing mostly iron. Impurities stress the surrounding lattice, and cause passing dislocations to get stuck.

Q: What are the implications of this for how easy the crystal is to deform?
A: Since the movement of dislocations is hindered, the crystal becomes harder to deform, and the material is therefore stiffer. This is the principle behind **alloying** metals: the deliberate introduction of impurities (e.g. carbon in steel) makes the metal less soft and bendy.

Recrystallisation

Stir up some of the raft using the skewers or an enthusiastic childâ€™s hand! This destroys the regular crystal structure and is analogous to damage caused by quick deformation (**work hardening**) of metals, or radiation damage in minerals.

However, the bubbles will soon rearrange themselves into a regular lattice again, forming new grains and grain boundaries. The grains will be small at first, but get bigger over time (**annealing**), especially if the tray is shaken to simulate thermal agitation.

Q: Why does this happen?
A: To minimise energy. A perfect crystal structure has lower energy than a random arrangement of bubbles, as each â€˜bondâ€™ between the bubbles is an optimal length. The mismatch at grain boundaries also increases energy, so energy is further minimised by minimising the total length of grain boundaries. However, doing this requires rearranging the bubbles, which is only possible if there is enough â€˜thermalâ€™ agitation to move them.

Q: Therefore, under what conditions is a coarse-grained metal / metamorphic rock formed, compared to a fine-grained one?
A: A coarse-grained texture requires the material to be held at a high temperature for a long time, to give the ions the chance to move into the most thermodynamically-favourable arrangement.

Packing away

Carefully empty the tray and gas generator and dry with the paper towel provided. Stack up the cups. Put everything back in the box.

Risk Assessment

Hazard: Pointy skewers

Description: Getting poked (particularly in eyes); splinters

Affected People: Demonstrator and demonstratees

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: No pointing skewers near peopleâ€™s faces. Donâ€™t let young children hold skewers (they can use fingers if not allergic to soapy water); sand down any rough and sharp bits before use

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Soapy water

Description: Skin irritation for people with cuts / eczema / allergies

Affected People: Demonstrator and demonstratees

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: I would advise against demonstrating if you are irritated by soapy water. Ask parent/ responsible child if OK to put their hands in soapy water. Otherwise, can do as demo only or only let them touch the water via the skewers. Do not let children drink the soapy water.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Soapy water

Description: Eye irritation

Affected People: Demonstrator and demonstratees

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Donâ€™t let anyone who touched the soapy water with their fingers touch their eyes without drying their hands first. Know where the nearest eye wash is (there should at least be some in the Safety box).

Summon first-aider to wash eyes if necessary.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Open containers of water

Description: Trips / slips / electrical shorts from spillages.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: I would advise doing this experiment outside or in a room with a wipeable floor. Do not put near electrical equipment. Do not use more water than is necessary (5mm depth is fine), and if possible fill the tray using a water bottle and then donâ€™t move it. Keep the gas generator in a place where it is difficult to knock over. Warn people of any spillages and clear them up promptly using the kitchen roll.

Summon first-aider in event of someone tripping and hurting themselves.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2022-06-06 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 22-06-09 - Emma Crickmore (elc75@cam.ac.uk)

Check 1: 2023-01-13 - Peter Methley (pm631@cam.ac.uk), **Check 2**: 2023-01-17 - Jamie Barrett (jb2369@cam.ac.uk)

Build a Tree

Talk about the different parts of a tree whilst building one out of craft materials - Can you build a tree?

Last initially checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk)

Tags

Plants

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Hard straws
- Soft straws
- Pipe cleaners (pale and brown)
- Tissue paper disks
- Elastic bands
- Black fabric with velcro
- Selotape and scissors

Experiment Explanation

So I challenge you to build a tree from the bits and pieces I have here, now where are you going to start?

Trunk here we have two different kinds of straws and they transport two different kinds of things - what do trees need to transport around themselves? Firstly what do they need to get out of the soil? - water and minerals. And can you think of anything that the tree needs to transport down from the top of the tree to the roots? Or what gets made at/happens the top of the tree? - sugar or food/photosynthesis. The thicker straws are used for sucking up water, they have to be really thick and strong to stop the straws collapsing under the negative tension that pulls the water up from the soil.

Roots keep the tree upright, help it get nutrients and water out of the ground, have a different pattern/structure depending upon nutrient/water availability. If there is less of something important, that the tree really needs to grow and live, the roots will be longer and less furry (fewer root hairs and smaller surface area) to try and grow into a space with more of that nutrient. See picture of white lupin grown with (left) and without (right) phosphate.

Branches spread the leaves out to maximise sunlight captured, trying not to shade out own leaves below, supporting the canopy. Trees will grow with different branch patterns depending on their surroundings e.g. open field vs forest - see sketch of the white oak trees (Quercus alba, sketches by C. Holdrege). Shade avoidance; neighboring plants are detected by the proportion of red to far red light in the available light, red light gets depleted and the trees reduce branch production, growing taller to try and grow above their neighbors [if you have a child friendly way of explaining that other plants use up *some* of the light then please write it down!]

Leaves to capture the light! Needed for photosynthesis, making food (forming the base of the food chain - primary producer), different shapes have different benefits (sun vs shade leaves, needles vs broad leaves, we know a v.limited amount about the reason for the huge variation in broad leaf shape). Encourage the kids to think about what benefits different shapes have; drip tips - allowing water to run off the leaves quickly, so water doesn't pool and permit fungal growth; banana leaves - have non-branching veins so that in high winds the leaves rip and don't act as sails (causing the whole tree to up root) [n.b. bananas are technically herbs not trees as their trunk dies down to the ground at the end of each growing season] Could also talk about different tree types such as conifers (often evergreen) vs deciduous (seasonally shed their leaves)

Bark protects the transport straws/vessels within the trunk, insulates from heat/fire (cork bark), protects from insect damage and diseases.

Et voila! We have a tree!

Can talk about different tree shapes - conifers vs deciduous trees (e.g. snow collecting on branches and damaging them or sliding off) oaks/beeches tend to have taller and thinner canopies than those in mixed canopies.

Risk Assessment

Hazard: Pipe cleaners

Description: Sharp ended pipe cleaners may scratch.

Affected People: Anyone using materials

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Fold over the tips and warn children about scratches. Call first aider in event of incident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Pipe cleaners/straws

Description: Eyes may be poked if children are silly with the straws or pipe cleaners.

Affected People: Everybody

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Encourage children to be sensible with straws/pipe cleaners, ask them to leave if they are being silly. Call first aider in event of injuries.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Elastic bands

Description: Elastic bands may be used as missiles or wound tightly round fingers, cutting off blood supply.

Affected People: Everybody

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Encourage children to be sensible with elastic bands, ask to leave if they won't. In case of injury call first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Straws

Description: Germ transfer from putting straws in mouths.

Affected People: Everybody

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Warn children not to put straws in mouths, dispose of any straws which have been eaten. Warn parents of the possibility of germ transfer if child has been eating straws.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Scissors

Description: Possible cuts.

Affected People: Everybody

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Younger children should be accompanied by an adult. CHaOS volunteers to oversee carefully. Ensure kids are behaving sensibly at all times. Use safety scissors. Call a first aider to deal with any cuts.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2016-02-12 - Sarah Wiseman (sw628@cam.ac.uk), **Check 2**: 2016-02-12 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2017-01-03 - Sarah Wiseman (sw628@cam.ac.uk), **Check 2**: 2017-02-12 - Fiona Coventry (fiona.coventry@cantab.net)

Check 1: 2018-01-25 - Sarah Wiseman (sw628@cam.ac.uk), **Check 2**: 2018-02-02 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2019-01-08 - Amanda Buckingham (abb53@cam.ac.uk), **Check 2**: 2019-01-13 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2020-01-18 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2020-01-23 - Holly Smith (hs606@cam.ac.uk)

Check 1: 2020-12-28 - Bryony Yates (by250@cam.ac.uk), **Check 2**: 2020-12-31 - Esmae Jemima Woods (ejw89@cam.ac.uk)

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Check 1: 2023-02-06 - Margaret Johncock (mllyj2@cam.ac.uk), **Check 2**: 2023-02-10 - Amy Migunda (aom36@cam.ac.uk)

Camera obscura and lenses

Peering at the outside world through a lens. - The camera obscura uses a lens to project an image of the outside world onto a white screen inside the CHaOS event. Can you figure out why it's upside down?

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Physics

Equipment Needed

- **Darkroom needed**
- **Electricity needed**
- Camera obscura lens in cardboard sheath, should be packed carefully to avoid scratches
- Wooden board painted white
- Ray box and 2 colour filter light boxes
- Power supply for lights
- Lenses ((i) "eye" lens, (ii) corrective lens(es)), should be packed carefully to avoid scratches
- Sheets of A4 white paper to go under ray boxes
- Sheet of A4 paper to act as screen for ray boxes
- Poster showing cutaway diagram of eye

Experiment Explanation

Overview

This is a large experiment with 3 parts.

1. A glass camera obscura lens in the side of the darkroom tent, and a wooden board. If you hold the board in the correct place inside the darkroom then an upside down image of the outside world will be projected onto it through the lens.

2. Ray boxes and lenses on a table. This is essentially a 2d representation of the camera obscura which you can use to explain it. You can show: why the image is upside down; why the lens is important; what focussing does; and how corrective lenses work in the eye.

3. Poster showing cutaway diagram of eye. Allows you to link in the bio factors, talk about the parts of the eye, nerves etc.

Set Up

- Position the darkroom, and the camera obscura lens, such that it is looking out on a brightly lit, active area with, if possible, plenty of depth for varying focus. Ideally it's a good idea not to let people (parents/ demonstrators) congregate just in front of the lens... out of focus legs blocking most of the picture aren't very exciting!

- Cut a hole for the lens at about child's eye level (or find a suitable hole), and tape the lens and sheath in place.

- Set up the ray box and light boxes on the table, and check they work. They should have switches on them.

[image1]

- Get the 2 sheets of paper showing the eye with/without corrective lenses and tape the light boxes in the correct place.

[image2]

- Tape up the poster of the eye somewhere

Demonstrating

(This is one approach to demonstrating this experiment. It's quite long so it might be wise to split it between 2 people.)

1. The camera obscura

1a. Encourage children to look through camera obscura lens from various distances, observing that they can see what's outside, but blurry and possibly upside down.

1b. Either holding the white board yourself, or getting the children to hold it, position the board so that the image is in focus on it. Ask them what they can see and get them to realise it's an image of outside.

1c. Ask them what's wrong with the image. Eventually they'll get that it's upside down. Try turning the board over and show that it doesn't make a difference. If one is wearing a white T-shirt, try getting the image focused on them, if not, use your arm... make it clear there's nothing special about the paper - it's the light coming in.

1d. Move the board around and show that the image is blurry unless it's in the right position.

2. The eye

(This seems to be well received by everyone, and is fairly interactive but not hands-on. There's loads you can talk about: cameras, eyes, shutter speeds, focussing, digital cameras, nerves. This is one approach).

2a. Say that this is how your eye works. Shock horror. DON'T move over to the eye poster yet - it seems to distract them and it's pretty dull. Instead, talk about it while you're holding the camera obscura board and point with your arm to where the eyeball would be.

2b. Start by talking about the pupil - "what's in the middle of your eye?" - most people know what its called and what colour it is so this is a good starting point. Then say its a hole that lets light into the eye, just like the hole in the side of the tent. Again, point with your arm to where the eyeball and pupil would be in the tent, relative to the board that you're holding.

2c. A hole isn't much use by itself, its the glass thing that does the work. You've got one in your eye too. Yes really. What's it called? A lens. What's it made of? Glass. How do you make glass? Heat sand to high temperatures. So can you do this in your body? No. So your body uses jelly to make the lens instead.

2d. Ask them what the eye is filled with. The eye is filled with clear jelly liquid. does light go through water? Yes. So (pointing with your arm again) the light goes through the hole into your eye until it hits the other side of the eye.

2e. So the light goes through the hole into your eye until it hits the other side of the eye. What happens on the other side of the eye? You get an image upside down, just like on the wooden board for the camera obscura.

2f. That's great but you still can't see. The neat trick is to cover the board at the back of the eye with electrical sensors that sense what colour light is hitting each point on the board. So here they say "yellow", here they say "red", etc. All this gets sent down wires to the brain so you can see.

2g. Now move over to the poster of the eye diagram and show them that it's all true. The orientation of the cutaway diagram isn't obvious at first so you have to help them with this.

2h. So, on to these wires. What're they called? Nerves. Have you seen wires in the house? What're they made of? The middle bits made of metal. It conducts. Do you think wires in the body are made of metal? No. What else conducts? Salt water. So the body uses salt water instead. What about the plastic? It insulates. Do you have plastic in your body? No. So use fat instead.

3. Ray boxes

(Younger children tend not to receive this part very well - they just don't grasp the correspondence between the 3d camera obscura and the 2d ray boxes. However there's still some mileage in shadows and light going in straight lines. If you've been talking to them for ages already it's better to get someone else to demonstrate this bit otherswise they tend to get bored.)

3a. Move to ray-box table, tell them we're going to explain why the image is upside down. Ask if they have any thoughts about it.

3b. You could show light travelling in straight lines- talk about shadows- caused because light can't go round corners, etc.

3c. Now with the lens in place, compare the system you have to the camera obscura - eg "we have the light coming in on this side, and here's the lens, etc...". Hold a piece of white paper up as "the board".

3d. Point out that the image is upside down - on one side of the lens, the red light is at the top and the green light is at the bottom, but on the "board" the reverse is true. Get them to work out that the lights cross over inside the lens, so the red light starts out at the top and goes to the bottom, and vice versa for the green light.

3e. Compare this back to the camera obscura, where light from the ceiling ends up at the bottom of the board and light from the floor ends up at the top of the board. The light crosses over inside the lens.

3f. Talk about focussing the light to a point by moving the "board". Relate this back to moving the board for the camera obscura.

3g. If they're already familiar with how the eye works then you could take them through corrective lenses. Use a mishaped eye (squashed black circle on white paper) with one lens and show that the light doesn't focus properly on the edge of the circle. Now add a corrective lens in front of that lens and show that it now focuses properly. Get them to relate this to contact lenses and glasses.

Risk Assessment

Hazard: Glass lens (breakages)

Description: Broken glass shards may cut people.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Make sure the lens won't fall on floor, e.g. by using tape. Clear up broken glass immediately and keep people away while doing so.

Call a first aider in the event of an injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Glass lens (positioning)

Description: If lens is positioned in direct sunlight, then the focussed sunlight can cause retinal damage and burns

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Demonstrator to make sure that the lens is not positioned in direct sunlight.

Call a first aider in the event of an accident.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-13 - Anna Kalorkoti (anna.kalorkoti@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

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Check 1: 2016-12-28 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2017-01-28 - Frances Victoria Western (fvw22@cam.ac.uk)

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Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Holly Smith (hs606@cam.ac.uk)

Check 1: 2022-01-22 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-01-30 - Lavinia Finalde Delfini (lf465@cam.ac.uk)

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Cantilever Bridges

Building a series of cantilever bridges - Can you build bridges across wider and wider rivers?

Last initially checked on 2023-01-14 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-14 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- Base boards
- Small blue box of blocks
- Laminated photos

Experiment Explanation

Basically you want to get across that you have to balance everything, and if the centre of balance goes over the edge of any support it will fall over.

Setting up the experiment:

Kids: works best on the floor, as the blocks don't fall too far when stacks topple! Get everyone to sit on the floor around the board/ pile of bricks Grown ups: we've run this at an adults-only science evening, on a table, which worked fine. But adults are much less confident about stacking blocks than kids are!

The challenge:

The challenge is to build three bridges across the river. There are two rules...

1. You're only allowed to use the wooden blocks
2. The wooden blocks can only stand on the support blocks, not on the land (it's marshland, too soggy!) or in the river (cheating!)

The first bridge (smallest gap)

Start with this one, as everyone can do it! The first gap is easy, as you can just put a block across it.

Extension: Why does the block not fall into the river? One answer is that the block is being pulled down (by gravity), but is being pushed up the same amount by the supports at each end. This balance (of forces) is why it stays still.

The second bridge (bigger gap)

Do this one next, once they've succeeded at the first bridge. This gap is the width of three bricks. If you hold a brick partially across the gap/on the end of the support and let it go, it falls- why? (The brick/the forces acting on the brick aren't balanced.) How can you balance the blocks? (Think of a see-saw.) How can you get more of the block to go across the gap? (Balance it on the other side).

Try to do this yourself before you demonstrate the experiment. The most obvious design uses 8 blocks (2 towers of 1;2;1), the fewest we've see it done in is 5, but this doesn't look much like any bridge we've ever seen! It's not as stable - why?

Look for mirror lines/symmetry: this is a simple way of making sure the towers are balanced. For the most common 8 block design the two towers are symmetrical, and each tower is symmetrical in the line above the support/ along the middle layer of bricks. (This is also true of the most common version of the third bridge).

It can be a bit of a surprise to find out how much of this is not obvious to some children. Many will start trying to build something like an arch, or want to put supports in the river. The first thing is to get them to see that combining bits of structure that tip over in opposite directions can produce something that balances.

The real trick is knowing how long to let them try to build the bridge without telling them how to do it. It's much better if they figure it out for themselves, but you want them to be able to build the bridges even if they can't spot the balancing trick! You want to give them a clue *just before* they get bored of trying - the real pro demonstrators can do this without being obvious that it's a clue, but that takes practice!

Once you've got to the end of this second bridge don't forget to tell them "well done" for completing a tricky challenge!

Here's an alternative version of our explanation for engineers/those used to thinking about moments: The second bridge requires you to start cantilevering. Get the kids to show you where they want to put the next block - and why it won't work - suggest that they need to counterbalance it with weight - another block. Making the smallest bridge from 2 balancing blocks can help to get them started on the others. Then get them to see that things further from the fulcrum have more tipping power (moment). You can demo this with the bricks, using one as a fulcrum another as a beam and more as weights. Or get them to hold the heavy mass from the spinny chair (another CHaOS experiment that may be nearby...) close to them, then at arms length. Comparison with see-saws might be useful, as most children should have played on one of these).

The third bridge (biggest gap)

This builds on the ideas in the second bridge - take how long that took as an indication for how quickly to go through this. If they really struggled on the second bridge you don't have to make them do this one themselves. Get them to help you do this one, as you can't hold all the blocks yourself (which is usually true - two pairs of hands makes it much easier!)

You can use the same idea as the bridge above to go across a bigger gap, but this time the towers need to be wider (which ends up making them taller if you pick the simplest design). The most obvious solution is 2 towers of 9 blocks (1;2;3;2;1), but we've seen it done in as few as 7 blocks. What's the smallest number you can build it in? (We're mainly aiming that challenge at you demonstrators, but you might also want to give it to kids that have figured out the first challenge quickly!)

Extension: If you add more blocks to the top, to look something like the Corbeled arch below, the bridge appears to be more stable. Why is that?

For engineers: The third gap is more difficult, with the number of blocks you have, you can't just pile up a counterweight near the fulcrum, you have to get some of it further out to counterbalance the bridge.

These bridges exist in reality!

Note: some of the pictures in the box are arch bridges that go with the arch bridge experiment (which doesn't have its own box). Try not to confuse the two - the forces aren't the same in each.

You can compare the bridge to the Forth Bridge: a real example of a cantilever bridge. There are photos in the box. This bridge is in Scotland, and is famous for being so long that by the time you've finished painting one end that you need to go and start painting the other end!

Look for the picture of the bridge in construction - here you can see the cores of the towers before sections were added to each side. That's analogous to our supports before we add sideways with extra blocks.

Two questions that seem to come up quite often with the bridge photos: Why isn't it solid like the blocks? The Forth Bridge is made out of metal, this behaves differently to wood, and if you can fix the pieces of metal together you can get away with less metal than something completely solid. Apart from anything else, that saves money on metal? Is our bridge weaker than real ones? Yes, because the blocks aren't joined. But it's very solid considering!

A primitive form of arch was called the Corbeled arch, this is basically two of the balanced cantilevers next to each other with the wall acting as the counterweight.

This was used in passages and tombs, before the true arch was developed.

Risk Assessment

Hazard: Tower of blocks

Description: A very tall tower may mean bricks have enough energy to bruise when the tower falls down.

Affected People: All (especially children)

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrator to monitor building, anticipate collapse, and get children to stand back.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Board/ Blocks on floor

Description: There is a trip hazard from the board or blocks placed on the floor.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Don't put the experiment in an area which is likely to be used as a thoroughfare.

Call first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Gaps between boards

Description: Children may pinch their fingers in between the boards on the floor.

Affected People: All (especially children)

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Demonstrator to ask children to not place their fingers where they can be pinched between the boards. Tape gaps between boards and boards and floor.

Call first aider in the event of an accident.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Blocks

Description: Possible splinters from the wooden blocks.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrator to make sure only wooden blocks with no splinters coming out are used. Report any blocks that arenâ€™t smooth/sand them smooth.

Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-14 - Aaron Barker (arb78@cam.ac.uk), **Check 2**: 2012-01-26 - Rosy Ansell (rosemary.a.r.hunt@gmail.com)

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Check 1: 2015-02-01 - Benjamin Lai (bl337@cam.ac.uk), **Check 2**: 2015-02-11 - Sarah Wiseman (sw628@cam.ac.uk)

Check 1: 2015-12-16 - Robert Gayer (rg478@cam.ac.uk), **Check 2**: 2015-12-27 - Andrei Ruskuc (ar720@cam.ac.uk)

Check 1: 2017-01-22 - Robert Gayer (rg478@cam.ac.uk), **Check 2**: 2017-01-02 - Matthew Le Maitre (msl54@cam.ac.uk)

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Check 1: 2020-01-10 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-01-24 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-02-01 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2022-02-04 - Lauren Mason (llm34@cam.ac.uk)

Check 1: 2023-01-14 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-14 - Johan Kidger (jpk51@cam.ac.uk)

Carbon Allotropes and Molecular models

Building molecular models - Explore some elements and different types of bond and explore ways carbon can bond to form different allotropes.

Last initially checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-08 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Periodic Table of Elements
- Molymod kits - general, graphite, diamond
- Sample of graphite (pencil lead), maybe some others

Experiment Explanation

Start off by discussing the Periodic Table, and how the valency of a compound can be determined from this. You'll need to talk about the groups going down the table and how the group number corresponds to the number of outer shell electrons of the elements in that group. You might want to talk a little bit about the behaviour of the elements in each group - like how group 1 alkali metals are really reactive in water (some kids might have seen Li or K in water at school), or perhaps how group 0 (Noble gases) are happy as they are and are unreactive. Introduce the idea of full outer shells - this should make covalent bonding a bit easier to understand.

Introduce covalent, ionic and metallic bonding, using the diagrams provided in the kit.

- Covalent bond = shared pair of electrons. Normally get this between non-metals, things with a small difference in electronegativity (this could be a little complicated to explain, but try to talk about the nucleus pulling the electrons towards it; more positive nucleus will be better at pulling electrons towards it than a big, diffuse one, kind of like a tug-of-war). Examples include CO2, O2, CH4... Also giant covalent structures, like diamond or SiO2 - very high melting points because covalent bonds are strong.
- Ionic = one atom pulls an electron off the other to form ions, then positive and negative ions (anions and cations) attract one another. Usually metal with a non-metal. Could talk about salt (NaCl) which has this sort of bonding.
- Metallic = the strong electrostatic attraction between the sea of delocalised electrons and positive ions in a lattice. Metal atoms donate electrons to this "sea", which is between the ions and you can say it holds the metal together. Emphasise the regularity of the structure - it's a lattice, with layers that can slide over each other when you shear them. Examples of metals should be things kids know, but they might get confused with some alloys - i.e. steel = iron and carbon, whilst iron is a pure metal.

Also refer to the samples of each provided. For example, metal is ductile as layer of ions can be made to slide over each other and the sea of delocalised electrons can move along with it. Whereas covalent bonding is directional so if a bond breaks, it just snaps. Metals conduct electricity - why does this happen? Encourage kids to think about what electricity is - the flow of charge (i.e. electrons or ions), so the sea of delocalised electrons in a metal means it can conduct. Also consider the idea of ionic materials - is salt conductive? Answer = no, but it can be in solution or when molten. Get kids to think about the fact that electricity has to flow, implying motion, but the electrons in ionic compounds are all too strongly held by the ions to move. But, in a liquid state, the ions themselves move (which they can't in the ionic lattice) and electricity can flow. Maybe extend to whether water can conduct (it can't) and the effect of having ions free to move in water on conductivity - do they think the water from the tap is going to be pure? Ionic compounds form strongly bonded salts, can explain solvation and why they dissolve in solution (water = polar molecule so the different ions can be "broken up" by water because of attraction to different parts of the molecule).

Then introduce the diamond and graphite structures. Ask them what they know about diamond, most should know it is the hardest material on earth. Ask them from looking at the structures to say which they think it is and why. Explain that it clearly isn't the graphite as the layers easily slide over each other. Then introduce graphite as pencil lead; say this is how it writes - layers of graphite slide over each other, leaving some on the paper. If people still follow, explain that there is a free electron from each C between the layers. These are delocalised so can conduct electricity. Next take a piece of graphite and show that you can put charge through it.

Allotropes of carbon include graphite, diamond, lonsdaleite (hexagonal diamond), C60 buckminsterfullerene, C540, fullerite, C70 fullerene, amorphous carbon, and single-walled carbon nanotube. Nanocarbons have lots of potential uses...

You can show how graphite is diamagnetic by balancing some pencil lead off the edge of a table and using either the north or south pole you can repel it. If you try this with a magnet balanced one way will attract. In contrast you may find some varieties are parmagnetic. These effects are small so you'll need a strong magnet.

Risk Assessment

Hazard: Small parts

Description: Choking on small parts.

Affected People: Small Children

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: Watch carefully over children, use pre-assembled models so fewer small parts. In the event of a piece being swallowed, encourage child to cough. Call a first aider, who may perform the Heimlich if trained and happy to do so.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Graphite

Description: Electric charge through graphite (small shocks).

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Use small charge. Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Magnets

Description: Magnets shattering, possibly causing cuts/splinters

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Warn visitors if you give them a magnet. Use the minimum number of free magnets. Keep the magnets under control. Cover with tape to reduce impact, and contain any shards. Call first aider in case of injury

After Mitigation: Likelihood: 1, Severity: 1, Overall: 3

Risk Assessment Check History

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Cathedral

How can we use arches to hold up a cathedral? - See how simple shapes can fit together to hold up a large structure, like a cathedral!

Last initially checked on 2023-02-10 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-11 by Asmita (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- Base - three sections connected with hinges x1
- Foundation blocks with metal connecting pins x4
- Large arch connected with elastic cord x1
- Small arches (buttresses) connected with elastic cord x2
- Thin walls x2
- Thick walls x2
- Weights x2

Experiment Explanation

*** OVERVIEW ***

Investigating how the ideas used to make arch bridges can be used to build cathedrals and other buildings. Looking at the foundations needed for arches and flying buttresses.

Possible Activities: Building a single large arch without walls but with foundations. Building a single large arch with thick walls. Building a single large arch with thin walls and weights. Building a single large arch with thin walls and flying buttresses.

Other things to talk about: Resolving forces in different directions. Examples in real cathedrals (see photos). Foundation depths and strengths.

Tips for demonstrating:

Best demonstrated if the children have already looked at the arch bridge experiment, as then you can link the two experiments nicely.

Be careful with the weights as they do pose a finger-trap and bruising hazard - best to get them to hold the wooden arches, well away from where the weights will drop, whilst you position the weights in the correct places. It is *very difficult* to get the weights to balance, so I often just get the kids to press vertically down on top of the block with their index finger. This achieves the same effect, but you should make clear that this is the same as putting a big weight on top.

*** BASIC PROCEDURE AND EXPLANATION ***

1. Starting off

Explain that it's a cathedral. We're trying to build one. What are cathedrals built from? Stone. How to get a stone roof, window or door to stay up? Show them a photo - why doesn't the roof fall in? Ask if they've ever been in a cathedral and what shapes did they see. Arches!

Explain that the model is a cross section of a cathedral. This is actually quite difficult - young children are not used to models and cut-away views so you'll have to wave your hands and show them what would go where.

2. Large arch falling in

Now you can do the actual experiment. Start with the large arch and place it straight on the base (without supports). Ask the children to hold the two ends of the large arch and ask them what happens when you let go of the ends. Let go of the ends and it falls down.

Why does this happen? Normally children say something along the lines of "nothing is holding it up" but you can go a bit further than this. Try to get across the idea that you need something to push the ends of the arch inwards, as follows.

Repeat it but rather than getting them to hold the ends of the arch, ask them to keep the arch up by pushing only with one finger. Most children then try different directions until they realise they have to push the ends of the arch inwards. It can be difficult to get this working with two children but let them persevere and give them clues if necessary.

When they've done it, ask which way they're pushing. If they're old enough you could talk about forces but be very careful! Bear in mind they might not have heard the word "force" before and even if they have they might not know what it means - it can prove a bit of a distraction and just bore them.

3. Large arch with foundations

Once you've done that, put the foundation bricks in (match up the numbers (1 & 2) to ensure a good fit) and ask what will happen when you let go now. Don't mention "foundation" yet.

The arch stays up. Why? Why didn't it fall down? Previously we had to use our fingers to push inwards to stop the arch falling down, and that's what the bricks do.

What are the bricks called? Foundations. Talk about house construction, danger of building houses on uneven or muddy/sandy ground.

4. Arch with walls and buttresses

What is the problem with this cathedral so far? No walls, ceiling very low!

Try putting the arch on top of the thin walls. What will happen when you let go? It falls down. Why? Get them to explain, using the finger method like before, that we need something to push the arch inwards. If we don't have anything pushing in then the arch falls down.

Now put the smaller arches (flying buttresses) in between the outer foundations (numbered 3 & 4) and the thin walls. Let go and it stays up! Why? Again, because the buttresses push inwards.

Explain that they're called flying buttresses. Have they seen any? Show photos - where are the flying buttresses in the photos. What are they holding up?

5. Thick walls and weights

This next bit is quite subtle and you might not want to try it with young children.

Instead of flying buttresses we could use thick walls and put weights on top. Try it. Why does it work? Extra weight adds extra force in direction required. This is very subtle - children need to understand forces and have some idea about how forces in different directions add up. Don't try it unless you think they'll get it!

This is quite tricky to do, so make sure you practice it before trying with the children. First place the thick walls at the locations marked on the base, then rest the arch (matching up the A and sides) on the marked part of the top of the thick walls. The arch won't stay up at this stage so keep holding it up. Next place the thin walls (upside down and oriented so that the top surface is flat) on top of the thick ones and add the weights to the top of the thin walls. The weights need to be as close to the centre as is possible without them falling off, the structure should now stand up on its own.

*** OTHER THINGS TO TALK ABOUT ***

Applications with bridges. How old buildings were made Cement as a glue for bricks. How modern buildings are made. Look at the buildings around you. How does your roof at home stay up? Look in the attic - timber beams...

*** SCIENCE BACKGROUND FOR DEMONSTRATORS ***

Using the science behind arch bridges to make buildings. Resolving forces - how adding weights/using thicker walls, stops the roof from caving in.

Risk Assessment

Hazard: Elasticated wooden blocks

Description: Could trap finger between the elasticated wooden blocks

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: The bungee holding the blocks together isn't too tight, but be aware of the problem and ask children to move fingers if they are in danger of being trapped. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Brass weights

Description: Dropping one of the brass weights on a finger.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Try not to leave or let kids lean on the floor by the bridge. Brass weights may easily be replaced by getting kids to press down with a single finger. Call first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Wooden blocks/base

Description: Getting splinters from blocks or the base.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Ensure all blocks and the base are well sanded. If not, sand them or don't use them. Call first aider in the event of an accident. Aim to keep children calm around experiment.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Wooden blocks on floor

Description: Wooden blocks may be trip hazards.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Keep blocks in same area and out of public walking areas. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

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** CHaOS with additional needs **

Guide to demonstrating via gestures - Advice for how to demonstrate experiments without speaking, seeing or anything else this may be for children who aren't fluent in English, have special educational requirements or various other reasons.

Last initially checked on nan by nan and double-checked on nan by nan

Tags

Advice

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Other

Equipment Needed

- **This experiment can take place outdoors**
- You'll need to pick another experiment in conjunction with this (and sign it's RA). Depending on the needs it's hard to say an experiment but the following recommendations work well for most:
- Cornflour
- Mini Explosions
- Animal Cognition
- Arch Bridge
- Cantilever Bridge
- Spinny Chair
- (Any experiment that has lots of touch, feel elements and less talking explanation)

Experiment Explanation

Firstly you should talk to the teacher/parents before starting to check exactly what the requirements of the group are. The teachers and parents will probably make these needs known to you and ask several questions about what they think will work well. This is probably best done by the floater who can relay their needs and information in here which is relevant. The floater should pay special attention to these groups and move them around to demonstrators prepared to take them with suitable experiments. There may be several needs within a group which may make things more complicated. You may be able to discuss this in the venue briefing if you have enough time and notice or at a break time.

Speech They should be able to say if you'll be restricted to simple English, can use a translator or even if they're deaf and you can't use words. The group may have a mixture in which case make sure you're sufficient for the lowest ability but you can add in simple words for everyone else's benefit. The main keys are lots of doing and touching. You might have to complete the actions and gesture for them to copy you. You'll also want to think about what words are key to the experiment, with limited English momentum may not be productive to mention as they won't understand what it means. Also experiments which play off hearing can be very interesting for hearing impaired, for instance if someone is deaf in only one ear then ear switching hat will be a very interesting experience.

Sight Again there are various This one is fairly hard however try and make experiments fairly tactile or feeling based. You may have some issue guiding them to complete tasks however hopefully they have someone to help them reach and touch things or get on to the spinning chair if they're very limited in size.

Wheelchair Fairly simple to deal with, make sure there's enough space for them to travel around.

Risk Assessment

nan

Risk Assessment Check History

Chromatin Pipecleaner Models

Explore the world of epigenetics, using pipecleaners and corks to model DNA and the chemical changes done to it to turn genes on and off.

- Humans have 19,000 genes. How are only certain genes turned on in each cell so that brain cells express brain genes, but not heart genes and vice versa? Here we make fun chromatin models to explore epigenetics.

Last initially checked on 2023-02-15 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk)

Tags

DNA

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Pipecleaners (much better if they are made of two different colours)
- Corks
- Plastic beads (prefereably all of the same shape and colour on the day but no specific colour or shape is needed)
- Paper bowls to put the separate components in
- Small circular stickers

Experiment Explanation

Humans have 19,000 genes. How are only certain genes turned on in each cell so that brain cells express brain genes, but not heart genes and vice versa? Genetic information (i.e. what makes you, you) is stored in DNA. All cells in the human body contain all of the DNA needed to make any cell in the body, but we don't want heart cells expressing genes that are meant to be specific to the liver and vice versa. How can we make sure that some genes are turned on and some genes are turned off? Here we need to look at the fascinating world of epigenetics - it's not what genes you have, but how you use them that matters!

(Put some corks and some beads in separate paper bowls for the kids to draw from when making their models).

DNA is a long complex molecule that contains all of the genes of the cell. It is formed of a double helix (show the pipe cleaner), which means that you have two strands wrapped around each other. It is very long and thin reaching 2m in every single cell in the human body. (Here you can show the kids how big 2m is relative to your height). If you stacked all the DNA from every cell in the human body it would be twice the diameter of the solar system! How on Earth can all of this DNA fit inside a cell, which is the is 25 times smaller than a grain of sand?

Histone proteins are essential for wrapping up the long, thin DNA, so it doesn't get all tangled and still fits into a nice, small cell. [For older children, you can explain how there are 5 main types of histones and how they come together to form a repeating unit called a nucleosome]. (Wrap the pipecleaner around a cork, twisting it at the end to hold it secure).

To read genes within the DNA, other proteins must be able to bind to the DNA. If something prevents this, the gene cannot be read and so is not expressed. **Epigenetic marks** can either make it easier or harder for the DNA to be read.

Methylation marks make it harder for DNA to be read by getting in the way of the gene reading machinery. (Show the kids the red beads and slide one on to the free end of the pipecleaner to show a gene which is not being read. You can add as many or as few as you like. You can then add the second histone on to the DNA in the same way that you did the first one).

Histone modifications can make it easier or harder for the gene reading machinery to reach the DNA that is wrapped around the histones. Some of these chemical modifications enhance the ability of histones to bind to DNA (i.e. increasing positive charge on histones such that they bind more readily to negatively charged phosphate groups in the DNA backbone), so it is harder for the genes to be read, whereas some loosen the histones' grasp on the DNA (i.e. neutralizing the positive charge on histones such that they are less keen to interact with negatively charged DNA). (Here you can add the circular stickers onto the corks. The final product should have two histones, a few methylation beads and several different coloured stickers).

[For older children, you can discuss how environmental changes which affect the mother can impact the epigenetics of the baby and so how the genes will be read during the child's life. For example, the children of overweight mothers are much more likely to become overweight themselves than the children of mothers of a healthy weight. However, if an overweight mother does regular, light exercise during the pregnancy, this risk is reduced considerably].

To renew stocks, get stripey pipecleaners and beads (9mm pony beads, roughly Â£6 for 1000, any colour works)

Risk Assessment

Hazard: Pipe cleaners

Description: Sharp ended pipe cleaners may scratch.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Fold over the tips and warn children about scratches. Call a first aider in the event of severe scratches.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Pipe cleaners

Description: Eyes may be poked if children are silly with the pipe cleaners.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Encourage children to be sensible with pipe cleaners, ask them to leave if they are being silly. Call a first aider if an accident occurs.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Beads

Description: Choking risk if the children swallow the small beads.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Do not let children under 3 make the models. Children below ~age 8 should be supervised by parents. CHaOS volunteers should also oversee carefully and prevent any beads going in mouths. In case of injury call first aider.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Corks

Description: Children may trip over corks if they have fallen on the floor.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Pick up corks immediately if they fall on the floor, or ask the children to. Call a first aider in the event of an accident.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

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Cleaning Coppers

Removing copper oxides from coins. - Those grubby coppers in your pocket or purse can be shined up in minutes, give it a try and find out how it works.

Last initially checked on 2023-02-17 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-18 by John Leung (cfl35@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Plastic containers (e.g. disposable cups) - broad shallow containers are generally better.
- Acids e.g. vinegar, cola, lemon juice, ketchup - at least a couple of different ones
- Salt
- Copper coated coins
- Waste bin
- Paper towels

Experiment Explanation

In a nutshell Copper coins are cleaned by putting them in vinegar/other acids to dissolve the copper oxide/copper chloride corrosion products, which are a lot more soluble in acid than the plain copper.

How to run the experiment

1. Make up cups of vinegar, cola, ketchup etc. before the event. Dissolving some salt in the acids makes them clean the coins faster, vinegar is a good one to add salt to as it is clear so you can watch the coin get cleaner.
2. Ask children/parents for copper coins - the dirtier the better (which will be returned, clean!)
3. Get kids to drop a coin into each liquid, for ketchup you can try to only cover half of a coin to see a before/after comparison
4. Wait a couple of minutes for coins to get clean. It may be better start trying to explain some science at this point rather than before the coins have been put in to avoid running out of things to say. Some potential discussion points:

- Would the coins come clean in water? Could have a cup of water as a 'control'. Why are these liquids better at cleaning the coins?
- What do all of the liquids have in common? All acidic
- Which of the liquids would they expect to clean the coins fastest? We might expect this to be the strongest acid. Acids can make things taste sour, which tastes the most sour?
- What metal are the coins made of?
- Why does the surface copper oxide get removed, but not the copper making up the coin? Copper oxide more soluble in acids than copper

5. Take coins out and see if their predictions on what liquids clean best were correct

What you need to know during the experiment

- Corrosion is a result of the reaction of the metal with oxygen in air, forming the black solid copper oxide. You can compare it with rusting of iron and, for older kids, you can talk about the reaction being faster in the presence of moisture.
- The black copper oxide reacts with the acetic acid in vinegar to form copper acetate, which is soluble in water and forms a pale green solution.

Want to know more?

- You can see the green copper acetate by putting lots of really dirty copper coins in vinegar. This should be done in a container with a lid.

- The green colour of many copper salts can be seen on the surface of copper roofs and constructions like the Statue of Liberty. Although it is soluble in acid, under normal conditions it is very stable, preventing corrosion of the rest of the copper underneath the surface.
- Reaction with cola is remarkable from the point of view of making the copper clean - it's very acidic - but you can't see it happening very well. What would happen if you put a tooth in it? Can relate this to drinking lots of fizzy drinks being bad for your teeth. Do they know what metal is found in teeth? Lots of kids have heard of needing to eat calcium for strong teeth/bones but don't necessarily know it's a metal.

Risk Assessment

Hazard: Copper dissolved in liquid

Description: Ingestion of copper salts can lead to the creation of free radicals in the body (which can damage DNA).

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Concentrations are very low, the tolerable ingestion limit of copper is about 10mg, much less than would be present in a container used to clean a couple of coppers. Change acid every 10 coins and dispose of used solution down a drain immediately. Empty and rinse container. If cleaning large numbers of coppers to observe green colour of solution use a closed (plastic) jar and tape down lid. Keep control of jar (at busy events may be advisable to tape jar to a length of string to prevent it "walking off"). Call a first aider in the event of ingestion.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Acids

Description: Use of lemon juice, coke, other culinary acids - will sting if they get into people's eyes or cuts.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Ensure children lower coins gently into solution. Encourage them to check for scratches before putting hands near solutions and to wipe fingers afterwards. Rinse out cuts, call first aider if required. If trained and confident to do so use sterile eye wash to clean out splash to eye.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Hazard: Coins

Description: Choking on coins

Affected People: Small children

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Watch small children carefully. In the event of a piece being swallowed, encourage child to cough. Call a first aider, who may perform the Heimlich if trained and happy to do so.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

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Cloud Formation in a Bottle

Demonstrate cloud formation as air pressure drops.

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Physics

Equipment Needed

- Lemonade Bottle
- Matches

Experiment Explanation

A smoking (recently blown-out) match is dropped into a lemonade bottle containing a little water. The bottle is closed and then squeezed, held for a few moments, and released. This step may need to be repeated a few times. When you release the bottle clouds should nucleate on the nuclei provided by the smoke particles.

By squeezing the bottle you increase the pressure inside it and also the temperature. This causes the liquid inside to evaporate and form water vapor. Then, when the bottle is released, the pressure decreases again and the temperature drops. This fall in temperature allows the water molecules in the bottle to condense around the smoke particles, forming a cloud.

Risk Assessment

Hazard: Matches

Description: Possibility of burns from lit matches.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Only demonstrator to use matches; ensure that matchbox is not available to be grabbed by children. Demonstrator to strike and extinguish matches away from self but also to take care not to strike immediately towards visitors. When dropping match into bottle, avoid having hand directly above match. Ensure match is no longer lit when dropped into bottle. (There should be visible smoke) Have a cup (or similar, not flammable) of water to hand to take matches which might be lit and not used. Run burns under tepid water for at least 10 minutes. Contact a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Lit matches (dropping)

Description: If lit match is dropped on something flammable there is a risk of fire.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: Keep flammable materials away from experiment. Avoid blowing on the match to extinguish it. Have a fire extinguisher available. Fight fire if safe to do so - can also use the cup of water if it is a small fire.

If fire gets out of control evacuate area and call 999.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Water

Description: Slip hazard in the event of spillages.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 12

Mitigation: Have paper towels handy and dry any spills immediately.

Contact a first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Smoke

Description: The amount of smoke over a long period of time may irritate the throat and eyes. It could also trigger asthma attacks.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Make sure demonstrator has access to water. Wear a face mask and safety goggle if possible. If they start to get irritated they should request to take a break and get some fresh air or request to swap experiment if they prefer. Demonstrators with asthma should be discouraged from demonstrating this experiment.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

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Computer Dissection

**Dissecting a computer ** - Break open a computer and see how it works inside.

Last initially checked on 2023-02-17 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Computer Science

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Parts of an old computer, floppy disks, cds, tapes, dissected hard drive. USB stick.
- Some electrical components, you might be able to see these but they're tiny.
- Old and new circuit boards.
- Induction charger and receiver.
- Dissected plug.
- Mouse/keyboard.
- 7" Vinyl Disk

Experiment Explanation

There are lots of pieces that go into a computer but what do they do?

Data

Data storage - This is a large part of what we do on a computer, what sort of things might be important? Size controls how much you can store. It might also be important to think about price and data access and transfer times. Flash memory and solid state drives are really quick but very expensive. Data is stored as 0s and 1s and each digit is called a bit. These are stored in various ways. Another thing to think about is 'volatility', we'd like things in memory to last when the device is powered off and also how it can be accessed, the main ways are 'serial' or 'random'.

Hard Drive (HDD)- data stored on disks by magnetic means. Imagine an iron nail, normally it's not magnetic however rub it with a magnet and it becomes magnetic. Run it again and we can demagnetise it. This stores the data by saying magnetised means 1 and not means 0. The arm swings across the platter and has a tiny magnet to read and write. Many modern drives have multiple platters inside and multiple heads, they're also normally double sided. Data is placed on tracks (concentric circles) broken up into sectors. Part of the drive is reserved for a sector map (Windows File Allocation Table - FAT) to allow the data to be found. Things that can go wrong include a 'head crash' where the read write head gets knocked into the platter and 'thrashing' where the platter spins back and forth to allow the computer to access files at different locations on the same platter. These give random access.

Flash memory (Solid State) - Used in USB sticks and new solid state drives. They have no moving parts (hence the solid state) so it's ideal for memory sticks. It uses transistors to alter the flow through a gate (very complicated, high charge causes electrons to be fired inducing charges...). It's much smaller and lighter as it doesn't need a moving arm or motor, it's also much faster access and is random like HDD, however is much more expensive.

Magnetic Tape - This is a much older method of storage which works by storing data on a magnetisable tape. It's very cheap and is still used in medium-large data centres. The main advantage of tape storage is it's very easy to swap tape cartridges into a reader than move HDDs and cheaper than installing connections for all these drives.

CDs - computer bounces a laser off the shiny side to read the data, three layers, plastic, shiny aluminium, see through coating. When it's made a very powerful laser burns 'bumps' into the disk which represent 0s and then copies are pressed. The burned pits scatter the light and unburned areas reflect. To read the laser shines of the disk and only the unburned parts reflect the light fully onto the detector. The spiral along which data is recorded is about 6km, each pit is around 2 millionths of a millionth of a square meter. Many CDs are now writable at home which this process isn't, these have an additional layer of dye before the reflective aluminium layer which can be burned by a slightly more powerful laser than the one used to read, re-writable disks have a metal alloy which phase-shifts between an orderly translucent crystalline form and a random opaque amorphous solid form under the laser. So CD drives need to have the correct laser fitted to do this. CDs hold around 700MB, DVDs have closer pits and so capacity of around 4.7GB. Bluray uses a blue laser which has shorter wavelength so the pits can be even closer bringing capacity to 25GB. HDDVD was a failed alternative to bluray, also using a blue laser, however the disc design meant only 15GB capacity leading it to be abandoned in 2008. There's also a mini CD which exploits that CD standard reads from inside to outside (opposite to vinyl). When the standard was set it was decided to go this way for this reason. With vinyl the human drops a needle at the edge whereas cds read outwards until they reach a stop.

You can talk about how these are also becoming obsolete, why? People want slim and light devices and these don't work with that. Some laptops don't come with USB ports anymore as they're too fat and there's whole ranges of USB C memory sticks and mice for these!

RAM - This is a volatile type of memory but has very quick access speeds. It pairs a transistor and capacitor and needs constant power to maintain capacitor charge, if not recharged they last milliseconds.

Floppy Disk - This has a tape like disk and is read like a hard drive. They're very low capacity getting up to 1.44MB.

Price wise tape is around $0.02/GB, HDD $0.033/GB and Flash $0.25/GB from a 2016 survey. RAM costs closer to $3/GB. HDD read/write speed is around 120MB/sec and Flash 525MB/sec, RAM can be 6-17GB/sec (note G not M) Talking about data transfer big companies like Google which need to transfer vast quantities of data often use hard drives shipped in trucks. Amazon snowmobile can transfer 100 Petabytes of data from your location to the amazon cloud in a week, versus gigabit internet (1gbps) which is very fast home internet taking 20 years.

This computer has two hard drives a 3.2GB one (western digital Caviar 13200) and a 4.3Gb one (Quantum Fireball SE). Many modern PCs come with 1TB hard drives and or 256GB solid state. For phones the iPhone x has 64-256GB.

NB - Vinyl - Some people may think of this as a method of storing data, and yes it is! However it's not one commonly used by computers as it's very specialised to sound data. To play them back one runs a needle over the record, in mono vinyl this moves up and down depending on how deep the groove is. Using a transducer (magnets to induce a current from these vibrations) it induces an electrical signal, this is passed to the speaker which vibrates in this pattern. When doing the etching we use a different transducer to turn the sound into an electrical signal which gets etched onto the disk. Stereo vinyl uses a clever trick to work on old mono players. It encodes the sum of left and right signals in vertical vibrations and use lateral vibrations to encode the difference. A mono player just picks up the sum but any stereo player can do the maths to separate left and right. There's also some great examples of data issues with vinyl, records come mainly in 7" and 12" (but sometimes also 10"). The bigger diameter gives more space for grooves, allowing longer tracks to be stored on them. They also come in different rpms, mainly 33 1/3 or 45 (but also 78). The faster the rpm, the less can be fit on the disk as it travels through the groove faster, however the quality is better as the details of the vibrations have more space to be stored.

Other parts

CPU (Central Processing Unit) - This sends signals and controls other parts of the computer. We often compare clock rates, the CPU completes one basic task in a tick of the clock. Overclocking increases the number of ticks a second, it's designed that computers can easily complete most tasks within a tick, so decreasing the time shouldn't cause most tasks to fail. The computer in front has 200MHz clock speed (I think), a modern intel i7-3970X (very good 2018 CPU) has a 3.5GHz clock speed and iPhone X has 2.39GHz.

Fans - These cool down the components, they're an active cooling method as they require power. This computer had several plastic pieces to control where the fans cooled. Other active cooling methods include water cooling (and other fluids) which is more common in high end gaming PCs and commercial data centres and servers. With water their is added risk as water and computers don't mix well! However water is better at transporting heat than air. There is a red ended cable labelled 'F' which goes from the red pins on the motherboard to the fan and controls it's speed and provides power.

Passive Cooling - You can spot one on the motherboard, it's noticeably cold to the touch, this is as it's designed to transfer heat well. Note the large surface area to transfer heat.

CD drive - this reads the CD, you can see the laser which reads the cd and the motor which spins the CD. It can spin 200-500rpm however some modern drives can read at higher speeds so spin even faster. Floppy drive - notice the read and write head like in a HDD, for portability.

Floppy drive - not very common anymore! This works like a HDD but the floppys are insertable.

Network card and antenna (old computers didn't have wireless!) - this processes data to be ready to send over a network. This is often using packets and we can do a quick demo to talk about these. We split the message into lots of individual 'packets' these are numbered and thrown between children until they land in the incoming box, some might miss and the network card will have to make a new copy and resend. The card sorts the data to be back in order, deals with any missing packets and the like. In here there is a Realtek GTS FC-515LS, there's also an external antenna from a different computer which was added on to allow WiFi connectivity.

Sound card - Does really what it says, converts signals from the CPU into a form that can be sent on, encoding it into various formats and outputting it. Also deals with things like microphones etc. The sound card in here is a HP Soundblaster 16. You'll notice a cable labelled 'A' (for Audio) which is attached to this card, it goes to the CD drive.

Video card / Graphic Card - Basically sound card but for video, many modern ones have a GPU (Graphical Processing Unit), this is a really specialised processing unit designed for computations to do with displaying images. They're also sometimes used for mining bitcoins as they do better than standard CPUs for these calculations. This computer has a Trio 64V2 which is on the motherboard and no external card, these became more common with the rise of video games.

Power supply - This is the unit with a standard IEC lead input and lots of cabling coming out. DON'T PLUG IT INTO THE MAINS. This supplies power to all the different parts, you'll see they're all labelled Px and if you look at other bits you can see some black tape which indicates there's a power lead going there. For instance P1 goes to the motherboard. You'll notice it has it's own internal fan to keep cool.

Modem - This stands for MODulator/DEModulator and comes from how people originally connected to the internet over telephone lines. Adults may remember the dial tones it made, this early internet connection was dial-up, transfer speeds where around 56kbit/s. It converts digital signal into analogue for transmitting over the telephone lines. (I'm not sure if I have a modem still lying around so if you have one let me know) Modern modems use cable and sattelite to connect and are often combined into a single unit (called a 'gateway') with a router.

Router - This allows multiple devices to connect to a LAN (local area network), you may encounter LAN games on consoles which don't require you to be connected to the internet and to link the consoles via Ethernet. Often these are combined with modems to form a 'gateway'.

Gateway - Modern combination of a 'modem' and a 'router' allowing multiple devices to connect to the internet often using wireless signals, WiFi.

Data Cables - You'll see these ribbon cables which transfer data to and from the CPU, there's three here labelled D1, D2 and D3. D1 goes to the CD drive, D2 goes through the 2 HDD drives (a second was fitted later to this computer) and D3 goes to the floppy drive.

Motherboard - On this PC it's a HP Brio 83xx board. Here's a picture of a motherboard to help identify some pieces. There are lots of parts to point out and too many to list immediately. You can probably also pick out some capacitors and conductors which there are examples of in the electronics components bag.

Cabling - There's quite a few cables people might be familiar with included inside, you can ask if they know what they're for and why we might have different types of cable. One thing to think about is what is being sent via the cable. Speakers require analogue signals whereas other things require digital. You also need to consider how far a signal can propagate down a cable, USB has a limit of around 5 metres, that's why you don't get really long USB cables. USB also (traditionally, this is changing with USB C which is less strict on master/slave and supplies more power) has a master and peripheral set up which is why cables always have a none USB end (which connects to the peripheral). These peripheral devices can't communicate with each other without going through the master and there is a hard limit of 127 peripherals. Cables also have a bandwidth, USB is 5Gbit/s and HDMI is 8.16Gbit/s, even this isn't enough bandwidth for a 5k/60fps screen like on a new iMac. Some devices when connected also need power to be supplied, USB doesn't standardly provide a lot of power, if you plug into a computer you'll probably notice a slow charge however you may notice modern computers may come with charging ports which supply a non-standard amount of amps to charge devices faster. Ethernet is great for long distances, it's easily boosted for even longer distances and can be switched via routers to form large networks.

On switch - There's a cable running from the one switch and LEDs there to a set of pins on the motherboard near where the data cables plug in.

Wireless Charging - This was a big thing for phones a few years ago and then people moved on to rapid charging and other things when people realised it was a bit rubbish then. Some phones still have it however there was lots of cheap Chinese charging pads and even fitting kits which is what we have here. If they've seen the electromagnetism experiment they should be familiar with this! Essentially in the charging pad (the top swivels to reveal the insides) you can see the coil and piece of metal this creates a magnetic field when plugged in (don't plug it in though). There's then a thin piece of plastic which I've peeled open which has a coil, magnet induces current in coil, this charges the phone. The major downsides of this are, it's not very efficient and everything gets very very hot, (you also have to have a case to hold the plastic and take it off to unplug the wireless to plug into the mains for a good charge most nights). I slightly broke the receiver when dismantling it, if you desired to fix it solder the other end of the coil to AC2.

Plug - This is an old and broken USB plug. You can see how the wires go in the inside. There's a plastic prong, this prong is usually an earth prong. In the UK plugs need to have these as most sockets require something to be plugged in here before opening the other holes (that's why it's slightly longer). Double insulated device's don't need the earth connection. In EU and US plugs there are earth connectors at the top and bottom, you find plugs that need earth are more circular so the can reach them, however those that don't are quite linear.

Risk Assessment

Hazard: There may be residual electrical charge in some components.

Description: Electric shock

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Never plug anything in

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Sharp and small bits

Description: Getting stabbed with computer parts, and the potential for swallowing / choking on small parts

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: Keep track of all the bits, don't let people run off with them. Visually inspect components for sharp points/edges. If children are being silly take bits off them. Don't let kids put them near their mouths.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

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Cornflour

Explore the remarkable properties of cornflour mixed with water. - Slimey, gooey and messy: cornflour is one of our favourite experiments! Come and stick your hands in, and figure out if it behaves like a liquid or a solid...

Last initially checked on 2023-01-12 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-01-12 by Jessica Trevelyan (jet81@cam.ac.uk).

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- **This experiment can take place outdoors**
- Washing up bowls 3-4 or large plastic trays
- Cornflour 3kg min
- Water
- Laminated cornflour picture

Experiment Explanation

In a nutshell

You and the children play with the gooey cornflour/water mix, exploring the concepts of solids, liquids and substances that have properties of both. Cornflour is lots of irregular shaped particles that are separated by water normally so are lubricated and can move. If you squash them together it will push the water sideways a little bit and let them touch - now they lock together and behave as a solid.

Cornflour under a confocal microscope, which takes a 2-D slice through an image rather than looking at the surface.

How to set up the experiment

Putting down a tarpaulin or taping bin bags to the floor first may make cleaning up easier. If possible set up near a sink or have an extra bowl of water nearby for hand washing.

Put about one packet of cornflour into a bowl or bucket. Slowly add water to the cornflour until it works - ask a committee member for help if you're getting stuck. A ratio of 2.5 parts cornflour to 1 part water is suggested, but the ratio may vary. Note that on a hot day the water will slowly evaporate so it will eventually need to be topped up.

Packing away

Let the cornflour settle to the bottom of the bowl. Tip away any excess water and let the cornflour dry out (if there is time; otherwise throw it away). It can then be returned to its container. Other cornflour-contminated things should be washed down with plenty of water.

What you need to know about the experiment

1. Cornflour is shear thickening. This means the higher rate of shear, the higher the viscosity (i.e. the thicker it is). (Note: Shear can be explained by considering 'layers' of cornflour particles sliding past each other.)
2. Try asking them whether it is a solid or a liquid. You may want to get them to come up with definitions of the terms solid and liquid - e.g. "what do we call hard things / things that flow...?" Cornflour is like a solid and a liquid - Acts as a solid under stress and a liquid otherwise
3. It's like a room full of people and when you try and make it move quickly, everyone tries to move at once (while also moving closer together) and they all get in each other's way and so no one can move anywhere.

And when you do stuff to it slowly, everyone has time to move out of the way and file out.

Want to know more?

Shear thickening is a problem in the oil industry, as when they are drilling they are getting rock fragments in the mud coming back up, if there are too many they behave similarly to the cornflour, with catastrophic results to pumps. Some people are talking about making liquid body armour using this effect, to make the body armour more comfortable. The opposite of shear thickening is shear thinning. Many substances are shear thinning because the higher rate of shear can break up interparticular interactions and reduce the viscosity - e.g. shampoo, toothpaste - when you shear them by squeezing them out of the tube, it flows, but when there's no shear, it sits quite happily on the toothbrush without flowing anywhere.

Explanation warnings

THICKENING SOUPS IS DIFFERENT: the cornflour grains open up when heated and release long starch molecules that tangle together forming a gel-like substance. THIS IS NOT THIXOTROPY, which is concerned with time related effects. Thixotropy is a long word and shouldn't be used with children. Adults should be politely and gently explained the difference! The longer you shear a thixotropic fluid the lower the viscosity (the thinner it becomes) - e.g. paint - as you progressively break up interparticular interactions. Many fluids that are shear thinning are also thixotropic. Rheoplexy / Anti-thixotropy is the opposite - i.e. the longer you shear a fluid the higher the viscosity (the thicker it becomes). Xanthan gum might do this under certain conditions, but it's very rare for substances to do this.

PLUS Explanation

The above explanation works well even with sixth-formers (they often just like playing with the cornflour). Perhaps focus more on real applications (e.g. the bullet proof vests, oil etc), and then add in some discussion of the points below.

CHaOS Plus Further Ideas

The starch granules themselves are composed of a mixture of long-chain polysaccharides - essentially lots of â€œsugar moleculesâ€ (glucose) stuck together.

The starch granules themselves are composed of a mixture of long-chain polysaccharides - essentially lots of â€œsugar moleculesâ€ (glucose) stuck together.

A simple model for describing a non-Newtonian fluid is

$$ \eta = k \left(\frac{d\gamma}{dt}\right)^{n-1} $$

Here η is the viscosity (how â€œthickâ€ the fluid is) and γ is the shear (how much the material is deformed). The differential with respect to t tells us weâ€™re interested in the strain rate (how fast youâ€™re shearing). k is a constant.

If $n=1$, we get classical Newtonian behaviour (no dependence on shear rate). If n<1, then the viscosity decreases with increasing shear rate (shear thinning) and if $n>1$, then the viscosity increases with increasing shear rate (shear thickening).

Below is a schematic shear rate vs stress graph for various materials (labelled). The gradient gives the inverse of viscosity:

The â€œproperâ€ definition of viscosity is the ratio of the shear stress γ to the velocity gradient $\Delta u/\Delta y$ in a fluid from a stationary boundary:

$$ \eta= \frac{\gamma}{\Delta u/\Delta y} $$

Higher viscosity means a larger stress is needed for a given velocity gradient to be achieved (basically need to push harder to move a viscous fluid).

Another graph of shear stress vs velocity gradient (this time the gradient is the viscosity):

A Bingham plastic is one which is solid up until some yield stress, and then subsequently deforms with increasing stress. Mayonnaise and toothpaste are examples.

There is no â€œoneâ€ theory for why shear thickening happens - there are a couple of mechanismsâ€¦ Talk about intermolecular forces (e.g. van-der-Waals forces), which hold molecules in suspension.

For large shear rates, intermolecular repulsion can be overcome, and the molecules are pushed out of their equilibrium positions and â€œmoshâ€ together. This essentially makes the suspension â€œless orderedâ€, and hence increases the viscosity (less easy for molecules to move past each other).

Another mechanism involves the molecules joining to form small groups (â€œhydroclustersâ€), which may be thought of as long rods of particles that cause a â€œtraffic jamâ€ and increasing viscosity.

Risk Assessment

Hazard: Cornflour

Description: Powder may trigger asthma attack.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Clear up spilt powder. Where possible, do the experiment outside. Do not allow children to help to mix in new powder without first checking that they do not suffer from asthma. In the event of an adverse reaction, move child out of area and sit them down. Call first aider.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Water/water-cornflour mixture

Description: Minor slip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clear up spills promptly; if the floor is smooth, ensure that a mop is available for this. Put wet floor sign down on cleaned floor. Set up near a sink or have a bowl of water for hand washing nearby so children don't drip cornflour on their way to a sink. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Cornflour

Description: Irritant to eyes.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Avoid contact with eyes and tell children to as well. Know where the nearest eye was is (there should at least be some in the Safety box). Call first aider in event of injury, who may perform an eyewash if trained and happy to do so.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Old cornflour mixture

Description: After a while, the mixture accumulates some dirt, which is not recommended for consumption.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Encourage children to wash hands after use. Do not allow children to ingest the mixture.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-22 - Hannah Ford (hf257@cam.ac.uk), **Check 2**: 2012-01-21 - Catherine Collett (chc47@cam.ac.uk)

Check 1: 2012-12-12 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk)

Check 1: 2014-01-23 - Peter Maynes (peter.maynes@cantab.net), **Check 2**: 2014-01-23 - Vamsee Bheemireddy (vrb23@cam.ac.uk)

Check 1: 2014-12-27 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2014-12-31 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2015-12-28 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2016-01-02 - Tim Morgan Boyd (tmb58@cam.ac.uk)

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Check 1: 2019-01-09 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-13 - Polly Hooton (prh43@cam.ac.uk)

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Creepy Crawlies

Looking at a variety of small creatures that you can find in your garden - Insects, worms, bugs and more: what lives in your garden? Get up close and personal and see for yourself!

Last initially checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk)

Tags

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Equipment Needed

- **Electricity needed**
- Large clear plastic box with holes in lid
- Small magnifying viewing boxes
- Creepy crawlies - collected either by lifting up rocks etc or by using traps made by sinking jars into the ground and covering with loose twigs etc. and leaving overnight.
- Dissection microscope (potentially)

Experiment Explanation

We will collect these hopefully from a variety of habitats. It's interesting to discuss how the insects are adapted/camouflaged to their environments, and what the larvae might become.

Some examples of things that might be collected are:

Insects

There are around a quarter of a million times more insects in the UK than humans, and more than a million different kinds of insects discovered on Earth (of these >20,000 species live in the UK). Beetles are the biggest group within the insects. (Note: All bugs are insects, but not all insects are bugs)

All insects have 6 legs and their bodies are divided into three main parts; the head, thorax & abdomen.

The skeleton of an insect is on the outside of its body (and is called an 'exoskeleton').

Insects breathe through little holes in their abdomen called spiracles (they don't have lungs). [for older kids] This way of breathing puts a size limit on the insects - they rely on diffussion (movement of particles from areas where there are lots to where there are fewer). When there was a higher concentration/more oxygen in the air (in the Permian), insects could be bigger - with wingspans as wide as your armspan! (As the greater difference in oxygen concentrations (between the air outside and within the insect) allows diffusion over a longer distance).

Examples of insects that you might collect are:

A few interesting facts are:

- Froghoppers are best known for their nymph stage, which produces a cover of frothy plant sap, "cuckoo spit" which hides the nymph from predators, insulates them against the cold, UV radiation and keeps them moist.
- Crickets and grasshoppers both have jumping hind legs

Woodlice

- Crustaceans with a rigid, segmented shell-like exoskeleton
- 14 jointed limbs
- Some woodlice can roll up into a sphere as a defensive mechanism
- Live in moist places (e.g. under rocks and logs) because they breathe through gills
- They eat mostly dead plants (decomposers)

- As woodlice grow they shed their exoskeleton in two stages, with the back half first followed a few days later by the front

Spiders

- Arthropods with 8 legs, they are not insects! (related to crabs!)
- They don't have antennae but instead use hairs on their body and legs to sense objects around them
- Spiders are carnivorous but have small mouths so in order to eat they inject poison into their victims which digests them
- Some spiders spin webs to catch their food - flies get trapped in the sticky strands of the web (made from silk produced by glands at the back of the spider's body).

Risk Assessment

Hazard: Insect/soil

Description: Stomach upsets if a child ingests an insect, or soil. Tetanus risk if people with deep cuts touch soil.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Watch very young children to ensure they do not put soil or insects in their mouths. Ensure that any child who has touched soil or insects washes hands. Do not allow people with cuts to handle soil - demonstrator to wear a plaster if they have a cut. In case of contact, tell them to wash out the cut and reassure that there will probably not be a problem, but to contact GP if any symptoms ensue.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Electrical equipment

Description: Dissection microscope, electrical equipment - hot and risk of electrocution if faulty or wet.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Switch off microscope between uses if it starts to become hot. Don't set up near taps or wet experiments. Switch off equipment in the event of an electrical problem, clear area, call first aider. If child burns themselves, keep affected area under running tepid water for 10 mins, call a first aider. Read attached electrical RA.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Loose insects

Description: Panic, especially if an insect gets loose.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure the insects are all kept in close range, and that children do not open tray lids without supervision. If an insect gets loose, clear the area, get adults to help keep their children under control, retrieve insects (call for help if necessary). In case of injury call first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Insect bites

Description: Itching or allergic reaction if someone is bitten by an insect.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Don't assign demonstrators with an allergy to insect bites to this experiment. Encourage children to be gentle when handling insects. Do not let very young children handle the insects themselves. If bitten, reassure that there probably won't be a problem, pull out any visible sting (get first aider), wash under a cold tap to soothe irritation. If irritation persists contact as first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

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Cryptography

Learn about codes and ciphers - Learn about codes and ciphers through a selection of demonstrations of different methods using whiteboards and padlocks.

Last initially checked on 2022-02-09 by Joshan Parmar (jp862@cam.ac.uk) and double-checked on 2022-02-09 by Sian Boughton (seb216@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Computer Science

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Morse code
- Morse buzzer and clicker
- Morse code chart
-
- Semaphore Flags (2 per transmitter)
- Semaphore Sheet
-
- Paper Telephones and Envelopes
- Two paper cups connected by string
- Third paper cup on a string
- Some envelopes
-
- Ceaser Shifts
- Whiteboards and pens
- Laminated alphabet wheels
- Laminated alphabets
-
- Wrap around codes
- Sections of pipe insulation
- Code strips
-
- Asymetric Encryption
- Two padlocks with keys
- Box with two padlock holes
-
- Public key encryprion
- Padlock with key (needs to lock without key)
- Box with at least one padlock hole
- Two led lights
- Transparent plastic cups
- Food colouring
- Water
-
- Quantum Cryptography
- Polarisation Experiment with extra filters
-
- Pollard's Kangaroo
- Kruskal's Count Experiment

Experiment Explanation

Firstly this is a large selection of small demos, each one is relatively fun and some link together well. They start of relatively easy however some of the demos at the end are really quite hard.

The main thing you'll get confused about is this technicality Code - converts whole words Cipher - acts letter by letter This means lots of things we call codes are ciphers!

Morse 'code' Press down and make a buzz, using the translation table you can transmit messages. Get one person to transmit and the others to try and transcribe the message. Most competent transmitters can manage 40 words per minute and the record is 75.2wpm. As words and characters have different lengths this is just an average though.

Semaphore Display the flags in the patterns for each letter. Similarly to Morse one group transmits and one transcribes. It was used pre-telegraph and Morse code to transmit messages long distance, using towers and spyglasses to relay messages faster than horse and rider. You can easily split the groups with one transmitting Morse and receiving semaphore and vice versa.

Paper Telephones and Envelopes These phones allow you to communicate like a telephone, it works by vibrating the string to transmit. If you loop on the third cup there's now an eves dropper (a wire tap). This transmission is not secure due to this. Similarly if two people pass envelopes between a third postman they can communicate. However the postman can open letters, or even just change them. We can think about what properties we want when sending messages there are a few contenders. Confidentiality - only the person meant to receive the message does. Integrity - the message has not been altered in sending. Authenticity - the message comes from the right person. How can we fix these? Let people come up with ideas. Seal envelopes to make it harder to open and close. Sign letters. Talk in code/cipher.

Caesar Shifts These are named after Julius Caesar even though they've existed long before. They work by rotating the alphabet and replacing letters like this. The code wheels are very useful to do this, they can do both the encryption and decryption. This code is really easy to break, there's only 26 options so we just have to try a few, you can even get people to do this. Just by trying a few letters you can decide to move on and try the next rotation, it's very unlikely the message starts 'zm'. This encryption sees only one common use, since it's so insecure it's mainly used for spoilers. They use a form called ROT13 which rotates 13 places, try it and try encrypting something twice! You'll find it's self inverting which saves on code. In these for someone else to decrypt they just need to know the number you've rotated by. Because it's so simple one way to add complexity is by also agreeing a word, write this under the start of the alphabet and then write out the remaining letters in order. This makes it harder for someone to guess as they need to get your word. Can we still break this code? Yes quite easily, write a long message in English, count up how many times each letter appears, are they all equal? Which letters appear most often? If we find these in a long coded message we can see which letter is most common and try and match them up. E, T, A and O are the most common, while Z, Q and X are rarest. We can also do this looking at pairs and find TH, ER, ON, and AN are the most common pairs of letters (termed bigrams or digraphs), and SS, EE, TT, and FF are the most common repeated letters.

Wrap around codes (I can't remember the name) Scytale These codes are written on strips of paper to read them you need to wrap them around a piece of pipe insulation and read downwards. The hidden key is the diameter of the insulation, try a different size and the message doesn't make sense.

Key Exchange

In this section, we'll look at sharing information between two people Alice and Bob. They want to pass messages to each other without them being read by their nosy friend Eve. We've got a box they can post messages between them in as well as an assortment of padlocks and keys, ask the children how they might send a message between them? You can act as the post, taking things between them, but also as Eve, reading and copying all the post they send.

The simplest way is having one padlock and giving Alice and Bob each a key that opens it. This works well but imagine Alice and Bob live on opposite sides of the world and can't meet in person? How can they both get a copy of this key? Whenever you're using the internet you need to do frequent key exchanges, if you're making a payment you need to send that information to the company, but don't want anyone else stealing your bank information, you need to exchange keys.

The next idea might be for Alice to post a key to Bob however if Alice puts a key in the post, Eve can intercept it and copy it. Now Alice, Bob and Eve all have keys so it isn't secure and everything is ruined. You'll have to think of ways to pass the boxes so Eve can't open them.

One way to exchange is as follows, each person has their own padlock and key. Person A wants to send a message to B, do so they follow this process: â€¢ They lock the message in a box using their own padlock and send it to B, â€¢ B receives the box but can't open it as they don't have A's key, they padlock it with their own lock and send it back to A, â€¢ A now can't open it either but they unlock their padlock and send it back to B, â€¢ B can now open the box and read the message.

This system is a private key system, with both keys and padlocks only known to A and B. In modern cryptography, lots of systems rely on public keys, these allow individuals to be able to send messages easily as to send a message to A you get A's public key (an unlocked padlock with no key) you then lock this and send it A. A is the only person with the key so only A can open it.

In public-key cryptography, keys are often exchanged using ElGammel or Diffie-Helmann, both of which work on a similar "double-lock" process. The process given above is actually insecure and vulnerable to a man-in-the-middle attack in a public key system, for this example it can be broken as follows: â€¢ E intercepts the box A sends (box 1) to B, â€¢ E copies the box (which will be empty a E doesn't know the contents and B can't open) to get box 2 which she padlocks sends to B, â€¢ B padlocks the fake box 2 and returns it, â€¢ E intercepts box 2, then adds her padlock to box 1 and returns this to A, â€¢ A receives box 1, removes his padlock then sends to B. â€¢ E intercepts box 1 and views the contents, â€¢ E creates a new box 3 with the contents and locks this with B's padlock (as padlocks are public keys)

One can create a valid model for Diffie-Helmann using lights. Optionally place the two led lights under the cups for darkroom use. Make up a private key which will be your own special colour. Between you make a public key which you can show everyone. Each take equal amounts of public and private keys and mix, you can share this with Eve while passing it between you. Then to the swapped colours add a shot of your private key to the new mixture. You'll find there's now a shot of each private key and a shot of public key in both A and B's mixture however E can't recreate it as she's only seen the following mixtures: public key, public+A private, public+B private. Any mix of these is going to have too much public key in! This works best if the colours are all different and very light, otherwise you end up with black as your secret colour and its hard to show eve not getting it (they've not got the same shade of black but its hard to tell).

One more modern encryption scheme is RSA, this is also an asymmetric scheme. Its a public key scheme, a public key here is an unlocked padlock which we leave them with a central repository, anyone wanting to send A a message goes and gets an unlocked A padlock uses it to seal the message to A and then only A can unlock it. There is one weakness with this, if the person in the repository is dodgy then they can read all messages, they give out their own padlocks, open the message then attach the correct padlock.

RSA (PLUS) For really competent groups who've probably already seen group theory you can go into detail of how RSA actually works. It's quite complicated though. You can link in Hexaflexagons to solve some equations.

Quantum Cryptography (PLUS) Digitally we encode using binary, we can represent this in any way punched holes, magnetism. However we've seen photons have a polarisation and we could use this. Alice has a light and polarizer and Bob has a polarizer and screen. On the screen the difference in brightness should be apparent between the filters being aligned, off by 45 or opposite. A simple way of transmitting messages is for Alice to rotate her filter horizontal for 0 and vertical for 1. Bob leaves his filter horizontal and can observe. This has all the same problems as paper telephones. You may wonder why polarisation is used, it turns out its a really robust property of photons. Now we move onto the full quantum scheme, we need to set up some random shared information. Alice and Bob both flip coins to generate this. Alice picks a string of test bits to send. Alice flips her coin and heads mean she uses the convention before of horizontal 0 and vertical 1, tails means she rotates this by 45 degrees and diagonal is 0 and antidiagonal(135) is 1. Bob sets his polarizer horizontal with a head and diagonal at tails. Bob records as before however if its intermediate he flips a coin and records that. Alice then reads her coin toss results to Bob and anyone else that wants to listen in. Bob knows anytime he flipped the same he can trust what he saw (this should be roughly half the string) To check there's no eves dropper he confirms some of the successes with Alice, if they don't agree they've outed an eves dropper. Eve to listen in needs a set up like Bob and then Alice. She tries to read Alice's message then re-transmit to Bob. So she needs to flip coins for both Alice and Bob. This means half the verification is expected to go wrong as she'll disagree. However anything that did get through can be used. In real quantum you'd want to use single photons, this method is vulnerable to slightly dimming the light in the middle but this isn't possible for single photons. https://spookyactionbook.com/2016/04/12/demonstrate-quantum-encryption-with-a-flashlight-and-pair-of-sunglasses/

Pollard's Kangaroo (PLUS) http://faculty.uml.edu/rmontenegro/research/kruskal_count/kangaroo.html So you can solve some discrete log stuff (which is used in DiffieHelam and ElGammel) using basically Kruskal's count with some fancy number theory rules...

Risk Assessment

Hazard: Paper

Description: Paper cuts

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure children don't get too over excited and call a first aider in the event of an incident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Morse Code Buzzer

Description: Electrocution from Morse code buzzer

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Make sure power is low (i.e. small battery) and people don't try and make connection using a finger.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Persons padlocked together.

Description: Persons padlocked together indefinitely.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Make sure padlocks have working keys before use. Make sure kids don't mess with them.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Padlock.

Description: Fingers caught in padlock.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure padlocks not messed with

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2018-12-12 - Matthew Le Maitre (msl54@cam.ac.uk), **Check 2**: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2020-02-04 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-02-04 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-17 - Sian Boughton (seb216@cam.ac.uk), **Check 2**: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk), **Check 2**: 2022-02-09 - Sian Boughton (seb216@cam.ac.uk)

Dark room

To be read before doing experiments in a dark room

Last initially checked on 2023-02-19 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-19 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Other

Darkroom

Equipment Needed

Dark sheets to cover windows etc.

Experiment Explanation

Some experiments are best performed in a dark room, read this RA in along with the experiment RA before demonstrating.

Risk Assessment

Hazard: Fire

Description: Dark room fabric may catch fire.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: We have tested fabric for flammability.Keep all electrics away from fabric, and off the floor if there is a risk of moisture getting into the electrics. Keep fire extinguisher in dark room. Check carefully behind tent for heaters etc. In the unlikely event of a fire, the tent walls can be lifted/detached quickly to allow exit.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Heat exhaustion

Description: The darkroom can get hot - may cause heat exhaustion

Affected People: Demonstrator

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: All demonstrators to have water bottles. Ensure demonstrators change round regularly and floaters visit the dark room to check everything's okay. Use fans and make sure the chimneys are providing ventilation.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 8

Hazard: Unseen drop

Description: If a stage or other raised area is used as a darkroom, curtain may mask drop

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not use a darkroom in significantly raised areas. Most "darkroom" experiments still work in well-lit rooms. Where possible leave a gap between a drop and the edge of the dark room. Clearly mark sides next to drops (e.g. hazard tape along inside). If possible site experiments to block access to drops.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Child abuse

Description: Risk of child abuse, or child abuse allegations, if demonstrator alone with children in darkroom.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Ensure a minimum of two demonstrators are present at all times. If this is not possible, close the darkroom.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

Check 1: 2023-02-19 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-19 - Asmita Niyogi (an637@cam.ac.uk)

Dissecting sheep's eyeballs

Dissecting a sheep's eyeball to show the structure of the eye - Only at "Crash, Bang, Squelch!": see the inner workings of the eye first-hand by dissecting a sheep's eyeball! Feel the smoothness of the lens, prod the gelatinous fluid and see the amazing coloured sheen of the layers that help sheep see better in the dark.

Last initially checked on 2023-02-12 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-02-14 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Medicine

Equipment Needed

- Dissection kit
- Chopping board
- Eye protection for demonstrators

Consumables:

- Sheep's Eyeballs, ordered from Blades (~25 required for CBS)
- Non-latex gloves
- Yellow clinical waste bags/other disposal system as appropriate and agreed with Zoology staff

Experiment Explanation

BASIC PROCEDURE AND EXPLANATION

STEP 1: Look at intact eye:

- See where the eye muscles insert. We have a small model with elastic bands to demonstrate how these work to move the eye in the socket, combinations of muscles mean you can move them in all directions.
- See where the optic nerve enters the eye, explaining what it does, plus talking about blind spot
- Curvature of cornea - also acts like a lens, but we can't change its shape like we can the lens inside the eye to focus on objects. In humans, the cornea contributes about 2/3 of the eyeâ€™s total refractive power (ability to focus light).

STEP 2: Cut around the junction between the cornea and the scelera to remove the cornea:

- Can then see the iris lying on top of the lens.
- Pupil just a hole, can change its size to let more or light in. So when youâ€™re in a dark room need bigger pupils to get more light to see things. When youâ€™re in bright light it need to be smaller to stop the light damaging inside your eyes. Itâ€™ s the iris that actually changes the size of the pupil. There are tiny muscles attached to the iris inside the eye that contract and relax to change the size of the pupil.
- This is a reflex (you donâ€™t have to think about making your pupil bigger, it just happens!). A good way to demonstrate this is in front of a mirror in a bright room. If you cover your hand over one eye and then move it away quickly you will see your pupil shrink as it is exposed to bright light from under the shadow of your hand.
- â€˜Red-eyeâ€™ in photos happens because the flash makes the iris constrict, but not quickly enough to stop most of the bright light entering the eye. The light from the flash goes into the eye and reflects off the retina at the back of it, making the pupil appear bright red.

STEP 3: Cut the globe in half (coronal slice - so cornea on one half, optic nerve on the other):

- Look inside!

STEP 4: Remove lens to look at it:

- What is the function of the lens? There are muscles around the lens that allow it to change its thickness. If itâ€™s fatter, it can refract light more and is therefore good for looking at things close to you. When people get older the lens is less elastic so theyâ€™re not as good at doing this and need glasses to read the paper...

STEP 5: In the back half of the eye:

- See where the optic nerve leaves â€“ ask the child where it goes (to the back of the brain where the visual cortex is). This is an opportunity to talk about the function of nerves if the child is keen.
- The point where the optic nerve leaves is called the blind spot. There are no light sensitive cells here so you are actually blind in this bit of your eye. You can talk here about when Mum/Dad is driving the car and they have to turn around to check their blind spot before overtaking.
- See that itâ€™s dark; this is so it absorbs the maximum amount of light
- In sheep's eye thereâ€™s an iridescent coloured part, called the tapetum lucidum (â€˜bright carpetâ€™ in Latin), just behind the retina. It reflects light back to the retina, increasing the amount of light that the retina receives. This helps animals such as the sheep to see better at night. We donâ€™t have a tapetum lucidum so we can hardly see at all in the dark. Ask the child if they have ever seen a photo of their/their friendâ€™s cat/dog. Animalâ€™s eyes often appear to glow blue, yellow or green in photos because of the light from the flash reflecting off the coloured tapetum.

OTHER THINGS TO TALK ABOUT

Once youâ€™ve discussed the main features of the eye there are a couple more things you could touch on:

Short/long sightedness and how it is corrected:
Short sightedness is when the lens is too thick so light focuses in front of the retina, and is corrected with a CONCAVE lens.
Long sightedness is when the lens is too flat so light focuses behind the retina and is corrected with a CONVEX lens.
This is discussed in the camera obscura experiment which can be found in the dark room with the Physics experiments.

The retinal cells (rods and cones), how they work (in simple terms!) and the differences between them.
Cones are used to see colour.
Rods are used when it is darker.
The retinal cells contain a photopigment (opsins) that absorbs light and produces an electrical signal.

Risk Assessment

Hazard: Preservative

Description: Splash of preservative in eye, on skin, or ingestion (preservative is Propylene phenoxytol 1%) slightly harmful by ingestion, may be mildly irritating to skin and eye.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrator to wear eye protection and to ensure that cutting does not take place close to where children are standing, especially during the first incision, when spurting is possible. Nitrile or neoprene gloves (NOT LATEX) to be worn by all who might touch the eyeballs. Call first aider if preservative goes in eyes. Demonstrator can administer eye wash if trained and confident to do so. Wash preservative off skin with ample water.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Apparatus

Description: Stealing of parts esp. scalpel.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Two demonstrators present, one to demonstrate, the other to mainly check that children aren't trying to take things or get hold of scalpels etc, and to look after people who faint. If equipment gets stolen, assisting demonstrator to relocate it and inform committee (especially if a scalpel has been taken).

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Eyeball

Description: Fainting at sight of eyeball/dissecton.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clearly signed and "separated" area for dissection, to keep away squeamish people. Chair nearby for light-headed-feeling people - may be preferable for them to sit on the floor as people can still faint off chairs. Call a first aider in case of fainting. Before starting demonstration, tell the public to let you know if they are feeling light-headed.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Scalpel

Description: Risk of cuts.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: Scalpels to be kept out of way of kids, demonstrator to be experienced and takes care. Call frst aider in the event of an injury.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

Check 1: 2012-01-05 - Ashley Smith (ashley.smith@cantab.net), **Check 2**: 2012-01-25 - Daniel Obute (rdo23@cam.ac.uk)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

Check 1: 2014-01-07 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-22 - Sharmila Walters (sw632@cam.ac.uk)

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Drosophila

This experiment aims to introduce kids to a wonderful model organism, the Drosophila fruit fly. - You'll have seen some of these fruit flies before: these cool and beautiful little creatures have shown us how genes can be inherited (by following patterns of features like eye colours), and how genes work.

Last initially checked on 2023-01-17 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-01-18 by Chiara Delpiano Cordeiro (cd796@cam.ac.uk).

Tags

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Equipment Needed

- **Electricity needed**
- Drosophila flies (wild-type, various mutants) in plastic vials with foam/cotton wool bungs. Plastic petri dishes with Drosophila larvae.
- Drosphilia flies in petri dishes allows easier viewing under a microscope.

Experiment Explanation

1. What are Drosophila? Often called 'fruit flies', they tend to be found around over-ripe or rotting fruit. We're interested in them because they've been the subject of lots of (mostly genetic) experiments since they're easy to grow in the lab, have a short (~12 day) life cycle and are easy to make mutants which can help us understand biological processes. Have a look at them - see how big they are. Can you identify males and females? (See below) What colour are their eyes (wild type have red eyes).

2. Drosophila development: Provided should be several Petri dishes containing different developmental stages of the fruit fly. Explain to the children the general concept of development (i.e. the process that helps us go from a sperm/egg to a full grown adult) and how it differs from species to species. Next, using the laminated descriptions/photos of the developmental stages (see below), ask the children to put the Petri dishes in the correct order of development. See lower down page for some pictures/descriptions.

3. Identification of Drosophila phenotypes: There will also be several vials of flies with various phenotypes (some of which are listed belowâ€¦the exact phenotypes we will be given depends on availability during the week of Crash, Bang, Squelch!). Discuss with the kids how mutations in the DNA of the fly results in various fly abnormalities â€“ ask them to look at the flies and try to pick out some of the phenotypes shown on the handout (shown below). You can use this to relate how differences in DNA make humans look different (hair colour, eye colour etc.) and say that we inherit these from our parents.

It may be easier to view the flies if they are in a petri dish so a microscope can be used however it's possible using test tubes.

Risk Assessment

Hazard: Glassware

Description: Petri dishes/plastic tubes may be dropped/broken â€“ risk of injury from broken containers.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure that the flies are kept in close range. Ask children to be careful when handling tubes/petri dishes. Use plastic vials (instead of glass) to contain flies if possible. Call a first aider in the event of cuts. Wash any small cuts with soapy running water. Compress and elevate large cuts.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Microscope

Description: May become hot and may be touched by children

Affected People: Children

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Switch off microscope between uses if it starts to become hot. In the event of a burn, hold area under tepid water for at least ten minutes. Call a first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Drosophila

Description: Petri dishes and plastic tubes may be opened - drosophila are non-harmful insects, but it could cause panic/great excitement/silly attempts to inflict the insects on siblings, which can be a safety risk in a crowded place.

Affected People: Children

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Secure the petri dish lids to the petri dishes using tape (stretchy lab tape is fine) so that it is obvious to all that the dishes should not be opened. Demonstrator to keep an eye on all plates. In the event of an incident, demonstrator must regain the petri dish/vial and diffuse the situation. Call for help if necessary.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

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Ear model

Anatomical model of the ear, with removable parts. - Use our large-scale model of the ear to discover how it enables you to hear sounds.

Last initially checked on 2023-01-18 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-02-02 by Emily Wolfenden (elw74@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Anatomical model of an ear.
- Water filled plastic tube to demonstrate the semicircular canal.

Experiment Explanation

Acivities - Ear Model:

- Show the model; it's important to orientate them; i.e. the white bit is the skull; get them to think about the fact that the majority of their own ear is actually inside the skull
- Take model apart; look at/identify individual bits - what might they do?

Activities - Semicircular Canal Demonstration:

- Point out semicircular canals on the anatomical model; show them the water filled circular tube and say that that's what they look like inside
- Get them to spin the water filled tube- the pink bits move- so the fluid moves as well (for things to say please see below)
- What else is important for balance: get them to stand on one leg and let them close their eyes; is it easier or harder with their eyes closed? (for things to say please see below)

Tips for demonstrating:

If the kids are a bit older, they will often know quite a bit about how hearing works. However, they often know very little about balance, so it's good to talk about that a little more.
If the kids are really interested and know a lot already, you could talk a bit about soundwaves.

Basic Procedure and Explanation

Ear Model:

What ears are for?
All our senses, ears, eyes etc there so we can get information from outside into our brains. In the case of ears we want to convert sound into something we understand, music, speech or whatever.

Sound:

- The outside bit of ear's a funny shape, helping it to collect sounds and tell us a bit about where they are coming from. Sound makes the air vibrate, different sounds make it vibrate different amounts. This causes our ear drum to vibrate.
- If you've got the direction-swapping device (ear defenders with crossed tubes and cones) to hand, you can use this to explain how we locate sounds according to which ear they arrive at.

Ear drum:

- Lots of kids have heard of this. I'm often asked about grommets (lots of kids have these): They are small tubes that can be put through the eardrum to help drain fluid and allow air to circulate in the middle ear.

Bones in the ear:

- Inside the ear we have the three smallest bones in our body. Think how much bigger this model is compared with our ears.
- The bones join the ear drum with the inside bit of our ear, they vibrate as well. They help make sure that as much of the energy from the sound outside gets passed into the inner bit of our ears as possible.
- There are also tiny muscles attaching to them that can help protect our ears against sounds that are too loud.
- The bones are called the malleus, incus and stapes (also known as the hammer, anvil and stirrup) because of their shape.

Inside the ear:

- This is really clever and quite complicated (!). Tiny little cells with hairs on can detect the vibrating. We have nerves taking messages from our ears to our brains to tell us about the type of sound we're hearing, they're a bit like electrical cables so these tiny cells convert the vibration into an electrical message.
- Compare ear model to skull to see where all this is going on.

What happens in people who are deaf?

- The message is lost somewhere along the way. Maybe the sound cant get to the eardrum because we have wax in our ears. We can get infections inside our ears behind our eardrums where the little bones are, if this gets filled with fluid the bones cant vibrate properly. Or the cells with hairs on or the nerves can be damaged so the message can't get from our ear to our brain.

Balance:

Do we use our ears for anything else?

- They help us to balance too, so even if we close our eyes we still have some idea of which way up we are. Get them to stand on one leg and close their eyes or something. What happens when they close their eyes? It's more difficult, so we need our eyes for balance, too.
- There are little tubes filled with liquid at different angles, which are called semicircular canals. When we move, the fluid moves (bit like a spirit level?!). We can sense the fluid moving-that's how our brain knows that we're moving - can then help us balance movements. What happens when we get dizzy? We spin around lots so the fluids move round the tubes (use model), when we stop the fluid keeps moving for a bit after. So our ears think we're still moving, our eyes say we've stopped and our brains get confused. Similar idea in car sickness - when you look down at a book, your eyes start to think you're not moving, but your ears still think you are, so brain get confused again.

Other things to talk about:

Ever noticed ears going funny in tunnels/on aeroplanes?

- Get them to breathe out, and then swallow while pinching the nose shut and with the mouth closed. There's a tube between our ear and throat that is normally closed but is opened when we yawn or swallow. It helps us by equalising the pressue in the inner ear and in the outside world, because if the air pressure (or better explain pressure without saying the word somehow!) around us is different to inside our ears our eardrum gets pulled in or pushed out, and opening the tube equalises the pressure, allowing the eardrum to return to its normal position. This is why sucking sweets helps when you go up in aeroplanes - I think because the sucking and swallowing causes the tube to open so the pressure difference is equalised frequently and so your ears don't 'pop'.

What is sound?

- Sound travels in waves. It's like when you throw a stone into a lake- waves travel from it. The stone is the sound (i.e. a word we say), and our words/music etc. can make waves in the air, just like the stone can make waves in water; the eardrum in our ear can then pick up the waves; our ear converts these waves into signals, they travel to the brain, the brain interprets them as words/music.

Risk Assessment

Hazard: Small parts

Description: Small parts could be swallowed or choked on

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Do not let children play with experiments unattended.

Call first aider in case of ingestion and encourage the child to cough.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Broken parts

Description: If broken, parts could be sharp and cause injury.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Remove broken models.

Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Pointed parts

Description: Some parts have fairly sharp points - risk to eyes/skin.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Sharp points filed down to be as safe as reasonably possible.

Call a first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2012-01-05 - Ashley Smith (ashley.smith@cantab.net), **Check 2**: 2012-01-25 - Daniel Obute (rdo23@cam.ac.uk)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

Check 1: 2014-01-17 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-22 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-06 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2015-01-22 - Jessica Gorman (jrg63@cam.ac.uk)

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Check 1: 2017-02-09 - Fiona Coventry (fiona.coventry@cantab.net), **Check 2**: 2017-02-10 - Jessica Gorman (jrg63@cam.ac.uk)

Check 1: 2018-01-27 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2018-02-04 - Esmae Jemima Woods (ejw89@cam.ac.uk)

Check 1: 2019-01-23 - Jennifer Simpson (jks61@cam.ac.uk), **Check 2**: 2019-01-25 - Matt Worssam (mdw47@cam.ac.uk)

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Check 1: 2021-01-20 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2021-01-22 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Ear switching hat

This magical hat will confuse your senses! - Sound cues can help us figure out where things are located in the environment - try confusing your brain with the Ear-Switching Hat!

Last initially checked on 2023-01-18 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-18 by John Leung (cfl35@cam.ac.uk)

Tags

Busking

Floating

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- **This experiment can take place outdoors**
- One piece hat

Experiment Explanation

The hat switches sounds from the left hand side to the right ear and vice versa. This leads to a couple of cool effects and is great as a way of attracting people who would otherwise pass by without stopping.

What to do (1):

Put the hat on a child or other volunteer - if they are very small you might have to get them to hold the ear defenders on. Fairly quickly get them to shut their eyes, then go to one side or another and ask them to 'point where it sounds like I am standing' (these words partially get around the effect of the cunning kid who catches on very quickly and consciously changes where they are pointing).

You have two main ways of telling which direction a sound is coming from, volume and time delay. Which one you use depends on the frequency of the sound. Below 80Hz there isn't really an effective method; between 80Hz and 800Hz humans use the phase difference between their ears to determine location; between 800Hz and 1600Hz we're again a little lost but above 1600Hz we start using volume to locate the source of the sound. What about telling the difference between in front, behind or above us? That's the shape of our ears and heads that make sounds slightly different if they come from a different one of those positions. It's not perfect though, and a new noise in front of us sometimes sounds like it's behind.

What to do (2):

Put the hat on a volunteer (as before). Instead of getting them to close their eyes, get them to look (with their eyes only) to one side (right for the sake of description, although this works the same reversed). Stand more two people one either side of the volunteer. The person on the volunteer's right (who they are looking at with their eyes whilst keeping their head pointing forwards) mouths a simple sentence (for example: "My name is ...". They do this when counted in by the person on the left, who speaks the same words. For maximum effect, choose people with different voices/accents/genders and hopefully the person on the right will sound like they are speaking with the person on the left's voice. Maybe practice with some other demonstrators beforehand.

More information:

The brain integrates a range stimuli from the environment to help ascertain one's relationship to these. Particularly important is the processing of auditory cues - hence the vast majority of animals employ a 'two detector', i.e. two ear, system to pick these up. By comparing the input from one ear with that on the other side, special centres in the brainstem figure out the 3D origin of a sound wave - at its most simple level by comparing the intensity (volume) of the input to each side and the delay from one side to the other, but also by the more complex changes in pitch (frequency) that occur due to a 'acoustic shadowing' effect (different frequencies are affected differently by passing through your head) that the head getting in the way of a sound wave has!

The importance of this is huge - as predators this may help us to hone in our prey, rustling in the undergrowth, or in the converse situation, helping us figure out how to avoid being someone's next meal! This is evident in how most predators typically have relatively small external ear parts compared with many more 'docile' creatures with very large external ears (pinnae) that in many cases (such as rabbits and hares) can even be directed (kids might then ask about elephants - their ears are large for a very different reason, for cooling, much as the 'sail' of some dinosaurs is speculated to be) to help them localise sounds better (and I can't begin to imagine how complex the neural network integrating ear position with auditory input must be.)

In theory, if someone wears the hat for long enough, processes of synaptic plasticity will take place in the brain re-mapping inputs so someone can adapt to respond to sound cues in the correct direction. But even in the short term people can get used to the switched inputs and respond appropriately, much like an experiment that involved volunteers wearing prism glasses that inverted their environment - they were asked to throw a basketball into a net, which initially was impossible for most, but over time, presumably through cerebellar motor learning they adapted to their new state and were able to function perfectly normally despite seeing everything upside down! (intriguingly, when the prism glasses were removed, although it still took them time to adapt back to 'normal' again, it took less time than it did to learn when they tried the glasses for the first time).

So in people who have reduced hearing on one side, it's often still possible for them to discriminate whether sounds are coming from one side or the other due to these plastic changes, although it may not be as accurate.

Hearing is even all the more clever when you take into account how the hair cells of the cochlea can 'tune in' to certain frequencies and desensitise to others. Insect hearing is rather different to the above but (I think!) a basic intensity compatator is still employed, together with other clever mechanisms to distinguish externally-produced sounds from internal ones via a mechanism of 'corollary discharge'.

Risk Assessment

Hazard: Loud noises

Description: Risk of hearing damage

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Warn children not to shout loudly into ears, and make sure you talk quietly into the ears.

Call a first aider in the event of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Hat

Description: Risk of disorientation and falling over, especially if they have closed their eyes.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Tell child to sit down if they feel disorientated/dizzy. Before letting the child close their eyes make sure the area has no sharp objects, near sharp drops and isn't too crowded.

Call a first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Tubing

Description: Tubing may get caught on wearer

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Warn child not to pull hat off quickly to avoid injury, especially with long hair.

Call a first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Hat sharing

Description: Risk of transfer of hair infestation (e.g. headlice).

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Visually inspect hat between use.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

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Check 1: 2023-01-18 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-18 - John Leung (cfl35@cam.ac.uk)

Electrical Parts

Read before demonstarting any experiment that uses mains electricity

Last initially checked on 2023-02-19 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-19 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

Other

Requires Electricity (Please also refer to the Electrical Hazards risk assessment)

Equipment Needed

Mains (240 V) power supply.

Experiment Explanation

Some experiments require electricity from a mains power (240 V) supply. Read this RA along with the experiment RA before demonstrating.

Risk Assessment

Hazard: Faulty/loose wiring and equipment

Description: Risk of fire or electrocution. This risk applies only to mains voltage equipment that plugs into the 240V mains supply; any part of an experiment that comes into direct contact with the public will use a power supply with a safe low voltage output.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 5

Mitigation: DEMONSTRATOR must visually inspect all electrical equipment before using it. Please look for loose cables, bare wires or anything else suspicious. If you spot faults then please do not use that equipment, and report it to a committee member.

DEMONSTRATOR to ensure that there is a PA test sticker dated within the last two years on any mains voltage equipment, or that the equipment was purchased within the last two years (should be marked with the date of purchase if there is not a PA test sticker). If the equipment was PA tested or purchased more than a year ago, DEMONSTRATOR to check that there is a sticker to show that the equipment has been formally visually inspected within the last year.

DEMONSTRATOR to ensure that electrical equipment is not placed next to or under flammable materials (eg. under a jumper).

COMMITTEE to ensure that all mains voltage equipment is PA tested every two years, or if possible, annually. Newly purchased (unaltered) equipment need not be tested immediately, but should be tested, at the latest, within two years of purchase, and then every two years thereafter. If newly purchased equipment is not marked with a PA test sticker, it should be marked with the date of purchase. Electrical equipment that has been modified in any way should be PA tested before first use

COMMITTEE to ensure that, if equipment has not been PA tested within the past year, it is formally visually inspected by a committee member approved by the committee to carry out such checks, and marked with the date of inspection

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Water getting in contact with the equipment

Description: Risk of electrocution

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: DEMONSTRATOR must think about the danger of water coming into contact with the equipment. Ensure electrical equipment is not near water, or on the ground in a place where water might pour in event of a nearby experiment breaking. If outdoors, DEMONSTRATOR to keep cables off ground and away from damp, especially if using the venue the next day as well (dew settles).

DEMONSTRATOR please make sure that you know the location of the electric wall socket where the equipment is plugged in.

VENUE SAFETY OFFICER should locate and make known the location of the cut-off switch for the room, if there is one.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Trip hazard on cables

Description: Risk of injury or pulling things over

Affected People: All

Before Mitigation: Likelihood: 5, Severity: 2, Overall: 10

Mitigation: Ensure all cables are safely taped down, take extra care in areas where people might be walking. If possible, keep cables behind experiments.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Risk Assessment Check History

Check 1: 2023-02-19 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-19 - Asmita Niyogi (an637@cam.ac.uk)

Electrolysis

Splitting water into hydrogen and oxygen, and using the recombination of these to launch ping-pong balls. - Electrolysis in the process of splitting water into hydrogen and oxygen using electricity, and then recombining them explosively! We'll use talking about energy as an excuse to launch a ping pong ball into the air...

Last initially checked on 2023-01-15 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-01-16 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Requires Electricity

Equipment Needed

- **Electricity needed**
- Electrolysis tower (~ 6' tall, white cover, don't drop it - you will need 2 people to move it)
- 0-15V variable power supply OR Power pack of doom
- Small red box (approx. contents): Water models, small air blower, $MgSO_4$, deionised water, funnels etc. power connectors, piezo-electric sparker, silencer, ping-pong balls)

Experiment Explanation

In a nutshell

Water is split into hydrogen and oxygen, which are then recombined explosively at different concentrations to launch a ping pong ball into the air. This means that you can investigate energy conversion, stoichiometry, what is an explosion, etc. etc..

Setting up Electrolysis

Note: Please do not attempt to set up or pack up electrolysis unless you have been shown previously how to do it and are confident you know how (one of the committee members at the event will be happy to show you what needs to be done) - if you get tap water in the electrolysing chamber you will get some very strange results (mainly due to metal oxide formation removing the oxygen as you make it), and the chamber may need to be cleaned.

1. Ensure the tower is secure, having been tightly roped to a fixed support, and won't fall over.
2. Attach the power cable to the current controller
3. The wires are connected (those with tape on inserted first, and the sparker can have its wires go in any way around, for the electrolysis apparatus itself, connect red and red, and black and black)
4. Ensure that the apparatus is not on wet ground (if outside use separate upside-down trays for the apparatus, and for the power supply and sparker)
5. Use a funnel to pour the MgSOâ„ solution into the back chamber (such that it goes to the electrolysis chamber), ensuring that no water enters the sparking chamber
6. Use a gravity siphon (use plastic tubing to suck some water, preferably not with your mouth, to insert the tap water into the front (mixing) chamber, again ensuring no water enters the sparking chamber)

To be safer, you can use deionised water in the front chamber (this is not strictly necessary, but it is a good precaution in case any gets into the electrolysing chamber), however try not to lose too much whilst setting up/packing up so we can reuse it.

How to run the experiment

1. Double check the tower is secure, having been tightly roped to a fixed support, and won't fall over. There is a sound muffler (the top of a plastic bottle) in the box, that fits over the ignition chamber. It is strongly advised that you use it if you are going to be demonstrating this for any length of time/are indoors.

2. Using the power supply, pass current between the platinum wires in the reaction chamber at the bottom, this splits water into hydrogen and oxygen, which are collected by two inverted burettes. ***Do not use too much voltage for the water splitting, as you may start causing some strange by-reactions.***
3. Holding the mixing chamber valve shut, release hydrogen and oxygen from their burettes in an appropriate ratio into the mixing chamber.
4. Release the mixing chamber valve to let the gas mixture into the explosion chamber, then use the piezo igniter to fire it (some off the gas will vent out around the ping pong ball - this is ok).
5. The electrodes that make the spark are now wet; if you need to repeat the explosion quickly the air blower may be used to dry them more quickly - in practice by the time you've done the introduction again the electrodes may be dry.

What you need to know about the experiment

Water is Hâ‚‚O and, if you apply enough energy (needed to break bonds), it can be split into its constituent parts (there should be some models).

You should be able to see that there is twice as much hydrogen as oxygen.

You can get the energy back out rapidly â†’ heat â†’ expansion â†’ acceleration of the ping pong ball.

The sparking electrodes become wet: you've made water! (most of it in vapour form but it condenses on the electrodes and the combustion chamber walls)

If the concentration and ratio is right, the hydrogen/oxygen mixture will **detonate** â€“ a detonation is an explosion which travels at supersonic speeds (you should hear it!)

Want to know more?

The main point to get across is that water is made out of hydrogen and oxygen and these are gases. But as you go on you can also describe the energy in â†’ energy out aspect, stoichiometry and molecular structure and also relate it to how we would have to make hydrogen for cars.

In starting the explaining at the bottom of the apparatus you can ask what the children can see in the bottle at the bottom. Water and wires. I then go on to say I'm going to put some electricity in the wires, now what can you see? Bubbles. What's in the bubbles?

I then explain how were are turning water into what it's made out of. So what's it made out of? Excellent if they can answer this. Otherwise, do you know another name for water? It's surprising how many kids get Hâ‚‚O. Why is it called Hâ‚‚O? Because it's made out of hydrogen and oxygen - "Hydrogen times 2, Hâ‚‚ and oxygen O."

Once that's settled, you can go for the molecular models. Breaking two water molecules up into two Hâ‚‚ and one Oâ‚‚ molecules. While this is in I explain what we're going to do next in recombining the molecules back to Hâ‚‚O giving them a good shake. Random collisions aren't a bad model for a chemical reaction.

Now is also a good time to talk about the energy in/out business if you're going to. Though for years 6 up really. Energy from electricity is used to split the O and H and is then stored in the Oâ‚‚ and Hâ‚‚ molecules. When they recombine the energy is released as heat. Cycling up a hill is the clear analogy, I always like pointing out that as you come down the hill you think that it's "speed for free" but it's not really, you're getting the payback for all the effort you put in cycling up the hill.

We then try some logic and I turn the power off and draw their attention to the bubbles at the top of the tubes. One is twice the size. Which one is the Hydrogen? Next explain how you're going to mix the gas and arrange your volunteers and check the trigger works.

As you mix the gases you can say, if we need 8 ml of hydrogen, how much oxygen do we need? Then we're pretty much onto the pop. Once that's gone grab the ball quick. With luck there should be some water on the bottom. Show them this, as this is your opportunity to hit home. "Can you see that? You've that made water!" Which is cool.

Parents and teenagers will be interested in the hydrogen cars angle. With this audience I probably would have started with the hydrogen cars. Anyway, you can be a bit environmental pointing out we have to use energy to make hydrogen, and it is only ever an energy store. you can also burn the hydrogen in an internal combustion engine (like at the top) or in the exact reverse of what happens on the electrodes at the bottom, to make electricity right out of the hydrogen and oxygen in a fuel cell, then driving a motor.

Risk Assessment

Hazard: Electrolysis chamber

Description: Explosion in the electrolysis chamber.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: Designed so any excess gas vents to the outside, so even if the power is left on there will be no major build-up of gas. The chamber is made out of a tough plastic (PET) that won't shatter. There is a polycarbonate blast shield in case something does go wrong.

Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Mixing chamber

Description: Explosion in the mixing chamber.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: The valve at the top of the mixing chamber is designed so it defaults to be open, so gas won't build up when you are not paying attention. The explosion is separated from this chamber by water so it shouldn't ignite. The explosion occurs behind a blast shield.

Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Chlorine

Description: Evolution of chlorine gas.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Use deionised water (chloride ions have been removed), and use $MgSO4$ as an electrolyte as this will not decompose before the water. Experiment must only be set up by a demonstrator familiar with the apparatus and the solution required.

In the event of an incident, turn off power, remove any casualty from area, call first aider and ventilate the area.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Explosion noise

Description: Loud explosion. Possible auditory damage.

Affected People: Demonstrator mainly (repeated exposure)

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Ignition is by modified kitchen lighter. Is on the end of a long wire, allowing everyone to stand well clear of the explosion (energy dissipates as rÂ². A sound muffler can be attached to the top of the column.

Use less gas if the explosions are too loud.

Seek GPâ€™s advice in the event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 3

Hazard: Ping pong ball

Description: Being hit by ping pong ball.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Make the explosion chamber quite high, so you can't look in the top. Ball is very light and would not hurt much.

Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Mains electricity

Description: Increased hazard from mains electricity due to presence of high ionic strength solution.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: Ensure that apparatus is secure and tightly roped to a fixed support before filling (also prevents risk of tower falling). Do not fill/top up apparatus whilst power unit is nearby. Keep power unit raised above level of base of apparatus.

If solution splashes onto power supply turn off immediately at mains and close experiment.

In case of injury call a first aider (and turn off power if safe to do so).

See electrical parts RA.

After Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Hazard: Tower

Description: Tower falling

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Ensure the tower is stable (i.e. on level ground). Do not allow children to climb/push the tower.

In the event if an injury, call a first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Water models and ropes

Description: Trip hazard from balls or ropes being left on the floor. Risk of children running into inappropriately placed ropes.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not leave these "loose" parts of the experiment lying around.

In the event if an injury, call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2011-12-22 - Hannah Ford (hf257@cam.ac.uk), **Check 2**: 2012-01-21 - Catherine Collett (chc47@cam.ac.uk)

Check 1: 2012-12-16 - Rachel Chapman (rc506@cam.ac.uk), **Check 2**: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk)

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Electromagnetism

Making electricity, and using it to spin a motor. - Generate electricity and learn all about how it works!

Last initially checked on 2023-02-18 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-02-18 by Timothy Wong (chw55@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Electricity needed** for some parts of the experiment, but you can still demonstrate the rest without power!

Generating power

- Small ammeter and coil. Bar magnet of some sort that fits through the hole
- Green rotating generator. Clamps to attach it to a table.
- Wooden box with bulbs/handle/generator

Dropping magnets

- Metal 'coin drop' setup, separate wooden base (base in box, the rest is separate)
- Two pipes, one copper, one plastic.
- Green 'iron filing' paper
- 'Stripey' magnet for use with green paper
- Selection of coin magnets (don't get more than a couple out an once).

Motors etc.

- Motor
- Power pack (stored in separate power pack box)
- Real motor (non-functional)
- Magnet/wire with 'indicator lights'
- Nail with coil of wire.

Experiment Explanation

_AS 2023 - Practically speaking this is still done all as one with Renewable Energy and Lenz's Law. I personally think we might want to keep it together. There are also several bits of this that we are missing or are broken such as the coin magnets, motors, nail etc. Personally I think a good story is: Start with Lenz's Law with the magnets in the perspex and copper tubes. Get a surprising result! Why might these be different? Let's try and see... Move onto the black box generator with the switches and bulbs. Turn the handle with increasing amounts of bulbs on. Where do the lights get their energy? From electricity in the wires, b ut ultimately from you! Note that the more bulbs the harder you have to work ie the more energy needed. Lets look inside (use the big green one to demo, its a bit temperamental to use actively to turn the handle) - note the magnet inside and the copper wire - almost like our Lenz's Law demo. The magnet turning and moving past the wire is creating electricity in the wire. But we also see this electricity flow is creating a force to make it harder to turn the magnet. The magnet falling in the copper tube works the same way by creating swirls (eddies) of electric current that resist its motion. In reality, if you wanted to watch TV, you wouldn't want to sit there turning a handle so where does power in your home come from? They usually say from the wall, try to question where does the wall get it? They might know about pylons etc. Segue to energy generation through renewable. Except solar cell, mostly just ways to turn a handle (steam turbine, wind turbine etc). They will often have seen "windmills" in fields and many homes and even schools now have PV cells on the roof.

TW 2018 - There are many bits to this experiment and it's reached the point we sometimes get two people to demo it at CBS and also lots of the bits don't work. I've moved it to minor repairs needed however I've begun the process of *splitting out several ideas and strands into new experiments, see Lenz's Law, Renewable Energy so far and then Induction, Coils and Transformers, Sparks and Motors experiments soon.*

There are lots of things to do, there are 2 nice stories, going through the generation and motors stuff, and some extra odds and ends. You shouldn't usually attempt to get through all of this in one go!

1. Generating Power

There are 3 different power generating bits, in increasing level of usefulness.

Magnet, coil and ammeter

This has a coil of copper wire attached to a small ammeter. When you wave a magnet through the hole in the middle of the wire you get a reading on the wire. Some things to talk about/do with it are:

- What are the objects? Coil is made of copper wire, this is a good electrical conductor. The setup as a whole is an electrical circuit (components linked together in a circuit). The meter looks like it might measure something (cf weighing scales), it measures the amount of electrical current (or just electricity) going round the circuit.
- Do we get more electricity by moving fast or slow? Does it work if we're not moving at all?
- Is this very much electricity? The scale on the ammeter is microamps (the funny squiggle is the Greek letter mu), talking (or asking questions about) millimetres, metres and kilometres is a good warm-up to explaining that microamps is a small unit. Older kids might know that fuses have amp ratings on them.
- What do the positive/negative readings mean? It tells us which way the electricity is going round the circuit, notice that it changes if we move magnet in a different direction, or swap north/south poles.
- How can we get more electricity? Good ideas are moving faster (and moving in circles is easier than up/down), stronger magnet or more coils.

This then leads nicely onto the next bit...

Rotating generator (green)

This has most of the improvements suggested above (show to them the larger magnet, more coils), and if you spin the handle fast enough it will give you enough electricity to light a bulb. Things to talk about:

- The faster you spin it, the brighter it is.
- Does it matter which way round you turn it? No.
- (more advanced) Rather than a filament bulb, the lights are two LEDs, connected with opposite polarity. Each LED will only light half of the time, with frequency=rate of turning the handle. This is because the current is alternating ('going backwards and forwards') and it only lights when the current is going one way.

Generator in a box

This is a better version of the previous one, but it's all hidden in a box which means visitors can't see what is going on as well. There are two bulbs that can be switched on or off, and also a voltmeter/ammeter. Things to do:

- Start someone off turning the handle and then increase the wattage of bulbs turned on gradually. They will find that it gets harder to turn as you do this. Talk about needing to put extra energy in to get more light out (the energy is coming from them, **not** from the magnet/coil which just convert kinetic/moving energy into electrical energy)
- Power generation: How many watts are the bulbs you have at home? If it's this hard to turn a handle to make 10W of bulbs light, how hard would it be to power all the bulbs in your house? How about all the bulbs, TVs,... in town X? This is really where our power comes from, what better ways are there of turning the handle (wind farms are the easiest example for small kids)
- (More advanced) Look at the ammeter/voltmeter. When a bulb is fully lit how do those readings compare to the wattage of the bulb ($P=IV$).

2. Dropping magnets

This uses the last part to do a neat trick. The three columns in the coin drop are made of plastic, aluminium and copper. None of these are magnetic, but a coin magnet will fall more slowly through the metals.

This is because the moving magnet is inducing an electrical current in the metal (like the magnet past the coil in part 1). There are two ways to explain why this causes it to slow down:

1. (easier) Some energy is needed to make the electrical current (like turning the handle before). This time the energy comes from the falling magnet, and when it loses kinetic energy it slows down.
2. (harder) Eddy currents of electricity are formed, and these create an electromagnetic effect opposing the motion of the magnet, hence it slows down.

You can also do this with the perspex and copper pipes (get a volunteer to hold the pipe, with their other hand below it to catch the magnet), the slowing effect with the copper pipe is really huge.

There is also green 'iron filing' paper, which shows up the movement of a magnet through it. You can use this to 'see' the movement of the magnet inside the copper pipe.

3. Motors etc.

There are various bits here, you probably won't want to do all of them. This is the opposite of what we have been doing so far. Now we are using electricity to make magnets, or electricity and magnets to make something move.

Compasses around a magnet/wire

Show what a magnet/current carrying wire do to a compass, compare the two.

Electromagnetic Nail

Wrap wire around a nail attach it to a power supply and see how it affects paper clips, with and without the power, try picking up a matchbox car as a use for electromagnets.

Jumping Wire with indicator lights

Put a current through the wire on top of the magnet, you should notice the wire is pushed by the magnet. If you reverse the direction of the current the direction of the force reverses.

Simple motor

This is a simple toy motor. There are two commutators one which keeps the polarity the same - you can show that you can get some movement but not rotation, and one which swaps the polarity, that will make it turn nicely.

- Have a look at the motor there are a load of wires near some magnets, so there will probably be some forces going on from the Jumping wire experiment.
- Using the first commutator, you need to keep swapping the polarity as when the motor gets half way round the direction of the current has essentially reversed (you are using the other half of the coil), so it gets pushed back again. You can get it to keep turning, by reversing the current. This however gets a little tedious...
- Luckly the second solves the problem, everytime the motor turns halfway round the two contacts swap, so it keeps turning. This is how all DC motors work, some AC ones use the changing direction of the voltage instead of a commutator, so have fixed speeds.

Tricks: It works best on the 7.5V range with the motor wired from the +ve side to the -ve side. The brushes should be touching the commutator, on either side (top and bottom won't work)

There is a real motor in the box too, which you can compare it to.

Risk Assessment

Hazard: Hot coils and wires

Description: Possible overheating could result in burns. Motor can short-circuit and get hot.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Do not put too much current through a coil/wire: if it is getting hot, turn it down. Demonstrator to turn off power supply to motor when not in use. If there is a burn, run under tepid water for ten minutes. In the event of any injury, turn off electricity at mains, and call first aider. In event of fire, follow procedure in venue RA (raise alarm, evacuate).

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Hazard: Powerful magnets

Description: Magnets may shatter, possibly leading to cuts. Magnets may trap fingers if mishandled.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Warn visitors if you give them a magnet. Use the minimum number of free magnets. Keep the magnets under control. Cover with tape to reduce impact, and contain any shards. Pad edges of magnet to reduce finger trap. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Copper pipe

Description: Copper pipe hitting people in face.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Demonstrator should hold pipe for younger kids and monitor use for others. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Hazard: Heavy generators/motors

Description: Can fall off tables and land on children/demonstrators, causing injuries.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Use clamps to keep generators and motor firmly attached to table. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Rotating motor

Description: Children could trap fingers in the rotating parts.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Keep kids' fingers away - if it needs pushing it should be done on the axle, not the armature. Call first aider in the event of injury.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Hazard: Generator

Description: Visitor or demonstrator catching fingers in generator as they turn the handle on the generator.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Place generator on flat surface so visitors can't catch their fingers underneath so easily. Tell visitors to hold only the rotating part of the generator handle and not the entire handle. Keep control of the visitors at all times and don't let them get overexcited while turning the handle. Call first aider in event of injury.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-01-14 - Aaron Barker (arb78@cam.ac.uk)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-16 - Jachym Sykora (js973@cam.ac.uk)

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Engines

What are the different types of engine, and how do they work? - Have you ever wondered what an engine is? Learn about how various types of engines work from the ubiquitous Internal Combustion Engine found in almost every car ever made to a small engine which runs on nothing but hot water!

Last initially checked on 2023-02-17 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **Electricity needed**
- Internal combustion engine model, Jet engine model, Stirling engine model, soft pencils, kettle, mug.
-
- WARNING: STIRLING ENGINE MUST NEVER BE LUBRICATED WITH OIL. It will gum it up. Lubricate bearings with graphite from soft pencil only.

Experiment Explanation

Engines Experiment - Explanation Last Update - Gareth Funk, April 2015

************** INTRODUCTION ************** I like to start with the Stirling Engine whirring away whilst I give the following introduction. To do this, the Stirling Engine should be placed on a mug of freshly boiled water and given a push to get it going. It will only go one way for reasons which should become clear.

Before looking in detail at any of the models, it is worth asking the question â€œwhat is an engine?â€, or alternatively, â€œwhat do you know that has an engine?â€ and as a follow-up â€œwhy does it need an engine?â€. Many of the children will not be able to give a good answer to the first, but can answer well enough the second two. The key thing about all engines is that they turn energy from one form into mechanical (or kinetic) energy and an engine is simply any device that does that. Examples of engines are:

- Electric motors
- Jet Engines
- Steam Engines
- Internal Combustion Engine
- Stirling Engine

Excluding the Electric motor, all the above are heat engines: they use heat energy as their input. Obviously this energy usually comes from burning something, but thermodynamically the input to the engines is heat. It is worth noting that the jet engine is also, strictly speaking, an type of internal combustion engine. Similarly it is worth noting that the steam engine and the stirling engine are examples of external combustion engines.

The Stirling Engine is the best one to demonstrate because it best exemplifies the idea of a thermodynamic cycle and gives a real-life demonstration of an engine in action. The Internal Combustion Engine and the Jet Engine models are just models and a lot of children canâ€™t see past the fact that a battery and an electric motor are what is making them turn. However, if there is time left after the Stirling Engine demonstration, feel free to move on to the others if you have time.

************** STIRLING ENGINE ************** The Stirling Engine we have is one of three commonly seen implementations of the Stirling Cycle. Out of interest, ours is a Gamma Configuration Stirling Engine. Most Stirling Engines used in practice are of different configurations but the thermodynamic processes they undergo are the same.

The following explanation requires that the children are familiar with the concepts of pressure and volume. A good, quick way to explain pressure is to get them to consider running around in a room with their eyes closed. Theyâ€™d bump into walls every so often. Theyâ€™d bump into walls more often if there were more of them in the room, or if the room got smaller.

Before we proceed, the following things need to be pointed out concerning the names we will use for the various different parts of the engine. Point out the two different pistons. Note that the black piston simply moves the gas to the hot space (when it lifts up) and to the cold space (when it comes back down). It is as such termed the â€œdisplacer pistonâ€ however during the demonstration I tend to stick to â€œblack pistonâ€ but it is nonetheless worthwhile to show them that is simply moves the gas around and does NOT compress it. The glass piston at the top changes the overall volume of the chamber: when it lifts up, the volume increases (expansion) and when it descends, the volume decreases (compression). The hot space of the engine is the metal surface in contact with the hot steam (please stress that this is not a steam engine!) and the cold space is the upper metal surface in contact with the surrounding air. Also tell them what the flywheel is and point it out (itâ€™s the large gold-coloured wheel which spins). The flywheel is there mainly to store the mechanical energy we extract but also to tip the pistons from one phase to the next.

Stop the Stirling Engine by keeping your finger on the flywheel so that we can slow the process down and step through the stages in turn. Let the engine get to the point where the black piston is about to come up and then proceed with the following explanation.

The idealised Stirling cycle consists of four thermodynamic processes acting on the working fluid (in our case, the air trapped inside the chamber):

Constant-Volume (known as isovolumetric or isochoric) heat-addition: The glass piston is staying roughly still at the bottom of its stroke during this process which means that the volume of the chamber is remaining constant. The big black piston is moving up which moves the gas into contact with the hot space and so it heats up. During this process, the pressure will also increase.

Isothermal Expansion: The small glass piston rises up thus expanding the hot fluid meanwhile the gas continues to be in contact with the hot space as the black piston is staying roughly still. It is NOT important to stress the constant temperature; the expansion of the gas and the intake of thermal energy are the key points.

Constant-Volume (known as isovolumetric or isochoric) heat-removal: The glass piston stays still (now at the top of its stroke), hence constant volume, and the black piston moves down moving the gas from the hot space and into contact with the cold space and so heat is lost.

Isothermal Compression: The glass piston now moves down and compresses the gas. The black piston stays still so the gas continues to lose heat at the cold space.

The cycle repeats: Now we are back where we started but in getting back to where we started we made the wheel spin! Now the cycle will continue over and over again until we run out of heat. This is the really important point to stress: by doing those four thermodynamic processes we extracted some mechanical energy!

Note here that these processes have to happen in this order hence why the wheel only spins one way.

To finish off, take the stirling engine off the heat, let it stop, and then ask â€œwhat would happen if we were to spin the flywheel in the opposite direction to the way it normally spins?â€. Think about the system we had before: Heat was added at the bottom, the wheel turned round. The answer to the question is that the opposite would happen if we were to spin the wheel in the opposite direction the bottom surface would heat up. This will not be practical the demonstrate as itâ€™s difficult to spin the wheel sufficiently fast but it is nonetheless true. Some children will instinctively get this without much prompting but in my experience most struggle with the concept.

************** INTERNAL COMBUSTION ENGINE **************

Our particular model is of a four cylinder, four-stroke engine. The piston completes four separate strokes which together comprise a single thermodynamic cycle. A stroke refers to the full travel of the piston along the cylinder, in either direction. The strokes are as follows: INTAKE: this stroke of the piston begins at top dead centre. The piston descends from the top of the cylinder to the bottom of the cylinder, increasing the volume of the cylinder. A mixture of fuel and air is forced by atmospheric (or greater) pressure into the cylinder through the intake port. COMPRESSION: with both intake and exhaust valves closed, the piston returns to the top of the cylinder compressing the air or fuel-air mixture into the cylinder head. POWER: this is the start of the second revolution of the cycle. While the piston is close to Top Dead Centre, the compressed airâ€“fuel mixture in a gasoline engine is ignited, by a spark plug in gasoline engines, or which ignites due to the heat generated by compression in a diesel engine. The resulting pressure from the combustion of the compressed fuel-air mixture forces the piston back down toward bottom dead centre. EXHAUST: during the exhaust stroke, the piston once again returns to top dead centre while the exhaust valve is open. This action expels the spent fuel-air mixture through the exhaust valve(s).

Focus on one cylinder when explaining these but make sure you are pointing out the correct stroke! Check the valves to check youâ€™re telling them the right stroke at the right time: If the valves are open then the stroke is intake or exhaust, depending on which way the piston is moving. If you get this wrong the spark wonâ€™t be at the right time and the valves will be open when youâ€™re saying the fluid is being compressed etc.

Note that the cylinders are not all moving together and even those that are do not fire at the same time. This is in order to deliver the power more smoothly with four smaller bursts per two revolutions than one large burst per two revolutions. Most cars have 4 cylinder engines like our model.

Side Note: The model can be switched off and on such that it gets out of sync with the spark. If it does this, turn it off and on again, stopping at a different point in the cycle, until it gets back in sync.

************** JET ENGINE ************** As of this update, the Jet Engine model has not been built yet. This section will need updating once the model is finished and I have decided what can be demonstrated with it.

The following is from wikipedia:

A turbofan engine is a gas turbine engine that is very similar to a turbojet. Like a turbojet, it uses the gas generator core (compressor, combustor, turbine) to convert internal energy in fuel to kinetic energy in the exhaust. Turbofans differ from turbojets in that they have an additional component, a fan. Like the compressor, the fan is powered by the turbine section of the engine. Unlike the turbojet, some of the flow accelerated by the fan bypasses the gas generator core of the engine and is exhausted through a nozzle. The bypassed flow is at lower velocities, but a higher mass, making thrust produced by the fan more efficient than thrust produced by the core. Turbofans are generally more efficient than turbojets at subsonic speeds, but they have a larger frontal area which generates more drag.[11] There are two general types of turbofan engines, low bypass and high bypass. Low bypass turbofans have a bypass ratio of around 2:1 or less, meaning that for each kilogram of air that passes through the core of the engine, two kilograms or less of air bypass the core. Low bypass turbofans often used a mixed exhaust nozzle meaning that the bypassed flow and the core flow exit from the same nozzle.[12] High bypass turbofans have larger bypass ratios, sometimes on the order of 5:1 or 6:1. These turbofans can produce much more thrust than low bypass turbofans or turbojets because of the large mass of air that the fan can accelerate, and are often more fuel efficient than low bypass turbofans or turbojets.

Risk Assessment

Hazard: Hot Water and Hotplate

Description: Risk of burns

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Warn of hot water (and steam) before experiment starts, keep hot water away from easy reach of children's hands. Mark mug as "HOT". If any burns occur, run under tepid water for an appropriate amount of time.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Water

Description: Spilled water is a slipping hazard

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Use stable mug for water. Do not over-fill.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: sharp edges

Description: Sharp edges may cause injuries if Stirling engine is dismantled.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Do not allow children to play with Stirling engine. If flywheel becomes detached, demonstrator to reassemble

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Fly wheel

Description: Fingers could get trapped or caught in fly wheel

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Flywheel is very light and has little angular momentum, even at high speed. Do not let children put their fingers near the flywheel.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Hazard: small parts

Description: choking risk from small parts

Affected People: Children

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Keep away from very small children. If engines break, close experiment and put parts in box.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

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Epidemiology (PLUS only)

Show kids how disease dynamics, with a model of Citrus Canker spreading through a population of orange trees - Exploring the concept of disease spread and biological modelling.

Last initially checked on 2023-01-18 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-02-14 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **Electricity needed**
- 2 CHaOS laptops
- WiFi access - ask a committee member and or one of the teachers present
- Http://www.webidemics.com/ - NEW WEBSITE - https://plantepidemics.github.io/interactive/ - we are awaiting it to be built! This computer model was developed by Nik Cunniffeâ€™s group http://www.plantsci.cam.ac.uk/research/nikcunniffe) in Plant Sciences. It models the spread of Citrus Canker under a variety of weather conditions, disease parameters and control efforts, allowing you to set initial conditions then watch the model run to a determined end point.
- *** Requires Adobe Flash which is no longer available, hence not working label added 12/01/21 by Miffles. I have found the website, and am hoping they will actually develop their new version - https://plantepidemics.github.io/interactive/ - there is a working game there, but the instructions below give all the theory without going through the game - it is really good though. Changed back to actibe ***
- Envelope with model component cards (maybe in Tree's box...)
- Collection of duplo blocks with eyes (for the population, stolen from maths and engines)

Experiment Explanation

Much of this is taken from the Citrus Canker RA which explains how to set it up and how the model functions. For Plus the equipment and concepts are basically the same but it is more maths heavy and takes things from first(ish) principles.

Intro to modelling Welcome, welcome! For the next 20 minutes or so you are going to be epidemiologists and are tasked with understanding and preventing or mitigating the spread of diseases.

So, before we get started, what do you think are the different ways epidemiologists can help fight against the spread of disease?

- understanding of the disease causing organism (lifecycle, habitat)
- understanding the population (who is vulnerable, what section of the population are most at risk)
- from these can work out what might slow/stop disease spread
- look at historical cases to understand how similar diseases have spread in the past
- model the spread of diseases to estimate best and worse case scenarios
- vaccinations, improved sanitation, improved diets/lifestyle

This morning we're going to zoom in on the modelling work; how would you define a computer model?

- simplification of some function of the real world, built to help understand how the world works
- all models are wrong, some are useful

Why do you think that models might be useful for epidemiologists?

- can't carry out these experiments in real life (unethical...)
- can test many scenarios; what ifs...
- allows you to test how well theory matches up with reality
- computers allow us to do this on a big scale quickly and cheaply

We now have a population which is starting to get sick. There are some broad categories which we can break the population down into to help us to start to build our model - not every individual is equally likely to get sick and these categories help us to see this. S Susceptible, not yet sick and can get sick I Infected, currently ill and infectious R Removed, either recovered or dead

Now we can use these three categories to build up our model

What do we need to know to understand how fast this disease will spread? How fast it is transmitted (beta). How fast is recovery (gamma). [expect lots of biological detail here]

Now we need to represent this mathematically (in order to get the computers to do all the hard work of calculation) Talk about change in one category depends on the number of organisms arriving in it and leaving it, talk through each.

R0 ("R naught") is the measure of the number of secondary infections caused by a single infected organism in a totally susceptible population for an epidemic to occur R0 > 1 (then the disease will spread) R0 = beta/gamma, for extent of spread depends on the number of organisms infected and the (inverse of) the rate of recovery

Useful info and set up

What is it? "Here I have a model of disease spreading between trees. We can see how quickly it spreads in different conditions and if our efforts to control it actually help."

Set up [Read through the descriptions of the parameters and get a feel for how changes to each parameter affects the spread of the disease, you can also hover over any of the text within the model for a short description. Don't forget to accept the changes before running a new simulation, or else nothing will change!]

Set up a fairly basic run of the model

Epidemiology

- Model type = non cryptic infection, no death
- Expected primary infections = 0
- Expected exposed period = 100 days
- Expected cryptic period = 100 days
- Landscape type = random
- Dispersal kernel =100m
- Kernel type = exponential
- Stopping condition = epidemic eradicated (this can take a long time but you actually see the infection end (you can speed up running time)

Weather

- low weather severity

Control

- Disable Control (second time around)
- Cull radius = 100m
- First survey = 0 days
- Fraction unsurveyed = 0
- Detection probability = 80%
- Survey interval = 90 days
- Expected notice period = 60 days
- Notice variability = 0

Start by talking about the spread of diseases:

"How do diseases spread?" - will probably get animal/human centred answers: sneezing, coughing, dirty hands, bad food, bad water, insects, bodily fluids

"What about how diseases spread between plants?" - insects (vectors) are more important, moving the bacteria/viruses/parasites between plants, humans move infected plant material between fields (on farm equipment etc)

[on computer] Here we can see a disease spreading between a bunch of orange/citrus trees: Green = healthy, orange = exposed, yellow = infected without symptoms, red = infectious, black = culled. "Can you see any pattern to how the disease is spreading?" - the disease doesn't spread randomly, but trees closer to a diseased tree are more likely become infected. With our model we can change how quickly the disease spreads [run the model with basic parameters (without cryptic infection), run it again with more initially infected trees, run again changing parameters to speed up spread of disease] Get the children to change the disease parameters (can split the group into two and use both laptops), trying to spread the disease the fastest. Ask them why they think the model is useful? - can see when the disease spreads fastest/which aspects of it make it most contagious, can see how it spreads through a landscape (which trees are most vulnerable to infection as the disease spreads)

[on computer] We can also try out different ways of stopping the disease spreading. "How would you stop a disease spreading?" Vaccination (doesn't work as plants don't have active immune systems like animals) Quarantine (you can't move trees away from each other, and it would be a lot of effort to seal the trees off from each other) Stopping insects (herbicides, this is one of our main ways of slowing the spread of diseases) Culling (killing/removing the trees, stopping the disease spreading away from trees which are known to be infected). Culling is the only effective way of controlling the spread of Citrus Canker, but there are different ways of doing it [run with control parameters, then run again with new parameters, chat through the differences] Get the children to change the control parameters, trying to save as many trees as possible, you can make it a competition between the two groups. Ask them why they think the model is useful? - can test how effective different control options are, then can use the results to find the optimal control mechanism, can run the same control plan many times to see how it is most likely to turn out.

Team Disease vs Team Control You can split the children into two teams; Team Disease; who are trying to kill as many of the trees as possible, and Team Control; who are trying to contain the spread of the disease (they tend to enjoy this challenge!)

[on computer] We can't always tell when trees are infected. This is called a cryptic infection and makes it more difficult to control the spread of the disease as the infected trees can infect other trees, without being infected. [run model with cryptic infection - should take longer to bring the infection under control]

Explaining the point of computer models:

[probably for older children] Computers are really useful for biologists. They make it easier to do calculations, work out statistics and can help us predict how a disease will spread.

"Why do we want to know how a disease will spread?" Work out who/what might get infect next, how we can slow the spread of a disease.

"Why is it good to have a computer to do this for us?" Makes it easier (not having to do the sums ourselves), donâ€™t have to infect animals or plants in real life, can put in specifics about our outbreak of disease (where it started, how many people/animals/plants [organisms, depending on age of child]) to make it more accurate.

Models simplify reality. To make it easier to understand the disease we can split all of our trees into different 'disease states/compartments', the most simple has just three compartments - Susceptible, Infected and Removed. More complicated models include Exposed and Cryptic Infections (like this model). Mathematical equations describe the movement of plants between the different compartments, the more compartments, the more complicated the equations get, but the more accurate the model gets.

Multiple Runs - [only for older, keen, kids who want to know more about modelling]. Each time the model is run (run new simulation) the results are different, partially because the initial conditions are different (two different trees are initially infected) even if the same trees were infected each time, the results would still be different as there are many variables not quantified in the model (e.g. precise landing spot of individual raindrops, wind speed and direction etc) we end up with a different result each time - chaos!(theory). To get a better grasp on the system you can run the simulation multiple times and watch the results of 100, 200 or 500 simulations run on a series of graphs which show the number/percentage of trees in each category (healthy, infectious and dead) change over time. You can see the typical pattern of infection e.g. that (given the initial conditions that you have set) most times about 250 trees will have to be culled, but that about 5% of the time only 600 trees will be left alive and the disease will run for over 8 years.

Demonstrator background info:

This is a computer model for a disease called Citrus Canker. It is caused by a bacteria (Xanthomonas axonopodis) and infects orange and lemon trees causing them to drop their leaves and fruit early. The fruit is safe to eat, but too ugly to be sold. It can be easier to model plant diseases because unlike animals plants arenâ€™t going to move around and spread the disease further themselves. The only way that the disease can be controlled is by cutting down infected trees.

Parameters

[Read through these descriptions and work out how the changes to each parameter affects the spread of the disease, you can also hover over any of the text within the model for a short description. Don't forget to accept the changes before running a new simulation, or else nothing will change!]

Talk through the model parameters in as much detail as you like. Less is more, probably chat through them in stages - run the model without controls to look at the epidemiology parameters, then keeping those parameters the same, introduce controls.

Epidemiology (change how the disease spreads)

Initial infection â€“ how many trees are infected right at the start (in real life this will depend on when the farmers spots that some of his trees are diseased)

Secondary infection rate â€“ how quickly the disease will spread from an infected to an uninfected tree

Typical kernel range â€“ a dispersal kernel is the area around an infected tree which the disease is likely to spread into, shows us which other trees are in danger, the type (either exponential or cauchy (apparently a better model for describing long distance dispersal)) probably doesn't make much difference.

Initial infections - number of trees infected at the beginning of the trial

Model type - different disease scenarios e.g. can it spread before it has been detected (cryptic infection) or not (probably easier to start off without cryptic infection or death)

Expected primary infections - the number of new infections which come from outside the trial (i.e. not from trees that you can see on screen, but the 'external environment') best to keep this at zero to avoid confusion

Expected exposed period - length of time that it takes for a tree to become infected (or how long it needs to be exposed for before becoming infected), once infected the tree can be discovered (as infected but not causing other infections) or start infecting other trees (if there is a cryptic infection period)

Expected detectable period - length of time a tree will be detectable for before becoming infectious

Landscape type - can simulate two neighboring plots of orange trees in a grove or citrus trees across a large landscape

Stopping condition - the simulation can either stop after a set period of time or once the disease has been bought under control (it's more satisfying to let it run until either you or the disease have 'won')

Weather Citrus canker is spread by in water droplets so it spreads more quickly between plants in high severity (wetter and windier) weather. It 'll be easier to start by keeping the weather the same throughout the trial (go for low severity throughout, you'll have a greater chance of 'beating' the disease)

Probability that a low/high weather severity index - these two parameters alter the changeability of the weather, if the cursor is to the right for both then the weather will remain constant throughout the experiment, if to the left then the weather will oscillate between high and low

Weather change interval - how often the weather status could change severity

Weather low severity factor - controls the difference in rate of infection spread between low and high severity weather conditions

Controls The main method for controlling Citrus Canker is culling visibly infected trees and a number of the surrounding trees.

Cull radius - all of the trees within this area are culled at the same time as the infected tree. The larger that this area is, the more likely you are to locally eradicate the disease, but you might end up killing all of your trees!

Detection probability - likelihood of spotting the symptoms of diseased trees

First survey - the time point at which the trees are first checked for disease

Survey interval - how often the trees are checked for disease

Fraction unsurveyed - proportion of trees which can't be accessed to check for disease (since they are on private property or are physically inaccessible), these trees will still be culled if within the cull radius of another tree

Expected notice period - average time between finding a diseased tree and culling it

Notice variability - standard deviation of time between finding and culling a given tree (makes the model more realistic - as you can't guarantee to remove all trees exactly 20 days after finding them)

Cull together - remove all trees simultaneously

Disable control - no intervention, watch spread of unopposed disease

Risk Assessment

Hazard: Laptop cable

Description: Trip hazard

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Set up close to power source, avoid cables crossing walkways and tape down cables. Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Duplo on floor

Description: Trip hazard

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Set up on a table or away from walk ways, making sure to pick up duplo if it gets knocked off table. Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Duplo

Description: Choking hazard

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Do not let students eat duplo (should not be a problem with older students). Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

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Evolution Games (PLUS only)

Modelling Evolution by Game Theory - Simulate populations and explore stable and unstable equilibrium by using Game Theory to model animal behaviour in sharing a food supply.

Last initially checked on 2023-02-15 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-16 by Lauren Mason (llm34@cam.ac.uk)

Tags

Evolution

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Demo only (Demonstration type experiments and lectures, not suitable for assignment for standard events.)

CHaOS+

Equipment Needed

- A selection of strategy cards with various bird pictures
- A whiteboard and pen (optional)
- Some lego brick success counters
- A photocopy of Chapter 5 of the Selfish Gene by Richard Dawkins (source of experiment)

Experiment Explanation

Talk about peopleâ€™s ideas about evolution. Try and say how most competition is in between members of the same species. Competition for mates etc. We can model that with maths.

Moles and blackbirds compete for worms; blackbirds and blackbirds compete for worms and everything else. Why don't blackbirds just kill off their competition (and eat them)? There's a risk attached to it, and it might end up help other animals to the detriment of the blackbirds.

A good example is that of elephants being hunted for their tusks. Those with larger tusks die, so tusk size decreases. (I introduced genes as parts of the DNA encoding some feature, you could go into more detail if you wanted.)

First, talk about how science works: we observe something and try and create a model of how it works. This can be linked nicely to Hand Model and Handy Engineering. It's often best to start with a simple model and add in more elements to improve it. That's what we do here for evolution. You could ask why they think a game is a good model for evolution/whether they think it's a good model. Some people win (propagate genes), there's the element of chance, making decisions/moves etc. Thankfully the mathematical and normal notion of games match well.

Give everyone 10 Lego/Duplo bricks; these are a measure of how 'successful' you have been at life. The game works by two people in the population 'randomly' meeting and competing over a resource (this could be a mate, food, nest). The resource is worth 5 blocks to whoever gets it, but only one can get it (no sharing). How can we decide who gets it?

Two ways: we either have a fight (this is risky, as the loser will come out badly hurt so takes a -10), or we can have an argument/show off/staring contest (think peacocks with their tails over mates or pacing in circles in cats). The latter is risk free, but in the time it takes to do this we could have found the object of the competition elsewhere - so there's a -1 score for losing the display. If someone tries to fight you, you're able to run away so you don't get injured. If there is a fight/stare-off/display etc., then flip a coin or do rock-paper-scissors for who wins.

We consider individuals behaving in a very simple way. They are either an aggressive hawk or a peaceful dove (this is untrue as doves are aggressive, and unhelpful as this is inter-species competition...). Hawks always fight and never run away, whilst doves never fight and will just stare off or run away when challenged to a fight.

We can now consider various different encounters...

- Between a hawk and a dove, it's obvious a hawk does well and a dove doesn't do badly.

- Between a dove and a dove, one gets a win and the other a slight loss. On average though across two fights both are in profit.
- Between a hawk and a hawk, one does well and one takes a massive loss. On average neither is doing too well.

You can now ask what would happen if...

- We had one hawk in lots of doves => the hawk would always win and the number of hawks would increase (they have lots of offspring).
- We had one dove in lots of hawks => slightly trickier as the dove would never win and would always score zero, but the hawks lose 2.5 points a fight on average, so the dove is actually winning by not suffering major injuries.

So from all hawks we're pushed towards more doves and all doves pushes towards more hawks. We can convince them this might have a stable point in the middle which both these push against. In fact it does when the population is 7/12 hawks and 5/12 doves.

With 6 people you can simulate this using one of the random cards (explaining it's like half hawk half dove) this also leads into the idea of polymorphism, not that individuals are intrinsically a hawk but they sometimes decide to act like one.

Phase plane diagram |->->->->->->->->->->->!<-<-<-<-<-<-<-<-<-<-<-<-<-<-| 0%doves Stable 100%doves

Now they've seen a simple model ask them how they think you could change it, thinking about how they see animals and themselves behaving:

- You could vary the rewards, this only really shifts the equilibrium - we pick them with a reasonable weighting. In fact we can actually back calculate these numbers from observing populations too. Increasing penalty for wasting time favours hawks, who never waste time, whilst increasing the penalty for losing a fight favours doves for the same reason. Changing the win value is more complicated. We could also make these random but we can take the expectation and it turns out to be equivalent in the long run. We can observe this in populations of very venomous snakes - they're very unlikely to attack as the risks are high.

- We can introduce new strategies - ask them for ideas. The simpler the better (we don't want to make our model too complicated). The next ones we normally consider are conditional strategists. They make decisions based on what the other person is doing. For example the retaliator stares off like a dove against a dove and fights like a hawk if fought against. Strategies like retaliator and prober-retaliator form a (nearly) Evolutionary Stable Strategy (ESS). They're vulnerable to slight invasions by each other and doves, and we get a polymorphism between them.

- We can also "break the symmetry" of the game. So far all fights are 50-50 who wins, but in reality this is really not the case. Some members of the species are bigger, more experienced fighters or are in home territory giving them an advantage in the fight. The idea of "bigger animal acts like a hawk, smaller a dove" is a stable strategy. Weirdly so is the reverse "smaller acts like a hawk, bigger like a dove" as anyone who chooses to break it is going to end up in lots of fights. Mexican Social Spiders are a species stuck in one of these paradoxical strategies, "if your nest is invaded, act like a dove; if you're invading, act like a hawk". One invasion leads to many, which is very costly. However, the risk of fighting manages to outweigh it in this species. Also rewards might be worth different amounts to different individuals: older ones might take more risks as they have less to lose, but if you have a large stash of food you're less likely to risk much on getting more.

- Memory. Crickets have past memory but can't identify individuals. They remember how well they've done previously and rank themselves on this (I lose 30% of fights). Monkeys can start doing individual rankings, I always lose to Frank, and Phil always runs away. This gives you ideas of what strategy other players are using.

We can work out optimal values for these games too. At the simple equilibrium in the original game on average everyone gets 0.625 points/encounter. We can now talk conspiracy theories. If everyone agreed to be a dove they'd average a reward of 1.5 which is much better, however individuals have no incentive to stick to it - become a hawk in this group and they rake in the points. "Stable not because it's good for the individuals within but because it's immune to treachery". (There are actually even better conspiracies to have)

If we want somewhere to go next we can go for wars of attrition. Like an auction but all bidders pay their bid and only the highest bidder gets the item. E.g. staring competition for a piece of food, both waste time staring and the loser gets nothing. Lots of things are unstable. An animal that values how much a piece of food is worth, stares as for as long as it thinks the food's worth, then gives up is outdone by someone who stares a second longer than the food is worth staring for. If you're not going to win ever you might as well never try so max bid population infiltrated by immediate quitters, then infiltrated by people who wait a second longer etc.

Imagine there was an indication you might give up, e.g. a whisker flicker when you'll give up in a minute. The strategy where you continued as you would but as soon as your opponent's whisker flickered you wait 61 seconds is optimal, but if you're going to give up in a minute and they haven't flickered it's best to give up sooner (without flicking your whiskers!) because you weren't going to win. Hence evolution of the poker face. Lying is unstable. Imagine people sitting down if they were in for the long game - people would give up if their opponent sat down, then liars emerge who sit down anyway, the people emerge to call the bluff. Lies and truth both unstable.

There's also competition inter species. A lion wants to eat an antelope. An antelope would prefer to not be eaten by a lion. These are mutually incompatible. Obviously lions could instead try to eat other lions but there's no much risk of retaliation. Antelopes don't fight back as it's too risky to attack the lion so they try and improve their running away. This is really just an example of (a rather large) asymmetry in participants.

There are often questions which actually highlight the one major flaw in this model. Humans are actually very bad at following it. There are various good examples in the Public Goods Game, Ultimatum game, Dictator (Trust) 'game' which give very counter intuitive results.

Risk Assessment

Hazard: Duplo/Lego/Coins

Description: Children swallowing Duplo or Lego pieces, choking hazard.

Affected People: Public

Before Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Mitigation: The Duplo pieces should be sufficiently large to discourage swallowing. Do not use Lego with very small children and keep a close eye on the box of Lego. This experiment is designed for CHaOS+ (i.e. 16+), so the risk of participants trying to eat the experiment should, hopefully, be very slim anyway when used for this. Call first aider if child swallows, if choking encourage child to cough. If the situation gets worse, i.e. child is suffocating and unable to cough the object out, call an ambulance immediately

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Duplo/Lego

Description: People falling/slipping on dropped pieces of Lego/Duplo

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: The pieces should be large enough that they don't present a large slip hazard. Be careful to keep pieces on the table and pick up anything that is dropped. Only use as many pieces as you need and keep the rest in the box. Call a first aider in case of accident.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Coins

Description: Tossed coins flying off and hitting someone.

Affected People: All

Before Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Mitigation: Check you can flip a coin without losing control of it, otherwise just spin it on the table. It's perfectly fine to let the children toss the coin themselves, but make sure they're capable of doing it safely with a trial flip first. In case of injury call first aider.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

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Exercise and Heart rate, Stethoscopes and Heart Model

When you exercise your heart beats faster! - Why does your heat beat faster after exercise? Come and find out why in this demonstration where you are the subject.

Last initially checked on 2023-01-20 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-01-31 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Stopwatch.
- (When done on tour, this experiment is often integrated with the Stethoscopes experiment. The Stethoscope experiment requires stethoscopes and antibacterial wipes/disinfectant and tissue, and also lives in a small blue box, often with the stopwatches. If using the stethoscopes, ensure you read the separate risk assessment for Stethoscopes).

Experiment Explanation

Exercise and Heart Rate

- Check for asthma. If child is asthmatic, check with parents (or teacher) about severity, and if the child can do five minutes of fairly heavy-impact exercise. If they can do it, ensure they have an inhaler, and ensure they don't push themselves too far.
- Take child's pulse (radial side of forearm), and write it down.
- Make child run on the spot 3 mins and then do starjumps for 3 mins or any other combination of the above.
- Check pulse again.
- There should be a difference. If not, it's an anomaly, and you can make them do the experiment again.
- If you're doing this experiment by taking the radial pulse, you need to start by asking questions ("Have you had your pulse taken before/seen it done on TV?" and "Why do doctors take your pulse?") to make sure they know that your pulse reflects your heart rate, and if they don't, make sure to explain it before carrying on!

So, why does your heart rate go up?

- What is the heart for? - They will usually say say pumping blood around the body/beating.
- My favourite question after this is "What is blood for?", to which the answer is always "It keeps you alive".
- You can then progress from here by asking why (which they often will not know, even in surprisingly old children), and then explaining why we need blood.
- I usually go along the lines of "What do we need to do to stay alive?", get them to work out that we need to breathe, eat and drink, then think about where air and food go into our bodies, and then how might we be able to transport these things from your lungs/stomach to wherever they're needed, like your muscles to jump around or your brain to think - and then you have ended up working out what blood does! (You can use the analogy of lots of lorries (blood cells) driving along roads (blood vessels) carrying cargo (oxygen/food). You can go further into the idea of cells needing energy from glucose and oxygen with older/interested kids.)
- With older/interested children you can then develop the idea by talking about the heart as a double pump and the pulmonary and systemic circulatory systems - this works well if you've got the heart model to hand (on tour), or if someone else has just explained the heart model to them!

- Then you can talk about how your muscles are more active when you're doing exercise so they need more 'fuel' (oxygen and glucose), therefore you need to get more blood to them in a shorter space of time, therefore the heart beats faster!

- You can also talk about breathing rate (are they panting?) and recovery times and fitness if you wish to. You need to breathe at a higher rate and more deeply to get more oxygen into your lungs, and then move it to the muscles more quickly, because they need more energy and so are using up oxygen faster.

(N.B. I find this experiment is quite useful with groups of lively children, as provided you can get them to be reasonably sensible and you have enough space, they can jump up and down until they're quite tired and then they will often sit down calmly and listen to the explanation afterwards!)

Heart Model and Diagrams

ACTIVITIES

- Let the kids take the model apart and let them figure out how it all fits together

THINGS TO TALK ABOUT

- What is â€œcirculationâ€ and why do we need it (see below)
- Structure and function of the heart
- Things that can go wrong (valve defects, heart attack etc)

TIPS FOR DEMONSTRATING

- It is quite surprising how little most people know about circulation. It is therefore very important to find out how much the kid knows already and work from that.
- I have included a very basic script for explaining circulation below - you would obviously have to adapt that to the age of the kid and to what he/she knows already.

BASIC PROCEDURE AND EXPLANATION

A) BASIC CONCEPTS

Look at the whole model. Ask the kids what it is (heart) and what it is used for (they will usually say that it pumps blood). Now comes the tricky bit: Why does the heart pump blood? It is quite surprising that many kids (and parents) have no idea about why we might want to pump blood through our body. If this happens, here is an explanation you could use to explain the basics of circulation (I have used a very simple one that even young kids can understand- you would have to adapt that for older kids/parents):

- Our body is made out of loads of little building blocks called cells. Each cell is like a small factory and it needs two things
- Get the kids to think about what these two things may be; i.e. why do we breathe (to get oxygen); why to we eat (to get food/nutrients)
- So the factories in our body need food and oxygen
- Where do they get that from? Ask them where the food they eat goes (stomach); similarly, the air they breathe in goes to the lungs
- So if the food is in the stomach and the oxygen is in the lungs, how can it ever get to all the â€œfactoriesâ€ that make up the brain, your toes etc.
- You need something like a street- these â€œstreetsâ€ are your blood vessels
- You also need something to transport the food and oxygen, i.e. a lorry â€“this â€œlorryâ€ is the blood
- So our blood transports food and oxygen to all the cells in our body
- But there is a problem - blood is a liquid - ask them what happens when you pour water/get water from the tap (water always â€œgoes downâ€ - so if this happens to our blood as well, it would all end up in our toes).
- So you need something that makes the blood go to the cells in the brain as well; i.e. you need an engine to drive a lorry or in other words, you need the heart to pump the blood through your body

B) STRUCTURE OF THE HEART

Let them take the heart apart and get them to think about what the individual bits may be and what they might be used for. Here are some things you could point out:

- Can they see the big blood vessels (â€œstreetsâ€) that come into and out of the heart; get them to think where they might come from and where they may go to; i.e. some go to/come from the lungs and others go to/come from the body (having explained circulation beforehand helps; i.e. the blood has to go to the lungs to pick up oxygen)

- Let them guess which ones might be the vessels that go to the lungs and which ones are the ones that go to the body

- The heart has chambers â€“ can they see them? How many are there?- how does the blood travel through the heart?
- Do they think that the blood can go back to the chamber it just came from? No; point out valves; if the kids are older, get them to figure out why this â€œone wayâ€ system is important
- The heart is a muscle; it contracts, when it contracts, the chamber gets smaller, this squeezes the blood in that chamber into the next chamber/ into the body/ to the lungs; valves prevent backflow

C) OTHER THINGS TO TALK ABOUT

- Can they see the small blood vessels going into the heart itself (coronary arteries etc)?
- Why is this important? â€“ the heart is a muscle, that has to work all the time for all your life - it needs a lot of food and oxygen, too!!!
- What do they think happens if you block one of these vessels? - Ischaemia, angina, heart attack (Parents are usually quite interested in this)
- What can you do when this happens? - Open up vessels (stents), make vessels bigger (drugs; vasodilators), but most importantly, remove anything that can block those vessels- this is why a healthy diet, exercise and stopping smoking are so important!
- Other things that can go wrong: Valve defects, heart failure
- When the heart pumps, it makes a noise - this is what you can hear with a stethoscope; refer them to the stethoscope experiment
- For older children - noise heard through the stethoscope is actually the closure of the different valves in the hear

Stethoscopes Using a stethoscope to listen to the heart and find out how it works Use the 'heart rate and exercise' explanation too!

1. Do they know what it is?
2. Do they know what it's used for?

- Use it to listen to: Lungs, Heart, Bowel sounds, Bruits (noise due to turbulence in blood vessels for various reasons) in the following vessels:
- Carotid
- Femoral
- Thyroid
- Hepatic

3. What makes the sound?

Normal Lungs:

- Normally turbulent air going in and out of bronchi.
- Sounds different over bronchi/trachea and lung fields.
- Same noise, but in the lung fields it is heard through large amounts of other tissue and so is soften (I think it cuts out specific frequencies - high or low -but don't quote me on that).

Abnormal Lung (probably talk about Asthma as most kids now about it)

1. Bronchial breathing over lung fields. Due to consolidation - solid debris in lungs with pneumonia- or fribrosis. Means sound can't 'disperse' (I'm sure physicists would have better description).
2. Wheeze (can demonstrate this one). Due to narrowing of the tubes. Asthma wheeze, COPD gives polyphonic. Tumour wheeze gives monophonic (because only blocks one tube).

Heart.

1. Have brief discussion about what heart does (see Heart Rate and Exercise or Heart Model explanations). Where is your heart? It is surprising how many children seem to think it's somewhere in their left shoulder!
2. What makes noise in heart?

- Valves - with older kids a discussion about why we have valves may be useful.

3. Normal heart sounds.

- Lub-dub.

4. Extra heart sounds:

- Note, can have third and fourth heart sounds.
- If you have both they make noise like train going over tracks - du-dub-du-dub.

5. Abnormal:

- Due to turbulent flow through valves (make the noises).
- Why do you get turbulent flow? - Valve doesn't fully open (stenosis) or Valve doesn't fully close (regurgitation)

Risk Assessment

Hazard: Over-exertion

Description: Asthma attack.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Check child's asthma status with parent or teacher (or with child themselves if old enough) before doing experiment. Do not allow child to exercise if asthma is severe, and DO NOT ALLOW AN ASTHMATIC CHILD TO DO EXPERIMENT IF THEY DO NOT HAVE AN INHALER.

In case of an attack, sit child down, keep them calm, locate inhaler for child to self-administer. Call first aider.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Running children

Description: Child running into things/people.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Make sure exercise area is clear, use on-the-spot exercise e.g. star jumps if space is limited.

Call a first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Exercise

Description: Physical injury e.g. falling.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Demonstrator to ensure floor area is clear and dry. If area becomes wet, locate a mop and dry the area.

Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Small Parts in Heart Model

Description: Small parts could be swallowed.

Affected People: Public (especially small children)

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: (The heart model is suitable for older children, so hopefully shouldn't be an issue). Do not let children play with experiments unattended.

Call first aider in case of ingestion and encourage the child to cough.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Pointed Parts in Heart Model

Description: Some parts have fairly sharp points - risk to eyes/skin.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Sharp points filed down to be as safe as reasonably possible.

Call a first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Earpieces of Stethoscopes

Description: Transferring infection via ear pieces.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Wipe ear pieces with antiseptic wipes or tissues and disinfectant before use and after you or a child has used it.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Stethoscopes

Description: Yanking or swinging of stethoscope causing injury

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure stethoscopes are removed before doing exercise. Keep children under control, and if children are misbehaving, don't give them a stethoscope.

Call first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Stethoscope

Description: Choking from stethoscope being tangled around neck.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Keep children under control, and if children are misbehaving, don't give them a stethoscope. Ensure stethoscopes are removed before doing exercise.

Call first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2012-01-05 - Ashley Smith (ashley.smith@cantab.net), **Check 2**: 2012-01-25 - Daniel Obute (rdo23@cam.ac.uk)

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Fire Extinguishers

Demonstrating the power of a carbon dioxide fire extinguisher. - What does a fire need to burn, and how can we put it out? Find out how we can put out a candle with a cupful of gas!

Last initially checked on 2023-01-15 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-01-16 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- *NB: this experiment does not have a box. It normally lives in mini explosions as it uses bicarb and acid.*
- Candle (Tea light)
- Matches
- Deep walled heat-proof container (e.g. ceramic mug)
- Plastic beaker
- Bicarbonate of soda
- Vinegar or lemon juice
- Cloth (useful to be able to wipe-up spillages)

Experiment Explanation

Setup note

This experiment will only work in very still conditions (somewhere not too draughty indoors) since if there is any wind the carbon dioxide will blow away rather than extinguishing the flame.

Experiment

Light a tea light (small candle in a metal holder).

Mix a small amount of vinegar (or lemon juice) and bicarb in a film canister.

Carefully, without spilling any of the liquid, pour the carbon dioxide over the candle. The flame should go out.

Take advantage of the shape of the container the candle may be in to trap the COâ,,.

Explanation

(NB, some kids will have seen the mini explosions experiment and so will have more idea what's going on than others)

Light the tealight. Discuss burning. What is needed for something to burn? Fire triangle- fuel, heat, oxygen.

How can we put out a fire? (Kids may talk about fire extinguishers... if they do, can draw that into how different extinguishers work- CO_2, water, powder.)

- Take away the fuel (like turning off a gas flame on a hob).
- Take away the heat (cool things down, part of how water puts out fires... takes energy to heat the water so less is available to carry on the fire).
- Take away oxygen (smothering the flame, what we're going to do here).

We're going to try putting out a fire by depriving it of oxygen using a gas called carbon dioxide which is heavier than air, and in which flames can't burn (used in fire extinguishers).

Make carbon dioxide by reacting vinegar (like on chips) with sodium bicarbonate/bicarbonate of soda/bicarb which they may have used for cooking. Discuss where the COâ,, comes from (locked up in carbonate in solid, let out by vinegar or lemon juice (acids), or by heating as in cake baking). Reaction is: Acid + Carbonate â†’ Salt + Water + Carbon Dioxide

Pour COâ„ over the flame... it should go out (will work better if candle has burnt down a bit in the holder, as it will hold some COâ„). If it doesn't, try again; you could discuss the effect of draughts on mixing oxygen back into the carbon dioxide.

This is the idea behind COâ„ fire extinguishers. However, there's an added benefit with extinguishers, they store the COâ„ as liquid using the pressure in the cylinder, when it turns from liquid to gas this also dissipate heat. It also means the cone of a COâ„ extinguisher gets very cold, in fact people get frostbite and other injuries from using them incorrectly and holding this cone.

Other types of fire extinguishers are powder or foam which work by smothering the fire and cutting off the oxygen supply to the fire. Water extinguishers remove the heat from fires by propelling liquid water and it taking away heat when it turns to steam.

Risk Assessment

Hazard: Candle & Matches

Description: Fire risk

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: Use a tealight rather than a more standard candle: short, stable candle contained within metal holder. Make sure tealight is on a ceramic plate or something that will not burn. Also make sure it's not in a location where it is under or can be accidentally knocked onto something flammable (e.g. knocking it from a table to the carpet).

Do not leave lit candle unattended.

Keep tight control of matches. Ensure no flammable materials are near the lighted candle. Know where the nearest (proper) fire extinguisher is.

In case of fire follow local procedure (see venue RA).

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Candle

Description: Risk of burns.

Affected People: Demonstrator mainly - Kids shouldn't be holding the candle / matches.

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Put the candle in a good place to run the whole experiment before lighting it, then do not touch the candle once it's been lit. Don't let kids get hold of candle/matches. Donâ€™t leave the tealight lit for extended periods.

Call first aider in event of injury. Run burns under cold water for at least 10 minutes.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Vinegar / Lemon Juice

Description: Acid could get into eyes/broken skin. Irritant to eyes and cuts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure children have no exposed cuts before starting the demonstration. Minimal contact with vinegar anyway. Use a small amount of reactants to avoid bubbles spilling out.

Don't let kids lean in too close to vinegar + bicarb reaction (to avoid possibility of bubbles splashing into eyes etc).

If vinegar gets in eyes, we have eyewash in the first aid box (and there should be some in the Mini Explosions box). The demonstrator must know where the eyewash is located and allow a trained first aider to perform eyewash.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

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Flame Tornado

Demo of a flame tornado - Watch a tornado form under the effects of moving air.

Last initially checked on 2023-02-18 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-02-18 by Timothy Wong (chw55@cam.ac.uk)

Tags

Demo only (Demonstration type experiments and lectures, not suitable for assignment for standard events.)

Physics

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Rotating turntable with attached mesh thingy
- Cotton wool & petroleum jelly
- Lighter

Experiment Explanation

Old explanation

Demo of a flame tornado - a small fire is made at the centre of a rotating mesh tube. The tube is rotated giving incoming air angular momentum, so it gets dragged in and makes a cool tornado effect.

To set up place a crucible at the centre of the tray. Let people give it a spin to show a tornado isn't formed like that. Place mesh around and spin again. This messes with incoming air and leads to vorticies and tornadoes through scientific magic someone should explain here!

New explanation

Ensure the turntable is placed on a flat surface outside. Cover cotton wool with petroleum jelly ahead of demonstrating because a) it's not nice to do and b) it will make demonstrating easier. Place some in the centre of the turntable and (very carefully) light it using the lighter (aim for the cotton wool as the jelly itself isn't flammable and will melt). Make sure people are standing out of the way when you do this! Then, spin the turntable (first without the mesh outside, then with the mesh outside) and you should see a flame tornado when the mesh is present.

Science explanation

Hot gas rises* so as the fire heats the air around it this rises, pulling more air in sideways at the bottom, which then also rises.** When the setup is spun without a mesh cage on, the fuel rotating doesn't really affect the flame and so it just rises like a pretty normal flame. When the mesh cage is added, that air being pulled in at the base is knocked by the cage as it gets pulled in, starting it spinning. As the air keeps being pulled in, it spins up faster, because it's being pulled into the middle of the spinning.*** As it reaches the flame, it heats up and rises, but whilst spinning, leading to the flame tornado effect. The flame tornado flame is higher than the normal flame. I think that this is because in the rotating cylinder of air the colder, denser air gets pushed to the outside more than the hotter, lighter, flame and so the flame pulls up the centre so that it's all as central as possible.

*hot air balloons and thermals are good examples of this. We might already be running hot air balloons as a separate experiment. You can also show this with the lighter (I'd assume) as the flame will pull upwards regardless of the orientation it's held in (mind your fingers).

**in space stations, with no gravity, flames are much less bright because they can't pull in oxygen like this.

***this is a whole experiment in itself (spinny chair). If they know that ice skaters start spinning wide then pull themselves into the middle to spin faster, or that pulling yourself to the middle of a roundabout makes you spin faster, then that's a reasonable demonstration.

Risk Assessment

Hazard: Hot surfaces

Description: People, and especially fingers, could get burned if they get into the fire or touch hot surfaces.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Only touch insulated surfaces (i.e. the turntable edge and not the mesh). Keep crowds back to make easier to control. Only to be done by an experienced demonstrator who has practised ahead of time. Audience to be told not to touch the experiment, and demonstrator to avoid continuously running the experiment to minimise contact with the hot jar lid/mesh.

The mesh cylinder is held onto the turntable very well and acts as a shield to stop people touching the flame itself, and stops the it from escaping.

The demonstrator should exercise caution when touching the lid especially, as it will be very hot when you come back to it. Keep trough of water nearby to submerge the lid and cool completely.

In case of accident, run burned areas under tepid water for 10 mins or until it stops hurting - whichever is longer. Summon a first aider to assist the casualty.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Burning liquid

Description: The burning liquid could escape, and cause a fire/burns.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Be very careful about where it is set up so there is nothing flammable nearby - to be done on a clear piece of flat ground only. The audience should be made to stand well back, and the demonstrator should maintain a safe distance while demonstrating, keeping long hair tied back and skin covered.

There should be a fire blanket close at hand (safety box).

Petroleum jelly is used because it is viscous so will not fly out too easily

The jar lid is constrained so it remains central.

Smother any flames with the fire blanket. If fire spreads call 999. In case of burns follow actions for burns above.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Petroleum Jelly

Description: Allergy to petroleum jelly.

Affected People: Demonstrator

Before Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Mitigation: Ensure demonstrator is aware of what materials are used in the experiment and that they will need to use touch petroleum jelly. Do not proceed if the demonstrator has an allergy. Wash jelly off hands after applying it.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

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Fruit Batteries and fuel cell construction

Use fruit to make a battery - How does electricity work? Find out how using a fruit!

Last initially checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-07 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Fruit
- Something to power e.g. LED, small clock
- Zinc rods/nails
- Copper rods/nails/coins
- Wires
- Electrical tape

Experiment Explanation

1. Connect the red wire on the LCD to a copper and the black wire to a zinc. Secure wires in place with electrical tape.
2. Get another copper and zinc and connect them with the connection wire using adhesive tape.
3. Insert the copper and zinc plates into the fruit to get power

How does it work? The copper acts like the positive electrodes of a battery, as it is less reactive than zinc. When the copper and zinc plates are inserted into the lemon, a chemical reaction takes place. Electrons (extremely small particles with negative charge) move from the zinc plates to the copper to form a current, thus activating the LCD. You can replace the lemon with a potato, a grapefruit or use soft drinks or vinegar and see what effect this has.

Extra points to get across... talk about circuits a bit, why does it all have to be connecting in a circuit, how does the electricity travel through the fruit!

More advanced info - for older kids In a battery there is a negative electrode, where electrons are produced, and a positive electrode where they are used up. The zinc is the negative electrode (anode). Zinc is more reactive than copper so gets oxidised and dissolves into the fruit juice: $Zn \rightarrow Zn^{2+} + 2e^-$

The electrons produced flow through the wires (and the LED/LCD) to the copper, which is the positive electrode (cathode). Hydrogen ions are reduced at the cathode: $2H^+ + 2e^- \rightarrow H_2$

As the hydrogen ions move through the fruit to the copper they create a current through through the fruit, completing the circuit - there are no electrons flowing through the fruit! For this to work there need to be hydrogen ions in the fruit, so it needs to be acidic. This is why lemons work well, they have lots of citric acid in. You could relate this to lemons tasting sour, which is due to their acidity. Potatoes also work as they have some phosphoric acid in, but they are less acidic than lemons so have a lower voltage (produce less electricity) - you should be able to show this using a multimeter.

Fun Facts The development of the battery started in 1775 when a scientist called Alessandro Volta invented a machine that produced and stored static electricity by rubbing cat fur across a metal plate. A few years later, a doctor called Luigi Galvani noticed that dissected frogs' legs twitched when they were in contact with two different metals. Volta realised that the electricity came from the metals and began doing experiments with different types of metal. In 1800, he made the first ever battery which consisted of copper and zinc strips separated by a piece of paper soaked in salt water and dipped in diluted acid.

Risk Assessment

Hazard: Sharp plates/nails/forks

Description: Could hurt people/cause cuts

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Monitor kids when they are using metals, and make sure metals are not too sharp

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Fruit juice

Description: Irritation if it gets in eyes.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Encourage metal rods to be put carefully into fruit to prevent squirting of fruit juice. Call a first aider if fruit juice gets in eyes, who may perform an eyewash if trained and confident to do so.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Fruit juice

Description: Juice is acidic and can cause damage if in contact with cuts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 1, Overall: 3

Mitigation: Clean rods between use so not covered in juice when children handling them. Check that children donâ€™t have uncovered cuts before starting demonstration. Demonstrators should wear plasters over any cuts they have. In case of accident, wash the affected area with clean water.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Hazard: Fruit juice

Description: Kids might be tempted to try to ingest the juice, thinking it might be food.

Affected People: Public (mainly children)

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Don't let the children consume anything or lick their fingers.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

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Giant intestine model

Functional model of the intestine - Everyone knows that your intestines are long, but how long is long? Find out with our scale fabric model, and you might be surprised!

Last initially checked on 2023-01-22 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-01-30 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Model of the intestine, which can be used to explain the digestive process to children.
- May also include tube made from chopped-off tights and a smooth plastic ball.

Experiment Explanation

ACTIVITIES:

- Show the model to kids, let them feel it and ask them to guess what they think it may be
- Illustrate the length of the intestine: get a kid to stand up and use the model to illustrate how long the intestine actually is (you can hide it in the bag and give the child one end to gently pull out and walk across the room until the whole thing is stretched out, if there's enough space and the child is sensible about it). Get them to imagine that such a long tube is actually rolled up within the small space of their tummies...
- Get them to feel the inside - there are ridges. You could use this to discuss surface area (i.e. â€œwhat would happen if all these ridges were smoothed out?â€)
- Use the plastic ball as a bolus of food and squeeze it through the tights tube to describe peristalsis.

THINGS TO TALK ABOUT:

- Basic theory of digestion, i.e. "what happens to the food once weâ€™ve eaten it?"
- What you need to make digestion effective: surface area of the intestine; how to increase surface area (ridges, length of intestine- use model to demonstrate)
- Things that can go wrong: diarrhoea, constipation, etc.

TIPS FOR DEMONSTRATING:

The idea is to get the kids involved as much as possible. The best way to do this is by using the model as much as possible when you explain things. Let the kids play with it as well- and get them to figure out things for themselves.

BASIC PROCEDURE AND EXPLANATION:

What do we use our intestines for?

- Our body is made up of loads of small factories, called cells
- What do they think these factories need? â€“ Food (Thatâ€™s why we eat...)
- However, the food we eat is very big and these cells are really small (so small that you canâ€™t usually see them with the naked eye!)- so the food needs to be broken down
- What do they think breaks down the food? Talk about teeth, stomach, also your intestine
- The pancreas secretes a special liquid that breaks down the food (If the kids are older, they will often have heard of enzymes, so you can expand on this point as much as you - and they - like...)
- So, once the food is broken down, how does it get to cells in the body? Via the blood (for young kids: the blood is a bit like a lorry - it can pick things up and bring them somewhere else)
- The intestine is the place where the food gets taken up into the blood (for older kids, talk about absorption etc.)
- How does food move through the intestine? Use the ball and tights tube to explain peristalsis - there are muscles in the intestine walls that contract to squeeze the food along (use your hands to represent the muscles)

What makes the intestine so good at what it does?

This point is all about absorption and how you can increase the latter by increasing the surface at which it can occur.

For young kids:

- Get them to imagine how long the intestine is by using the model.
- Can they imagine that such a long tube is actually folded up within their tummies (see activities)?
- So there is a lot of space for the food to get into the blood...

For older kids:

- Talk about the length of the intestine as before.
- Also get them to feel the ridges inside - what do they think would happen if they were all smoothed out?
- Just for reference, the surface area of the small intestine in an adult person is about 250 square meters â€“ thatâ€™s about the same size as a tennis court!
- How can such a large area fit into our tummies - by folding it up (so all the ridges are folds of the intestinal wall...)

What happens to the food we donâ€™t absorb?

- It moves through the intestine and leaves our body as poo - small kids often find this strangely fascinating.

OTHER THINGS TO TALK ABOUT:

- There are two types of intestine (small and large) - they have different functions (parents may ask you about this.)
- Things that can go wrong: diarrhoea, constipation, malabsorption, inflammatory bowel disease etc... see below for ideas:

Diarrhoea â€“ ask who knows what this is?!

- Itâ€™s watery, frequent stool.
- Very important to kids in developing countries especially â€“ losing so much water (and you can lose blood too â€“ this is called dysentery, which happens with Shigella and Amboebiasis) can be fatal.
- With cholera you are losing so much water so quickly that it is pretty much literally a battle to give the patient enough water.
- Common agents:
- Bacterial: E. Coli 0157 (the E Coli K we have on display is entirely safe though), Salmonella
- Protozoa (one-celled, primitive, parasites in this case): Amoeba, giardia - much commoner in the third world.
- Viruses: rotavirus (most common in kids), Norwalk virus (causes diarrhoea and vomiting on cruise ships, calling for impeccable hygiene standards).

Older kids might understand the principal of isotonic drinks for rehydration â€“ the ions are needed because so many are being lost, and the water enter cells more quickly due to osmotic attraction and as some ion channels co-transport water. Explain that ions are chemicals like sodium, chlorine, and potassium, and that they spread themselves out in the body into all the cells, with water following them. Ask them if they think itâ€™s important that you keep your cellular ions at a constant level. Ions are lost into the intestine because inflammation at its mucosal surface makes it leaky.

Malabsorption:

- What if a surgeon cuts out half your small intestine because it got damaged in a skiing accident or whatever?
- Do you think your intestine will work as well?
- What do you think happens if your villi are destroyed?
- This is what happens in celiac disease â€“ it is an inappropriate immune reaction to gluten in the diet.
- The patient (usually a child) becomes thin and malnourished, slows down their growth and can become deficient in micronutrients, eg. vitamins, which are usually absorben in the small intestine.

Villi are also destroyed in Inflammatory Bowel Disease (these diseases are Crohnâ€™s disease and Ulcerative Colitis).

- Ulcerative colitis tends to affect the large bowel almost exclusively, decreasing its ability to absorb water. Therefore someone with Ulcerative Colitis will get watery stools. The tissue gets so inflamed (or I guess you could say â€œattackedâ€ to younger kids) that it bleeds, which can be noticed in stools.
- Crohnâ€™s can affect the small intestine and cause malabsorption of lots of nutrients, carbohydrates, and lipids.

We mentioned that the pancreas makes enzymes â€“ I like to describe them as being like tiny scissors which chop up the smallest nutrients up into a form which they can just nicely be absorbed into villi. If someoneâ€™s pancreas isn't working properly (eg. it gets clogged up in cystic fibrosis, or if they have a gallstone obstructing its outflow) they canâ€™t absorb a lot of things like lipids, proteins and fat-soluble vitamins (A, D, E, K).

Bacteria in the intestines- these play an important role too in breaking down components in your food. There are about 100 trillion bacteria in your intestine, more in the large intestine than the small intestine. Some of these are beneficial, others are pathogenic. Probiotics are to help encourage growth of bacteria that are beneficial. Examples of bacteria that are damaging in the gut include Campylobacter and some types of Salmonella.

Risk Assessment

Hazard: Tube

Description: Risk of strangulation if model or tights tube is wrapped around neck.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Supervise children carefully and do not allow them to wrap model around neck.

Call first aider in case of accident

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Stretched intestines

Description: Risk of tripping and falling if child runs across room to stretch the intestine out (especially if stopped suddenly by reaching the end of the intestine); risk of other people tripping on stretched intestines.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Supervise children carefully, only allow them to walk (not run) across the room and do not allow it at all if there is insufficient space or the room is busy.

Call first aider in case of accident

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Plastic ball

Description: Risk of tripping on escaped plastic ball

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Only have one ball out at a time and keep an eye on where it is. Pick up ball if it falls on floor.

Call first aider in case of accident

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

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Graph Theory

Find out about the mathematics of Graphs. - Experiment with graphs finding out about what structure we can find in randomness, how to colour maps with few crayons and what shapes you can draw without taking your pen of the paper.

Last initially checked on 2023-02-12 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-13 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Either: Lots of plain paper, coloured pens
- Or: Whiteboards, coloured markers

- Optional CHaOS Graph Theory Booklet with sketches of some of the things you may like to do.
- The following booklets formed the inspiration and may be useful.
- Http://jdh.hamkins.org/math-for-seven-year-olds-graph-coloring-chromatic-numbers-eulerian-paths/
- Http://jdh.hamkins.org/math-for-eight-year-olds/

- Utility Problem Mug (Please Draw on it with erasable pens)
- K7 Mug (Please don't draw on it)

Experiment Explanation

We might want to understand various properties about different mathematical structures. A graph is a very simple structure, it has points (or vertices) connected by lines (or edges). We can think of edges as meaning close by or related to.

Can we think of some graphs in daily life? Maybe a family tree where vertices are people and edges are between parents and their children. We could also have cities and trains between them.

There are lots of directions you can then take for this experiment, it really depends on the demonstrator but here are all good ideas. Some of these can then be combined into CHaOS+ activities.

Vertex Colouring

One thing we might want to do is colour in our vertices so ones connected by edges are different colours. Ask people to draw some graphs and colour them in. Most people seem to avoid drawing crossing edges so you should be able to keep colours low.

Ask people with three colours what they have that's stopping them using only 2 colours. You can normally find a triangle or pentagon (or larger odd cycle) which is preventing them.

How can we increase the number of colours we use? Add a new vertex and an edge to all existing colours or more edges between things of the same colour. Can we keep doing this indefinitely? Yes as long as we don't mind edges crossing when we draw them. If we mind about that people will struggle when you try and draw a K5. Most people seem to believe this is hard. We call a graph with no crossing edges planar.

You could divert to talk about the utilities problem. Given 3 houses and 3 utilities (gas, water, electricity) can you connect each of the houses to the utilities without any of the 9 edges crossing? Again you can be convinced this isn't possible. If were allowed to glue edges of the paper together though we can actually do it on a torus. You can use the mug to demonstrate this fact, notice you need to draw some lines over the handle. Note topologically mugs are torus shaped.

What about if we start talking about maps. What is a map? It's just a collection of regions (or countries or faces) and we'll colour it so neighbouring things need different colours. If they share only a point as a boundary they can be the same colour.

You'll find people use 2-4 colours, if they use more they've gone wrong. (This is the 4 colour theorem). Can they see a correspondence between the graphs and maps? If we stick a vertex in the middle of each region and connect with edges those sharing a boundary. We can make this so the edge goes through the boundary and doesn't cross.

We can also colour the entire outside one colour too. See if they can do this and find what this does to the graph. You might also like to turn planar graphs into maps by doing the reverse to this.

If you've convinced them about the colouring you can show them the K7 mug. This has a K7 drawn and it's map coloured on the surface of a mug. Maybe it isn't the same as a plane?

Eulerian Cycles

What shapes can we draw without taking our pen off the paper or going over a line twice?

Have a go at drawing things and seeing what's possible. The famous counter example is the Bridges of KÃ¶nigsberg. There may be objections this graph has multiedges, we could just put more vertices in though to make them distinct.

Let's try counting how many times we pass through vertices. In the middle we need to enter and then leave the vertex, each time we do this we use two edges so we need things in the middle to have an even degree (number of edges coming out). This gives us a good idea of where to start when we have 2 vertices of odd degree as we'll need to start and finish at these two points. If we have more than 2 we know we've got an odd one in the middle so it's impossible. What if there are no odd vertices? Well we'll need to start and finish in the same place, count the edges out of the start and we need to make it even.

You may get some questions about what happens if there is only one vertex of odd degree. See the handshake lemma for this case.

How do we know these cases with 0 and 2 odd vertices are possible?

We didn't really prove it just showed others weren't and constrained how we find them. We can do this by induction. Take a graph with this property with the smallest number of edges, remove an edge and we know we can do this (else what we get has less edges) and then use this final edge. We can check what we get is only 0 or 2 odd vertices and everything matches up.

Handshake Lemma

How many vertices of odd degree can we have? Draw and try. Let's start adding edges and try and add up the total degrees. We find as we add an edge the total increases by 2 each time so we have some vertices of even degree which sum up to an even number and some odd vertices, we'll need these to sum to an even number so we need an even number of them, hence we can't have an odd number of vertices of odd degree.

-**Edge Colouring**

We can also colour the edges we have, one way might be that all edges meeting at a vertex have to be different colours. We need to look at something called the max degree, this is going to be the largest of the degrees any vertex has. We know all edges out of this vertex will need different colours, so this is a lower bound on the number of colours we need. Try colouring some things and see how many more you can get too. An odd cycle is a good example that you might need more. Vizing's Theorem says that one more colour is the worst possible, so we divide up everything into two classes.

++One could prove this again by induction removing an edge and considering an alternating path of different colours.

Ramsey Theory

Lets try a different way of colouring the edges. We'll only use two colours (wlog red and blue) and can colour edges however we'd like. We're going to look at what we can find in the edges of the same colour. We'll look at graphs where all vertices are joined by an edge. Take 6 vertices and colour all 15 edges. Can we do this to avoid making a triangle? What about if we only have 5 vertices? This shows that the Ramsey number called R(3,3)=6. R(4,4)=18 so it's probably a bit far, but you could talk about antisymmetric ones like R(3,4)=9 which avoids a red K3 and blue K4. By doing this we've found some order in the graph, even if we'd coloured it randomly we've found a smaller nice substructure which is very important in physics.

It's actually really hard to find these numbers. In fact all we know about the next ones is 43<=R(5,5)<=48, 102<=R(6,6)<=165, 205<=R(7,7)<=540. Why is it so hard? How many ways can we colour these? We have n vertices so n choose 2 edges, this is like n squared. We can colour these each either red or blue so that's (2^(n^2)) possible colourings. This number is very big, for around n=16 there are more configurations than atoms in the universe and n=20 we surpass possible games of chess. This means we can't use a computer easily at this point and need to do it mathematically.

Euler Characteristic

We want to try and find something special about connected planar graphs. One thing we could do is look at some parts. Lets count the number of edges, E, and vertices, V. We'll also want to count something else, we'll call these the regions or faces of the graph, R. (These are slightly different to the countries we had when map colouring as we're using the edges as borders.) We also need to count the outside as a face. Let's calculate a few examples of V-E+R. One should always find that this gives us the answer of two. We call this the Euler characteristic of the graph. Can we see why it's always 2? Start with 2 vertices connected by a line, this has characteristic two. If we add a new vertex we'll need to also add an edge to make the graph connected and this won't make a new region so we remain unchanged. If we add a missing edge between two existing vertices then E and R increase by 1 and so we don't change the characteristic.

If you talked about the utility problem you can try and calculate it's Euler characteristic, the regions are more tricky to see however it only has three (easy to see on a torus). This gives it an Euler Characteristic of 0.

Using the utilities and K7 mug you can work out the Euler characteristic of a mug which is also 0, and is why K7 and K3,3 are draw able on a mug but not a plane. On the mug you may get more questions about what a face is? The technical definition of a face on a surface is if we remove the edges and vertices a face is a connected component.

5-colour Theorem

If you are feeling brave it's possible to prove this with very advanced groups. You'll need to have covered Euler Characteristics and Map Colouring. Firstly look at the Euler Characteristic and think about relating faces and edges.

We'd like to say there are not many edges relative to vertices. We can add lots more edges where possible to keep the graph planar. Let's say we have a non triangular face we can draw a line across it and get closer to triangles. If we have an edge that's only in one face then we can add another edge to make two faces. You may need to demonstrate this to convince people it's possible.

Then each edge is part of two different faces. Each face has 3 edges making it up. So 3R=2E.

Then we have V-E+R=2 so V-E+(2E/3)=V-(E/3)=2

So E=3V-6.

But we added edges to get this new E so we know originally we had E<=3V-6.

What does this say about the minimum degree? Well if we add up all degrees that's bigger than V times the smallest. Also this sum is 2E<=6V-12. So the smallest must be less than 6.

This means we can easily prove the 6-colour theorem, colour a graph minus something of degree <=5 and there's a colour remaining when we stitch it back together.

Lets say we take the graph with the fewest number of vertices we can't 5 colour. And find a vertex of degree <= 5. If we remove it we can colour the rest (by induction) so we only need to colour that one. If it was degree <=4 or had 5 neighbours with a colour in common it's easy as we can use that free colour. Otherwise we have one neighbour of each colour. Consider in the drawing two colours not next to each other.

Risk Assessment

Hazard: Scissors

Description: Risk the children will grab scissors and injure themselves.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Make sure you cut out any required paper before the kids arrive. If you need to have scissors on the table, have the safety scissors.

If there are any cuts, call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Coloured pens

Description: Risk that children will take and possibly eat coloured pens.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Watch small children with pens. Alert parents immediately if children arenâ€™t being sensible and call a first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Utilities Problem Mug

Description: Porcelain mug could smash into sharp pieces and cause cuts.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: If the mug smashes, move children out of the area and sweep/vacuum for pieces. Call a first aider in the event of an injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: K7 mug

Description: Possible ingestion of the paint on the mug.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: It shouldn't be used as a mug ever. The mug shouldn't be used for drinking or licked. Keep out of childrenâ€™s reach. If children do ingest paint, inform parents to take them to GP if illness develops. Call a first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

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Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-01-18 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2020-02-05 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2020-02-05 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-22 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2021-01-22 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk), **Check 2**: 2022-02-09 - Conor Cafolla (ctc43@cam.ac.uk)

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Hand Model

Large working model of a hand and forearm, with all the tendons to show how a hand works. - Take control of an *enormous* hand, playing the part of the muscles that control it! Can you work out how to make a fist? Why are there tendons running down both sides of the fingers? And exactly how are your thumbs different to your fingers?

Last initially checked on 2023-01-20 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-01-20 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Working hand model ("Emily").
- Short lengths of string (optional)
- Small Paper Hand (stored in wallet attached to box)

Experiment Explanation

This experiment is a bit of a crowd-pleaser. There is a subtle technique of keeping kids' fingers out of the wooden joints, and after this has been achieved, all ages will be amused by playing with it.

Explanation

1. Guess what the model is of â€“ nice and easy start!
2. Ask what do the pieces of wood represent = bones, and where in the body they are.
3. Talk about moving your fingers, and ask what in the body moves them = muscles (after several shouts of veins, ARGH!!), then where are the muscles that move your fingers = forearm not in the hand, and the fact the muscle belly mostly ends quite before the wrist. You can get them to wiggle their fingers and see if you can see the muscles moving in the forearm, but not above the elbow (this is often more visible on demonstrator/parent than child!)
4. Leads onto the fact that muscles are in forearm, but need to join onto fingers in order to move them â€“ how? Gives off strings that run along fingers and attaches to the bones (show on model) â€“ what are the strings called? = tendons (after more shouts of veins!!). So, to move, muscles contract (tighten up/become shorter), and pull the tendons, which pull the bones.
5. Then let them play around a bit â€“ I usually get them to pick a blue string (but avoid thumb for now), and then a white string, and see the difference between them. Blue string goes all the way to the end bone, so can bend the end joint, whereas white string canâ€™t because it doesnâ€™t attach to the end bone.
6. Get them to bend all the fingers (tests if theyâ€™ve remembered which strings bend the fingers)
7. Then ask how to make the fingers straight again. Most will try to push the blue/white strings â€“ tell them that doesnâ€™t work because muscles can only pull. Get them to look at fingers closely and spot any other strings. Eventually theyâ€™ll realise to pull the yellow/purple string
8. Ask them why yellow/purple strings makes the fingers straight. If they struggle, get them to see the difference between blue/white and yellow+purple = different sides of the hand. Therefore muscles on front of arm (flexors) pull blue/white tendons on that side, which flex the joints, and vice versa with other side with the extensors.
9. So, all around the body, muscles work in pairs to do opposite actions. Point out biceps on you and say it bends the elbow, then ask where the muscle will be to make it straight = on the other side, triceps.
10. Then ask whatâ€™s telling the muscles to contract and pull the tendons = brain. And how = send messages = nerves, and briefly explain concept of nerves sending messages
11. I usually end by saying that to play the piano for example, or type on a keyboard, your fingers have got to move in lots of different ways, so your brain has got to send all those messages in the right order to the right muscles, to pull on the right tendons. So, itâ€™s actually really complicated just to move your fingers.

Thumbs

The pink string pulls the thumb across the palm. You can use this to talk about how thumbs can move in an additional special way so you can pinch things - show them how you can oppose the pads of your thumb and fingers, but not of your fingers. They may have heard of opposable thumbs - some will tell you the word, others will recognise it. You can talk about different animals not having opposable thumbs and thus not being able to use tools etc.

If you've got the short (c. 6 inches) lengths of cord, you can challenge them to tie a simple knot in one. When they triumphantly present you with the resultant knot, get them to do it again without using their thumbs (police this vigilantly, people cheat without even noticing!). Usually this is much much harder. If somehow they do it easily, tell them to undo it without their thumbs. This is more challenging!

General stuff

â€“ Useful to refer to your own or their hand while describing stuff, for example show the extensor tendons on the back of your hand (theyâ€™re a lot easier to see in adults than on themselves). Get them to feel the muscles working on themselves or on you. Do this by getting them to place their whole hand over their arm (both sides!) and then wiggling their fingers! Then they have to believe you!

- This can be a good experiment to do with really quite small kids, but keep it nice and simple with them (i.e. I wouldnâ€™t bother talking about tendons, just say â€˜stringy like things that pull on our bones to make them moveâ€™!)
- This is a great "How-Science-Works" experiment even if you don't know the biology. Ask about how we can find out about how our hands work, we have hands so look how they work. We can feel muscles moving and see tendons. We can get an X-Ray to see the bones, an ultrasound gives us more information on muscles. We can do a dissection too. Then we build a model to test our theory. The paper model is a nice simple model, what can't we do with it? We don't have as much movement, bones aren't as accurate, make the wooden model with more motion.

Additional stuff:

1. Carpal tunnel syndrome:

- Carpal ligament bridges wrist bones, making a small tunnel for nerves and tendons to go through.
- Median nerve goes through â€“ sensation to most of hand (not little finger), and muscle control of some thumb muscles.
- Compression of tunnel walls (due to repeated wrist movements) or swelling (due to injury/arthritis), causes pressure on median nerve
- Symptoms â€“ aches, pins+needles, pain, numbness, loss of fine finger movements e.g. writing.
- Treatment - stretching exercises, anti-inflammatory drugs, surgery (cut carpal ligament = relieve pressure)

2. Difference between ligaments and tendons

- Explain that a joint is where 2 bones come together and they can move. But the bones need something to hold them in place, this is what ligaments do, connect bones to other bones. Tendons connect muscles to bones so they can move the joints.

Risk Assessment

Hazard: Joints

Description: Finger traps.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Do not allow the kids to touch the hand itself when someone is pulling the tendons.

Call a first aider in case of accident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Wooden corners

Description: Splinter risk.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Hand is sanded and shaped to try to reduce this.

Call a first aider in the event of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Model (weight)

Description: Heavy model which moves easily when strings are pulled.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 1, Overall: 4

Mitigation: Do not let the people pulling the tendons get too violent. Hold on to the model to prevent it from sliding along the desk, or place it on the floor if possible.

Ensure kids are behaving sensibly. Inform people to be away from the hand model while someone is pulling the tendons.

Call first aider in case of injury.

After Mitigation: Likelihood: 3, Severity: 1, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-05 - Ashley Smith (ashley.smith@cantab.net), **Check 2**: 2012-01-25 - Daniel Obute (rdo23@cam.ac.uk)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

Check 1: 2014-01-17 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-23 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-06 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2015-01-09 - Kym Neil (kym.e.neil@gmail.com)

Check 1: 2016-01-05 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2016-01-07 - Natalie Cree (nc434@cam.ac.uk)

Check 1: 2017-02-09 - Fiona Coventry (fiona.coventry@cantab.net), **Check 2**: 2017-02-10 - Jessica Gorman (jrg63@cam.ac.uk)

Check 1: 2018-01-27 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2018-01-27 - Matt Worssam (mdw47@cam.ac.uk)

Check 1: 2019-01-24 - Jennifer Simpson (jks61@cam.ac.uk), **Check 2**: 2019-01-25 - Matt Worssam (mdw47@cam.ac.uk)

Check 1: 2020-01-16 - Jean Pichon (jp622@cam.ac.uk), **Check 2**: 2020-01-20 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-07 - Samuel Amey (sra44@cam.ac.uk), **Check 2**: 2021-01-22 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2022-01-26 - Hayoung Choi (hc585@cam.ac.uk), **Check 2**: 2022-02-09 - Sian Boughton (seb216@cam.ac.uk)

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Handy Engineering

Build a small working model hand from card and straws! - Build a model of the inner workings of your hand! Learn about how muscles and tendons work together to control the movements of our fingers, and have a model to take home, made of simple household objects!

Last initially checked on 2023-01-20 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-01-21 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Drinking straws
- Sellotape
- A4 card
- Printout attached below
- String

Experiment Explanation

1. Cut out around the hand.
2. Collect 5 pre-cut straws.
3. Tape down a piece of string over the end of each finger.
4. Thread a pre-cut straw onto each piece of string.
5. Using the sticky tape secure the straw between each of the joints.
6. Cut the straws a little way below the bottom of the fingers.
7. Cut another 5 short segments of straw and tape these by the wrist of your hand model.
8. Thread each piece of string through a separate straw.

You can also demo with a "How science works" theme if you have no clue about "how the hand" works. We study various models of how the hand works of various complexities. The paper model we make is simple but has more flaws than the more complicated Hand Model. You can get them to try and recreate motions on the two models and their actual hand and look for muscles moving.

What does the model show?

The strings running up each of the fingers represent the tendons of muscles that originate in the forearm and insert onto the distal phalanges of each finger.

The main muscle is flexor digitorum profundus that flexes the distal interphalangeal joints (between the phalanges of the fingers) and metacarpophalangeal joints (between proximal phalanx of finger and metacarpal bone of hand).

When the muscle contracts it pulls on the tendons, bending the fingers at each of the joints. Damage to the tendons will compromise flexion of the fingers.

Risk Assessment

Hazard: Scissors

Description: Risk of cuts.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Younger children should be accompanied by an adult. CHaOS volunteers to oversee carefully. Ensure kids are behaving sensibly at all times. Use safety scissors.

Call a first aider in the event of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2014-10-28 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2014-10-29 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2016-01-05 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2016-01-09 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2017-02-11 - Fiona Coventry (fiona.coventry@cantab.net), **Check 2**: 2017-02-12 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2018-01-27 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2018-02-07 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2019-01-25 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2019-02-02 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2020-01-26 - Samuel Amey (sra44@cam.ac.uk), **Check 2**: 2020-01-27 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-21 - Samuel Amey (sra44@cam.ac.uk), **Check 2**: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-09 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2022-02-09 - Jessica Trevelyan (jet81@cam.ac.uk)

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Hearing High Sounds

See who is better at hearing high pitched sounds: kids or adults! - See who is better at hearing high pitched sounds: kids or adults!

Last initially checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **Electricity needed**
- Smart phone or computer
- People of different ages

Experiment Explanation

Download a frequency sound generator app on your phone. It should be able to play sounds at different frequencies. Starting at 1000 Hz, gradually increase the frequency. What is the highest frequency you can hear? What about the lowest? Test the hearing of people of lots of different ages. Record your results.

Risk Assessment

Hazard: High Pitched or Loud Noises

Description: Listening to high pitched or loud noises for long periods of time can cause headaches or auditory damage.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Only listen to each sound for as long as you need to tell if you can hear it or not. Make sure you don't have the volume too loud, especially if using headphones to listen to the noise. If you start to get a headache, stop the experiment.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2021-01-18 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-19 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-01-23 - Jessica Trevelyan (jet81@cam.ac.uk), **Check 2**: 2022-02-09 - Conor Cafolla (ctc43@cam.ac.uk)

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Hexaflexagons

Groups, symmetries and hexaflexagons - Turning a hexaflexagon inside out almost seems like magic. Find out what kind of cool patterns emerge as you do it.

Last initially checked on 2023-02-15 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-16 by Lauren Mason (llm34@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Pre-printed Hexaflexagon templates (preferably prefolded as well) as well as a guide on how to fold them
- Scissors
- Glue
- Pens to colour them and stickers.

Experiment Explanation

Hexaflexagons are a good experiment for young kids up to adults.

For the young kids you can treat it more as a logic puzzle; they need to figure out how to take a hexaflexagon and turn it inside out by only folding it (emphasise that you're only allowed to fold- you can do it by just 'pulling' the inside face through, but this is cheating and really damages the paper hexaflexagons). This (or other guides on the internet) show you how to do it correctly: http://www.puzzles.com/hexaflexagon/img/how_to_flex_a_trihexaflexagon.pdf Once they've mastered that (get them to do it a few times), then ask them if they can do the opposite flex. See, there are 2 types of flexes, the one in the guide (the down flex) and the similar up flex. You do this by getting the other three corners and lifting them up to meet at the top, then opening out the bottom. Try to make sure they don't flip over the hexaflexagon as they do this. One way to encourage them to find the up flex themselves and not flip it over is to start the entire group off with their hexaflexagons with the same colours on the top and bottom as each other. Say green on top, pink on the bottom. Then ask them to, in one move, get pink on top and yellow on the bottom. Once they have up and down, if you still have their attention then you can get them to figure out equations: up up up= back to the start. flip up flip= down (this is a good one). If they're too young for that (or get confused with how many flips they've done- this happens a lot), move them onto the patterns.

A really fun one to get them to solve is, draw a sad face on a hexaflexagon (this has to be done in a particular way but there should be an example in the box). Ask them to figure out how to make it smile. This will illustrate to them that when you do one flex, the face that's still showing from before is now actually inverted. Give them each a blank hexaflexagon and get them to decorate it with this in mind- lines from the centre out and circles in the middle etc look really cool when flexed. There should also be one with pictures on it like a snake and a planet etc. Show them these for them to get some ideas for designing their own.

For more capable people, you can start talking to them about equations and even solving equations. For example, if any equation like (up flip up up) x (down down flip)=flip you can solve this. But to work up to this, get them used to the idea that ax=b means x=a^-1 b not x=ba^-1. Explain it as, order matters. Putting an action on the left means you do it last, where as putting it on the right means do it first.

----------Advanced------------- Obviously, all Vihart's videos on Hexaflexagons are compulsory watching: https://youtu.be/VIVIegSt81k

The group here has 6 elements, and is in fact D_3 (or some people call it D_6). For very advance and capable students, show them that the hexaflexagon group is actually isomorphic to D_3 by using the triangle in the box. Ask them which elements get identified and how many rules they need to show to show that's true.

If you want to talk about more group theory, there are lots of shapes in the platonic solids experiment. Think about symmetries of these shapes. We can discover the whole D family of groups. You could also use a whiteboard to discover the symmetric groups. From here you can talk about subgroups, you should see D_3 and S_3 are the same and D_4 fits 'nicely' inside S_4. In fact Cayley's theorem says every group is naturally a subgroup of a symmetric group.

Risk Assessment

Hazard: Scissors

Description: Risk the children will grab scissors and injure themselves.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Make sure you cut out hexaflexagons before the kids arrive. If you need to have scissors on the table, have the safety scissors. If there are any cuts, call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Glue

Description: Risk that children will take and possibly eat glue.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Put the glue behind you (in the box) after you use it each time. Glue isn't toxic, however, do alert parents immediately of ingestion and call a first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Paper

Description: Paper cuts

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Call a first aider if necessary. Make sure children are sensible and not grabbing paper out of each other's hands etc.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2017-02-06 - Mithuna Yoganathan (my332@cam.ac.uk), **Check 2**: 2017-02-08 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2018-01-02 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-01-18 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2020-01-05 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-01-27 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2021-01-22 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk), **Check 2**: 2022-02-09 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2023-02-15 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-16 - Lauren Mason

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Horse Racing

Probabilities of rolling dice. - Understanding the probabilities behind throwing pairs of dice.

Last initially checked on 2023-02-12 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-14 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Probability

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

-
    - Duplo blocks (horses) and cardboard racetrack
-
    - 2 giant write on/ wipe off dice
-
    - 3 giant normal dice
-
    - Lego blocks and baseplate
-
    - Drywipe pen for writing on dice and lego
-
    - Laminated sheet of paper for use as whiteboard
- (* There are other misc dice in the box which may be useful, including a D12)

Experiment Explanation

Explanation and Demonstrating

The Horse Race

This can be done either with duplo horses on the boards, or if space permitting with the children playing the part of the horses.

(If children are playing the part of the horses make sure they're all taking steps of the same length roughly, chances are they'll all take the biggest steps they can but particularly tall children might have to have their ambitions tempered a little)

Each horse has a number associated with it, in the most basic formulation, with two normal dice, the numbers range from 2 to 12, although with less children it's better to assign them numbers nearer the middle rather than the edges.

Each step, roll both dices, get everyone to shout out what they both add up to and whoever's number is shouted out moves forward one step. Done like this, horse number 7 should win pretty comfortably everytime (although the shorter a track you use, the more likely 6 or 8 or even others might win).

What's the reason for this, simply put a seven is the most likely number to be rolled. The easiest way of explaining this is showing them how many different ways there are to add up two dice to seven (1+6, 2+5...5+2, 6+1). There are 6 ways to add up to seven, 5 to add up to six or eight and so on until only 1 for two or twelve. There are 36 total possibilities (and each is equally likely), so the chance of getting a seven is 1/6. Depending on ages you may find they've seen some of this before in schools so you may move through it quite fast.

People might ask how 6+1 and 1+6 are different. The formulation used above ensures all 36 possibilities are equally likely, which makes all the calculations much easier. One way to look at it is throwing the dice one at a time and showing that the two different possible orders shows that there are twice as many ways to get, for example, 1 and 2, than there are to get 1 and 1. This point is quite subtle and I wouldn't advise going into it unless prompted or if you have a really great explanation!

Now, using the wipe clean dice, try changing up the rules to see what effect it has on who wins. I advise having explained all the different probabilities to them already. Maybe even make a chart of how many different ways there are to add up to each outcome.

There are lots of things you can try here, but here are a few ideas, you may find some work better with different ages:

1. Change Dice Numbers

Subtract one from each side of one dice (or better yet, change the six to a zero!) - Now six and seven should be neck and neck. You can either show them this beforehand, or get them to guess which horse they're going to be and see whose understood it (nothing wrong with letting more than one person be represented by the same number now, but keep them in separate lanes).

Change all sides except three and four of both dice to one - Firstly get them to pick horses, explain why now there are only 6 options (2, 4, 5, 6, 7, and 8), as 7 is still a possibility many will likely go for it, but of course now number two should fly ahead, as there are hugely more ways of making 2, and all others should stay roughly level (two ways to make all other numbers)

Change how many steps some numbers get to take - Why not let all numbers less than 4 and more than 10 take two steps each time they're picked, now the race should be much more even. Ask them to work out how many steps the people with numbers 2, 3 and 4 would need to take each go to be neck and neck with seven (the answers are six, three and two respectively). This introduces the concept of an expectation value, the product of probability and result (here counted in steps forward), and that events with the same expectation value should have roughly the same total result after a lot of tests.

There is also a D12 in the Maths box which can be used, this obviously makes the game totally fair.

2. The two dice

This is a very nice demonstration of why the previous experiment works. Simply ask people to throw two dice, and put a lego brick in the column relating to their result. Quite quickly a pretty uniform distribution should build up, looking like a pyramid (this isn't actually the underlying distribution, just the fact that we've got very few different possibilities flattens the sides of what should look like a bell curve). That said, at times it will look quite irregular and it's a good chance to talk about error, lots of people will think the dice must be weighted to cause irregularities but actually it's simply that there is a natural variation to any test and that only for a large number of tests is this smoothed out (error in mean scales as 1/sqrt(N) and roughly speaking so does all the variations, where N is the number of tests).

Now try it with three dice, this should give a smoother curve, but will take much longer to build up as there are now 15 possible values. You should see something akin to a bell curve with long tails, a rise in the middle with a flat top, and symmetric across the line between 11 and 12.

You can put name labels on both curves but you may want to periodically deconstruct the two dice curve, so you can keep talking about the variation from the expected shape. Definitely put labels on the three dice curve, and encourage people to try multiple times and to come back and see how it's developing.

See here for how it evolves for one, two three or four:
http://www.syque.com/quality_tools/toolbook/Variation/measuring_variation.htm

You could link this to central limit theorem and talk about how heights are distributed roughly normally, as are most other things.

3. How long until you roll a six

Very simple premise but a slightly more complex explanation this one: throw a dice as many times as necessary until you get a 6. What distribution would you expect to see?

What we actually see is that the highest possibility occurs on the first throw (1/6th of total bricks should be here) and then reduces in a smooth curve that in theory goes on to asymptote to 0 at infinity.

Now get them to do the same but now waiting for either a five OR a six. And then again with either four, five or six. (Make sure they do all three tests so that there are about the same number of bricks in each distribution)

You should see that the second has a higher peak then drops quicker and even more so for the third experiment.

These are all geometric distributions (http://en.wikipedia.org/wiki/Geometric_distribution) relating to some probability p (p=1/6 for the first, 1/3 for the second and 1/2 for the third)

If the person you're explaining to seems comfortable with fractions, you can try the full explanation:

Firstly (and this works with all ages), try and get them to work out the probability of throwing the particular value, and show them that this fraction is almost exactly the fraction of bricks in the first column.

Secondly, ask them what the probability is of NOT throwing the required value, explaining that probabilities must add up to one (or do it in percentages adding up to 100%). Obviously this is the fraction NOT in the first column.

Thirdly, (and this is where you may want to stop for younger kids) show them that for every throw that you don't throw a six, the probability compounds by 5/6ths, and on the final throw that you do there is an added fator of 1/6th. Or more fully, the probability of throwing the first six on the nth throw is (5/6)^n-1 * (1/6).

The main thing to get across here is that all probabilities must add up to one, and some idea that the more likely situation should have the tallest peak at n=1 and then drops off much faster.

Write the initials on each brick that someone places on the distribution and watch how it builds up over the event.

Risk Assessment

Hazard: Small parts

Description: Children swallowing dice, Duplo or Lego pieces

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: The Duplo pieces should be sufficiently large to discourage swallowing. Do not use Lego with very small children and keep a close eye on the box of Lego and dice. If child swallows, call first aider and encourage child to cough if choking.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Dice/Duplo blocks/lego pieces

Description: Dice/Duplo blocks/lego pieces could be a trip hazard if dropped on floor.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Keep an eye on where any dice go, and try to confine them to a desk or fixed area. Do not let multiple unattended children use dice at the same time. Quickly pick up any items which have fallen. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2014-02-02 - Zephyr Penoyre (jp576@cam.ac.uk), **Check 2**: 2014-02-08 - Nunu Tao (nmt26@cam.ac.uk)

Check 1: 2015-01-07 - Tim Morgan Boyd (tmb58@cam.ac.uk), **Check 2**: 2015-01-31 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2015-12-18 - Joanna Tumelty (jt574@cam.ac.uk), **Check 2**: 2016-01-02 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2017-01-09 - Joanna Tumelty (jt574@cam.ac.uk), **Check 2**: 2017-01-06 - Mithuna Yoganathan (my332@cam.ac.uk)

Check 1: 2018-01-02 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2020-01-07 - Matthew Le Maitre (msl54@cam.ac.uk), **Check 2**: 2020-01-27 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2020-12-28 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2021-01-22 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk), **Check 2**: 2022-02-09 - Margaret Johncock (mllyj2@cam.ac.uk)

Check 1: 2023-02-12 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-14 - Asmita Niyogi (an637@cam.ac.uk)

Hot Air Balloons

Making hot air balloons with plastic bags and a toaster. - Make your own hot air balloon with a plastic bag and a toaster!

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-12 by Jessica Trevelyan (jet81@cam.ac.uk).

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Electricity needed**
- Bottle with balloon attached to the top (thinner balloons that expand more easily work better, check that there are no holes in the balloon near the neck of bottle).
- Toaster with cardboard shield to fit around it.
- The "balloons": Bin liners (preferably white) - Tesco drawstring swing bin liners fly really level. Otherwise, bits of gaffer tape should be attached to the open end to weight the balloons a little (a roll may be found in the box, else look in the gaffer box).

Experiment Explanation

This is a neat experiment which kids often find quite exciting, particularly in a large room (preferably away from any outside doors on windy days, even small amounts of wind are a pain for this one). You can draw nice links to with the vacuum demonstrations (which can involve similar ideas of the particle theory of gases and show that air is not nothing!)*.

Bottle with balloon

It's nice to start by asking the kids what is in the bottle (lots of kids will say nothing [more rarely they say water if the bottle hasn't been fully dried!], this experiment is a good way of seeing that air isn't nothing!), and what will happen if we heat it up (the balloon expands, some of them will wishfully say it explodes). Depending on how old they are and how much they know you can talk about the following while you do the heating:* Air is a gas (some children will be confused by this as they think it's a mixture of different gases which is not relevant here, but can be something to talk about if they're interested).

- Gases usually expand when they get hot.
- What this means in terms of particles, ie they gain energy, move faster so fill up more space. A reasonable analogy is that of a class of children all walking round past each other needing less space than the equivalent class running (you can extend this to sitting still in rows in assembly [solid] and walking in a line back to class [liquid]).

Heating is best done by running it under a hot tap, then you can cool under the cold tap, but you can use the toaster if you don't have a sink (for obvious reasons don't do a mixture of the two!). If using the toaster, you need to hold it a good distance away (at the top of the shield) to avoid melting the bottle.

Balloons

You could ask the kids to think of something powered by hot air (many get it straight away, some need a remarkable amount of prompting and loads say aeroplane...).

To make a balloon fly:* Put the cardboard shield around the toaster, it's easiest if you turn it on first.

- Put the bag over the shield, pull it all of the way down to the bottom (or, hold on to the top, and hold it about as high as possible - this way the top of the balloon is further from the heat source and less likely to melt and deform).

- Let the air inside heat up and off it goes.

You can get sensible kids to do this themselves.

PLEASE TRY TO SET THE EXPERIMENT UP TO AVOID OVERHEAD STRUCTURES SUCH AS LIGHTING RIGS

Things to talk about include:* What is at the bottom of a hot air balloon? Aside from the basket with people in, there is a burner that heats the air, and gives it more energy.

- Pretend that the bag is air tight (actually not far off being true, very little air escapes out the bottom), thus it only has a finite amount of air in it, which initially weighs the same as all the surrounding air. When heated the gas expands, which can be seen as the balloon puffs up slightly (although the effect is subtle sometimes) and hence there is the same amount of weight spread over more volume, so each "bit" of air i.e. fixed volume element, weighs less than it did before, thus less than the surrounding air and the balloon experiences buoyancy (you could use an analogy about the difference between a sponge and a brick of similar sizes dropped in the bath and say that if you expand the brick it would become more like a sponge).
- Now pretend like air is lost. Where does the air go when it expands? It fills up the bag then escapes out the bottom. This makes the bag lighter, so it floats up to the ceiling. N.b. either explanation works, the first is more thorough but the second may be more intuitive especially for younger children. They are both in part true, though the first is probably dominant. If they all say "it rises", you can explain that we're trying to understand why it rises, or hold the bag down and say that it can't be rising because there's a bag in the way!
- Get them to make a prediction for what will happen - it's usually a balance of the bag will explode or the bag will rise up - you can then test their competing scientific hypotheses!
- Why do we have the bits of tape on the bottom? They are weights helping the bag go up in a straight line, if it gets tipped over sideways a bit then the weight pull it back straight again (hold the bag over your arm and tip it to demonstrate this). Some kids will know that real hot air balloons carry sand bags as ballast, this is more to help them control their height than to stop tipping, the weight of the basket/passengers is enough for this. You can try launching a bag without any weights, you should find that it tips over and falls back down quite quickly, though you need a relatively high ceiling to see this. Even with the weights, the bag often tips over with the opening at the top - here is a good chance to prove that the hot air is what gives it buoyancy (not the bag itself) because the bag quickly deflates (as the air can now rise out of the hole) and sinks back down.
- How can we make it go higher/faster? Heat up the air more at the beginning by holding down the bag. Be a bit careful doing this, you can melt the plastic bag quite easily and it all gets quite hot. Different sizes of bag would be an option as well - some definitely fly better than others!

Further discussion:* What difference does the temperature of the room make?

- Will the balloon stop going up? Would this balloon work in space, why not? What would happen as it approached space? (tip: as it rises density of surrounding air drops until the weight of displaced air = weight of balloon and it stops rising)
- How does this relate to buoyancy in water? Can lead into some great discussions about how fish and submarines change depth (by expanding and contracting their volume, one way or the other)

*(We used to have a vacuum chamber as well as the spheres and bazooka, this allowed you to show that air does have some mass, so the bag does really get lighter when you lose some air, this will surprise most children and their parents. With good groups this is best done after the balloons, though less attentive children may lose interest once they've seen the exciting bit. Vacuums can however be used to start off the theory and lead into the idea of gas particles.)

Risk Assessment

Hazard: Heat

Description: Heat may cause burns from direct contact. Tube or crumbs may catch fire. Bin liners can be melted.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Make the tube out of card, which isn't very conductive and will not melt and stick to people. Use a cool-wall toaster which will therefore not get too hot. The tube should make it very difficult to put fingers in the hot parts of the toaster. The tube is supported so it can't fall over easily. Use a toaster that hasn't been used to toast bread so there are no crumbs. The card is white so will go brown before it burns - if it goes brown turn it off. If there are burning smells turn it off! Do not hold bin liner over toaster for longer than a few seconds or use multiple bags. In case of burns run under tepid water for at least 10 minutes. In case of fire, turn off electricity then follow procedure in venue RA (raise alarm, evacuate...) Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Toaster cable/electrical

Description: Electrical hazard and cables present a trip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Use a new or PAT tested toaster. Ensure cable is either positioned where people will not be walking or taped down. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Bin liner

Description: Risk of suffocation if it lands on a childâ€™s head.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Make sure spectators are not standing too close where the bag could land on their heads, and try to catch before it can land on them. Suspend experiment if the children are getting silly and trying to catch it with their heads. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-01-14 - Aaron Barker (arb78@cam.ac.uk)

Check 1: 2012-12-16 - Rachel Chapman (rc506@cam.ac.uk), **Check 2**: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk)

Check 1: 2014-01-10 - Zephyr Penoyre (jp576@cam.ac.uk), **Check 2**: 2014-01-17 - Ophelia Crawford (oc251@cam.ac.uk)

Check 1: 2015-01-04 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-07 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

Check 1: 2016-12-29 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2017-01-29 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2018-01-01 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2019-01-01 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-01 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-01-05 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-01-05 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2021-01-17 - Sian Boughton (seb216@cam.ac.uk), **Check 2**: 2021-01-19 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-01-22 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-01-28 - Lauren Mason (llm34@cam.ac.uk)

Check 1: 2023-01-12 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-12 - Jessica Trevelyan (jet81@cam.ac.uk)

** How to Busk **

**Recruiting passersby by experiments. ** - Taking experiments out of the venue to convince passersby to turn up.

Last initially checked on 2023-02-17 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Other

Equipment Needed

- **This experiment can take place outdoors**
- Suitable Experiment
- These work well:
- Prism Goggles
- Ear Switching Hat
- Mould Effect (Short Chain)
- Bubble Guns
- Boris
- Skulls

Experiment Explanation

Busking is a CHaOS activity slightly unlike any other, instead of aiming to teach people science you're aiming to street sell them an opportunity to be taught science. You need to think about where you're busking, too far away from the venue and you'll struggle to convince them to go out of their way and also think about why people are walking past. While a railway station will give you a high footfall most people are rushing for trains. Ideal places are markets, libraries and city centre shops (where people might go to browse). If you're near enough to the venue that you can catch people who are leaving, it can be good to take some evaluations forms and encourage them to fill them out as they leave! You want to grab people's attention and tell them something about the science, get them to have a go and touch if possible. You're really aiming to get them to move on to the venue so don't dive into heavy science. Emphasis on that it's free parents may be worried you're trying to sell them things. You can also tell them how it can be only 5 minutes (once they're in the venue they'll hopefully be kept through other means). It's fine to send non-committee out to do this too. If the venue is really empty, setting out experiments that take up lots of space outside can be a good way of drawing people in (provided you have appropriate space, power supplies etc.). Due to the limited amount of science you need to send people out with whatever they're comfortable with. Simple experiments are best, like ear switching hat or prism goggles, but be careful not to obstruct pavements or cause an accident (i.e. with prism goggles) if it's busy. It's helpful to take it in turns to busk, particularly if it's chilly outside! It's also good to busk in a pair - that way you get more people and have some company if it's a bit quiet.

It's worth noting some councils in the UK have restrictions on street trading and similar. As our events are (almost always) free to enter we should not be classed as selling goods or services, if the event is behind a paywall then no busking should be done unless explicit permission has been granted by the local authorities. CHaOS does not seek licences do street trade currently. If asked to move on from an area by a landowner or law enforcement you should oblige. You should aim to restrict busking to public areas, these are ones which one may walk into without payment and consider if it's appropriate to walk on grassed areas. The other legalities which may be broken while busking are 'Obstruction of a Highway' or 'Trespass', to avoid this it's worth ensuring one sticks to major areas, for instance public squares and streets. If busking next to a vehicle road be careful to allow both traffic to flow on the road as well as the passage of people along the footpath, this includes wheelchairs and prams. It's worth noting that highways include verges and footways at the side of public roads. For 'Trespass' the main application would be where busking obstructs a private road or driveway, takes place on private land (say inside a shopping centre) Keeping regularly moving and being cautious of these areas should mitigate any risks of prosecution for these. In any situation complying with demands of land owners, their representatives or law enforcement should be sufficient. Leafleting may cause issues with some councils and should be avoided as it could cause litter and waste anyway.

Risk Assessment

Hazard: Rights of way

Description: Itâ€™s possible that you could accidentally block a thoroughfare when demonstrating or with the experiment you take to busk.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Think about where youâ€™re busking before you start â€“ donâ€™t stand in the middle of a pavement/road. If you do catch some people in the middle of a street/any kind of thoroughfare, try to take them to one side before you begin demonstrating. Take a small experiment (i.e. oven shelf) thatâ€™s self-contained and portable.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Roads

Description: Possibility of being hit by a car if obstructing/crossing a road.

Affected People: Demonstrator

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Donâ€™t demonstrate in a road. Ensure no traffic before crossing a road (Green Cross Code). Ideally, busk indoors or away from roads, unless roads are closed (e.g. Mill Road Winter Fair). In the event of an accident, call 999.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Weather

Description: Weather may change suddenly â€“ i.e. rain, storms etc. and demonstrators can be caught in this.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Check weather forecast before busking or look at the sky. Donâ€™t go too far from the venue (no more than 2 minutesâ€™ walk should be a big enough radius). Take an umbrella/waterproof and dress appropriately â€“ donâ€™t send a demonstrator in shorts to busk in the middle of winter. Take cover until adverse weather conditions pass. Bring plenty of spare tee shirts (for example) to allow busking demonstrators to change in the event of heavy rain.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Experiments

Description: Fatigue from carrying the experiment for too long. Associated risks from the experiment.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Donâ€™t busk with heavy experiments; floating experiments are the most suitable for busking. Donâ€™t go too far from the venue and read and sign the experiment RA before demonstrating.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Police

Description: It may appear that weâ€™re breaching street trading regulations; weâ€™re not because weâ€™re not selling anything.

Affected People: -

Before Mitigation: Likelihood: -, Severity: -, Overall: -

Mitigation: In the event of being approached by an official, explain that CHaOS is not selling anything, but giving free science demonstrations. This shouldnâ€™t be a problem, but if youâ€™re asked to stop then do.

After Mitigation: Likelihood: -, Severity: -, Overall: -

Hazard: Losing a demonstrator!

Description: If demonstrators go too far, they might become lost/wander off and be difficult to contact and find.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Demonstrators and committee should agree where theyâ€™re going to busk beforehand (e.g. in a certain shopping centre, along a particular road). Agree a time to come back to the venue. Buskers to carry phones (possibly even CHaOS mobile) so they can be contacted easily. Ideally, send pairs to busk in the same area and tell them to stick together.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2019-01-21 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-21 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2020-01-15 - Beatrix Huissoon (beh37@cam.ac.uk), **Check 2**: 2020-01-28 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2023-02-17 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-18 - Asmita Niyogi (an637@cam.ac.uk)

** How to Float **

**Keeping demonstrators happy. ** - nan

Last initially checked on 2023-02-17 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Other

Equipment Needed

- **This experiment can take place outdoors**
- **Darkroom needed**
- Bounce
- Admin box
- Floaty Experiment e.g.
- Mould effect
- Prism Goggles
- Ear Switching Hat
- Oven Shelf
- Bubble Guns
- Boris the Skeleton

Experiment Explanation

What you have to do as a floater is very venue specific; this role is almost always done by committee members (however there's no reason a very competent person who's been on tour for weeks couldn't do it). You'll also need to think of how many floaters the venue requires, normally one is sufficient, however venues with multiple rooms and areas may benefit from a second (as may some large school events). There are several distinct aspects to the role and the proportion of time spent on each, and consideration as to whether they're needed at all is a major aspect of the venue. Getting the balance right is part of the skill of the role. They're listed below by task.

Bouncing demonstrators: You need to be responsible for making sure demonstrators are fed and hydrated. This means refilling water bottles and offering snacks of varying kinds. Some people like sugary things, some prefer biscuits, savoury things, some even like fruit, so make sure you vary it up. You'll need to decide how forceful you are at doing this; in more structured events like schools regular breaks and lesson changes makes it easy for people to grab things and there's often free experiments you can feed up while they're waiting for a group. In public events don't be afraid to sometimes interrupt the flow to get them something - if you do, be very forceful as they're likely to instinctively say no. You can also drop items on their table. If facilities permit you can make teas and coffees and deliver them too.

Demonstrating your experiment: Floaters often carry a small experiment which can be used to entertain people for a varying length of time. This is especially important at school events and can be detrimental at public events; busking is often done instead at public events, which is a very different job. At schools, due to the format, you may find a group finishes and has seen all available free options, at which point you are required to demonstrate until something new becomes free. It can be helpful to be signed off on multiple floating experiments so you can show kids something different if you end up entertaining the same group twice. Remember you're not a demonstrator, so you should be able to move them on quickly to an actual demonstrator when one becomes free - a good floaty experiment can be easily cut off but also teach something. Some good ones are Boris, Ear Switching Hat, Sounds From an Oven Shelf and Mould Effect.

Admin and feedback: It's usually the floater's role to check people are happy with experiments and make sure they've signed risk assessments. This will include passing round and checking signatures on the RA signup sheet and moving round the demonstrators while they're setting up to check they're okay. In schools you'll need to give a teacher questionnaire towards the end of the day; ideally they should be completed and returned on the day. There may also be teacher packs to hand over as well as an invoice. In public events you should set up feedback forms from About CHaOS near an exit and point people towards them as they head out. All forms go into a wallet and should be labelled with date and venue and go into the Phil folder in Admin.

Lunch: Outside of schools it's usual we demonstrate through lunch at reduced capacity. This means sending 2-3 people for lunch at a time; start from around 11:30 (you'll probably find a few hungry people) and continue until everyone has eaten, this includes you at some point. Emphasise lunch breaks should be relatively short (20-30 mins). Normally people stick to this, but if there are people around chatting for a long while ask if they're ready to return. You need to eat at some point - you should get someone else to cover floating if you're the only floater. It's handy to keep a list of who you sent and what time they went to make sure you remember everyone - that includes you!

Recruiting and being friendly: If a demonstrator isn't doing anything (and you don't have anything to do), talk to them. Ask them their thoughts on the experiment (writing them on the RA is a good idea) and any other bits. We want them to do more CHaOS events in future so you could tell them about the options and upcoming events.

Promoting CHaOS: Talk to the teachers and members of the public, explain CHaOS and what we do. They may have useful contacts or ideas and it's generally good press. You can also take photos if appropriate, but make sure you get permission from the school (who should have parental permission) or parents (at a public event).

Communicating plans (Summer Tour): There's often complicated logistics or dinner being planned so shoppers need to make an early getaway. As a floater, you may be needed to co-ordinate these as best you can. This may mean passing notes or messages and trying not to confuse anyone.

Closing experiments (when should I demonstrate?): One of the first things a floater should check is if people are happy with experiments, often before demonstrating starts as well as after people have had a few attempts. You may need to advise new demonstrators on a few things: maybe they were very quick and struggled to explain a few ideas, or perhaps they took a long time explaining something too complex. However, if they ask a question you can't answer, be willing to admit you're not the best and direct them to someone who's better placed to advise them if you can. Only give them ideas to tide them over. There'll be times when you have to close an experiment: it may be due to toilet breaks, lunch or experiment malfunction. For a malfunction, if it's busy and you'll need more than a few minutes to fix the experiment properly, it's probably not worth it. Get the demonstrator to look through and pick and sign for a new experiment - in a school this could be one they did recently and signed for, then let them choose properly at a break. Otherwise you should use an "experiment closed" sign and ensure people don't touch it while you're floating. Get the demonstrator to tidy so it looks boring - drop things in boxes and hide things under tables. Ensure anything dangerous is well out of the way (i.e. the knife from Kiwi DNA). Try and make it quick to reassemble though. There might be times you want to float onto the experiment, in which case you a) need to be signed on the RA and b) consider the number of floaters remaining and if it's really necessary to have an extra demonstrator. Try not to get too distracted from your main job of floating if you do this.

The weather: With the outside there's all kinds of unpredictability, these include: Rain: you should pack away experiments and bring demonstrators inside. Remember the slip risk if you want to continue in light rain. Sun: make sure everyone is hydrated; sun stroke and heat exhaustion is a real risk. You'll also want to get people sun cream and remind them to reapply regularly. There's some in safety normally. Snow: like rain but colder, it's probably best to get people and experiments out of there and warm everyone up.

Incidents If you're floating you're likely to be the first point of contact for any incidents that occur, in this situation it's always best to get help from a second person, especially a experienced committee member, close their experiment and decide who's going to lead response. Here are some incidents that can happen.

Lost Children This happens occasionally on public events, if the child is wandering aimlessly and seems lost approach, don't take them anywhere at this point, ask where their adult is, they may just be confused by the amazing choice of science they have and can't decide where to go next! If they're not sure then implement the venues lost child policy, if we're part of a larger event that means getting a friend and taking them over to a central desk normally. If it's a CHaOS ran event then the best course of action is to reassure them, ask if they had a meeting point or time agreed, then get their name and you'll look around for their parents, you can sit them down with a demonstrator at a new experiment while they wait to keep them occupied and try and reduce the worry, their parents often have just popped out and will be back shortly. Look in another room or outside for parents, they may have nipped out to take a call or followed a younger child, ask if they're looking for a child and what their child's name is. If it's a match on names bring the parents towards the child, try and stop them before to give the child chance to approach them to confirm. You can also ask if they know any phone numbers, in the worst case a call to the police will need to be made.

Theft

Injury In the event of a serious injury follow common sense, for demonstrator injuries it may be more appropriate to use a CHaOS driver to transport to A&E, this person can expense reasonable food and miles at A&E so make sure they eat! After resolving the accident consider what this means for the event, especially on levels of committee, closing the event to the public and packing away may be the best option. It may also mean people need to sort alternative transport back to the site, using bus, train or a second run in the mpv, especially as this could take out two drivers. Consider also effects of being unable to move a vehicle, contacting a venue to make arrangements or paying for additional parking. Try and ensure keys don't leave with the casualty. Home contacts should be able to help with other logistics situations on tour as replacement drivers may be required to continue the next days events. After the injury it is useful to have an idea of what caused it and how to prevent it happening again, collect statements and details and reassess experiment RAs. This is often best done by emailing the committee email list.

Risk Assessment

Hazard: Getting in the way!

Description: You might find that you get in the way of people, particularly in crowded spaces. This may result in falls or injuries as a result of the experiment/collisions.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Think about where youâ€™re floating before you start â€“ donâ€™t stand in the middle of a thoroughfare or really close to somebodyâ€™s experiment. If you do find yourself in the way, try to take them to one side before you begin demonstrating. Taking a small experiment (i.e. oven shelf) thatâ€™s self-contained and portable will help you move easily!

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Forgetting lunch

Description: If your lunch is forgotten, youâ€™ll be hungry, irritable and possibly faint!

Affected People: Floater

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure youâ€™re on the lunch list! Get another floater/committee member to swap with you at a given time so you definitely get a lunch break. If you miss lunch, be sure to eat plenty of bounce!

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Hazard: Experiments

Description: Fatigue from carrying the experiment for too long. Associated risks from the experiment.

Affected People: Floater

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Donâ€™t float with heavy experiments; pick something from the Floating box with the fancy tape. Read and sign RA for floaty experiment and mitigate risks accordingly.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Risk Assessment Check History

Check 1: 2019-02-04 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-02-04 - Esmae Jemima Woods (ejw89@cam.ac.uk)

Check 1: 2020-01-15 - Beatrix Huissoon (beh37@cam.ac.uk), **Check 2**: 2020-01-28 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2023-02-17 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-18 - Asmita Niyogi (an637@cam.ac.uk)

Jaw Model and Giant Teeth

Anatomical model of the half jaw, parts can be removed to show structure of the teeth. - An enlarged model of the jaw with some giant teeth that can be opened up. Find out why we have milk teeth, why there are different types of teeth, and why different species have different teeth.

Last initially checked on 2023-02-12 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-02-14 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Anatomical model of the half jaw and three giant teeth

Experiment Explanation

ACTIVITIES:

- Show whole model- what do they think it is? Let them point to their own jaws
- Take the model apart - any ideas what individual bits are?

OTHER THINGS TO TALK ABOUT:

- Losing teeth; getting new ones (especially when the kids are at that age)
- Teeth are different - why do you need different shaped teeth? If we've got the animal skulls out, you could get them to go and have a look at those afterwards and think about why different animals have differently-shaped teeth.
- Toothache - look at nerves coming into teeth - that's how you can feel pain

TIPS FOR DEMONSTRATING:

- Focus your explanation on the age of the audience; if you have 6/7 year olds that are just getting their adult teeth, talk about that; if you have teenagers, you could talk about braces etc.

BASIC PROCEDURE AND EXPLANATION:

- Compare model to skull so they know what they're looking at. How the jaw bone fits onto the skull so we can open and close it to speek, eat etc. Let them feel the joint on themselves by putting their fingers on the sides of their head just in front of ear, moving their jaw around. Explain how it can slide forward so we can open our mouths further.

- Different types of teeth have different functions. Flat ones at the front for cutting things, pointy ones for tearing/ripping, flat big ones at the back for grinding. When do we get new teeth? baby ones, adult ones, wisdom teeth. Look how deep the teeth go into our gums, can see on skull X-ray too.

- See where the blood vessels and nerves go to teeth. Think about what nerves are doing, funny that they go to bones. When do we know about them being there... toothache. Why might we get it? Protection covering teeth damaged by sugar, bacteria, etc.

OTHER THINGS TO TALK ABOUT:

- Numbers and names of teeth: 20 primary teeth (8 incisors, 4 canines, 8 molars); 32 permanent teeth (8 incisors, 4 canines, 8 premolars, 12 molars + 4 wisdom teeth)

- Medical procedures on teeth: fillings, braces, dentures; the idea is to get them thinking about what could go wrong and how they would fix it if they were a dentist

Risk Assessment

Hazard: Tripping over Loose Teeth from Model

Description: Teeth are quite large and could represent a tripping hazard if on the floor

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: If teeth fall on the floor, stop the demonstration and pick up the teeth as soon as is safe. Warn anyone who is walking nearby about the teeth on the floor.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-11 - Elizabeth Mooney (erm40@cam.ac.uk), **Check 2**: 2012-01-23 - Ashley Smith (ashley.smith@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

Check 1: 2014-01-21 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-23 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-23 - Jessica Gorman (jrg63@cam.ac.uk), **Check 2**: 2015-01-31 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2016-01-05 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2016-02-02 - Jiali Gao (jg732@cam.ac.uk)

Check 1: 2017-02-11 - Fiona Coventry (fiona.coventry@cantab.net), **Check 2**: 2017-02-12 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2018-01-27 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2018-02-07 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2019-01-25 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2019-02-05 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2020-01-26 - Samuel Amey (sra44@cam.ac.uk), **Check 2**: 2020-01-27 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2022-01-14 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2022-02-09 - Margaret Johncock (mllyj2@cam.ac.uk)

Check 1: 2023-02-12 - Emily Wolfenden (elw74@cam.ac.uk), **Check 2** 2023-02-14 - Asmita Niyogi (an637@cam.ac.uk)

Kiwi DNA

Breaking open cells of a kiwi fruit and making the DNA inside visible to the human eye - In this experiment we get DNA out of living cells in kiwi fruit. The DNA can be made fully visible to the human eye - no microscopes or magnifying glass needed! Done in less than 5 minutes in front of your eyes.

Last initially checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-11 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **Electricity needed**
- *Consumables*: Kiwi fruit, salt, washing up liquid, 96% ethanol or 99% isopropanol (*caution*)
- *Equipment*: Slow cooker, plastic pint glasses, half rolling pin (for mashing), sieve, plastic champagne flutes, ice bucket, bowl (for liquid waste), cloths (it's generally messy), sharp knife (*caution*), chopping board, spoon/fork/cocktail stick/pipette, model of DNA, posters about DNA and proteins
- *NB. Ethanol/isopropanol need to be kept out of reach of children, as does the sharp knife. If possible, keep the knife and any spare alcohol in the box when demonstrating*

Experiment Explanation

Kiwi DNA repack for the 2011 Summer Roadshow

â€¢ Slow cooker, run on high for 30 mins in setup, then turn down to "warm" heat before visitors arrive. â€¢ Stores box (small blue) has spares of most of the kit in the kiwi DNA box. â€¢ Please use only 1-2 cm3 of ethanol/isopropanol per experiment to conserve our supplies for the whole roadshow. There are some plastic pipettes to help you with this. â€¢ Poking the DNA at the end. As well as the cocktail sticks described in the main explanation weâ€™ve now got some clear plastic cocktail stirrers, which are easier to get into the cocktail glasses when youâ€™re getting the DNA out. â€¢ RNA model: in a plastic Tupperware tub in the main box, and new for 2010. Donâ€™t feel you have to use this, but if you want to talk about DNA being used as a template to make proteins itâ€™s a nice prop, and has the same colour coding. â€¢ Laminated sheets: provide some useful images, and thereâ€™s a wheel to show how DNA code is used to encode amino acids. Please try to dry these if they get damp during the day. â€¢ DNA model in box. Roughly 1.4bn times bigger than real life (if my maths + memory is correct).

Overview

Breaking open the cells of a kiwi fruit to extract the DNA. You can demonstrate it to one family or a whole crowd as a show, discussing cells, DNA and proteins!

Tips for demonstrating:

- It's difficult for the audience to participate in the practical activities, so it's more of an interactive show with lots of questions and answers.
- Do the preparation work before the audience arrives! I work the experiment as a continuous process and maybe use five kiwis in the day.
- Be aware that young children won't know a lot of science. For instance, don't assume they know about cells (most don't), they know about humans being animals and that plants and animals have a lot in common. They might not even have reached the stage where they relate the idea of parts of the body having different structures and functions.

Preparation

You need to have:

- Isopropanol or ethanol on ice (as it works best when cold). If no ice is available, isopropanol seems to work better at room temperature than ethanol.
- Water bath heated to "warm"
- Use masking tape or similar to divide the water bath into pint-glass sized sections so that the glasses don't fall over when you put them in the water bath
- A kiwi or two peeled and cut into 1 cm chunks
- A bottle of lysis buffer - contains washing up liquid, salt and water. As a general guide, in a bottle, put about 1/8 volume salt and dissolve in 3/4 bottle of warm water, then top up with washing up liquid and invert a few times to mix. You don't want it particularly thick, so err on the side of less washing up liquid - you can always add more.

Basic procedure and explanation

The steps of the experiment are below in bold, with an example way of talking through the experiment for younger children. It includes questions and answers (of course if you get the right answer modify your reply). Try and use simple words and up the language as you deal with older kids or adults. You can use this experiment as a basis for talking about scale, with respect to cells and molecules and also as a basis for discussing what DNA does, and how similar our DNA is to kiwis (>50%).

You may want to have some mashed DNA in lysis buffer incubating, and use that rather than the one the group with you has prepared as it takes a while for the cells to lyse. Preparing a couple before you begin demonstrating also means you can check the lysis buffer is ok.

Do you know what this is? It's a kiwi fruit. And what's a kiwi fruit made out of? (you'll probably get seeds, flesh, skin types suggestions)

What are all living things made out of? If I scratch my nail across this what do I have under my finger nail? Cells. *Just as a house is made out of bricks every living thing is made out of cells but they're very small.* There are different cells in the flesh to what there are in the seeds or in the skin and in you their are hundreds of types of cell. Different types of cells in your eyes, blood, brain and skin too.

First what I want you to do for me is mash up some kiwi fruit.

Add a lump of Kiwi to a plastic cup and get them to mash it with the rolling pin (gently!). You can explain that what they're doing is like demolishing a house, all you've got left is a pile of bricks.

Now what I'm going to add is some washing up liquid.

Add lysis buffer to the cup containing the kiwi to a depth of about 1cm and put the cup in the water bath. You can ask: what does washing up liquid do? (You'll probably get "it makes bubbles" at this stage!) What do you use it for? Cleaning plates. Well what does it take off the plates? The grease and fat. It does this by dissolving the fat: this is like what happens when sugar or salt disappears into water. A cell is basically a bag full of water and other important things like DNA, and the bag is made from fat so the washing up liquid dissolves and breaks up the material the bag is made from (the cell membrane). This releases everything that is inside.

What do you know about DNA? Discuss! DNA is like the plans for building us. Just like you need plans for building a hospital. But if you build a hospital it's useless unless you know how to build the doctors, nurses and beds inside them and the doctors and nurses know what to do. So it's not just the plans for building you it's also the instructions for how you should be run. Alternatively, DNA could be like an instruction manual for how to build a person (or kiwi), and there is some inside almost every cell in our body and every cell in the kiwi. What we're going to do is we're going to take the DNA from the kiwi fruit.

Take the kiwi mush/lysis buffer mix out of the water bath. So this liquid here is full of DNA.

Pour the liquid from the cup into a plastic flute through a sieve to remove the lumps. We need to separate the DNA from everything else in the mixture.

Get out the alcohol and pass it around the noses present, taking care to keep control of it. What does that smell like? (kids often recognise it as hand gel) It's not water, it's pure alcohol. I emphasize this as children commonly think anything that is liquid has water in it.

Using a pipette, put about two pipettes-full of isopropanol into the glass by pouring it down the sides of the glass so it doesn't mix too much with the rest of the mixture and forms a layer on the top. Show the glass around. What you can see here are two layers, the green layer is the water with the DNA in and the clear layer is the alcohol layer.**Now do alcohol and water mix? Sure they do. Because if you look at a bottle of whiskey or beer there's only one layer there. So what's happening is the water is moving up into the alcohol layer and the alcohol is moving down into the water layer *wibble your fingers about* and the two are mixing.

The DNA is the stringy white stuff that collects between the two layers. Can you see anything appearing between the two layers? Some stringy white stuff forming? That's the DNA. It takes a while to see this sometimes, so you can either show them a previous group's glass or pick up some of the bottom layer with a pipette and slowly release it through the top layer. It's helpful to have a few really good examples lying around to show "one that we made earlier", to make sure that they see the DNA even if the experiment didn't work for them.

Possible discussion points:

Now what I'm going to do is try and pick up a single molecule of DNA. (showman mode, on the end of a spoon I fish a little bit out.) What's the largest number you can think of? Because what i have here on the end of this spoon is billions molecules of DNA. Just as the Kiwi is made up of the bricks we call cells the cells are made up of molecules.

So how big do you think one of these molecules is? It's about a millionth of a millimetre across. But because DNA is an especially long molecule it's a metre long. Now what I want you to do is use your imagination and I'm going to pick up one molecule of DNA *pretend to pick up a very thin strand and pass it to a child to hold and stretch it out to about a metre*

Now this is a molecule of kiwi DNA and if we use your imagination again I can pick up a molecule of your DNA and that's about a metre long too. Now in your right hand we've got a molecule of kiwi DNA, this is the instructions on how to build and run a kiwi and in your left hand we have your DNA which is the instructions on how to build and run you. Now how similar do you think these two are.

How much is the same? (Sweepstake the entire audience) About 85cm is the same (alternatively 85% the same), that's this much. (Mark out 85 cm and you've got around percentages!)

That's because both you and the kiwi are made up of cells and the cells in the kiwi do the same sort of thing as the cells inside of you. They make more cells, they use sugar and oxygen to make energy and use protein and fat. So who do you think is the most similar person in the worl to you? It's your brother or sister, not your mum or your dad. Which is why you've got to look after you're little brother as they're the most similar person in the world to you. You're all but a tenth of milimeter the same as you're brother or sister and you're all but about millimetre the same as anyone else in this room. You're all but 2 cm different from a chimpanzee. Which is why I think we should look after everything in this world as we're really not very different from anything else.**

Risk Assessment

Hazard: Ethanol/isopropanol

Description: Irritant, flammable, and very toxic if ingested

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Only have a small amount of ethanol/isopropanol out, away from naked flames AND THE PUBLIC. Avoid contact with skin and eyes. Do not ingest. Only allow parents and children to mash kiwi on its own - not once mixed with detergent or ethanol/isopropanol. Ensure eyewash is nearby and that you know the location of it. In case of contact, wash off skin. Use eyewash to wash out of eyes if trained and confident to do so, and call first aider. If ingested call first aider immediately.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Water bath

Description: Hot water can scald.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Maintain the water bath at 60Â°C out of reach of children. Ensure has passed PAT test in last 2 years. Ensure cables are taped to the ground/table to reduce risk of person tripping on/pulling the cables. In case of burns, run tepid water over affected area for at least 10 mins. Call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Glassware and plastic containers

Description: If broken can cause cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Dispose safely of any broken glassware immediately. Keep spares out of reach. Check plastic container and ethanol/isopropanol are compatible. First aider to be summoned in the event of an accident.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Kiwi/detergent solution

Description: Solution is harmful, especially if splashed into the eyes.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Do not allow children to mash the kiwi once it has been mixed with detergent or ethanol/isopropanol. Keep all mixtures within demonstrator's reach. Avoid contact with eyes or the mouth. Try to work on a surface which is not at eye level. Demonstrator can show children how to mash the kiwi without splashing kiwi everywhere. If any does splash out of the container, clean up immediately. Know the location of the nearest eyewash. In case of contact with eyes, use eyewash to wash out of eyes if trained and confident to do so and call first aider. If ingested call first aider immediately.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Sharp knife

Description: Possible cuts/other injuries.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Supervised use only. Keep sharp knives away from children. It's impractical to cut all the kiwi beforehand, but after cutting fresh kiwi, keep the knife in the pencil case provided and keep this in a drawer/out of sight. First aider to be summoned in the event of an accident.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Wet surfaces

Description: Slip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Wipe up any spills. Use wet floor sign if necessary. Keep experiments away from electrics. First aider to be summoned in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Kiwi fruit

Description: Small risk of allergic reaction to kiwi fruit in a small minority of people, and potential consequent anaphylactic shock.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Demonstrator to check that visitors are not allergic to kiwi fruit before commencing the experiment. In case of contact, call first aider. Rinse skin with clean water.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Heating element/stirrer

Description: Risk of heat element and stirrer overheating if not covered by water.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrator to ensure that element is always covered with water and stirrer is always rotating. In case of accident, turn off electricity at mains. Call first aider if necessary. Allow to cool before using again.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Small parts

Description: Small pieces in model may present choking hazard.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Keep model completely assembled and prevent children taking it apart. Keep the black stopper on top of the stand as this prevents the rest being disassembled. If child ingests small part of model, call first aider immediately.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-24 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Kruskal's count

Players follow playing cards around a circle and watch as they magically come together - Players follow playing cards around a circle and watch as they magically come together

Last initially checked on 2023-02-12 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-14 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Probability

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

-
    - One pack of giant cards
-
    - Two normal packs of cards (red and blue backs)
-
    - Various coloured duplo pieces
-
    - Monopoly board print out

Experiment Explanation

By placing cards on the floor in a circle and assigning a number of steps around the circle to each card, it can quickly be seen that people starting on cards all around the circle will converge. The question is why does this happen, and what will make them converge quicker?

You can then predict the future by laying out a whole deck of cards and predicting (with about 90% accuracy) what the last card they'll pick is.

Setup You can either set up with standard or oversized cards. For the large ones spread the cards in a large circle, not every card needs to be used if space is limited, with plenty of space around the cards. For standard cards you can set up on a table, either in a circle or as multiple rows of around 8 cards, you may want to set up with cards in between or curving to make more of a snake shape as well so people know what to do when they reach the end of a row. If you need to skip cards for space you'll probably find leaving out picture cards saves the complication of explaining how to move on them. With the small cards duplo pieces can be used as placeholders. With the large cards, everyone can be their own placeholder, standing on the cards. (Warning, the whole point of this experiment is that everyone ends up on one card, so don't play with so many people that it becomes a scrum)

Explanation and Demonstrating

1st part. The circle Much of the point of this experiment is that you can, with the children's instruction, vary the rules of the game somewhat to examine the effects. However a basic idea of the rules is et out here:

Lay about half the deck on the floor in a circle (can use the whole deck, or even more than one, but the game will take longer and space is an issue), it doesn't really matter which cards go down, although lower cards will lead to a shorter game.

For cards 2-10 players will move that number, aces will move 1 and jack, queen, king 5 places each. If you're not using all the cards you may want to have some of the high numbers move less spaces but try and see what works.

Once everyone's moved, they check their current card, and move again as appropriate.

Repeat, indefinitely. Although at some point everyone will end up on the same card, or at least going round the same sequence of cards ad-infinitum.

You can challenge people to try and work out who needs to move to catch everyone up to each other, or challenge them to see who the first person to land on a particular card is (if you pick one not on the circuit it becomes much more clear that they're confined to a small subset of cards)

Now, why does this happen?

It's not too hard to see that everyone on any particular card will then stick together for the rest of the game, as they are all on the same card being acted on by the same rules.

However, there are more than one 'routes' to most card (not true for all, and abundantly true for some), meaning that it's not just people coming from one particular card that might end up on the next card. Thus the group slowly accrues people as others happen to find their way into it.

This explanation is simple enough, and most children should grasp it. But what we really want to ask them is what happens when they change the rules. Particularly, what can we change to make the game quicker or longer.

What happens when we increase the number of cards? The game gets longer as there are the same number of people spread out over more possible spaces.

What about if we reduce the number of steps, try -1 or even more? On writing this I'm not even sure, have a go yourselves!

Why do we set a low value for all face cards, what happens when we increase it? In the long run this should make the difference between the mean amount of time, and that found in experiment, bigger. I.e. increases the standard deviation, but this is hard for anyone to grasp. What you will instead see is that people flit about the board much faster, and even if it doesn't prove that the system has higher uncertainty, it'll certainly feel like it.

What about if you multiply all the step values by 2? Actually groups should form at the same rate as before, but you should eventually see two, roughly equal sized groups, unable to meet, as of course, if they are an odd number of cards away from each other there's no mechanism by which they'll come together. Once you've done this sometimes it's fun to try with multiplying by 3. People may feel that three groups should form however as 3 doesn't divide 52 you just end up moving further and still bunching up. It might increase the chance of independent cycles though. If they're really keen try 13 afterwards.

2nd part. The ladder

After you've shuffled and layed out the deck, pick one of the first 9 cards and play the game, as before, reading the cards left to right, going down line by line like a book. (If there's space you can even lay them out in a very long line) When you go past the far end, take a note of the last card of the deck you were on (e.g. if you land on a five, with only three cards left, that's your card).

There's now roughly a 85% chance that any card picked on the first row will lead to this particular card. The reason for this is much like the first part, that there are many routes to one card, but only one route off of it. I suggest getting the first volunteer to do it on their own, when you can astound them by guessing where they'll end up, and then letting the rest all go together, and they may begin to notice that they've all grouped together long before the end.

P(success)~1-(1-x^-2)^N x = average card value N=number cards

Again you can experiment with changing the rules and see how well your guesses work. Adding more cards or reducing the step length will increase your likelihood of being right, simply put, the more steps people take, the more likely they are to coincide.

--Real World Applications--

What we're really demonstrating here is a many to one mapping, where there are lots of paths onto one card, but only one path of it. I wouldn't really recommend going into too much detail about this with children, but we can talk about some other interesting examples of many to one mappings.

Buses bunching up are a fun example, there the reason for the bunching (that the first has to pick up lots of passengers, taking a long time allowing the next bus to catch up and as the gap shortens, the number of passengers the next bus has to pick up reduces markedly) is different, but the effect is much the same, showing that once these things come together, the only way to split them apart is ending the game (or in this case the bus line) or artificially holding one back.

This experiment also links to ideas of when things coincide, for example with only even valued cards, it's clear that separate groups that will never meet must form. A really cool example of this in nature is with cicada lifetimes. Predators have a boom, bust style life cycle, where food is plentiful, they over populate, over predate, food becomes scarce, populations dwindle and thanks to low predation the populations of prey increases and the cycle repeats. The cicadas who only emerge after a number of years, don't want to emerge during any of the predator booms, as this would decimate their populations, so in order to avoid this, they have developed prime number life cycles, such that the number of years between periods when they emerge during high predator populations is maximised. As this will happen every lowest common multiple of both the lifecyles, prime numbers maximise this time. You can try and visualise this experimentally by getting people to move around different multiples of the value, those who have common factors should land on the same card more frequently than those whose multiples are coprime. It's important to note that they haven't "chosen" their life cycle, only that the ones with the favourable length cycles have survived best and reproduced to form the largest remaining populations a la natural selection.

There are a few more abstract examples, like water in rivers, that joins together from many different tributaries into one body of water that flows to the sea. You could even talk about the way new technology is invented and sold, different companies often follow the same path (touchscreen on a phone? preposterous!) but lag behind or jump ahead of each other in much the same way that people on the cards lag behind or stay ahead of others.

There are also plenty of examples in computing of many to one mappings, and if you think of any other good ones let us know and we'll add them in to this description!

You could also relate this to other Markov Chains, if random walks is out that's a good example of a slightly different Chain where what you do is not deterministic at each step. You could even do a random walk on this by flipping a coin to decide if you go clockwise or counter-clockwise at each step. Who knows what will happen. You could also talk about this process as being a 'smoothing out' of the randomness of where people start. You can predict very well what card someone might be on after 1000 steps just by picking one in the cycle people get trapped in, no matter where they choose to start. This can then be related to Brownian motion (a continuous time Markov Chain) imagine dropping some food colouring in a fish tank, at the start it's particularly random just a series of droplets, after an hour everything has smoothed out and your fish tank has pale coloured water. If you're feeling brave relate this to Entropy rates and Entropy. An example lots of people like is Monopoly, it's an irreducible markov chain and has an interesting stationary distribution. Essentially as there are lots of ways to go to jail that skewes the distribution to around 9% jail time, then rolling a double to get out skewes further for Trafalgar square at 3%. You can then use this to estimate how many houses you should optimally buy, however it's all probabilistic, you can get people to think how long it takes to realise these expectations, for Monopoly it's quite a while but for Kruskal it's pretty quick. This introduces mixing times.

Risk Assessment

Hazard: Small parts

Description: Children swallowing Duplo pieces, potential choking hazard.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: The Duplo pieces should be sufficiently large to discourage swallowing, but keep an eye out for children putting them in their mouths anyway. Call first aider if child swallows, if choking encourage child to cough.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Limited cards

Description: Many children trying to occupy the same card and people get pushed around.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Keep the number of children playing the game on the giant cards under a sensible limit, I would suggest 8 at a time, and discourage them from running or any form of pushing and shoving. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Cards

Description: Cards are slippery if stood on.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Discourage people from actually stepping on the cards. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 2

Risk Assessment Check History

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Larynx model

Functional model of the larynx - A working model of the larynx which uses a hand pump to force air across two closely-apposed rubber sheets (i.e. vocal cords) to make a sound.

Last initially checked on 2023-02-14 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Model of the larynx
- Laminated endoscopy images of vocal cords and pathologies
- We also have a plastic medical model of the larynx, which can be used in conjunction with the functional model

Experiment Explanation

ACTIVITIES:

- Use the model to generate different pitches/ how do get low/ high tones (ensure the children are gentle with the model - they usually want to hit the pump as hard as possible to make a loud noise, but this will break it and you can't change the tone unless you press the pump gently)
- Use the pictures to illustrate how the larynx works + things that can go wrong with it...
- Get the kids to feel their own thyroid cartilage/hyoid bones (could show Adamâ€™s apple if they are accompanied by an older male sibling/their fathers)

THINGS TO TALK ABOUT:

- What is the larynx? Where is it? What does it do?
- How do we generate high/ low pitch (use model)
- Things that can go wrong (cancer, polyps etc.)

BASIC PROCEDURE AND EXPLANATION:

What is the larynx/ voicebox and where is it?

- Get the kids orientated - let them feel their own thyroid cartilage + use the pictures - so the voicebox is the entry to the airways (could show them the Adamâ€™s apple if they are accompanied by an older male sibling/ their father)
- What is it made off? Well, itâ€™s hard when you feel it, so itâ€™s made out of something similar to bone... Do they know anything besides bone that is hard? Cartilage...
- However, cartilage is not the only thing that makes up your voicebox - also contains muscles, membranes, mucous membranes... (for older kids, use the anatomical pictures to illustrate this, but donâ€™t go into details...)
- So on top of the larynx sits the epiglottis - the epiglottis acts like a â€œlidâ€, closes when you swallow to protect the airways â€“ Why is this important? Ask them what happens when they eat and talk at the same time - you â€œmis-swallowâ€ and have to cough - donâ€™t want food to get into airways; vocal cords can also close to protect the airway
- So is the larynx always closed? No, of course not - it needs to be open so that the air can get into the lungs (that is why you have cartilage - itâ€™s a strong material, it helps to keep the entry to the airways open!)

What are the vocal cords and how do they function?

- Use the model to generate different pitches (The kids should really enjoy this), try to get them to figure out what they have to do to get a higher or lower pitch (i.e. do the vocal cords get longer or shorter for higher pitches?)

- So this is how our vocal cords generate sounds - cartilage is moved by muscles (i.e. you use your hands (â€œmusclesâ€) to move the plastic bits (â€œcartilageâ€) to lengthen/ shorten the yellow balloon bits (â€œvocal cordsâ€))
- What else do you need? Air!!!! This is what the pump is for! Show them that it doesn't work if you donâ€™t use the pump
- So when we breath out, air travels from the lungs through the wind pipe and gets to the vocal cords - they can then vibrate and this generates sound
- Do we need anything else for speech? Talk about pharynx, tongues, mouth, teeth, lips, i.e. they all help to â€œshape soundâ€

OTHER THINGS TO TALK ABOUT:

- Things that can go wrong: use the pictures - can they find anything that looks funny? Talk about cancer, polyps. What causes them? Cigarette smoke!!! (Your larynx is pretty much the first thing that is exposed to cigarette smoke...)

Another approach:
I was running this model alongside the lung model, so after asking them why you need to breathe (it appears that quite a lot of the general public believe we can extract carbon dioxide from the atmosphere......) I then asked them to try to talk without breathing out, and used that to introduce the idea that breathing out enables us to talk. I got them to put their hands on their throats and hum, then asked if they could feel anything, and explained that the buzzing was their 'voice box' and vocal cords. I then showed them the model, using the lung model to orient it, and explained that in place of bits of balloon we have flaps of 'skin'/membrane in our throats, and that when we speak we force air up between them. I then let the kids play around making noises with the model, getting them to work out how to change the pitch/volume etc. Finally I tried to relate this to how we make sounds by asking them to talk to me without moving their lips or their tongue - the sounds they made were very similar to the 'honking' of the model, so I could explain that the actual sound and how high or low it is is produced by the 'voice box' , but to form words we use our mouth/teeth/tongue/lips/etc. The sound of the model is also quite similar to babies crying, which again is noise made without fine control of the mouth etc.

Risk Assessment

Hazard: Small parts

Description: Risk of swallowing or choking

Affected People: Children

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Close experiment immediately if small pieces become detached (it won't work then anyway). Do not let children play with experiments unattended. Advise parents to take child to A+E if an item is swallowed. Call a first aider in the event of choking and perform the Heimlich manouvre if confident to do so.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Broken parts

Description: Broken parts could be sharp â€“ risk of cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: If model breaks, close experiment immediately and remove broken models. Call a first aider in the event of accident.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Moving parts

Description: The functional larynx model has moving parts - narrower end of the air pump is a finger pinch hazard.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 1, Overall: 4

Mitigation: Reduce the finger-pinch hazard by ensuring the pump is placed on a flat surface (table/floor) and only allowing children to press the pump gently with the hands. Ensure fingers are free from the narrow end of the pump and do not let children hold the pump with both hands.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Risk Assessment Check History

Check 1: 2012-01-11 - Elizabeth Mooney (erm40@cam.ac.uk), **Check 2**: 2012-01-23 - Ashley Smith (ashley.smith@cantab.net)

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Check 1: 2015-01-10 - Alisha Burman (arb95@cam.ac.uk), **Check 2**: 2015-01-23 - Jessica Gorman (jrg63@cam.ac.uk)

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Check 1: 2019-01-25 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2019-02-03 - Esmae Jemima Woods (ejw89@cam.ac.uk)

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Leaning Tower of Lire

Balancing blocks on the edge - Explore this famous block stacking problem and see how far you can build off the edge of a table.

Last initially checked on 2023-02-09 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-02-11 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Table/ small ledge (Turn over one of the cantilever bases)
- Blocks (from Cantilever Bridge)

Experiment Explanation

This is a great follow on to Cantilever bridges, if they've seen that experiment this expands on one of the initial things many people try. Your challenge is given N identical blocks place them in a stack (one on top of each other) and try and maximise the overhang over a table edge. If they've seen Cantilever they may try the cantilever solution, however the twist here is you're only allowed one brick per layer (this means the tower must be N bricks tall).

We'll now talk through some physics that we'll need to figure out how well we can do.

Centre of Mass - We can view gravity as acting through one point of the block, we call this the CoM, if the block is uniform it'll be in the centre, sort of where you'd expect.

Try placing the block on the edge of the table and moving it's CoM around, where can it balance? You'll find that you can get out until the CoM is right on the edge but no further. This means for N=1 we've solved the problem! The answer is 1/2 (times the length of the block).

Moments - A Moment is a turning force, this is what we get when the block is on the table. For a moment, we need a pivot. With one block our only pivot is the point on the edge of the table, friction holds the block enough so that what we experience here is just a turning force (initially you'll notice a slip later once it's started falling, see the falling toast experiment for more on this though). The forces are the gravitation acting through the CoM and a reaction force from the table supporting the brick.

Levers - levers increase the force with distance. With moments we need to consider a levered force by multiplying the force by distance from the pivot. If the forces clockwise and counterclockwise (ccw) balance then there's no tip. If we have an unbalanced force twisting us into the table then it won't tip but we could extend further!

So going for N=2 case now. We can keep extending like before but we need to decide which order is going to give us the best overhang. As we need to consider the CoM it would be better if there was the least total overhang, this means that the overhang between blocks on one layer and the one above should increase as we get higher up.

Obviously don't tell them this let them try it. If they place something on top of the N=1 solution it'll pivot (unless it's not more overhanging). They'll actually need to place something underneath it. The maximum turns out to be 1/2 + 1/4 = 3/4.

Ask them how far out they think they can reach? Can they get arbitarily far if they can make N large?

It turns out you can, the optimum is $\frac{1}{2}* \sum_{i=1}^{N} \frac{1}{i}$. This is half the harmonic series so it does in fact diverge, which you can show as 2^n terms in a row are all greater than $(\frac{1}{2})^n$ so sum to 1. However it doesn't diverge quickly! To span a gap of 1,2,3,4,5,6,... you need N=4, 31, 227, 1674, 12367, 91380, ...

Asymptotically this is roughly log(N)

You can allow multiple blocks per level if you like, this copies cantilever bridges and the solution is the same.

Counterbalancing gives the optimum and it scales like $N^{1/3}$.

Risk Assessment

Hazard: Tower of Blocks

Description: A very tall tower may mean bricks have enough energy to bruise when the tower falls down.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrator to monitor building, anticipate collapse, and get children to stand back. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Board/Blocks on floor

Description: There is a trip hazard from the board or blocks placed on the floor.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Don't put the experiment in an area which is likely to be used as a thoroughfare. Call first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Gaps between boards

Description: Children may pinch their fingers in between the boards on the floor.

Affected People: Demonstratees

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrator to ask children to not place their fingers where they can be pinched between the boards. Tape gaps between boards and boards and floor. Call first aider in the event of an accident.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Blocks

Description: Possible splinters from the wooden blocks.

Affected People: Demonstrator / Demonstratees

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrator to make sure only wooden blocks with no splinters coming out are used. Report any blocks that arenâ€™t smooth/sand them smooth. Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2019-01-09 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2019-12-29 - KÃ¤the-Marie White (kmw54@cam.ac.uk), **Check 2**: 2020-01-24 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-02-01 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2022-02-06 - Lauren Mason (llm34@cam.ac.uk)

Check 2: 2023-02-09 - John Leung (cfl35@cam.ac.uk), **Check 2**: 2023-02-11 - Asmita Niyogi (an637@cam.ac.uk)

Lenz's Law

What happens when we drop a magnet through a pipe? - What happens when we drop a magnet through a pipe? Experiment with dropping them through perspex and metal pipes and see if there's any differences.

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Busking

Floating

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- Perspex Pipe
- Copper Pipe
- (We don't have but an aluminium pipe would also be useful)
- Some small magnets
- Green Iron Filling Paper

Experiment Explanation

Lives in Electromagnetism Box. Commonly done alongside Electromagnetism and Lenz's Law.

Get a volunteer to hold the pipe and challenge them to put the magnet in it and catch it as it comes out. If you've got a group ask them if they'd like the copper or perspex pipe, the copper pipe is the much better choice as it means you'll have more time.

This is because the moving magnet is inducing an electrical current in the metal. There are two ways to explain why this causes it to slow down:

Easier - Some energy is needed to make the electrical current (like turning the handle before). This time the energy comes from the falling magnet, and when it loses kinetic energy it slows down.

Harder - Eddy currents of electricity are formed, and these create an electromagnetic effect opposing the motion of the magnet, hence it slows down.

There is also green 'iron filing' paper, which shows up the movement of a magnet through it. You can use this to 'see' the movement of the magnet inside the copper pipe.

People may say it's to do with the metal being magnetic, but it's really not. Copper is not magnetic, try sticking the magnet to the outside of the tube and it won't.

Risk Assessment

Hazard: Magnets

Description: Magnets shattering, possibly causing cuts/splinters.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Warn visitors if you give them a magnet. Use the minimum number of free magnets. Keep the magnets under control. Cover with tape to reduce impact, and contain any shards. Pad edges of magnet to reduce finger trap.

Call first aider in case of injury

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Magnets

Description: Magnets that are not caught may be a trip hazard or encourage children to dive after them

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Recover magnets quickly but sensibly.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Pipes

Description: Any pipe hitting people in face/eye.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Demonstrator should hold pipe for younger kids and monitor use for others.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-12-12 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-01-30 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2020-01-30 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2020-12-31 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2021-01-03 - Holly Smith (hs606@cam.ac.uk)

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Life Cycles

Perpex blocks with specimens of frogs and bees from different lifecycle stages. - Ever wondered what happened to a creature between it being an egg and an adult? Look at our life cycles collection for Bees and Frogs and see for yourself!

Last initially checked on 2023-02-05 by Chiara Delpiano Cordeiro and double-checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk).

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Sets of preserved life cycles of frogs and bees.
-
- Honeybee - egg, larvae, and pupa; worker bee, drone, and queen bee; pollen, honey, and royal jelly; foundation honeycomb, drone cells, and queen cell; worker bees collecting nectar
-
- Frog - eggs, tadpole, various stages from tadpole to frog, adult, magnifying glass
-
- Beeswax candle set

Experiment Explanation

*** OVERVIEW/THINGS YOU MIGHT LIKE TO TALK ABOUT ***

- The life cycles of frogs and bees. Can use butterfly life cycles as an introduction for younger kids as they should know about this.
- Social structure of bee colonies and communication amongst bees.
- Using stages of insect development to "date" a decomposing corpse.

*** BASIC PROCEDURE AND EXPLANATION ***

1. Let them pick which life cycle they want to look at first. Ask if they know what animal it is.

2. Tell them the blocks show the lifecyle of the animal. Explain the concept of lifecycles i.e. that animals change throughout their lives and then the adult can reproduce to start the cycle again.

3. Ask the child to put the blocks in the correct order. Talk them through it when they're done. The blocks were numbered so stickers have been put over these to stop the kids using this. The frog order goes red, yellow, blue, orange, blue, yellow, green. The bee box should have a sheet explaining what is in each block.

4. Start by describing the egg. This is one cell (a tiny ball of nutrient and information (DNA)) which divides lots and lots of times to produce larvae.

5. Next discuss the larvae/tadpole. Emphasize how the larvae spends all its time eating and eating and eating so it can grow really fast and store energy for metamorphosis!

6. Explain the pupae stage for the bee - at this point the larvae undergoes metamorphosis and becomes an adult! What is metamorphosis? It refers to something changing from one form to another completely new form. Isn't it amazing that the larval form can change into the adult form in just about two weeks?!

7. After you've finished explaining the life cycle of the animal, you might ask the child if humans go through metamorphosis. Explain that while humans don't go through metamorphosis, we do change a lot in our mummy's tummy! We also go from an egg (one tiny cell smaller than the full stop at the end of this sentence) which divides lots of times to create a baby!

*** EXTRA INFO ***

BEES

Larvae -> Pupae -> Worker/Queen

1. Social Structure of Bees (http://www.indianchild.com/honey_bee.htm)

- Each bee colony has a very organized social structure.
- Bees tell each other where food is through different dances - call these waggle dances Males/drones:
- Develop from unfertilized eggs (parthenogenesis) - means females can produce as many males as they want to (as don't have to mate with male first)
- Mate with queen to produce new bees Worker bees;
- Develops from fertilized eggs
- jobs like clean/ incubate eggs/feed drones and larvae/guard hive/find food Female bee: Queen
- Develops from fertilized eggs
- lays eggs, mother to all bees in the colony. ~2000 eggs/day
- Produces pheromones which controls the behavior of her workers
- Fed lots of food! Fed royal jelly from larvae rather than normal honey which has epigenetic factors which cause it to develop into a Queen rather than a worker.

2. Communication Among Bees (http://www.indianchild.com/honey_bee.htm)

- Bees communicate by pheromones (chemicals produced by the queen that the other bees "smell") and dances.
- This communication is very important to maintain the organization/social structure within the colony so that all of the bees can survive (the queen, workers, and drones cannot live alone - they depend on each member of the colony).
- Dancing - round dance, go in a circle and waggle in the direction of food is in (long distance). Waggle dance, food is nearby direction of run indicates direction and length of waggle shows how far.
- Stingers - die after they've stung as pulls organs with it. (different in wasps)

Honey. Why do they make it? What from? Uses nectar to feed larvae. Honeycomb, useful to farmers as pollinators.

FROGS

1. Egg -> Frogspawn -> Tadpoles -> Frogs

2. Frogspawn is like jelly, provides a food source for the growing embryo (the black spot)

3. Tadpoles - sometimes eat each other (cannibalism). They start with no legs, then develop hind legs, then front. Then become froglets.

4. Tree frogs; where do they lay their eggs? - in the water collected at the bases of leaves. Are often brightly coloured and very poisonous (used to make poison arrows). The Golden Tree Frog is toxic enough to kill 20 people or two elephants, chickens and dogs have died from touching paper that has been touched by a frog! Poison stops nerve impulses leading to muscle contraction.

Amphibian, need to stay damp as they breathe through their skin. They're vertebrates and have a backbone.

BUTTERFLIES Ova -> Larvae -> Pupae -> Adult

1. Patterns/colouration - eye spots deflect attack from the butterfly's body, camouflage is another way of increasing the likelihood of survival allowing it to rest undetected

2. Forensic Entomology: (http://www.forensicentomology.com/appear.htm)

- Forensic Entomology examines the stages of development of insects in a decaying corpse to determine when the body died!
- For example, many insects will lay eggs on a corpse. These eggs will hatch and become larvae, which feed on the decaying corpse. By examining the size/weight of the larvae, these scientists can determine how old the corpse is!

Caterpillars can be poisonous and brightly coloured to warn predators. Some butterflies only live a couple of weeks. Monarch butterflies migrate from Canada to Mexico (3000 miles) using landscape (mountains/sun) to navigate. Some moths use earth's magnetic field. Some eat plants like milkweed which make them poisonous to other animals.

*** SCIENCE BACKGROUND FOR DEMONSTRATORS ***

More information on Forensic Entomology (http://www.forensicentomology.com/appear.htm) "What information can a forensic entomologist provide at the death scene?"

Forensic entomologists are most commonly called upon to determine the postmortem interval or "time since death" in homicide investigations. The forensic entomologist can use a number of different techniques including species succession, larval weight, larval length, and a more technical method known as the accumulated degree hour technique which can be very precise if the necessary data is available. A qualified forensic entomologist can also make inferences as to possible postmortem movement of a corpse. Some flies prefer specific habitats such as a distinct preference for laying their eggs in an outdoor or indoor environment. Flies can also exhibit preferences for carcasses in shade or sunlit conditions of the outdoor environment. Therefore, a corpse that is recovered indoors with the eggs or larvae of flies that typically inhabit sunny outdoor locations would indicate that someone returned to the scene of the crime to move and attempt to conceal the body.

Similarly, freezing or wrapping of the body may be indicated by an altered species succession of insects on the body. Anything that may have prevented the insects from laying eggs in their normal time frame will alter both the sequence of species and their typical colonization time. This alteration of the normal insect succession and fauna should be noticeable to the forensic entomologists if they are familiar with what would normally be recovered from a body in a particular environmental habitat or geographical location. The complete absence of insects would suggest clues as to the sequence of postmortem events as the body was probably either frozen, sealed in a tightly closed container, or buried very deeply.

Entomological evidence can also help determine the circumstances of abuse and rape. Victims that are incapacitated (bound, drugged, or otherwise helpless) often have associated fecal and urine soaked clothes or bed dressings. Such material will attract certain species of flies that otherwise would not be recovered. Their presence can yield many clues to both antemortem and postmortem circumstances of the crime. Currently, it is now possible to use DNA technology not only to help determine insect species, but to recover and identify the blood meals taken by blood feeding insects. The DNA of human blood can be recovered from the digestive tract of an insect that has fed on an individual. The presence of their DNA within the insect can place suspects at a known location within a definable period of time and recovery of the victims' blood can also create a link between perpetrator and suspect.

The insects recovered from decomposing human remains can be a valuable tool for toxicological analysis. The voracious appetite of the insects on corpses can quickly strip the remains down to the bones. In a short period of time the fluids (blood and urine) and soft tissues needed for toxicological analysis disappear. However, it is possible to recover the insect larvae and run standard toxicological analyses on them as you would human tissue. Toxicological analysis can be successful on insect larvae because their tissues assimilate drugs and toxins that accumulated in human tissue prior to death."

Risk Assessment

Hazard: Breaking the blocks/jar/magnifying glass

Description: Smashing a specimen block/jar or magnifying glass could cause cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: It is very unlikely that the perspex blocks would break, even with a significant amount of force. However, demonstrators should keep a careful eye on the blocks and jars and magnifying glass, account for all specimen tubes every time a demonstration is completed. Call first aider in case of injury (cut). Clear up perspex (using the dustpan and brush from Set Up and Clear Up), wrapping up in paper or similar so that it won't rip through the bin bag. Place in broken glass box if available at a school. In case of injury, call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Tripping over blocks

Description: Blocks are quite small and their transparency means that it might be difficult to see them, creating a potential tripping hazard.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Demonstrators should make sure that blocks are not played with by young children without supervision. If a block is dropped, it should be picked back up as soon as the area is safe to do so. In case of a child (or adult) tripping over, call first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Perspex blocks

Description: Kids may throw them or drop them on feet

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Take away from kids if they are being silly with them.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Magnifying Glass

Description: Kids (or demonstrators!) may set fire to paper or dry grass if very sunny day.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Take away from kids (and scold demonstrators) if they are deliberately trying to set fire to things

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2013-12-25 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2014-02-02 - Raghd Rostom (rr415@cam.ac.uk)

Check 1: 2015-01-05 - Arporn Wangwiwatsin (Koi) (aw584@cantab.net), **Check 2**: 2015-01-23 - Zephyr Penoyre (jp576@cam.ac.uk)

Check 1: 2016-01-07 - Natalie Cree (nc434@cam.ac.uk), **Check 2**: 2016-01-24 - Fiona Coventry (fiona.coventry@cantab.net)

Check 1: 2017-01-13 - Alfred Chia (ac939@cam.ac.uk), **Check 2**: 2017-02-09 - Matt Worssam (mdw47@cam.ac.uk)

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Check 1: 2019-01-13 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2019-01-13 - Grace Exley (gae23@cam.ac.uk)

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Check 1: 2023-02-05 - Chiara Delpiano Cordeiro (cd796@cam.ac.uk), **Check 2**: 2023-02-06 - Margaret Johncock (mllyj2@cam.ac.uk)

Locusts and Glowsticks

Using glow sticks to talk about chemical kinetics. - What do glowsticks and locusts have in common? Watch what happens as we heat them up and cool them down - how long can you get your glowstick to glow? How fast can you make the locusts move?

Last initially checked on 2022-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-07 by 2023-02-07 - Joshua Wu (jw2311@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Chemistry

Equipment Needed

- **Darkroom needed**
- **Electricity needed**
- Lamp (heat only if possible)
- 2 tanks of locusts
- Glow sticks
- Knife/ scissors to open glowstick packet
- Ice cubes for cooling
- Washing up bowl

Experiment Explanation

Use cooling glow sticks in ice to stop the light-emitting reaction to show that reactions happen faster when they're warm.

Locusts (cold blooded) in warm and cool environments can be used to point out that this is true of the reactions of life too, but this is not essential.

Possible activities:

- Demonstrating how cooling slows down reactions using glowsticks and ice.
- Demonstrating how cooling slows down reactions using locusts and ice.

Other things to talk about:

- Other reactions which are affected by heat which we see in our everyday lives.

Tips for demonstrating:

- It is quite useful to be aware for this experiment how much difference the "Really Cool Show"/liquid nitrogen demonstration makes to how quickly children pick up the ideas you feed them, especially about temperature/ reactions and the fact that solid carbon dioxide takes up much less space than the gas.

BASIC PROCEDURE AND EXPLANATION

- Place tanks of locusts side by side, shine the lamp on the outer face of one of the tanks.

- Break and cool a couple of glowsticks in icy water as "ones I prepared earlier".

- Start with glowsticks- get a glowstick out. Remove end-cap and ribbon as they cause confusion (children think they're important).

- Have the children seen glowsticks before? When? Fireworks night? Parties?. If not, it may be best to snap the glowstick first and see what it does.

- Do they know how glowsticks work? The usual answer, if any, is "You bend them".Explain that what happens when you bend them is that the inner glass tube breaks and the two chemicals mix. (With the yellow glowsticks you can see the glass tube before breaking it

- Get one of the children to snap the glowstick and give it a shake now that it's glowing.

- How can we stop it? Suggestions usually include "bend it again", "unmix it", "open the tube". Deal with these ideas first - unmixing could be compared to mixing red and green paint to make brown then trying to unmix. Quite often a parent will prompt the child to say "put it in the freezer" in which case the next bit is explaining why, not drawing out what!

- A possible route to how to stop a reaction is through how we stop food from going off... work children round to "put it in the fridge".

- Explain that everything is made up of little bits moving around and banging into each other, and if things are hotter the little bits move faster and bang into each other harder.

- Describe reactions as bits banging into each other and knocking bits off/ getting new bits stuck on, possibly pointing out that you hurt yourself more if you fall off your bike/ fall over when running than if you trip up when walking.

- Get the icy water out and explain that it is colder than room temperature, more like your fridge at home. Put the glowsticks in the water and put it away again.

- Move on to locusts and ask the children to look at the locusts, and to decide which set are moving about more. In general they're pretty obliging and it will in fact be the "warm tank" locusts which move about more.

- Explain to children that the locusts, like them, get their energy to move about from reactions of their food. Tell them that their (the children's) bodies have lots of systems to make sure they stay at the same temperature... they are warm-blooded (many will have heard the term before).

- Explain that locusts haven't got these systems (they are cold-blooded) so they can only get energy out of their food to move about if they're warm enough. Point out that this is like the glowsticks, which only give off light if they're warm enough.

- This all tends to be very counter intuitive to the less scientific parent, some have trouble with the idea that locusts don't just want to lie down if it's hot, like they do themselves!

- Get the icy water out again and show that the glowsticks are glowing much less. They probably won't have gone out yet (unless the group were particularly fascinated by the locusts!).

- How can we start the glowstick glowing again/much brighter?. Warm up the glowstick by removing it from the water (carefully, it will be very cold!) and holding it.

- Explain that now the particles can bang into each other again as they have enough energy (are moving around fast enough).

- If children are still engaged, can talk about the magnetic molecular models.

- Give the glowstick to one of the children. Repeat 'til fade.

OTHER THINGS TO TALK ABOUT

- Other reactions which are affected by heat which we see in our everyday lives.

- The differences between hot-blooded and cold-blooded animals.

NOTE: DRY ICE At one point this experiment was done using dry ice. If doing so in the future this needs to be separately risk assessed - currently we have no source of dry ice.

- If using dry ice: be aware that a box of dry ice with a glowstick inside it will have a fascinating (at least to a small child) glow. It is very important to retain control of the experiment (I often achieve this by sitting on the lid of the polystyrene dry ice box) whilst giving your demonstration since if a small sibling loses interest in your talk (s)he may try to conduct an experiment of her/his own!
- If using dry ice, can talk about dry ice and what it is, maybe put a couple of pieces in a bowl of water and watch them bubble, talk about the gas expanding and taking up more space. If Dry ice is used for packing away purposes, it can be left in well ventilated area to boil.

Risk Assessment

Hazard: Glow stick contents

Description: Glow stick contents are non-toxic, but contents are potentially damaging to eyes. Glass ampoule inside the glowstick is broken to activate stick, but small chance of contents leaking.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Take care not to break outer skin of glowstick. Demonstrator must know the location of the nearest eyewash. If giving glowsticks to children to take away, warn the parents/guardians that contents should not be allowed to come into contact with eyes and that glowsticks should not be put in the mouth or chewed. Ideally do not give glowsticks to children below the age of about eight years. If glowstick contents come in contact with skin, rinse immediately. If they get into an eye, demonstrator must call a first aider and may perform an eye wash if trained and confident to do so.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Salt and ice mix

Description: Salt ice mix is cold. Contact with it can hurt and prolonged contact could cause skin damage.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not allow anyone else to touch the ice water. If cold solution is spilt onto anyone rinse off with copious cold (but not freezing cold) water. Call a first aider in the case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Salt mix

Description: Salt solution is strongly ionic and therefore electrically conducting. Risk of electric shock in contact with lamp.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Ensure that all electrical appliances and plugs are above ground level and safe from spills of salt solution. Do not allow children to put their hands in the cold solution. Do not allow anyone else to touch the lamp, dry hands if you need to touch it. Call first aider in the case of an injury/shock. Turn off electric power at mains. Read attached electrical RA.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Salt solution

Description: High ionic strength solution will hurt on contact with eyes.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Advise children not to touch their eyes, if they have touched the wet glow sticks, as the salt will sting. If an accident occurs, call a first aider, who will consider giving an eyewash.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Lamp

Description: The lamp warming the locusts can get hot - risk of burns.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Warn children not to touch lamp. Do not leave lamp on for unnecessarily long periods of time. Call a first aider in case of injury. Bathe affected area under tepid water for at least 10 minutes if you suspect a burn.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Rare earth magnets

Description: Reaction model contains rare earth magnets which are very strong - risk of them slamming together and smashing, or trapping skin.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrator to check at beginning of experiment that the magnets are firmly in place in the wooden "molecules". Do not use if magnets are not firmly in place. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Locusts

Description: Repeated exposure to locusts could cause the demonstrator or the public to either have an asthma attack (if they already have asthma) or for them to develop an allergy to locusts.

Affected People: All

Before Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Mitigation: Demonstrator should be aware of any breathing changes, rash, runny nose that occurs to them when they are near the locusts, and should not perform experiment if they get these symptoms. Demonstrator should also be aware of the possibility that others may be allergic/get an asthma attack. Do not demonstrate if you find yourself to be allergic to locusts. Call a first aider in the event of an asthma attack. Calm person down, sit them down. Get person to use inhaler if they have one.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Locusts

Description: Repeated exposure to locusts could cause the demonstrator or the public to either have an asthma attack (if they already have asthma) or for them to develop an allergy to locusts.

Affected People: All

Before Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Mitigation: Demonstrator should keep tanks away from table edges and should watch lively children so they don't knock the tanks over.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2011-12-22 - Hannah Ford (hf257@cam.ac.uk), **Check 2**: 2012-01-20 - Catherine Collett (chc47@cam.ac.uk)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-16 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2014-01-23 - Peter Maynes (peter.maynes@cantab.net), **Check 2**: 2014-01-25 - Nunu Tao (nmt26@cam.ac.uk)

Check 1: 2014-12-27 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-07 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2015-12-28 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2016-01-09 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2017-01-25 - James Nicholas (james.nicholas@cantab.net), **Check 2**: 2017-02-09 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2018-01-17 - Georgia Harris (grh37@cam.ac.uk), **Check 2**: 2018-02-04 - Giedre Sirvinskaite (gs508@cam.ac.uk)

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Check 1: 2020-01-15 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-01-15 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2021-01-02 - Lucy Hart (ljfh2@cam.ac.uk), **Check 2**: 2021-01-03 - Esmae Jemima Woods (ejw89@cam.ac.uk)

Check 1: 2022-01-29 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2022-01-31 - Jessica Trevelyan (jet81@cam.ac.uk)

Check 1: 2023-02-06 - Margaret Johncock (mllyj2@cam.ac.uk), **Check 2**: 2023-02-07 - Joshua Wu (jw2311@cam.ac.uk)

Measuring the Speed of Light in Butter

Measure the speed of light - Measure the speed of light using butter and a microwave!

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Light

Waves

Active (Experiment has working equipment at the time of last update, and is available for events.)

Demo only (Demonstration type experiments and lectures, not suitable for assignment for standard events.)

Physics

Equipment Needed

- **Electricity needed**
- Microwave
- Cardboard
- Butter/Margarine/Cheap Spread (alt. chocolate, anything melty, wax could work and be reusable?)
- Ruler

Experiment Explanation

Explain how light is a wave and that microwaves are just some wavelength of this. A microwave has a generator, the nodes and antinodes have different energy levels, the rotation means food gets heated evenly. (Antinodes max heat, nodes have no heating bar diffusion) Remove the turntable from the microwave, this allows us to identify the hotspots. To do so take some cardboard/paper plate and spread a fine layer of spread evenly across it. Place in the microwave for a few seconds. You should notice a pattern in the melted butter, if not keep microwaving it until you see things. Use the ruler to measure the distance between the hotspots. this gives us half the wavelength of microwaves. Then speed of light = wavelength * frequency. The frequency of microwaves is around 2.5Ghz. The speed of light is 29,979,245,800 cm/sec (as you'll probably measure the distance in cm) For thought how can you improve the accuracy? Choose some other EM wave, better generator, deal with reflection inside the microwave.

Risk Assessment

Hazard: Microwave

Description: Can cause sparks or explosions if metal microwaved.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Don't put any objects potentially containing metal in the microwave, ever.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Burns

Description: Hot things removed from the microwave could cause burns.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Be careful when removing things from the microwave, avoid using bare hands. Microwave for appropriate time and don't over cook. Ensure children adequately supervised. Allow item to cool before children measure if needed. Run any burns under a tepid water for an appropriate length of time.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Food Contamination

Description: Food cooked in the microwave may be contaminated with results of the experiment.

Affected People: Demonstrators

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Don't use the microwave for food preparation

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Electrical Cables

Description: Trip Hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Try to keep cables out of thoroughfare. If cables must be placed somewhere people are likely to be walking, tape them down.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2019-12-26 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2020-01-20 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2022-01-23 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-01-30 - Lavinia Finalde Delfini (lf465@cam.ac.uk)

Check 1: 2023-01-12 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-13 - Johan Kidger (jpk51@cam.ac.uk)

Mechanical advantage

Using pulleys and levers to explore mechanical advantage - Check out this huge tripod with weights and pulleys, then try using pulleys and levers to explore the idea of "mechanical advantage"

Last initially checked on 2023-01-14 by Johan Kidger (jpk51@cam.ac.uk) and double-checked on 2023-01-15 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- Tripod
- Various pulleys
- Water weights in bag

Experiment Explanation

Here is a hopefully not too ropey write-up of what is an awesome experiment (I hope you wonâ€™t string me up with all these puns)! You start with the contraption up and the bag containing 4 filled 2 litre water bottles out loose

(NB: At the moment there are currently only 3 bottles)

The bag

First, get the kids try and lift the bag, and then like a Christmas turkey get them to guess the weight. Wild guesses will ensue. Tell them there are 4x2L bottles in the bag. Ask them how heavy 1L of water is. (Wild guesses). Tell them that 1kg = 1L of water. Then get them to tell you how heavy the bag is (4x2=8 is surprisingly difficult). 8kg of weight is how heavy the bag is (or 80N downwards), so how much force do you need to apply to lift it slowly? Just over 8kg worth of weight (or 80N). I think we have bagged that idea, letâ€™s move on. Maybe say that as far as you pull down, the bag lifts up, as it maybe is useful to say that at this point so they are thinking of itâ€¦

First Pulley

Put it on to the pulley that looks like the first picture in figure 1 (I know the diagram isnâ€™t great, but I am not artistic and was using paint). Ask them how much weight is pulling down (8kg/80N), then ask how much force you need to lift it up (just over 8kg/80N), then ask how much one rope must pull up to lift it (just over **8kg/80N**). Get all people to lift weight (try and get everyone to do it, so they appreciate the change in other pulley system). *Make sure you are holding on to the leg opposite pulley one, or else it will shift across the floor.*

Second Pulley

Move the bag on to pulley two. Before you get them to lift it ask how many ropes are there *(ensure the one you pull it with is pulled out to the side so they donâ€™t mistakenly count it â€“ there should be two of them)*. Then ask them how much weight is pulling down (8kg/80N), then ask how much force you need to lift it up (just over 8kg/80N), then ask how much one rope must pull up to lift it (just over **4kg/40N**). Get all people to lift weight (try and get everyone to do it, so they appreciate it is easier to lift). Some may spot that you have to pull it twice the length to get it to lift the same amount of distance (donâ€™t worry if they donâ€™t yet).

Third Pulley

Move the bag on to pulley three. Before you get them to lift it ask how many ropes are there *(ensure the one you pull it with is pulled out to the side so they donâ€™t mistakenly count it)*. They will say 3 or 4 usually, so then say no and ask them to actually count. It is 5 taking the weight. Then ask them how much weight is pulling down (8kg/80N), then ask how much force you need to lift it up (just over 8kg/80N), then ask how much one rope must pull up to lift it (this is a bit trickier - just over **1.6kg/16N**). With the first person, ask them to hold the rope, and walk backwards, and keep on going, keep on going, keep on going. They realise now how much more rope you have to pull. Thus you can now discuss how to lift it the same distance, you must do the same work, so in total put in the same amount of force. Thus as the force is less, you have to go further (5x the distance). Get all people to lift weight (try and get everyone to do it, so they appreciate it is much easier to lift).

Closing Comments

Whilst everyone else is having a go at the Third Pulley, ask them if you had a very heavy weight, which system is better (some will say first here as you have less far to pull â€“ this is incorrect as very heavy things you couldnâ€™t pull). The answer is three â€“ easiest to do work. Therefore you use two and three to help you lift heavy weights. So what is the point of 1 then? Get lots of answers about how it is easier to carry, and you then point out to them that it doesn't change the weight they are carrying. What it does is that it changes the direction in which you are pulling, so you are pulling downwards. You can also ask them which system did they use the most energy while lifting. The answer is that it doesn't matter which one you use, you will expend the same amount of energy. This is because the height you lifted the weight through was the same for all three systems; it doesn't matter whether you pulled with a large force and moved the rope a small distance (first pulley), or whether you pulled with a small force but moved the rope a large distance (third pulley).

Appendix

You want more? You must be pulleying my leg. For advanced people, you can talk about why a pulley system with an odd number of pulleys may be beneficial (as in fig. 3) as it allows the user to pull down, using their weight to their advantage. With an even number (fig. 2) you'd have to pull up, which is harder. You may also want to explain uses of pulleys getting cargo out of ships etc... how would you use them to move a heavy weight horizontally, whilst keeping it off the floor (or out of the sea!)... you could talk about components here and forces pulling against each other etc.

Figure 1:

Figure 2:

Figure 3:

Risk Assessment

Hazard: Weights

Description: Injury due to weight dropping suddenly and hitting someone.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Water weights are used - intrinsically soft with no sharp edges. Demonstrator to inspect the ropes prior to use for signs of wear and replace as necessary. The ropes have soft stoppers on them (knots which get stuck at the pulley) so that the weight can't hit the ground. Also make sure small humans don't suddenly let go of the rope. Ensure people don't walk underneath frame.

Call a first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Weights

Description: Injury from people trying to pick up the heavy bag with a bent back.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: The weight isn't that much (6kg or so) in the first place. To mitigate, do not let small humans pick up the bag themselves. Hand it to them slowly. If you see them start to bend over (either pulled by the weight or otherwise), take the bag off them.

When picking it up, bend at the knees. Or if you must bend at the hips, make sure to keep your back straight.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Rope

Description: Rope burns if rope is allowed to slide through hands.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Ropes are relatively short, making it difficult for sufficient heating to cause burn to occur. Demonstrator to discourage audience members from running rope through hands. Demonstrator ready to hold onto rope or bag if necessary.

Call first aider if required.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Pulley

Description: Entanglement/finger trap in pulley blocks/ropes.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Demonstrator to maintain control of experiment. If the experiment must be left unattended in a public area the pulley blocks should be detached and stored safely, and the frame folded down. Verbal warning initially will draw attention to risk and so be preventative.

Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Water in weights

Description: Water spillage from weights presents slip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Water weights should be double wrapped with translucent/transparent plastic, or bottle caps gaffered in place. Cloth/mop should be available to mop up spills. Situate experiment away from mains electricals where possible. If any electrical equipment may be affected make sure it is turned off.

Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Frame

Description: Impact injury due to frame collapsing or sliding.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Frame is designed to be stable and far stronger than it needs to be, and should not collapse if correctly put up. It would, however, be possible for it to be pulled over by kids pulling hard on the ropes after raising the weight to its maximum height and pulling sideways, demonstrator should familiarise themselves with the stability of the frame so that they know what directions and forces might present a risk.

Demonstrator can lean/pull on the frame to counter these forces and prevent frame from sliding. Demonstrator to secure opposite leg to pulley in use. Ensure bolt at top is secure. Experiment should always be closely supervised when in use.

Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Rope

Description: Rope lying across floor may be trip hazard.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Ensure rope does not lay across anywhere the public may walk.

Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-14 - Aaron Barker (arb78@cam.ac.uk), **Check 2**: 2012-01-21 - Rosy Ansell (rosemary.a.r.hunt@gmail.com)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-01-18 - Benjamin Lai (bl337@cam.ac.uk), **Check 2**: 2014-02-14 - Nunu Tao (nmt26@cam.ac.uk)

Check 1: 2015-02-01 - Benjamin Lai (bl337@cam.ac.uk), **Check 2**: 2015-02-12 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2015-12-16 - Robert Gayer (rg478@cam.ac.uk), **Check 2**: 2016-01-02 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2017-01-22 - Robert Gayer (rg478@cam.ac.uk), **Check 2**: 2017-02-02 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2017-12-09 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk)

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Microbes: bacteria, viruses and parasites

Cuddly microbes to explain microbiology - Learn about the fascinating world of microbes with our fun cuddly toy bacteria, viruses and parasites, plus awesome slides and pictures. Now with added Covid-19! Use our cuddly poliovirus to learn how we can prevent and eradicate diseases!

Last initially checked on 2023-01-22 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- One large black box containing all types of microbes.

Experiment Explanation

Overview

Weâ€™ve put together three boxes to talk about microbes. This can be combined into one big experiment, or split into three separate ones. Please try to keep each type of microbe in its rightful box.

Bacteria box

In the box: â€¢ 9 x cuddly bacteria â€¢ 1 x cuddly penicillin bug (to talk about antibiotics) â€¢ 1 x cuddly yeast (to say that not all microbes are bacteria) â€¢ 1 x plate of plastic bacteria (E.coli) â€¢ 2 x bacteria viewers (look a bit like small microscopes) â€¢ 3 x slides sets for bacteria viewers â€¢ 1 x flask for growing bacteria â€¢ Packets of tools for growing bacteria â€¢ Laminated fact sheets for cuddly bacteria â€¢ Laminated instructions sheets for hand washing activity â€¢ UV hand wash cream (this is Â£15 per bottle, so use only minimum amount per group) â€¢ UV light for hand wash activity

If you want to do the hand wash activity you'll need a soap, warm water and bowl and some paper towels to dry hands on.

There are several things to do: lots of cuddly bacteria to talk about (everyone loves these), UV hand-washing experiment (good for younger kids) and bacteria viewers and lab props (better for older kids).

Stories you could tell:

- How some bacteria are really good for us and others are bad (with the cuddly bacteria)
- How you can pass on bacteria (good and bad) on your skin- see hand wash activity notes (good for younger kids)
- How to grow bacteria in the lab (with lab props and slide viewers)

Element One: Cuddly Microbes The following explanations are also found on laminated sheets in the box, and there is some additional information on labels attached to the cuddly bacteria:

1) *E. coli (Escherichia coli)*: Gram negative, rod shaped *SLIDE in microscope box* Found in the intestines of most mammals- itâ€™s there inside you only hours after youâ€™re born! There are lots of bacteria in our digestive system that are harmless to us â€“ in fact they stop harmful bacteria from living and growing there instead. Sometimes E.coli can make us ill; some unusual strains produce toxins which can give us food poisoning. Biologists like *E. coli*: Itâ€™s very easy to grow in the lab and can make lots of proteins and DNA very quickly.

2) *Salmonella (Salmonella enterica)*: Gram negative, rod shaped *SLIDE in microscope box* Can infect humans and animals, so sometimes infects people of food isnâ€™t cooked properly (particularly chicken or eggs). Causes gastroenteritis (diarrhoea and vomitingâ€¦) The bacterium itself can actually live inside certain types of white blood cell, which is a very effective way of hiding from the cells of the immune system that circulate in the blood.

3) *Typhoid Fever (Salmonella typhimurium)*: **Gram negative, rod shaped** Very closely related to the Salmonella bacteria that cause food poisoning. Typhoid fever is a lot worse than food poisoning however: its symptoms include a high fever, abdominal pain, a skin rash and headaches. Some people can be infected without having symptoms, but can still pass it to other people making them carriers of the disease. 'Typhoid Mary' (Mary Mallon) was the first recognised asymptomatic carrier and spread typhoid around New York in the early 1900s in her work as a cook, over 50 have fatalities have been linked to her. It is spread by drinking water or eating food contaminated with the bacterium. Typhoid fever is most common in India and its spread can be prevented by good hygiene.

4) Diarrhoea (*Campylobacter jejuni*): Gram negative, spiral shaped Most common cause of food poisoning in the UK, linked to handling raw chicken. It produces a toxin that kills certain human cells, which helps the bacteria to survive, without being attacked by the immune system.

5) TB (*Mycobacterium tuberculosis*): â€˜Acid fastâ€™ will not gram stain Infects the lungs when the bacterium is breathed in. Here it gets contained by the immune system in a tough shell. Only about 1 in 10 people who have the bacterium get ill: this usually happens when the immune system is weak and cannot contain the bacterium. The disease can cause damage to the lungs and in really bad cases it can spread to other parts of the body.

6) Cholera (*Vibrio cholerae*): Gram negative, comma shaped Usually spread when water is contaminated by the bacterium. Produces a toxin that stops you absorbing water through your intestines. This causes really bad diarrhoea, which can be fatal as you lose too much water and salt from your body.

7) Listeria (*Listeria monocytogenes*): Gram positive, rod shaped Causes fever and muscle pains. If the bacterium can get to the brain this can cause meningitis. Pregnant women are the most commonly infected â€“ the mother usually gets a mild fever but the baby might be badly affected or born early. The source of the infection is often food â€“ pasteurising dairy foods helps kill the bacteria and reduce the numbers of infections.

8) Stomach Ache (*Shigella*): Gram negative, rod shaped Very closely related to E. coli. When the bacterium is ingested it can get inside the cells of your intestine. It produces some toxins that can also make you ill.

9) Yogurt (*Lactobacillus bulgaricus*): Gram positive, rod shaped One of a number of species of bacteria that can be used to make yoghurt. What Wikipedia has to say about the use of *L. bulgaricus* in the manufacture of yoghurt: â€œLactobacillus delbrueckii subsp. bulgaricus is commonly used alongside Streptococcus thermophilus as a starter for making yoghurt. The two species work in synergy, with L. bulgaricus producing amino acids from milk proteins, which are then used by S. thermophilus. Both species produce lactic acid, which gives yoghurt its tart flavour and acts as a preservative. The resulting decrease in pH also partially coagulates the milk proteins, such as casein, resulting in yoghurt's thickness. While fermenting milk, L. bulgaricus produces acetaldehyde, one of the main yoghurt aroma components. Some strains of bulgaricus also produce bacteriocins which kill undesired bacteria. It is often helpful to sufferers of lactose intolerance, whose digestive systems lack the enzymes to break down lactose to simpler sugars.â€

**10) gonorea, syphilis, chalmydia

YEAST/FUNGUS (Yes, we know that they're not bacteria, but we'd found that people ask about antibiotics, so we think that they're a nice bonus to have in the box)

Penicillin (*Penicillium chrysogenum*) This is a fungus that makes penicillin, an antibiotic that kills some types of bacteria. It does this to kill off the bacteria that are competing for the food it needs for growth, but we have used penicillin from this fungus to treat bacterial infections in humans.

Yeast for bread and beer Also a kind of fungus. It's one cell, just like the bacteria, though the cell is much bigger. In bread the yeast can use the sugars in the dough for its growth; it breaks them down in a reaction that produces the gas carbon dioxide, which make the bread rise. In beer the yeast converts the sugars to alcohols.

Element Two: Growing Bacteria in the Lab The kit: â€¢ 1 x plate of plastic bacteria (*E. coli*) â€¢ 1 x flask for growing bacteria â€¢ Packets of tools for growing bacteria

NB. The kit we have has not been used in a lab and the 'bacteria' on the plate are not real!

Under sterile (no other bacteria) conditions:

1. You can grow some types of bacteria in the lab. *E. coli* is happy to grow on agar plates, as long as it has all the nutrients it might need. The L-shaped spreader is used when you put the cells on the new plate, to make sure that the bacteria aren't too close together.
2. If you want more cells than this, get some bugs you're interested in with the green tool.
3. The plastic flask can be used to grow bacteria in a growth medium/ broth. (Extra detail: For *E. coli* you'd usually use Luria-Bertani medium (LB) at 37 degrees C to provide the necessary nutrients. This contains 10g Tryptone (enzymatically digested milk protein casein - supplies amino acids), 5g of Yeast Extract (supplies lots of nutrients), 1g glucose, 10g NaCl pH ~7.2, deionized, distilled water to 1 litre.)

Element three: bacteria viewers The kit: â€¢ 2 x bacteria viewers (look a bit like small microscopes) â€¢ 3 x slides sets for bacteria viewers

These are essentially a more durable version of a set of slides and a microscope. In the set of slides (which come with a booklet for information) you can see various different shapes of bacteria - just like in the cuddly bugs:

1. Round (1= "coccus", 2+ = "cocci")
2. Rod (1= "baccilus", 2+ = "baccili")
3. Spiral

These shapes are determined by the cell wall (the tough outer layer) and the cytoskeleton (internal "scaffolding"). They matter because they affect how the cells can absorb nutrients from its environment, how they can attach to surfaces and how they're able to move.

Element four: Handwashing Activity

Why should we bother washing our hands? This activity uses glow in the dark stuff to show how easy it is to miss the bits of your hands where bacteria are...

The kit: â€¢ Laminated instructions sheets for hand washing activity â€¢ UV hand wash cream (this is Â£15 per bottle, so use only minimum amount per group) â€¢ UV light for hand wash activity *Also needs a bowl and paper towels that are not supplied in the box*

There is a set of laminated instructor notes in the box, taken from the Wellcome Trust. A full version can be viewed online here: http://www.yourgenome.org/downloads/pdf/teachers/handshake/handshake_tnotes.pdf

Essentially: â€¢ No hand washing: Form a â€˜lineâ€™ around your group of children. Squirt UV cream on the first childâ€™s hand and get them to rub their hands together, then shake the hand of the next person in the group, then they shake the next personâ€™s hand... Shine the UV torch onto each of the kidsâ€™ hands to show up the â€˜bacteriaâ€™. All should now wash their hands thoroughly. â€¢ Compare the results with hand washing: Repeat the procedure but get each person to wash their hands in the bowl after the UV cream has been rubbed in but before they shake the hand of the next person. â€¢ If the group activity isnâ€™t suitable, you could always compare before and after hand washing on the same child. â€¢ This should show that washing hands helps to remove microbes â€“ and washing with soap does this better than with just water as the soap breaks down some of the natural oils on your hands that help the bacteria to stick. Look at where the bacteria were found â€“ itâ€™s easier for bacteria to stay between our fingers and under our nails â€“ and thatâ€™s why itâ€™s important to wash your hands properly!

Viruses box

In this box: â€¢ 12 x cuddly viruses â€¢ 1 x plastic model HIV virus (in box) â€¢ microbiology text book

VIRUSES: Can be as simple as DNA or RNA in a protein coat. They use the cells of their host to make lots of new viruses. Often these new viruses get released by causing the cell to burst. Viruses canâ€™t survive for very long outside of cells so new viruses quickly find a new cell to infect.

HIV (Human Immunodeficiency Virus): Retrovirus (RNA genome copies itself into DNA, using viral reverse transcriptase. The DNA integrates into the host chromosome and new viral genomes are produced by host transcription/translation machinery) Can be spread via some bodily fluids and blood. Lives in white blood cells (CD4+ helper T cells) and eventually kills them, which means the immune system cannot function properly. People where HIV has killed too many white blood cells have AIDS (acquired immune deficiency syndrome), and this means that they can become very ill or even die from diseases that would not harm a healthy person (opportunistic infections â€“ a big killer is tuberculosis caused by *Mycobacterium tuberculosis* â€“ cuddly bug in the bacteria box).

Common Cold (Rhinovirus): positive sense RNA Spreads easily from infected people when they sneeze or contaminate surfaces. The virus is very happy at the temperature and conditions in the human nose which is where they initially infect. There are lots of different types of rhinovirus whose protein coats all look different to the immune system, which is why we donâ€™t get become immune to the common cold.

Measles (Morbillivirus): negative sense RNA virus Usually spread by breathing in virus from droplets in the atmosphere. Causes a fever, rash and red eyes. Most people will have been vaccinated against this with the MMR jab, which mostly eradicated measles from the UK. However since the scare about the MMR jab (spuriously linked to autism), the disease has been cropping up in affluent areas of London! (Vaccine scares can destroy herd immunity, the protection the population has when enough people are vaccinated and the virus cannot find enough hosts to spread to.)

Kissing Disease (Epstein-Barr Virus): DNA virus Most of you will have this virus right now. It is usually spread via saliva, causing a mild fever in the majority of the population in early childhood. (Lots of people have asked me why this is and the answer is we donâ€™t really know â€“ scientists think it might be something to do with how the immune response develops over childhood.) However some people who donâ€™t get the virus in early life might get it when they come into contact with other peopleâ€™s saliva in their teenage years - they then get Glandular

Fever. An interesting thing about the virus is that you never really get rid of it; some of its DNA forms little circles in the nucleus of the white blood cells it infects, and it can remain dormant (latent infection) for a long time (occasionally getting out into saliva but not making you ill). The virus that causes chicken pox can do this in nerve cells.

Influenza: Negative sense RNA virus Infects almost all mammals (eg. swine flu, bird flu), aquatic birds are primary host. Common problem in humans - see most in winter when low air humidity allows the visus to spread more effectively. Spread by breathing in virus particles (Respiratory tract). Causes symptoms including fever, headache, cough, muscle aches and less commonly vomiting and diarrhoea. It can be vaccinated against, however it is able to change its structure (by mutating its genome which is a random process) so it can evade the immune system. This means flu vaccines keep having to be updated to protect people against the new variations of the virus. This, and the fact that influenza virus also infects birds, is the reason why it would not be possible to eradicate influenza. Could compare this to viruses like smallpox and polio which have or have nearly been eradicated because they have more stable genomes and no animal reservoir.

Rabies: Negative sense RNA virus Enters via skin and exits via saliva - spread through being bitten by an infected animal (usually dog). Results in death by killing brain cells in the cerebellum. The virus travels to the brain from the bite site up the nerves and it progresses slowly, so it is possible to stop the progression of the disease by vaccinating after being bitten.

Ebola: Negative sense RNA virus Spreads by direct contact. This virus has a high fatality rate of up to 90% (but closer to 40% in the most recent outbreak). It causes symptoms including fever, muscle aches, skin rash, vomiting + diarrhoea, weakness, bleeding from nose, mouth etc. The virus can infect many cell types and it spreads within the body through the circulatory system. It causes such severe disease because it causes clotting within the blood vessels, bleeding inside the body (haemorrhage) leading to a drop in blood pressure and multi-organ failure. It is also so severe because it originated in a different animal to humans - the fruit bat - and transmitted to humans relatively recently. This is in contrast to viruses such as the common cold which have been in human populations for a long period of our evolution meaning we have adapted to survive it.

Winter Vomiting Disease (Norovirus): Positive sense RNA virus Very common in the UK and very contagious. Causes vomiting and diarrhoea. Spread can be prevented by washing hands regularly.

Polio: Positive sense RNA virus See "Polio, vaccination and disease eradication" experiment

Chicken Pox: Double stranded DNA virus Otherwise known as Varicella-Zoster virus, a member of the herpesvirus family. Highly contagious; Spread through direct contact, coughing and sneezing, and causes red spots on the skin all over the body. Causes mild symptoms if caught when young, but causes Shingles in adults which is more serious. After initial infection, the virus goes dormant (latent) in the nervous system, and later in life it might reactivate to cause shingles.

T4 (T4-Bacteriophage): Bacteriophage are viruses but they do not infect humans â€“ they infect bacteria. One day this might be useful to us for treating bacterial infections (â€˜phage therapyâ€™) where you can infect specific bacterial cells with genes that kill them/stop them reproducing.

HPV, here's, cancer (not virus) Parasites Box

â€¢ 6 x cuddly parasites (4x protozoa, 2x insects) â€¢ 2 x cuddly mosquitos (parasite "vectors") â€¢ laminated fact sheets â€¢ laminated parasite matching game â€¢ microbiology text book

What is a parasite?

- Being a parasite is essentially free-loading off the host that it feeds on.
- Some parasites live on the surface of their hosts, these are ectoparasites (e.g. some mites/lice, ticks).
- Some types parasites live inside their "prey", these are endoparasites. Some of these live in gaps between the host tissues (eg trypansomes, tapeworms) while others live inside the host cells (eg malaria parasites)
- Most parasites live in more than one species at some point in their lifecycle (see individual descriptions).
- The parasites that you're most likely to hear about are single-celled Protozoa (including the parasites that cause malaria and trypanosomiasis), and parasitic worms (such as tapeworms).
- There is constant conflict between parasite and host: the hostâ€™s immune system is trying to kill the parasite, and the parasite is trying to hide from the immune system. Co-evolution of the parasite with the host has led to them becoming well adapted to each other â€“ a good parasite is one that manipulates the host so it can reproduce maximally but doesnâ€™t kill the host because it needs somewhere to live!
- Parasitic diseases are a massive problem for global health. Malaria kills nearly 1 million people per year, most African children under 5 years old. Parasitic worms might reduce your quality of life so much that you canâ€™t care for your family, leading to a wider impact (eg elephantiasis). In many regions where parasitic diseases are a problem there is very basic healthcare, making treatment more difficult to access.
- Also a big problem in animals - cost to pet owners of preventative treatment (to avoid illness), most farm animals have a significant parasite burden (gives economic costs of reduced production, greater food intake required, medications etc.

Some examples of parasites

PROTOZOA: Single-celled eukaryotes

1) Malaria (*Plasmodium falciparum*): 4 parasites cause malaria: *Plasmodium falciparum* (the most common and most deadly), *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale*. These are carried by *Anopheles* mosquitoes, the vector, which are active and hence bite people at night. When they bite an infected person they take up the parasite into their digestive system (parasite stage = sporozoite), and then secrete it into the next person they bite in saliva (used to inject anticoagulants to keep the person bleeding so the mosquito can get its blood meal). The parasite then travels in the bloodstream to the liver where cells are infected (parasite stage = merozoite). Parasites are released and enter red blood cells in the circulation, where they multiply and burst the red blood cell, causing the symptoms of malaria. Inside some red blood cells the parasites become gametocytes which are taken up by another mosquito if it bites the person. Symptoms at first include fever, chills, headache and vomiting. In some cases this can rapidly progress to severe anaemia, respiratory distress or cerebral malaria - and can be fatal. However if you live in a malarial area (and get infected often) you may develop partial resistance to malaria and be infected without symptoms (asymptomatic infection). When you travel to a malarial area (Asia, South America, Africa - but the range is spreading) you use chemoprophylaxis (drugs to stop an infection becoming established), in combination with avoiding being bitten (mosquito nets, DEET mosquito repellent) - and there are also drugs available to treat malarial infections.

2) African Sleeping Sickness (*Trypanosoma brucei*): Parasites are injected into you by the bite of a tsetse fly in Africa (tsetse fly = the vector), or they can cross the placenta to infect a fetus. Trypanosomes donâ€™t live inside cells like malaria but they live in the blood stream â€“ this means they have to do clever things to hide from the immune system, such as constantly changing their protein coat so that the immune system can't recognise them as a parasite. 2 different trypanosome subspecies cause sleeping sickness: *T. brucei rhodesiense* gives a rapidly-progressing disease (death in weeks to months) whereas causes a slowly-progressing disease (you might not have any symptoms for years!). Sleeping sickness occurs when the trypanosomes enter the brain and start to destroy the areas that control sleep and wakefulness, leading to blurred sleep/wake transitions and falling asleep at inappropriate times, progressing to coma and death! Trypanosomiasis (disease caused by trypanosomes) is treatable - but it's much easier at the early stage (drugs: pentamidine/suramine) than once the parasites enter the brain (drugs: melarsoprol - which comes from arsenic and has nasty side effects that can be fatal themselves!). African trypanosomes also infect cattle, making agriculture in areas with tsetse flies really unproductive - cattle become really thin and so can't work (pulling ploughs etc) and aren't useful as food for people either!

3) Chagas disease/ American trypanosomiasis (*Trypanosoma cruzi*) Chagas disease, also known as American trypanosomiasis, is caused by the protozoan parasite *Trypanosoma cruzi (T. cruzi)*. 10 million people in the world are infected, mainly in South America. The vector transmitting the trypanosomes to humans is the triatomine bug ('kissing bugs'). These live on the walls of houses and are nocturnal, biting people on their exposed faces when they are asleep at night. Unlike the African trypanosomes, South American trypanosomes aren't injected with the bug's saliva but the bug defecates next to the bite and it's the faeces that contain the parasites. They get into the person's bloodstream when they rub their face and smear the faeces into the bite! The first sign of infection is often a large swelling of the eyelid on the side of the face that was bitten. Parasites can then enter the heart (30% cases) causing problems with the heartbeat, and maybe sudden death. Digestive problems can also occur (10% cases) when there is enlargement of the oesophagus as food can't enter the stomach - the food that gets trapped can start rotting which is pretty disgusting! Chagas disease is highly treatable though, with nearly 100% of people cured if treated early (benznidazole or nifurtimox).

4) Toxoplasmosis (*Toxoplasma gondii*) *Toxoplasma gondii* is a species of parasitic protozoa.The definitive host (where the sexual stage of the life cycle occurs) is the cat - gametes are formed in the digestive tract and exit in the faeces. Then they enter another host (intermediate host) when they eat or drink contaminated food or water. So far every warm-blooded animal tested can act as a host - including humans. Here the parasite can enter any nucleated cell and replicates to form a tissue cyst. This can be passed on to another intermediate host or a cat by carnivory. Usually toxoplasmosis has very mild symptoms (there might be some fever) and in France up to 90% of adults are infected (due to the French love of rare meat)! However serious disease can be caused in immunocompromised people (AIDS sufferers or post-transplant patients on immunosuppressive drugs) and pregnant women (increasing the risk of spontaneous abortion and birth defects). This is why pregnant women are advised not to touch cat litter! (also explains why pregnant women are advised to clean fruit/veg thoroughly as gametes can contaminate them, and women become infected this way) *T.gondii* infection of the brain can lead to changes in behaviour by changing the amounts of chemicals in the brain (dopamine). Rats and mice lose their fear response to the scent of cats (tested using cat urine) and are more curious - very important effect, as means rats are more likely to be caught and eaten by cats giving greater rate of infection of cats (completing the parasites life cycle). Studies in humans have linked toxoplasmosis to schizophrenia (including hallucinations and reckless behaviour), slower reaction times and greater chance of causing traffic accidents.

PARASITIC WORMS:

(There's some slides for these in "Microscopes & Cells" which can be borrowed. Please sign the respective risk assessments before using items from them).

Flukes (Trematodes): Adult flukes are leaf-shaped flatworms. Prominent suckers at the mouth and on the stomach help maintain position. Flukes are hermaphroditic (both male and female) except for blood flukes (schistosomes), which are bisexual. The life-cycle includes a snail intermediate host.

Tapeworms (Cestodes): Adult tapeworms are elongated, segmented, hermaphroditic flatworms that inhabit the intestinal lumen. You can eat the cysts in undercooked animal tissues (pork is probably the greatest risk if undercooked), and then they develop in your intestines. They eat your food from your intestine â€“ instead of you getting the nutrients. They attach to the intestinal wall using suckers in the head. Problematic in the developing world where there is already malnutrition. People used to use tapeworms as a slimming aidâ€¦ They can grow up to 15 metres long and live for 20 years! Larval forms live in extraintestinal tissues.

Roundworms (Nematodes): Adult and larval roundworms are bisexual, cylindrical worms. They inhabit intestinal and extraintestinal sites.

1. **Schistosomiasis** (caused by a fluke/ trematode) â€¢ Schistosomiasis is a chronic, parasitic disease caused by blood flukes (schistosomes) â€¢ At least 230 million people require treatment every year â€“ praziquantel â€¢ Infection from larval forms released from freshwater snails in contaminated water â€¢ Penetrate the skin and live in circulation where females release eggs â€¢ Cause damage because of the host immune response to the parasites

2. **Liver fluke** (*Fasciola hepatica*) (caused by a fluke) â€¢ Freshwater snail intermediate host, where reproduction occurs, then they are released as cercariae and swim through water to be ingested by ruminants normally, or sometimes humans eating uncooked foods like watercress â€¢ Adult lives in the liver where they feed on the lining of bile ducts â€“ makes cheese-like holes in the liver â€¢ Produce eggs â€“ up to 25000 a day per female

3. **Dracunculiasis** (guinea-worm disease, caused by a nematode) â€¢ Dracunculiasis (caused by Dracunculus medinensis, a long thread-like worm) is a parasitic disease on the verge of eradication â€¢ Exclusively transmitted by drinking water contaminated with parasite-infected fleas such as rural isolated ponds â€¢ Takes 10-14 months for worm to mature in the body

4. **Hookworm** (*Ancylostoma duodenale* and *Necator americanus*, kinds of nematodes) â€¢ Soil-transmitted helminths (parasitic worms) â€¢ Major burden of disease worldwide - estimated 576-740 million people infected with hookworm â€¢ Hookworms live in the small intestine, eggs are passed in faeces of infected person â€“ this is a problem in the developing world where people may defecate outside (near bushes, in a garden, or field) of if the faeces of an infected person are used as fertilizer, eggs are deposited on soil. â€¢ Eggs then mature and hatch, releasing larvae (immature worms). â€¢ The larvae mature into a form that can penetrate the skin of humans, and infection is mainly acquired by walking barefoot on contaminated â€¢ Most people infected with hookworms have no symptoms. Some have gastrointestinal symptoms, especially persons who are infected for the first time. The most serious effects of hookworm infection are blood loss leading to anemia, in addition to protein loss. â€¢ Infection is treatable â€“ anthelminthic medications eg. albenadazole

PARASITE VECTORS:

(There are two cuddly toys for this, so you can show a second uninfected mosquito feeding off a human host)

Mosquito (*Culex pipiens*): â€¢ Most mosquitoes are harmless but some can transmit disease â€¢ Viral diseases, such as yellow fever, dengue fever and Chikungunya, transmitted mostly by Aedes aegypti â€¢ Parasitic disease malaria, carried by mosquitoes of the genus Anopheles â€¢ Lymphatic filariasis (the main cause of elephantiasis â€“ worms block lymphatics impairing lymph drainage causing swelling of the limbs) â€¢ We have cuddly toys of mosquitoes â€“ in the parasites box

ECTOPARASITES:

(There's some cuddly toys and slides for these, and hopefully some preserved samples borrowed from the "Horrible Housemates" experiment) **1) Head louse** (*Pediculus humanus capitis*) â€¢ Lice are wingless biting or sucking insects. Lice infestation of any part of the body is called pediculosis! â€¢ Live on your head (an ectoparasite) - has a single strong claw on each leg that can grab onto 6 hairs so they can move rapidly (may be on several heads in one day). But their short stumpy legs mean they canâ€™t jump or walk well on flat surfaces. â€¢ Your head provides a source of food - blood â€¢ Eggs are called nits and the female attaches the eggs close to the scalp with a transparent quick-setting glue â€¢ The time taken to hatch depends upon temperature â€¢ Head lice have no lungs! They take in air by muscle contraction of the abdomen (via spiracles) â€¢ Head lice have been recovered from prehistoric mummies!

2) Bed bug (*Cimex lectularius*) â€¢ Ectoparasites that feed on human blood (haematophagous) â€¢ Live in houses and especially beds â€“ most active at night so they can feed on the host without being noticed â€¢ Adults can survive more than a year without feeding â€¢ They donâ€™t usually spread disease but they can cause allergic skin reactions â€¢ Light brown flattened oval-shaped body, vestigial front wings, microscopic hairs on abdomen that give a banded appearance

Polio, vaccines, and disease eradication

There are a few key concepts you can talk about with polio, depending on how keen the children are and their level of understanding: â€¢ The virology of poliovirus; how it replicates etc. â€¢ How poliovirus causes disease â€¢ Vaccination â€¢ Disease eradication

The Virology This is quite hard to explain without getting bogged down in detail. For most children, Iâ€™d restrict it to explaining that polio is a virus, so it needs to hijack our cells to make more of itself. Polio is a virus which can cause a disease called poliomyelitis. Viruses are incredibly small particles (virions) containing the genetic instructions needed to make more virions. To infect a cell, the virus sticks to the cell surface then injects its RNA (the genetic instructions) into the cell (if weâ€™re being precise, the whole virion is internalised by receptor-mediated endocytosis before the genome enters the cytoplasm, but we can probably skip this). The host cell is then â€˜trickedâ€™ into producing thousands of new virions; the RNA has the instructions to make the viral proteins and also acts as a template to produce more genomes. Eventually, the cell bursts, releasing up to 10,000 new virions into its environment, ready to infect more cells.

How polio causes disease Polio spreads by the faeco-oral route; ie poo contaminating drinking water. Thatâ€™s why itâ€™s often seen in areas with poor sanitation (eg. poor sewage disposal, no water treatment). Itâ€™s also the reason that young children are more likely to get infected, since they tend to have lower standards of hygiene! The vast majority of people infected get a fairly harmless infection in the gut or get vague â€˜flu-likeâ€™ symptoms. Polio becomes a problem if it infects cells called motor neurones in our spinal cord. We need these cells to control our muscles, so if lots of them are killed then the muscles become paralysed (because information can't get from the brain to muscles to tell them what to do). The resulting disease is paralytic poliomyelitis, which is what most people think of when you mention polio. Interestingly, infecting the cells in the central nervous system does not help the virus transmit to other hosts (it is 'accidental' infection - the virus would benefit more from infecting cells which can allow replication and transmission to new cells, so infection of these motor neurons is a waste of its resources).

What effects can paralysis have? It depends on where is affected. Obviously, if the legs are affected the patient wonâ€™t be able to walk. Even worse is bulbar poliomyelitis, where the muscles we use to breath can become paralysed. There isnâ€™t a cure for polio. All we can do is support the patient to keep them alive. If their breathing muscles become paralysed then they need mechanical ventilation, meaning that a machine is used to do the work for them. Famously, in the 1950s this took the form of negative pressure ventilation, aka the iron lung.

Vaccination Polio affected thousands of people in the Western world in the 1950s. But ask the children how many people theyâ€™ve met whoâ€™ve had polio. The answer should (hopefully!) be none. Why? Because thereâ€™s a vaccine to prevent it! Normally our bodies fight infections using our immune systems. Our immune system â€˜learnsâ€™ how to fight an infection when itâ€™s exposed to the pathogen, so it fights it more effectively the second time around. Thatâ€™s why we normally only get chickenpox once, even though itâ€™s a really infectious disease. Vaccines are a way to teach our immune system to fight a disease. Different vaccines work in different ways; some use a dead pathogen or part of a pathogen, while others use a live one thatâ€™s been deliberately weakened so that itâ€™s no longer able to cause disease, but still similar enough to the dangerous one that our immune system learns to fight that one too. In the case of polio, there are actually vaccines that work both ways; the live vaccine is more â€˜realisticâ€™ so it produces more effective immunity, but thereâ€™s a risk that the â€˜safeâ€™ strain can mutate back into a â€˜dangerousâ€™ one. In the UK we use the dead vaccine, since youâ€™re highly unlikely to be exposed to polio anyway, but in areas where polio is still common we use the live one, since the benefit outweighs the risk. In the (hopefully unlikely) event you end up talking to an anti-vaxxer about this, feel free to try and explain the science behind why vaccines do indeed work and are safe, but keep it a calm and cordial discussion and don't spend too long on this - you're meant to be entertaining the children more than educating the parents!

Disease eradication The polio vaccine is important because it might be possible one day to use it to eradicate polio completely. In fact, weâ€™re tantalisingly close to doing so! Have they heard of any other diseases that have been completely eradicated? Thereâ€™s only one human disease: smallpox. For the vets, thereâ€™s also rinderpest - infected cows, buffalo, deer, giraffes etc. Polio has certain special features which are needed for a disease to be eradicated: â€¢ It doesnâ€™t change so much over time that the vaccine stops working. Contrast with flu, where we need a new vaccine very year, and even that isnâ€™t guaranteed to work! â€¢ It doesnâ€™t infect animals. Animal viruses which also infect humans are basically impossible to eradicate, since it just needs one person to be infected by an animal and weâ€™re back to square one. Sadly, this applies in the case of Ebola. Weâ€™ve come incredibly close to eradicating polio in recent years, and itâ€™s now largely confined to Nigeria, tribal regions of Pakistan and Afghanistan. However, these areas are all highly politically unstable and health workers have been targeted by violence, so it remains to be seen whether the final push will be successful.**

Risk Assessment

Hazard: Microbe toys and accessories

Description: Trip hazard if dropped on the floor.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Keep all props in contained area and pick up any fallen toys as soon as is safe. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Microbe toys and accessories

Description: Germ transmission if put in mouth or chewed, which may be more likely since these do resemble toys.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Wash between events if possible. Encourage children not to put near face/mouth.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: UV cream

Description: UV cream in eyes.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: When giving UV cream to children, tell them not to put their fingers near their eyes and ensure they rinse it off. Call first aider in case of injury. If washing up liquid gets into an eye, demonstrator must call a first aider and may perform an eye wash if trained and confident to do so.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: UV cream

Description: Slip hazard if spilled.

Affected People: All

Before Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Mitigation: All spills should be cleared up immediately. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Hazard: UV cream

Description: Possible allergic skin reaction to cream.

Affected People: All

Before Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Mitigation: Suggest that volunteer from group isn't one who is known to have sensitive skin. If it starts to itch/hurt, wash off immediately and call first aider. Seek further medical advice where appropriate.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Sensitive Topics

Description: We have a cancer cell and some things here which can cause cancer which affects lots of people. There are also several other potentially fatal diseases, in particular SARS-CoV-2 which is responsible for the ongoing pandemic and could lead to distress.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Deal with topic respectfully, move on if it seems distressing. Move to different experiment if required.

After Mitigation: Likelihood: 4, Severity: 1, Overall: 4

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2019-01-20 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2019-01-23 - Amanda Buckingham (abb53@cam.ac.uk)

Check 1: 2020-01-24 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2020-01-25 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-12 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2021-01-19 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-02-01 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2021-02-09 - Sian Boughton (seb216@cam.ac.uk)

Check 1: 2023-01-22 - Jessica Trevelyan (jet81@cam.ac.uk), **Check 2**: 2023-02-10 - Amy Migunda (aom36@cam.ac.uk)

Microscopes & Cells

Examining a variety of objects under a microscope, including a variety of slides - All sorts of things can be viewed down a microscope! This might include the biology lesson classic of an onion skin, the shapes of salt and sugar crystals, the eye of the insect you found in your tent, a drop of puddle water...

Last initially checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **Electricity needed**
- Microscopes
- Slides
- Model cells (pillow model and inflatable plant and animal cells)
- Video camera for microscope and laptop

Experiment Explanation

Microscope kit for 2011 Summer Roadshow

Microscopes are now in 4 boxes.

2 x Slide microscopes: Two small blue boxes- each set is labelled alpha or beta to help stop them getting muddled up. In each box thereâ€™s the main body of the microscope (stored in two pieces, undo the screw, slot together, tighten screw), and 4 lenses in small pots. Unscrew the lenses from the lids of the pots, and screw them in to the lower part of the microscope. The upper lenses are stored in the same box as the microscope slides- you wonâ€™t really need them if youâ€™re using the microscope cameras and the CHaOS laptops (use Crick) to show visitors the slides, but feel free to. Ask a Committee member to help you set up if youâ€™re not sure!

Dissecting microscope: Small grey box. This is good for introducing microscopes in primary schools, though youâ€™ll need to find some props to use with it. Everyday objects like money and textiles are good to look at with this. You can always raid the CHaOS food boxes for stuff like lettuce, kiwis and tomatoes, or look outside for a selection of leaves. Thereâ€™s a couple of squishy toy microscopes in the box too (just for fun!)

Microscope slides: This box contains: â€¢ 6 x boxes of slides for the slide microscopes (labelled man-made materials, human body, invertebrates, plants, parasites and microbes) â€¢ A box of lenses for the slide microscopes (labelled alpha and beta) â€¢ A box of accessories for the microscopes (dust covers and anything else you might want) â€¢ A magnifying glass (to show that lenses can make an image bigger) â€¢ A ruler (which can sometimes help to explain scale) â€¢ Cameras for the microscopes (1 x silver, 1 x black and 2 x low res for backup), which work like webcams when attached to the CHaOS microscopes. (The software has shortcuts on the desktop of each of the CHaOS laptops) â€¢ Laminated sheets with extra info for the 3 x slides in a pond life food chain that are in the invertebrate box (water organisms -> daphnia -> hydra) â€¢ 3 x microscope books, which might give you some ideas for demos

Model cells: Small grey box containing 2 inflatable cell models (inflate by mouth) and a cushion cell model.

How to explain what microcopes do/ what cells are

There are lots of different slides to choose from â€“ feel free to talk about whatever youâ€™re interested in!

- Introduce cells using the cell models
- Cells are very small (typically 10 um for an animal cell... that's 1000 times smaller than 1 cm (you can use the ruler to show 1 cm)
- Cells are analogous to a building brick - houses are built of lots of bricks, like people are built of lots of cells

(50-75 trillion!)

- Cells aren't just bricks - they are alive, and make things, use things, and process information
- Have a phospholipid membrane â€“ barrier to extracellular environment
- Nucleus is the â€˜control centreâ€™ - contains instructions on how to make proteins, from which the rest of the cell is made. Instructions are written in a 4-letter code on very long molecules called DNA (see Kiwi DNA experiment). DNA to mRNA (transcription), transported out of nucleus, translation on ribosomes to proteins. Proteins go to the ER (endoplasmic reticulum) for further folding, then to Golgi apparatus (more modifications), then on export pathway to exit the cell.
- Cells need energy - this is supplied by mitochondria (they convert energy from sugars into ATP, the energy currency of the cell)
- Plant cells - cell walls and chloroplasts (we have a root tip squash slide where the cell walls are visible and the nuclei are nicely stained, but they don't have chloroplasts because it's a root. If they want to see more plant cells, there's a whole demo on plants...)
- Bacteria are also cells, but they are smaller and don't have a nucleus (associate bacteria with disease e.g. food poisoning caused by E. coli). Bacteria can be lots of different shapes (look at E. coli, Staphylococcus, Spirillum).
- See below for labelled diagrams of some of the slides!

Microbes: Parasites slides ========================

Flukes (Trematodes): Adult flukes are leaf-shaped flatworms. Prominent oral and ventral suckers help maintain position. Flukes are hermaphroditic (both male and female) except for blood flukes, which are bisexual. The life-cycle includes a snail intermediate host.

Tapeworms (Cestodes): Adult tapeworms are elongated, segmented, hermaphroditic flatworms that inhabit the intestinal lumen. You can eat the cysts in undercooked animal tissues, and then they develop in your intestines. They eat your food from your intestine â€“ instead of you getting the nutrients. They attach to the intestinal wall using suckers in the head. Problematic in the developing world where there is already malnutrition. People used to use tapeworms as a slimming aidâ€¦ They can grow up to 15 metres long and live for 20 years! Larval forms live in extraintestinal tissues.

Roundworms (Nematodes): Adult and larval roundworms are bisexual, cylindrical worms. They inhabit intestinal and extraintestinal sites.

1. **Schistosomiasis** (caused by a fluke/ trematode)

- Schistosomiasis is a chronic, parasitic disease caused by blood flukes (schistosomes)
- At least 230 million people require treatment every year â€“ praziquantel
- Infection from larval forms released from freshwater snails in contaminated water
- Penetrate the skin and live in circulation where females release eggs
- Cause damage because of the host immune response to the parasites

2. **Liver fluke** (*Fasciola hepatica*) (caused by a fluke)

- Freshwater snail intermediate host, where reproduction occurs, then they are released as cercariae and swim through water to be ingested by ruminants normally, or sometimes humans eating uncooked foods like watercress
- Adult lives in the liver where they feed on the lining of bile ducts â€“ makes cheese-like holes in the liver
- Produce eggs â€“ up to 25000 a day per female

3. **Dracunculiasis** (guinea-worm disease, caused by a nematode)

- Dracunculiasis (caused by Dracunculus medinensis, a long thread-like worm) is a parasitic disease on the verge of eradication
- Exclusively transmitted by drinking water contaminated with parasite-infected fleas such as rural isolated ponds
- Takes 10-14 months for worm to mature in the body

4. **Hookworm** (*Ancylostoma duodenale* and *Necator americanus*, kinds of nematodes)

- Soil-transmitted helminths (parasitic worms)
- Major burden of disease worldwide - estimated 576-740 million people infected with hookworm
- Hookworms live in the small intestine, eggs are passed in faeces of infected person â€“ this is a problem in

the developing world where people may defecate outside (near bushes, in a garden, or field) of if the faeces of an infected person are used as fertilizer, eggs are deposited on soil.

- Eggs then mature and hatch, releasing larvae (immature worms).
- The larvae mature into a form that can penetrate the skin of humans, and infection is mainly acquired by walking barefoot on contaminated
- Most people infected with hookworms have no symptoms. Some have gastrointestinal symptoms, especially persons who are infected for the first time. The most serious effects of hookworm infection are blood loss leading to anemia, in addition to protein loss.
- Infection is treatable â€“ anthelminthic medications eg. albenadazole

PARASITE VECTORS:

(There are two cuddly toys for this, so you can show a second uninfected mosquito feeding off a human host)

1. **Mosquito**:

- Most mosquitoes are harmless but some can transmit disease
- Viral diseases, such as yellow fever, dengue fever and Chikungunya, transmitted mostly by Aedes aegypti
- Parasitic disease malaria, carried by mosquitoes of the genus Anopheles
- Lymphatic filariasis (the main cause of elephantiasis â€“ worms block lymphatics impairing lymph drainage causing swelling of the limbs)
- We have cuddly toys of mosquitoes â€“ in the parasites box

ECTOPARASITES:

(You can borrow cuddly toys (in parasites box) and some preserved samples (from "Horrible Housemates") to help you demonstrate.)

1. **Head louse** (*Pediculus humanus capitis*)

- Lice are wingless biting or sucking insects. Lice infestation of any part of the body is called pediculosis!
- Live on your head (an ectoparasite) - has a single strong claw on each leg that can grab onto 6 hairs so they can move rapidly (may be on several heads in one day). But their short stumpy legs mean they canâ€™t jump or walk well on flat surfaces.
- Your head provides a source of food - blood
- Eggs are called nits and the female attaches the eggs close to the scalp with a transparent quick-setting glue
- The time taken to hatch depends upon temperature
- Head lice have no lungs! They take in air by muscle contraction of the abdomen (via spiracles)
- Head lice have been recovered from prehistoric mummies!

2. **Bed bug** (*Cimex lectularius*)

- Ectoparasites that feed on human blood (haematophagous)
- Live in houses and especially beds â€“ most active at night so they can feed on the host without being noticed
- Adults can survive more than a year without feeding
- They donâ€™t usually spread disease but they can cause allergic skin reactions
- Light brown flattened oval-shaped body, vestigial front wings, microscopic hairs on abdomen that give a banded appearance

HYDRA:

- Hydra live in freshwater (unlike other members of their phylum, Cnidaria, like coral)
- Attached via basal disc to a surface like rocks
- Hydra eat small water organisms like water fleas
- Have nematocysts â€“ tiny stinging cells that inject toxin into their prey to paralyze them. The tentacles are sticky. The tentacles then move to bring the prey to their mouths, then prey is enzymatically digested. Sometimes they â€˜swallowâ€™ their tentacles so have to pull them back out.
- Thereâ€™s only one entrance and exit to the internal cavity â€“ so indigestible parts come back out the same way!
- Hydra mostly reproduce by budding â€“ young polyps mature attached to the parent and then detach. There is also some seasonal sexual reproduction with mature polyps developing gonads on the external body wall.
- Hydra have an amazing ability to regenerate. If you cut them in half, the head will grow a new foot and the foot a new head!

Risk Assessment

Hazard: Microscopes

Description: Electrical hazard, especially near possible water-based samples.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Keep water-based samples away from the microscope. Take care. See separate electrical parts risk assessment. In case of accident, call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Glass slides

Description: Using thin glass slide could result in broken glass with risk of cuts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: If children are very young or being silly, the slides should only be handled by the demonstrator - this will reduce the risk of breakage. If slides are broken, carefully collect/sweep up broken pieces, wrap in paper and dispose of carefully. In case of accident, call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Microscope light fitting

Description: The light fitting under the microscope becomes hot, and could cause burns.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Warn children to be careful, turn off lamp when not in use, if it's getting hot put a cardboard shield around (but not touching) the lamp to prevent accidental contact. In case of accident, call first aider. In case of burns, encourage victim to run affected area under tepid water for 10 minutes.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Model cells

Description: Inflating model cells could cause pulmonary distress e.g. asthma attacks.

Affected People: Demonstrator

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Avoid inflating the model cells if a sufferer of asthma. In case of incident, use inhaler. Call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Model cells

Description: Model cells could present a trip hazard if dropped on the floor.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Keep all props in contained area. If dropped, pick up immediately. In case of accident, call first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2013-12-26 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2014-02-02 - Raghd Rostom (rr415@cam.ac.uk)

Check 1: 2015-01-05 - Arporn Wangwiwatsin (Koi) (aw584@cantab.net), **Check 2**: 2015-01-08 - Kym Neil (kym.e.neil@gmail.com)

Check 1: 2015-12-30 - Natalie Cree (nc434@cam.ac.uk), **Check 2**: 2016-02-11 - Craig Burns (cpb57@cam.ac.uk)

Check 1: 2017-01-11 - Roxanne Armfield (rea41@cam.ac.uk), **Check 2**: 2017-02-08 - Alfred Chia (ac939@cam.ac.uk)

Check 1: 2018-01-08 - Gemma Shaw (gcs33@cam.ac.uk), **Check 2**: 2018-02-02 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Check 1: 2020-12-28 - Bryony Yates (by250@cam.ac.uk), **Check 2**: 2021-01-12 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Mini Explosions

Exploding film canisters with lemon juice and bicarb. - Make an impressive explosion with kitchen ingredients and find out more about what makes things go with a bang.

Last initially checked on 2023-01-15 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-01-15 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Lemon Juice (or vinegar, but this reacts faster and smells bad!)
- Bicarbonate of soda
- A couple of washing up bowls
- Teaspoon or similar for scooping bicarb
- Clear plastic box with the hinged lid
- (All of this lives in a large blue box with white lid â€“ note that this is shared with Fire Extinguishers)
- Green or black tray to catch any leakage from clear plastic box (doesn't live in blue box)

Experiment Explanation

In a nutshell.....

Acid + Carbonate â†' Salt + Water + Carbon Dioxide Production of carbon dioxide in a sealed container to produce explosions.

How to set up the experiment

Set up the clear plastic box in a large tray, with the lid opening towards you. **Important:** Stick some gaffer tape along the hinge line facing the audience to prevent lemon juice escaping through the crack. Fill one of the smaller Tupperware containers with water to use for washing out film canisters.

Demonstrating the experiment

Initially, mix lemon juice (about 1/8 fill the canister) and bicarb (1/4 of a teaspoon) in the film canister with the lid off, so that the kids can see it frothing up. If the kids seem responsible, you can add the bicarb and let a volunteer add a squirt of lemon juice. Ask them where they think the bubbles are coming from/what's in the bubbles (space for a bit of a discussion of different gases here, many of them will have heard of COâ‚‚).

Get them to think about what lemon juice is like (sour therefore an acid), and what else is sour (vinegar, other citrus juice..) and discuss that any acid can let out the gas that's "trapped" in the powder. Possibly also discuss use of bicarb in baking - heating it up releases gas, which puts bubbles in your cakes.

The bubbles should froth well over the top of the canister. Ask them to predict what will happen if you put a lid on (does the gas have anywhere else to go?)

Now try it and see if they're right! With older kids you can discuss how molecules create pressure, ask them to push their hands against each other a bit to demonstrate reaction forces.

Some children ask why there is no 'fire' if it is an explosion. It can be worth explaining that an explosion is simply a rapid expansion of gases and release of stored energy, often with heat being produced, though this is not a necessary condition. Sealing the canister causes the pressure to build up, which stores energy, until the lid can no longer resist the force of the trapped gases. The stored energy is then released rapidly when the lid pops off and gases expand, causing the explosion.

There are 2 slightly different approaches:

Method 1 (easier and effective)

Fill the canister about 1/6 of the way with lemon juice (or let a responsible volunteer do it), press bicarb into the well in the centre of the lid. Invert the lid and make sure the bicarb stays stuck in there. Inside the plastic box, with the lid partly shut, gently put the lid on the canister; the bicarb is now held at the top of the canister away from the lemon juice.

Invert the canister, place it on the bottom of the box, and shut the lid fully (it's often a good idea to have the lid partially shut before you invert the canister to reduce the risk of it getting on you). The bicarb and lemon juice will mix, pressure builds, and the pot will explode upwards. The less lemon juice there is, the more time you have before the explosion but the explosion is no less vigorous (assuming the seal is good), since the film canister will always pop at the same pressure and a slower reaction will build up pressure more slowly. You could ask older children to work this fact out for themselves.

Method 2

Put some lemon juice in the canister, put a piece of tissue paper over the top of the canister with bicarb on top of that, push the lid on so it hold the tissue paper. The bicarb is now held at the top of the pot away from the lemon juice. Put the canister upside down in the clear plastic tank and shut the lid (it's often a good idea to have the lid partially shut before you invert the canister to reduce the risk of it getting off you). The bicarb and lemon juice will mix and the pot will explode upwards.

It's usually a good idea to try both methods before the kids arrive and see which one works better for you and the type of film canister you happen to have.

Some film canisters explode better than others, so it is worth trying different ones to make sure you are using the right lid. The translucent white plastic ones work really well. Ask a committee member or experienced demonstrator.

Other things to think about

Vinegar (acetic acid) is a stronger acid than lemon juice (citric acid); if using vinegar expect this reaction to be quite quick... (can talk about why stronger acids cause a faster reaction). You could also link the experiment to a rocket launch â€" the canister shoots upwards because the gas pressure pushes the COâ‚‚ and liquid out of the bottom, generating an upwards reaction force. Rockets work in the same way by forcing gas out of the back at great speed (though this is normally powered by combustion rather than an acid-base reaction).

Packing away

Give everything a wash, ideally with hot, soapy water. Dry the box (by leaving it out or using paper towels). Put everything (except the big tray) back in the big blue box â€" to make everything fit you will probably need to put smaller components (e.g. the tub of film canisters) inside the clear plastic box.

Risk Assessment

Hazard: Liquids

Description: Spillages pose a slip hazard.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Clear up spills as soon as possible if on a slippery floor. Do experiment outside if possible. Do experiment in tray to avoid spilled liquid going on floor. Put wet floor sign down if needed.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Explosions

Description: Explosions could get out of box, (or occur before the canister has been put in the box) and get into eyes, or box could jolt and hit children if they are too close.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: Do experiment in a clear lidded fish tank so kids are not peering over the top to see what is happening and tell them to stay a good distance back, keep lid opening faced towards demonstrator. It is important to keep the kids under control. Try to keep control over at least one of the reagents, so the kids can't just do it themselves.

Ensure the top of the tank is not at eye level (it is possible for a small volume of the reagents to be propelled through the crack between the top of the tank and the lid). Run a length of plastic tape along the hinged side (which should be closest to your audience) to prevent splattering.

Tissue paper may be used as a "fuse" to increase the time taken for the reactants to come into contact with each other - this gives more time to get the canister into the tank. Lemon juice is usually better than vinegar, as it reacts more slowly, so again, there is more time to get the canister into the tank. In addition, eye protection should be provided for demonstrators to minimise possible risk of solution splashing into demonstrator's eyes.

Eyewash should be kept in Mini Explosions box. If solution or reactants have entered eyes, call first aider, who will use eyewash to wash out of eyes if trained and confident to do so.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Reactants

Description: The reaction mixture could be eaten by a child and cause a stomach upset.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Do not let the kids do the reactions themselves or leave them alone with the experiment.

It is important to keep the kids under control. Try to keep control over both reagents. Warn children not to eat/put hands in mouth.

In the event of eating, advise them that the reactants are all edible but to seek medical attention if they start to feel very bad as experiment has been in cupboard for unknown amount of time.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

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Mini-beasts

A variety of sea life and freshwater animals observed using microscopes - nan

Last initially checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Equipment Needed

- **Electricity needed**
- Volvox, rotifers, daphnia, paramecium, algae, hydra (ordered from the schools supplier Blades Biological)
- Microscope (ideally with a link to a tv) - for CBS we have historically borrowed the video microscope from the zoology lab
- Petri dishes
- Pasteur Pipettes

Experiment Explanation

Look at miniature sea life and freshwater animals under a microscope. Key message is that there are organisms that are smaller than we can see just with our eye.

Possible Activities:

1. Look at different animals under the microscope â€“ discuss their characteristics
2. Discuss microscopes and the concept of scale/size (i.e. with hairs under the microscope, etc)

Focus less on the biology and more on scale for much smaller children. Focus on the idea that every puddle is full of little animals so small they can't see them. Be sure to use simple language!

BASIC PROCEDURE AND EXPLANATION

1. Fill a small petri dish with water from a sample jar and introduce a hair for scale. Ideally a fair hair, as the sample is illuminated from below.
2. Then start looking at the rotifers.

Talking points:

a. Do they know what a microscope is? It can help to compare it to a telescope (telescopes let you see things far away, microscopes help you see very small things that are close by). Make it clear that what they are seeing through the microscope is the stuff in the dish of water.

b. You can get them to look at a hair through the microscope and try and guess what it is (a fair hair works better). You can often see the scale-like texture and so can talk about how things can appear quite different when you look at them close up.

c. Find a rotifer - talk about how small they actually are (compare them to the hair), identify anatomical parts. Talk about the corona which are two wheels covered in little hairs on his head. When these spin, it makes the water spin which shoots any food in the water straight into its mouth. You can often see its jaws moving, which they might think is its heart beating but rotifers don't have hearts, or brains, or eyes. Talk about where they live - gutters, bird baths, puddles (anywhere wet that occasionally dries out). When it dries out, they dry out too and stop moving etc. - this is called anhydrobiosis. They replace the water in their body with sugar and can live for years like this. Within 5 minutes of being in water, they 'come back to life'.

d. Rotifers are about 50-60 cells but paramecia are single cells (a big difference in size). The paramecia are covered in cillia which beat like a mexican wave to power them through the water and have a trench in their body in which they hold their food (bacteria, algae and yeasts).

e. Amoeba are also single cells, but they move by extending their membrane in some places (a â€˜pseudopodâ€™) and retracting it in others, unlike paramecia which use cilia. Often find them in decaying vegetation in fresh and salt water. They eat by endocytosis â€“ they engulf food in their membrane.

f. Volvox â€“ these are made of numerous cells each with 2 flagellae all interconnected and arranged in a sphere (filled with glycoproteins) â€“ all the cells swim together in a coordinated way. Can see daughter colonies developing inside. Found in ponds, ditches and shallow puddles.

g. Daphnia â€“ â€˜water fleasâ€™ (0.2-0.5 mm long). 5 or 6 pairs of legs. Can see heart beating (~180 bpm). Mainly eat single-celled algae.

h. Hydra. Freshwater animals. A few mm long. Tubular body, anchored at one end and with mouth and surrounding tentacles at other end. Some live in mutual relationship with algae â€“ the algae photosynthesize to produce food for the hydra, and the hydra give the algae protection from predators. Can produce young by budding.

i. Algae. Simple plant-like creatures. Some unicellular, others multicellular. Can photosynthesize. Bottom of lots of food chains.

Risk Assessment

Hazard: Organisms/Protozoa

Description: Could cause harm if ingested or enters via wounds.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Do not let children eat organisms. Remind them to wash hands afterwards if they have touched apparatus. Make sure any wounds are covered by a plaster. Only let older children move the petri dish. Keep stocks away from children. We only use protozoa from standard school suppliers. If ingestion occurs, advise family to see GP if signs of sickness are shown and provide notes of what was ingested.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Glassware

Description: Cuts from broken glass.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep children under control. Dispose safely of any broken glassware immediately (sharps bin). In case of accident, call first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Plastic pipettes

Description: Poking risk especially to eyes.

Affected People: Children

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Supervised use of pipettes only. Do not let very young children use them. Keep away from eyes. Take off of children if they are messing about. In case of accident, call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: TV

Description: Microscope is a heavy object which could cause injury if falls, electrical risk (especially in connection with water and sea water) - sea water contains more ions and conducts electricity better than fresh water.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Place TV away from the edges of table, preferably against a wall so that it cannot be knocked off easily. Ensure electrical equipment has been PAT tested within the last 2 years. Keep equipment dry by keeping hands dry. Do not put TV near water, especially sea water. See separate electrical parts risk assessment. Switch off power at mains if a problem arises with the TV. Clear the area of people and call first aider if anyone is injured. In case of electrocution, do not go near casualty. Try to isolate the power without danger to yourself, and call ambulance.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Lamps

Description: Hot objects which could cause burns, electrical risk (especially in connection with water and sea water).

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Only switch lamps on when necessary. Do not touch and warn visitors not to touch them either. Ensure electrical equipment has been PAT tested within the last 2 years. Keep equipment dry by keeping hands dry. Do not put lamps near water, especially sea water. See separate electrical parts risk assessment. If person gets a burn, run tepid water over affected area for at least 10 minutes, and call a first aider. Switch off power at mains if you suspect an electrical problem. Call first aider if there is a casualty.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Sea water collection

Description: Risk from tide.

Affected People: Demonstrators

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrators only to collect sea water, and only if it is safe to do so (eg. don't go in a place where the tide is about to trap you). Cover cuts. Wash hands well afterwards. Ensure that if the volunteer gets wet they warm up properly. Contact GP should illness develop. Call a first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Check 1: 2015-01-11 - Arporn Wangwiwatsin (Koi) (aw584@cantab.net), **Check 2**: 2015-01-23 - Kym Neil (kym.e.neil@gmail.com)

Check 1: 2016-01-07 - Natalie Cree (nc434@cam.ac.uk), **Check 2**: 2016-02-11 - Craig Burns (cpb57@cam.ac.uk)

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Miscibility (Sugar Rainbows)

Make a rainbow in a glass - Explore the density of different sugary syrups and make a rainbow in the process.

Last initially checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-08 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Food colouring - range of colors
- Sugar
- Water
- Measuring cylinder or something equivalently long and thin
- Vegetable oil
- Other containers for mixing
- For ice part
- Plastic measuring cylinder
- Dyed ice cubes
- Castor oil

Experiment Explanation

Here's How:

Line up five glasses. Add 1 tablespoon (15 g) of sugar to the first glass, 2 tablespoons (30 g) of sugar to the second glass, 3 tablespoons of sugar (45 g) to the third glass, and 4 tablespoons of sugar (60 g) to the fourth glass. The fifth glass remains empty. Add 3 tablespoons (45 ml) of water to each of the first 4 glasses. Stir each solution. If the sugar does not dissolve in any of the four glasses, then add one more tablespoon (15 ml) of water to each of the four glasses. Add 2-3 drops of red food colouring to the first glass, yellow food colouring to the second glass, green food colouring to the third glass, and blue food colouring to the fourth glass. Stir each solution - might want to prepare the solutions before, depends how long this actually takes. If making or replenishing solutions while demonstrating, you can get children to stir (watch they don't eat it!). Now let's make a rainbow using the different density solutions. Fill the last glass about one-fourth full of the blue sugar solution. Carefully layer some green sugar solution above the blue liquid. Do this by putting a spoon in the glass, just above the blue layer, and pouring the green solution slowly over the back of the spoon. If you do this right, you won't disturb the blue solution much at all. Add green solution until the glass is about half full. Now layer the yellow solution above the green liquid, using the back of the spoon. Fill the glass to three-quarters full. Finally, layer the red solution above the yellow liquid. Fill the glass the rest of the way. The sugar solutions are miscible, or mixable, so the colours will bleed into each other and eventually mix. If you stir the rainbow, what will happen? Because this density column is made with different concentrations of the same chemical (sugar or sucrose), stirring would mix the solution. It would not un-mix, like you would see with oil and water.

Do they know about dissolving things? Especially if making the solutions with them, you might want to talk about salt in the sea and sugar in tea - how you can no longer see the bits of sugar but it's still there, just broken into smaller bits and surrounded by the water.

Explain that dissolving more sugar in the water leads to it being more dense. Ask if they know what that means, more mass per amount of volume, could say that adding more sugar to the water makes it have more mass but doesn't change how much space it takes up. Makes sense that the lighter ones will sit on top of the heavier ones.

It might be beneficial to show what happens if you add a more dense solution on top of a less dense one to see what happens (they just mix)!

Now repeat with oil and water, try stirring and see them separate out after a while. (You don't need a lot of oil to see this). See if they have any idea why we cannot mix the water and oil, hopefully some will same something like this is because they are unmixable. From here it will probably depend on audience how much you can explain but should try to explain what makes them not miscible, i.e. that one is polar and that the other is none polar, these terms will need explaining. MODEL FOR THIS.

Ask them to tell you what they can tell about the oil because it sits on top of the water. Encourage them to think about the sugar and water earlier. Hopefully some should be able to tell you that it is less dense.

Other ideas: A measuring cylinder filled half with castor oil, half with water, with blue ice cubes floating on the top. The ice melts and the blue water drifts down through the castor oil to sit on the meniscus.

Tips: Try to avoid using gel food coloring. It is difficult to mix the gels into the solution. Darker colours e.g. black can also cause problems when they bleed into the other colours so you can't see the rainbow.

Risk Assessment

Hazard: Solutions

Description: Solutions getting in eyes.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Pour solutions carefully so as to minimise splashing. Call first aider in event of incident. Use eyewash to wash out of eyes if trained and confident to do so.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Liquids and Sugar

Description: Drinking of solutions. Children may try to drink water/oil or eat the sugar.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Watch children carefully, donâ€™t allow them to do experiment unsupervised. Explain to children that they must not eat/drink anything used in any experiment. Call first aider in event of ingestion.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Ice Blocks

Description: Choking hazard

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Watch small children, and don't let them handle the ice. Do not let children do the experiment unsupervised. Call first aider in the event of an emergency.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Spillages

Description: Slip hazard from spillage.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep solutions in secure locations. Mop up any spillages immediately. Use wet floor sign if necessary. Call first aider in the event of an emergency.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Potential for Broken Glass

Description: Potential for cuts to children or demonstrator if glasses are broken.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Keep glasses away from the edge the table. Do not allow the children to play with the glass. If possible, use clear plastic beakers instead of glass. Call first aider in the event of an emergency.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

Check 1: 2015-02-12 - Tim Morgan Boyd (tmb58@cam.ac.uk), **Check 2**: 2015-02-13 - Joseph Hooton (jh795@cam.ac.uk)

Check 1: 2015-12-27 - Charis Watkins (czrw2@cam.ac.uk), **Check 2**: 2016-01-09 - Haydn James Lloyd (hjl43@cam.ac.uk)

Check 1: 2016-02-06 - Tim Morgan Boyd (tmb58@cam.ac.uk), **Check 2**: 2016-02-06 - Fiona Coventry (fiona.coventry@cantab.net)

Check 1: 2017-01-22 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2016-01-07 - Fiona Coventry (fiona.coventry@cantab.net)

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Monty Hall's Perplexing Goat

A wonderful experiment of probability involving a cuddly goat called Bertrand, a couple of coins, three doors, and three boxes. - A wonderful experiment of probability involving a cuddly goat called Bertrand, a couple of coins, three doors, and three boxes.

Last initially checked on 2023-02-15 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-03-16 by Lauren Mason (llm34@cam.ac.uk)

Tags

Probability

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- [Cuddly] Laminated goat called Bertrand
- Fair coin
- Coin with two Head's (also known as Bertrand's Coin)
- Three mini-suitcases of Bertrand (also known as boxes)
- Six coins, 3 gold, 3 silver (2 to go into each mini-suitcase)
- New contraption with 3 doors behind which Bertrand can hide (aka Bertrand's home)
- Marbles, in case committee have lost any (optional)

Experiment Explanation

WARNING: "This is written by an entirely mad CHaOS committee member a bit to close to Christmas. Please do the experiment however you want, and don't feel you need to imitate a goat or the style this is written in. This summary will give you some idea what is going on... A wonderful experiment of probability involving a cuddly goat called Bertrand, a couple of coins, three doors, and three boxes. It involves tossing a fair coin, and seeing how many heads you get in a row before getting a tail (and the probability distribution you get from that). It explains the Monty Hall Problem, and the importance of prior probabilities (three doors, with the prize behind one door). There are then more complex problems, involving three boxes, each with two coins inside them!"

Monty Hallâ€™s Goat (Bertrand)

Hello boys and girls. I said HELLO boys and girls

Hello Bertrand

That wasnâ€™t very loud now was it â€“ you can do better than that. HELLO BOYS AND GIRLS

Hello Bertrand

Deary me, you still seem to be hung over from the new year. I said **HELLO BOYS AND GIRLS** *HELLO BERTRAND*

Oh dear, oh dear, no need to shout. Honestly what are the young like these days. I think I should tell you a little bit about me before I got here. I used to have a job as a pantomime horse, but quit while I was a head.

So what is probability? Well it is the chance of something happening to you. What is the probability that I am going to give you Â£50000? Given that I am a goat with no worldly possessions, 0. What is the probability that I am going to be sitting on this table in 2 seconds time â€“ 100%. We can measure probability from a scale of 0-1, or multiply it by 100 to get

Right, now where did I put down my coin

Itâ€™s behind you

Oh no it isnâ€™t

Oh yes it is

Oh NO IT ISNâ€™T

Oh yes it is!

Oh yes, so it is. I thought you were just telling me my career was behind meâ€¦ Anyway, who wants a fun game where I make up the rule. How many times do I have to toss this coin before it I get a tail? Hands up for once. Hands up for twice. Anyone thinking I am going to get three heads in a row before getting a tail? Anyone more than that? What is the best one to go for? Well if you think about it, you have a 50% chance that it is going to be the first one. Then a 25% chance that I will get precisely one head followed by one tail, and then 12.5% two heads and then a tail. Three heads 6.25%, four heads 3.125% etcâ€¦ We can draw this in a tree diagram, and get some stick for thisâ€¦ Perhaps we ought to turn a new leafâ€¦ OK, are you ready for thisâ€¦ Drumroll please â€“ no no no â€“ I mean hit the drum with a stick in a rapid way, not roll the drums down the hill and of a cliff into water (bom bom tish). Right ready for this, here we goâ€¦.

[Bertrandâ€™s coin has two heads]

We have a head. Bad luck to those who said that you would get zero heads. Now let us see if the one headed people were correct

[Second toss]

No head again. What about two heads?

[Third toss]

Still a noâ€¦ Hmm that is unfortunate. Is Three a magic number?

[Fourth Toss]

No. Hmmm, letâ€™s keep going

[Fifth, Sixth, Seventh Toss, till]

You are cheating â€“ there is no tails on this coin

Oh No I am not

Oh Yes you are

Oh no I am not

Oh yes you are

Oh no I am not

Oh Yes you are

Oh well maybe you are right. Fine fine, spoil all my fun. Letâ€™s use an actual coin â€“ here you can check it does have a head and tail. Letâ€™s note down on a piece of paper what it will look like â€“ remember it is the number of heads we get before getting a tailâ€¦

[Paper should look like 0 â€“ iiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiii 1 â€“ iiiiiiiiiiiiiiiiiiiiiiiii 2 â€“ iiiiiiiiiiii 3 â€“ iiiiiii 4 â€“ iiiii 5 â€“ ii 6 â€“ i 7 â€“ 8 â€“ i 9 â€“]

Right, well you kids (in America) have had the time of your life tossing all those coins â€“ let us see if we can take tree diagrams just that little bit furtherâ€¦ This is now a Mony Hall Problem. Here is my house, which has three doors. I am going to hide behind one of themâ€¦ So which one am I behind?

[Kid picks one]

Ah wrong one. But how much chance did you have? Draw out a tree digram â€“ 1 in 3 chance, right? How much chance do you have of getting it right both times? Less right? Compared to not getting it right either time, a lot less, right? So then, let us place a variation, where this time I use my beautiful assistant

[Looks at demonstrator]

ARGH! You were not my beautiful assistant from last week. Where has he gone? What I am stuck with you? But you donâ€™t even have a beardâ€¦ Oh well, needs must I suppose, but do try and grow a beard for next time.

Right, so like last time, I am hiding behind one of the doors of my house [the one with three doors where they have no idea which one you put Bertrand (the goat behind)]. Pick one, but this time you donâ€™t get to open it yet.

Beautiful assistant, open one of the doors I am not behind. Right here is the tricky question â€“ you now have a chance to swap doors from your original choice â€“ should you swap or not? Does it make a difference?

OOoooooohhhhhhhhh â€“ thatâ€™s more like it â€“ audience participation and all that jazz. Take your time, think carefully. Does it matter??? Drum roll please NNNNOOOOOOOOO not another one down a hill and off a cliff (bom bom tish). Look, that is getting expensive. Anyway, so what is the answer. Surely it doesnâ€™t matter?

Firstly, my name is not Shirley, it is Bertrand. Secondly, it does matter. You should always swap. Donâ€™t believe me? Letâ€™s do it a few times, and see which action would have won you me (because heck, I am better to win than the demonstrator standing next door to me).

Swap - iiiiiiiiiiiii

Donâ€™t Swap - iiiiiii

So why do you win it about double if you swap than if you donâ€™t swap? Simples â€“ You have a two thirds chance of getting the goat rather than a one third chance. And no, I havenâ€™t suddenly become a well dressed meerkat. By the not-that-beautiful-but-still-helpful assistant (you can grow a beard one day, I have faith in you) removing the wrong choice out of those two, you get two choices for the price of one.

Right, my still-not-attractive assistant has got annoyed with me now, and has put on a pair of horns [put on devil horns]. In this one, I am hiding behind one of the three. You get to pick one door. Out of the other two doors, he will open one of the doors and take away whatever is behind it. He will always take away me if he can, else he picks randomly from the two doors. Should you swap, or not swap?

Swap - Donâ€™t sway - iiiiiiiiiiiiiiiiiiiiiii

You now only have a one third chance of getting me, and that is only if you picked me at first. If you didnâ€™t pick me, then you cannot get me. If you did pick me, then I am protected. Thus you should never swap

Right, remove those horns, and put on a halo instead. This time my wonderful-yet-not-bearded assistant allows you to choose one of the three doors. He then looks at the other two doors, and opens a door where myself (Bertard the goat) is not standing. He then ONLY offers you the chance to switch from your current door if it is beneficial i.e. if I am standing behind the door that you havenâ€™t currently selected. It is therefore always beneficial to switch

Right, remove that halo, and put on the Dunceâ€™s cap instead. This time, my brilliant-yet-lacking-facial-hair-clearly-showing-lack-of-intelligence instead randomly picks one of the other two doors without looking. There are therefore the following outcomes

Dunce picks the goat â€“ iiiiiiiiiii Donâ€™t swap to win â€“ iiiiiiiiiii Do swap to win â€“ iiiiiiiiiiii

Equal chance of all 3.

Thank you, thank you for the applause, (hint hint), but there is more, as I know you were all shouting for an Encore. Just before we do, do any of the rest of you want to grow facial hair? I always think a goatie is the pinnacle of fashion, being a goat myselfâ€¦

There is more!!! I now have three boxes sitting on the table, or mini-suitcases of mine, in case I want to go on holiday somewhere. Now in one of them, box GG, there are 2 gold coins, in another, box SS, 2 silver coins, and in a third, box GS, one gold and one silver coin. I can thankfully tell the difference through feel â€“ my optician recently told me I was colour blind. It was a real shot out of the orange. Hoorah! Hope you are not feeling all boxed in!!!

I want you to pick one random box â€“ good that one. Which box is it â€“ you have a 1 in 3 chance of guessing.

OK â€“ to make it easier I will pick out one coin at random and tell you there is one gold coin â€“ what is the chance of getting each box. OK â€“ you are predicting 50:50 between box GG and box GS. That is incorrect. Let us see what actually happens

Pick G out first Box GG â€“ iiiiiiiiiiiiiiiiiiiiii Box GS â€“ iiiiiiiiiii Box SS â€“

Pick S out first Box GG â€“ Box GS â€“ iiiiiiiiiii Box SS â€“ iiiiiiiiiiiiiiiiiiiiii

As you can see, if we combine both scenarios together, there is an even chance of getting any of the three boxes. But as if I pick out a gold coin it is twice as likely to be box GG rather than box GS, as box GG has two gold coins in itâ€¦

What, you want another encore? OK, here is the scenario, but before I do, did you know I have been married sixteen times! four richer, four poorer, four better, four worse. After the loss of each partner, I was down in the dumps and got a new hat. No wonder my hats always looked terrible.

Three CHaOS demonstrators, Alice, Bob and Charlie are sitting out the back. However, I want my house cleaned, and I need two demonstrators to do this. I have decided which two will need to do this, but havenâ€™t told any of them yet. Alice comes to me, and begs me to tell her one person who is definitely cleaning my house. I tell her Bob is definitely cleaning my house. She then goes and tells Charlie, believing that she now has odds of 0.5 of getting off cleaning my house. But Charlie believes that he now has odds of 0.6666 of not doing cleaning â€“ who is correct?

The answer is Charlie. Alice was guaranteed to be told someone who has to do cleaning, and so it hasnâ€™t affect her chances of having to do the cleaning. However, Charlie didnâ€™t, and so his chance of not doing the cleaning has gone up. Confused? Me too. Letâ€™s put this into a table

| Not cleaning | Me: "B cleaning" | warden: "C cleaning" | sum | | --- | --- | --- | --- | | Alice | 1/6 | 1/6 | 1/3 | | Bob | 0 | 1/3 | 1/3 | | Charlie | 1/3 | 0 | 1/3 |

So being told that Bob is cleaning means that Bob has a 0 % chance of getting off, and relatively Charlie has twice the chance than Alice of not cleaningâ€¦ Bob was the most depressed about this news, and ate 15 litres of low-fat yoghurt â€“ no wonder he was Mullered by the end of the dayâ€¦

Right, if you want further discussion, go and look at Bayes Theorem

https://en.wikipedia.org/wiki/Bayes%27_theorem

Thatâ€™s all folks! Now itâ€™s time to make my exit before anyone makes me their escape goat.

Sources:

https://en.wikipedia.org/wiki/Monty_Hall_problem https://en.wikipedia.org/wiki/Three_Prisoners_problem https://en.wikipedia.org/wiki/Bertrand%27s_box_paradox

PS By the way, you have spent the last twenty minutes talking to a goat â€“ I suggest you find your marbles once again!!!

Risk Assessment

Hazard: Coins

Description: Coins could go into people's eyes if flicked.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Keep control of coins. Call a first aider in the event of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Bertrand the Goat

Description: Goat or doors could be dropped and slipped on.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Make sure goat / doors are not on the floor. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Doors

Description: Paper cuts from overexcited kids grabbing the doors quickly

Affected People: Kids, but also anyone handling the doors

Before Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Mitigation: Keep the kids under control, watch they don't lunge for the doors etc. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Risk Assessment Check History

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Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-01-31 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2019-01-31 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2019-02-05 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2020-01-07 - Matthew Le Maitre (msl54@cam.ac.uk), **Check 2**: 2020-01-27 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-20 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2021-01-22 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk), **Check 2**: 2022-02-09 - Maggie Goulden (mcg58@cam.ac.uk)

Check 1: 2023-02-15 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02016 - Lauren Mason (llm34@cam.ac.uk)

Malaria, Mosquitoes, and Medicine: how we stop malaria from spreading

Talk to educate about mosquitoes and how we eradicated malaria

Last initially checked on 2023-02-16 by Amelia Ford (af727@cam.ac.uk) and double-checked on 2023-02-19 by John Leung (cfl35@cam.ac.uk)

Frequency of use: n/a

Tags

Talk (Lecture to be given at CBS)

Active

Biology

Equipment Needed

- Projector and visualiser
- Slides
- Mosquitoes IN CAGE
- Electric insect swatter
- Ointment

Experiment Explanation

The history of malaria, how mosquitoes spread it, and how we eradicated the disease

The risk assessment is for bringing in live mosquitoes to demonstrate the malaria vector and what I use in the lab.

The mosquitoes are **uninfected** by any malarias and non-native to the UK (not able to survive cold weather).

The mosquitoes are kept in a cage in the lab. I will take that cage and place it into a plastic box to transport the mosquitoes. They will also stay in the box at all times except when I take the cage out of the box for approximately 10 minutes for the demonstration after which I will replace the cage into the box.

I will be the only person to handle the box and the cage.

At no time will the mosquitoes be able to leave the cage.

Risk Assessment

Hazard: Live Anopheles Stephensi mosquitoes

Description: The mosquitoes could escape and bite someone (either children, their parents, or other members of the public), or establish a colony in the wild

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: The mosquitoes will only be handled by the demonstrator and their cage will be kept in another container outside of the 5 minutes or so of the demonstration. Use electric insect swatter so the demonstrator can quickly kill it. Ointment should also be brought to the session in case of bites.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2023-02-16 - Amelia Ford (af727@cam.ac.uk), **Check 2**: 2023-02-19 - John Leung (cfl35@cam.ac.uk)

Mould Effect (Self-Siphoning Beads)

Letting a chain pull itself out of a beaker under its own gravity - Why on earth do the beads have to go up to come down?! Watch them fly out of a beaker, looping and corkscrewing, and find out about the amazing Mould Effect!

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Physics

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **This experiment can take place outdoors**
- 25m chain of metal beads (in 5m sections)
- A shorter length of chain
- Lidded pot/beaker to store them in and siphon them out of
- Something to wrap the chain round (e.g a reel) in order to stop it getting tangled in storage.

Experiment Explanation

https://www.wired.com/2013/07/the-physics-of-that-gravity-defying-chain-of-metal-beads/

https://www.youtube.com/watch?v=6ukMId5fIi0

Method:

Place the chain inside the beaker, hold the beaker in your hand then throw one end over the side so that the end outside the beaker is longer than the section going between the top of the beaker and the coiled up chain (so that gravity is able to pull the rest of the chain out of the beaker). For the small plastic beaker currently in the box, 15cm works best.

Let go and watch as the rest of the chain flies out of the beaker, producing a surprisingly wide arc into the air as it goes. If you're lucky you may see coils and loops, appearing to be frozen in space even as the chain continues to move.

Explanation:

The weight of the chain outside the beaker is greater than that of the free section inside the beaker, so the chain is pulled out, at some speed. However, due to Newton's 1st and 2nd laws, the individual beads of the chain can't change direction instantaneously. Instead, it takes a continuous force pulling them round in a circle until they are travelling downwards towards the floor - hence the arc.

If the chain hits the side of the beaker as it's doing this, the disturbance will attempt to travel away from the point of contact - i.e. back towards the bottom of the beaker. However, the chain is moving fast enough to counteract this, and so the net effect is that this disturbance barely moves. This is the reason for the standing coils and loops you might observe (it may be that the wave velocity equals the speed of the chain at this point, but I'd have to check this).

Further Points: You could try drawing an analogy with siphoning a liquid using a long hose/straw.

Floating This experiment can work well for floating however, you'll want to use the short chain and be careful not to fiddle while carrying it else you'll tie it in knots. 2 goes is probably sufficient for a 5 minute demo and ask them to think about the forces, gravity and acceleration before trying it. Bring in momentum for advanced groups and talk about needing all the beads to move at the same speed and how they can't change direction instantly. Analogy with running round a corner and needing a wide bend to keep the same speed (400m running track).

Risk Assessment

Hazard: Beaker

Description: The beaker may fall and hit someone.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Do not hold directly above anyone. Do not use glass beakers; use plastic to avoid any cuts.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 4

Hazard: Beads

Description: The beads may hit someone.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ask audience to step back (at least 1m) to avoid being hit and hold the beaker away from your body. If standing elevated to demonstrate then ask audience to stand back further. Do NOT carry out in a crowded space. Make sure audience is paying attention. Pick up the beads yourself after it finishes, do not let children play with it.

In case of injury, call a first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Beads

Description: The beads present a strangulation risk. Either through latching onto someone or children playing with them.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Ask audience to step back (at least 1m) to avoid being hit and hold the beaker away from your body. Do NOT carry out in a crowded space. Make sure audience is paying attention. Pick up the beads yourself after it finishes, do not let children play with it.

In case of injury, call a first aider.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Chain on floor

Description: Trip hazard due to beads on floor.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Tidy up the beads as soon as the demonstration finishes. Ask viewers to step back until you're done. Potentially siphon beads into a large tray.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Chain

Description: If swallowed the chain presents a choking hazard.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Do not let anyone play with the beads or place them in their mouth.

If a long length has been swallowed, do NOT attempt to pull it back out, but cut off the free end. Call a first aider.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Nickel

Description: Possible allergic reactions.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Do not let anyone play with the beads or place them in their mouth. Check with audience that none are allergic to nickel. Do not demonstrate if you are allergic to nickel. Call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Heights

Description: Demonstrator falls from chair/high place.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Do not climb onto very high places; a step or perhaps a chair (if safe) is plenty. If standing on a chair or at the top of steps then ensure firm footing and descend before explaining. Do not climb onto tables or other high places. Only do one elevated demonstration per group to avoid getting on/off the chair whilst distracted by explaining.

Call a first aider in case of emergency.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2018-01-26 - Sarah Wiseman (sw628@cam.ac.uk), **Check 2**: 2018-02-03 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk)

Check 1: 2019-01-02 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-02 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-01-19 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-01-19 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2021-01-19 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2021-01-19 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-02-09 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2022-02-09 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2023-01-12 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-13 - Johan Kidger (jpk51@cam.ac.uk)

Near IR webcam

Use a modified webcam to see into the near infrared. - There's a whole spectra of light beyond the visible, why not see one side of it through a modified webcam?

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Darkroom needed**
- **Electricity needed**
- Laptop
- Small grey box containing:
- Webcam (modified)
- Lights (Incandescent and compact fluorescent)
- Coke
- CD
- Shaver (blades removed)
- Paper with CHaOS logo written with different pens
- Paper with words written one with letter in different pens which contains a hidden message
- Small white remote control

Experiment Explanation

What is it?

Take a normal webcam, remove the IR filter and replace it with crossed polars or a piece of exposed colour film and hey presto you have a near IR camera. Practical point: the webcam has a focusing ring in front of the lens, which may be turned during an event, causing the image to become blurred. If this happens, ask a committee member to show you how to focus it (there is a knack, and if you do it wrong you can jam the focus).

What is light/ IR light?

The light most of us are really familiar with is white light. But that's actually a mixture of different colours. Most of the time we can't tell that, but sometimes we can see these colours split up, like in a rainbow.

Do you know the colours of the rainbow? Ask them to tell you! [Red -> Orange -> Yellow -> Green -> Blue -> Indigo -> Violet (basically purple!)]

It turns out that there are more kinds of light than our eyes can see. Some kinds of light are "redder" than red is - we call that kind of light "infra-red" . You might have seen images from cameras that can detect this kind of light, perhaps watching animals at night on TV, or police chase criminals with helicopters. At the other end of the rainbow there are other kinds of light that we can't see. These are more blue / more purple than violet, and we call this kind of light "ultra violet".

It's weird to think that there are kinds of light we can't see, but not all kinds of eyes detect the same light. For example, some people can't tell red and green apart, which is called "colour blindness". Another example: some insects, such as bees, can see UV light. Some types of flowers have extra patterns in UV, so this helps them find the nectar in the middle of a flower! (How cool is that?!)

But what about wavelength/ spectra?

Add this extra level of detail with caution: it can be too much detail to take in if they've never thought about IR/UV before, and you can overwhelm them. You can come back to this later on once you'rve showed them some of the cool things you can see with the IR camera!

EM Spectrum: we call all the kinds of light (including UV, IR, visible) "electromagnetic radiation". One way of understanding this is to say that all these kinds of light have different sizes of wavelength. There are some charts in the box that you can point at when you explain this. Start with the rainbow: Red light waves are wider/longer than blue light waves. Following on from that, infra-red has longer waves than red light; UV has a shorter waves than blue. If you go further outside that you can see microwaves (that you can cook with) and radio waves (which can hold information, like music). These have a longer wavelength, much longer than infra-red. If you go the other way you get to X-rays - these have smaller waves than UV!

What do I look at with the camera?

Firstly, plug the *new* camera into a laptop and use VLC player (open up the video devices settings and select USB input owtte). [Or maybe do ->Open Capture Device (Ctrl+c)-> PC Camera this sometimes also works] [The camera often lags or gets stuck, the best solution is closing and reopening VLC]

Things to look at:

Coke is transparent, as are some plastics (shaver casing, sample of smoked glass).

Bank notes have lines. Try looking at the Queen's head on a Â£5 or Â£20 note (old ones or new polymer ones both have the same effect!)

CD can be used as a diffraction grating to produce a 'rainbow' - shifted position.

Incandescent vs compact fluorescent - about the same luminosity in visible, former is much brighter under IR (Note: This looks more convincing if you give the fluorescent bulb 30 seconds or so to reach full brightness).

Different materials - some black clothing appears white under IR, often patterns on clothing disappear.

On the paper with the CHaOS logos, one shows up in IR and the other doesn't (written in different pens) - there is also the Normal/IR vision one with the same effect.

The laptop screen appears blank.

Remote control- uses IR, point at the camera while pressing buttons. Many camera phones lack IR filters so can test this on parents phone use it to see light from the end of the remote control.

Crookes' Radiometer

A Crookes' radiometer has four vanes suspended inside a glass bulb. Inside the bulb, there is a good vacuum. When you shine a light on the vanes in the radiometer, they spin -- in bright sunlight, they can spin at several thousand rotations per minute!

The vacuum is important to the radiometer's success. If there is no vacuum (that is, if the bulb is full of air), the vanes do not spin because there is too much drag. If there is a near-perfect vacuum, the vanes do not spin unless they are held in a frictionless way. If the vanes have a frictionless support and the vacuum is complete, then photons bouncing off the silver side of the vanes push the vanes, causing them to rotate. However, this force is exceedingly small.

Over the years, there have been many attempts to explain how a Crookes radiometer works: Crookes incorrectly suggested that the force was due to the pressure of light. This theory was originally supported by James Clerk Maxwell, who had predicted this force. This explanation is still often seen in leaflets packaged with the device. The first experiment to test this theory was done by Arthur Schuster in 1876, who observed that there was a force on the glass bulb of the Crookes radiometer that was in the opposite direction to the rotation of the vanes. This showed that the force turning the vanes was generated inside the radiometer. If light pressure were the cause of the rotation, then the better the vacuum in the bulb, the less air resistance to movement, and the faster the vanes should spin. In 1901, with a better vacuum pump, Pyotr Lebedev showed that in fact, the radiometer only works when there is low-pressure gas in the bulb, and the vanes stay motionless in a hard vacuum. Finally, if light pressure were the motive force, the radiometer would spin in the opposite direction, as the photons on the shiny side being reflected would deposit more momentum than on the black side where the photons are absorbed. This results from conservation of momentum - the momentum of the reflected photon exiting on the light side must be matched by a reaction on the vane that reflected it. The actual pressure exerted by light is far too small to move these vanes but can be measured with devices such as the Nichols radiometer. Another incorrect theory was that the heat on the dark side was causing the material to outgas, which pushed the radiometer around. This was effectively disproved by both Schuster's and Lebedev's experiments.

A partial explanation is that gas molecules hitting the warmer side of the vane will pick up some of the heat, bouncing off the vane with increased speed. Giving the molecule this extra boost effectively means that a minute pressure is exerted on the vane. The imbalance of this effect between the warmer black side and the cooler silver side means the net pressure on the vane is equivalent to a push on the black side and as a result the vanes spin round with the black side trailing. The problem with this idea is that while the faster moving molecules produce more force, they also do a better job of stopping other molecules from reaching the vane, so the net force on the vane should be the same.

The greater temperature causes a decrease in local density which results in the same force on both sides. Years after this explanation was dismissed, Albert Einstein showed that the two pressures do not cancel out exactly at the edges of the vanes because of the temperature difference there. The force predicted by Einstein would be enough to move the vanes, but not fast enough.

The final piece of the puzzle, thermal transpiration, was theorized by Osborne Reynolds in an unpublished paper that was refereed by Maxwell, who then published his paper which contained a critique of the mathematics in Reynolds's unpublished paper. Maxwell died that year and the Royal Society refused to publish Reynolds's critique of Maxwell's rebuttal to Reynolds's unpublished paper, as it was felt that this would be an inappropriate argument when one of the people involved had already died. Reynolds found that if a porous plate is kept hotter on one side than the other, the interactions between gas molecules and the plates are such that gas will flow through from the cooler to the hotter side. The vanes of a typical Crookes radiometer are not porous, but the space past their edges behaves like the pores in Reynolds's plate. On average, the gas molecules move from the cold side toward the hot side whenever the pressure ratio is less than the square root of the (absolute) temperature ratio. The pressure difference causes the vane to move, cold (white) side forward due to the tangential force of the movement of the rarefied gas moving from the colder edge to the hotter edge.

There are lots of cool things to look at according to this: http://www.hoagieshouse.com/IR/

Link to UV

This experiment often links well if placed near UV or demonstrated as a pair. You'll find the lights in IR can be too bright to see UV florescence. If separate demonstrations try and place slightly further apart or use the boxes as a screen if paired then switch off when moving across.

Risk Assessment

Hazard: Lightbulbs (glass)

Description: If the lamps are knocked over, the bulb may shatter and cause cuts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Take reasonable level of care with lamps. Do not place near desk edge. Prevent children playing with lamps. Call first aider in case of injury

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Incandescent light

Description: Incandescent light gets hot if left on, causing burns or possibly fire.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Do not allow children to touch lamps, do not place too near the darkroom wall, or any flammable object. Turn off between demonstrations.

In the event of broken glass, move public away and clear up mess carefully as soon as possible. In the event of injury, call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Fluorescent bulb

Description: Compact fluorescent bulb contains (very small) quantity of mercury.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Ensure lamp is stable and not easy to knock over. Consider using LED bulb rather than fluorescent bulb for the energy efficient one if available. If lamp becomes broken, keep the public well away from the area, and ventilate area where breakage occurred. Take usual precautions for collection of broken glass. Do not use a standard vacuum cleaner for cleaning up dust; instead, pick up pieces/dust with a damp cloth or damp paper towels, or sticky tape for the smallest dust. Place materials, including the cloth/towels, in a sturdy closed container to avoid generating dust. After you have picked up all that you can, then vacuum the area. Finally, ventilate the room where the breakage occurred.

Call first aider in case of injury

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Lightbulbs turned on in a darkroom

Description: Lightbulbs can appear very bright when just switched on in dark room. Eyes are not used to that brightness, so children may be dazzled.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 1, Overall: 3

Mitigation: Warn children/visitors not to look directly into the lamps when you switch them on.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Hazard: Electrical cables

Description: Trip hazard.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Try to keep cables out of thoroughfare. If cables must be placed somewhere people are likely to be walking, tape them down.

Call first aider in case of injury

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Out-of-date Coke

Description: Children may drink the Coke â€“ possible stomach upset.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Do not let children drink the Coke. In the event of drinking, call first aider. Coke bottle is sealed with tape.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Crooke Radiometer

Description: May fall and smash - possibility of cuts

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep excitable children away from the radiometer. Don't let them touch the radiometer - there's no need to. Keep it in a safe place, either in sight, or away and consider taping down. If the radiometer does smash, clear up immediately and clear the area until safe.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-13 - Anna Kalorkoti (anna.kalorkoti@cantab.net)

Check 1: 2014-01-21 - Holly Davis (hd308@cam.ac.uk), **Check 2**: 2014-01-22 - Brett Abram (ba305@cam.ac.uk)

Check 1: 2015-01-04 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-07 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

Check 1: 2016-12-29 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2017-02-01 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk)

Check 1: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk), **Check 2**: 2018-01-17 - Lucy Hart (ljfh2@cam.ac.uk)

Check 1: 2019-01-01 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-01 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-01-05 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-01-16 - Jean Pichon (jp622@cam.ac.uk)

Check 1: 2021-01-20 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2021-01-20 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-01-23 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-01-30 - Lavinia Finalde Delfini (lf465@cam.ac.uk)

Check 1: 2023-01-12 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-13 - Johan Kidger (jpk51@cam.ac.uk)

Non-Transitive Games

What's the best option in games of chance? - Some games really aren't fair. Even if your opponent knows your exact move you can still beat them. Explore some of these games and find out there might not be a sensible best choice.

Last initially checked on 2023-02-15 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-16 by Lauren Mason (llm34@cam.ac.uk)

Tags

Games

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- A set of Grimes Dice (currently dots are drawn on, hopefully engraved/painted in future)
- General Dice
- (There's also a set of Effron Dice in the box too)

Experiment Explanation

There should be a set of dice in the box with the following numerals red - 9,4,4,4,4,4 blue - 7,7,7,2,2,2 olive - 5,5,5,5,5,0 (They're slightly larger than normal so we can move onto 5 dice later using the same ones) Take turns with your opponent to pick a dice and see who can roll the highest number. Try a best of three or five to decide which dice to pick, if they pick first you can always beat them. What you'll find is Red > Blue > olive > Red. Get them to construct two of the chain and ask them to guess what happens with the third pairing. Most will think that it's going to be transitive and Red will beat olive, however it isn't! Easy way to remember the order is increasing word length. Any easy way to relate this is to rock, paper, scissors. Here Rock > Paper > Scissors > Paper. When we pick at different times this games becomes very unfair. With the dice there's no certainty but you can explain by playing multiple times you make it more likely. You can take some maths and try and work out the winning probability. Red beats Blue if we get a 9 straight away, that's probability 1/6. If we get a 4, 5/6 probability, then we win when Blue gets a 2, probability 1/2, these are 'independent events' so we can get a total probability of 1/6 + 5/12 =7/12 > 1/2. You find this is the same for all pairings. If they've understood flip it around and let them beat you. Then move to two dice and keep going first. You'll want to increase the number of rolls to make it a best of 5 at least. You'll notice that in fact the order swaps around when you look at the totals. It should decrease to about 57%. Lets add in 2 more dice. We want to be able to beat 2 players simultaneously yellow - 8,8,3,3,3,3 magenta (pink) - 6,6,6,6,1,1 There's an alphabetical chain and a word length chain. Alphabetical chain has a higher win probability if there's only one player. If there's two you can find a unique dice to beat both. This analogues Rock,Paper, Scissors, Lizard, Spock (from The Big Bang Theory TV show) with new rules Scissors cuts Paper, Paper covers Rock, Rock crushes Lizard, Lizard poisons Spock, Spock smashes Scissors, Scissors decapitates Lizard, Lizard eats Paper, Paper disproves Spock, Spock vaporises Rock, (and as it always has) Rock crushes Scissors. In this game the doubling of dice reverses the word length chain and the alphabetical chain remains more or less the same apart from the fact red and olive flips technically but remains very close to 50-50. Overall 59% win chance. For beating two players we're at 44%. You may think that's bad as you still lose fairly often but you only lose to both 22.7% of the time. Consider a game where both opponents pay Â£1 and you'll pay out Â£1 to anyone who rolls higher. For 100 rolls you make Â£88 on the games you beat both on 44 rolls, lose Â£46 when you lose to both on 23 rolls and the rest of the time you make nothing (but don't lose anything either). So you're Â£42 in profit!

Inspired by the experiment here: http://singingbanana.com/dice/article.htm

We now have several addition sets of Microsoft-branded dice with the following colour combinations (see aka.ms/ntdice): Orange - 2,2,2,2,6,6 Yellow - 3,3,3,3,3,3 Green - 1,1,1,5,5,5 Blue - 0,0,4,4,4,4 such that G>B>Y>O>G...

If you have a spare table this is a very easy experiment to float with by only going up to the Rock-Paper-Scissors part of the experiment. Demonstrate you can always win and sometimes "better than" isn't transitive.

Risk Assessment

Hazard: Dice

Description: Children swallowing or choking on dice.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Don't use with small children and keep the dice attended. Call first aider if child swallows, if choking encourage child to cough.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Dice

Description: Dice could be a slip hazard if dropped on floor.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Keep an eye on where any dice go, and try to confine them to a desk or fixed area. Do not let multiple unattended children use dice at the same time. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2017-02-09 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2017-02-11 - Fiona Coventry (fiona.coventry@cantab.net)

Check 1: 2018-01-02 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2020-02-05 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2020-02-05 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-22 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-05 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk)

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Oil and Pyrex

Using the refractive index of vegetable oil to make a glass bowl 'disappear'. - Ordinary glass objects seem to disappear as you submerge them in a bath of oil. This experiment is spectacular and very messy!

Last initially checked on 2023-01-29 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-01-29 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- 2 pyrex bowls (1 big, 1 small)
- Vegetable oil (note: works less well/not at all if other types of oil are used)
- Paper towels
- Sodium polyacrylate spheres - optional
- Pure water - optional
- Coffee jar with pre-prepared spheres - optional
- Rope to illustrate wavefronts/boundaries -optional
-
- USED TO contain the box for Waves at Boundaries, which should in turn contain
-
- A wave model
- Plasticine for weights
- Clamps

Experiment Explanation

What to do

1. Fill the large bowl with oil.
2. Parts of the smaller bowl which are fully surrounded by the oil become invisible - you can either pull the bowl out of the oil, or put a bowl in, the effect is the same.

Why this works

Glass is see-through, so how come we can see things made of glass at all?

It's all down to the fact that light travels through glass and air at different speeds. [1] When light moves from one material to another, it changes direction (refraction). When we look at a glass object, we don't see the glass itself, we see the bending of the light from objects behind it. [2]

Light travels through vegetable oil and pyrex glass at the same speed: they are said to have the same *refractive index*. When the Pyrex bowl is surrounded by oil, light passing though them doesn't change speed, and hence doesn't change direction, as it moves into the different materials. You don't have any way of seeing the smaller bowl, you only see the edge of the oil or the outer bowl.

Why does the light bend?

If the wavefronts of the light hit the interface at an angle, then one end ends up moving more slowly than the other end. This makes the light bend. This is really an example of Huygens' principle of wavelets.

Go and see the water-tank experiment for a hands-on demonstration of refraction.

(For a better explanation, take a look at the Making Pyrex Invisible experiment on the Naked Scientists).

I like to talk about this by getting the audience to consider how fast they would go in really sticky mud as opposed to on a well-made path. Then, lay some rope for a boundary and get them to hold another piece as a wavefront. Have them walk towards the boundary at an angle so one foot crosses first then say that foot is "stuck" - hopefully they will turn, carrying the wavefront with them!

If the balls have been prepared...

The same effects can be observed using sodium polyacrylate spheres in pure (de-ionised/distilled) water. Sodium polyacrylate is a super-absorbent polymer which can absorb a few 100 times its own mass in water - hence it effectively has the same refractive index as water. The spheres take a few hours to absorb the required quantity of water so this part can only be done if the spheres have been pre-prepared.

In a non-cross linked form the polymer absorbs water much more quickly but sadly isn't transparent. This form is used in baby nappies.

Waves at Boundaries (for older visitors)

At CHaOS+ events, or if you are confident at public events, this can be used to demonstrate how waves change speed indifferent mediums. To set up, clamp the wave model between 2 tables and add weights to skewers on one end. Playing around with this you should be able to see reflected waves and a noticeable change in wave speed at the boundary.

[1] The "speed of light" is defined in a vacuum; in denser materials it travels slightly more slowly. [2] And any impurities in the glass - this is why most glass is green if you look at it side-on. Optical glass (for optical fibres, etc) is much higher purity.

Risk Assessment

Hazard: Vegetable oil

Description: The oil is very slippery, and could cause a nasty slip hazard if spilled.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Be very careful to minimise the chance of this happening, probably use a towel on top of a plastic sheet to contain any small spills if it is done inside. Mop up any spills carefully. Use slip hazard sign. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Pyrex Bowl

Description: If the Pyrex bowls broke they would be sharp and could result in cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Check for cracks before starting demonstrating. If the Pyrex does break, dispose of it carefully. Be especially careful of any pieces that are in the oil as they will be INVISIBLE, so it is better to pour the oil out rather than fishing for them. In the event of an accident call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Sodium polyacrylate spheres

Description: Children eating sodium polyacrylate spheres and spheres bursting/choking hazard if children swallow spheres.

Affected People: Demonstratees / Bystanders

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Ensure only one child is 'investigating' the spheres at a time so that they can be monitored. If they burst the sphere ensure that they don't rub their eyes and that they wipe their hands. Call a first aider in the case of an injury, who may perform an eyewash if trained and happy to do so.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Skewers

Description: Ends of skewers could be sharp (could stab/cut people)

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Don't set up in a high-traffic area (where people might walk through it), and make sure people don't lean in close. Ends of skewers have plastic on, so should be non-issue. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Hazard: Swallowing sweets/marshmallows

Description: Audience could try to eat them, which is unsanitary.

Affected People: Demonstratees

Before Mitigation: Likelihood: 2, Severity: 2 Overall: 4

Mitigation: Keep an eye on children, and mention not to eat the sweets or Plasticine In the event that something is eaten, warn parents/relevant adult.

After Mitigation: Likelihood: 1, Severity: 2 Overall: 2

Risk Assessment Check History

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Optical Illusions

Display of several optical illusions, to illustrate the way the brain perceives certain visual stimuli - Confusing our brains and eyes.

Last initially checked on 2023-02-15 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-15 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- **Darkroom needed**
- Various optical illusions (laminated sheets)
- Optical Illusion Book

Experiment Explanation

IN GENERAL:

These optical illusions are best used with the eye model/blind spot test. Some explanations may be a little difficult for younger children.

STROOP EFFECT

To do:

â€¢Get the kids to read out the colour of the words (tell them specifically that they should not read the actual words) â€“ first with the sheet where the colours and words match, and then on the sheet where they donâ€™t â€“ and time them (or get their friend/sibling to time them if youâ€™re working with more than one child) â€¢Is there a difference? (Hopefully it will take them longer to say the one where the names and colours donâ€™t match!) â€¢Ask them why this might be â€“ basically, the words have a strong influence over your ability to say the colour â€“ the interference between the different information (what the words say and the colour of the words) your brain receives makes it more difficult â€¢Couple of different theories â€“ words might be read faster than colours are named (speed of processing theory) or possibly naming colours requires more attention than reading words (selective attention theory) â€¢Might be quite nice to do this comparing very young children with older ones if possible â€“ might expect that younger children, who are less confident at reading, might experience less interference and therefore see less difference in their times

Extra stuff:

â€¢There is some evidence that the anterior cingulate area/dorsolateral prefrontal area might be active while performing the Stroop test â€“ thought to be important for conflict monitoring/resolution â€¢You can see similar effects if youâ€™re scared of spiders and the words are related to spiders e.g. â€œhairyâ€ and â€œwebâ€ â€“ it takes you longer to read the colours of these words than a set of neutral words. Again, this is thought to be because the scary words grab your attention too much and slow you down.

CHECKERBOARD SHADOW ILLUSION

To do:

â€¢Very simple â€“ ask the child if squares A and B are the same colour (probably will say they arenâ€™t) â€¢Then show them second picture â€“ they are! â€¢If still not convinced â€“ might be worth making a mask with holes in the appropriate places so you can see that they are in fact the same

Explanation:

â€¢Visual system needs to determine the colour of objects in the world â€¢Has to take into account shadows â€“ a white surface in shadow might be reflecting less light than a black surface in full light â€¢Visual system uses several tricks to determine where the shadows are and how to compensate for them â€¢First trick â€“ check that is lighter than neighbouring checks is probably lighter than average, and vice versa â€¢In figure â€“ light check in shadow is surrounded by darker checks â€“ even though check is physically dark, it is light when compared to its neighbours â€¢Dark checks outside shadow â€“ surrounded by lighter checks â€“ look dark by comparison â€¢Second trick â€“ shadows often have soft edges, while paint boundaries (like the checks) often have sharp edges â€¢Visual system tends to ignore gradual changes in light level so that it can determine the colour of the surfaces without being misled by shadows â€¢'Paintness' of checks â€“ aided by form of â€œX junctionsâ€ formed by 4 abutting checks â€“ this type of junction is usually a signal that all the edges should be interpreted as changes in surface colour rather than in terms of shadows or lighting â€¢Effect really demonstrates successes rather than failure of visual system â€“ visual system not very good at being a physical light meter â€“ but that is not its purpose â€“ important task is to break image information down into meaningful components and thereby perceive the nature of objects in view

HERMANN GRID ILLUSION

To do:

â€¢Stare at the central intersection of white lines â€¢Black dots appear to flash in the peripheral intersections of white lines but not in the one weâ€™re staring at

Explanation:

â€¢Complicated â€“ probably more for older children/adults â€¢Lateral inhibition between centre and surround of receptive field (analogy of positive and negative numbers â€“ if you have the same amount of both, they cancel each other out. Light hits the receptive fields â€“ the particular pattern of activity determines what information is transmitted to the rest of the brain) â€¢Receptive field that lies at the intersection of the white cross has more light falling on its inhibitory surround than does receptive field that lies between 2 black squares (see lower bit of diagram) â€“ excitatory centre of receptive field between squares yields a stronger response than that which lies at intersection of white cross â€¢Upper part of diagram â€“ receptive fields in central fovea â€“ much smaller than rest of retina (as we have lots and lots of receptors here)â€“ so in all cases, both the centre and surround are completely in the white sections, and you donâ€™t see the illusion at the intersection where you stare

YOUNG GIRL AND OLD WOMAN (or other similar illusions)

To do: â€¢ Duck or rabbit? â€¢ Native American Indian or Eskimo? â€¢ Girl or woman?

Explanation:

A lot of optical illusions are caused by ambiguities in 'perception'. Our eyes contain receptors that send signals to our brain about the light that we see. 'Perception' is how our brain interprets these signals and tries to make sense of them. Where there are ambiguities in perception there can be more than one interpretation of what we see, this is whatâ€™s happening here. The lines and shapes of an image have two different meanings depending on which perception you have at that particular moment. E.g. what is the young woman's chin is the tip of the old woman's nose. Once you see both interpretations, you cannot see only one of them. The other will keep "popping" into your vision from time to time.

NECKER CUBE (and similar)

To do:

â€¢Is the red dot inside or outside the cube? â€¢Cube appears to flip â€“ sometimes appears to be inside, sometimes appears to be outside â€¢(The other one is similar â€“ perceptual flipping â€“ get them to try with this one when they have seen the â€œflippingâ€ with the Necker cube)

Explanation:

â€¢The drawing is obviously 2D â€“ but our brains automatically perceive it as a 3D cube â€¢However, the drawing does not give enough information for the visual system to know exactly which face of the cube is at the front â€¢Makes the point that what we see is merely a â€œbest guessâ€ made by our visual system (the 2 different orientations can be thought of as 2 different hypotheses that the brain selects between)

If you can get hold of a computer â€“ there is a really nice spinning female silhouette illusion as well which makes this point even more nicely (http://www.flavor8.com/images/spinningwoman.gif) You have to stare for a while â€“ but she should suddenly start rotating in the opposite direction! If you have a group, you could also ask which way they start seeing the figure rotating and see if any way (clockwise or counterclockwise) is more popular than any other.

Risk Assessment

Hazard: Display boards

Description: It is possible that the display boards could fall on someone.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Use light professional display boards so they are not too heavy. Make sure the display boards are stable. Do not use them flat without taping them to something solid. Mark boards with highly visible stuff (e.g. hazard tape, white paper) if they are being used in the dark room. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Hazard: Optical Illusions

Description: Children might get dizzy / feel strange after staring at some illusions. Could result in feeling ill, or wandering into walls / hitting things.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Monitor everyone, and stop if someone seriously expresses discomfort.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

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Organ Vest

A velcro apron with detachable 3D organs, to show what's inside your body. - See if you can correctly place body organs using this wearable felt and velcro vest.

Last initially checked on 2023-02-15 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-15 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Apron
- Organs as listed below.

Experiment Explanation

This game can be tailored to the particular child, and depending on how old they are you can just either ask them to put the organs in the right place, or talk about each one in a little more detail.

I usually do the organs in the following order (getting more difficult as the game progresses) and talk about/ask the child what each one is for:

HEART: Ask them to look at the colour and guess what goes inside it. Tell them that it acts as a pump, and is needed to push blood around the body.

Keen: could go into why blood is needed etc. Ultra keen, try and grab a spare stethoscope and find their their heart beat at the appropriate place.

LUNGS: Talk about breathing; try and get them to link up lungs to the mouth with the trachea (NB trachea does not currently exist as a component of the vest, but you can talk about it anyway!). Interesting fact: If the inner surface of the lungs could be stretched out flat, they would occupy an area of around 80 to 100 square meters â€“ about half of a tennis court!

DIGESTIVE SYSTEM: Try and get them to link it all up, and explain what it does in terms of breaking your food down into smaller bits so it can be used to re-build things inside your body. Also talk about what happens in the end, and try and get them to guess what it comes out as (usually good for getting a giggle, but be warned sometimes the kids come up with very rude words much to the embarrassment of everyone around...)

KIDNEYS/ BLADDER: Get them to link them up and talk about what happens when you drink too much water etc. Get them to try and guess what's in the bladder by its colour (also often gets another giggle). A surprising number of kids know about kidneys, or at least that they exist- ask them about why there are 2, whether they think we could survive with just 1-some may know people who have had kidney transplants etc.

LIVER: Difficult one to explain. I usually go along the lines of it's like a big factory in your body where things are broken down and important things like stuff in your blood is made. Ultra keen: talk about it also being needed to break things like poisons and alcohol, and try and mention what might happen to the liver for instance in alcohol poisoning.

INTERESTING FACTS / TIPS: Small intestine is 7m long, but is coiled up to fit inside the body. Furthermore, due to villi total surface area is 2000 square meters = half a football pitch.

By the time you turn 70, your heart will have beaten two-and-a-half billion times (figuring on an average of 70 beats per minute) = 175 million litres of blood = 50 Olympic swimming pools!

The liver is able to regenerate to a certain extent, so you can donate part of your liver and the donor and acceptor will both be fine.

Risk Assessment

Hazard: Vest

Description: Risk of small children tripping on apron whilst wearing.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Do not allow children to run around while wearing vest. Be more aware if vest is especially long on the child. In case of accident, call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Vest used by multiple children

Description: Germs could spread between children using the vest

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Don't let children lick the items / the vest. Wipe off spit etc if child drools over vest.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2012-01-11 - Elizabeth Mooney (erm40@cam.ac.uk), **Check 2**: 2012-01-23 - Ashley Smith (ashley.smith@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

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Outdoors

Read before doing any experiment outside -

Last initially checked on 2023-02-19 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-19 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

Other

Outside (Recommended to demonstrate outside at CBS - see separate risk assessment)

Equipment Needed

An outside area

Experiment Explanation

Some experiments can be demonstrated outside. Read this RA along with the experiment RA before demonstrating outside.

Risk Assessment

Hazard: Hard and potentially uneven floor

Description: Risk of potentially enhanced injury if person falls over whilst engaging with experiment.

Affected People: All, particularly children

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Ensure the experiment is set up on flat floor, away from potential trip hazards (e.g. steps) or drops (e.g. gutters). If experiment involves lots of motion (e.g. spinny chair), take extra care while supervising visitors, and do not leave the experiment unattended. If the experiment is to be held and carried around (e.g. floating experiments such as prism goggles) then demonstrator should ensure that the experiment is being done safely, avoiding e.g. accidentally walking into a gutter.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Weather (Part I)

Description: Rain and/or ice could make the outside floor slippery. Wind could blow objects into people or push visitors off of relevant apparatus.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: >In the event of adverse weather, encourage children to behave sensibly and not run about. If the demonstrator or committee deem the weather to make the experiment too dangerous to operate, close the experiment (e.g. too windy or wet).

After Mitigation: Likelihood: 1, Severity: 4, Overall: 3

Hazard: Weather (Part II)

Description: Cold / hot weather causing adverse effects to visitors or demonstrators

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Demonstrators should be dressed appropriately for the weather. If hot, demonstrators should seek water from committee members. If cold, demonstrators should have sufficient layers. If very uncomfortable, demonstrators should be moved inside. Visitors should also be monitored, and offered e.g. water if severely affected by the weather.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Crowds

Description: There will be a queue of people nearby, and people walking in and out of the area, posing a risk of being bumped into / invading experiment spaces.

Affected People: All (mainly visitors)

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Experiments should be set up far enough away from each other such that there is minimal risk of visitors engaged in separate experiments from taking up required space from another experiment. Experiments should be set up away from the queues, and the way in/out of the building(s). If the experiment is to be held and carried around (e.g. floating experiments such as prism goggles) then demonstrator should be aware of their surroundings at all times, and ensure visitors do not accidentally hit other people potentially walking by.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2023-02-19 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-19 - Asmita Niyogi (an637@cam.ac.uk)

Peak flow

Using a peak flow meter to measure peak flow rates - A peak flow meter often used by medical staff to measure the maximum speed you can expel a 'huff' of air. This can be used to gather useful information about the function of the lungs.

Last initially checked on 2023-02-17 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-02-18 by Andrew Sellek (ads79@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Medicine

Equipment Needed

- Peak flow meter & disposable mouth pieces
- Peak flow meter
- Models of normal and constricted airways (made from foam and tape)
- Straws
- Bung with a hole in it, plus blu-tac (possibly, if I have finished making it!)

Experiment Explanation

This experiment allows kids to have fun competing to see who has the highest peak flow and also acts as a starting point for discussion of lungs, breathing and conditions such as asthma.

ACTIVITIES:

- Get kids to use a peak flow meter

Image 1: (https://old.chaosscience.org.uk/sites/default/files/peakflow.jpg)

THINGS TO TALK ABOUT:

- What is a peak flow meter and what might it be used for?
- Basic explanation of how the lungs work
- Why do you want to know about your peak flow rate? asthma, fibrosis, COPD etc

TIPS FOR DEMONSTRATING:
It's very important to establish in the beginning how much the kid knows already. Generally, kids either know a lot (i.e. if they are asthmatic) or very little. If they know very little, keep things very basic. If they know a lot, you can go into more detail; i.e. how the lungs work; that lungs are made out of tissue; tissue structure can change (inflammation; fibrosis)- how this affects your breathing.

BASIC PROCEDURE AND EXPLANATION

Peak Flow

1. Establish how much the child knows already:

- Ask them if they know what a peak flow meter is.
- If they do ask them what it's used for (chances are a good chunk of them have asthma and will have used one).
- If they don't know what it is, ask them what they think it might be used for.
- This should be quite easy to guess from the design, but if they're struggling, work them round to it.
- Point out the meter - i.e. it's for measuring something.
- At the 0 end of the meter there's a wacking great mouth shaped hole, so how do you think you get the meter to move?
- If they say blowing into, then ask them what sort of diseases it might be used for. asthma, emphysema, bronchitis.

2. Then link what it's for to a discussion on asthma.

- So if it's for seeing how well someone with asthma breaths, do you think asthmatics can blow more or less on it?
- Why do they blow less. (see diagram below)
- Lungs = set of bags at end of set of tubes.
- Ref them to lung model for how lungs work, but basically say muscles make air move in and out.
- In asthmatics, the tubes are narrower.
- Tubes are narrower because...
- Need to pitch this depending on age of kid.
- Mention allergy.
- Mention other things that can trigger, eg asthma, cold air.

3. Do only kids have asthma?

- No - adults can get it as well. Late in life onset and child onset forms of asthma are common.

4. So do you thinks astmatics blow the same thing on the peak flow all day?

- No - they are usually worse in the morning that they are in the evening.

5. Finally, see what the kids can blow and match it vs. the diagram below.

Image 2: (https://old.chaosscience.org.uk/sites/default/files/peakflow2.jpg)

6. For older kids it might be worth going into:

- Why narrower tubes stop you blowing as well.
- Inflammation.
- Other things that you use lung function tests for: COPD, Sarcoidosis, Fibrosis etc.

You can also get kids to put a straw in their mouth and breathe out through it for a few breaths, to demonstrate how much more difficult it is to exhale through smaller tubes. Only let them do this if they are sensible, breathe normally for only a few breaths, and are SITTING DOWN while they do so!

It might also be possible to plug the end of a mouthpiece with the rubber bung, put a straw through the bung (you will need blue tack to make it airtight) and then compare the peak flow reading that can be achieved blowing through the straw to that blowing straight through the mouthpiece, again demonstrating the effects of narrowed airways.

Risk Assessment

Hazard: Mouthpiece

Description: Transfer of infection from mouthpiece.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure to use a new mouth piece each time, and dispose of old ones.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Over-Exertion

Description: Fainting risk due to over-exertion.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: The risk of this is probably low, but keep an eye on people using the peak flow meter to ensure that they are not over-exerting themselves to this point. Be aware of what participants might fall on in the event of fainting. Only allow them to try the exhaling through straws part if they are SITTING DOWN, and only let them do so for a few, gentle breaths.
In case of accident, call a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2012-01-11 - Elizabeth Mooney (erm40@cam.ac.uk), **Check 2**: 2012-01-23 - Ashley Smith (ashley.smith@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

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Pendulum Waves

nan - Different length pendulums swing at different frequencies - see pattern of waves develop as they come in and out of phase with each other.

Last initially checked on 2023-02-16 by Lauren Mason (llm34@cam.ac.uk) and double-checked on 2023-02-17 by John Leung (cfl35@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- Long Wooden Piece with dangling strings and washers (uncoupled pendulums)
- Cardboard with string and washers wrapped around (weakly coupled pendulums)
- Long pipe segment
- The piece of wood with all the washers hanging off of it.
- Another long pole to set it off

Experiment Explanation

2 pendulum experiments - one that usually gets wrapped in clingfilm? which can be done alone and one in a cardboard box that can be done with resonance

Uncoupled Pendulums To set this up you'll need to have two equal sized supports, using a combination of tables and boxes works well. You'll want to view them from above or down the length (e.g. from under the table).

There are several uncoupled simple pendulums of monotonically increasing lengths which dance together to produce visual travelling waves, standing waves, beating, and random motion. One might call this kinetic art and the choreography of the dance of the pendulums is stunning! Aliasing and quantum revival can also be shown.

The period of one complete cycle of the dance is t (60) seconds. The length of the longest pendulum has been adjusted so that it executes some number (51) oscillations in this t (60) second period. The length of each successive shorter pendulum is carefully adjusted so that it executes one (perhaps) additional oscillation in this period. Thus, the 15th shortest pendulum (or however many there are) undergoes 65(ish) oscillations. When all 15 pendulums are started together, they quickly fall out of syncâ€”their relative phases continuously change because of their different periods of oscillation. However, after t (60) seconds they will all have executed an integral number of oscillations and be back in sync again at that instant, ready to repeat the dance.

One instance of interest to note is at t/2 (30) seconds (halfway through the cycle), when half of the pendulums are at one amplitude maximum and the other half are at the opposite amplitude maximum.

It's worth noting the mass has no effect on the period of the pendulum (however gravity strength does) so it doesn't matter about the number of washers on the strings. The demonstration is used in the Czech Republic under the name Machuv vlnostrojâ€”the "Wavemachine of Mach." Harvard also have one which is used in one of their museums.

James Flaten and Kevin Parendo have mathematically modelled the collective motions of the pendula with a continuous function. The function does not cycle in time and they show that the various patterns arise from aliasing of this functionâ€”the patterns are a manifestation of spatial aliasing (as opposed to temporal). Indeed, if you've ever used a digital scope to observe a sinusoidal signal, you have probably seen some of these patterns on the screen when the time scale was not set appropriately. You could talk about sampling and trying to guess the pattern if you know about this.

You can also talk about Reset times, after t seconds we're back to where we started and the system has reset, this is an important part of Markov chains and other probabilistic results, if the system resets (or regenerates). This means we can treat parts of the process as independant statistically. It could be used to simulate quantum revival. So here you have quantum revival versus classical periodicity! Quantum revival is when we complete a full period of the system wave function, something which often takes a long time - but not always, when components of the superposition have equal spacing in frequency!

Coupled Pendulums You want to hang the string between two fixed boxes and then try swinging various pendulums, you'll notice as there weakly coupled you can occasionally get other pendulums to also swing due to them having resonant periods.

Risk Assessment

Hazard: Weight/wood

Description: Dropping on feet/other injuries due to falling weights or wood.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure weights are attached properly. Make sure the stand is secured properly. In case of emergency contact a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: String

Description: Tangling and tripping in the string.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not let people run around, or play around the strings. In case of an accident, untie/cut the string if necessary. If necessary, call a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Wood

Description: Splinters from wood.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Make sure the wood is smooth, if not, sand it smooth. In case of an injury, contact a first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Pendulum support

Description: Pendulum support bar is a large piece of wood and could hurt if dropped on a foot

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Set up with stable supports. Tape ends to table so it won't slide

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Washers

Description: Finger trapping

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Encourage people not to stick their fingers in the washers lest they get stuck

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

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Check 1: 2019-01-01 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-01 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-02-05 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2020-02-05 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2023-02-16 - Lauren Mason (llm34@cam.ac.uk), **Check 2**: 2023-02-17 - John Leung (cfl35@cam.ac.uk)

Penguins, Poo and Populations

Counting when we can't count - How can we count the number of penguins, there's far too many? Investigate several ecological techniques to use statistics to help us out.

Last initially checked on 2023-02-10 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-12 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Ecology

Stats

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- 100ish uniquely identified ducks
- A whiteboard
- A dozen penguins, with markings on the base
- Satellite poo photos
- Plastic area grid
- Giant calculator

Experiment Explanation

If we're studying animals in the wild then it'd be useful to know how many there are. We'll look at some techniques ecologists use. One key thing to think about is tradeoffs, mainly between how accurately we need to know the population and the costs in time and money of working it out.

We want to estimate how many ducks are in the pond, take out a large handful and hide them away so the numbers are at random. Kids may try and count, it works fine for rubber ducks, but they'll have issues if they try with real ones! They move around, all look the same, are right in the middle of the pond, fly off or are hiding. In reality we'll have to make do with an estimate! There's two ways of doing this. [you may get some people guessing based on the numbers on the bottom, this is also very interesting but not in the context of ducks (which rarely come uniquely numbered). Its called the German tank problem and you can explain if you know about it, even though its not related to ecology!]

Capture Recapture

One way we could do this is via sampling. Take a sample of ducks (around 12-16 works well if you've removed a dozen or so) and mark on the whiteboard which numbers you saw. Replace the ducks and mix well. This represents our first sample and we've now made sure our next sample is 'independent' by shuffling it. Take another sample of ducks and count how many are in both. We then need to do some maths, the sample size over total number of ducks will be our probability of picking any given duck from the first sample in sample 2. So if we times this by the sample size it gives how many ducks we'd expect to see both times. Doing the product of sample sizes divided by the number in both gives us our estimate. You can now ask questions about the population. Drawing a venn diagram may be useful. Can we say anything about the minimum size? Yes, it's at least the number of unique ducks we saw... What about the maximum? Nothing at all, however we can think about it, if there were lots of ducks we'd not get any repeats and if there were only a few more than the sample size we'd get mostly repeats. Other ways to improve include making the sample size bigger. (Presumably with a vague prior on duck populations you could use Bayesian inference to get the most likely population size?)

You can talk about the effects of sample size on the estimate, what do you think increasing it does? Increase variance or uncertainty. Why don't we take big samples, it's expensive

You can also talk about bias, if you don't mix, you'll probably get some bias.

This is where you might see marked, chipped or collared animals as part of these estimates.

Can also talk about quadrants.

Biased Sampling

This is a quick demo to talk about it and isn't majorly about animals. Take an opaque bag with 20 small balls and 5 large of different weights. Tell people they can pick a sample to guess the weight of the bag of balls. Tell them there's 25 balls in it, but don't mention the different types. People will gravitate to picking bigger balls so it'll bias their sample and throw their weights off.

Penguins by poo

Even capture recapture gets expensive if we want to estimate penguins. Why? They're far away, not good infrastructure, it's chilly, etc. So we want to find a better way. As penguins live on ice sheets which are white we can use photos to pick them out. Show some photos from a satellite (a few are actually drone photos but very similar). It's hard to count penguins in this as they move and are slightly camouflaged. Huddles are confusing as varying density. So we count the amount of poo! You can pick it out in the photos. So how might we estimate the number of penguins. Count the area of poo, use the grids over the picture to work out the poo area. We now need to work out poo area a penguin produces! Here are some penguins, lift them up to reveal their poo areas. You'll need to take a sample and average. You'll also notice the babies are a source of bias... This is similar to before. If you do the maths you can estimate the population. Where are the errors? Where did our sample come from, zoos is a nice controlled environment for it, but might not give the best accuracy for wild penguins, different food and environment. There's also the depth factor which we ignore. Our measurements weren't perfect for the area either, however satellites can do much better.

Risk Assessment

Hazard: Ducks/penguins/balls/other small objects

Description: Child may swallow or choke on these small objects if put in their mouths

Affected People: Children

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: Inform them they are rubber/plastic and not edible. Keep track of all the ducks. Most items are too large to cause ingest easily. Call first aider if child swallows, if choking encourage child to cough.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Ducks/penguins/balls/other small objects

Description: Trip hazard if dropped

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Keep track of all the ducks. Pick up if dropped. Don't let children run around.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Whiteboard Pens

Description: Children could be tempted to lick the pens and become sick as a result.

Affected People: Children

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Monitor the pens and don't let very small children use them (at least without supervision). In case of licking, call first aider, or tell parent to contact GP if child feels ill later.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: The Squeak

Description: Children may loudly squeak ducks, especially in people's ears.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Remove squeakers if necessary. Don't allow children to have extended contact, keep track of ducks currently off the table. Don't let ducks be squeaked around ears. Sit person down if required after ear squeaking

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

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Phase Game

Game introducing the phases of matter and phase changes - Outside game introducing the concept of different phases of matter and the different ways to transition between them.

Last initially checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk) and double-checked on 2023-02-18 by Peter Methley (pm631@cam.ac.uk).

Tags

Group Activity

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- Some method of marking a playing area. Some playgrounds have markings
- Otherwise cones etc. Inside a hall
- The entire room may be used

Experiment Explanation

When you have a large number of children to entertain for an unknown period of time, who do you call? Phase busters!

This game is designed to be run in schools or on jamborees when there are a large number of children who need entertaining

The principles of the game are simple. You yell a phase, or a phase transition, and the children act in a manner akin to molecules in that phase.

Basic calls

Solid: The children stand still, with their hands by their sides. Some huddling may be encouraged, but isn't necessary. You could get them to sway while keeping their feet in the same place, representing thermal vibrations.

Liquid: The children walk slowly, I generally also bring my hands up, palms together, wiggling in front of me to worm around. They should probably come close together too.

Gas: Walking (or running if they seem trustworthy) as far apart as possible, bouncing off the edges of the container.

Melt: Transition solid to liquid

Evaporate: Transition liquid to gas

Condense: Transition gas to liquid

Freeze: Transition liquid to solid

Sublimate: Transition solid to gas

Deposit: Transition gas to solid

Other call options

Oxygen or **Nitrogen**: Children are a gas in pairs (holding hands with a partner)

Ozone: Children are a gas in 3s (have some demonstrators there to make up to a multiple of 3 if necessary)

Neon: Children are a monatomic gas, as per the previous gas description

Benzene: Children are in rings of 6 (behaving in same way as liquid) etc. (make up as you like)

Spiel

To start with I introduce that we're stood in a beaker (or something similar) and that the children are the molecules. Maybe some discussion here of what molecules/atoms are; don't need to go too complicated. See if they know what the molecules do in a solid, liquid and gas. Then start making some calls and get them to do the appropriate actions. This is a good time to gauge how well the group is behaving and point out that those misbehaving/pushing/running everywhere may have to go stand with a teacher. Use solid to stop them for more instructions.

More Q&A. How do we get between phases (or states, or types, whatever they can handle)? If you hold ice in your hand what happens? What's that called? Try a few out, remember you can still call solid to get them all to stop. I'd only stick with what they're likely to have heard of at this stage.

Trickier now, sublimation and deposition are added. See if anyone knows the word, maybe get them all to say it back. Examples include dry ice (solid carbon dioxide), pieces of ice in cold dry conditions, formation of snow and frost.

Variant

Knock out game (maybe once they're getting tired, or from the start because you're bored of running the other one. Don't make it knock out for a bit so that they get the hang of it and all get a chance to do something. Use the alternative calls, sometimes people won't have a full group. These people (or the last group formed) are out. They can cheer on their compatriots as they play on or be gradually siphoned off to home time etc.

For example:

- 14 children in room, call "Benzene", two rings of 6 form, other children out.
- 12 children in room, call "Ozone", last ozone to form is out.
- 9 children in room, call "Nitrogen", lonely child out.
- 8 children in room, "Benzene" again, 2 spare children out.
- 6 children in room, "Ozone" again, last ozone formed is out.
- 3 children in room, call "Neon", they all look confused as no one is out.
- 3 children in room, call "Nitrogen", lonely kid is out, other 2 children are winners.

Risk Assessment

Hazard: Children running around

Description: Falling over or banging into each other.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Children should be asked be careful and to be aware of falling over risk. The speed of the game should be limited to a safe one (get them to walk instead of run if they are behaving dangerously). Over-excited children should be asked to stand out for a round or two. Make sure that the floor isn't slippery before starting (wet hall floor, leaves outside, wet grass etc. Call first aider in event of injury. Stop experiment if required.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Static objects/other children

Description: Collisions/tripping over objects leading to injuries.

Affected People: Children

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clear away or keep the game away from any static objects likely to cause danger. Use area markers which are not dangerous to run into. As for falling over risk, limit the excitement of the game as required and make the children aware of the risk. Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2014-04-07 - William Benfold (wjb42@cam.ac.uk), **Check 2**: 2014-04-07 - Beatrice Tyrrell (bet23@cam.ac.uk)

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Check 1: 2017-01-18 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2017-02-01 - Matthew Le Maitre (msl54@cam.ac.uk)

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Check 1: 2019-01-01 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-01 - Matthew Le Maitre (msl54@cam.ac.uk)

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Plant evolution & pollinator game

Plant evolution timeline and matching plants with their pollinators - Find out where plants come from and how their form is shaped by the pollinators interacting with them.

Last initially checked on 2023-01-22 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Evolution of plants: timeline on green mat, plant fossils, ginkgo leaves, set of cardboard tiles
- Pollinator game: game tiles (x16) *Note, all pictures with copyrights or courtesy to someone other than CHaOS were sourced from Wikimedia Commons. The remaining 3 now belong to CHaOS.*
- Fresh, real plant specimens may be collected beforehand.

Experiment Explanation

Evolution of plants A lot happened to allow cyanobacteria to evolve into the wide range of land plants we see today. This timeline shows some of the main points and key developments that give rise to modern plants

Expansion of the main points on the timeline (with tile number):

Cyanobacteria â€“ are bacteria (prokaryotes) but they can photosynthesise (1, blue-green algae) **First eukaryotes** â€“ skip this point if the children havenâ€™t learnt about mitochondria and cholorplasts yet, if they have, explain that scientists think that eukaryotes evolved via symbiosis, with one bacteria engulfing another, but not digesting it. Chloroplasts were originally cyanobacteria engulfed by an organism that had mitochondria. **Multicellular organisms** â€“ again, may need to skip, otherwise discuss how bacteria have just one cell and that is the whole organism, whereas we have many cells, as do plants (13, anabaena) - this allows us to have specialised cells. **Primitive land plants** â€“ Explain that previously all organisms were in the water. Scientists think that the colonisation of land occurred only once, and that all land plants evolved from the Stoneworts (4, Charophyceae) **Liverworts** â€“ the first plants, still needed a lot of moisture, and live clinging to rocks in damp environments such as near waterfalls. Can be seen in Scotland still today (one is sketched on the timeline) (6) **Mosses** â€“ mosses have the first identifiable transport systems for water â€“ xylem vessels. Can also explain the haploid/diploid thing here using standard wall moss â€“ the green carpet part is the haploid and is the main part of the life cycle, the diploid emerges to spread spores and are on little stalks. (7) **Hornworts** â€“ developed the cuticle (which helps to reduce water loss) and stomata so are more independent of water than liverworts. All land plants except liverworts have these two features (9) *Next a true vascular system evolved* that was capable of not only transporting water but also supporting the plant structurally, all other plants on land are â€˜vascularâ€™ (they have veins like us). **Club mosses** â€“ First plants to have leaves! Also developed roots which grew in the dark and needed photosynthate (sugars), so needed phloem too. (11) **Horsetails** â€“ Had a hollow stem surrounded by a ring of vascular tissue, were therefore light. Still survive today, but are much smaller than their ancestors (2) **Spore producing ferns** â€“ have proper complex leaves. Bracken, seen in most woodlands, is the most successful and widespread of all vascular plants. Reproduction is still water dependent. (3) *Then evolved all the seed plants!* **Seed ferns** â€“ now extinct, but different to their surviving spore producing ancestors. See the fossils for examples, note the different leave shapes. **Cycads** â€“ the dinosaurs favourite food! We think some dinosaurs used to swallow pebbles to help them digest the tough leaves. (12) **Ginkgo** â€“ see the leaves, a living fossil in itself! (5) **Gymnosperms** â€“ mostly conifers (8). The have a novel method of growth, with an expanding ring of growing tissue round the outside of the stem. Both the largest organism and longest lived organism on Earth are conifers! Can they guess the largest? (Californian Redwood or Giant Sequoia, same tree) 200 MYA â€“ insects evolved wings **Angiosperms** (the flowering plants) â€“ very exciting and the most diverse group of plants, still only evolved very recently (10)

Number order of photos: 1, 13, 4, 6, 7, 9, 11, 3, 2, 12, 5, 8, 10 (from most basal to most recetly evolved)

Plant fossil details: All the fossils came from the Dover area and illustrate the horsetail point at 400 million years ago, NOTE, the ferns are seed ferns, which developed after seeds evolved, they are not the spore producing ferns we see today and evolved with the horsetails. The sketch of a horsetail on the timeline should help the children envisage what Annularia and Calamites looked like. -Alethopteris: these are the leaves of seed fern (which are now extinct). The leaves are relatively long and thin and end in more of a point compared to neuropteris, see number 1. -Neuropteris: also leaves of an extinct seed fern. These are the fat leaves with blunt, rounded ends, most of the leaves in the fossils are neuropteris. -Annularia: also called Asterophyllites - don't think there is a difference. These are the leaf whorls of an extinct horsetail. (The leaves are spread concentrically about a point). There is only one of these in the fossils, next to number 3. -Calamites: the stems of the horsetail. Can be recognised by the segmented stems. These are related to the modern horsetail. See number 2 for some well segmented ones, but also the largest one.

Ginkgo facts: The leaves are from the Dept of Plant Sciences. It is the species Ginkgo biloba (maidenhair tree) and has no living relatives! It even has its division (equivalent to an animal phylum). Phylum is the next classification step down from Kingdom, so to illustrate how different it is, you can explain that within the animals there are the â€˜chordataâ€™ (or vertebrates). Ginkgo is as different to a fellow plant as vertebrates are to invertebrates, e.g. tigers and insects! Expansion of the main points on the timeline:

Major developments in the evolution of plants:

1. Multicellularity Plants have different tissue types, like we do, so needed to be made up of more than one cell.
2. Cuticle Once out of the water, plants needed to avoid drying out, so they evolved a waxy layer that prevented water loss (C)
3. Stomata This waxy layer is a barrier to gas exchange â€“ plants need carbon dioxide for photosynthesis so they evolved little openings in the cuticle to let carbon dioxide in and oxygen out (E)
4. Xylem Plants needed to transport water from the base if they were going to be able to grow upwards, xylem allow for water transport (see coloured flowers demonstration). Xylem also provide support for upward growth as they are reinforced with lignin (G,I)
5. Phloem Some parts of the plant are underground, and hence canâ€™t photosynthesise, so need sugar delivered to them, phloem tubes transport these sugars (D,I)
6. Roots Plants have had some kind of anchoring since the movement of plants onto land, initially role fullfilled by fungi, but in order to grow up, plants first had to grow down. (F)

Xylem, phloem and roots all evolved at roughly the same time, with all three features supporting each other, there is also confusion due to the limited evidence provided by the fossil record (roots particularly fossilise poorly). Leaves evolved multiple times, early leaves (microphylls) had a single vein, whilst the leaves we recognise today (megaphylls) evolved on four independant occassions (in the ferns, horsetails, progymnosperms, and seed plants)

7. Dominant sporophyte Previously the haploid phase (like our sperm) had been the main part of the life cycle, but these need a lot of water, there needed to be a switch to the more resilient diploid (like us) in order to develop further
8. Seeds As the world dried out 250 million years ago, plants needed to protect their â€˜eggsâ€™ and evolved seeds (A)
9. Pollen tubes These allow the pollen to grow down to the egg and fertilise it (and can be seen in another demonstration) (B)
10. Showy flowers Once flowers had evolved, they could be adapted to as many different forms as there were pollinators (see the pollinators game) (H)

Pollinator game Flowers are a plantâ€™s way of manipulating somebody else, usually an animal but sometimes the wind, into carrying its pollen around for it. Start by asking them to think of pollinators, theyâ€™ll probably say bees. Then introduce the other forms â€“ and show them the tiles (1-8).

A few facts: â€¢ There are between 250,000 and 400,000 species of Angiosperms (flowering plants) â€¢ Thatâ€™s roughly a sixth of the total number of living species currently known â€¢ Aside from the insects, the Angiosperms are the group with the most species

They are so diverse because, once youâ€™ve mastered the ability to manipulate somebody, you can radiate into as many different sorts as there are different somebodies to manipulate.

Then ask them to match up the flower to the pollinator. Note â€“ you may have to tell them some of their guesses are good particularly between beetle and moth as the key difference is not apparent just by looking. You may like to tell them at the start that C (the gardenia) opens at NIGHT to distinguish it from G.

More detail on the tiles: 1 = Birds (This one is a female hummingbird, species Thalurania colombica) 2 = Bees (Buff tailed bumblebee â€“ Bombus terrestris) 3 = Beetles (pollinating beetles are small, these are Mordellidae beetles) 4

= Moths (Peppered moth â€“ Biston betularia) 5 = Bats (Mostly fruit bats) 6 = Wind 7 = Fly (generic diptera is pictured) 8 = Butterfly (Red admiral) A = Snapdragon (antirrhinum) B = Grasses C = Gardenia, note this flower has a distinctive scent at nighttime D = Buddleia davidii (aka the butterfly plant, but that gives it away, normally call it Buddleia) E = Red columbine F = A Compositae flower, part of the daisy family (Asteraceae), Bellium bellidiodes G = Magnolia H = Jade vine, Cambridge Botanic gardens ANSWERS: A = 2, B = 6, C = 4, D = 8, E = 1, F = 7, G = 3, H = 5

Extra Idea for the Game (from summer tour 2013) - Make it vaguely competitive. Go through each of the different types of flowers and say what would be attracted to them. Don't go through the pollinators. Or do that vice versa. Then get them to match up the flowers to the pollinators as fast as possible. 15 second time penalty for every wrong answer. Keep track of the times for the day, as it gives this added excitement. From my vague recollection, the best time was around the 1 minute 15 second mark...

More details:

The concept of a broad association between flowers and the types of animals that pollinate them is called a pollination syndrome.

A pollination syndrome classically describes a suite of adaptations shown by a plant to a particular group of animals, usually a taxonomic order, and by those animals to a particular group of flowers, which may not be phylogenetically related to each other. The adaptations shown by the animals may be behavioural or morphological, while plants can only show morphological adaptations to animals.

Can they think of another method? There is also deceit pollination, where flowers pretend to be something, e.g. a bee in the case of some orchids. Or where flowers mimic those of another species but do not actually contain nectar so trick the pollinator into collecting pollen for free.

A = 2 Bee pollination (Melittophily) Bees carry pollen on their bodies in a range of increasingly specialised structures from simply having hairy feet to having pollen baskets on the hind legs. Then they groom this pollen off and feed it to their larvae. Bees can see in ultra violet, blue and yellow, but not in red. They have the ability to perceive depth, and they usually have long tongues. Bee flowers are usually quite big to bear the weight of the animal, and often have a landing platform. Bee flowers are usually brightly coloured. Yellow and blue are considered classic bee colours, but in fact many bee flowers are red despite the inability of bees to see red. The presence of UV absorbing pigments presumably modifies the red to a colour that is visible. Bees are sensitive to nectar guides, which enable them to handle the flowers more quickly by directing them straight to the nectar. Examples: snapdragon, nettles.

B = 6 Wind pollination Wind pollinated plants do not have showy flowers, but instead have very large stamens and feathery stigmas to catch pollen from the air. This method is much less precise than using insect pollinators and requires the plants to make much larger quantities of pollen, although needs to investment in nectar (the reward to animal pollinators).

C = 4 Moth pollination (Phalaenophily) The flowers are often white, which stands out well at night, and may close completely during the day. The moth usually hovers alongside the flower, which is bilaterally symmetrical with the rims bent backwards. Like butterfly flowers, moth flowers have nectar in long tubes. Another characteristic of moth flowers is the large quantity of nectar produced, as moths have higher energy requirements of the moth - hovering is a great deal more energy consuming than landing. Moth flowers usually attract pollinators by a strong scent, which can be quite overwhelming when the flowers open at night. Examples: gardenia, some honeysuckles.

D = 8 Butterfly pollination (Psychophily) Butterflies usually alight on flowers, and psychophilous flowers have flat structures, held horizontal. Butterflies have long tongues, often 1 to 2 centimetres, and butterfly flowers have nectar in enclosed tubes, which can be quite deep. Butterflies have good colour vision, and can see red, so butterfly flowers are usually brightly coloured. Examples: Daisies, Buddleia.

E = 1 Bird pollination (Ornithophily) The classic pollinating bird is the humming bird, which is American, but a variety of other groups also feed on nectar, including the African sunbirds, Australian lorikeets and American honey-creepers. Hummingbird pollinated flowers are either pendant or stand out so that there is free space for the animal to hover in. Sunbird pollinated flowers have a perch with the flower facing towards it. Bird flowers are usually either brush or tube shaped, and the nectar is secreted into spurs, which are usually shorter and wider than those on butterfly flowers. They also have to be quite tough, as a beak is both stronger and harder than a butterfly tongue. One of the key features of a bird flower is the quantity of nectar secreted. They produce very large quantities of a very concentrated nectar, so much so that it will actually drip from the flowers at certain times of the year. Ornithophilous flowers are almost always red, often with contrasting yellow markings. Unlike most insects, birds can see red, and in fact canâ€™t see ultraviolet. Examples: red columbine, poinsettia, eucalyptus, hibiscus, passion flower.

F = 7 Fly pollination (Myiophily) The Diptera, the fly order, show the greatest variation in methods and habits of pollination of any group of insects. Many plants flowering in adverse conditions or at odd times of the year can be entirely dependent on flies for their pollination, as they are the only group of insects which are not strictly periodic. Because they do not feed their offspring they do not require much food, and so myiophilous flowers need supply only a small quantity of nectar. Flies are more visual animals than beetles, and have a positive preference for pale and yellow colours, and for nectar guides. Fly flowers do not often have much scent but they are usually palely coloured. Examples: Umbilliferae, Compositae.

G = 3 Beetle pollination (Cantherophily) This is widely believed to have been the first pollination syndrome, the one used by the first Angiosperms, as the Coleoptera, the beetles, constitute one of the oldest groups of insects and were already numerous at the time that the higher plants came into existence. Beetle pollinated flowers provide extra pollen and nectar in a flat surface. Beetles do not have good colour vision, but rely heavily on scent. Beetle pollinated flowers are usually greenish or off white in colour, with a strong fruity smell. Examples: Magnolia, lilies, wild roses, poppies.

H = 5 Bat pollination (Chiropterophily) A quarter of all bat species use flowers for food to some extent. The anthers of bat flowers open at night, and the flowers often only last one night. The flowers are usually white to cream or sometimes a greenish pink colour. Bats are colour blind, so strong colours are not relevant. The main attractant is scent. Bat flowers generate a very strong scent. Bat flowers produce the most nectar of any flower type - up to 15 millilitres at a time. A few bats have become totally dependent on flowers, and eat pollen as their only protein source. The flowers have to be very large and strong, with narrow tubes or bowls from which to lap nectar. Because the bats have to find the flowers at night they are not usually within the foliage, but either hang below it for easy access or actually develop on the trunk of the plant itself. Examples: cacti, Bignoniaceae.

Risk Assessment

Hazard: 2m long fabric timeline

Description: Trip hazard if timeline placed on floor

Affected People: all

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Place timeline on table if possible. If little space is available, try unraveling the timeline like a scroll in the demo. If you have to have it on the floor, put it in a safe place â€“ i.e. not across a likely walkway, and ensure children do not walk/run across it. In case of injury, call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: 22 sellotaped card tiles

Description: Scratching/poking from the card tiles.

Affected People: all

Before Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Mitigation: Don't allow anyone to throw the tiles, keep them flat on table/floor. In case of injury, call a first aider.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Hazard: Specimens

Description: Possible allergic reaction and small scratches from seeds/plants/soil/leaf specimens. Also possibility of small children eating plants.

Affected People: all

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Ask parents if child is allergic to any of the plants before beginning the demonstration. Ensure demonstrators who are allergic do not handle the specimens. In case of adverse reaction, call a first aider. Ask public to handle specimens carefully and encourage them to wash their hands afterwards. Make sure children do not put specimens in their mouths.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2013-12-26 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2014-02-02 - Raghd Rostom (rr415@cam.ac.uk)

Check 1: 2015-01-08 - Kym Neil (kym.e.neil@gmail.com), **Check 2**: 2015-01-24 - Chloe Hammond (cjh214@cam.ac.uk)

Check 1: 2016-01-07 - Natalie Cree (nc434@cam.ac.uk), **Check 2**: 2016-02-03 - Sarah Wiseman (sw628@cam.ac.uk)

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Check 1: 2019-01-16 - Amanda Buckingham (abb53@cam.ac.uk), **Check 2**: 2019-01-18 - Polly Hooton (prh43@cam.ac.uk)

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Plants

Plants - looking at germination, their structure and how they produce energy by photosynthesis - nan

Last initially checked on 2023-02-15 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Equipment Needed

- **Electricity needed**
- *Needs significant preparation in the days running up to the event*
-
- Beansprouts in plastic containers, germinated prior to event, under different conditions (e.g. light/dark/water/no water/warm/cold)
- Magnifying boxes
- Microscope and slides showing section through plant leaves, stem, stomata, germinating seed

Experiment Explanation

Ideas to explain:

For younger children

- Talk about what plants need to grow (water, warmth, light)
- Look at sequence of development i.e. seed, beansprout, small plant, larger plant, bigger plants flower and produce seeds (life cycle)
- Plants need light to produce energy - they don't eat like animals do (avoid using the term 'photosynthesis' with small children)
- Might want to look at plant cells in the microscope. They have a cell wall, so have a rigid shape, unlike animal cells. Green because of the pigment (chlorophyll) that they use to produce energy from light.

Older children

- More detail on the different events happening in early plant development

- More detail on photosynthesis i.e. carbon dioxide converted into sugars, and oxygen is produced (the opposite idea to respiration)
- Gas exchange (Carbon dioxide for oxygen) happens through pores on the underside of leaves called stomata (you should be able to see these on one of the slides - see below).
- Light is absorbed by the green pigment (chlorophyll) in the leaves
- Plants have to transport sugars made in the leaves to other parts of the plant - this happens in the phloem (visible on slides)
- Water is transported from the roots in xylem (visible on slides - see below)

Risk Assessment

Hazard: Microscope

Description: Electrical hazard (microscope), especially near sources of water.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: See separate electrical parts risk assessment, keep microscope away from water as it is not required for this experiment. In case of injury, call first aider.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Thin glass slides

Description: Using thin glass slide could result in broken glass with risk of cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: If slides are broken, carefully collect/sweep up broken pieces, wrap in paper and dispose of carefully. In case of injury, call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Microscope light fitting

Description: The light fitting under the microscope becomes hot, and could cause burns.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Warn children to be careful, turn off lamp when not in use. If it's getting hot, put a cardboard shield around (but not touching) the lamp to prevent accidental contact. In case of accident, call a first aider and encourage children to run burns under tepid water for 10 minutes.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Specimens

Description: Possible allergic reaction to seeds/plants/soil/leaf specimens.

Affected People: Demonstrator/Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Ask parents if child is allergic to the plant we are using before beginning the demonstration. In case of adverse reaction, call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Seedling jars

Description: Injury from dropping seedling jars/plants.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Have seedlings in plastic container, and use plastic plant pots. In case of injury, call a first aider.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Hazard: Electrical cables

Description: Trip hazard from microscope cable/extension cord.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Avoid setting up so wires are in a walkway, tape down cables. In case of injury, call a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2013-12-26 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2014-02-02 - Raghd Rostom (rr415@cam.ac.uk)

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Platonic Solids

Explore the five platonic solids and other 3D shapes. - Making 3D shapes out of 2D ones. Look at how angles combine to tessellate and then form 3D corners.

Last initially checked on 2023-02-18 by Andrew Sellek (ads79@cam.ac.uk) and double-checked 2023-02-18 by Peter Methley (pm631@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Polydron kits (we have 2 sets of platonic solids and a 'small' set of Archimedean solid pieces)
- Selection of Solids
- Some laminated cards that came with one of the sets

Experiment Explanation

If we take a look at our shapes you'll see they use lots of 2D shapes as faces. There are lots of ways for us to build up solids.

We can talk about Euler's Formula. The concept of face, edge and vertex (corner) should be easy to explain. Then get them to count up the number of each (hide the curvy edged shapes). Now consider the magic formula, $V-E+F$, if you keep on trying it you should always get two!

Platonic solids are special as all their faces are exactly the same, there's also not many of them. The faces are all regular (same angles and sides) and the same number of faces meet at each vertex. So we can start trying to build some. The first thing to focus on is around a vertex, what sort of shapes fit?

The five solids are the Tetrahedron, Cube, Octahedron, Dodecahedron and Isocohedron.

For simplicity of notion here I'm going to use Schlafli symbols {*p,q*} where p is number of edges each face has and q is how many faces meet at a vertex. These leave {3,3} {4,3}, {3,4}, {5,3} and {3,5} as our platonic solids.

Try building things up, at a vertex the things that meet must have angles less than 360 degrees or else they won't fill space. So we eliminate several options, in fact we get rid of anything with $p>5$ as $q<3$ makes no sense and {6,3} encodes a tessellation of the plane by hexagons. Similarly {4,4} and {3,6} are tessellations, leaving us with only five options. It turns out all of these work, you can show this by making them or getting out the dice.

This embodies a fairly basic proof which you can talk about.

Prisms, Antiprisms and Archimedean Solids

Archimedean Solids are the next step from platonic, removing the requirement that all the faces are the same. There are two infinite classes the prisms and Antiprisms (which have a belt of triangles and are slightly skew). These are sort of Archimedean but we exclude them as there's infinitly many of both. Then let's look at other ones. There's between 11-17 (roughly should double check) depending on your definition of 'the same', i.e. allowed isometries.

The easiest to find are the truncated platonic solids, you get these by slicing corners off the solids, this doubles the number of sides and creates new faces. This gives 5 Archimedean Solids.

You can also form some manageable ones with vertex patterns (3,4,5,4), (3,5,3,5), (8,6,4), (3,4,3,4), (4,4,4,3). There's also a very large one with pattern (10,6,4) notable for how large it is. Patterns describe the number of sides in each shape clockwise around a vertex.

PLUS - There's a few weird 'Archimedean Solids' which depends on definition. There's two alignments of the shape (4,4,4,3) which has a belt of squares around the middle, this is formed with either the triangles alligned or not, the number of belts changes. There are also two snub shapes (3,3,3,3,4), (3,3,3,5), these expand the cube and dodecahedron with a belt of triangles. These two have a chirality which you can change by folding the net up and down.

PLUS - You can also do a topological proof using Schlafli symbols, from Euler's formula and the following fact: $pF=2E=qV$, you can bound things by eliminating F and V in Euler and then getting $\frac{1}{q}+\frac{1}{p} = \frac{1}{2} + \frac{1}{E} > \frac{1}{2}$. Then as $p,q >2$ we can find the only five possibilities. Again this just shows there are at most five, by giving the shapes we show there are at least five. We need to check this as we could have introduced new false solutions when doing this manipulation or reasoning.

PLUS - Dual solids take faces â‡” verticies. We do this by placing a vertex in the centre of each face and an edge between these vertices if the faces touch. Tetrahedrons are self dual and then cubes and octahedron and iso and dodecs form dual pairs. This operation swaps p â‡” q in the Schlafli symbol.

PLUS - You can link this to hexaflexagons by talking about symmetry groups. It may be easier to start with symmetry groups of faces then move to the 3D shapes. You can talk about order and also associativity.

PLUS - Talking about tessellations, there's a fairly interesting link as the platonic solids biject with tillings of the sphere (positive curvature) by projecting. The boundary cases {3,6}, {4,4} and {6,3} are plane tessellations and then any other {*p,q*} defines tessellations of hyperbolic surfaces (negative curvature).

Nets

Once you've built a shape, detach a few edges and flatten it out to form a net. A net is a 2D representation of a 3D shape. There's a few interesting questions you can ask. How many different nets does a cube have? I think there are eleven, up to symmetries, but I may be wrong. Try the same for an open cube (one face missing).

History

The platonic solids have been historicaly important, with Greek philosophers believing they corresponded to the five elements (we now know of more than 5 elements). The tetrahedron, cube, octohedron, dodecahedron and iscohedron match to fire, earth, air, ether and water. Of these none are elements, especially ether which doesn't exist. Kepler also believed the platonic solids formed shells on which the planets orbited, while close (coincidentally), it's not true either.

Risk Assessment

Hazard: Plastic pieces

Description: Children swallowing or choking on plastic.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Keep the experiment attended at all times. Do not give small plastic parts to very young children (or let them take them).

Call first aider if child swallows, if choking encourage child to cough.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Polydron pieces

Description: Fingers could get caught in them.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Keep a close eye on children using them. Advise caution.

Call first aider in case of injury.

After Miigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Larger polygons

Description: Larger polygons, especially the decagon, may fit over the head of a child. May cause strangulation if looped around neck and pulled.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: Keep decagons out of reach of small and/or badly behaved children (they aren't really necessary for the Platonic solids, but may be useful for some of the more general solids that you might build with older children).

Call first aider in case of injury.

After Miigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2020-01-16 - Jean Pichon (jp622@cam.ac.uk), **Check 2**: 2020-01-27 - Beatrix Huissoon (beh37@cam.ac.uk)

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Polarisation

Discover how polaroid filters block light as you turn them round - Experiment with the properties of light as certain filters block light, but only in certain directions!

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Darkroom needed**
- **Electricity needed**
- Blue light box
- Two polaroid filters.
- Some bits of clear polythene
- Rulers, set squares etc, for bending.
- Some pieces of calcite
- A partially dismantled LCD screen
- Card model for demonstrating birefringence
- Slinky
- A bunch of photographic CPL (see explanation)
-
- PLUS only:
- Two circularly polarising glasses
- Michel-Levy Chart + diagram of LCD screen and of twisted nematic structure

Experiment Explanation

OVERVIEW

Demonstrating the use of polarisers with crossed polars, polythene strips, plastic rulers and a light box.

Possible activities:

- Demonstrate how crossed polars work by rotating two pieces of polaroid with respect to each other and looking through them to see how the light changes.
- Looking at stressed plastics under polarisers.
- Demonstrate the colour change when a strip of polythene is stretched when viewed under the polariser material.

Other things to talk about:

- LCDs and how they work.

Tips for demonstrating:

- Let the children experiment with different objects under the polarisers as this will keep their interest.
- Use paper strips with waves drawn on to help to demonstrate how polaroid filters work.

BASIC PROCEDURE AND EXPLANATION

1. Show them the light box and the polarising filters

Top tip: scroll down if you're reading this online- there's photos of the various bits of kit!

- The box gives out "normal" white light. Experiment generally works best if set on the floor/ somewhere low enough that everyone can easily see from directly above.
- Take the top piece of polariser and give it to them, get them to look at it in the light. What does this look like -> grey piece of transparent plastic.
- Put the polariser on the light box the way round so light can get through. Still look normal?
- Get them to rotate the polariser around, and see what happens... This normally gets their interest. Get them to turn it upside down.
- Ask what is happening: looks almost black one way round, turn it 90 degrees and it looks bright again

2. Introduce the idea of light as a wave

Do they know what a wave is?

- Ask them what types of waves they know about: sound, water, etc.
- Can they make a wave along their arms? (An awesome dance move if you can pull it off!)

Light behaves like a wave, this wave can be in all directions

- Explain that light is a wave using a wave sketch on a bit of paper
- Light can wobble in different orientations - polarisations. It can wobble up-down, side-to-side, and everything in between
- You can imagine this as a 2D wave like the one sketched on the paper (Yes, we know that there's a second component of the wave, but if you consistently talk about the same component of the wave the explanation is right..)

Polarising filters are like grills that let light through in only in some directions

- Using your fingers as a grill demonstrate what the polariser looks like. Get them to try and get the piece of paper in the through the grill parallel and perpendicular to the grill, i.e. in the two different polarisations.

- Only half the light can get through - this is why the plastic looks slightly darker normally.

- Then add another grill parallel to the first which will allow the light from the first grill to get through. Rotate it by 90 degrees to demonstrate that light can't get through with any orientation. This makes the polariser look black.

- You'll have lots of hands available, you can show the effect of as many twice as many polaroid filters as you have people! You can show that if the light passes through the first filter if it stays at that orientation it can't get through the second one.

Demonstrating polarisation with a slinky

If you have the space and at least 3 people, then instead of using finger grills, you can illustrate polarisation using the slinky:

- Get someone to hold each end of the slinky.
- Tell one of them to shake their end up and down, sending waves along the slinky. Then have them shake the end from side to side, sending waves with a different polarisation.
- Get someone to stand with their legs on either side of the slinky, acting as a polarising filter. Now when waves are sent down the slinky, only up-and-down waves can pass through.
- You can then stand over the slinky as a second polarisation filter, and show that nothing changes.
- Then, sit down with one leg above the slinky and one below it, so that the filters are crossed. Now no waves can get through both filters!

3. Twisting the direction of the light

Demo with the filters

- Ask them what you would have to do to the light (wave drawn on paper) between the crossed polars to get it through. They normally tell you to twist it.
- You can introduce a third polar at 45 degrees to do this (current kit only has two though, unless you use the sunglasses)

Polythene (bags) can twist light

- The polythene normally doesn't affect the light but if you stretch it, it will twist the light.
- Let them have a go at stretching the polythene strip in the light box under the polaroid filter (this can take a while as they find it fascinating!). You should see many colours.
- The different colours twist the light by different amounts. So pick a red bit (best as they know what colour you get if you mix blue and green). You may rotate red by 90deg so it will get through, blue by 180deg so it won't, and green by 360deg so it won't...
- Now get them to look at a red bit while you turn the polariser through 90deg - it should now look turquoise... Now the polars are parallel so red is twisted 90deg so it doesn't get through, blue is by 180deg so it does... -> turquoise light gets through.

Plastic rulers can twist the light

- Put a ruler between crossed polars, you should see lots of colours. These are because they are made by injection moulding, so the plastic is effectively stretched in manufacture.
- The place where the most stretching happens is where the plastic was squirted in - you should be able to see this and you can probably see the rough bit where the sprue was attached.
- There are some rulers that have been cooked, and you should see the shape has changed most in the place where there was the most stress.
- You can also bend the ruler and see stress. A ruler with a crack in it should concentrate stress.

Calcite crystals can twist light

- The crystals of calcite twist light as it travels through, so can appear lighter or darker than the background when placed between the crossed polarisers.
- If v. keen can try and explain birefringence - section below.
- Calcite crystals make double images! The images can be blurry so this may be hard to see. Try looking through the crystal at a line drawn on paper or the numbers on a ruler.
- Light slows down and travels at a different speed in some materials, so the light path bends (refraction). In calcite the speed is different for the two polarisations (birefringence - see below), so the bending is different for the two polarisations. This means there are two paths for the crystal and so you see two images (double refraction).

CPLs

- Photographic circular polarisers (CPLs) are directional. In the direction of photographic usage, they feature a linear filter (distal of the sensor), followed by a quarter-wave plate (proximal) The latter turns the (now) linearly polarised light into circularly polarised light.

4. Uses of polarisation

Possible uses of polarisation (you don't have to mention all of these!):

In physics: light reflecting from a surface or scattered from a material is partially polarised, and polarising sunglasses use this to cut out glare.

In chemistry and materials science: certain molecules rotate polarised light, and we can use this to identify and analyse substances.

In engineering: observing a material undergoing stress through crossed polars

In biology: some animals (such as certain insects) use polarised light for navigation, since the sky is naturally polarised, and even humans can observe polarised light with practice due to a quirk of biology: https://en.wikipedia.org/wiki/Haidinger%27s_brush

In geology: certain rocks give different colours when placed between crossed polars (see Michel-Levy chart in box)

3D cinema glasses (there's some in the box) use circular polarisers. More info: http://en.wikipedia.org/wiki/Polarized_3D_system#Circularly_polarized_glasses

5. Extension: LCD screens- how they use polarisation

The black object with a window and several buttons is an LCD which has had the polarisers removed (and the wiring completely mangled) so you can see that they work through polarisation. Look at it in normal light, then in between the crossed polarisers.

The display consists of two pieces of glass with a 'liquid crystal' in between. This consists of long rod shaped molecules which move around at random like a liquid, but are all aligned like a crystal. There are lines scored on the glass and the liquid crystals tend to align along them, the lines on the top are at 90 degrees to those on the bottom, so the molecules twist as you move through the liquid crystal.

If polarised light passes through the liquid crystal the light rotates by 90 degrees, however if you apply a voltage between the two glass plates by pressing the buttons, the rods rotate so they are end onto the light and stop rotating the light.

So by applying a voltage you can turn on and off the rotation of the light, which with 2 polarisers means you can make it go from clear to black, and by patterning some wires on the glass you can produce a display. which are used everywhere from watches to TVs. This is why if you look at a monitor through a polariser the image can disappear by rotating it.

PLUS Explanation

This explanation is intended to serve as an addition to the main explanation.

Additional points to include when demonstrating to taller than average children (use your own judgement as to how interested the students are, and which topics are appropriate to their subject area - sometimes it might be better to stick to the main explanation):

Malus's Law

For students interested in maths and physics, you can derive Malus's Law for the intensity of light transmitted through a polarising filter - which is that the transmitted intensity is cos^2(Î¸) relative to the incident intensity, where Î¸ is the angle between the axis of the polariser and the polarisation of the light - using a fairly simple argument which doesn't require too much maths.

Show the students that you can write an arbitrary polarisation as the sum of two polarisations, one parallel to the axis of the polariser and one perpendicular to it, using arrows (draw a right-angled triangle). Since the length of the side parallel to the axis is cos(Î¸) times the length of the hypotenuse, the amplitude is reduced by cos(Î¸). Intensity is amplitude squared (possibly use the analogy that kinetic energy depends on velocity squared), so the intensity is proportional to cos^2(Î¸).

If they're especially keen you can get them to sketch this. To explain why the curve is smooth and not pointy when it hits the x-axis, you could talk about x vs x^2.

Birefringence

The box contains two pieces of card, with waves drawn on them, which slot together to form a model which can be used to demonstrate birefringence. By explaining that in certain materials one polarisation will travel slower than the other (possibly with reference to a drawing of a polymer structure, to explain why this happens), you can then demonstrate with the model that if one of these polarisations is shifted by half a wavelength the overall polarisation will rotate by 90Â°. You may need to explain that an arbitrary polarisation can be broken down into components parallel and perpendicular to the slow axis of the material.

You can then explain that, since the rotation depends on the second polarisation being shifted by a integer-plus-half multiple of the wavelength, only certain wavelengths of light will be transmitted through the second filter. This accounts for the colours observed - an extinction spectrum. You can use the Michel-Levy chart to show how the colour depends on the thickness of the material. The sellotape board is a good prop for explicitly showing this dependence, since the colours only change when pieces of tape cross over.

You can also expand on what sort of materials exhibit birefringence - typically these are materials with some sort of preferred direction (anisotropic), such as polymers in which the molecules are aligned in a certain direction (e.g. due to injection moulding - this can be seen in the pieces of ruler) or certain crystal structures.

The calcite is more strongly birefringent and thicker than the rulers: if you place the calcite over a line and look through it, you should see the line splitting into two (provided the calcite is clear enough!). This could be related to the difference in 'speed' between the two axes corresponding to a difference in refractive index. The difference in refractive index, through Snell's law, creates a difference in the angle of the light leaving the block, causing two images to be seen (Double Refraction).

LCD Screen

The box contains a diagram of a twisted nematic structure (as found in a liquid crystal), as well as the construction of an LCD screen - use this to explain how it operates.

The liquid crystal molecules in the screen, under normal conditions, take the structure of a helix with a 90Â° twist from top to bottom. This will rotate polarised light passing through by the same angle. However, if a voltage is applied to the crystal, the molecules instead line up with the electric field, breaking the structure and preventing the rotation of polarised light. This causes a liquid crystal sample between crossed polars to go dark. This can then be exploited to build a display. You could comment on how the screen uses ambient light, and not backlit, being energy efficient.

Circular Polarisation

You can also use the model to demonstrate how circularly polarised light is possible - by shifting one of the pieces of card by 1/4 of a wavelength, you can show the direction of polarisation rotates around as you move along the wave. Use this to explain how 3D glasses work, and ask them why it's beneficial to use circular polarisation and not linear polarisation in that scenario.

Brewster's Angle

If there's time, and the conditions are right, you could comment on the Brewster Angle. At this angle unpolarised light incident on a reflective surface will be reflected with a plane of polarisation parallel to the surface. If there is a shiny horizontal surface (metal is best) in the area, you could ask them to look at it through a linear polariser (ideally polarising sunglasses if there are any to hand). With the polariser in a certain orientation, the glare should be greatly reduced. This is how glare reducing sunglasses work.

Risk Assessment

Hazard: Broken objects (i.e. rulers)

Description: Possible cuts from sharp edges.

Affected people: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Do not allow children to bend items to point where they are likely to break. Remove items which are broken.

Call first aider in event of injury. Stop experiment if required.

After Mitigation: Likelihood: 2, Severity: 2, Overally: 4

Hazard: Light box and cables

Description: Box is a trip hazard if placed on the floor. Electrical cables also present a trip hazard.

Affected people: All

Before Mitigation: Likelihood: 4, Severity: 3, Overally: 12

Mitigation: Make sure equipment is safely and securely placed, at the side of the dark room out of the way of where people are walking. Do not allow the power cable to run across a walkway. Ideally tape down cables if necessary.

Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Light box

Description: Electrical hazard

Affected people: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: See electrical parts RA

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Light box (bulbs heating up)

Description: Possible burns due to contact with hot surface.

Affected people: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Turn off box between demonstrations to prevent excessive heating, or otherwise monitor for overheating and be prepared to take a break and let it cool down. Do not let children touch the light box.

Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Fast moving slinky.

Description: Someone could get hit by the slinky or trip over it.

Affected people: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Donâ€™t have the slinky across somewhere people will be walking, and make sure that no one is standing where they could be hit.

Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

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Pond Life

A selection of organisms from a local pond or rock pool - nan

Last initially checked on 2023-02-18 by Maggie Goulden (mcg58) and doubled checked on 2023-02-18 by Jessica Trevelyan (jet81@cam.ac.uk)

Tags

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Equipment Needed

- **Electricity needed**
- For Crash, Bang, Squelch! the specimens are acquired by pond dipping around Cambridge
- For the summer roadshow and other events, specimens may be acquired from ponds (freshwater) or rock pools (saltwater) locally
- Identification charts (sourced from the field studies council)
- Pond dipping net and bucket (see [Microscopy UK guide to pond dipping])
- White trays
- Aeration pump, tube and stone
- Plastic pasteur pipettes
- Possibly a microscope and some petri dishes
- Possibly also pH paper, or water testing sticks

Experiment Explanation

Using identification charts to look at and identify pond life (either with the naked eye or with the aid of a microscope). Can be extended to testing water quality, using invertebrates as indicator species.

You'll have the pond/rock pool water and creatures in a white tray to make it easy to see them. Let the kids choose a creature to identify then use the pictures/flow charts on the identification sheets to help you. There are lots of different things you could talk about - predators and prey, how animals breathe under water (see lesser water boatman, frogs), metamorphosis and life cycles (see dragonflies, frogs).

FACTS ABOUT COMMONLY FOUND PONDLIFE

Great Diving Beetle - a very large diving beetle, blackish-green in colour, with a yellow border to the thorax and around the wing cases. They predate smaller invertebrates, tadpoles and even small fish. FUN FACT males have suction pads on their front feet in order to grip the females when mating.

Caddis Fly larvae - moth-like insects with hairy wings. There are almost 200 species of caddisfly in the UK. The largest species is over 3cm long. The larvae live underwater where they make cases by spinning together fragments of stone, sand, plant material, even tiny, old snail shells with a silk they secrete from glands around the mouth.

Lesser Water Boatman - a herbivorous insect with legs like oars that help it swim. FUN FACT Water boatman need air to breathe so they have a clever trick that allows them to stay under water for a long time: they collect air from the water's surface and then carry it around as a bubble on their body

Common backswimmer, aka the 'Water Boatman' - a fearsome predator that hunts small invertebrates, tadpoles and fish. It has strong oar-like legs and swims upside-down, near the water's surface. It injects toxic saliva into its prey so it can suck out the prey's insides.

Dragonfly and damselfly nymphs - Dragonflies and damselflies are part of the Odonata order, which means 'toothed ones', reflecting their predatory habit. There are 57 species of Odonata in the UK: 36 dragonflies and 21 damselflies. Although we're familiar with these insects in their adult, winged forms, they spend most of their lives as nymphs (larvae). Dragonfly nymphs metamorphose gradually - they shed their skins 5-14 times before they emerge from the water. When they do emerge, they shed for a final time, becoming adult dragonflies. They then wait for about an hour until their wings harden and they can fly. Note this is very different from butterflies, which only undergo a single metamorphosis step. The nymph stage lasts up to 4 years, whereas the adult stage lasts only a few weeks. FUN FACT - The nymphs are ferocious predators - they have a hinged jaw that they can shoot out to catch their prey. ID TIP - you can tell the difference between adult mayflies and dragonflies by how their winds are positioned when they land - dragonflies sit with their wings open (horizontal) whereas mayfly have their wings closed together. NOTE - the key given says that damselfly nymphs have more than two tails but this isn't always true as particular specimens may have lost one!

Mayfly larvae - these are flying insects that look a little bit like damselflies, but they have broader wings and long tails. Their larvae also live underwater. Often the adults hatch out and take flight simultaneously and in their hundreds. Once they reach adulthood, they may only live for a matter of hours - just enough time to mate and lay eggs before they die FUN FACT - The adults of many mayfly species don't eat at all as their sole purpose is to reproduce (they die soon after). ID TIP - the larvae are long and slender with three distinctive "tails"

Common frog (demo may have frogspawn or tadpoles in it) - Common frogs are amphibians. They feed on invertebrates and sometimes smaller amphibians. They lay their eggs in rafts of jelly-like frog spawn that hatch into black tadpoles. A single female lays up to 4,000 eggs in one spring! When the tadpoles hatch they look like small black blobs with tales. As they get older they start growing legs and get bigger until they resemble tiny versions of the adult frogs. This is an example of metamorphoses (you could compare this to dragonflies and butterflies, also see resources for life-cycles demo). Male common frogs have 'nuptial pads' on their front feet to help them grip on to females during the breeding season (note this is similar to the great diving beetle). The male frog wraps himself around the female and fertilises her eggs as she deposits them. FUN FACT - frogs breathe through their skin, allowing them to stay underwater without drowning. Their skin is thin, with an extensive network of blood vessels under its surface. Oxygen is absorbed through the skin and goes into the blood stream which transports it around the body. (compare to the lesser water boatman)

WILD ABOUT GARDENS CAMPAIGN

If people are interested about how they can encourage wildlife, you can direct them to the Wild About Gardens Campaign, run by the Wildlife Trusts and Royal Horticulture Society https://www.wildaboutgardens.org.uk/. It has loads of useful tips on wildlife gardening and their focus this year (2020) is on ponds!

Some info from their booklet: "Weâ€™re losing our ponds, rivers and streams at a rapid rate. The loss or degradation of these places â€“ to development, drainage and intensive farming â€“ is linked to a huge decline in wildlife, from frogs and toads, to water voles and insects. " "There is a lot we can do in our own gardens and communities to help. Even a small pond can be home to an interesting range of wildlife, including damsel and dragonflies, frogs and newts. It could also become a feeding ground for birds, hedgehogs and bats â€“ the best natural garden pest controllers!" "Your pond neednâ€™t be big. A washing-up bowl, a large plant pot, or a disused sink could all be repurposed as ponds, providing you make sure creatures can get in and out."

Risk Assessment

Hazard: Specimen collection

Description: Risk of slipping/tripping/falling or getting caught by the tide when collecting specimens from pond or rock pool.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Send two demonstrators to collect specimens and exercise caution when choosing location (e.g. make sure there is something solid to stand on near the edge of the water). Check tide tables/observe the tide movement before going to rock pools to collect specimens. In case of injury, call first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Microbes in water

Description: Possible infection from infectious microbes in water.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Encourage hand washing after touching experiment. Hand washing facilities made available. Cover up any cuts whilst handling water. Call first aider in case of injury. If child ingests anything from the aquarium, advise parents to take child to GP if child becomes ill, and give them notes about where water was collected.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Spillages

Description: Slipping on a wet floor.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Clear up spills immediately. In case of injury, call first aider. Use wet floor sign.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Microscope

Description: Electrical hazard from microscope, especially in conjunction with water.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: If water is spilled on microscope, turn it off, clear up, then turn it on again. Ensure microscope has been PAT tested within the past 2 years. See separate electrical parts risk assessment. In case of injury, call first aider.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

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Prism Goggles

**Demonstrate how the brain adapts to changes in environmental input using prism goggles. ** - See how quickly your brain adapts by wearing our prism goggles whilst playing a target-hitting game.

Last initially checked on 2023-01-20 by Emily Wolfenden (elw74@cam.ac.uk) and double-checked on 2023-01-21 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Floating

Equipment Needed

This experiment can take place outdoors

- Prism goggles (currently on loan from Steve Edgely, Dept of PDN)
- Small objects to aim at box (e.g. beanbags)
- Box (e.g. small blue experiment box, bigger one if working with younger children!)

Experiment Explanation

Interim explanation copied from http://www.umich.edu/~nkids/Neurokids_Program/Lessons_files/NeuroKids-Prism%20Goggles%20Lesson.pdf

INTRO/BACKGROUND: The following is an example of what the leader might say during the introduction, including some specific questions to keep the kids engaged. It does not need to be repeated verbatim, and probably will contain more information that is necessary to explain.

Can anyone describe what learning is? Scientists like to say that â€œLearning is the way we acquire information about the worldâ€, but this can mean a lot of things, information can mean things like phone numbers, friends names, times-tables, but it can also be things like friends faces, how to make a free throw, or how to draw a picture. When scientists over the last century have thought about learning, they realized something very important, and that is that some kinds of learning are require conscious activity and others happen unconsciously, and they refer to these kids of learning as explicit and implicit learning.

Consciousness can be tricky to talk about, maybe you think you know exactly what we mean by conscious and unconscious activity, but lets look at it a different way. If we asked you to describe how you learned that 6x8 is 48, you could probably describe how math works, that if you took a bunch of M & Mâ€™s and made a square with 6 rows of 8 M&Mâ€™s each that you could count each one and make 48. Some things that we learn are easy to talk about, but others are more difficult, take free throws for example, somebody probably showed you how to hold the ball, but how exactly do you know how to make the shot? Scientists look at it this way, times tables and correct free throws are both kinds of information that can be learned. The type of information that you can easily think about and describe is termed explicit {think explained-explicit}, and the kinds that you kind of just do are termed implicit {less easy to remember, think implied}. Now in everyday life not everything fits nicely into one category or the other, but for today weâ€™re going to stick with that definition.

When you learn something new individual cells in your brain change. One thing that scientists are currently studying is where in your brain specific cells are changing. Were going to show you a little game that will change a few cells in a part of your brain called the cerebellum. One thing that your cerebellum helps you do is compare what you see with what your body is doing. You have lots of sensors in your muscles that keep track of where your body is. If you move your arm, you know where itâ€™s moving even if you cannot see it, or arenâ€™t paying attention. A copy of this, along with a lot of other information goes to your cerebellum.

Your cerebellum helps you by comparing what you want to do with what you actually did. So if youâ€™re playing a beanbag toss game, and you throw a beanbag at a target then you either hit the target or miss the target. Part of your cerebellum is working like a little computer, and each time you throw a bag, it keeps track of how close you were to the target. It takes the information about how much you missed the target by and uses it to change the way your arm moves the next time you throw.

When you play the beanbag toss game, were going to move where the target appears to be, so you will end up throwing it further away from the target than you would expect, but if you take enough throws your cerebellum will do the work for you and change the way your arm moves without you even having to think about it. And your throws will get closer and closer.

ACTIVITY:

- Volunteers will lead groups of 4-6 students.
- Students will be trying to throw a beanbag into a target.
- Each student will first get an opportunity to practice a few throws and then they will be given a pair of Prism Goggles.
- Prism Goggles distort the field of vision to about 20 degrees in one direction and make it very difficult to hit the target and beanbags will probably be thrown all over the place.
- Other students that arenâ€™t participating can help collect stray beanbags.
- While wearing the goggles, each student should get 20-30 attempts to hit the target.
- Students should be encouraged at this time to â€œlet their brains adapt to the situationâ€ rather than manually adjusting where they aim (many students will attempt to adjust their aim).
- After they begin to consistently hit the target, ask the student to remove the goggles and throw again.
- Many of the students will accidentally miss in the opposite direction.
- Some students may not show these effects of compensation.
- Allow each student to have his turn to wear the glasses and try the experiment.

DISCUSSION:

- Once we put on prism goggles, there are two ways to adjust and hit the target.
- One strategy is explicit, we tell ourselves that our aim is off and try to throw the beanbag where we think the target is, rather than where it appears. This type of strategy quickly adjusts our performance, but requires us to guess where the beanbag should be thrown. For students that use this strategy, when the goggles are removed, and they are asked to throw again, they will not experience an opposite shift in their aim.
- When using the implicit learning strategy we throw the beanbag where the target appears to be. This strategy requires several attempts, each time we throw a beanbag, our brain makes a tiny adjustment, in a brain circuit that we do not have conscious control over. The adjustments last for a while which is why after removing the prism goggles, our aim has been adjusted in the opposite direction, and takes a few more trials to re-learn.

Some questions to ask {feel free to add your own}:

- Is one kind of learning better than the other? {each have their own benefits, think about the attention demands of explicit learning}
- What is an example of an activity that is more effectively learned implicitly/explicitly? {maybe something like soccer/friends names}
- Why would we want to learn things without having to pay attention to them?
- Are there any subjects in school that are best learned implicitly? {foreign language}

Risk Assessment

Hazard: Goggles

Description: Child becomes disorientated wearing goggles or on removing them and is more likely to fall over.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Ask child to stand still on one spot if they are wearing the goggles. If they feel dizzy, remove the goggles and tell them to sit down on the floor. Do not allow them to run around wearing the goggles. Remember that they may be equally disorientated on removing the goggles - do not allow them to run off immediately and again make them sit down if they are dizzy. Ensure the surrounding area is resonably clear, particularly of sharp objects and is on level ground away from any sharp drops, to prevent injuries and falls. Call first aider if necessary.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Small objects

Description: Small objects being thrown towards target escape and present a trip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep an eye on the whereabouts of the objects, do not get too many out at once. Where possible, use objects such as beanbags which will not bounce and roll all over the floor. Do not set up the experiment in a throughfare. Call first aider if necessary.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Various activities

Description: Small objects to be thrown towards target, and attempts at high-fives - may hit other people.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Do not allow children to collect objects while the subject is still throwing them. Position the experiment so that other people are not in the firing line. Use soft, light objects where possible. Warn children to high-five gently. In case of accident, call a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Dropped objects

Description: Child picking up objects from floor may hit head on nearby objects due to lack of peripheral vision.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Demonstrate away from obstructions - especially shelves/tables/sharp corners - as far as possible. Pick up balls for child if hazards are nearby. Try to stand between child and hazard. Make sure child takes off goggles before picking up objects. Call first aider if necessary.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2012-11-27 - Elizabeth Mooney (erm40@cam.ac.uk), **Check 2**: 2012-11-27 - Beatrice Tyrrell (bet23@cam.ac.uk)

Check 1: 2014-01-07 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-26 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-08 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2015-01-09 - Kym Neil (kym.e.neil@gmail.com)

Check 1: 2016-01-05 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2016-01-21 - Natalie Cree (nc434@cam.ac.uk)

Check 1: 2017-02-01 - Joanna Tumelty (jt574@cam.ac.uk), **Check 2**: 2017-02-02 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2018-01-27 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2018-02-03 - Andrew Sellek (ads79@cam.ac.uk)

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Check 1: 2022-01-23 - Jessica Trevelyan (jet81@cam.ac.uk), **Check 2**: 2022-01-29 - Conor Cafolla (ctc43@cam.ac.uk)

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Projective Dobble

The maths of Dobble - Introduction to axiomatic maths and projective geometry via the card game Dobble. Learn how to make your own Dobble decks by constructing the "axioms of Dobble" from the rules, then developing methods to build these.

Last initially checked on 2023-02-19 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-19 by John Leung (cfl35@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

Games

Pure Maths

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Equipment Needed

- Requires the printouts as follows:
- 4 x symbol cards (14 symbols)
- Railway Track picture
- Fano Plane Picture
- 3x3 Grid Extension Picture
- Fano Plane Dobble Deck (7 cards)
- 3x3 Dobble Deck (13 cards)
- (optional) Dobble Deck (55/57 cards)

Experiment Explanation

Dobble (or Spot it!) is a card game that's similar to snap. A Dobble deck contains a set of cards, each card has several symbols (normal Dobble is 8 per card, kids 6) on it and the unique property that any two cards share exactly one symbol. To play reveal one card, players look at it, then reveal a second, the first to shout the symbol matching wins. The winner claims the first card, the second card stays face up and the game continues with a new card revealed. Try playing a few games using the deck with 4 symbols.

We now want to link everything back to maths. Dobble has some interesting properties and we want to study decks of Dobble cards. To do so we need to say the rules we want Dobble decks to have, these are called axioms. In maths axioms are our basic assumptions about any objects, so our axioms of Dobble better be true of any deck of Dobble cards. Our first axiom is simple:

1. For any two cards there exists exactly one symbol appearing on both cards.
2. Each card has the same number of symbols.
3. No symbol is repeated on a single card.

We'll discover our next axioms by trying to make Dobble Decks with an increasing number of symbols. Dobble with only one symbol is boring. We just have lots of copies of the same card! We don't like this so we stop it.

4. Each card is different.

This does allow us to have a deck with only a single card (if you like this or not depends, we'll introduce another axiom later to stop it). When we get to two symbols we need to make sure we're actually using them.

5. Each symbol appears on at least one card.

With these rules so far our Dobble decks only have a single card, but when we get to three we get our first (slightly) interesting Dobble deck. This looks a bit like Dominoes. So with 3 symbols and 2 per card we get our first Dobble Deck!

Now with 4 symbols and 2 per card we can't quite have dominoes like before but we can do something (laminated example). With one symbol in common between all three cards. This makes a very boring game of Dobble, so we add another rule.

6. For any symbol, there's a card without that symbol. (If you want to allow 1 card decks you'll need to rephrase this)

What about 4 symbols and 3 per card? Have a try and whatever happens it seems like axiom (1) keeps failing, we can't get exactly one symbol. But we'll actually need to prove it! If we have three symbols and two cards then there are six symbols we need to pick however there are only 4 symbols available. Since we need to stick to (3) we end up with two symbols in common. This argument is called the pigeonhole principle. Formally we'd argue there's a symbol on both cards, 4 remaining slots and 3 symbols that can be used (as by (3) the repeated one can't appear again) thus by pigeonhole there's a repeat.

Now we move up to 5 symbols and 3 per card. We can get two cards but then get stuck trying to make a card without the common symbol. So if we move to 6 symbols we get a 3 card deck! But we can actually do better. We can add a fourth card by taking the unmatched symbol from each and making a new card.

So far we've found nice Dobble decks at 3 and 6, is there anything special about these? It turns out the triangular numbers have an important link and we can make Dobble decks with a triangular number s of symbols per card we can make $(s+1)$ cards using $T(s)$ symbols using the same pattern.

Projective Geometry

Lots of times in Maths we want to take our axioms (which describe a thing we want to find out about) and then show some kind of object we understand satisfies those axioms. For Dobble one such setting is that of geometry. We'll now start interpretting our original Dobble axioms but in a geometric sense. Instead of saying "symbol" we're going to say "point" and instead of "card" we're going to say "line". A line has lots of points much like a card has lots of symbols. A deck is now a collection of lines. So now our axioms become.

1. For any two lines there exists exactly one point appearing on both lines. (i.e. Every pair of lines has a unique intersection)
2. Each line has the same number of points.
3. No point is repeated on a single line.
4. Each line in the collection is different.
5. Every point has at least one line passing through it.
6. For any point, there's a line not passing through that point.

This roughly lines up with what we expect of geometry with a few exceptions. To make sense of (2) we insist on their being only a limited number of points, for instance just imagine a grid of points where if you go off one end you wrap around and appear at the same point on the other side. Then the only problem is (1), we have parallel lines which can never meet!

This requires us to take an alternative idea of geometry, mathematicians call this projective geometry. Look at the picture of the train tracks. It looks like the parallel tracks eventually meet on the horizon. In projective geometry they do. The general rule of projective geometry is our equivalent axiom (1) holds. Look at the Fano Plane diagram which has 7 points and 7 lines. Notice that because we this new axiom (1) we don't end up with straight lines when we try and draw it on our normal (non-projective) piece of paper.

Our first challenge is to lay the symbols out so each line matches up with a card. Try this with the Fano Plane deck. You'll find you're able to make the cards into a triangle shape, then add a card in the middle. Our final line ends up being a circle. However we never said our lines had to be straight. Here each "card" corresponds to a "line" as in our axioms.

The next concept that makes projective planes interesting is duality. This means swapping "lines" and "points". We can actually do this. Try lying out the cards in the deck so each "card" is now a "point" and every "line" has some "symbol" in common. We call this duality.

We can also make projective planes from usual planes by introducing some new "points at infinity" for each direction we could head towards infinity in. On a 3x3 square grid this is up, right up diagonal, right, right down diagonal. While we could go down to infinity as we wrap around that's the same as going up.

Now let's show how we make a Dobble deck from a grid like this. We work through each of the parallel lines in those four directions. For each of the three parallel lines we choose a symbol and place that on all 3 cards, we also place this symbol on the "point at infinity" for this direction. This gives us 4 symbols on all our finite cards and 3 on all our "point at infinity" cards. However the easy way to solve this is to add a new infinite symbol to these four "points at infinity" cards. This represents the "line at infinity".

The actual game of Dobble is made in this fashion! It just uses a 7x7 grid and there are more points at infinity corresponding to making "knights moves" in different directions. You can lay out an actual game of Dobble like this and try it. Sadly with 8 symbols per card and 57 symbols you can get 57 different cards, however a commercial game of Dobble only has 55.

When the cards are printed out I'll add some cool tricks about duality. You should be able to find the dual symbol to a card then choose a card, look at it's dual symbol, find all cards with that symbol on them, then look at the duals of all these cards and that should be the symbols on the original card (careful if it's dual to a symbol on it's self "self-dual"). This is an example of taking the dual of a dual and coming back.

We can also show take theorems in projective geometry and find them in Dobble. For instance Pappus' Hexagon theorem says take two lines, pick three points on both lines, draw the lines between pairs these, the three points of intersection form a line. (See picture). If you do this in Dobble pick two sets of three cards that share a symbol. for each pair find the (unique) card sharing both symbols. The three cards you get from this all share a symbol.

Risk Assessment

Hazard: Laminated card

Description: Edges of plastic may be sharp, which could lead to cuts or minor injuries. Young children may try to put them in their mouth, leading to spread of infection.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure sharp corners on the cards have been rounded out. Don't let very young children who could potentially hurt themselves handle the cards.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Hazard: Cards

Description: Cards could be dropped and slipped on.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Make sure cards are not on the floor. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2023-02-19 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-19 - John Leung (cfl35@cam.ac.uk)

Psychedelic Milk

See the amazing patterns made by food colouring and detergent in milk. - A little milk, a little food dye, a little washing-up liquid... and an amazing display of colour. See the stunning swirling effects from disrupting the surface tension.

Last initially checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-07 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Some milk (usually have UHT in stores)
- A few colours of food colouring
- A few drops of washing up liquid
- A fairly flat bottomed bowl

Experiment Explanation

Taken from Dave's Naked Scientists explanation:
http://www.thenakedscientists.com/HTML/content/kitchenscience/exp/psychedelic-milk/

In a nutshell

Investigate how reducing surface tension can lead to pretty patterns that move in milk using food colouring and washing up liquid.

How to set up the experiment

1. Add about 1cm depth of milk to the bottom of your bowl.
2. Pour a few drops of each colour of food colouring onto different places on the surface of the milk (be sparing)
3. Add a drop of washing up liquid somewhere in the bowl.
4. The food colouring moves! You should find that at first the food colouring moves away from where you added the washing up liquid, and then it starts welling up from below the surface of the milk, forming beautiful patterns.
5. After a minute or so and everything has stopped moving, add another somewhere else.

What you need to know during the event

1. Milk is mostly water, and water has a property called surface tension. This is because all the water molecules are strongly attracted to other water molecules, but not to air. Therefore the water molecules try to make the surface (the interface between the water and air) as small as possible. This is why raindrops are approximately spherical - the shape with the minimal surface for its volume.

2. The food colouring is less dense than the milk so it floats on the surface. This is because the milk has lots of substances dissolved in it such as calcium, making it more dense than the food colouring (which is almost entirely water).

3. Washing up liquid is designed to reduce the surface tension so water can dissolve fats and grease. This means that where you add the washing up liquid, the surface tension is much weaker than everywhere else. The surfactant spreads across the surface away from the drop, making the rest of the surface shrink.

4. The food colouring is forced downwards and there is a current below the surface flowing back towards the washing up liquid pulling the food colouring along. It then floats back up to the surface producing beautiful patterns.

Want to know more?

A washing up liquid molecule is made up of a water loving head and a water hating tail, so when you add it to water the molecules arrange themselves over the surface - head inwards. The water is strongly attracted to the heads of these molecules, so is now stops trying to reduce its surface area, and the surface tension is far weaker.

The bubbles in washing up liquid are not originally there - they get added because people associate bubbles with cleanliness...

Risk Assessment

Hazard: Surfactant (I)

Description: Could get in eyes and result in irritation.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: If children get their fingers in the washing up liquid, tell them not to put their fingers near their eyes and ensure they rinse it off.

If washing up liquid gets into an eye, demonstrator must call a first aider and may perform an eye wash if trained and confident to do so.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Surfactant (II) and other liquids

Description: Could be harmful if ingested

Affected People: All, particularly small children who try to ingest things

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Use a relatively harmless surfactant (standard washing up liquid) and watch the kids so they don't try to lick their fingers or drink any part of the experiment. Food colouring probably shouldn't be ingested in large quantities, and the milk has likely been in the cupboard for a while.

In the event of an incident, call a first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Spilled milk (or water)

Description: Slip hazard.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: All spills should be cleared up immediately. Call first aider in case of injury. Donâ€™t cry over it.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2011-12-22 - Hannah Ford (hf257@cam.ac.uk), **Check 2**: 2012-01-20 - Catherine Collett (chc47@cam.ac.uk)

Check 1: 2012-12-12 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk)

Check 1: 2013-12-15 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2014-02-16 - Benjamin Lai (bl337@cam.ac.uk)

Check 1: 2014-12-27 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-02 - Holly Davis (hd308@cam.ac.uk)

Check 1: 2015-12-30 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2016-01-16 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2017-02-09 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2017-02-09 - Tim Morgan Boyd (tmb58@cam.ac.uk)

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Check 1: 2020-01-12 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2021-01-17 - Andrew Sellek (ads79@cam.ac.uk)

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Check 1: 2023-02-06 - Margaret Johncock (mllyj2@cam.ac.uk), **Check 2**: 2023-02-07 - Jamie Barrett (jb2369@cam.ac.uk)

Pulsars

An experiment to introduce children to pulsars, explain what they are and how they can be used as clocks and to find out about the interstellar medium.

Last initially checked on 2023-02-09 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-02-09 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Physics

Equipment Needed

- **Darkroom needed**
- Pulsar Model
- Sheet of translucent material (I think a sheet of paper may work)

Experiment Explanation

Pulsar Experiment/Demonstration

1. Get out model pulsar, preferably in a dark/dim place. Turn on the fairy lights and spin the model around so that the kids get the idea that you can only see the light/emitted radiation when the beam is pointed towards them. Explain that this is because the axis of rotation is different to the axis along which the radiation is emitted.
2. Explain that these stars spin very fast because they are the remnants of much larger stars that exploded (The sun's rotation period is about 25 days at the equator and 36 at the poles. Caveat: it won't form a pulsar after it dies). These larger stars were spinning much more slowly but, after the explosion, they because much smaller. Hence, to conserve angular momentum, the rate at which they spin had to go up. Make comparison to ice skater/ point at spinny chair if thatâ€™s out as well.
3. Give them some numbers â€“ the range of pulsarsâ€™ periods is from 1.4 milliseconds to 8.51 seconds with a typical period being around 1 second. Try and impress upon them how fast this is for a star to be rotating. Earth takes a whole day, so that's 86400 times faster!
4. Tell them how some kinds of pulsars have such reliable periods that they can be used as clocks. Demonstrate how this would work by using the model.
5. Get out the screen of translucent material. Ask one of the kids to hold it between the star and the audience and then ask the audience what they notice about the pulses from the star. Hopefully theyâ€™ll say that the pulses are less bright. Explain how this means that pulsars can be used to examine the properties of the media that lie between the pulsar and Earth.

Other talking points: Explain what a neutron star is/ how one forms. Talk about how all the space between the atoms has been squeezed out and that one teaspoon of neutron star would weigh the same as a mountain. How to use pulsar clocks - have seen changes in the frequency due to the effect of planets (in fact this is how the first exoplanet was discovered in 1992, though the more famous first, 51 Pegasi b was the first around a still living star - Mayor & Queloz 1995), also ideas that we could use them to detect gravitational waves (ripples in the fabric of spacetime) passing through a large number of them (Pulsar Timing Array)

Risk Assessment

Hazard: Fairy lights inside the model

Description: Fairy lights inside model could heat up- potential fire or burn risk

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Turn off fairy lights when model not in use. In the event of a burn call first aider and run the burn under tepid water for an appropriate amount of time. In the event of fire, follow procedures in venue RA.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Spinning model

Description: Could accidentally hit a child with the model while spinning it.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Carry out demonstration at a safe distance from the children. Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Bright lights

Description: Risk of dazzling if child looks directly into the lights

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Tell children not to look straight into the lights. The fairy lights used are very dim.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2018-02-07 - Benjamin Akrill (bja32@alumni.cam.ac.uk), **Check 2**: 2018-02-07 - Sarah Wiseman (sw628@cam.ac.uk)

Check 1: 2019-01-01 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-01 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-02-02 - Lucy Hart (ljfh2@cam.ac.uk), **Check 2**: 2020-02-03 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Andrew Sellek (ads79@cam.ac.uk)

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Random Walks

Choosing direction using a coin flip. - See how biased coins and random chance can lead to surprising conclusions.

Last initially checked on 2023-02-15 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-16 by Lauren Mason (llm34@cam.ac.uk)

Tags

Maths

Probabilities

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Duplo blocks
- Dry wipe pen
- Duplo baseplates (2 stuck together for the race)
- Fair coin (10p)
- Biased coin (2p)
- Selection of Dice (Biased and unbiased)
- Print out of a monopoly board
-
- (n.b. if there isn't a biased coin, because it's got lost for any reason, you can always just use a bit of sleight of hand and lie, saying it's heads two thirds of the time...)

Experiment Explanation

A variety of experiments can be done with random walks, showing not only the idea of a biased probability, but also that even when an outcome is weighted one way, random chance can lead it to come out the opposite.

Setup There are a few fun games to play here. Most involve building up individual children's results into a nice smooth distribution, by building duplo bricks with their names on them into a nice smooth wall.

Explanation and Demonstrating

The simplest thing to start with is with a brick on the middle of a baseplate and an unbiased coin. If you set the rule that when the brick gets to an edge it falls off and the game is over, that a head moves you in one direction, and a tails in the other. They should see that there's a good bit of back and forth, but eventually you should end up dropping off one side or the other.

Then try doing the same with the biased coin (roughly 66% of the time it gives heads) making sure the coin is allowed to land on the table (preferably on a piece of paper to damp bounces and speed up the whole process), show that if repeated a few times the brick has a tendency to fall off the same side.

Alternatively, as the first method can sometimes take too long, use about six bricks build a tower: placing the next brick on top of the previous one and one set of teeth to the side depending on the toss being heads or tails. Then repeat this a couple of times with both coins and you should see that with the biased coin the tower of bricks tends to lean to one side.

Now set up a few bricks, all starting different distances along the board, and watch which one is the last one left, it should be the one initially roughly two thirds of the way along, not as many people might assume when first introduced to a biased coin, as far from the side it's biased towards as possible.

If you can't find the coin then there are also some dice, use the convention even moves one way and odd the other. There are several non-standard dice which can be used for a biased coin.

--ORIGINAL PLAN--

Finally, you can build a really lovely distribution by starting the block at one end of two mats put together and using the biased coin. With every flip you move the block one space forwards (one block length, not one set of teeth) and one space in whichever direction the coin dictates. When the blocks reach either side, that's where they stop. Keep everyone else's blocks on the board as well, and a nice distribution should build up. It should look, very roughly speaking, like a pear cut in half, with a bulge at the near end and then at tail trailing off. Write their name on the block with the dry wipe pen, you'd be surprised how keen they are to come back later and see how the distribution's evolved around their block.

You should see roughly the same distribution on both sides, just with significantly less blocks on the side that is biased against. You can discuss with them things like why there are no blocks at all in the first few spaces, why there is a peak (it roughly corresponds to the balance between a point which there are a lot of various paths to, and where the probability the brick hasn't already fallen off the board, balance out).

--ALTERNATIVE PLAN-- (experiment still developing so let us know what works best!)

Some demonstrators, rather than building up a distribution over the day, which can take a long time and still won't look exactly smooth even after all the pieces have been used, prefer to just trace the path of one random walk, placing a new brick for each step. This gives a clearer memory of the rambling nature of the walk, and there should be sufficient bricks for two or three paths simultaneously.

This also helps defend against the odd child who comes along and tries to tear the whole thing down...

It may be the better options for events with younger children, where the concept of a distribution is a bit much, and also it just looks really cool!

--Real World Applications--

If you fancy it, there's a great analogy between this experiment and genetic drift. Genes that develop in populations of animals normally have some selective bias for either adoption throughout the population or deletion. But genetic drift is the process of random genetic evolution, and has a strong analogy in a biased coin toss. From this it's possible to see that even a positive evolution (one that natural selection favours some percentage of the time) may be deleted by chance, or a deleterious one spread throughout the entire population.

The key idea here is that when there is one or more boundary, i.e. the edge of the board, we see markedly different behaviour to that we'd expect for an infinite number of tests, where deleterious mutations would never remain in the population and we'd always expect to the brick to end up on the side that it's biased towards eventually.

There are many other examples of random walks in nature, like photons in the solar atmosphere which take thousands of years to complete a 'drunkard's walk' from the centre to surface of the sun and only eight minutes to make it all the way out to earth. More complex examples include the game of life, a simulation of how populations grow, receded and migrate over time. You could even mention the fact that for some random walks, even in infinite time you would not expect it to pass through all points.

If you wanted to link to something else you can use the monopoly print out to demonstrate a random walk on the board. If you land on community chest or chance there's another random element you could move else where but it's possibly best to ignore this. If you roll 3 doubles in a row you go to jail. If you can find put properties of this walk you'd be able to gain an advantage at this game. You can see the Kruskal's Count experiment for some other ideas related to this.

--Transience/Recurrence-- By flipping two coins you can do a random walk in 2d, ask people if you think you'd be able to get back to the start, will it take longer to fall off an edge. Then repeat in 3d where this isn't true.

Risk Assessment

Hazard: Duplo blocks/coins/dice

Description: Swallowing or choking on Duplo blocks and coins.

Affected People: Small children

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Duplo blocks should be sufficiently large that they are safe from swallowing for all ages, but keep an eye out just in case. Don't let small children handle coins. Keep an eye on all the equipment. Call first aider if child swallows, if choking encourage child to cough while awaiting first aider.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Losing objects

Description: Tossed coins / thrown dice flying away and can either hit someone, or get lost e.g. under tables, resulting in kids running after them and hitting something.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Check you can flip a coin without losing control of it, otherwise just spin it on the table. It's perfectly fine to let the children (if older) toss the coin themselves, but make sure they're capable of doing it safely with a trial flip first. Don't let children retrieve lost coins. Call a first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Objects on the floor

Description: Slip hazard if things dropped on floor.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep an eye on where any objects go, and try to confine them to a desk or fixed area. Pick up anything that falls immediately. Do not let multiple unattended children use objects at the same time. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Pens

Description: Children may be tempted to lick the marker pens and fall ill as a result.

Affected People: Children

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep an eye on the pens and don't let small children use them without supervision. In the event of an incident, tell parent to contact a GP if child feels unwell later.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

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Red cabbage

Making a natural pH indicator. - We use a little red cabbage juice to find out more about acids and bases in the world around us.

Last initially checked on 2023-01-19 by Joshua Wu (jw2311@cam.ac.uk) and double-checked on 2023-01-20 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Red cabbage
- Knife
- Rolling pin or other mashing device
- Large bowl
- Cups
- Vinegar or lemon juice
- Bicarbonate
- Absorbent white paper - scientific/coffee filter paper are good, kitchen roll less good
- Litmus paper
- Pipettes

Experiment Explanation

Overview:

Cabbage juice is used as a pH indicator to demonstrate the concept of pH. Paper dipped in cabbage juice will change colours when dipped in an acid (vinegar/lemon juice) or base (bicarb).

Tips for demonstrating:

- If the kids want to, let them take home the pH paper!
- Adding indicator to the liquids gives a much better colour change than using the filter paper.

Basic Procedure and Explanation:

Before Event:

1. Cut up half a head of red cabbage.
2. Crush it using a rolling pin. Put crushed cabbage in a bowl/cup with water and mix. Strain the liquid into another cup, and you should have a bluish/dark purple liquid â€“ this is your natural indicator. When added to acids it should go pink, and in alkalis or bases it should go blue/green.
3. Set up cups with cabbage juice, lemon juice/vinegar, bicarb in water and water.

At Event:

4. If the cabbage still needs to be crushed/strained into a cup, ask the kids to help you.
5. Dip a strip of paper into the juice and explain that this juice will act as a pH indicator â€“ in other words it will tell us whether something is acidic or basic.
6. Ask them if they can name some acids/bases. (Lemon juice, bicarb, vinegar, orange juice, etc)
7. Ask them if they know what pH is? -tailor your explanation to the age of the child -pH scale is a logarithmic scale defined by pH = -log10[H+] â€“ for older kids -pH is a number that tells you how acidic or basic something is [neutral substances, such as water, have a pH of seven, acids (vinegar/lemon juice) have a pH of less than seven, and bases (sodium bicarbonate) have a pH of more than seven.]
8. Explain that the cabbage juice will turn blue/green when dipped in a base and pink when dipped in an acid.
9. Show them your â€œmysteryâ€ liquids (vinegar, water and bicarb/water) â€“ ask them to use the indicator

paper to determine which one is an acid/base.
10. Discuss why the indicator paper doesn't change colour when dipped in water as it's neither an acid nor a base - explain the concept of neutral substances.
11. You can also use a pipette to add a couple of drops of acidic/basic solution to the cup with cabbage juice in to make that change colour.
12. Ask them what will happen if you add an acid and base together. Try mixing lemon juice and bicarb, then testing the pH.

Other things to talk about:

1. Structure of atoms

- Get kids to simulate and atom by having one kid be the nucleus and the others be electrons that orbit the nucleus
- Talk about how electrons have negative charge and protons in the nucleus have positive charge
- Can they explain how the electrons orbit rather than flying off? Get them to think about magnets attracting each other if struggling
- Talk about how acids are solutions with free protons and how this allows most indicators to gain a proton/H+ in acidic conditions to change colours (contrast with how red cabbage loses an OH group as described below)

2. How can the cabbage juice act as an indicator?

- Red cabbage contains coloured pigments called â€œanthocyaninsâ€ which have antioxidant properties
- In acidic conditions they lose an â€“OH group, and gain it in basic conditions
- Most indicators gain an H+ in acidic conditions and lose in again in basic conditions
- This change in the physical structure will change the wavelength of light reflected off it, and so it changes colour

Risk Assessment

Hazard: Knife

Description: Sharp knives may cause cuts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Only demonstrators to use knives to cut cabbage, which should be done before the event starts. Knives to be kept concealed and out of reach for the duration of the experiment. Knife to be sheathed when not being used.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Lemon juice/vinegar/bicarb

Description: Lemon juice/vinegar and bicarbonate of soda irritant to eyes

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Only use small amounts, avoid pouring out more reagents while demonstrating.

If in contact with eyes, wash with emergency eye wash provided if trained and confident to do so. Call first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Lemon juice/vinegar/bicarb

Description: Children eating/drinking bicarbonate, lemon juice or vinegar.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Don't leave children with experiment unsupervised. Put all unnecessary reagents back in the box and always leave the experiment safely packed away when closed.

If ingested, advise parents that reactants are all edible, but to seek medical attention if child is feeling unwell as reactants may have been in box for unknown amount of time.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Liquids

Description: Mixing acidic and alkali solutions would result in a reaction, causing bubbles to form. Spillages may be a slip hazard, but are unlikely to happen since acid and base used are weak.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Do not mix the solutions.

Clear spills promptly, use wet floor sign if needed.

Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

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Relative Senses

A variety of experiments to show how our senses are relative rather than absolute: - Find out for yourself how our senses are relative and not absolute, and experience this phenomenon with this demonstration working on sight, touch and temperature.

Last initially checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-11 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- **Darkroom needed**
- 3 bowls of water - 1 hot, 1 cold, 1 in-between
- 3 different textures of sandpaper - 1 rough, 1 smooth, 1 in-between
- Dim room + Kitchen Roll Tube

Experiment Explanation

What we're going to do is think about how our senses work, ask about what sense we have and maybe think about what the extremes of these are? How precise are our senses? What are they designed for? For instance lots of our senses are designed to protect us, we shouldn't touch hot things for instance. In this experiment we'll find out our sense are sensitive to quick changes in conditions and often can be quite paradoxical, in that we can get different results from different sensors to the same conditions. There are three senses you can try:

Temperature

Get three bowls of water, one hot (not so hot as it will hurt anyone), one cold, and one in between get them to put one hand in the hot, and one in the cold. Wait a few seconds, then get them to put them both in the warm one.

You should find they look very confused as one hand will feel the warm water as hot and one as cold.

Try the 2 "opposites" with different hands, then use the intermediate one with both hands, and see if they feel different.

This shows that a lot of our senses are relative rather than absolute, you are much more sensitive to a change in temperature than the absolute temperature. I suppose this is an extreme, where a lobster won't really react if the water temperature is increased slowly enough...

Brightness

If you go from a dark room into bright sunlight it feels very bright but if you are in a light room and go outside it doesn't seem so bright as there is less change in brightness. We can try this in a dim room with a kitchen roll tube. With one eye open everything is the same level of brightness. Now try with one eye but looking down the tube, here you have really dark walls of the tube and a brighter area out of the tube. Now what happens looking out of both eyes, one tubed and one not? You should see a bright circle in your vision caused by the end of the tube, it's because from the sense from the tubed eye it's much brighter, even though both eyes see the same.

Roughness

Another manifestation of this is rubbing your hands on rough and smooth sandpaper, and then both on some intermediate sandpaper...

You get a similar reaction as the temperature - it is very strange, as there is nothing physical changing in your hands this time...

I think you have vibration sensors in your skin which detect the amount of vibration, instead of each movement, and the nervous system must just be more sensitive to changes than absolute values in general??

Additional background for demonstrators

The same is true of temperature and vibration. If you put one hand in a bowl of hot water it feels hot because the nerves which detect higher temperatures become more active. If you leave your hand there the nerves gradually become less active even though the temperature is staying the same. The same works for your other hand - the one in the cold water. The nerves that detect raised temperature become less active initially so you feel cold but if you leave your hand there then they become a bit more active even though the temperature is the same. When you move both hands into the normal temperature water your brain compares the temperature with the previous temperature. The hand from the hot water is used to warm temperatures and so feels cold. The hand from the cold water is used to cooler temperatures so feels hot.

This makes sense, as the important things are more normally the changes in a sense rather that the absolute value, eg it is interesting that the temperature has suddenly changed, as this may mean a change in the weather, your house has fallen down, etc. but if your nervous system kept shouting 'It's quite warm' all day, you would be distracted from the sabre tooth tiger creeping up on you...

"Thermal receptors are very sensitive to differences between the temperature of the skin and the temperature of objects that are touched. Rapid changes in skin temperature evoke dynamic responses, with increases in temp. signalled by warmth receptors firing and cold receptors silencing and vice versa. If contact with the object is maintained for several seconds, the firing rate of the receptor falls to a lower rate. This adaption of the spike discharge corresponds to the phenomenon of sensory adaption."

This is a bit of an aside: Sensory adaption is commonly talked about with touch receptors, and means that the receptor notices changes in pressure, not the actual level of pressure. It is an economical way of saving on neural transmission. Receptors in the skin which do this are called rapidly adapting sensory receptors. Some rapidly adapting sensory receptors, eg. Pacinian corpuscles and Meissner's corpuscles, can detect vibration - they give a spike of an action potential for the peak of every bump in a bumpy surface.

Now Pacinian corpuscles work at high frequencies (like fine sandpaper - I haven't lost the thread of my argument yet!), while Meissner's work at middle range frequencies, and Merkel's discs, which are not rapidly adapting (so they just fire all the time to say what's going on), work at the lowest frequencies, which I think might equate to rough sandpaper. This means that the smallest skin indentations from sandpaper, if close to the optimal frequency for a certain receptor, will only activate one sort of receptor, as it is the only receptor good enough to detect such small indentations at the frequency.

The "amount of bumpiness" you perceive (not the frequency), according to my book (well, it calls it the "intensity of vibration signalled"), is based on how many nerves are firing at once - if loads are firing, it means that the indentations made into the skin are deep (ie. you're pressing harder or could this also be from the grains of sand being bigger?) and so loads of the optimal, and a great many sub-optimal receptors are firing.

I think we must be able to perceive the frequency of the bumps by amassing information from which specific fibres are firing action potentials.

I wonder then, why it is that when you go from v. bumpy to q. bumpy, the resultant feeling is "smooth" (and why from smooth to q. bumpy the feeling is "v. bumpy")? I'd say it might be to do with the sorts of receptors that are firing changing so quickly - perhaps this is a brainstem or a cerebral mechanism for alerting you to changes? You could wire things up in the brainstem so that a decent period of all one frequency/intensity pattern caused all the receptors that weren't involved in that pattern to senstize. Or perhaps the sensitization occurs higher up in the consciousness scale - the brain is actively in the lookout for changes.

On a neural/receptor level, it is hard to account for because the changes to the receptors are not gradual (eg. a slow warming of the hand as it enters warmer water) but instant. But I may be entirely wrong...!

As far as the eye is concerned, I think the small size of the iris makes the room look dark when you come indoors, but there's also something the eye does to adjust its way of looking at things to enable it to see changes in light and dark at any level of light on an absolutely enormous scale (10^1 - 10^{20}, I think). This it does chemically, i think, by allowing the light to "bleach out" the activity of some receptors... I think...

Risk Assessment

Hazard: Hot water

Description: Burns from hot water.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure hot water is not hot enough to burn. If it is a burn, run under running tepid water for 10 mins. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Spillages

Description: Slipping.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Clear up any spills immediately. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Sandpaper

Description: Grazes from sandpaper.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure sandpaper is not rough enough to cause injury, demonstrator should try to ensure kids do not rub sandpaper too hard. Call first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Tube

Description: Children may bash tube into friend or foe's eye or child falls on tube bashing into their own eye.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Use cardboard or paper tube so crumples. Encourage children to be sensible. Don't get them to move with the tube to their eye. No pretending to be a pirate.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

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Renewable Energy: Uses of Electromagnetism

Making power using wind and water! - Explore how we can use the power of electromagnetism to power our day to day lives!

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-12 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Electricity

Magnetism

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- Generating power
- Small ammeter and coil. Bar magnet of some sort that fits through the hole
- Green rotating generator. Clamps to attach it to a table.
- Wooden box with bulbs/handle/generator
- (these are taken from the electromagnetism experiment)
- Invitica Renewable Energy Kit
- This has a base station, a extension piece, wind turbine, water turbine, solar panel (not that useful for this) and some plastic tubing. There's also a manual explaining how it links into curriculum. The base station has 4 inserts which you can use, an ammeter, a buzzer, a light and some gear things.

Experiment Explanation

Lives in Electromagnetism Box. Commonly done alongside Electromagnetism and Lenz's Law.

1. Generating Power

There are 3 different power generating bits, in increasing level of usefulness.

Magnet, coil and ammeter This has a coil of copper wire attached to a small ammeter. When you wave a magnet through the hole in the middle of the wire you get a reading on the wire. Some things to talk about/do with it are:

- What are the objects? Coil is made of copper wire, this is a good electrical conductor. The setup as a whole is an electrical circuit (components linked together in a circuit). The meter looks like it might measure something (cf weighing scales), it measures the amount of electrical current (or just electricity) going round the circuit.
- Do we get more electricity by moving fast or slow? Does it work if we're not moving at all?
- Is this very much electricity? The scale on the ammeter is microamps (the funny squiggle is the Greek letter mu), talking (or asking questions about) millimetres, metres and kilometres is a good warm-up to explaining that microamps is a small unit. Older kids might know that fuses have amp ratings on them.
- What do the positive/negative readings mean? It tells us which way the electricity is going round the circuit, notice that it changes if we move magnet in a different direction, or swap north/south poles.
- How can we get more electricity? Good ideas are moving faster (and moving in circles is easier than up/down), stronger magnet or more coils.

This then leads nicely onto the next bit...

Rotating generator (green) This has most of the improvements suggested above (show to them the larger magnet, more coils), and if you spin the handle fast enough it will give you enough electricity to light a bulb. Things to talk about:

- The faster you spin it, the brighter it is.
- Does it matter which way round you turn it? No.
- [more advanced]If the bulb is an LED rather than a filament bulb then it will only light half of the time, with

frequency=rate of turning the handle. This is because the current is alternating ('going backwards and forwards') and it only lights when the current is going one way.

Generator in a box This is a better version of the previous one, but it's all hidden in a box which means visitors can't see what is going on as well. There are two bulbs that can be switched on or off, and also a voltmeter/ammeter. Things to do:

- Start someone off turning the handle and then increase the wattage of bulbs turned on gradually. They will find that it gets harder to turn as you do this. Talk about needing to put extra energy in to get more light out (the energy is coming from them, **not** from the magnet/coil which just convert kinetic/moving energy into electrical energy)
- [More advanced]Look at the ammeter/voltmeter. When a bulb is fully lit how do those readings compare to the wattage of the bulb (P=IV).

Generating in real life Power generation: How many watts are the bulbs you have at home? If it's this hard to turn a handle to make 10W of bulbs light, how hard would it be to power all the bulbs in your house? How about all the bulbs, TVs,... in town X? This is really where our power comes from, what better ways are there of turning the handle (wind farms are the easiest example for small kids

- Hamster in a wheel. This is like bike light dynamos! Sadly hamsters don't travel in our boxes very well.
- Wind power. You can try the model turbine with a hair dryer or fan.
- Water power. We use these in dams where the water flows down and through a turbine. To use this put one end of the tubing on a tap and the other in the sink, this model the water flowing down hill. Fossil fuel and nuclear power plants use the same sort of turbine, but powered by steam rather than water.

There's also the solar power but that uses a different principle - semiconductors.

Risk Assessment

Hazard: Coils and wires

Description: Possible overheating could result in burns.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Do not put too much current through a coil/wire, if it is getting hot, turn it down. If there is a burn, run under tepid water for ten minutes, call a first aider. In event of fire, follow procedure in venue RA (raise alarm, evacuate).

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Powerful magnets

Description: Magnets may shatter, possibly leading to cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Warn visitors if you give them a magnet. Use the minimum number of free magnets. Keep the magnets under control. Cover with tape to reduce impact, and contain any shards. Pad edges of magnet to reduce finger trap.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Rotating parts in generators

Description: Children could trap fingers in the rotating parts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Keep kids' fingers away - if it needs pushing it should be done on the axle, not the armature. Contact a first aider in the event of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Generator

Description: Visitor or demonstrator catching fingers in generator as they turn the handle on the generator.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Place generator on flat surface so visitors can't catch their fingers underneath so easily. Tell visitors to hold only the rotating part of the generator handle and not the entire handle. Keep control of the visitors at all times and don't let them get overexcited while turning the handle.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Heavy generators

Description: Generators falling on people.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Use clamps to keep generators firmly attached to table, ensure table is stable; Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

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Resonance

What is the link between earthquakes and cello strings?

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-12 by Johan Kidger (jpk51@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Electricity needed**
- For earthquakes (large blue box):
- Earthquake table (wooden box with handle)
- Sections of tower for the above, made of perspex, magnets and springs.
- Dog on a swing.
- Optional:
- Pan pipes
- Tuning fork
- Whirly woo
- Spare springs, mass hanger

Experiment Explanation

It's a collection of experiments illustrating resonance: the Earthquake Table lets you build towers and see what happens to them when vibrated near the resonant frequence, the Dog On A Swing gets across the basic idea of resoanance, the Giant Pan Pipes show how resonant air makes music, and the 'cello is a string driven by an oscillating electromagnet, which gets excited at resonance.

Overview:

When you shake things too quickly or slowly, nothing much happens, but if you shake them at just the right rate - the rate they naturally shake at if you push them - the shaking builds up and builds up.

Possible activities:

- Trying to make the tower fall over by wobbling it at just the right rate.
- Comparing this to pushing a dog on a swing.
- Hitting or blowing across the pan pipes to make a noise.
- Hitting the tuning fork and talking about its resonant frequency
- Putting your ear to the pan pipes - they make a noise even when not hit or blown (not sure if this works with small pan pipes?)
- Whirling the whirly woo so that it makes a sound (check the whirly woo is working before demonstrating, if no sound can be heard there may be a hole that needs covering with tape)

Other things to talk about:

- Building design to withstand earthquakes.
- Seismic waves.
- How wind instuments work

- Resonance in cars, taps etc.

Tips for demonstrating:

- Everyone enjoys turning the handle on the earthquake table. Try to make people, even little children, take turns.
- The experiment links well with Seeing Sound, and can share equipment and demonstrators.

Basic procedure and explanation:

- Start by getting someone to turn the handle of the earthquake table slowly. A tower three blocks high works best. It shouldn't shake very far. Then ask what they think it will do if they shake it much faster. Will it wobble more?

- It doesn't (or, at least, not much). Now get them to try an intermediate speed. It should be possible to get the tower shaking a long way at just the right speed. You may need to practise doing this to show unconvinced children with poor handle control.

- Try to explain why this happens. The swing is useful here: to make someone swing higher, you push them once every time they come past, so that they build up a little bit more each time. Get the kids to do this to the dog. Also show them that pushing at the wrong rate means that you're sometimes speeding him up and sometimes slowing him down, which is why it doesn't work properly. Then show them that it also works when you wobble the base of the swing: just the right rate makes the dog swing high.

- The kids may then be able to explain why the tower swings most at a particular frequency, and you might want to talk about designing buildings to withstand earthquakes.

- The pan pipes make a sound if you blow across (not into) the ends, or hit them with bats or bits of card. Explain that this is the air inside shaking, and link in with the Seeing Sound experiment if it's about. It's possible to use the slinky spring to get across the idea of a standing wave.

- The pan pipes also make a sound when you put your ear next to the end and listen. This is becasue any sound in the room at the right frequency is magnified by the resonant pipes.

-The whirly woo only makes a sound when you rotate it at the right frequency. Similar ideas to the above but 100x more exciting for kids than a panpipe.

- Hit the tuning fork and explain that the note that you hear corresponds to the resonant frequency of the tuning fork. Again, draw a parallel to the swing and that the note you hear is the frequency at which the tuning fork 'likes' to vibrate. With older kids you can talk about how initially the fork is vibrating at lots of frequencies but all the ones which aren't the resonant one decay quickly, like how the swing's amplitude quickly decays if you push it at the wrong frequency.

Other things to talk about:

- All sorts of things can resonate, and we'd often rather they didn't. Many people will have heard about the millenium footbridge in London, which wobbled as people found themselves walking in step with the wobbling. It had to be closed, and was fixed by fitting damping, which is also the way a car's suspension tries to avoid resonating. Going further back, the Tacoma Narrows bridge failed catastrophically due to resonance with the wind.

Science background for demonstrators:

Anything that you know about resonance will come in useful for this experiment. Most things can be modelled as damped, driven harmonic oscillators, yielding a second-order differential equation with a sinusoidal right-hand side and a familiar set of solutions. Trying to go into mathematical detail with little children is a mistake, though. Even the words 'resonant frequency' can be off-putting.

You may like to note (so to speak) that the pan pipes are tuned to a pentatonic scale.

Risk Assessment

Hazard: Box on table

Description: Falling box or tower blocks could hit children on the head, hands or foot.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Tape the box to a table, and not so high that falling tower blocks could hit children on the head. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Finger trap

Description: Finger trap between the handle of the box and the table on which it's mounted, or between magnets.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Mount the box with the handle far enough clear of the table that there's no possibility of a finger trap. Be careful when setting up/packing away. Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Whirly woo

Description: Child or demonstrator hitting someone with the whiry woo while swinging it.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure there is a clear space in which the whirly woo can be used. If the children seem too excited, demonstrate the whirly woo yourself. Swing the whirly woo above your head so that it is above the height of the children watching and so can't hit them. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Pan pipes

Description: Multiple people blowing on them could transmit diseases.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: If public are offered to use it, make sure they don't actually touch the ends of the pipes when blowing. Consider wiping the ends of the pipes with some anti-bac wipes when they're done. Consider having only one person (the demonstrator) using the pipes.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Mass Hanger

Description: When oscillating the mass hanger on a spring, it can jump off near resonance and may land on someone's hand or foot.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure that people keep their hands out of the way from under the mass hanger. Perform at low height over a table rather than over the floor. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-14 - Anna Kalorkoti (anna.kalorkoti@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-01-26 - Zephyr Penoyre (jp576@cam.ac.uk), **Check 2**: 2014-02-14 - Nunu Tao (nmt26@cam.ac.uk)

Check 1: 2015-01-04 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-12 - Tom Comerford (tafc2@cam.ac.uk)

Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-05 - Joanna Tumelty (jt574@cam.ac.uk)

Check 1: 2016-12-29 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2017-02-01 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk), **Check 2**: 2018-01-20 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2019-01-01 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-01 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2019-12-16 - Lucy Hart (ljfh2@cam.ac.uk), **Check 2**: 2020-01-16 - Jean Pichon (jp622@cam.ac.uk)

Check 1: 2021-01-20 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2021-01-21 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2022-01-23 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-01-28 - Lauren Mason (llm34@cam.ac.uk)

Check 1: 2023-01-12 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-12 - Johan Kidger (jpk51@cam.ac.uk)

Reversible Flow

Turn syrup one way, then the other, and see that it gets back where it started.

Last initially checked on 2023-02-18 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-02-18 by Peter Methley (pm631@cam.ac.uk).

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Physics

Equipment Needed

- Two concentric cylinders with a gap in between and a handle to rotate the inner cylinder (Couette geometry)
- Golden syrup - enough so that the depth of golden syrup is a good couple of inches.
- Anything like icing sugar for "drawing" on the surface of the syrup. Helps if it's edible in case children try to eat it (but they should be discouraged from doing so!)

Experiment Explanation

This experiment demonstrates the ideas of time reversability in fluid flow.

It consists of two concentric cylinders that can be rotated relative to one another, with the space between the cylinders filled with syrup. Using icing sugar, draw a picture or write an initial on the surface of the syrup. Turn the inner cylinder about one rotation, and see the picture get stretched and maybe even vanish. Now rotate the inner cylinder back again (slowly!) and watch your picture come back. Simple!

What to do

Put three cans of golden syrup in the white bucket. Sprinkle some of the icing sugar(or similar) in a straight radial line on the surface of the syrup. Whilst holding the bottom of the bucket firmly, get the children to SLOWLY turn the handle to rotate the inner cylinder (say 90Â°). Then get them to rotate it back slowly. The powder should be in the same pattern as initially.

How to explain it

Imagine the syrup as little blobs of syrup. When you turn the inner cylinder they experience a force and so move. When you turn the cylinder back, they experience the same magnitude of force but pushing them in the opposite direction. So in the end it's as if they never moved at all.

Related stuff

A fish which swims in water by wiggling its tail from side to side wouldn't get anywhere if you put it in syrup. Moving the tail one way and then the other in syrup just puts the fluid back where it started, with no forward push. Sperm get round this by having a spiral tail which rotates, so their swimming motion is never 'reversed' and they can travel forwards.

What are we seeing?

'The syrup is sticky so all the bits next to each other stay together' - close...

If the syrup is deep enough and the turning was not too fast, the flow has very little turbulence. This is not just because the syrup is "sticky" - if you turn too fast you will lose the picture no matter how sticky the syrup is! How a flow behaves depends not only on the stickiness of the fluid, but also on speed of flow (and density of flow and lengthscales). In the case of very low Reynolds number and nice boundary conditions, reversing the boundary conditions reverses the flow almost exactly - which is why the picture comes back almost exactly and why flapping fish can't swim in golden syrup.

Science background

Golden syrup has a very high viscosity, so the flow should be laminar. It is the little bit of turbulence that is unavoidable that will mean that you will have to occasionally clean it out and put fresh syrup in! The slowly is to minimise turbulence. This causes turbulent mixing which stops the demonstration working.

Other things to talk about

Dimensionless numbers in fluid dynamics (e.g. Reynolds number, etc.) and how these can be used to describe flow in systems of completely different size, but same dimensionless number.

Some background information from 'Chemistry & Industry' 02/01/06

Mixtures are Reversible by Lisa Richards

"When you were making your Christmas pudding last month, did you consider that if you chose to stir the mixture anti-clockwise, not only are you breaking a tradition and giving yourself bad luck, you may also have caused the mixture to separate rather than combine?

As crazy as this may sound, it has been discovered that two liquids seemingly irreversibly mixed can be returned to their original components.

David Pine and his team at the University of California describe this phenomenon as the 'equivalent to reversing time' (Nature 2005,438,997).

Using two concentric cylinders and tiny beads suspended in solution, Pine and his colleagues showed that, when stirred in reverse, the beads retrace their movements and return to their starting positions.

Troy Shinbrot, of Rutgers Univsersity, New Jersey, believes that this has great implications for pharmaceuticals. Shinbrot explained that viscous fluids such as honey have been known to have this property for some time, but it was generally assumed that suspensions behave irreversibly. Many pharmaceutical preparations are sold as suspensions, for example children's antibiotics such as Amoxicillin. Understanding mixing behaviour helps in the understanding of which suspensions will mix, and the way in which this occurs.

Applications such as tissue engineering performed on carrier particles, or cell cultures grown in viscous, slowly agitated sugar solutions, may also benefit from this new knowledge."

Risk Assessment

Hazard: Falling apparatus

Description: Equipment is heavy when filled with golden syrup and may fall on feet etc.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure equipment is secure on a flat surface. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Contaminated golden syrup

Description: Ingestion/ inhaling of golden syrup/ icing sugar that's been in a lab environment.

Affected People: Children

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: If syrup gets on hands/arms, make sure children don't lick it off, and that they wash their hands once they've finished the experiment. Warn children not to inhale when you are pouring any icing sugar. Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-14 - Anna Kalorkoti (anna.kalorkoti@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-02-14 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2014-02-16 - Benjamin Lai (bl337@cam.ac.uk)

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Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

Check 1: 2016-12-29 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2017-02-01 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2018-01-20 - Benjamin Akrill (bja32@alumni.cam.ac.uk), **Check 2**: 2018-01-20 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2019-01-02 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2019-01-02 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2020-01-23 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2020-01-25 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Holly Smith (hs606@cam.ac.uk)

Check 1: 2022-02-05 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk)

Check 1: 2023-02-18 - Jessica Trevelyan (jet81@cam.ac.uk), **Check 2**: 2023-02-18 - Peter Methley (pm631@cam.ac.uk)

Robotics on tour! & CBS Workshops

Challenges that can be done with robots in a relatively short time period. Robotics workshops run during CBS. - Learn to programme LEGO Mindstorms and learn about IF statements and LOOPs.

Last initially checked on 2023-01-21 by Asmita Niyogi (an637@cam.ac.uk) and double-checked on 2023-01-30 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Computer Science

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **Electricity needed**
- Lego Mindstorms EV3 Robot kit (There are four robots in two cases)
- 18 x AA Batteries (Currently there are 16 rechargeable and 2 non rechargeable)
- 2 x Recharge stations
- 1 x Green fabric with blue fabric "pond" sewn on
- Worshops:
- 8 x Robotics Kits, consisting of Lego Mindstorms NXT brick, motors, assorted sensors, associated connectors, structural lego components and moving parts (i.e. gears) - On loan from Robogals Cambridge
- 8 x laptops with software installed to program Mindstorms NXT bricks - On loan from Robogals Cambridge
- Assorted paper and pens
- As many charged batteries as possible for CBS

Experiment Explanation

On Tour Set up:

For the computer:

Turn on the CHaOS laptop (currently 2,3 and 4 have the software installed but it is free to download from the lego website) To login the password is CHaOS (capitalised correctly) Start the lego mindstorms program Go to file -> new project. If you want to be able to find programs you have created more easily I recommend you go file -> save as. It is also possible to double click on the program name to rename it. At public events I like to ask children their names and name it that so which program is theirs can be easily seen.

For the robot:

If you aren't sure of the level of charge immediately start charging its batteries.

If you are confident the batteries are suitably charged, put the batteries into the EV3 Brick.

If the robot is damaged, fix it (I need to take pictures so everybody knows what it looked like).

The Ev3 Brick should be put onto the robots base.

Connect the colour sensor to port 3, and the motors to ports B and C. The motor wires **should** cross due to way the steering works.

The programming

Ideally you should experiment with the robot before you start demonstrating. All programs consist of series of blocks that contain instructions which the robot will follow in order.

There are four blocks that I use more than the others:

Green Tab, 3 along. This is "Move Steering" with this you can control which direction the robot turns and how tightly, which direction it will travel and how fast and how long it will do so for. Alternatives to this would be the "Move Tank" and "Large motor" Blocks which I feel are less intuitive.

Green Tab, 7 along. This is "Brick Status Light". It can be set to three different colours and be on continuously or flash. It is useful for identifying sensor inputs easily. An alternative to this would be the "Sound" block which I find is too quiet too be heard in a room full of children. The "Display" block can also be used too.

Orange Tab, 3 along. This is the "Loop" Block. Loops are an important concept in programming and quite simple. It works especially well in combination with the next block.

Orange Tab, 4 along. This is the "Switch" block and is the most interesting block I frequently use as it allows the robot to make decisions based on inputs. I use the colour sensor but if you wanted to make modifications there is potential for other sensors to be used. If you want to follow the edge of a colour I would recommend using compare colour. If you wanted to stay with in a coloured area separated by two different colours you would use measure colour. Compare is more reliable as it can tell whether or not something is a certain colour quite well, but with measure it can be hard to determine what the robot will decide it is e.g. purple when you are asking it to choose between red and blue. The two 'paths' of the switch should have the robot turning different directions or travelling in different directions in order for something interesting to be observed.

There's full support for variables (but that doesn't mean you want to use them and it's easier if you don't however for advanced groups) you drop a variable box to create a variable ad it's name is in the upper right and it's data type in the lower left. Operations performed using maths boxes and the lower left box sets the operation and the next two boxes the arguments, these can be variables connected via a data wire. The output can be saved as a variable using a data wire and setting data type as write number.

Demonstrating:

I start off by asking them their names so that we have an easily identifiable program (In schools the groups will likely be too large for this. I then ask them, what do robots do? You will get a range of different responses, sometimes close to the answer of "they follow instructions". I then introduce the program to them and tell them that the blocks are just instructions for the robot.

Depending on the age of the children you can ask them what they want it to do e.g. "Do you want it to turn left or right?" and program it yourself or tell them "this slider controls how it will turn" and let them do it. After they have made their block they need to download the program to the robot.

Connect the cable to the computers USB port and the pc port on the output side of the robot. Press the download arrow in the bottom right of the screen. It may be grayed out if you have just connected the robot. After you have pressed download the robot will make a noise. This means it has downloaded. You will now need to look for your program on the robot. Go to the file tab, pick the correct project, then scroll down to the correct name. Get the child to verify that that is their name on the program that is about to be run. Place the robot in a suitable space and let them press the middle grey button.

You can then move on to making the program more complex, normally by making lights flash and a second movement block. If you think they are mature enough move on to using the sensor. Delete the previous program and put the loop and switch in place. Let them chose what they want in each option but give hints so that it ends up doing something interesting.

If they really want to do more let them, but I normally end by discussing in which jobs are robots most useful. The boring ones (painting cars), and the dangerous ones (missions to mars).

To get ready for the next child create a new program and keep the old ones as some may do interesting things which take time to program. However keeping too many programs can resulting in downloading taking more time.

Advice for demonstrating in Schools:

- It is more important that you don't keep the children for too long, this experiment can easily take 20 minutes if you try to get them to do the line following even with significant prompting.
- Try to ensure that all students make an input to the program, this becomes more difficult with larger groups
- For primary school students it is probably fine to ignore the sensor completely and just let them play around making a basic program with flashing lights, sounds and movement.
- For older secondary age (Y9+) students you should try to get them to do line following.
- For children in Y7&Y8 ask them whether they want a challenge (line following) or just to play around.

Braitenberg Vehicles - fast to demonstrate, easy to explain, but still produces complex behaviour

A possible easy way to demo robots is to teach the kids about some of the earliest robots - things called â€œBraitenberg Vehiclesâ€. To set this up, just hook up some light sensors to output numbers straight to the motors. If we have two light sensors, each outputting light-intensity, and we just whack those numbers into the motors, we can create some â€œlife-likeâ€ behaviour. Setting this up means you have to have a light sensor on either side of the robot, and feeding that number to the â€œmove tankâ€ block by using the variable drag and drop lines on Mindstorms:

`![](/sites/default/files/Screenshot 2019-08-31 at 15.19.14.png)`

There are two possible behaviours, where the robot will speed towards lights, or speed until theyâ€™re facing away from them, â€œaggressiveâ€ (charges towards lights in a search-and-destroy fashion - this might be part of the reason Moths fly towards lights, I think I read that they have a biological feedback similar to this) and â€œcowardlyâ€ (runs like crazy to get away from light):

`![](/sites/default/files/Screenshot 2019-08-31 at 15.02.45.png) ![](/sites/default/files/Screenshot 2019-08-31 at 15.02.40.png)`

If we multiply the sensor output by -1 (use an arithmetic block), then another two behaviours are possible, â€œexplorerâ€ (goes all over the place), and â€œlovingâ€ (lovingly and slowly approaches the lights). You can let the kids fiddle with the numbers and rewire the sensors to other motors.

`![](/sites/default/files/Screenshot 2019-08-31 at 15.02.59.png) ![](/sites/default/files/Screenshot 2019-08-31 at 15.02.51.png)`

Depending on age and time, you can use the Braitenberg vehicles to talk about perception-action loops - what's the loop going on here, what about if we wanted to give it instructions, what about if the robot is now on the moon and we want to give it instructions, what problems are there now (the moon is 1 light second away...). Could also talk about reactive vs deliberative behaviour - are the vehicles reactive or deliberative, why? (reactive because there's no planning going on, you could mention that they don't need to remember anything).

For people who really know what's going on, you could talk about vehicles with more sensors - you can combine them in lots of different ways, even having multiple sensors wired to each (motor) output... if the outputs are a linear combination of the inputs, we have a complicated Braitenberg vehicle. But... if we want a *non-linear* combination of the input variables, then we can use a *neural network* to add up inputs in any which way we want. Now you could get them thinking about their bodies... we have a series of inputs (feel, smell, sight etc.), which go through something inside our skull which is a bit like a neural network... which outputs to a series of *actuators* (muscles). Proceed into philosophical discussion about consciousness until the kids are either forced to leave by terror or boredom.

PLUS Explanation

The line following works well for this age as most have not done significant amounts of programming so it will still be a challenge. For students who complete that quickly you can push them further. Instruct them to start far from the blue and travel in a straight line until they hit the pond then follow it around, stopping when they get to a red piece of card.

You should not let yourself be restricted by these instructions if you have other ideas of how to run this. There is a huge potential of things that could be done.

The below sections are not part of a demonstration but are retained as they could be used in future designs

Maze

A simple maze can be created with the wooden blocks or cardboard. The challenge is to program the robot so that it can navigate its way through the maze without any outside influence once it has started. This can be be done in several ways that progressively advance in difficulty:

1. Dead reckoning: the robot is programmed to move forward a certain angle, turn, move forward another certain amount and so on. This requires no sensor use and the robot is likely to generate errors in its positioning as it moves further. The robot could potentially fitted with a missile to try and hit targets once it has been through the maze.
2. Sensors with knowledge of the maze: The robot is equipped with touch/light sensors on its front and detects when it hits an obstacle. With knowledge of the maze, it will be possible for children to have set the correct direction for the robot to turn. The robot should be able to progress through the maze with smaller errors.
3. Sensors and a generic maze: The robot will be programmed to turn whenever it hits an obstacle and if that turn leads to another obstacle it will turn the other way. Through use of counters it could even find its own way back through the maze with little crashing. Sensors on the sides could be used to correct its course if it has a glancing impact with the wall.
4. Maze with coloured tiles. Using the ability of the robots to detect colours we can tell them to perform certain actions when they see a certain colour. This compares well with the simple Turtle Robots which are often used like this and you can read the RA for that to find information about programming them in this style.

Robot Writer

The A3 sheet will be placed under the wooden blocks used for the maze so that it does not slide. The robot will be equipped with a pen holder arm that will be raised or lowered as necessary. This arm could be stationary relative to the robot or could move, allowing more effective writing to be used. The movements are likely to be by dead reckoning.

Children could be instructed to program the robot to make letters of the alphabet and write words. A simple task could be for them to write the word CHaOS. They would create a sub-program for the letter "H" and then add it to to subprograms created by the demonstrator that write the other letters.

Potential inputs could be morse code claps to be picked up by a microphone and subsequently written down by the robot. This bit is likely to be too advanced for the time we have but could be used in less time sensitive places such as public events.

Risk Assessment

Hazard: Power cables

Description: Trip hazard.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Ensure wires are either taped securely to surfaces, or are placed behind tables, so no one walking past will catch themselves on the wires.

In case of an accident, turn off power at the mains, do not touch any other components, such as the laptop or its battery. Call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Electrical components

Description: Various risks associated with electrical components.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: All laptop chargers will be PAT checked for safety and will be kept out of reach of children. See electrical parts RA.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Small Lego parts

Description: Choking hazard for small Lego components.

Affected People: Mainly young children

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: All participants will be monitored regularly by demonstrators to ensure they do not put Lego in their mouths. The robots are largely pre-built, minimising visitorsâ€™ use of individual parts, and any modifications will be supervised by a demonstrator. Particularly young children will be supervised closely and if at CBS, will also be under parental supervision, though it is unlikely that very young children will be present as the workshop is targeted at older children.

Call a first aider if choking occurs.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Robots and laptops

Description: Robots/laptops falling off tables and hitting small children/sitting children.

Affected People: Children

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Robots should be used on the floor unless they are immobile or all children present are standing and have their heads above the edge of the table. Laptops if used on tables shouldnâ€™t be moving around, and should be far enough away from table edges.

Call a first aider if required.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Motors

Description: Short circuits.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Motors are sealed in a robust manner, so any short circuits will result in a simple failure, with no risk to users. In the very unlikely event of an exposed short, voltages and currents used are very low (powered by 4 AA batteries), so present no significant risk to users.

If short circuit occurs, power down the robot and do not use the kit further. Call a first aider if required.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Gearing system

Description: Things like hair wrapping around moving motors.

Affected People: All, particularly those with long hair

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Motors are sealed, so hair is unlikely to be caught, though it may be caught by gearing systems. All visitors will be made aware of the risk and asked to ensure any dangling objects on their person are kept out of the way and advised to tie long hair up if they might lean near the gearing system. They will also be made aware of the emergency stop, which will shut off all motors instantaneously.

Immediately stop robot if anything is caught in motors. Call a first aider if required.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2015-10-23 - Tim Morgan Boyd (tmb58@cam.ac.uk), **Check 2**: 2015-10-23 - Robert Gayer (rg478@cam.ac.uk)

Check 1: 2017-01-22 - Robert Gayer (rg478@cam.ac.uk), **Check 2**: 2017-02-06 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2018-02-06 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2018-02-06 - Joanna Tumelty (jt574@cam.ac.uk)

Check 1: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2019-02-05 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2019-08-31 - Matthew Le Maitre (msl54@cam.ac.uk), **Check 2**: 2019-09-01 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2020-01-30 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2020-01-30 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-19 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2021-01-20 - Polly Hooton

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Check 1: 2022-02-09 - Joshan Parmar (jp862@cam.ac.uk), **Check 2**: 2022-02-09 - Margaret Johncock (mllyj2@cam.ac.uk)

Check 1: 2023-01-21 - Asmita Niyogi (an637@cam.ac.uk), **Check 2**: 2023-01-30 - Jamie Barrett (jb2369@cam.ac.uk)

Rocks and Fossils

A box of rocks and fossils - Find out about explosive volcanoes, shiny crystals, and the exotic animals that lived millions of years ago.

Last initially checked on 2023-02-15 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-17 by Lauren Mason (llm34@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Geology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- In this box there should be:
- DK fossil book
- DK rocks and minerals book
- viewer (a magnifying glass on a stand)
- Box 1 - Clear plastic box with the main rocks and minerals collection in
- Box 2 - Orange plastic box with rocks, minerals, gem stones and fossils in
- Small box of plant fossils
- Laminated visual aids including some activity sheets
- Larger rocks (4cm - >fist sized) in bubble wrap, includes meteorite in box, green peridotites in bag, granite, gneiss, basalt, limestone and sandstone
- 2 large plant fossils; not usually needed.

Experiment Explanation

Note: If youâ€™re confident with demonstrating and know your geology give this kit a go though, and please write down the bits that work and donâ€™t work. (A sheet of paper that stays in the box would be great!)

Most of this kit was bought by a biologist (Lia) who claims to know nothing about geology, so if thereâ€™s more kit that would be useful please let us know!

You may also want to read Fabulous Fossils, More Fabulous Fossils and Dinosaurs and their Ocean Friends (which relate to kits we used to borrow from the Sedgwick Museuem)

Ways to do this demo

1. Use the little rocks and fossils in the plastic boxes to talk about whatever you want - a lot of info is given below about what these boxes contain/ possible things to talk about.

2. 'Journey to the centre of the earth!': use the larger rocks to do a virtual journey to the centre of the earth from the surface (sandstone, limestone, basalt) to the crust (granite, gneiss), to the mantle (xenoliths in bag - green peridotite and black pyroxenite) to the core (meteorite in bag). Will help to draw this out on whiteboard/ paper etc.

3. 'Where do these rocks come from': use the larger rocks. Talk about igneous rocks erupting at the surface (gives small crystals as they cooled really quickly - 2018 Iceland Basalt) versus cooling intrusively (large crystals, slow cooling, the granite). Sediments: think about where we get sandstone (deserts, rivers, beaches) or limestone with shells in it (the bottom of the sea).

4. 'Guess how old these rocks are': Use the larger rocks and ask children to put them in age order - which they will invariably get wrong! Then put them in the right order and talk about where the rocks came from. (Basalt: 2018 eruption in Iceland - younger than the kids!, Granite; about 50 million years old, lake district, Gneiss: 3 Billion years old from northwest Scotland - oldest rock in the UK!, Meteorite: around 4.5 billion years old. Start of solar system. Not actually sure how old the sediments are; but for the purposes of this demo, say the limestone is around 70 million years old; cretaceous (possibly from near Cambridge) and that the sandstone is 1 billion years old (from Scotland).

5. Mix of the above!

*****The explanation below is out of date but is kept as it has useful information about the specimens - i.e. read this if you want to know about the small rocks in the plastic boxes. Skip to the bottom for a list of these specimens and their places in the boxes (see the attached pictures for how to put it back) as well as some suggested activities that could be carried out with the samples. *****

Intro: This demonstration consists of a large number of different rocks and fossils, which may seem a little bewildering at first. Donâ€™t worry, Iâ€™ve studied Geology for three years and I still donâ€™t know much about some of the specimens we have. If youâ€™ve done 1A Geology/Earth Sciences or something similar, you should know enough to demonstrate a decent number of the rocks and fossils. If you need help on specific specimens, there is a list of contents with each set, Iâ€™ve prepared this guide to hopefully give additional explanation, and there are books on fossils and minerals in the box too.

I like letting the children hold the rocks and fossils, and look at them under the magnifying glass, as I feel it makes things a lot more interactive. This is fine; just make sure theyâ€™re careful with them, as the fossils in particular are quite fragile. It might be best not to let the smallest children handle them, for the sake of the fossils and the childrenâ€™s windpipes.

There are a few ways to go about this demonstration, which you can vary depending on the venue youâ€™re demonstrating in, and what suits you best. You could keep the boxes closed and only bring out specimens one or a few at a time which you want to talk about, or you could leave out all or lots of them, and let the children lead the demonstration a little more. I find the second option more interesting, and it tends to draw children in more easily in a public event, but I might keep most of the specimens in their boxes at a school, especially if the children want to just grab everything in sight! However you choose to do demonstrate, you donâ€™t have to talk about anything youâ€™re not confident about. You can either leave specimens in their boxes, or admit you donâ€™t know much about them if children ask.

One thing I find interesting about this experiment is the variety of opinions about geology. Some children will think rocks are really boring, while others will love fossils or crystals, and want to talk to you all day! It can be really rewarding convincing people that rocks and fossils are interesting, or talking to a child who is fascinated by everything you say, but if sometimes youâ€™ll talk to kids who really donâ€™t want to know. I usually try showing them the bits I think theyâ€™ll find most interesting, but in the end I might just send them to another experiment if theyâ€™re clearly not getting anything from this demonstration.

You can use the specimens as links to talk about almost anything you (or the children) want. A lot of them come from the Atlas Mountains in Morocco, so I might use this to talk about continental drift and mountain-building, as they were formed by the collision of Africa with Europe. I often end up talking about the rock cycle and how fossils are formed and preserved (or not). I also like talking about the structure of the Earth, and why itâ€™s hotter underground. The visual aids are there to help you with this sort of thing, especially if like me you end up rambling about something completely unrelated with a group of intelligent and interested children! If thereâ€™s anything else you feel would be useful to include, by all means mention it to a committee member, write it in the tour diary, or even print it yourself - this experiment is still relatively young, so any input would be appreciated.

I should perhaps include a warning that you may occasionally have to deal with people, who do not believe in evolution, think crystals have healing powers, or something similar! Unfortunately itâ€™s unlikely youâ€™ll manage to persuade them against these beliefs, but you could have a go!

The rest of this guide provides brief details about each specimen, and some ideas about what to talk about with each one, but remember, this guide is in no way complete, and there are probably interesting things I have left out or simply donâ€™t know about plenty of the specimens. Weâ€™ve included the box of plant fossils in this experiment box, which is written up as part of the plant experiment (biology) [is it I can't find - TW 2018]. There are some notes to go with this, but youâ€™ll probably only want to use these if youâ€™ve studied plants at some point. Itâ€™s fine to just leave them in the box and use the rest of the kit.

All specimens should be labelled.

The Fossils Box: At some point it is a good idea to ask children if they know what fossils are and how they form. If they arenâ€™t too sure, explain how hard parts of animals â€“ teeth, bones, shells â€“ can be buried under layers of sediments, and eventually become fossilised. However, plants, footprints, tree sap and excrement can all be fossilised too. The fossil we see may be as it originally was, it may have recrystallised, or it may be an imprint. The details of fossilisation processes are actually very complicated, but fortunately a general idea of what happens is sufficient. The book in the box explains this for a general audience, so it's probably worth a look through.

Wikipedia says that: "Fossils (from Latin fossus, literally "having been dug up") are the preserved remains or traces of animals (also known as zoolites), plants, and other organisms from the remote past. The totality of fossils, both discovered and undiscovered, and their placement in fossiliferous (fossil-containing) rock formations and sedimentary layers (strata) is known as the fossil record. The study of fossils across geological time, how they were formed, and the evolutionary relationships between taxa (phylogeny) are some of the most important functions of the science of paleontology. Such a preserved specimen is called a "fossil" if it is older than some minimum age, most often the arbitrary date of 10,000 years ago.

Hence, fossils range in age from the youngest at the start of the Holocene Epoch to the oldest from the Archean Eon at several billion years old. The observations that certain fossils were associated with certain rock strata led early geologists to recognize a geological timescale in the 19th century. The development of radiometric dating techniques in the early 20th century allowed geologists to determine the numerical or "absolute" age of the various strata and thereby the included fossils.

Like extant organisms, fossils vary in size from microscopic, such as single bacterial cells only one micrometer in diameter, to gigantic, such as dinosaurs and trees many meters long and weighing many tons. A fossil normally preserves only a portion of the deceased organism, usually that portion that was partially mineralized during life, such as the bones and teeth of vertebrates, or the chitinous or calcareous exoskeletons of invertebrates. Preservation of soft tissues is rare in the fossil record. Fossils may also consist of the marks left behind by the organism while it was alive, such as the footprint or feces (coprolites) of a reptile. These types of fossil are called trace fossils (or ichnofossils), as opposed to body fossils. Finally, past life leaves some markers that cannot be seen but can be detected in the form of biochemical signals; these are known as chemofossils or biomarkers."

An awkward question I have been asked a few times is how do we know that a given fossil is 50 million years old? This is a hard one to answer, since most of the fossils are old enough to be dated using Uranium decay series. If children are old enough to understand Carbon-dating, you can make an analogy with this, otherwise you may have to make do with talking about relative dating using layers of sedimentary rocks and volcanic ash. The timeline should be useful for talking about ages of various fossils, since large numbers of years become a bit meaningless, but saying that something lived twice as long ago as the first dinosaurs impresses most children.

ï€ Bivalve These molluscs have lived in a huge variety of situations. They can be marine or freshwater, live in deep or shallow water, above or buried in the seabed, or even swim like scallops or attach themselves to rocks along the coast like mussels (both kinds of bivalve) do. Their shell consists of two usually symmetrical halves called valves, but some bivalves, such as Gryphaea (or Devilâ€™s toenails) have one valve much bigger than the other. They have been around since the Cambrian.

ï€ Amber Amber is fossilised tree resin (not sap apparently, although Iâ€™m not entirely sure what the difference is). Animal and plant material is often preserved in amber, particularly insects which have become stuck in the resin. As far as I know, this is the only way in which insects can be preserved, as their exoskeletons are simply too weak to be fossilised normally. Children may have seen Jurassic Park, in which the DNA of a dinosaur is extracted from blood that a mosquito has drunk before becoming trapped in resin and fossilised. This idea has some basis in fact, since the preservation of fossils in amber is so good that fragments of DNA may be recovered. Unfortunately, unless weâ€™ve found a new piece of amber, there are no insects in this one.

ï€ Gastropod Gastropods are another group of animals which have lived in various different situations. They can be freshwater, marine, or even live on land (e.g. the snail), and have been around since the Cambrian. They can be recognised by their coiled shell. I often just use the words â€œsea snailâ€ here, since Iâ€™m not sure the word â€œgastropodâ€ will add much, but itâ€™s up to you.

ï€ Shark Teeth The box contains a variety of sharkâ€™s teeth. These are some of the most easily recognisable fossils we have. There is an opportunity here to talk about why sharks have such sharp, and often serrated, teeth, as well as why they are such common fossils (sharks have many sets of teeth and frequently lose and replace them). Sharks have skeletons made from cartilage, which makes them unlikely to be preserved, and have been around for more than 420 million years. One of the teeth is from a shark related to the Megalodon, which some children may have heard of. It lived roughly 28 to 1.5 million years ago, could grow up to around 20 metres in length, and had huge impressive jaws!

ï€ Brachiopod These shelled organisms used to be far more common, occupying many of the marine environments which bivalves do today. Their shells are made from two halves, or valves, which tend to be different, and can be distinguished by a mirror plane down the centre of each valve. They have been around since the Cambrian, and were most common during the Paleozoic.

ï€ Ammonite These marine molluscs had spiral shells and were alive during the Mesozoic- the same time as the dinosaurs. These should not be confused with Nautilus, an animal with a spiral shell more closely related to the straight Nautiloids. They can be told apart by the position of the siphuncle â€“ a tube used to move water between the shellâ€™s chambers and control buoyancy â€“ which runs along the outer edge of ammonitesâ€™ (and all ammonoidsâ€™) chambers, but through the centre of Nautiloidsâ€™. Ammonites vary in size from a couple centimetres to a couple metres, and are commonly found on the Dorset and Yorkshire coastlines.

ï€ Goniatite These are another type of ammonoid (the subclass to which ammonites belong) which rarely exceeded 15cm in diameter. They can be told from ammonites by their simpler suture line (the line where the divisions between chambers make contact with the edge of the shell) and lived earlier than ammonites â€“ during the late Paleozoic.

ï€ Trilobite These are an extinct class of arthropods which lived during the Paleozoic, though they declined towards the end of it. Trilobites were some of the first animals to evolve hard parts (which is why they are also some of the earliest fossils that are regularly well-preserved) and eyes. Their hard shell meant that they could roll into a ball to protect themselves (as I think this specimen is doing). Their eyes were made from calcite crystals which had to be orientated correctly to avoid a double-image (you can demonstrate the double-image with the calcite crystal in the minerals box). Some had their eyes on stalks, while others were blind. Most moved over the sea-bed, but some swam, and they could be predators, suspension feeders or scavengers. The name trilobite refers to their three â€œlobesâ€ â€“ one that resembles a spine down the middle of the trilobite, and one on each side of it. I usually liken trilobites to woodlice to help children to imagine them.

ï€ Triceratops Bone Whole fossilised bones, and especially whole skeletons, from land-dwelling animals are pretty rare, as they will only be buried and fossilised in an area where deposition is taking place, such as the sea or a delta; much of the land is being eroded. If the animal does not die in a place where its bones are quickly buried, the bones may be separated from each other, bashed around, or even fragmented before finally being buried. This is probably what happened to this piece of triceratops bone. The small holes are most likely where the marrow used to be. Triceratops was an herbivorous dinosaur with three horns on its head (two above its eyes and one on its nose), a large bony frill, and a beak-like mouth. It walked on four legs and grew up to 9 metres long and 3 metres high. It belongs to a suborder of dinosaurs called ceratopsians, which had similar features, but different numbers of horns. There is discussion as to whether the horns were primarily for defence against large predators such as Tyrannosaurus Rex, or for fighting amongst each other for mates. Triceratops lived at the very end of the Cretaceous, which provides an opportunity to talk about the mass extinction at the end of this period which wiped out the dinosaurs (one of several that have been identified throughout the Earthâ€™s history). A lot of children will know the most popular theory- that the Earthâ€™s collision with a huge meteorite caused the extinction. Far fewer may know about the less popular hypothesis, that an enormous set of volcanic eruptions covering half of India in lava flows known as the Deccan Traps in less than a million years contributed to this extinction event, or may even have been the primary cause. Both of these events happened, but there is debate as to which was the main cause of the mass extinction.

ï€ Mammoth Bone This fragment of woolly mammoth bone has much bigger holes in it than the Triceratops bone. This implies that it had a lot bone marrow, which led a scientist I was talking to to suggest that it might be from a femur (thigh bone). Most children will have seen Ice Age, so describing woolly mammoths as â€œManny the big hairy elephant from Ice Ageâ€ seems to work quite well. These animals lived from roughly 150,000 years ago until 10,000 years ago, although a race of dwarfed mammoths continued to live on Wrangel Island (about 200km north of Siberia, just inside the Arctic Circle) until about 4000 years ago. There is debate as to what led to the extinction of mammoths and other large ice age mammals such as sabre-tooth tigers and giant beavers around 10,000 years ago. The main hypotheses are hunting from humans and climate change; although in reality it may have been a combination of the two.

ï€ Mosasaurus Tooth From the canine-like shape of the tooth, we can tell that this is from a carnivorous animal. Mosasaurus was a huge sea-reptile that reached 15-20 metres in length (I like to compare this something real, like the length of the room Iâ€™m in). It was alive during the late Cretaceous, and was another victim of the mass extinction at the end of this period.

ï€ Echinoid/Sea Urchins The sea urchin is a member of a class of animals called echinoids. Echinoids are related to star-fish and tend to have a similar five-fold symmetry, though this may be less obvious depending on the specimen. During life, sea urchins are colourful balls of spikes that live on the sea-bed, feed mainly on algae, and can be found shallowly enough in warm seas such as the Caribbean that people occasionally step on their spines (which can hurt a lot!). The spines are designed to protect sea urchins against predators. They fall out within several days of the animal dying, leaving fossil sea urchins with tiny holes where each of their spines were attached during life.

ï€ Coral Coral have been around since the Cambrian, but the kind we know today (called Scleractinian coral) such as this fossil only evolved during the Triassic when the old Rugose and Tabulate corals became extinct. Corals (with the exception of some Rugose corals) are colonial organisms which form huge coral reefs. These can be hard to explain to children; I find it helps if theyâ€™ve seen Finding Nemo. I like to use coral to talk about continental drift, as I have found fossil coral in the Lake District- clearly not the warm shallow sea favoured by these organisms.

ï€ Turtle Shell The oldest known turtles lived during the Triassic. The fossils we have are individual plates (or scutes), many of which together would have made a whole turtle shell. There is an opportunity here to talk about the usefulness of having a huge shell you can hide inside.

ï€ Straight Nautiloid Nautiloids have been around in one form or another since the late Cambrian, and are today represented by the spiral-shaped Nautilus (mentioned in Ammonite). Straight Nautiloids are often cut and polished to be sold by crystal-sellers. The animals that lived inside these shells were predatory and squid-like, but from a different sub-class to squids.

ï€ Crinoid/Sea Lily Sea lilies are crinoids which are attached to the sea bed by a stalk. Crinoids have lived since the Ordovician, and, despite their name and plant-like appearance, are actually animals. They use their arms to trap small particles of food.

The Minerals Box: Or, more accurately, the minerals, gemstones and other stuff box. The colours of many minerals such as quartz and calcite are determined by the presence of impurities, particularly transition metals. Whether they dissolve or precipitate in a particular setting depends on the solubility of the mineral in groundwater, which depends on a number of things, including temperature and pressure. The growth of crystals in this way can be likened to the growth of salt/sugar crystals in a bowl of salty/sugary water left out to evaporate, except that it is changes in temperature/pressure etc that mean that the water is over-saturated and a mineral will precipitate rather than the evaporation of water. This is how geodes (balls of crystals) of amethyst, quartz etc can form in water-filled cavities deep underground. The most impressive crystals I have heard of are the 12m long crystals of gypsum (which is softer than fingernails) in the Cave of Crystals in Mexico, which is essentially a giant geode.

See book for more detailed notes than those I have included.

Wikipedia says that: "A mineral is a naturally occurring solid chemical substance that is formed through biogeochemical processes and that has a characteristic chemical composition, a highly ordered atomic structure, and specific physical properties. By comparison, a rock is an aggregate of minerals and/or mineraloids and does not have a specific chemical composition. Minerals range in composition from pure elements and simple salts to very complex silicates with thousands of known forms."

â€¢ Pyrite Pyrite is also known as Foolâ€™s Gold due to its similarity in physical appearance to gold. It is found in quartz veins, coal beds, sedimentary and metamorphic rocks, as well as a replacement mineral in some fossils. It is associated with other oxides and sulphides, and often forms during diagenesis- low pressure and temperature alteration to deposited sediments during early compaction which may result in recrystallisation and precipitation of minerals. Its chemical formula is $FeS2$.

â€¢ Calcite Calcite is a form of Calcium Carbonate, and is one of the two main minerals from which animal shells (as well as Trilobite eyes) are made. It is rare to see such well-formed calcite rhombohedra as the one in the box. Calcite is strongly birefringent, which means that it has different refractive indices for light oscillating in different directions. This means that light entering a calcite crystal splits up into two beams polarised in the directions of the highest and lowest refractive indices, causing a double-image if you look through it. The reason is that the $CO3$ groups are aligned in parallel planes, with a high electron density on each oxygen which will slow down light travelling in that plane (see: birefringence demonstration). Limestone is mostly made up of calcite, and this can recrystallise during metamorphism, or calcite can form stalactites and stalagmites in limestone caves. It often cements together other sediments if it has precipitated from the water trapped between individual grains of sediment, forms veins particularly in fractures in rocks, and can be found in some mantle-derived rocks. It is harder than fingernails but softer than steel (Mohs hardness of 3), and is colourless and transparent with no impurities. I find a lot of children assume that calcite and quartz are the same thing because they are both clear- this is an opportunity to talk about other ways of telling different minerals apart such as crystal shape, hardness and birefringence.

â€¢ Red Aragonite Aragonite is the other main form of Calcium Carbonate from which animal shells are made. It is metastable and will revert back to calcite over 10s to 100s of millions of years and means that aragonite fossils are often replaced by calcite. It is often found in sedimentary rocks and cave deposits. The red colour is probably due to impurities such as iron.

â€¢ Connemara Marble Marble (not a mineral but still lives in this box) is a rock formed by the metamorphism of limestone and other carbonate rocks. However, Connemara Marble, which comes from the region of Ireland of that name, is not technically a marble. It is a serpentinite breccia. Ultramafic rocks are close to the composition of the mantle, are brought up from the mantle in magma, and tend to contain a lot of a mineral called olivine. Heat and the presence of water can metamorphose olivine into another mineral, serpentine, transforming the rock into serpentinite. A rock made from broken up pieces of serpentinite is a serpentinite breccia, such as this Connemara marble (see Breccia). The main other minerals in this rock are carbonates. The green colour is common in ultramafic rocks, probably due to nickel and reduced iron.

â€¢ Quartz Pure quartz is $SiO2$. It is very hard (Mohs hardness of 7) - harder than steel â€“ which is why most sand is made up predominantly of quartz, as softer minerals wear away more quickly when battered by waves on the coast or the winds of the desert. Quartz is the main ingredient of window glass, usually in the form of sand. It can be formed in a variety of ways, including as a metamorphic or igneous mineral, a cave deposit, or as quartz veins in fractures in rocks. It can crystallise in fluid-filled cracks and holes underground to form geodes â€“ balls of quartz crystals. Pure quartz is clear and colourless, but often quartz has impurities which change its colour, and can make rose quartz (pink), smoky quartz (grey) and other varieties. Quartz is piezoelectric, which means that it distorts when a voltage is applied across it, and can generate its own voltage when the applied voltage is removed as it returns to its original shape. This sets up a circuit with a frequency determined by the resonant frequency of the quartz crystal, and is used to keep time accurately in watches.

â€¢ Amethyst Amethyst is a variety of quartz which is purple in colour due to impurities including transition metals such as iron and titanium. Discussing the similarities in crystal shape may help to convince children that this is indeed the same mineral apart from these impurities.

â€¢ Tigerâ€™s Eye It is thought that Tigerâ€™s Eye is a gemstone which used to be blue asbestos (also called crocidolite), a fibrous mineral. During metamorphism, the asbestos is dissolved, and quartz precipitates in its place. This replacement allows the quartz to maintain the fibrous nature of the asbestos; some of the iron oxide in the asbestos is left behind, and becomes an impurity in the quartz, giving it its golden colour. This leads to Tigerâ€™s Eyeâ€™s appearance of parallel layers with slightly different golden shades that reflect the light in different ways.

â€¢ Agate Agate is yet another form of silica (since the crust is mostly made up of silica it shouldnâ€™t be too surprising that there are so many forms of it). This most commonly forms in water-filled cavities, where the silica precipitates on the walls of the cavity as layers of tiny crystals of quartz and moganite (a polymorph of quartz, so also SiO_2). The multi-coloured banding is due to the different impurities in each band.

â€¢ Crackle Quartz The colours in this crackle quartz are man-made. They are added by heating up quartz in dye, allowing the dye to permeate along cracks between see-through grains in the sample. This is a good opportunity to extend the discussion into melt production, generation and storage in rocks, with the more interested members of the public.

â€¢ Flint/Chert Flint and chert are very similar rocks, differing only in the type of carbonate rock in which they form. Flint forms in chalk, whereas chert forms in other rocks such as limestone. They are made from microcrystalline silica, with impurities and occasional fossils. It is not yet well-understood why the silica in these sediments has localised in this way, but is probably to do with dissolution and reprecipitation of silica in the buried sediments before the water has been squeezed out by compaction. It is thought that the shape of flint/chert nodules may be related to burrows in the sediment, and the source of the silica is likely to be either skeletons of tiny zooplankta such as diatoms and radiolaria, or sponge spicules, which are all made from silica. Flint and chert are also very interesting from an archaeological perspective due to two important properties. The first is their ability to be hammered (or â€œknappedâ€) into hard sharp blades, which led to them being used as the main material for tools by Stone Age people. The second is that when iron (or a mineral containing iron such as pyrite) is struck against flint, it produces sparks which can be used to light a fire. In general flint was better for these purposes than chert as it tends to be harder and more pure.

â€¢ Red Jasper Jasper is an impure form of silica (SiO_2), quite similar to chert (see Flint/Chert). Its colour varies according to the impurities, and the red colour in this jasper is probably due to ferric iron.

â€¢ Mookaite Mookaite is an impure form of silica, and in fact a kind of chert (see Flint/Chert) formed from sediments which have a very high proportion of microfossils from zooplankton called radiolaria. Radiolaria make their tiny skeletons out of the silica dissolved in water.

â€¢ Magnetite This mineral began its life with CHaOS with the label â€œHematiteâ€. However, not only does the colour seem slightly wrong, but, more importantly, hematite cannot be made into as strong a permanent magnet as the pieces in the box. Therefore Dave worked out that this must be another iron oxide, Magnetite. Magnetite is an early mineral to crystallise from most magmas, and is stable to high temperatures, so can be found in small amounts in a lot of different kinds of rocks. When found naturally, magnetite may be weakly magnetised, but not to the same degree as those in the box â€“ these have been artificially magnetised. However, in rocks with a lot magnetite, such as the basic igneous rocks of Skye, even the natural weak magnetism can be enough to offset compass needles and confuse hikers! Small, elongate, single crystals of magnetite are the best magnets due to the difficulty in switching the polarity of such a small magnet in one fell swoop. Magnetite crystals have been found in bacteria, as well as the brains of some animals (including pigeons and us). They are thought to be useful for navigation, using the inclination and declination (3D direction) of the Earth's magnetic field as a reference.

â€¢ Lepidolite Lepidolite is a lithium-rich mica, a major source of rubidium (which was first discovered in this mineral) and caesium. It can be found in pegmatites (granites with crystals larger than an inch, which is thought to be due to the presence of water), as well as other granites and high-temperature quartz veins. Like all micas (see Mica), it is a sheet silicate with one well-developed cleavage plane, and contains OH, so can only form from magmas containing dissolved water..

â€¢ Moonstone Moonstone is a gemstone formed by the intergrowth of two kinds of feldspar â€“ albite and orthoclase. These are minerals which crystallise during the cooling of magma. The two minerals may grow together in such thin flat layers that they are close enough to the wavelength of optical light to scatter it, producing a milky glow in the presence of light, said to resemble moonlight. This is called adularescence.

â€¢ Peacock Ore Peacock ore, also called Bornite, has the chemical formula Cu_5FeS_4. It can be found in igneous rocks, contact metamorphic rocks (those heated up by a nearby igneous intrusion such as a magma chamber) and shales. It is an important copper ore and is iridescent.

The Rocks Box: You might want to talk about rocks in general, and define what they are. (Ask something like â€œCan anyone describe what a rock is like?â€) Depending on the age of the kids, they might be able to name rocks such as limestone, chalk and marble. (â€œDoes anyone know the names of any types of rock?â€) You could ask where rocks are used (old buildings mostly). You could say that newer buildings arenâ€™t made of quarried rocks as man-made materials like brick and concrete are cheaper.

Warning to geologists: you may have to resist the urge to murder people who name some of the specimens as â€œjust a normal rockâ€. The box should contain a key to these rocks and rock-forming minerals, and I will use the same numbering system.

I like to ask people to describe each rock: there's a lot that you can deduce by simple observation of things like crystal size, colour and texture.

ROCK-FORMING MINERALS: A selection of the most common minerals which make up the majority of rocks in the Earthâ€™s crust.

1. Quartz See minerals section. The specimen in the minerals box has a well-formed (â€œeuhedralâ€) crystal shape, whereas this one has not â€“ perhaps it was rounded while being transported by water in a river?

2. Feldspar (Microcline) Feldspars are the most common mineral in the Earthâ€™s crust â€“ almost two thirds may be made from feldspars. They most commonly grow from magmas during crystallisation, and can crystallise in veins (e.g. as part of impure quartz veins) and some metamorphic rocks at temperatures around 600 Â¬oC. They are also found in some sedimentary rocks, but as they are much softer than quartz, are worn down far more quickly in high energy environments. There are two main groups of feldspars: alkali and plagioclase feldspars. Alkali feldspars, such as microcline, tend to be pink in hand specimen, and are the pink blocky minerals found in some granites (but not the one in this box).

3. Mica (Muscovite) and

4. Mica (Biotite) Micas are a group of sheet silicates, which means that their molecules are arranged in flat layers. This is why they have such a perfect cleavage (flat shiny surface, yes I know the word is hilarious) and grow in sheets. In fact, you can take tiny individual flakes off these micas, though I wouldnâ€™t recommend it if you want them to last! Micas all have OH in their chemical formulae, and thus are described as hydrous minerals â€“ this means that they require the presence of water to grow. If the micas form from cooling magma, the magma must have some dissolved water. For example, granite (but not the one in this box) often has muscovite and/or biotite. If the micas grow as a result of metamorphism (putting rocks under heat and pressure), the OH will come from other hydrous minerals such as chlorite, or even from mud. Muscovite is a white mica, and biotite is a dark brown mica. They form in similar circumstances.

5. Calcite See minerals section This crystal is probably opaque due to small amounts of impurities.

6. Hornblende Hornblende is a type of mineral called an amphibole. These have two cleavages at 56Â¬o to each other, which you can see if you look at one shiny surface of a crystal, and then rotate it through 56o in the correct direction. Hornblende is found in many intrusive igneous rocks, and some metamorphic rocks such as amphibolite.

IGNEOUS ROCKS: Rocks formed by the solidification of magma in a magma chamber (intrusive) or on the surface of the Earth (extrusive). Magma = underground, lava = above ground

7. Pumice Pumice is solidified magmatic froth. Magma has dissolved volatiles such as water and CO2Â¬, and these are more soluble under high pressure than low pressure. For a volcano to erupt there must be a build-up of pressure which forces the magma up towards the surface. When the volcano begins to erupt, this pressure is rapidly released, and so the volatiles are no longer as soluble in the magma. This means that bubbles of water and CO2Â¬ will form, and as they travel in the magma up to the surface from the magma chamber, the pressure drops even more, so that more volatiles exsolve. Because the gas is much more compressible than magma, the bubbles grow even more as the pressure decreases. This creates a froth of magma and gas analogous to opening a fizzy drinks bottle. If the magma travels quickly to the surface so that pressure is quickly released, and there is a high volatile content, and the magma is sufficiently viscous (e.g. andesite), then the bubbles may not fully escape the magma. There may be so much gas expanding so quickly that the magma fragments, creating an explosive eruption, as ash and pumice are thrown high into the air, creating an eruption column which may rise high up into the atmosphere or fall back to earth and form an ash flow (also called a pyroclastic flow). The pumice is solidified froth, which cools so quickly that it is technically a glass (it has no mineral structure, see Obsidian). Pumice often has so much gas inside it that it floats on water (this one does), and some people use it to rub the dead skin off their feet, as all the vesicles (bubbles) make its surface very rough. Examples of explosive volcanoes which erupted pumice include Vesuvius, Mount St Helens and Krakatoa. They tend to be mature hotspot volcanoes or subduction zone volcanoes (formed when old ocean floor sinks underneath another plate) because these have water-rich, silica-rich (and therefore viscous) magmas. The other extrusive (erupted) igneous rocks in this box are from non-explosive volcanoes.

8. Obsidian (Most children will have heard of this from Minecraft. In the game you can make it from adding lava to water, which is close to the truth, but emphasise that the game isn't factually accurate.) Obsidian is also known as volcanic glass. During crystallisation, it takes time for the molecules to arrange themselves into a given crystal structure. If a liquid is cooled quickly enough (such as when window glass is made it is cooled quickly in water), there will be no time for this to happen, and so the resulting solid, called a glass, will have the molecular structure of a liquid despite being solid. Obsidian is made when lava cools very quickly and becomes a glass. This is most likely to happen to thin rhyolitic (very silica-rich) lava flows, as other compositions of lava would have to be cooled more quickly than could naturally happen. Obsidian is metastable at the Earthâ€™s surface, and thus none has been found older than the Cretaceous, as, particularly in the presence of water, it changes into another rock type, perlite. Obsidian is archaeologically interesting, because it is hard, and can easily be made sharp (I think the hand specimen already has some fairly lethal

edges), and so was used by Stone Age man to make knives and other tools, though not as frequently as flint/chert due to its comparative rarity. It could also be polished to create rudimentary mirrors.

9. Basalt Basalt is an extrusive igneous rock. This means that it formed from the cooling of lava which flowed from a volcano. It has cooled quite quickly to allow only small crystals to grow (you can make out some shiny surfaces under the magnifying glass, although the bigger crystals may have started to grow in the magma chamber â€“ most of the crystals will be too small to see). The main difference between basalt, andesite and rhyolite is composition. Basalt is more iron and magnesium-rich and less silica-rich than rhyolite; andesite is intermediate between the two. When magma cools in a magma chamber, iron-rich and silica-poor minerals crystallise first and fall to the bottom of the magma chamber. This means that the remaining magma becomes more silica-rich, iron-poor, magnesium-poor, and therefore lighter. The system becomes more complicated if new (SiO_2-rich Fe-poor) magma is injected into the magma chamber, or if crustal material from the edges of the magma chamber (SiO_2-poor Fe-rich) is assimilated into the magma. Thus in general magma moves slowly from basaltic to andesitic to rhyolitic composition until it completely solidifies, is erupted, or is mixed with new material. Magma of basaltic, andesitic or rhyolitic composition may erupt as lava.

10. Andesite See Basalt for how extrusive igneous rocks are formed. Andesitic lava will only flow in a non-explosive eruption if it does not have a high volatile content (see Pumice).

11. Rhyolite See Basalt for how extrusive igneous rocks are formed. Rhyolitic lava will only flow in a non-explosive eruption if it does not have a high volatile content (see Pumice). It forms a glass if cooled quickly (see Obsidian) and so only thick rhyolitic lava flows would cool to make rhyolite like that in the box. The larger crystals in this rock would have formed in the magma chamber, and didnâ€™t fall to the floor of the magma chamber due to the high viscosity of rhyolitic magma (and perhaps also because of a similarity in density between the crystals and the magma). The rest of the rock is composed of tiny crystals (called groundmass) which formed when the lava cooled subaerially.

12. Granite This is an intrusive igneous rock â€“ a rock formed when magma trapped underground in a magma chamber cooled and solidified. Other intrusive igneous rocks include gabbro, which has the same composition as basalt, and diorite, which has the same composition as andesite. Granite has the same composition as rhyolite. Its larger crystal size is due to its slow cooling rate. There are three types of crystals to see in this granite: â€¢ Quartz â€“ the shiny grey ones â€¢ Plagioclase feldspar â€“ the dull white ones â€¢ Hornblende â€“ the shiny black ones Alkali feldspars (such as microcline) and micas can also form in granites, but not in this specimen. All the minerals mentioned are in this box. Granites can have much bigger crystal sizes than this, and those with crystals more than 2.5cm in size are called pegmatites. These are thought to have grown in the presence of water, which furthers the growth of existing crystals by inhibiting the nucleation of new, small crystals.

METAMORPHIC ROCKS: When sedimentary and igneous rocks experience high temperature and/or pressure they change, becoming metamorphic rocks. Four of the metamorphic rocks (mica schist, slate, gneiss, garnet schist) could have been made from the same protolith (original rock) â€“ a shale. Very high pressure is usually associated with orogenic (mountain building due to continental collision) belts, whereas high temperature may be due to depth of burial, or the presence of a nearby magma chamber.

13. Mica Schist Shale is made up of clay minerals and silt-sized particles (which are finer than sand) of other minerals such as quartz. The clay minerals become unstable at a lower pressure than the quartz, and so if shale put under sufficient heat and pressure, they will start to change into other minerals â€“ usually micas. Micas tend to be aligned so that their cleavage is perpendicular to the direction of maximum compaction. All of the shiny minerals you can see in this rock are these micas.

14. Slate A slate can also be made from the compaction of shale. This is a lower metamorphic grade than schist, the difference being that a slate has not experienced new crystal growth. The silt and clay minerals have aligned themselves in response to the pressure they have experienced, creating this characteristic slatey cleavage. It is this cleavage (a foliation along which the rock tends to break) which allows slate to be broken into the big flat slabs used for roof tiles.

15. Quartzite Quartzite is metamorphosed sandstone. Since sand is often largely made up of quartz, it is simply formed by the recrystallisation of this quartz under high temperature and pressure.

16. Gneiss Gneiss has undergone a higher grade of metamorphism than a slate or schist, but also made from shale. The high pressure and temperature conditions allow the rock to develop compositional banding perpendicular to the direction of maximum compaction. For this to occur, there must be both diffusion and recrystallisation happening. This allows the rock to have bands of white felsic (SiO_2-rich, Fe-poor) and dark mafic (SiO_2-poor, Fe-rich) material.

17. Garnet Schist This is rather like the mica schist â€“ it is also a metamorphosed shale in which recrystallisation has occurred, producing crystals visible to the naked eye. However, the large crystals in this specimen are of a mineral called garnet. This is a very dense mineral, and consequently is most likely to form under a lot of pressure (decently higher pressure than would be required to form the mica schist). This means that this garnet schist probably formed deeper in the Earthâ€™s crust than the mica schist, but otherwise is rather similar in its

formation.

18. Marble Marble is metamorphosed limestone. Since limestone is mostly made up of carbonate minerals (calcite, dolomite etc), so marble is predominantly composed of carbonates which have recrystallised under high temperature and pressure. Kitchen surfaces are often made of Marble, so you can tell them they're eating off dead sea creatures to add interest.

SEDIMENTARY ROCKS: Bits of sand, mud, dead organisms (which may become fossils) and other matter fall to the bottom of lakes, seas and rivers. As more layers of this sediment accumulate, the buried sediment gets squashed together, a lot of the water is squeezed out, forcing the sediments together into a sedimentary rock. During this compaction (which at a much lower pressure than metamorphism), minerals such as quartz and calcite that may be dissolved in the water may recrystallise between the sediments to form a cement, holding them together more securely. Not all sedimentary rocks are made beneath bodies of water â€“ for example, some sandstones are formed in deserts. However, they must all be formed by the compaction of grains of sediment together during burial. If you can see layers in any of these rocks, it is probably the bedding, which is formed by the deposition of each new layer of sediment.

19. Sandstone Sandstone is a rock composed almost entirely of sand grains which have been compacted together. They can form in a range of environments, including deserts, rivers, deltas, lakes or seas. Due to the currents or waves required to transport sand, softer minerals are often broken down before deposition, leading to very quartz-rich sand in many cases, as quartz is a very hard mineral.

20. Shale Shale is a rock composed of silt-sized grains and clay which have been compacted together. They are formed in low energy environments, as currents and waves would wash away such small grains of sediment, and carry in and deposit heavier grains such as sand. This includes very slow rivers and deep lakes or seas.

21. Arkose Sandstone This is a rock formed by the burial and compaction of sand with the softer minerals still intact. By definition, there should be at least 25% feldspar, but other minerals such as micas and calcite may also be present. To prevent the breakdown of these minerals physically or chemically, the sand must be deposited rapidly (for example at the base of a mountain range where a river slows down and spreads out, called an alluvial fan), preferably in an arid environment. A likely source rock for the required feldspar-rich sediments is an igneous rock such as granite.

22. Conglomerate This rock is made up of pebbles, so must have been deposited in a particularly high energy environment, such as a beach with strong waves or a fast-flowing river. The pebbles are from fragments of rock which have been eroded, and then bashed into a smooth shape by the river or the waves. There may also be finer material if a river has quickly changed from being fast-flowing to slow-flowing.

23. Breccia Breccia is made up of angular fragments of rock which have been eroded and deposited by a landslide or a river, without enough time spent in the river to be smoothed into rounded pebbles.

24. Limestone Limestone is a sedimentary rock made up mostly of carbonates. This may be organic â€“ from the shells of animals and the skeletons of microfossils â€“ or inorganic â€“ from calcium carbonate which has precipitated from sea/lake water where the water is oversaturated in calcium carbonate (this happens because to solubility of calcium carbonate in water is dependent on a number of things including pH and temperature).

Plant fossils: The explanation for this experiment is included in the sheets in the box, and as part of the plant experiment (biology).

References for Images: â€¢ The Rock Cycle â€“ By Kreislauf_der_gesteine.png:Chd at de.wikipedia derivative work: Awickert (Kreislauf_der_gesteine.png) [CC-BY-SA-3.0 (www.creativecommons.org/licenses/by-sa/3.0)], from Wikimedia Commons â€¢ Map Plate Tectonics http://vulcan.wr.usgs.gov/Glossary/PlateTectonics/Maps/map_plate_tectonics_world.html â€¢ Earth Structure â€“ adapted from Earth-G-force.png: derivative work: KronicTOOL (Earth-G-force.png) [CC-BY-SA-2.5 (www.creativecommons.org/licenses/by-sa/2.5)], via Wikimedia Commons â€¢ Geologic Time Scale â€“ adapted from United States Geological Survey [Public domain], via Wikimedia Commons â€¢ Fossil map â€“ By jmwatsonusgs.gov [Public domain], via Wikimedia Commons â€¢ Volcano X-Section â€“ adapted from MesserWoland (own work created in Inkscape) [GFDL (www.gnu.org/copyleft/fdl.html), CC-BY-SA-3.0 (www.creativecommons.org/licenses/by-sa/3.0/) or CC-BY-SA-2.5-2.0-1.0 (www.creativecommons.org/licenses/by-sa/2.5-2.0-1.0)], via Wikimedia Commons â€¢ Mosasaur Skeleton â€“ By Mike Beauregard from Nunavut, Canada (Prepare To Meet) [CC-BY-2.0 (www.creativecommons.org/licenses/by/2.0)], via Wikimedia Commons â€¢ Sea Urchin (echinoid) â€“ Copyright Â©2003 Daniel P. B. Smith. Licensed under the terms of the Wikipedia copyright. â€¢ Straight Nautiloid â€“ By Nobu Tamura email:nobu.tamura@yahoo.com www.palaeocritti.com (Own work) [GFDL (www.gnu.org/copyleft/fdl.html) or CC-BY-3.0 (www.creativecommons.org/licenses/by/3.0)], via Wikimedia Commons â€¢ Crinoid Anatomy â€“ By William I. Ausich (http://www.tolweb.org/Crinoidea/19232) [CC-BY-3.0 (www.creativecommons.org/licenses/by/3.0)], via Wikimedia Commons

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Up-to-date Information This experiment can be demonstrated by either just taking the samples that you feel confident talking about, or by following a certain story or activity. Some suggested activities are outlined below and can be found on laminated sheets and at the bottom of this page.

Sheet 1: Igneous Rocks (Box 1) This is an activity that explains how igneous rocks (formed from molten magma, which is called magma below ground and lava above ground) can be made of similar starting materials but form different rocks because of different cooling rates. Obsidian (B2) cools very fast, often in water, forming a volcanic glass rather than any crystals, essentially a frozen liquid (may know from Minecraft or Game of Thrones...) Pumice (A2) cools quite fast in air, fine crystals that can only just be seen floats on water because of all the trapped air bubbles Granite (F2) cools slowly underground, has big crystals made out of Quartz (A1 â€“ used in microchips), Feldspar (B1) and Biotite Mica (D1)

Sheet 2: Sedimentary Rocks (Box 1) This activity aims to show how sedimentary rocks form and how they turn into metamorphic rocks (morph means change) under high temperatures and pressures. Sandstone (A4) â€“ Quartzite (C3) Mudstone (B4) â€“ Slate (B3) â€“ Schist (A3), very high T and P, silly word..., contains muscovite mica Limestone (F4), made of crushed up dead sea creature shells â€“ Marble (F3), often used in kitchen surfaces, we eat off dead sea creatures!

Sheet 3: Interesting Points (Box 2) This sheet just offers some interesting rocks and fossils to look at and describe F5, F6 â€“ Trilobite, ancient ancestor of woodlouse, extinct, hard eyes made out of calcite $CaCO_3$ in Box 1 E1 B5 â€“ Mosasaurus tooth, a Mosasaurus is huge, as big as a room, extinct A1 â€“ Pyrite, fools gold, thought it was gold but actually FeS, Iron and sulphur (stinky egg smell) B1 â€“ Magnetite, magnetic D1 â€“ Agate, crystallised out from pools of dissolved silica in lava E1 â€“ Crackle Quartz, same as box 1 A1 but impurities give colour C1 â€“ Tektite, meteorite hits ground and mixes with rock on ground and explodes out across the globe

Other possible activities Another option is to sort the Box 1 specimens into Igneous, Sedimentary and Metamorphic rocks, as well as minerals. Or these specimens could be placed on a schematic of the rock cycle.

Box 1: Main Rocks and Minerals Collection Row 1 - Minerals A1 â€“ Quartz B1 â€“ Feldspar (Microcline) C1 â€“ Mica (Muscovite) D1 â€“ Mica (Biotite) E1 â€“ Calcite F1 â€“ Hornblende Row 2 â€“ Igneous Rocks A2 â€“ Pumice B2 â€“ Obsidian C2 â€“ Basalt D2 â€“ Andesite E2 â€“ Rhyolite F2 â€“ Granite Row 3 â€“ Metamorphic Rocks A3 â€“ Mica Schist B3 â€“ Slate C3 â€“ Quartzite D3 â€“ Gneiss E3 â€“ Garnet Schist F3 â€“ Marble Row 4 â€“ Sedimentary Rocks A4 â€“ Sandstone B4 â€“ Shale C4 â€“ Arkose Sandstone D4 â€“ Conglomerate E4 â€“ Breccia F4 â€“ Limestone

Box 2: Rocks, minerals, gem stones and Fossils A1 â€“ Pyrite (Foolâ€™s Gold) B1 â€“ Magnetite C1 â€“ Tektite and Flint D1 â€“ Agate E1 â€“ Crackle Quartz (and Mookaite?) F1 â€“ Quartz A2 â€“ Calcite B2 â€“ Aragonite C2 â€“ Marble D2 â€“ Tigerâ€™s Eye, Jasper, Mookaite? E2 â€“ Peacock Ore F2 â€“ Amethyst? A3 â€“ Turtle Shell B3 â€“ Nautiloid (straight-shelled) C3 â€“ Gastropod D3-4 â€“ Unknown? E3-4 â€“ Amethyst F3-5 â€“ Assorted Gems A4 â€“ Shark Tooth B4 â€“ Shark Teeth C4 â€“ Echinoid A5 â€“ Crinoid stem B5 â€“ Mosasaurus Tooth C5 â€“ Coral D5 â€“ Bivalves E5-6 â€“ Woolly Mammoth Bone F5-6 â€“ Trilobite A6 â€“ Brachiopod B6 â€“ Dinosaur Bone C6 â€“ Ammonites D6 â€“ Ammonoids

PLUS Explanation

This experiment has no explicit PLUS explanation. It's more a case of how much of the above detail you discuss with the kids.

Risk Assessment

Hazard: Small pieces

Description: The smaller samples are a choking hazard for small children if ingested.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Ensure that small samples are not in the reach of small children. Keep an eye on children with samples and make sure they don't put things in their mouths. Would advise keeping the very small gemstones in their plastic bag. Call a first-aider in event of ingestion.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Shattered samples

Description: Dropping samples may cause them to shatter, producing sharp edges and possibly dust for some samples.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Keep fragile samples in clear plastic bags for protection and to prevent dust if breakage occurs. If any samples do break, carefully remove the broken bits from display to avoid people cutting themselves. In case of injury call first-aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Samples with scary shapes

Description: Children may be trypophobic (i.e. afraid of samples with many holes/pores) or scared of some of the fossil creatures.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Take care with woolly mammoth bone, turtle shell and vesicular basalt. If a child is distressed, put away the sample, assure the child that it's just a rock, and allow them to calm down elsewhere.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Heavy samples

Description: Could cause injury if dropped

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure children do not pick up samples that are too heavy for them. Keep all heavy samples over the table or close to the floor; do not allow children to hold them where they could be dropped on feet. Call a first-aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-22 - Hannah Ford (hf257@cam.ac.uk), **Check 2**: 2012-01-14 - Adam Casey (ac675@cam.ac.uk)

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Check 1: 2015-01-19 - Matthew Kemp (mk775@cam.ac.uk), **Check 2**: 2015-01-19 - Elizabeth Pearmain (ejp69@cam.ac.uk)

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Rod Climbing

A polyacrylamide solution, which "climbs up" a rod when it is rotated in the solution - Discover a strange goo with some strange properties. Watch as it is able to climb up a rod in front of your eyes!

Last initially checked on 2023-01-15 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-01-17 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Chemistry

Equipment Needed

- Pot of pre-made polyacrylamide-in-glycerine. (x2)
- Stirring rod (plastic)
- Box of string "spaghetti"
- Fork
- Hand Drill with rod attachment

Experiment Explanation

In a nutshell

Twisting a rod in the polymer solution causes long molecules to wrap onto the rod and creep slowly upwards (like spaghetti on a fork).

How to set up the experiment

The premade solution is polyacrylamide (between 0.5 wt% and 1 wt%) dissolved in glycerine (same thing as glycerol) with food colouring, which goes with the rod. The fork and spaghetti can be used to demonstrate how a polymer behaves when it moves.

What you need to know during the event

1. Get the kids to twist the rod in the slime. Wait for them to notice that it's doing something weird... Explain that all materials, like the slime, are made of molecules. The slime contains a polymer called polyacrylamide, with molecules that are really long and thin, like spaghetti! The solution has some properties of a liquid, for example it finds its own level in a container, and some of the properties of a solid, for example it is elastic.

2. Let them have a play with the spaghetti-string and fork, and see that the string climbs up the fork. Encourage them to see how the length of the molecule makes the spaghetti get tangled, creating a viscous solution. Explain what's going on - as the string wraps onto the fork out of the mixture, it pulls more string with it. As it pulls tight, some of it gets forced up over the surface, pushed out of the way as more string wraps on. This is what's happening with the polyacrylamide, but on a much smaller scale so we can't see the individual "strings". *Demo only works with the prongs of the fork on the plate as otherwise the spaghetti is squashed out the bottom (which is preferred because of gravity)*. This occurs due to the circular flow of the liquid around the rod becoming sheared, which causes the forces perpendicular to the surface (upwards) to become much larger than those effects causing the circular motion, leading to the liquid rising up onto the rod. This effect (called the Weissenburg effect) can occur in any liquid capable of shear (think batter or similar things in baking partially rising up the whisk when mixed), but as the rising is due to shearing effects, this will become magnified for more viscous liquids, such as the polyacrylamide. Also, note that this effect just requires some rotational motion, and if this can be achieved without the rod, a bump will still form around the vortex formed by the stirrer. As seen in this youtube video: https://www.youtube.com/watch?v=tK2ajzCfNBU

What kind of molecule do they think might pour much more easily? (e.g. water, sand, sugar which are small and round molecules instead of chains).

Sometimes they will ask why it forms a 'blob', and doesn't just rise up, this is because of this effect falling off as the width of the 'blob' decreases (less shearing can occur), and so gravity pulls the layers down until a blob is formed

3. Try lifting the rod out of the slime or touching the surface of the slime lightly with the rod. The solution has a very high extensional viscosity (resistance to flow when pulling as opposed to pushing, which is how we usually think of viscosity). Imagine trying to pick up one strand of cooked spaghetti from a huge pile â€“ itâ€™s the same thing (except that youâ€™re pulling out hundreds, if not thousands of strands of spaghetti).

Tips for demonstrating

Don't let them put their fingers in the slime!

- Acrylamide (the monomer) is toxic, but there is none of this in the solution. The slime (**poly**acrylamide) that we're using is not harmful to touch or ingest. The degree of polymerisation (the length of the chains) is so high that even the shortest is several thousands of monomers long.
- Despite this, it is also very sticky and if it starts getting on people's hands, then we'll lose it all very quickly.

Want to know more?

Polyacrylamide is a polymer; this means that the molecules (the smallest parts that are still polyacrylamide) are very long and thin like cooked spaghetti, lengths of string or long hair. Polyacrylamide is used to thicken foods.

Polymers behave elastically due to the different states they can adopt - extremes being the coiled and extended states. In the coiled states, there are lots of different conformations which come about from molecule rotating in different parts along its length, but only one that makes it straight. That means that the coiled state is much more likely (this is entropy!), and so the polymer tries to go back to it if stretched.

The glycerine that the polyacrylamide is dissolved is used as a cough mixture and is also added to icing to keep it soft.

Risk Assessment

Hazard: Polymer

Description: Eating polymer (note: polyacrylimide is not harmful)

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Stop kids from eating polymer. Use a very high molecular weight of polyacrylimide so there are no monomers. Children must not handle the slime during the activity!

Polyacrylimide is not harmful if ingested or touched. Advise parents if it is ingested and to see their GP should illness develop.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Fork/wool model

Description: Tines of fork could stab/scratch if children aren't sensible with it.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Encourage children to be sensible and warn them not to run/play with the fork. Keep track of the fork location at all times and put away if necessary.

Call first aider in event of injury

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Slime

Description: Slip hazard if on floor.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clear up any spills immediately.

Call first aider in event of injury

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

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Rolling Down Hills

Racing jam jars down a gentle slope, to see how filling them affects the speed. - Find out about rotational mechanics by racing jam jars of differing weights downhill.

Last initially checked on 2023-01-18 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-01-19 by Lauren Mason (llm34@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- *In the box there should be:*
- Empty jam jar
- Jar half full of water
- Jar full of water
- Full jar of jam
- *You will also need:*
- Gentle slope - Large wooden board. There is one dedicated to this purpose, but if that cannot be found, the archbridge base should work instead if not in use.
- A couple of things of obvious different weights to drop that won't break. Two rolls of gaffa of different sizes works nicely.
- Foam block/thick pad/sleeping mat - something soft to place at the bottom of the ramp to stop the jars escaping. The foam covering lungs works. Alternatively use an opened t-shirt box to catch the jars. Hitting the t-shirts gives them a soft landing. Some padding around the sides of the ramp is needed in case the jars roll off the ramp.
- (Optional) Some sort of release mechanism to release all the jars at the same time.

Experiment Explanation

Race the jam jars down a slope to see which one is faster.

In a Nutshell

Show people that rotational motion is a bit weird - you have to account for the distribution of mass not just the overall properties.

Setup

Not much to do. Place the ramp on the floor (if using a board then use a couple of jars/ spare box or find something else to hold the back end up). If using an opened t-shirt box to catch the jars, place at the bottom of the ramp, or if using foam, place about 10cm past the end of the ramp (taping it down helps if its small).

The Experiment

Gain attention by telling people they'll be racing jars down a hill. Explain what's in the jars.

First, bring out the drop test objects and ask kids which one is heavier (they can feel this for themselves) and ask which one will hit the ground first if they're dropped from the same height at the same time. Both should hit at the same time (demonstrate a couple of times, from different heights if necessary). Get them to tell you what force pulls things down. The heavier something is, the stronger the gravity. BUT, the heavier something is, the harder it is to get it to move (it's not as easy to pick up something heavy). These effects cancel each other out so all objects fall under gravity at the same rate.

Now ask them to think about what will happen on the ramp - if gravity doesn't care how 'heavy' things are, should the weight of the jars make any difference? Will they all reach the bottom at the same time? Feel free to prompt some more (why do you think X, what might cause Y) if the group is old enough to engage.

Let the kids pick up the jar of jam and the empty jar to get a feel for the weights, and then race! (if the kids are eager and you can get them to release when you say, then they can hold the jars and let go when you tell them to. Alternatively, a pole or stick can be used as a release mechanism). The jar of jam should beat the empty jar.

It looks like the heavier jar wins but this makes no sense since we've already seen gravity doesn't care about weight. What is the difference between falling and rolling? When falling (or sliding on the slope), the jar stays one way round (in one orientation) whilst moving. When rolling, as well as moving down the slope, the jar is also spinning. This is what changes things. Gravity needs to put in extra effort to get the jars spinning as well as going down.

Get the kids talking about it a bit and then ask them if they've been on a roundabout/ merry-go-round/ turntable thing at a park. Does it just start spinning on its own without any pushing? What about pushing the thing if someone else is on it - is it easier to make it spin fast if the other person is in the middle or at the edge? (You can also try to connect this to Spinny Chair experiment if it is also out.) Exactly the same thing is happening here with the jars. The empty jar has almost all of its mass concentrated in a very thin layer of glass a long way from the axis of rotation whereas the one full of jam has a lot of mass quite close to the middle. It's therefore much 'easier' to make the full jar spin than the empty jar (could be worth mentioning, to reinforce the idea that weight is irrelevant, that if there were no friction the jars would all slide (not roll!) down the hill in the same amount of time).

Next try the jar of jam vs the jar of water. The jar of water wins, why? Whatâ€™s the difference between the water and the jam? Answer: Jam is sticky, but water isnâ€™t. When the jar of the water rolls down, the water doesnâ€™t have to spin, only the jar, whereas in the jar of jam both the jar and jam are spinning. This means the jar of water can go faster.

The interesting case of the half-full jar and the jam jar can now be the ultimate race. The jam jar has the extra weight, but the half-full water jar doesnâ€™t have to spin as much, so you can get the kids to bet on which will win. This one is actually quite close, so youâ€™ll have to see which wins on the day!

In conclusion for linear motion the distribution of mass is irrelevant, only the total, whereas for rotational motion it's not just the mass that matters, its position is important as well.

PLUS Explanation

First, bring out the drop test objects and ask kids which one is heavier (they can feel this for themselves) and ask which one will hit the ground first if they're dropped from the same height at the same time. Both should hit at the same time (demonstrate a couple of times, from different heights if necessary). Get them to tell you what force pulls things down. The heavier something is, the stronger the gravity. BUT, the heavier something is, the harder it is to get it to move. These effects cancel each other out so all objects fall under gravity at the same rate.

Explain that we are ignoring air resistance (or get them to tell you that). Use Newtonâ€™s second law to explain how mass doesnâ€™t affect acceleration under gravity. It seems odd that the inertial mass term in Newtonâ€™s second law happens to be the gravitational mass. Einstein used this empirical fact in his â€˜Equivalence Principleâ€™ where he equates the gravitational force experienced by an observer to the same force that would be experienced if the observer were accelerating. This then lead to his Theory of General Relativity: The currently used theory that describes the effect of gravity.

These effects can also be understood if the falling masses are described by their energies. As the mass falls, gravitational potential energy is converted into kinetic energy, but again (use equations to show) the speed at which they fall is the same.

Now ask them to think about what will happen on the ramp - if gravity doesn't care how 'heavy' things are, should the weight of the jars make any difference? Will they all reach the bottom at the same time? Feel free to prompt some more (why do you think X, what might cause Y).

Let them pick up the jar of jam and the empty jar to get a feel for the weights, and then race! A pole or stick acts as a good release mechanism. The jar of jam should beat the empty jar.

It looks like the heavier jar wins but this makes no sense since we've already seen gravity doesn't care about weight. What is the difference between falling and rolling? When falling (or sliding on the slope), the jar stays one way round (in one orientation) whilst moving. When rolling, as well as moving down the slope, the jar is also spinning. This is what changes things. Gravity needs to put in extra effort to get the jars spinning as well as going down.

When two objects fall through the air under gravity we only need to consider their centre of mass motion. However, when the jars roll down the hill we also need to consider their rotational motion. The jars have linear kinetic energy due to the movement of their centre of mass and rotational kinetic energy from their rotation.

Does a roundabout just start spinning on its own without any pushing? Sixth form students should be familiar with F=ma, can introduce them to G=I x angular acceleration. G is the torque, the equivalent of force for rotational motion, students may have come across this before in the context of pivots. I is the moment of inertia. This is the equivalent of mass for rotational motion and is a measure of how easy it is to rotate an object. For linear motion, a larger mass makes it harder to move something. Here, a larger moment of inertia makes it harder to spin something. The difference between mass and I is that I is related to both mass and the distribution of the mass. Referring back to the roundabout, is it easier to make it spin fast if a person is sat in the middle or at the edge? (You can also try to connect this to the 'Spinning Chair' experiment if it is also out.) The larger the mass of an object, the harder it is to move and the larger the moment of inertia the harder it is to get the object to rotate. Additionally, the further away this mass is from the axis of rotation, the harder it is to move and the higher the moment of inertia. Link the two equations together and explain that we can treat angular motion is a very similar way to linear motion.

When different masses of the same shape are dropped and fall through the air they hit the ground at the same time. The larger the mass of the object the the larger the force due to gravity, but also a larger force is required to move it. Can think about how easy/hard it is to pick things off the ground that weigh different amounts. Can also relate back to F=ma. In this case F=mg, so a=g. Acceleration is constant. Now instead of just thinking about F=ma, need to think about G=I*angular acceleration. The torque, G is proportional to mass. Moment of inertia is also proportional to mass, but with different prefactors depending on the distribution of mass within the object. The means that accelerations for the empty jar and the jar of jam are different because the distribution of mass is different.

As rotating need to think about moment of inertia. The jar of jam has a larger mass than the empty jar and it also has a larger moment of inertia. However, because the jam is distributed uniformly throughout the jar, the mass increases by a larger fraction than the moment of inertia compared to the empty jar. The empty jar has almost all of its mass concentrated in a very thin layer of glass a long way from the axis of rotation whereas the one full of jam has a lot of mass quite close to the middle. Objects with more mass closer to the axis of rotation are easier to rotate than objects with more mass closer to the edges of the object. This means that relatively speaking gravity finds it easier to rotate the jam jar. This means that the jam jar travels faster down the slope. If instead we compared an empty jam jar made of glass and an empty jam jar of the same shape but made of lead, the jars would reach the bottom of the slope at the same time. The important point isnâ€™t that the jam jar has extra mass but the fact that the extra jam mass is distributed throughout the jar.

(could be worth mentioning, to reinforce the idea that total mass is irrelevant, that if there were no friction the jars would all slide (not roll!) down the hill in the same amount of time).

Next try the jar of jam vs the jar of water. The jar of water wins, why? Whatâ€™s the difference between the water and the jam? Answer: Jam is sticky, but water isnâ€™t. Because of this the jam is stuck to the outside of the jar and rotates with the jar when it rolls down the slope. The water however, isnâ€™t â€˜stuckâ€™ to the side of the jar so only sloshes slightly as the jar rolls. This costs less energy, so more energy goes into the linear kinetic energy of the jar down the slope. Overall energy must be conserved and both jars start with the same energy. (Neglecting the difference in mass between water and jam). So the water jar travels faster and wins the race.

The interesting case of the half-full jar and the jam jar can now be the ultimate race. The jam jar has the extra weight, but the half-full water jar doesnâ€™t have to spin as much, so you can get the kids to bet on which will win. This one is actually quite close, so youâ€™ll have to see which wins on the day!

In conclusion for linear motion the distribution of mass is irrelevant, only the total, whereas for rotational motion it's not just the mass that matters, its position is important as well.

An energy argument

What force is it that causes something to spin in the first place? (Friction acts at the point of contact of the jars). All of the problems can be explained by considering the energy of the jars. When the objects were dropped before, gravitational potential energy was converted into kinetic energy, but with spinning added, we need to incorporate a new energy term for the rotation of jam about the centre of the jar - rotational kinetic energy. The amount of rotational energy that you need to put in depends on where the mass is, so the empty jar has the worst distribution of mass and rolls slowest. For the full jar of water the water isnâ€™t rotating so the rotational energy is only for the glass, meaning it can roll quicker.

We can write the rotational kinetic energy down in an equation similar to the linear kinetic energy: LKE = (Â½)mv^2 RKE = (Â½)Iw^2 w is how quickly the jar is spinning. I is called the moment of inertia, and increases as mass gets further away from the centre, so more energy will be required. Actual definition is sum of mass * (distance from rotation axis)^2. E.g. figure skating: if a skater brings their arms in they've reduced their MOI but to keep the same rotational energy the same they spin faster"). Can demo this in the playground - several people stand at the edge of a roundabout spinning fairly slowly and walk in to the middle. The roundabout should speed up and if they walk back out it should get slower again.

The wikipedia page on 'moment of inertia' has more information and a nice gif animation of (front to back) a solid cylinder, cylindrical shell, ball and spherical shell racing down a slope. http://en.wikipedia.org/wiki/Moment_of_inertia#Scalar_moment_of_inertia_...

Risk Assessment

Hazard: Rolling objects

Description: The objects rolling into people, and tripping them up.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Make sure the base of the slope is not heading towards a gangway or towards people's legs. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Jam jars

Description: The objects bouncing off things and breaking, then possibly making sharp objects as a result which can cause cuts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Put something soft at the base and as much as you can around the sides of the slope (particularly near the base) to catch the objects. Consider wrapping the jars in sellotape. In case of breakage, close experiment until broken glass and spilled water is cleared up. Call a first aider in the event of an injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Liquid in jars

Description: Slip hazard from spilled water if jars break.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep children away from any spillages and dispose of safely and quickly. Put something soft at the base and as much as you can around the sides of the slope (particulary near the base) to catch the objects. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Objects on surfaces

Description: Jars falling off the bench and hitting people, or breaking and making sharp pieces of glass which can cause cuts.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do the experiment on the ground. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

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Scale of the Solar System

By comparing sizes and distances we can scale our solar system all the way up from the Earth and the Moon, up to our nearest star, and you might be surprised how far that actually is! - By comparing sizes and distances we can scale our solar system all the way up from the Earth and the Moon, up to our nearest star, and you might be surprised how far that actually is!

Last initially checked on 2023-01-18 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-01-19 by Lauren Mason (llm34@cam.ac.uk)

Tags

Astrophysics

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- Golf ball - Moon
- Globe - Earth
- Marbles - Earth/Sun on different scales
- Red foam ball - Jupiter
- Card with pin-prick hole - Sun/Solar system on bigger scales
- Diagram/pictures of solar system

Experiment Explanation

Place the different objects at varying distances and combinations to give kids a sense of scale of how big objects in the Solar System are, and how far they are from each other.

The kid may not necessarily know all of the planets in the Solar System yet, so you can ask them to name the ones they know and fill in the rest. Feel free to throw in some facts about them to get them interested.

Different scales, and corresponding distances:

For globe earth: Golf Ball moon - at a distance of 4m Speed of light c = 6ms-1

For 2m (roughly demonstrator height) Sun: Earth marble Jupiter ball c=1ms-1 (GUESS!?!)

Sun marble Earth 2m away Jupiter 10m Neptune 60m

Sun 1mm (pin prick hole in card) Neptune 4m Alpha Centauri 29km

Solar System (sun to neptune) 1mm Alpha Centauri 10m

Risk Assessment

Hazard: Balls/marbles

Description: Tripping or falling over stray rolling balls/marbles.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Demonstrator must emphasise that children must walk, should stop everyone walking to actually do explanations. Take note of any trip hazards (cables, other experiments, etc.) that may block the path of children walking & warn them to be careful of these if necessary. Must be made very clear to children that they may not kick or throw the balls ever. Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Small parts (marbles)

Description: Small balls used in some parts of the experiment being swallowed with potential of choking.

Affected People: Children

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Do not use small balls parts of experiment for audiences of very young children. Keep track of all small parts. Don't lose your marbles! Call a first aider in the event of swallowing/choking

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2014-12-06 - Zephyr Penoyre (jp576@cam.ac.uk), **Check 2**: 2014-12-07 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Seeing Sound

Use an oscilloscope and slinky spring to see how sound travels - Find out what sound is, the difference between low and high sounds, and loud and quiet sounds, and learn about sounds we can't hear

Last initially checked on 2023-01-18 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-01-19 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Electricity needed**
- Box in which is mounted a signal generator and audio amplifier, with cables.
- Loudspeaker
- Oscilloscope
- Microphone + battery box
- Concertina, recorder, etc.
- Antiseptic wipes (to clean the recorder)
- Slinky spring

Experiment Explanation

Overview

Seeing Sound uses a signal generator and loudspeaker to make sounds, as well as various musical instruments. There is a microphone and oscilloscope to 'see' the sound, to allow kids to learn about what sound waves are and some of their properties. If the oscilloscope isn't working, or is too complicated to figure out, a reasonable alternative is to download a free mobile app instead. If doing this, keep your phone in your possession at all times.

Possible activities:

- Explaining what sound is, and how you can hear things, using the signal generator and loudspeaker.
- Looking at your voice on the oscilloscope when you say different words and vowels etc.
- Comparing the voices of different people looking at pitch and volume.
- Looking at how simple musical instruments work.

Other things to talk about:

- How sound travels through the air.
- How the oscilloscope displays a sound wave.
- How people lose their upper hearing range and application to mosquito alarms.
- That many animals can hear ultrasound just like children can hear things adults can't e.g. dog whistles and bat squeaks.

Tips for demonstrating:

- Get the whole family to talk into the microphone so that you can look at the different pitches and volumes of their voices.
- Get the children to try different vowel sounds, low sounds, and high sounds etc.
- There's a lot which can be done in this experiment; you don't have to do it all, and you don't have to follow the order below...

Basic Procedure and Explanation

- Start by explaining how we can hear things. Ask the children if they know anything about waves - water waves, sound waves etc.

- When sound travels through the air, it is in the form of a wave, a little bit like the waves that you get on the surface of water (although longitudinal compression wave rather than transverse).
- Use the slinky to show how longitudinal waves travel. Normally we can't see these waves in the air, but our ears can pick them up. It's like people jostling all the way across a room.
- Using the signal generator and amplifier, get the loudspeaker oscillating at 10-20 Hz and get the kids to notice this. If they are careful they can touch the speaker gently to feel it move.
- Then turn up the frequency so you can hear it (make the connection between the wobbling and the sound) and can still feel it 50-80Hz. Get them to feel the air above the speaker they should be able to feel it moving. Say that the air wobbles above the speaker, and then wobbles all the way to their ear (you could use the slinky to demonstrate this - a picture of an ear and loudspeaker may help here too) and your ear hears the wobbles as sound.
- Turn up the frequency again, and get the kids to make the connection between speed of vibration and pitch.
- See what they highest they and their accompanying adults (and you!) can hear - should be just below 20 kHz for us and them, can easily be around 15 kHz for (proper) adults. If they seem to have superhuman hearing and claim to hear e.g. 30 kHz, secretly turn it off and see if they can still hear it!
- Explain that you can't see sound, because the air is transparent and it's moving too fast anyway. Then introduce the microphone and oscilloscope and look at the sound from the loudspeaker. (If the oscilloscope isn't working well, there are free mobile phone apps make a reasonable alternative if your battery can hold out. The following explanations still hold though the output isn't always as clean!) The children can also make some simple noises into the microphone. Vowels are good for this. Explain that each sound has its own particular shape - saying the alphabet can prove invaluable here. A long vowel sound should create a quite stable wave on the 'scope.
- Ask the child to sing a quiet note and a loud note, and see that the picture drawn gets taller with volume.
- Get child to sing a long note moving from a high note to a low note (dads may be useful here for very deep notes), and show that the wiggles on the screen get further apart the lower the note, and closer together the higher you go. This is a measure of increasing frequency - when things vibrate faster, we get a higher note (e.g. car accelerating).
- They can also feel their larynx vibrate when they talk - easier with lower sounds.
- Now for the musical instruments! Let them try to make different notes with recorder and concertina, and with the big pan pipes from the resonance experiment. Look at how different pitches, different volumes, and different timbres (types of note) appear on the oscilloscope. Ask if they play any instruments and explain how that creates vibrations.

Other things to talk about

- Introduce the idea of wavelength with long wavelengths corresponding to low frequencies and vice versa.
- A couple of features of the oscilloscope can be explained. You can explain that the microphone converts the air wobbling into an electrical wobble which makes the dot on the screen wobble up and down (you can show this by turning the freq very low on the oscilloscope and you should be able to see the dot going up and down). Speed the dot up again a bit and kids can normally work out that fast wobbles make short wavelengths on the screen, and from stuff earlier they should be able to work out that high pitch makes short wavelengths too.
- You can go into more detail of the biology of hearing, or use this point to encourage them to go onto the biology experiments afterwards!
- You can think about why the ear and loudspeaker are the shapes they are, and why these are quite similar. This is also quite like an amphitheatre.

Science Background for Demonstrators

Sound is a longitudinal (compression and rarefaction) wave through the air. The signal generator produces an oscillating electrical signal, made bigger by the amplifier; the loudspeaker contains a coil of wire which acts as an electromagnet, so that the speaker cone oscillates at the same rate as the signal. We hear because the sound wave makes our eardrums vibrate: the vibration is passed on through a series of bones which amplify its magnitude to the cochlea, where tiny hairs inside the fluid-filled tube pass a signal through the auditary nerve to the brain when they resonate with the vibrations. (The action of these hairs is complex, and only recently becoming understood.)

The microphone is capacitative, so needs a battery and resistor (in the little box) to produce a voltage signal for the 'scope.

Recorders (and suchlike) produce standing waves of air in the tube. The concertina is a free reed instrument: air is blown past a tongue of metal, which vibrates at a rate determined by its length and mass, in such a way that the air going past is caused to vibrate too.

Risk Assessment

Hazard: Heavy Objects

Description: The oscilloscope is heavy and could be dropped or knocked off table, possibly injuring children.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Keep oscilloscope away from edges of table, or keep in the opened box if convenient. In the event that the oscilloscope falls, switch it off. Clear up broken glass.

Call first aider in case of injury. Close experiment if necessary.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Recorder mouthpiece

Description: Spread of infection via recorder mouthpiece.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clean mouthpiece of recorder with antiseptic wipes between uses. (During COVID, maybe worth not doing this part)

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Amplifier

Description: The amplifier can be quite loud, so there is the possibility of auditory damage.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Take care not to have amplifier on too loud.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Oscilloscopes (electrical)

Description: Electrical hazard.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: See electrical parts RA.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

Check 1: 2012-01-02 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-01-14 - Aaron Barker (arb78@cam.ac.uk)

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Check 1: 2014-01-25 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2014-02-15 - Brett Abram (ba305@cam.ac.uk)

Check 1: 2015-01-04 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-22 - Tom Comerford (tafc2@cam.ac.uk)

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Seismometer (PLUS only)

A seismometer and lots of explanation - Find out about the structure of the earth, and how we have found it out despite only digging down 0.2% of its depth.

Last initially checked on 2023-02-15 by Sophie Miocevich (srm81@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Geology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **Electricity needed**
- In this box there should be:
- Lego Seismometer (including magnets, weight, coil, spring and lego structure)
- aux cord
- micro-usb to usb cord
- seispy converter
- 4/5 tennis balls (under development)
- One magnet in labelled sealed box (under development)

Experiment Explanation

The following are some suggested talking points for the seismometer experiment. You do not need to do all of them, but there should be enough here for an interested person. A lot of it is not directly related to the seismometer, but the larger field of seismology. Drawing diagrams and asking questions is a good way to keep it interactive. Keep the seismometer set up and refer to and use it throughout the experiment.

For when we have a tennis ball with magnet: Start off by using the tennis balls to discuss how we might work out what is inside something without just opening it. Get participants to experiment with the tennis balls; e.g. shake, compare weights, test with the magnet in the box, to think about what might be inside them. Then start discussions about what kind of techniques we can use to see inside the earth.

Otherwise - rely on drawn diagrams.

What is the earthâ€™s structure? (figures 1 and 2)

There are two dominant classification schemes:

â€¢ Crust, mantle, outer core, inner core are the popular terms. The boundaries between these are defined by chemical compositional changes, i.e. the rock type changes from one side to the other. The crust/mantle boundary is called the 'moho boundary'.

â€¢ You can also describe the crust and mantle by the lithosphere (which covers the crust and upper part of the mantle) and the asthenosphere, which is everything deeper up to the outer core (mesosphere is sometimes also included). The lithosphere and asthenosphere are different in elasticity. Across the boundary, the temperature increases, making rock more ductile and less rigid (A famous example of the importance of this transition is the failure of the titanic: In the icy temperatures, the metal hull became brittle and was subject to a brittle failure).

The earth structure classifications are therefore chemical and physical respectively.

How do we know what the earthâ€™s structure is?

How far do you think weâ€™ve drilled? Earthâ€™s radius is 6371km. We certainly havenâ€™t drilled down very far: Kola Superdeep Borehole in Russia continent went 12.3km. The earthâ€™s crust is ~8km deep in the ocean, and ~27km deep in the continents, so we havenâ€™t even reached the bottom. Why? Calculate what the pressure might be at 12.3km depth (continental crust density = 2.83* that of water, ocean crust even denser ~3.3*water). This is a hydrostatic pressure, so there is the same pressure pushing upwards. Quite hard to push down.

We donâ€™t have samples from very deep: ~400km. The peridotite in the 'Rocks and Fossils' experiment will be from a similar depth. This is only partly into the mantle! How do we have this if we havenâ€™t drilled down to it? 'Rocks and Fossils' has a rock cycle explanation.

The solution: Earthquakes!!! They naturally probe the earth for us. What is an earthquake? Earthquakes occur by â€˜elastic reboundâ€™. Over time, tectonic processes (possible digression to plate tectonics here, much higher pressures at convergent plate boundaries) build energy. Once this overcomes friction, rupture occurs, and seismic waves radiate off. Deepest earthquakes are around 300km and occur almost exclusively at convergent plate boundaries. Why are none found deeper? Ans: refer back to discussion of ductile vs brittle, hot rock flows better and stresses are dissipated.

How do waves move through the earth? (figures 3 and 4)

As we get deeper, waves get quicker (wave speed is a function of density and elastic moduli). Now for a diffraction explanation, maybe huygens wave principle? As they get deeper, waves get slower, and they curve! So waves emitted initially away from the surface come back.

Arrival Times (figures 5 and 6)

We use different arrival times to figure out where an earthquake originated, called the hypocentre (you may have heard of the epicentre: that is the point on the earthâ€™s surface above the earthquakeâ€™s origin). Can you figure out roughly how fast they are going on the seismogram above (assuming direct travel...)? Hawaii â†’ Albuquerque ~5000km. Therefore wave speed is O(10km/s). This is not too far wrong (see figure 6 below). Why is this not right? We havenâ€™t considered the different paths of the waves, varying speeds etc.

There are different types of wave, P is longitudinal, S is transverse. P is faster. Finally, there are surface waves which appear at the boundaries, such as earthâ€™s surface. Why canâ€™t we separate the different wave types on our seismogram? Use the speed result above.

Evidence for Earthâ€™s Structure (figure 7)

Now for structure. Waves are reflected and transmitted at surfaces (maybe relate to 'Waves at Boundaries' experiment if thatâ€™s out). The reflected bits return to earthâ€™s surface, so we can figure out where the major changes in earthâ€™s structure are. These are due to basically anywhere the structure dramatically changes. E.g. Crust/Mantle Lithosphere/asthenosphere, core/mantle, core/inner core. See above diagram for shadow zones.

Iron inner core: At the temperature and pressure we predict for the earthâ€™s core, an iron composition would replicate the wave speeds we observe. Iron is abundant in the solar system due to its high binding energy We have samples of iron meteorites from proto-planets which we think have a similar specified structure to the earth. We need a magnetic element to generate the earthâ€™s magnetic field

Liquid Outer Core: No s-waves pass through this region. Transverse waves canâ€™t pass through fluids. (NB: the mantle is not therefore molten as lots of people seem to think. It does flow, but on much longer timescales, so to an earthquake, it appears solid) The earthâ€™s magnetic field needs a flowing magnetic material. A-level physicists will probably have heard of faradayâ€™s law.

Solid Inner Core: The sharp wave speed change here us not likely possible in a purely fluid region. There is a small amount of evidence for inner core s-waves, generated at the inner core/outer core boundary. They have small amplitudes, so weâ€™re not sure we trust the observations yet.

Transition Zones: Generally due to solid-state phase transitions, and therefore their height is temperature sensitive [related by the Clausius-Claypeyron relation]. The low velocity zone between lithosphere and asthenosphere may be due to some degree of melt.

Appendix It would be good to see whether geophysics is possible to explain without all the jargon. Possible ideas: P waves --> ~sound or pressure waves S waves --> transverse waves Astenosphere --> weak solid layer Lithosphere --> strong but brittle solid layer

Risk Assessment

Hazard: Jumping

Description: Whilst jumping a child may injure themselves

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Do not ask them to jump if the floor seems dangerous or they do not seem steady on their feet. Avoid doing this activity near to steps / uneven floors. In case of injury call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Lego parts / tennis ball fillings

Description: Small parts can be swallowed or choked on.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Keep the seismometer in one piece. If small children are watching, no touching. Keep careful watch on tennis ball fillings and don't allow very small children to open the tennis balls.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Sharp seisometer parts

Description: Some parts are sharp or could trap fingers.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: If small children are watching, no touching. Warn children of any sharp or trappy parts. Demonstrator be aware of risk and be careful of sharp parts.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Filled tennis balls

Description: Tennis balls could be thrown which may cause minor injury.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Be aware of what children are doing with tennis balls and restrict their use if necessary.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Magnet to test tennis ball innards

Description: Small, choking hazard. Risk of trapping fingers. Could affect pacemakers etc.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Keep magnet in labelled, sealed box at all times. Do not allow magnet to leave experiment area. Warning sign regarding presence of magnet.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2020-02-05 - Sophie Miocevich (srm81@cam.ac.uk), **Check 2**: 2020-02-06 - Beatrix Huissoon (beh37@cam.ac.uk)

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Sheep Skeleton

Investigate a sheep skeleton and see if you can reconstruct it - Put together a sheep skeleton like a jigsaw puzzle! How is a sheep skeleton different to a human skeleton? How is it the same?

Last initially checked on 2023-02-19 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-02-19 by Peter Methley (pm631@cam.ac.uk)

Tags

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Biology

Equipment Needed

- Sheep skeleton, containing bones numbered 1-11
- Board with sheep anatomy diagram
- 2x printout of sheep skeleton (one numbered for demonstrator use, one without)
- Printout of human skeleton
- Bonus sheep anatomy printouts (tailbone; feet; ribs)

Experiment Explanation

In a nutshell

The aim of this experiment is to show children a (half) complete animal skeleton, so they can see how some parts are very different (legs, feet) and some parts are quite similar (spine, ribs) to how a human skeleton looks. Even the "very different" parts have similar bones, because we evolved from a common ancestor that had similar bones. They can also handle the bones directly and notice just how well the joints slot together.

Set-up

Lay the anatomy diagram board flat on a table or other hard surface. Spread out the sheep bones nearby. Place the unnumbered sheep skeleton on the table for children to reference. Keep the numbered skeleton for demonstrator use, as the numbers match numbers on the sheep bones and will let you confirm everything is in the right place.

How to demonstrate

1. Start by asking the children if they know what the skeleton is. They'll probably guess because the anatomy diagram board has a wooly sheep outline, but you can also have them look at the sheep's teeth and notice it's a herbivore (see notes) and at the feet and notice it only has two toes. Give them progressively easier hints (eg "found on a farm, wooly, baas") and they'll guess it quickly.

2. Have the children assemble the completed sheep skeleton. Note that we have HALF a sheep skeleton here to make it easier to lay out on the anatomy board: there is a complete skull and spine, but only half the ribs, 1x forelimb and 1x hindlimb(including just one scapula (shoulder blade) and half of the pelvis). As the children are assembling things, see how many bones they can name. Help them work out where leg bones go by noticing which bones slot together at the joint. Compare with the numbered diagram to correct them.

3. Discuss the bones themselves and how they differ from human bones and how they're similar. Can do this as they assemble or after, depending on how quickly the children finish it. Talk about what the bones do -- ribs protect the internal organs, the skull protects the brain, etc. Also have the children bend the legs at the joints appropriately -- notice how the "wrist"/"ankle" joints are the lower joints we see and NOT the knees or elbows, because a sheep's foot is extended. See notes for more information.

Notes

1. Skull

- Point them towards Animal Skulls to discuss the teeth/skull in more detail, but can discuss how the teeth tell us this is a herbivore. Big, flat molars/premolars are good for grinding and crushing up vegetation. Incisors are good for pulling grass and other vegetation. Note that sheep are lacking upper incisors; instead, they have a hardened gum line called a "dental plate" to pinch grass against.

2. Spine

- The spine can be divided into the cervical vertebrae (neck), thoracic vertebrae (ribcage), lummbar vertebrae (lower back), sacrum (where the pelvis attaches) and **normally** we should also have coccygeal vertebrae that make up the tail, but our sheep is missing its tailbones.

3. Ribs

- Sheep have 13 pairs of ribs: 8 pairs are sternal/true ribs that would connect directly with the sternum; 4 pairs are asternal/false ribs that don't connect directly with the sternum because they connect to the ribs above; and one pair of floating ribs that don't connect with the sternum at all. See "ribs printout" -- this is a human diagram, but the structure is similar.

4. Front foot

- Made up of the phalanges in the toes, the metapodial/cannon bone in the "palm" (equivalent to fused metacarpals), and carpals in the "wrist". See "front foot printout" for how the bones differ from a human hand. A sheep's foot is made of some of the same bones a human hand has, and would be equivalent to a human hand with just the middle and ring finger. Notice how sheep, like many animals, walk on just their toes. Sheep toes are normally covered by horn material to make hooves, similar to horses. Note that the first "bend" in the front leg is equivalent to the wrist.

5. Radius and Ulna

- Would be the lower arm in a human, and joins at the elbow with 6 (humerus). Have the kids move the bones in a hinge fashion like a human arm would.

6. Humerus

- Would be the upper arm in a human

7. Scapula / shoulderblade (note the absence of clavicle)

- Similar to the shoulderblade in a human, but note that unlike humans, sheep (and horses) lack a clavicle/collarbone connecting to the scapula. In humans, the clavicle acts as a strut between the shoulderblade and the sternum, connecting the arm directly to the spinal column; but in sheep the front limb attaches only via muscle and tendons. The missing collarbone improves running efficiency because without the collarbone the shoulderblade can act almost like an extra limb segment, creating a longer stride.

8. Hind foot

- Made up of the phalanges in the toes, the metatarsals, and the tarsals in the hock. See "hind foot printout" for how the bones differ from a human foot (the printout shows a horse foot but they are structurally similar, minus a sheep having two toes vs a horse's single toe).

9. Tibia

- Would be the lower leg in a human, and joins at the knee wth 10 (femur).

10. Femur

- Would be the upper leg in a human. Notice how high up in the body the knee joint is; this is why some people think an animal's "knees" are where we now know the ankles are, and why some people think their "knees bend backwards". Their knees bend the right way, they just have them hidden under wool!

11. Pelvis (half)

- Joins with the sacrum at the sacroiliac joints, and with the femur at the hip joint. Notice the hip is a ball and socket joint, unlike the hinge joints of the elbow/knee. Swivel the bones in the joints to show how much freedom of movement there is.

Risk Assessment

Hazard: Sharp parts of the bones.

Description: Some bones may have sharp edges, especially around the skull.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Remind children to handle bones carefully. The skull has been inspected and sharp edges filed down, but some may have been missed, or breakages could produce sharp edges. Demonstrator should visually inspect skulls before use - any skulls with sharp edges may need to be smoothed off or replaced.

Call first aider in event of incident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Broken bones

Description: If dropped, bones may fall on feet or shatter, causing cuts and other injuries.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrator to keep a close eye on anybody holding the skull, as this is the most likely to shatter if dropped. If a skull smashes, clear it up immediately with dustpan and brush. Any damaged skulls with sharp edges should be repaired as soon as possible - demonstrator should notify committee if this is needed. Most of the bones are quite light, but demonstrator should watch all children handling bones, especially the more club-like ones like the femur. The number of bones out has been limited by e.g. wiring feet together and threading the spine together to make it easier for the demonstrator to monitor.

Call first aider in event of injuries.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Unsanitary bones

Description: Possible infection risk from bone if skin is cut by touching the bone.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: All bones have been sterilised by soaking in bleach for several hours. Please note, however, this does not necessarily mean that the skulls are completely sterile now. One could give the skulls a gentle clean with disinfecting wipes if they're on hand.

Call first aider to properly dress and sterilise wounds. Warn parents of the possibility of infection if a child does cut themselves on the skull. Advise parents to take child to a doctor if the cut looks infected.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2023-02-19 - John Leung (cfl35@cam.ac.uk), **Check 2**: 2023-02-19 - Peter Methley (pm631@cam.ac.uk)

Skeleton and bones

Meet Boris, the friendly CHaOS skeleton. - Boris is a friendly life-sized plastic skeleton- come and say hello!

Last initially checked on 2023-01-22 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-01-22 by Emily Wolfenden (elw74@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- **This experiment can take place outdoors**
- Full size articulated skeleton called Boris.
- Collection of individual bones
- Foetal skull to show differences to the adult skull
- Artificial hip replacement

Experiment Explanation

Working with the skeleton can be an art. I usually don't have a formal "speech" but have lots of little topics and let them mess around with the bones filling in as appropriate.

Some things to talk about:

- Fitting individual bones to where they are on skeleton. What is skeleton for?

1. Upright - Ask them to imagine what we would be like without a skeleton
2. Movement - muscles pulling on bones, joints
3. Protection - skull-brain, ribcage-heart and lungs, vertebral column-spinal cord

- Ask them to guess where certain bones go. Easy ones are skull, hand and foot. Harder ones are pelvis, spine, collar bone etc.

- Feeling bones on themselves - collarbone, kneecap, shoulder blade moving, jaw moving out

- Why we have 2 bones in forearm

- How many bones in fingers/hand/body (3, 27, 206)? Often good to get them to guess how many bones there are in the hand and then explain why each finger has 3 bones etc.

- Where are smallest and largest bones?

- If all else fails, get the little kids to make up the arm from the individual bones

SKULL:

- Ask them obvious things like where the eyes are to get them orientated.
- Ask them why there are no ears or nose.
- Describe what the skull is for. I like to use the "helmet" protecting the squishy brain analogy.
- Explain how must have holes so all the nerves can reach the brain - like phone cables.
- Show them some of the holes - optic chiasma, foramen magnum etc.
- Talk about jaw and how it hinges.

FOETAL SKULL:

Foetus = not fully formed - several bone plates coming together. Point to fontanelles.

- Why? Needs to be able to change shape - fit through birth canal
- Small brain compared to adults thus need rapid growth in 1st year

- Growth almost complete at about 6yrs (vs chimp = 3yr) - gives time for learning thus different capabilities of humans (intellect, sybolism, abstract thought, complex tool use, complex social behaviours etc)
- Adults often ask about the 'squidgy bit' on their child's head when they were born - you could talk about the anterior fontanelle and how it can be used clinically to assess the level of hydration of the child.
- N.B. Boris is male and his pelvis won't allow you to birth this skull!

JOINTS:

- Explain how even without joints we couldn't move.
- Different types of joints:

1. Ball and socket - get them to put one together (hip is best). Show how it allows movement in all directions. Get them to move their arms in all directions
2. Hinge - get them to put one together (elbow is best). Ask them to move their elbows and knees. Point out how birds are weird as their knees bend the other way.

HIP REPLACEMENT

- This is one of my favourite bits to talk about!
- I usually start by getting them to guess what it is. Some will get it instantly, others will come up with odd suggestions ("A gun!"). You can tell them that it is used to replace a part of the body and get them to look at the skeleton and see if they can think where it might fit. Let them hold it and move it around at different angles etc. If all else fails I usually hold up a spare femur and the hip replacement next to each other in front of me until someone realises!
- Talk about why you might need to have a hip replaced - arthritis, fractured neck of femur results in death of the head of the femur due to the poor blood supply so it must be replaced as it will not heal (many of them will know of people like grandparents who have had such replacements).
- They often ask about why the ball is so much smaller than the head of the femur, explain that we've only got half of it and there would be a replacement socket too (if you've talked about arthritis in the reasons for needing a replacement you could get them to think that you need to replace both damaged surfaces with new smooth ones).
- Then I often start pretending to be a materials scientist and briefly get them to think about what properties you'd want a replacement joint to have - e.g. ask them why it isn't made out of wood! Get them to work out that it needs to be strong, light, non-toxic and unreactive (not go rusty!). I assume ours is made out of titanium, newer and more expensive ones I believe are made from titanium (the head) and then some sort of ceramic which is much lighter. If they want more details about materials I tend to then have to send them off to ask a physicist/real materials scientist!

Risk Assessment

Hazard: Protruding parts

Description: Poking injury from protruding parts.

Affected People: Anyone touching Boris

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure children do not go too near protruding parts; use tape or sugru (kind of like blue-tack but it sets, can often be found in Boris' box or toolbox) to cover up the more dangerous parts of the skeleton. Call first aider if necessary.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Bones

Description: Finger trap between bones (e.g. ribs, and joints).

Affected People: Anyone touching Boris

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Make sure children do not put fingers between bones, and ensure that skeleton is in a stable position when they do touch it. Call first aider if necessary.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Boris

Description: Skeleton can be unstable and may fall on children/demonstrator (this includes the possibility of things falling off of Boris).

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Keep a careful eye on the skeleton, and stay near it to be in a position where you can stop it from falling on anyone. Do not leave the experiment unsupervised. Consider tying skeleton to a chair if demonstrator is not able to be close to the skeleton throughout. In case of accident, call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Hip bone

Description: Hip joint is heavy and could cause damage if used as a weapon.

Affected People: Children

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Do not let children hold the hip joint if you do not trust the group to be sensible. Call first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Psychological aspect of experiment

Description: People may not like psychological aspect of this experiment. Could faint or feel faint.

Affected People: Visitors

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Be aware that a small percentage of people may feel uneasy or unwell when talking about skeleton and organs. Stop if someone looks unwell/ goes pale. Fresh air/sugar/lying down all help recover or avoid injury. Call first aider if necessary.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Heavy Box + Boris

Description: Boris' coffin and Boris himself are quite heavy - could cause back injuries for people attempting to carry these.

Affected People: Demonstrators

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Don't carry the box by yourself - usually need at least two people. Use standard heavy box lifting procedures (i.e. bend knees, not back!) Boris himself may be light enough to carry, but only do so if confident and comfortable (and necessary). It is difficult to keep Boris' limbs under control when single-handedly carrying him, so best not to do so particularly in crowded areas. Always watch where you're going with either the box or Boris. Also watch for things falling off Boris!

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2012-01-11 - Elizabeth Mooney (erm40@cam.ac.uk), **Check 2**: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk)

Check 1: 2013-02-02 - Alex Davies (ad578@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

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Check 1: 2015-01-10 - Alisha Burman (arb95@cam.ac.uk), **Check 2**: 2015-02-12 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Slug Bubbles

Does a tube of water drain more slowly with a bung in the top? - Does the diameter effect how fast water drains from a sealed tube? Watch the bubbles produced and see which is fastest.

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-17 by Jessica Trevelyan (jet81@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **This experiment can take place outdoors**
- 3 tubes of different diameters but similar lengths held vertically on a board.
- Frame
- Experiment Box
- Bolts
- Plugs that fit the tubes
- A small pile of straws - "small pile of straws" may mean "1 straw" - can find some more in air streams / stores if necessary.
- A jug for filling tubes.
- A couple of differently sized funnels for filling tubes.

Experiment Explanation

This experiment uses perspex tubes which are clamped to a board, and can be filled with water. When the bung at the bottom of a tube is pulled out, it empties. If there is a bung in the top, it empties much more slowly, as the air has to get in the bottom (a 'slug bubble').

What to do.

Put a bung in the bottom of a tube. Fill it up with water using funnel and jug. Kids really want to help fill them up, and this is a good way of getting them involved. Ask what they think will happen when the bung is removed: does the water rush out, drip out slowly, stay in etc.? Ask if they think it'll come out fast enough to get their shoes wet. Then ask if they're willing to test their hypothesis in reality, or take a few steps back and remember where their shoes were at the time (I normally look at the parents for confirmation of feet wetting next!) Count down and remove the plug. SPLASH :-) What happened? Water rushed out etc...

Why? Gravity pulled the water towards the ground and when the water came out of the tube, and air replaced it from the top. (Notice the subtle hint for the next stage.) Get it filled it up again, but this time put a bung in the top as well. WARNING: Make sure you hold the bottom bung on when you put the top bung in as water is not particularly compressible, and you can easily force the bottom bung out by pushing the top one in. Now ask them what'll happen. Then demonstrate - you can ask one of them to remove it this time :-) Did they see the bubble go up the tube? Get them to try to explain what was going on. My explanation is just that for water to come out of the tube, air has to get in, as there can't be nothing in the tube (vacuum) as the high air pressure around will not allow it. However, it did not all stay in there because the hole at the bottom was nice and large allowing air and water to swap. You can see the air going in - it goes up the middle in the form of a big bubble, called a 'slug bubble'. The water flows out down the sides.

Next we have a race... Fill up all the tubes, put bungs in both ends, and recruit some help to get it started. (You will probably have to loosen off the bungs in the bigger ones, as they are quite difficult to remove. Which one is going to empty fastest? Why? See what each spectator thinks - often people have different views. They can be encouraged to argue it both ways: perhaps the big tube will empty faster, as there is more space at the bottom, perhaps it will empty more slowly, as there is mor water to come out, or perhaps these effects will cancel out and they will empty at the same speed.

Ready, steady, Go!

The biggest one empties fastest. Why did it do that? A smaller hole at the end means that there is even less space for the water to swap over, so it comes out much slower. The more space there is for the air and water to squeeze past one another, the faster it can come out.

If you like, you can then move onto some straws, saying that straws are exactly the same, but they have even smaller holes at the bottom. Straw under water, thumb on the top. Remove from water, remove thumb. A straw has such a small hole that the surface tension of the water cannot be broken.

An interesting addition [Stolen from the Independent (2/8/06)] Poke a hole in the side of a cup, cover the hole, fill with water, uncover the hole: water comes out Repeat, only this time drop the cup at the same time as uncovering the hole: water stays in, so you can talk about gravity acting on water and the cup, and things falling at the same speed etc. Probably not a tremendously exciting addition, but maybe something to talk about with very interested people, or something... [Plastic cups tend to shatter when dropped on concrete, and are a pain to make holes in, so maybe paper would be better.]

Another point of interest (stolen from a demonstrator at CBS) is if you take out the top bung slightly from the small tube as well as the bottom one you can slowly stop the water (by gradually putting it back in) and this will allow you the same 'floaty' water as with the straw. Disturbing the bottom with a piece of grass allows an air bubble to form and causes it to stop floating. You make a hole in the surface to allow an air bubble to form.

One final nice thing to mention... This experiment in particular can be used to demonstrate the "scientific process", where you make a hypothesis, test it, then modify your theory to explain what you saw. Then you can tell the kids that they're real scientists now.

Risk Assessment

Hazard: Board

Description: The board could fall if not properly mounted.

Affected People: All, particularly small children

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure that the board is properly bolted to the frame. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Water

Description: Slip hazard due to spilt water.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Use the box to catch the water. Clean up excessive spillage. Do the experiment outside if appropriate. Check also that the box is placed on a suitable surface that won't mind getting wet (e.g. not an expensive antique wooden chair). In case of injury, call a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-02-14 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2014-02-15 - Brett Abram (ba305@cam.ac.uk)

Check 1: 2015-01-04 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-22 - Tom Comerford (tafc2@cam.ac.uk)

Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

Check 1: 2016-12-29 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2017-02-01 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2018-01-20 - Matthew Le Maitre (msl54@cam.ac.uk), **Check 2**: 2018-01-20 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

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Sodium Acetate

Rapid crystal growth from sodium acetate. - Find out about how handwarmers work, and see solid crystals form in seconds right in front of your eyes.

Last initially checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-07 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Chemistry

Equipment Needed

- **Electricity needed**
- Sodium Acetate
- Saucepan + cooker ring of some sort
- Stirrer (not glass)
- Metal cups for pouring
- Plastic cups (ideally clear)
- Cling film (not value cling film as it doesn't cling very well in this situation)
- Cold water tray
-
- **You will probably need one person making the solution and the other demonstrating.**

Experiment Explanation

In a nutshell...

Sodium acetate forms a very stable supersaturated solution quite easily, so it is possible to grow crystals in front of the kids' eyes. First make a supersaturated solution and cool it, then add a crystal of sodium acetate to provide a nucleation centre for rapid crystallization.

How to set up the experiment

1. Add the sodium acetate (just crystals) to the pan and begin heating- add small amounts of water (you really don't need much) until the crystals have dissolved. Once they've dissolved, don't heat it too much as the water will be driven off. NOTE: If the sodium acetate does not seem to be going into solution, check carefully that you are heating it before adding more water. The solution in the pot usually has a thin crust on top and it still works fine.
2. Use the metal pots to pour the solution into plastic ups, and place cling film over the top, so you don't get small crystals forming on the surface and triggering the crystallisation.
3. Cool the cups down in cold water or ice. A mixture of cold water and ice works well. Make sure the cups are as stable as possible and only touch them when you demonstrate it. Even so, expect at least a third of solutions to crash out before demonstrating!

Demonstration

Start by explaining that there is loads of stuff in the water and that it wants to from crystals but it can't, because water is holding it apart, so it's easy to grow crystals but hard to start them off. In explaining what sodium acetate is, possibly call it a cross between salt and vinegar or explain that it comes from a reaction between bicarb and vinegar.

Get a kid to feel the temperature of the cup (it's cold).

Remove the cling film, get a kid to drop a crystal into the solution and it should grow crystals really rapidly, starting at the nucleation crystal. There ought to be different shapes of crystals growing at different speeds, too, so you can talk about that and rates at which they grow (maybe tie with liquid nitrogen ice cream).

Get the kids to feel the heat given off from the crystallisation process.

Heat is usually released when things crystallise in the same way it is when they condense or freeze; this release of heat is why steam is dangerous. Get kids to realise that they have to heat things to get them to melt/boil/often dissolve, so that energy is trapped in the liquid/gas/solution and is released again when the process is reversed (here crystallisation).

You can also use solutions to make towers in a plastic dish by pouring the solution out, this should be enough to trigger crystallization.

Where do we see this?

Nucleation: Clouds won't form unless they have nucleation points so people have tried adding dust to clouds to stimulate rain - The Soviets used to seed clouds before they got to Moscow to stop it raining on days of the big parades. The commercial hand warmers have a little clickey thing that you click to make it start crystallising. Apparently these work by trapping little crystals in the crack, but trapped deep so they can't act as nuclei, when you click the thing it releases them - starting the crystallisation.

Sodium acetate solution has a much lower freezing point than water (like brine). It is used to de-ice planes as it is less environmentally damaging than NaCl, KCl or ethylene glycol (the traditional alternatives). It is used as a commercial deicer in airports and similar places, because it is attracted to water so strongly it will decrease its melting point significantly.

Risk Assessment

Hazard: Hot sodium acetate

Description: Risk of burns from hot sodium acetate solution.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: The samples used must already have been cooled in order to crystallise, so the hotplate/hot liquid can and should be kept out of reach of the public at all times. In practice, for a long event, this may mean that two demonstrators are needed, one to heat the solution, the other to demonstrate. Demonstrator to wear eye protection (goggles) when heating up the solution. Run any burns under tepid water for at least 10 minutes, and call first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Hotplate

Description: Risk of burns or fire from hot stove and pan

Affected People: All but particularly demonstrator

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Ensure hotplate is kept out of reach of public and is attended while switched on. Keep away from flammable items, and be careful when handling hot pan. Switch off when not in use. Have tepid water nearby to cool burns.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Sodium acetate solution

Description: Risk of solution splashing into eyes - it has a high osmotic potential, so will sting like salt.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Demonstrator to try to stop the kids putting their fingers in the liquid or splashing it everywhere. Demonstrator must ensure eyewash is nearby, and know its location. Demonstrators should wear eye protection and avoid rubbing eyes for the duration of the experiment. In the event of an accident, call first aider. Use eyewash to wash out of eyes if trained and confident to do so.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Liquids

Description: Slip hazard from spilled water/salt solution.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Use a tray to catch spills, and mop up any spills immediately. Call a first aider if an accident occurs.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Glassware

Description: Risk of cuts from broken glass beakers.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Avoid using glass beakers to prepare sodium acetate solution if possible; otherwise, clear up broken glass immediately. Call a first aider if thereâ€™s an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Heating apparatus

Description: Electrical parts risk - see Electrical Parts RA.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: See Electrical Parts RA.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-22 - Hannah Ford (hf257@cam.ac.uk), **Check 2**: 2012-01-20 - Catherine Collett (chc47@cam.ac.uk)

Check 1: 2013-01-07 - Rachel Chapman (rc506@cam.ac.uk), **Check 2**: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk)

Check 1: 2014-01-25 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2014-02-16 - Benjamin Lai (bl337@cam.ac.uk)

Check 1: 2014-12-27 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-02 - Holly Davis (hd308@cam.ac.uk)

Check 1: 2015-12-28 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2016-01-16 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2017-02-09 - Tim Morgan Boyd (tmb58@cam.ac.uk), **Check 2**: 2017-02-09 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk)

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Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Sounds from an oven shelf

Get very strange sounds from an oven shelf.

Last initially checked on 2023-01-18 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-01-19 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Busking

Floating

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **This experiment can take place outdoors**
- Oven Shelf
- String
- Something to hit the shelf with (your finger nails will do!)
-
- You could also use a slinky instead of an oven shelf
- In this case a plastic cup works as an amplifier

Experiment Explanation

Get very strange sounds from an oven shelf. Hang it from two pieces of string, wrap string around your fingers, put your fingers in your ears, hit the oven shelf. It will sound like big ben!

Why does it happen?

First of all we have to understand that sound is all about vibrations. When somebody speaks, their voice box vibrates, and this makes the air around it vibrate. These vibrations carry information about what someone has just said. When these vibrations reach your ear, they make your eardrum vibrate and this is processed by your brain as sound. The amount of energy (or the volume of the sound) that manages to make the journey from voice box to ear depends on what the sound is travelling through and what kind of sound it is.

In the case of speaking to a friend or when you listen to the oven shelf, the vibrations must travel through air. Air is really sloppy, fluid and not very stiff. Water is quite similar - if you put your hand in water and slowly move it around, the water feels very soft and fluidic. However, if you slap the water then it suddenly feels very hard and stiff. This is because the water doesn't have time to get out of the way so it has to form waves. Although it is not quite so obvious, this is the same for air. If you move something through it very quickly, the air feels stiffer and it's much harder to move through it, so high frequency vibrations will transfer more energy into the air.

The ability of sound to reach someone's ear also depends on the ability of the air next to the ear drum to vibrate. In the same way as a high frequency (pitch) vibration can transfer more energy to the air from the oven shelf because it has less time to get out of the way, a high frequency sound will transfer more energy from the air to your eardrum so the sound is loud. Low frequency sounds vibrate the air much more slowly, and so the air seems relatively more sloppy and doesn't transfer energy so well so they sound much quieter. So both low and high frequency sounds are produced by the oven shelf but it's only the high frequencies that vibrate the air by your ear drum much so the shelf sounds tinny and high pitched.

In order to hear the low frequencies, you need to create a stiff connection between the oven shelf and your ears. The string wrapped around your fingers provides this connection. The string is taut and stiff and can transmit both high and low frequencies. When you add the high and low frequencies together, the oven shelf suddenly sounds like a gong.

What about in the real world?

This is why your voice sounds different to everyone else and when you hear it recorded. Everyone else just hears you though the air, but you hear yourself through the bones in your skull as well, so different pitches will reach your ears than other people's.

For more see: http://www.thenakedscientists.com/HTML/content/kitchenscience/exp/the-secret-sounds-of-the-oven-shelf/

Extra information In case someone of a more mathematical background is asking, it's the impedance mismatch between the shelf and the air that filters out the low sounds (acting as a high pass filter). We could get those sounds to the air better if we passed them through a series of media with different impedances instead of a big jump. The string has an impedance much closer to that of the shelf (being a solid and all) so there is less of a mismatch and better transmission.

One of the most familiar forms of impedance matching from school is the use of special gels with ultrasound scanning to ensure that more of the sound passes into the body rather than being reflected from the skin.

In fact, there are even more everyday occurrences. Some instruments such as acoustic guitars have a "soundboard" - essentially the front face of the instrument - and air cavity, connected to the strings via a bridge. The structure of this system amplifies the vibrations, particularly low frequencies, not by adding any energy (as in an electric guitar, which use electromagnets to sense the vibrations), but by a kind of impedance matching. If I understand correctly, the larger area of the soundboard, as well as the ability of the air in the cavity to resonate, are key to this.

Why labour this? Well, you can get the same oven-shelf effect from a slinky, and the listener can excite the vibrations by nodding their head. The extra cool part is that rather than sounding like a boring old gong or clock tower, the complex pulses reverberating up and down sound like a Star Wars laser battle.

If you listen very carefully without the strings you can hear the low laser battle sounds. But, if you put a plastic cup in the top of the slinky, it couples to its vibrations and the cup is able to act like a soundboard of a guitar and everyone can hear the effect without the need for string!

Risk Assessment

Hazard: Fingers

Description: If fingers are pushed into ears with long nails/too far it could cause some minor damage.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Encourage children to put their knuckles, not their fingers, in their ears.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Head

Description: Head banging - with the slinky version, over-vigorous nodding not in a clear space may cause someone to bang their head.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Make sure the participants have sufficient space to take part.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2012-01-02 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-14 - Anna Kalorkoti

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Check 1: 2014-01-17 - Zephyr Penoyre (jp576@cam.ac.uk), **Check 2**: 2014-01-21 - Holly Davis (hd308@cam.ac.uk)

Check 1: 2015-01-05 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-07 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Fiona Coventry (fiona.coventry@cantab.net)

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Spaghetti Loading

This experiment uses uncooked spaghetti to explore elastic buckling of vertical columns and 3-point bending of horizontal beams.

Last initially checked on 2023-01-19 by Toni Renz (ir331@cam.ac.uk) and double-checked on 2023-01-19 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Materials Science

Standard (A standard CHaOS experiment, useable for all hands-on events.)

CHaOS+ (More complex explanations suitable for older children are available)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- 1 pack of spaghetti (will need replacing periodically)
- 2 wooden blocks to hang spaghetti across
- 9 steel nuts
- 1 pack of elastic bands
- 1 tray to catch spaghetti fragments
- 1 hollow cylindrical beam (pending)
- 1 small I-beam (pending)
- Photos of the Pantheon/Acropolis, crushed concrete column, and wooden roof beams.

Experiment Explanation

This demonstration uses a spaghetti model to demonstrate elastic buckling and 3-point bending. I personally like to put it into the context of building a house out of equal-sized wooden logs. You can start by discussing use of spaghetti as a building material, because the more materials science we put into this experiment, the less likely it is that the engineering coordinators will try and claim it. Spaghetti would not make a good building material because it goes soft when wet. It is also quite brittle so may not fare well in heavy wind. Some people may suggest that it is weak, but large bundles of spaghetti are probably surprisingly strong.

Axial Loading:

How will we hold the ceiling up? Most students will say using a wall or pillar. Try to guide them towards pillars/columns since this is what you're actually going to be talking about. The job of a column is to keep the ceiling up. Hold up an intact piece of spaghetti by the palms of your hands, as this will enable you to load it under compression and demonstrate buckling. Buckling is bad as it allows the ceiling to move downwards, which could warp it and cause it to fail.

Push your hands together gently with your palms flat to demonstrate elastic buckling in the spaghetti. It is elastic because removing the force allows the spaghetti to return to its original shape. Ask the students how we can make the column stiffer i.e. resist buckling.

$$\ Ïƒ_{EB} = \frac{cÏ€^2E}{4(L/R)^2} $$

The above expression tells us that a smaller stress (force) is required to cause buckling if the aspect ratio, the ratio of the column length to its radius is larger. The column can be made stiffer in two ways: by making it shorter, or by making it wider. This can be demonstrated by giving the students pieces of spaghetti of different lengths and getting them to feel how much force it takes to make them buckle. Shorter pieces should be much more difficult to buckle.

The problem with making it shorter is that it has to span the distance between the floor and ceiling in order to hold up the ceiling. So the column length isn't easily customisable.

If you don't explain the aspect ratio thing to students, most of them will probably say that adding more logs to the column will make it stiffer. By adding more logs you make the column wider which also decreases the aspect ratio, thus making the column more resistant to buckling.

By this logic, we want an infinitely thick column. There are a couple of problems with this. Firstly, the wider the column, the more space it takes up. So we want an optimal thickness which will hold the ceiling up without using too much space. The other problem is that if the buckling stress is too high, the column will instead fail by crushing. A crushed column cannot bear any weight, but a column which is buckling still can provided it doesn't break. Therefore, it is better for a column to buckle slightly than break, and short fat columns may not be desirable.

3-Point Bending:

In the context of house-building, I claim that roof beams are loaded under a 3-point bend. To be honest, I have no idea if this is the case. So if someone has a better way to put it into context then let me know.

First, ask the student if you can make stronger roof beams by laying them out individually or bundling them up. Hopefully they will say bundling up. There are two reasons why bundling them up is better. Firstly, The more logs you have in the roof beam, the more weight they can bear since the weight is shared between the logs. Laying them out side by side means that you can't fit as many logs along the length of the ceiling that if you bundle them up, and make use of the vertical space.

Secondly, by bundling them up, you increase the second moment of area of the roof section. This makes the beam stiffer under a 3-point bend, and it can therefore take more weight without flexing. The equation for 3-point bending is shown below:

$$ y = \frac{Fx}{48EI} (3L^3 - 4x^2) $$

Place a piece of spaghetti so that it is resting horizontally on top of the two wooden blocks. To make this part more interesting (if that's even possible), you can ask the students to take bets on how many of the steel nuts it will take (threaded onto the centre of the spaghetti beam) to break it. Usually, two or three is enough. After this, take a bundle of 5 pieces of spaghetti, and wrap an elastic band around one end to hold it all together. Ask the students whether it will take more or less weight to break the bundle (they should say more) and then ask how many nuts they want you to put on. Even with all 9 of the provided nuts, the bundle will not break. But you can show that however many they select, the bundle doesn't flex that much. **note:** it is difficult to demonstrate the effect of bundling vs. loose because loose spaghetti tends to bundle up when threaded through the nuts.

When bending the spaghetti bundle, the bottom surface ends up under tension while the top surface gets put under compression. Just like many materials, spaghetti is much stronger under compression than tension. This discrepancy is especially pronounced in concrete, which is extremely strong in compression and weak in tension, hence they are used for support columns rather than cables. You can show this using spaghetti by loading it in compression (trying to crush a piece between your fingers by pressing across its diameter) and then in tension (by pulling from opposite ends). Students should find that it is impossible to crush the spaghetti, but quite easy to pull it apart. If anyone does manage to crush the spaghetti, send them my way as I may have a job for them.

What this means is that the piece of spaghetti at the bottom of the bundle, which is under the most tension, will fail first. This is followed by the rest of the bundle as the stress is redistributed. The bundle fails in a 'chain reaction' as the fracture propagates from the bottom to the top surface of the bundle, with each piece of spaghetti breaking in sequence. This failure happens very suddenly and catastrophically. Macroscopically, there are no early warning signs as the failure of one log in the bundle leads to the instant failure of the entire bundle. Spaghetti is also brittle, meaning it will fail suddenly without plastic deformation. Therefore, this is something we want to try and avoid.

Hollow sections and I-beams (CHaOS+)

Hopefully by now someone has acquired a hollow beam and an I-beam. While these won't be loaded or broken in the demonstration, it is interesting to discuss how engineers can save on materials without sacrificing much strength.

Hollowing out a beam will decrease its mass significantly, with a less than proportionate loss in strength. This is because the larger the second moment of area of a beam (effectively a measure of the distribution of mass away from the central axis of the beam), the greater the 'beam stiffness' which is a product of second moment of area and young's modulus. A hollow beam will be much stiffer than a solid beam of the same mass.

Solid Beam

$$ I = \frac{wh^3}{12} $$

Hollow Beam

$$ I = \frac{wh^3 - w_{in}h_{in}^3}{12} $$

An I-shaped beam is used by engineers because it can achieve a similar strength to a beam with a solid cross section but requires less material to make and is also lighter. Some manufacturers even go as far as to cut holes in the stem of the 'I'. The further away material is from the central axis of the beam, the more it contributes to the stiffness of the beam. This is why cross sections with a greater second moment of area give stiffer beams. The beam is an 'I' rather than an 'H' because this orientation of the beam provides the most resistance to elastic deformation when the beam is under a vertical load, which it usually is in service.

Risk Assessment

Hazard: Uncooked spaghetti

Description: Public

Affected People: Sharp ends from spaghetti fracture scratching or stabbing people.

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Clear spaghetti debris from table throughout the experiment. Instruct kids to throw away spaghetti pieces as the experiment progresses rather than at the end. Also make sure fractured pieces are not held near the face. Do the experiment in a tray.

Call a first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Slippy spaghetti

Description: All

Affected People: Spaghetti debris on the floor could be "slippery" if stepped on.

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clear spaghetti debris as much as you can throughout the experiment. As above, do the experiment in a tray to try to contain most of the shards.

Call a first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Spaghetti shards

Description: All

Affected People: Loose pieces of spaghetti flying into eyes when bent and fractured.

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Forewarn students and when bending spaghetti, bend away from self and away from others.

In case of injury call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Masses

Description: Public

Affected People: Masses falling onto feet or fingers.

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Set-up on table to avoid toes. Have â€˜drop zoneâ€™, no fingers under masses. Use light masses (10-50g) to avoid heavy masses hurting fingers.

Call a first aider in event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Spaghetti

Description: Public

Affected People: Transfer of bacteria if students try to eat spaghetti that others have touched.

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Instruct students to not eat the spaghetti. Use different strands for each student, and for each group.

In case of contact, advise parents to take children to GP if illness develops.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

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Spinning Eggs

How to test if an egg is uncooked or hard boiled. - Can you tell the difference between a hard-boiled egg and a raw egg without breaking them?

Last initially checked on 2023-01-18 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-02-18by John Leung (cfl35@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Physics

Equipment Needed

- Eggs
- A mixture of uncooked and hard boiled (you'll probably want more hard boiled ones
- As they tend to crack).

Experiment Explanation

Basic experiment Spin an egg, either cooked or fresh. Stop the spin with one finger for a moment, then let go. The fresh egg will start spinning again because the inside of the egg will carry on spinning when the outside stops and will cause the outside to accelerate again. The cooked egg will stop dead. It's probably nicer to get people to try to think of ways to tell the cooked and uncooked eggs apart before you show them how to do it! After you have explained why the uncooked eggs carry on spinning get the kids to spin a random egg and tell you whether they think it's cooked or uncooked.

Other stuff to talk about You can also ask them what would happen if you filled an egg with syrup and spun it and stopped it? Would it spin for a longer time or a shorter time than an uncooked egg? It should spin for much less time than an uncooked egg as it is very viscous and therefore the momentum diffuses much faster through it (don't use words viscous, momentum or diffuses though).

You could also try explaining why it's harder to spin an uncooked egg then a cooked egg. I found it a bit complicated to explain but if you talk about the fact that when you spin the egg initially only the egg shell and the fluid very close within the egg (in the boundary layer of the fluid) actually spins and then more and more of the fluid starts to spin but this slows down the fluid that was originally spinning (this is due to momentum diffusion with the fluid).

If you're feeling brave... Apparently if you spin a hard boiled egg fast enough on a very smooth surface it will start tipping upwards and spinning around its axis of symmetry rather than lying flat (not unlike those toys you can't knock over I suppose). That is, at fast enough speed the stable orbit becomes the upright one rather than the flat one. Not sure how easy this is to make work in practice though...

Risk Assessment

Hazard: Smashed eggs

Description: If dropped on the floor eggs may smash, causing a slip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Spin eggs in a shallow tray to reduce risk of dropping them and/or perform experiment well away from table edges. Have equipment available to clear up broken eggs (e.g. paper towels). If breakage does occur, watch the area until it's clean and don't let kids run around (they shouldn't be running around anyway). Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Eggs

Description: Some people have very severe egg allergies (especially raw egg), with potential for anaphylactic shock.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Ask if comfortable with eggs around, and the possibility things might get a little messy. If an egg is broken ensure it is thoroughly cleared up, keep visitors away from area until area has been cleaned. Anyone with a level of allergy which might cause a major issue should be carrying appropriate drugs etc and they (or their carer) will know what to do. Risk is no greater in this case than going into a supermarket. Call a first aider in the event of an emergency.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Contaminated eggs (salmonella)

Description: Salmonella risk from raw eggs.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Only use lion-marked eggs which have been declared salmonella free. Donâ€™t allow people to ingest raw egg / lick fingers having touched a broken egg etc. As above, ensure egg breakages are cleaned up as soon as possible.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

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Spinny Chair

Use a freely spinning chair, some masses and a bicycle wheel to see some unintuitive physics.

Last initially checked on 2023-01-20 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-29 by John Leung (cfl35@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **This experiment can take place outdoors**
- Spinny chair *(Heavy - be careful when lifting)*
- Masses - 2 small and 2 large (bags of rice covered in gaffer tape)
- Bicycle wheel with handles, with spokes covered in cardboard to minimise finger trap risks

Experiment Explanation

Overview

By using a spinning chair, weird effects due to conservation of angular momentum can be felt.

Set up:

Try to make sure the chair is level, there is more than a metre of clear space around it in all directions, and the floor is something that won't graze anyone who lands on it (e.g. carpet).

Find somewhere convenient to keep the bits of kit so that people don't trip over them.

If you're unsure that you've got the screws in correctly, check with a committee member.

Things to demonstrate:

Demonstrate the effect of the masses by starting the child spinning on the chair with the masses close to their body and then asking them to extend their arms (make sure you do it this way round as otherwise they can pull their arms in and start spinning too fast).

With the child on the ground, start the wheel spinning and then hand it to the child vertically. Ask them to rotate the wheel so that itâ€™s horizontal. They will feel a force in the opposite direction. Ask what they think might happen if they were on the chair.

With the child on the chair, start the wheel spinning vertically and ask them to rotate it to the horizontal. They will start to spin. Ask them if they notice anything about the direction the wheel is spinning vs the way they spin.

Ask the child to try the experiment with their feet on the floor. The chair will no longer spin. Ask them if they can say why.

Show the child the difference in the bicycle wheelâ€™s behaviour if you let it dangle freely from the string when itâ€™s not spinning vs when itâ€™s spinning. Hold the wheel by one handle with the axis pointing from you to the child - ask them to gently waggle the end up and down, it's heavy but doable.

Start the wheel spinning and repeat - they will find it less controllable.

Things to be aware of:

Smaller children may not be able to lift the masses. In this case, itâ€™s probably enough for them to just hold their arms and legs out. Smaller children may also not be able to lift the wheel/ their arms may be too short. Either ask their adult to do it and explain what they feel to their child or sit on the chair yourself to demonstrate the effects (this can be tricky if you make yourself dizzy).

If youâ€™re at a school, make sure you let different kids in the group have a go and get them to explain what they notice to each other. There is some potential for slipping off the chair and landing badly. Get people to sit well back on the chair - that way they have good contact with the seat, and they can easily adjust their centre of gyration by leaning forwards. Small children need to be lifted onto the chair. Only use moderate speeds when spinning the chair.

Only continue for as long as the child is remaining engaged/ understanding what youâ€™re saying. If you get to the section on precession and feel like the child isnâ€™t following anymore, you can just demonstrate it to them as a cool effect, rather than trying to explain it.

Explanation:

My general tip here would be donâ€™t get too technical. A lot of the point of this demonstration is to try and get the kids to notice the weird effects and predict what might happen because of them. In general, young kids will not understand vector addition and will quickly get bored if you mention it.

The masses:

The approach here is age dependent. For younger children who might find moments of inertia and angular momentum a bit complicated, you can ask them to look at how quickly the bags move if youâ€™re spinning at a constant rate with arms out, and compare it with their speed with arms in. It might be helpful here to talk about a runner going round a racetrack - does the runner on the inside or the outside track travel further? If they both complete a lap in the same time, whoâ€™s running faster?

So when your arms are out, the bags will travel faster than when your arms are in (for the same rate of rotation). This means that when you pull the bags in, theyâ€™ll now be moving â€œtoo quicklyâ€ for the rate at which youâ€™re spinning - and so theyâ€™ll start to â€œovertakeâ€ you and your arms naturally pull on them to slow them down, speeding you up in the process! The reverse explains why you slow down again when you put your arms out. You can also fit in Newtonâ€™s first law here, to explain why the bags donâ€™t slow down until you pull on them. You will probably need to do a lot of acting out holding the bags and demonstrating the direction of forces.

For older children, you can introduce the idea of angular momentum (or spinniness). Explain that angular momentum depends on two factors. First, the rate at which a system is spinning and second, the distribution of mass within the system (i.e. the moment of inertia). The further away the mass is from the axis of rotation, the larger the moment of inertia is. Next you need to introduce the idea that the angular momentum of a system is a fixed quantity (in a closed system but the distinction doesnâ€™t matter here). This is a strange idea but it can be related to spinning on roundabouts. Ask the child what they would do on a roundabout in order to speed up (lean in) and slow down (lean out). When they lean in they are moving their mass closer to the axis and so decreasing the moment of inertia. To compensate for this reduction in the moment of inertia, the rate of spinning must increase, hence they speed up.

In a similar way, when they start with the masses close to their chest, they are in effect â€˜leaning inâ€™ and the system has a small moment of inertia, meaning a high rate of spin. When they move the bags away, itâ€™s like theyâ€™re leaning out and they increase the moment of inertia and so spin more slowly.

The wheel and the chair:

Ask the child what you have to do to make the wheel start spinning. Hopefully they will say you need to push it/ apply a force. When the child rotates the wheel from the vertical to a horizontal plane, they are changing the axis about which it spins. In the same way that starting an object spinning about an axis requires the application of a force, so does changing the axis about which the object is rotating (in the same way as it requires a force both to start moving and to change your direction of motion). This means that the child must be applying a force to the wheelâ€™s axis in order to rotate it. By Newtonâ€™s Third Law, the axis of the wheel is causing an equal and opposite force on the child, which is why they experience a force. (If theyâ€™re older you can try and explain the difference between a force and a couple here but itâ€™s not necessary).

When the child is on the chair, rotating the wheel causes them to start to spin. This is because the force on the child gets transmitted to the seat of the chair, causing a torque which makes the seat spin.

When it comes to the relative directions of the spin, they should notice that they rotate in the opposite direction to the wheel. Here you can link back to the idea of angular momentum. Explain that the total angular momentum of a system doesnâ€™t change. Initially, the child and the stool were a system with no angular momentum. Then they got the wheel and rotated it so that it lay horizontally. This means that the wheel has some angular momentum oriented along the z axis. In order for the whole system to still have 0 net angular momentum, the child and the stool must rotate in the opposite direction to the wheel so that their angular momentum points in the opposite direction.

When the childâ€™s feet are on the floor the force is transferred through their feet to the Earth rather than to the chair (this is technically a lie but one I can live with telling children). The Earth has essentially infinite mass and so the force has no visible effect on its motion. (You can draw a comparison with what happens when they jump- when they land they exert a downwards force on the Earth but that doesnâ€™t make the Earth actually move â€˜downwardsâ€™ as it's so much more massive than they are).

Precession:

(By this stage you may have already lost a few of the younger kids so it's a judgement call as to whether you try and explain the precession or just demonstrate it as a cool effect and mention that you can find similar things in your smartphone to let it know which direction is which).

A fairly intuitive explanation of why the wheel doesnâ€™t fall over is as follows. Consider the direction of the acceleration of two points on the extreme sides of the wheel, due to gravity. Assuming the axis of the wheel tips by some small angle theta, the motion is as drawn below:

`![](https://old.chaosscience.org.uk/sites/default/files/spinny chair pic.png)`

Looking at it like this, the wheel should clearly continue to fall over. However, this fails to take into account the fact that all the points on the wheel are rotating around the wheelâ€™s axis and so, half a cycle later, the points shown will be on the opposite side of the wheel. Things that have already started moving in a given direction have a tendency to keep moving in that direction (cf Newtonâ€™s First Law) and so the point of the left-hand side will now be moving up and the point on the right down. This creates a rotation in the opposite direction to that caused by gravity, returning the wheel to its original upright position and preventing it from falling over.

(This can also be used as a very hand waving explanation to nutation â€“ the slower the wheel rotates, the longer it takes for the wheel to complete half a rotation and so the further it will fall before the direction of motion reverses again â€“ why nutation is clearer when a top is spinning more slowly)

This also (kind of) explains why the wheel is harder to push down once it's spinning. By pushing down on the wheel, the child is effectively trying to do what gravity was doing in the above. Thus, their push will be opposed by the wheel while it's spinning for the same reasons that gravity was.

You can also do a â€˜proof by impossibilityâ€™. First, go back to the fact that, for an object to rotate about a given axis, there must have been some force applied to cause that rotation. In the case of the wheel itâ€™s obvious; you have to push tangentially on the wheel. Now ask what force makes the wheel rotate round so that it falls over. The answer to this is that gravity causes a torque that makes the wheel rotate about an axis in the x-y plane. Now, consider the case where the wheel was spinning, and it did somehow fall down. It would have to be spinning about the z axis. However, the only force acting on the system was gravity and we already decided that causes a rotation about an axis in the x-y plane. Thus, there are no forces in our system that would cause the wheel to have a rotation about the z axis and, if there are no such forces, there can be no way that the system ends up in this state.

Risk Assessment

Hazard: Chair

Description: Falling off chair.

Affected People: Anyone on the chair

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Demonstrator must maintain control of the chair and should not allow it to spin at speeds at which there is a significant risk of the child falling off. Starting children with arms tucked in and moving them out to slow down is a good way to ensure this. Make sure that the chair is placed on a flat floor, or grass which is sufficiently flat to ensure stability, with no corners or edges to fall against. If there is an area of flat grass or carpeted or wooden floor, this should ideally be used, though carpet introduces the possibility of grazing - warn the users of the wheel of this. Avoid placing the weights, and other hard objects on the floor haphazardly near the chair, which could injure children if they fall off. Sit well back on the chair to ensure good contact with the seat and allow easy adjustment of the centre of gyration by leaning forwards. Similarly avoid dizziness in both yourself and children by not spinning too fast or for too long.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Hazard: Chair instability (possible incorrect assembly)

Description: Chair could fall with a child on it, causing injuries to visitors.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Stop children/ members of public getting too violent - do not allow them to spin too fast. Ensure chair is on flat ground. Tell children to step off if it is spinning too fast. Stop the chair if it gets out of control. Make sure other children stand away from the chair whilst it is spinning. Use chair with stable base. Small children need to be lifted onto the chair by an accompanying adult to avoid pushing it over.

Demonstrator to ensure the chair is correctly assembled (all parts are labelled). If unsure, ask an experienced member of committee to help.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Children on chair

Description: Hitting someone while spinning

Affected People: All around the chair

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Keep viewers back, possibly by marking an area with hazard tape. Encourage people not to spin too fast and to stay aware of their surroundings when spinning.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hzard: Chair and bags of rice

Description: Heavy chair and bags of rice can be dangerous in transport.

Affected People: Demonstrator

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: The person carrying the equipment should be strong enough to do so, or get someone to help carry it. Use standard manual handling techniques.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Bike wheel

Description: Rotating bicycle wheel could hurt fingers.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: Bicycle wheel is covered in stiff plastic to stop fingers being inserted between spokes. Be ready to help child with rotating wheel if it gets out of control.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Bicycle wheel

Description: Bicycle wheel is fairly heavy, and could damage people if dropped.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrator should assess the size/strength of a child before getting them to hold the gyroscope. If the child cannot hold it comfortably in both hands, with arms horizontal and the wheel easily not touching them then they are too small and/or weak (remember they will have to hold it for a while, and not drop it when it feels like it's fighting them). The demonstrator ought to be ready to take the wheel back if required or help support the wheel by the other handle, and take some time to practice and get a feel for how it moves before demonstrating it to the public (it's not hard to do, but it's difficult to think of why people might drop it if you've not had a play yourself).

Ensure that people (particularly smaller children) don't have the string around their wrist whilst holding the wheel so that it doesn't sprain/damage the wrist if dropped. Possibly best to wrap it around one of the handles while holding it so it doesn't flail about and hit someone. Another dropping risk comes from dangling it on the end of a piece of string. This is a good bit of the demo to do, but make sure that the string is both well tied, and not frayed, before doing this. Only do this part of the experiment if the demonstrator is comfortable lifting the wheel.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-14 - Anna Kalorkoti (anna.kalorkoti@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

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Surface Tension

Exploring surface tension through floating paperclips and racing boats - nan

Last initially checked on 2023-02-07 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-02-08 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- Bowl or tray of water
- Paperclips
- Plastic fork or paperclip sized pieces of kitchen paper
- Paper
- Scissors
- Washing up liquid and some toothpicks or a pipette
- Rubber bands or balloon (as an analogy for surface tension).

Experiment Explanation

Overview

Showing that surface tension can support paperclips, but can be broken down by washing up liquid (surfactant) - this can be used to make 'boats' move across the water. This works well when demonstrated with psychedelic milk where you can see patterns forming with food colouring in milk due to flows driven by variations in surface tension.

What can you show with it?

Paperclips lowered gently onto the surface of water can float.

Pieces of paper floating on the surface will move away rapidly when surface tension is reduced by adding washing up liquid.

Other things to talk about

Washing up liquid breaks down the surface tension of grease on pans, allowing it to be easily removed from the pan. This is related to how insects like mosquitos and water striders can stand on relatively still water.

What makes an object float or sink?

Tips for demonstrating

Alternatively, I found that the water needs to be REALLY clean to float the paperclips (as do the paperclips), so it can be easier done separately in a cup that was easy to wash. This also means the paperclip can be left floating while playing with boats.

Use a generous amount of washing up liquid to reduce the surface tension.

Basic Procedure and Explanation

'Will a paperclip float or sink when dropped in water?'

Get the children to drop a paperclip into the water from a sensible height (>5cm) to show that paperclips usually sink. You can also usefully talk about what makes things float or sink - ask about common objects e.g. apples (apple bobbing at Halloween), boats, etc.

'What about if I put the paperclip in gently?'

Now lower a paperclip in gently by placing it on one side of another paperclip bent at 90 degrees. This leaves the paperclip floating on the surface of the water.

This may require a bit of practice beforehand and if this doesn't work then try lowering it with the paperclip at the end of a plastic fork or above a small piece of kitchen paper, which will eventually sink into the water.

Now get the children to look closely at the paperclip. They should be able to see that the paperclip is pushing down the 'skin' of the water.

Without the paperclip, the surface of the water in a large container is nearly flat. This is because all the water molecules are strongly attracted to other water molecules, but not to air. Therefore the water molecules try to make the surface (the interface between the water and air) as small as possible.

The paperclip pushes down on the water. This is balanced by the surface tension of the water which acts outwards in all directions on the surface. The children should be able to see that the surface of the water rises directly next to the paperclip and this gives the upward force needed to balance the weight.

'What about pieces of paper?'

Get the children to cut up some small (about 4cmX4cm) bits of paper to make the boats. *They can do this while you rinse out the tray at the beginning of the experiment.*

Get them to place the pieces of paper on the surface of the water - gently, so as not to sink the paperclip!

Using the pipette, or a toothpick dipped in washing up liquid, put some washing up liquid into the water. Try to do this gently so that you don't get accused of making ripples. Also, try to put the washing up liquid between some pieces of paper so that they move apart in different directions.

The paper pieces should move away fairly quickly, and the paperclip should sink. This also works well when it is done as a race between two people starting at the same end of the tray. You may find that the boats stop moving after a while even as more washing up liquid is added.

What is happening here?

By adding the washing up liquid, the surface tension is reduced. Thinking about rubber bands or balloon, a stretched rubber band will ping away when cut (the tension in the band is reduced, but the tension at the ends remains). Reducing the surface tension in the water makes the water ping away, carrying the paper with it. The paperclip sinks because the surface tension is reduced so much that it can no longer be supported. The paper boats still float as they are less dense than the (now slightly soapy) water. The boats eventually stop moving as the washing up liquid has now spread evenly across the surface, reducing the surface tension evenly across the surface.

What happens if we add soap to the floating paperclip?

You might want to remind them that the surface tension is keeping the paperclip 'floating'". Smart kids say that the paperclip would whizz. REALLY smart kids say that the paperclip would sink. You can make a big deal of the fact that they are making a prediction based on previous observations in relation to a hypothesis and then testing it, just like 'real' scientists.

The paperclip sometimes whizzed a little bit before it sank, but not much.

Get the kids to put soap in with their fingers, and have towels available for cleanup.

Some of the kids might think that you made a wave by putting your finger in the water but get them to test this by putting a soap-free finger in and actually trying to make a wave. Obviously, the boats didn't whizz.

Another demo of surface tension

We don't do this demo but I've seen it before and can easily grab the stuff. You'll need a see through glass, some coins and a ping pong ball. Fill the glass to the brim, float the ping pong ball on top. Gently lower coins successively in the glass, you should be able to get the water to rise above the rim. The surface bulges upwards in the middle, doing this also pulls the ping pong ball to the centre, I'm not sure why though but it demos how high it is in the middle. This is a surface tension effect, you could probably talk about bubbles too as that seems similar.

TW - I believe this demo should also work if you use fountain pen ink (or other easier to clean alternative ink) instead of washing up liquid. This should give a more visual but also more messy approach. You should also be able to dip the tails of the paper boats in the ink and briefly dry them instead of trying to add washing up liquid behind.

Risk Assessment

Hazard: Scissors

Description: Using scissors to cut out boats from card/paper â€“ possibility of cuts.

Affected People: All, particularly small children

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Use safety scissors. Hand scissors to parents of small children. Supervise use at all times.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Water

Description: Slip hazard from spillages.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Clean up spills quickly. Ensure mopping materials are available.

In the event of an accident, call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Surfactants

Description: Surfactants can be harmful if ingested.

Affected People: All, particularly small children who may try to ingest things

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Only use harmless surfactants; keep a track of where they are. Supervise the experiment well.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 1, Overall: 1

Hazard: Paperclips, toothpicks and other small objects

Description: Paperclips and toothpicks could be sharp (especially if broken). Also possible that a small child could eat one.

Affected People: Mainly small children

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Don't let children take paperclips away. Supervise use of all the objects in the experiment.

Don't use visibly broken and sharp paperclips.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Paper and wounds

Description: Child / Demonstrator could get paper cuts or wounds could already be present, which could subsequently become irritated by liquids uses.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Careful using paper and cutting it up.

Cover up any wounds (either received during experiment or preexisting).

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-14 - Anna Kalorkoti (anna.kalorkoti@cantab.net)

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Suspension Bridge

A suspension bridge made from rope and wood that children can walk across. - Walk across our bridge, then find out what makes it stay up.

Last initially checked on 2023-01-14 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-16 by Emma Crickmore (elc75@cam.ac.uk)

Tags

Tour only (Experiment is only used on tour.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- One suspension bridge (two supports, two ropes with clips to suspend deck, deck, two anchors; this -should all be set up already, if not, ask a committee member)
- Selection of moveable weights (small children)
- 3-4m of rope
- Weights on a hanger
- Rope tied into a knot to have three ends coming out in different directions (optional; for vector addition)

Experiment Explanation

Overview

A suspension bridge made from rope and wood that children can walk across!

Possible activities:

1. Children enjoy just walking over the bridge!
2. Have one child stand on the bridge and trace the forces down to the ground. Unclip the roadway to see what holds it up. Tension.
3. Put one kid on and see how much the bridge is bent. What if we add more children?
4. Why do we want the cable to sag? Use a seperate rope with a weight in the middle. Need to pull very hard to hold up the weight with the cable horizontal, but less hard if you let the rope sag.

Other things to talk about:

1. Real life suspension bridges
2. Why build suspension bridges?
3. How to build suspension bridges - sinking piers into water, digging to bedrock, anchoring cables, etc.
4. Material science - tension and compression and cracking.

Tips for demonstrating: Don't be fazed by the crowds - keep control and take time to ask questions and demonstrate the science. If children are beginning to run over the bridge or get overexcited, limit the number of children on the bridge to one at a time.

Basic procedure and explanation

Get children to walk over the bridge, then ask them questions. On a busy day you could stand blocking the entrance to the bridge until a group have listened to the science, then let them walk over.

What holds up the roadway? You can unclip it to show that it hangs from the sagging cables. suspension means hanging.

How does it work? Have one child stand in the middle of the bridge. He's pushing down on the roadway because he's heavy. What holds up the roadway? It's hanging from the sagging rope. Pushing and pulling forces - the rope is being pulled. Trace tension in rope over the piers and down into the ground. Get them to touch the various cables feel the different tensions. Ropes are anchored to the ground by the stakes so they have something to pull on. What would happen if we took out the stakes? Which way do the wooden piers get pushed (down into the ground).

Why do we have the rope sagging and not taught horizontal? Use a seperate rope with a weight in the middle. One child holds each end. Ask them to raise the weight into the air by pulling on the ends of the cable. Need to pull very hard to get the rope horizontal. Why? Because they're pulling sideways but they're trying to pull the weight upwards. So most of their pulling is wasted. Much easier if the rope is sagging.

Because the rope is sagging, we need these big wooden piers to hold it up. We don't want the whole roadway to sag though - cars would have to drive up to the top of the pier and down and up and down again - very silly! We want a flat roadway. So we hang the flat roadway from the sagging rope.

What about the roadway bending? Put one kid on and see how much the roadway is bent. Will the roadway be more or less bent if you add more kids all along the bridge? So the roadway doesn't bend if you spread out the load. Real suspension bridges don't bend as cars go across them! This is because the deck is usually either a beam or a truss, so can spread out the loads like when people stand all along our bendy roadway. If a train goes over the bridge then the engine is a very heavy load in one place so it will bend, so we don't tend to use suspension bridges for railways.

Other things to talk about

Real life suspension bridges. Severn bridge. Clifton bridge in Bristol. Menai and Conwy suspension bridges in Wales. Humber bridge. Union bridge (over River Tweed). Brooklyn bridge in new york. Golden Gate bridge at the entrance to San Francisco Bay.

Why build a suspension bridge rather than another type of bridge? Imagine building an arch bridge. Would need lots of bricks, which are heavy. Rope is very light and cheap, so easier to make longer bridges. Arch bridge would need lots of arches and more piers on the river bed, suspension bridge only needs two. Can be built high to allow ships to sail underneath.

Building them in real life. Steel cables not rope. Need to sig down through earth to bedrock to start building piers. May need to dig underwater using a pressurised diving chamber called a caisson - this was first done when building the Brooklyn bridge in New York. Anchor cables by dropping a heavy lump of rock on them. May have two bits of rock with interlocking teeth and cable between.

Talk about tension and compression. Rope is good under tension, brick cracks under tension. Making steel rope - wind strands of iron into a small length, wind many of them together. Testing for strength!

Science background for demonstrators

'Why' suspension bridges are a good idea is to do with the stability of tension - no need to waste strength and weight resisting buckling, so can make lighter and hence longer spans. Resistance to buckling is mostly a geometric effect. We really need a good demo to communicate this. This is in contrast to the strength of materials in tension and compression - most do better in compression as cracks are such a big problem in tension.

'How' they work is a matter of vector addition of forces. When explaining on tour, I used a knot with three strands of rope coming from it. That was enough for a very basic feel for what is happening, but I would really like something with springs in it to demo the actual vector addition, explain resolving into components and so on (i have an idea using some peg-board and newton-meters to do this, but making the geometry of the vector addition clear will be a real challenge).

Pedestrian suspension bridges often place the deck under tension to resist bending.

Suspension bridges aren't used for trains because they can apply such concentrated force, requiring a more concentrated deck so that a suspension bridge is no longer an efficient solution.

Risk Assessment

Hazard: Ropes

Description: Trip hazard from ropes and, especially, stakes near the ground. (Falling onto a stake could cause a severe head injury.)

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: When PUTTING UP, mark the pegs and/or stakes with hazard tape, and, if they are in an exposed position, cover them with boxes. Cover stakes with a cut-open tennis ball to provide cushioning. Call a first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Falling parts of the bridge

Description: Injuries from parts of the bridge falling on someone walking over it, or near to it, should the bridge fall over.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: The bridge must be PUT UP under the supervision of someone suitably experienced. It must be put on level ground, and pegged down adequately (or tied to an adequately fixed object). The piers must be attached to the rope so that their tops can't slide. The DEMONSTRATOR must be aware that the bridge can fall sideways if pushed hard, or swung on. The bridge must be closed if it's fallen or partly fallen or about to fall. Call first aider/999 if required.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Bridge

Description: Falls to the ground from the bridge, possibly complicated by entanglement in the ropes.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: The bridge should not be PUT UP on a hard surface. Grass is preferable, or mats may be used. The DEMONSTRATOR must supervise children carefully while crossing, and be ready to catch very small children if the parent isn't.

Control how many children are on it at a time, and do not allow jumping, swinging or climbing on or off part way through.

Anyone tangled in the ropes may need to be untangled.

Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Piers

Description: Banging head on the crossbars of the piers.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: The crossbars should be covered with hazard tape when PUT UP, and more hazard tape tied on slightly below, to make them obvious.

Call first aider if required.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Separate rope and weight

Description: Trip hazard from the separate rope and weight used to explain the principle.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: The rope and weight should be put safely out of the way - e.g. under the bridge - when they aren't being used by the DEMONSTRATOR.

Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Finger trap

Description: Finger-trap between planks on the deck of the bridge, and in the karabiners.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: The bridge is designed to minimize this problem. The DEMONSTRATOR should keep children away from the underside while it's in use, and warn that karabiners can pinch during assembly.

Call first aider if required.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2011-01-26 - Rosy Ansell (rosemary.a.r.hunt@gmail.com), **Check 2**: 2012-01-30 - Coryan Wilson-Shah (cw412@cam.ac.uk)

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Sweet Chromatography

Using chromatography to investigate the colour of food. - Using just water and bits of paper, split up the colours in pens and food colourings to see how they're made up of a mixture of differently coloured dyes.

Last initially checked on 2023-02-18 by Andrew Sellek (ads79@cam.ac.uk) and double-checked on 2023-02-18 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Chemistry

Equipment Needed

- Cotton wool buds
- Water
- Sweets - M&Ms, Smarties, other sweets with suitable food colouring, water soluble felt-tip pens
- Filter Paper
- Plastic containers
- Scissors for cutting filter paper
- Pencil for marking filter paper

Experiment Explanation

In this experiment the children will investigate the food colourings found in sweets, and dyes from felt-tip pens using chromatography. This will show that colours like brown actually consist of other colours, which we can separate using water.

Possible Activities:

Separating the food colouring components from sweets and dyes in felt-tip pens.

Tips for demonstrating:

Prepare some in advance, so if it takes a long time, or you want to show multiple dyes at once, you have some examples.

Label the dye samples so that you can remember which is which!

Test similar dyes from different sweets, e.g. brown Smarties and brown M&Ms.

The best dyes are brown colours as they tend to have the most components.

The pens tend to work better than the sweets as they cause a stronger trail.

*** BASIC PROCEDURE AND EXPLANATION ***

- Moisten the end of one of the cotton wool buds with water. = Use this to get some of the food colouring off the sweets.
- Use water to moisten a piece of filter paper, or better still fill a plastic cup with water and use a paperclip to suspend the filter paper so it only has a small amount of paper under the water level.
- Transfer this dye to the piece of filter paper near the water.
- Leave for a while until the dyes separate.
- Talk about the solubility of the different dyes and how this affects how far the water 'carries' the dye up the filter paper.

[Slightly more advanced explanation- Chromatography in general involves a stationary phase (in this case filter paper) and a mobile phase (in this case water). Different compounds have different levels of affinity for the stationary phase, and so are carried over it by the mobile phase at different speeds, resulting in their separation.]

*** OTHER THINGS TO TALK ABOUT ***

Different ways of separating components from a mixture.

Uses of chromatography.

*** SCIENCE BACKGROUND FOR DEMONSTRATORS ***

Simple chromatography.

Risk Assessment

Hazard: Sweets

Description: Children will want to eat the sweets which will not be clean.

Affected People: Public

Before Mitigation: Likelihood: 5, Severity: 3, Overall: 15

Mitigation: Explain to the children that the sweets are not clean, and that they should never eat any food used in an experiment/in the lab.

Don't leave sweets unattended and/or in easy reach of children without supervision.

If ingested, warn parents to seek medical advice if illness develops in their child after the event.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Sweets

Description: Choking hazard with very small children if they swallow the sweets.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Watch small children, and don't let them play with the sweets.

In the event of an accident, call first aider, who may perform the Heimlich if confident and trained to do so.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Water

Description: Slip hazard from spilt water or loose papers, particularly on laboratory floors.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Place plastic cup in a place where it won't be knocked over easily. Mop up any spilt water and pick up dropped papers immediately. Use wet floor sign if necessary.

Call a first aider if an accident occurs.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Scissors

Description: Risk of injury if children grab or attempt to use scissors.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrator should be the only one to use the scissors and should cut the filter paper in advance. Use safety scissors if available and keep out of reach of the children (and preferably out of sight when not in use).

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2011-12-22 - Hannah Ford (hf257@cam.ac.uk), **Check 2**: 2012-01-20 - Catherine Collett (chc47@cam.ac.uk)

Check 1: 2012-12-12 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk)

Check 1: 2014-02-05 - Peter Maynes (peter.maynes@cantab.net), **Check 2**: 2014-02-13 - Nunu Tao (nmt26@cam.ac.uk)

Check 1: 2014-12-27 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-02 - Holly Davis (hd308@cam.ac.uk)

Check 1: 2015-12-28 - Haydn James Lloyd (hjl43@cam.ac.uk), **Check 2**: 2016-01-16 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2017-02-09 - Tim Morgan Boyd (tmb58@cam.ac.uk), **Check 2**: 2017-02-09 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk)

Check 1: 2018-01-17 - Georgia Harris (grh37@cam.ac.uk), **Check 2**: 2018-02-04 - Giedre Sirvinskaite (gs508@cam.ac.uk)

Check 1: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2019-02-04 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2020-01-31 - Beatrix Huissoon (beh37@cam.ac.uk), **Check 2**: 2020-02-02 - Lucy Hart (ljfh2@cam.ac.uk)

Check 1: 2021-01-17 - Sian Boughton (seb216@cam.ac.uk), **Check 2**: 2020-01-17 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2022-01-29 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2022-02-06 - Peter Methley (pm631@cam.ac.uk)

Check 1: 2023-02-04 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2023-02-18 - Joshua Wu (jw2311@cam.ac.uk)

The Mathematical Bridge

How can a bridge stay up without bolts? - Self supporting bridges using only wooden poles.

Last initially checked on 2023-01-16 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-01-17 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- 10 long poles
- 5 short poles
- Optional pick up sticks

Experiment Explanation

The Mathematical Bridge at Queens' College in Cambridge, legend has it, was built by Isaac Newton without using bolts. The present bridge has bolts, thanks to some curious students who disassembled the bridge to study it, but failed to replicate Newton's genius.

Of course, this story is entirely false - the bridge was built just over 20 years after Newton's death by James Essex to a design by William Etheridge. As with arch bridges, it derives its strength from the material's response under compression - wooden beams are strong in this manner and their tangential nature to the curve of the bridge helps ensure they are not bent.

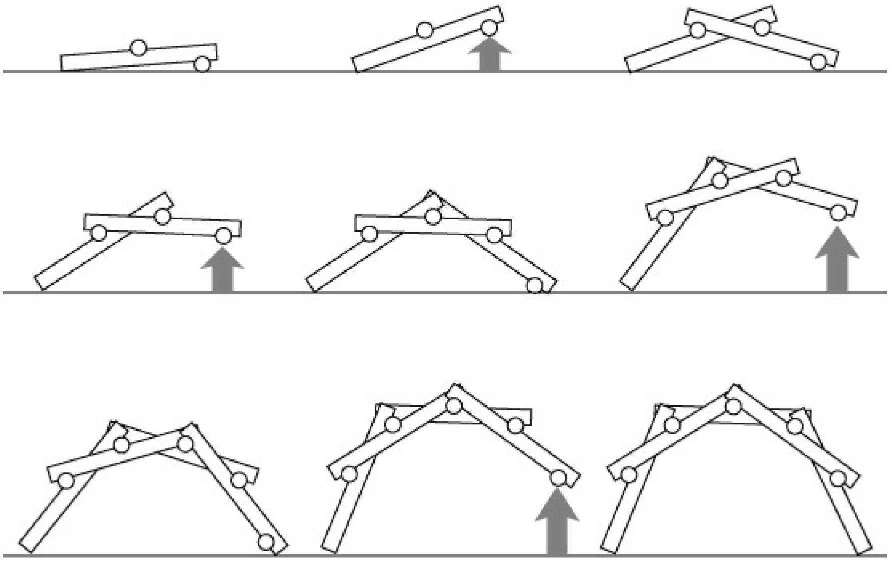
However, a similar design of bridge, entirely self-supporting, was invented by Leonardo da Vinci (and such designs may have been known to Eastern cultures for a long time before that).

It is very hard to make this bridge on your own - you ideally need a small team of people who can help support bits. It should be built with care as it is quite unstable. This has been achieved however with a scout group who didn't appear to speak any English, so it is quite possible!

To make the bridge, first get four long poles. Prop them up at an angle, two facing one way separated by a bit less than the length of the short poles, and two the other way, such that they cross over ~ 2/3 of the way up. Now introduce the short poles as cross beams, slotting in between the protruding ends and the pole it crosses. Gently adjust (lower) the structure until it settles at a point that the poles interlock: one of the slanted poles leans on the cross beam, which leans on the poles slanted the other way, which lean on the other cross beam in the pair, which leans on the original pole. This means you can look at it two equivalent ways - where the poles cross there is an x shape: the cross beams mean that each pole rests on the other and neither moves. Alternatively, from above, you should be able to trace two squares of each one laying on another. (Note that if the angle between the slanted poles is too great, too much of their force is pushing the cross beams outwards - the angle needs to be small enough that the friction can overcome this - this could be a good angle for a plus event [though I haven't thought it through enough!] - how does the angle required relate to the material and its coefficient of friction? [I think it should be tan theta = mu, for angle 2 theta between poles]).

In summary, the downwards force causes members to interlock due to sheer and bending.

Now you've done this once, you can place a cross beam under one of the ends on the ground, carefully use it to lift the structure, and build the same arrangement again - you can keep iterating to build a bigger and bigger bridge!



How could we make it more stable? We could add notches to the poles - this would stop them rolling or sliding.

Risk Assessment

Hazard: Sticks

Description: People use them as swords/lightsabers/maces/etc - may injury someone through deliberate or accidental contact

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Keep close eye on children, firm warnings if they try anything, suspend experiment if they persist.

Call a first airder in the event of injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Bridge

Description: Not weight bearing, people may stand on it and it collapse, could topple sideways onto someone

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Make sure bridge held by demonstrator, warn people not to stand on it, don't use in high wind.

Call a first aider in the event of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Entrapment

Description: Catching fingers between poles when assembling bridge

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Demonstrator to warn people about their fingers and where not to put them. Make sure no weight put on bridge.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Splinters

Description: Potential for splinters from the wood

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Demonstrator to visually inspect poles at the start. In case of injury call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2018-12-12 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2020-01-05 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2020-01-20 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-21 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2022-02-01 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-06 - Lauren Mason (llm34@cam.ac.uk)

Check 1: 2023-01-16 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-01-17 - Jamie Barrett (jb2369@cam.ac.uk)

Mixing Bowl Magic: The Science of Baking

CBS Talk to teach about the science behind baking

Last initially checked on 2023-02-17 by Elizabeth Brown (erb64@cam.ac.uk) and double-checked on 2023-02-19 by John Leung (cfl35@cam.ac.uk)

Frequency of use: n/a

Tags

Talk (Lecture to be given at CBS)

Active

Chemistry

Requires Water

Equipment Needed

- Projector and visualiser
- Slides
- Various baking ingredients (water, flour, yeast)
- Plastic bottle
- Balloon

Brief talks outline

Introduction â€“ why is science important for baking?

What different ingredients do

Same ingredients different results â€“ cake vs brioche

Why cakes rise?

What happens in the oven?

Final product

Risk Assessment

Hazard: Spilled water

Description: Water spillage could cause slip hazard

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Use tray to catch spills, have wet floor sign ready, mop up spills immediately

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Inflated balloons

Description: Balloons could burst, hitting the eyes of anyone closeby

Affected People: Demonstrator / Bystanders

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Demonstrator should wear eye protection, do not let anyone stand too close

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Glassware

Description: Glassware could break, with risk of making cuts

Affected People: Demonstrator / Bystanders

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Use plastic bottles instead

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2023-02-17 - Elizabeth Brown (erb64@cam.ac.uk), **Check 2**: 2023-02-19 - John Leung (cfl35@cam.ac.uk)

Thinking Caps

nan - Can you work out the colour of your own hat?

Last initially checked on 2023-02-15 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-16 by Lauren Mason (llm34@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Maths

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- Paper hats in 4 colours, with at least 5 in 2 different colours. Contact Josh (jlg70) for instructions on how to make paper hats, or just watch a youtube video.
- Charts detailing possible configurations of hats for a couple of the problems.

Experiment Explanation

This demonstration involves getting visitors to solve problems using paper hats. Presented below are some ideas for problems, but feel free to come up with your own. This was developed for and used on mini-tour 2017 for CHaOS PLUS, but some of the ideas can be presented to our general audience. The following are presented roughly in order of ascending difficulty, but anything with a star is more difficult. Only do starred ones if you are very comfortable with the material.

I like to present this in the context of a jail, with me being a sadistic jailer forcing people to cooperate and solve puzzles to escape.

a) 2 people, 2 colours of hats. Put one hat on each person, and let them see the other person. Can they work out anything about the colour of their own hat: no, decisions were independent.

What if they can speak to each other: yes, just tell the other person their hat colour.

Suppose they guess one after the other, is there a way that at least one of them can be correct: yes, the first person just guesses the other person's colour.

*What if they guess at the same time, agreeing a strategy beforehand: Often people say guess randomly. this has a 75% chance of working. get them to work this out. What other strategy could they use, incorporating the information about the other person's hat? They could guess the same, which has a 50% win rate. They could guess differently, which has a 50% win rate. one person guesses the colour they see, the other person guesses the opposite of the colour they see has a 100% win rate, combining the above 2 strategies.

Note: The above strategy means that 100% of the time exactly one person gets the right answer. This is the best we can do - i.e. no strategy exists that works 100% of the time where sometimes both people get the right answer. The reason for this is that regardless of strategy the expected number of correct answers for each person is 1/2, so any strategy averages 1 correct answer between the 2. Thus if it ever exceeds 1 it must also sometimes fail.

*b) As in the last part above, but we have 3 people. This is easy, because 2 people just play the game and ignore the other person. So what if there are 3 potential colours of hats? In this case the strategy is harder, and you will need to teach a bit of modular arithmetic. A nice way to approach this is to rephrase the 2 hat strategy. One person was right when there were an even number of red hats, and the other right when there were an odd number. Instead of calling the hats red and blue, lets call them 1 and 0, and have one player assume that the hats add up to 0 and the other to 1. They can then determine the colour that their own hat needs to be for them to be correct. But wait, what if the sum of the hats is 2? Well, in order to make this work we are going to have to do a funny sort of math where 2=0. So what is 1+1 you ask? 0 they say. There are no other sums, since all numbers are 0 or 1, and they can probably do 0+0 and 1+0.

Now, for 3 hats, instead of calling them red and blue and green, call then 0 1 and 2 and do the same thing. Here we use a different sort of funny maths where 3=0. Get them to do all the sums in this maths (2+1 = 0 and 2+2 = 1). If one player assumes the sum is 0, another assumes it is 1 and the last assumes it is 2 then one of them has to be correct. the challenging part of this is trying to get kids to come up with most of it themselves. This should be possible with older kids (15+) but I haven't tried with young ones.

c) A line of n people, 2 possible colours of hats, one hat on each person. Each person can see all the hats of people in front of them in the line, none of the hats behind them. People guess one after the other, starting at the back of the line. They can agree on a strategy beforehand. Can we guarantee somebody gets it right: yes, person at back just says the colour they see on next person, next person says that colour.

How many can we guarantee: Half (rounding down), using the above stratergy.

What if there are 3 people, can we definitely get 2 right (half rounded up): yes, the person at the back says red if they see 2 of the same colour, blue if they see 2 different colours. This tells the next person if their hat is the same or different to the one they see. Then the person at the front knows if their hat is the same or different to what they just heard.

*In general, what is the best we can do: n-1, since the person at the back reports the parity of the number of red hats they see (red = even number for example), and then everyone can determine their hat from what they have heard before.

*d) As before, but the line goes infinitely far forward. What is the best you can do (will infinitely many people always get it wrong). It turns out that the answer is no, you can make sure that at most finitely many people get the answer wrong (if you assume the axiom of choice). When discussing strategy, divide all possible sequences of hats into equivalence classes based on whether 2 sequences are eventually the same, and then pick a representative from each class. All people answer as if they are in the representative of whatever class they are in. Since the sequence they are answering in and the sequence they are actually in differ only finitely many places, only finitely many people will be wrong.

e) Now we have 3 people and 2 possible colours of hats. The rules are as before, except at least one person has to get it right and nobody can get it wrong. Strategy can be discussed. What is the best we can do: 12.5%, since if nobody can get it wrong everyone must be right.

What if we allow passing: a simple strategy is to have one person guess, and the other 2 pass, giving a 50% win rate.

Can we do better than this? It turns out that there is a better strategy. Since each person who guesses is wrong/right 50% of the time, the only way we can do better is to have the correct answers spread out but have everybody be wrong at the same time. To do this, we use the following strategy - if you see 2 of the same colour hat say the opposite colour, otherwise pass. Thus exactly one person will be right 75% of the time, and 25% of the time everybody will be wrong. A table illustrating this should be included in the maths box.

Risk Assessment

Hazard: Hat corners

Description: Risk that children will poke their eyes with pointy hat corners.

Affected People: children

Before Mitigation: Likelihood: 2 , Severity: 2, Overall: 4

Mitigation: 'Make sure that children handle hats as little as possible, and mostly just wear them. When they do handle them make sure you know who has them and whether they are being sensible. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall:2

Hazard: Hats

Description: Risk that hats will fall on floor and children will slip on them.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Make sure you know where hats are at all times and that children are not running around in a way that could be dangerous if hats fall. Call a first aider in the event of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Paper

Description: Risk that children will cut themselves on paper edges.

Affected People: children

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Make sure that children handle hats as little as possible, and mostly just wear them. When they do handle them make sure you know who has them and whether they are being sensible.\r\nCall first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk), **Check 2**: 2018-01-16 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-02-04 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2020-01-07 - Matthew Le Maitre (msl54@cam.ac.uk), **Check 2**: 2020-01-27 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2020-12-12 - Yian Aaron Koh (yak23@cam.ac.uk), **Check 2**: 2021-01-22 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2022-02-09 - Grace Exley (gae23@cam.ac.uk), **Check 2**: 2022-02-09 - Conor Cafolla (ctc43@cam.ac.uk)

Check 1: 2023-02-15 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**:

Trebuchets

Using a medieval inspired siege-weapon to launch bean bag bunnies - Fire projectiles across the room using our trebuchets! Can you work out how to make them go really far?

Last initially checked on 2023-02-12 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-13 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Engineering

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- 2 x collapsible trebuchet
- Rice in balloons + gaffer tape
- (all in a big red box)
- Bolts (with wingnuts) to assemble trebuchet in plastic tub
- Release pins (also in plastic tub)
- Note for future: An artificial soft surface (e.g. piece of roll mat) would lower the wear rate of the weights, esp. on tarmac or dry mud. If they start leaking nuts during a session, repair with gaffer tape!

Experiment Explanation

The Challenge:

Split the group into two teams. This could be two groups of children at schools or a child and their parents at events. Each team gets a trebuchet. Compete to try and launch the projectile the furthest or to get it into a box if space is limited.

Optional challenge to beat the day's record.

Explanation:

The trebuchets can be modified in two main ways, the pivot position and and the angle of release.

The optimal pivot position seems to be the third or fourth hole from the weight (don't tell them this). With the weight close to the pivot, it cannot accelerate the arm fast enough. This can be explained via the analogy of opening a door via pushing it near the hinge, which is much harder than doing it normally. However, with the weight too far from the hinge, the acceleration of the arm is greater, but speed of the projectile end is small as it is now too close to the pivot. This time, the structure of the trebuchet also needs to be taken into account, as the weight hits the ground before completing the full swing. As it is not good at either end, the best position needs to optimise the balance between these two ideas.

The angle of release can be altered by the position of the spaghetti spoon launcher. The best launching angle should be 45 degrees, or a bit less accounting for air resistance. However, it will not necessarily fire at the same angle when the pivot position changes so this may also have to be adjusted.

If the projectiles have a string attached, this can act as a sling to launch them further. At the moment that the projectile leaves the trebuchet, it is swinging relative to the arm, so its relative speed adds up with the normal launch speed. Show them this after they have tried it normally.

Things to talk about:

- Levers: the more the distance to the pivot the less the force, but the greater the distance moved. It might be worth starting off with a brief explanation of how levers work using an arm.
- Why it's best to have the projectile far from pivot.

- Angle of release: 45 deg should always be best for range, neglecting wind. How can we control the angle? - the projectile is ejected from the trebuchet when centrifugal force overtakes any force the holder exerts on it. (Centrifugal force gets bigger as the arm accelerates through the swing.)
- Using a sling to get extra velocity.

(more suggestions welcome) Set up instructions:

The spagetti spoon end should be on the same side of the base which has the small loop and the 2 prongs. Use the firing pins (narrow metal rods attached to brown pipe cleaners and strings) to connect the metal end of the looped rope to the ring under the spagetti spoon. The looped rope can be attached to the prongs to adjust the launch height. Fire the trebuchet by pulling out the firing pin with the string.

Risk Assessment

Hazard: Projectile-carrying arm

Description: Injury from projectile-carrying arm flying up and hitting audience member or demonstrator in the face. This is a bigger problem when the weight is far from the pivot, as the arm flies up with large force. Also has the potential to be especially nasty if pointy bits of spaghetti spoon hit someone in the eye.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Instruct kids and demonstrators to fire the trebuchet by standing to one side and pulling out the firing pin. Do not let them stand over it and put their face in the way. Safety goggles should be available for anyone who wants them. In the event of an accident, call a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Weights

Description: Injury due to weight dropping suddenly and hitting audience member or demonstrator.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Weight - has been made from nuts - no sharp edges and will deform on impact. Make sure small humans stand out of the way of the weight as it drops. Also don't let them be thrown/launched. Call first aider if required.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Projectile

Description: Could hit audience member or demonstrator and injure them.

Affected People: Mainly bypassers or observers

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Projectile - light rice bag, trebuchet designed to have limited range and velocity, and will not hurt on impact, even at high speeds. Make sure people do not stand in front of the trebuchets when firing - could indicate firing zone with some hazard tape. Avoid busy areas/thoroughfares. If the area happens to get busy mid-demonstration, either ask people to evacuate the 'smash zone' or wait until they have moved. Call first aider if required.

After Mitigation: Likelihood: 3, Severity: 1, Overall: 3

Hazard: Firing pins

Description: Ends of rod and pipe cleaners could be sharp and cause injury.

Affected People: Anyone operating the trebuchets

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Ends of firing pins should be sanded down to remove any sharp edges. Demonstrator to check edges are suffiently blunt before using. Instruct people to hold firing pin by the pipecleaner. Demonstrator to check no pipecleaner ends are stick out. Call first aider if required.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Hazard: Arm and support gap

Description: Trapping fingers between arm and support when the trebuchet is fired.

Affected People: Anyone operating the trebuchets

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: The supports are solid to reduce possibility of fingers being in way of arm. Given the launch position, it is highly unlikely that the person discharging the weapon will be at risk of this. Therefore, one must be aware of anyone else who may get in the way. Firing pins have string attached so trebuchet can be fired from a distance. Call first aider if required.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Spare projectiles

Description: Spare projectiles may act as a trip hazard on floor.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Ensure all spare projectiles are near to the experiment, and don't end up in walkways. Preferably keep them in the box when not in use. Call first aider if required.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-26 - Rosy Ansell (rosemary.a.r.hunt@gmail.com), **Check 2**: 2012-01-30 - Coryan Wilson-Shah (cw412@cam.ac.uk)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-01-18 - Benjamin Lai (bl337@cam.ac.uk), **Check 2**: 2014-01-23 - Vamsee Bheemireddy (vrb23@cam.ac.uk)

Check 1: 2015-02-01 - Benjamin Lai (bl337@cam.ac.uk), **Check 2**: 2015-02-12 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2015-12-16 - Robert Gayer (rg478@cam.ac.uk), **Check 2**: 2016-01-02 - Tim Morgan Boyd (tmb58@cam.ac.uk)

Check 1: 2017-01-22 - Robert Gayer (rg478@cam.ac.uk), **Check 2**: 2017-02-10 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk), **Check 2**: 2018-02-06 - Joanna Tumelty (jt574@cam.ac.uk)

Check 1: 2019-01-20 - Yaron Bernstein (yb258@cam.ac.uk), **Check 2**: 2019-01-30 - Helen Gildersleeves (hcg31@cam.ac.uk)

Check 1: 2020-01-16 - Jean Pichon (jp622@cam.ac.uk), **Check 2**: 2020-01-20 - Beatrix Huissoon

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Check 1: 2021-01-05 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2021-01-20 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-06 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-09 - Lauren Mason (llm34@cam.ac.uk)

Check 1: 2023-02-12 - Emma Crickmore (elc75@cam.ac.uk), **Check 2**: 2023-02-13 - Asmita Niyogi (an637@cam.ac.uk)

Tree

Tree - Tree? Tree!

Last initially checked on 2023-02-06 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2023-02-09 by John Leung (cfl35@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- **This experiment can take place outdoors**
- Lumps of wood in a small grey box, including pieces of trunk, and bamboo
- Pictures and explanatory diagrams

Experiment Explanation

OLD VERSION

A small grey box filled with a various bits of tree. For keen plant scis mainly, but we think you could use it to explain transport of water/nutrients in the xylem and sugars in the phloem. You can also talk about aging a tree by counting the number of rings present, and how you can tell when the tree lived by comparing the relative size of each ring to trees of known age (thicker rings correspond to favourable growing conditions, while thinner rings correspond to a harsher climate).

NEW VERSION

Tree trunks â€“ general facts and information â€“ *donâ€™t worry, you wonâ€™t get too much stick for knowing thisâ€¦*

References - Many thanks to http://www.forestry.gov.uk/website/pdf.nsf/pdf/GrowingGreenActivityPack-Trunk.pdf/$FILE/GrowingGreenActivityPack-Trunk.pdf for a lot of information. Also usual thanks to Wikipedia (especially the bamboo article, and for half the pictures).

The structure of a tree trunk

1. The outer bark protects the tree from extreme temperatures, bad weather, insects and fungi.
2. The phloem (bast) is also called the inner bark. It conveys the food-bearing sap developed in the leaves down to the various parts of the tree.
3. The cambium is a thin layer of cells, which produce phloem on one side and xylem (sapwood) on the other.
4. Sapwood is the living wood in the tree through which the raw sap rises from the roots to the leaves.
5. The heartwood consists of old cells. This is the dead part of the tree that nevertheless provides structural strength.
6. The pith is the central core of the tree (missing in many species).

In areas where there are pronounced seasons, tree form new cells, arranged in concentric circles called annual rings or annual growth rings. These annual rings show the amount of wood produced during one growing season. Rings are made up of a light and a dark band. At first, the cambium produces numerous large cells with thin walls that form the springwood (earlywood). If you look at a cross section of a tree, this is the light-coloured band. The function of springwood is to help the transport of water to the buds. Then, towards the end of the summer, growth slows down. The cells manufactured at this time of year are small, with thick walls. They form the summerwood (latewood) which appears as a darker band on the tree cross section. This wood is primarily for support and strength.

The darker wood is not formed in winter, as some people believe, because the cambium is completely inactive in the winter.

The following year, a new two-part ring is added. The older rings are closest to the centre of the tree. The tree grows in diameter because it manufactures new cells around its circumference, not because the old cells get larger.

The old annual rings form the heartwood of inactive cells: this is the dead part of the tree. The live portion includes only the most recent rings. Depending on the tree's age and species, this portion is 1.5 to 7.5 cm wide. The dead wood is the largest part of the tree. Often, it takes on a darker colour.

Rings are narrower in years of low rainfall. The three main things we can tell from tree rings are

1. Age of the tree
2. Clues to the growth of the tree and factors affecting it e.g. reaction wood, fungal attack, where branches grew (knots), site conditions
3. Past weather patterns, particularly rainfall.

Bark facts *â€“ I wouldnâ€™t want you to bark up the wrong tree* â€¢ The bark is essential for protecting the tree against animals, fungi, disease, and from drying out. □ â€¢ For most trees, when the bark is damaged, it allows a way for fungi and disease to get into the tree, affecting the health of the tree. Tree sap will ooze out of the cut and harden in an attempt to seal the damaged area. However, if the bark is stripped off all around the tree, most species of tree will die. â€¢ Cork oak trees can survive the outer bark being stripped halfway around the trunk as it will regenerate. □ â€¢ The Wellingtonia, or giant redwood, has spongy, fibrous bark that can be up to 30cm thick. Itâ€™s fireproof - protecting the tree from forests fires □□ â€¢ The bark of many young trees is fairly smooth â€“ it develops cracks as it grows older â€¢ The horizontal dashes seen in birch bark are called lenticels. They are pores that allow gases from the air to reach the wood beneath. All plants take in gases through their stems /trunks as well as their leaves. You may notice that birch bark peels off naturally. When the lenticels become blocked with algae or pollution, fresh bark is grown beneath, allowing the old bark to peel away, cleaning the trunk. A birch tree - □□ **Trunk facts** *â€“ stemming up with new ideasâ€¦* â€¢ The centre of the trunk is called heartwood. It is very strong and enables the tree to grow tall, supporting the weight and spread of branches. This gives the tree an advantage as it gains good access to sunlight, shading out the ground plants below. â€¢ Each year the girth of a tree increases, a new ring grows just under the bark, and this is necessary to support the extra height and spread of longer / new branches. â€¢ The trunk also houses the transport network of the tree. There are two different types of tubes running up the length of the trunk â€“ phloem that carry food-bearing sap, and xylem that carry the water and minerals from the roots up to the leaves. â€¢ A mature oak tree can absorb 50 gallons of water in a day â€“ thatâ€™s the equivalent of 227 litres, or 689 cans of lemonade! On a hot day it can be more than this. â€¢ The tallest tree in the world (an therefore the longest trunk) is called â€˜Hyperionâ€™ - a coastal redwood 115.5m high. □ â€¢ The type of tree with the largest trunk (the greatest volume of wood) is called â€˜General Shermanâ€™ â€“ a giant redwood or wellingtonia □ **Story of a treeâ€™s life** *â€“ you are in for a treet* Examining tree rings to tell the story of how a tree grows

Dendrochronology is the dating of past events (such as climatic changes) through the study of tree ring growth. A treeâ€™s growth can be affected by rainfall, sunlight levels, wind, temperature, soil properties, snow accumulation and competition from other trees.

Using the wood, what can you find out about the treeâ€™s life? Each year a tree grows a new ring just beneath the bark. Each ring is made up of two bands: â€¢ A light band (the quick growth of spring) â€¢ A darker band (the slower growth of late summer) □

Not every annual ring is the same: â€¢ In warmer, wetter years, trees grow well so the ring will be thicker â€¢ In colder, drier years, trees do not grow so well so the ring will be thinner. â€¢ If the rings are narrow on one side of a tree with wide rings on the other, the tree was either crowded on the side of the tree where the rings are narrow or exposed to the wind. â€¢ The side with wider rings shows the tree had more space to grow or was sheltered from strong winds. □

BAMBOO

Time to branch out a bitâ€¦

Brief(ish) version:

Stop pining for better jokes

1. Bamboo is actually a grass and not a tree, but it is very woody and very strong (some is apparently stronger than steel).
2. Each bamboo stick typically grows in one season only â€“ it does not have branches, gets no wider the older it gets (as it appears at the diameter it will be), and reaches a maximum height in that one growing system.
3. There is a mass of interconnected roots, called the rhizome, under the soil, from which all the bamboo sticks appear from.
4. The middle hollow bit essentially acts as the xylem â€“ that is the root up which all water flows from the rhizome.
5. Every so often, certain flowing bamboo flower â€“ though this can be 65 to 130 years apart. They seem to

flower all together at the same time, no matter what the climate is or where they are in the world â€“ like an â€œalarm clock). The adults then die after flowering as they spent all their energy in making the fruit.

6. One hypothesis why is that if an area is flooded by huge numbers of seeds, then at least some will survive predators eating them, and so make a new generation. Furthermore, as there is such a long time between mass flowerings, it is longer than the lifespan of things that may eat the fruit, so they will die of starvation waiting for the next flowering.
7. Fire cycle hypothesis is a different version â€“ the mass flowering and death creates a disturbance in the force, I mean in the habitat, allowing the seedlings a gap to grow in, as dead bamboo is very flammable and so there is an increase in the likelihood of wildfire. As bamboo is a very fast grower, they can outcompete and so grow up very rapidly indeed.

Long version (courtesy of Wikipedia):

Time to turn a new leaf

â€œ**Bamboo** Listeni/bÃ¦mËˆ buË/ (Bambuseae) is a tribe of flowering perennial evergreen plants in the grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae. Giant bamboos are the largest members of the grass family. In bamboos, the internodal regions of the stem are hollow and the vascular bundles in the cross section are scattered throughout the stem instead of in a cylindrical arrangement. The dicotyledonous woody xylem is also absent. The absence of secondary growth wood causes the stems of monocots, even of palms and large bamboos, to be columnar rather than tapering.

Bamboos are some of the fastest-growing plants in the world, due to a unique rhizome-dependent system. Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia and East Asia, being used for building materials, as a food source, and as a versatile raw product. High-quality bamboo is stronger than steel, a property that has made it a choice in building materials and weaponry.

############## **Aside â€“ rhizome** *â€“ bet yew never knew this!*

In botany,[dendrology], a rhizome (from Ancient Greek: rhÃzÅma "mass of roots", from rhizÃ³Å "cause to strike root") is a modified subterranean stem of a plant that is usually found underground, often sending out roots and shoots from its nodes. Rhizomes may also be referred to as creeping rootstalks or rootstocks. Rhizomes develop from axillary buds and are diageotropic or grow perpendicular to the force of gravity. The rhizome also retains the ability to allow new shoots to grow upwards.

If a rhizome is separated into pieces, each piece may be able to give rise to a new plant. The plant uses the rhizome to store starches, proteins, and other nutrients. These nutrients become useful for the plant when new shoots must be formed or when the plant dies back for the winter. This is a process known as vegetative reproduction and is used by farmers and gardeners to propagate certain plants. This also allows for lateral spread of grasses like bamboo and bunch grasses. Examples of plants that are propagated this way include hops, asparagus, ginger, irises, Lily of the Valley, Cannas, and sympodial orchids. Some rhizomes are used directly in cooking, including ginger, turmeric, galangal, and fingerroot.

Stored rhizomes are subject to bacterial and fungal infections making them unsuitable for replanting and greatly diminishing stocks. However rhizomes can also be produced artificially from tissue cultures. The ability to easily grow rhizomes from tissue cultures leads to better stocks for replanting and greater yields. The plant hormones ethylene and jasmonic acid have been found to help induce and regulate the growth of rhizomes, specifically in Rheum rabarbarum otherwise known as rhubarb. Ethylene that was applied externally was found to affect internal ethylene levels, allowing for easy manipulations of ethylene concentrations. Knowledge on how to use these hormones to induce rhizome growth could help farmers and biologists producing plants grown from rhizomes with better ways on how to cultivate and grow better plants.

######### **More detail about the bamboo** - *time to blossom into new avenues*

Bamboo is one of the fastest-growing plants on Earth, with reported growth rates of 250 cm (98 in) in 24 hours.[2] However, the growth rate is dependent on local soil and climatic conditions, as well as species, and a more typical growth rate for many commonly cultivated bamboos in temperate climates is in the range of 3â€“10 centimetres (1.2â€“3.9 in) per day during the growing period. Primarily growing in regions of warmer climates during the late Cretaceous period, vast fields existed in what is now Asia. Some of the largest timber bamboo can grow over 30 m (98 ft) tall, and be as large as 15â€“20 cm (5.9â€“7.9 in) in diameter. However, the size range for mature bamboo is species dependent, with the smallest bamboos reaching only several inches high at maturity. A typical height range that would cover many of the common bamboos grown in the United States is 4.6â€“12 metres (15â€“39 ft), depending on species. Anji County of China, known as the "Town Of Bamboo", provides the optimal climate and soil conditions to grow, harvest, and process some of the most valued bamboo poles available worldwide.

Unlike all trees, individual bamboo stems, or culms, emerge from the ground at their full diameter and grow to their full height in a single growing season of three to four months. During these several months, each new shoot grows vertically into a culm with no branching out until the majority of the mature height is reached. Then, the branches extend from the nodes and leafing out occurs. In the next year, the pulpy wall of each culm slowly hardens. During the third year, the culm hardens further. The shoot is now considered a fully mature culm. Over the next 2â€“5 years (depending on species), fungus begins to form on the outside of the culm, which eventually penetrates and overcomes the culm. Around 5â€“8 years later (species and climate dependent), the fungal growths cause the culm to collapse and decay. This brief life means culms are ready for harvest and suitable for use in construction within about three to seven years. Individual bamboo culms do not get any taller or larger in diameter in subsequent years than they do in their first year, and they do not replace any growth lost from pruning or natural breakage. Bamboos have a wide range of hardiness depending on species and locale. Small or young specimens of an individual species will produce small culms initially. As the clump and its rhizome system mature, taller and larger culms will be produced each year until the plant approaches its particular species limits of height and diameter.

Many tropical bamboo species will die at or near freezing temperatures, while some of the hardier or so-called temperate bamboos can survive temperatures as low as âˆ’29 Â°C (âˆ’20 Â°F). Some of the hardiest bamboo species can be grown in places as cold as USDA Plant Hardiness Zones 5â€“6, although they typically will defoliate and may even lose all above-ground growth, yet the rhizomes will survive and send up shoots again the next spring. In milder climates, such as USDA Zone 8 and above, some hardy bamboo may remain fully leafed out year around.

Mass flowering *â€“ I oak you are ready for acorn-y joke about trees!*

Flowering bamboo

Most bamboo species flower infrequently. In fact, many bamboos only flower at intervals as long as 65 or 120 years. These taxa exhibit mass flowering (or gregarious flowering), with all plants in a particular species flowering worldwide over a several-year period. The longest mass flowering interval known is 130 years, and it is for the species Phyllostachys bambusoides (Sieb. & Zucc.). In this species, all plants of the same stock flower at the same time, regardless of differences in geographic locations or climatic conditions, and then the bamboo dies. The lack of environmental impact on the time of flowering indicates the presence of some sort of â€œalarm clockâ€ in each cell of the plant which signals the diversion of all energy to flower production and the cessation of vegetative growth. This mechanism, as well as the evolutionary cause behind it, is still largely a mystery.

One hypothesis to explain the evolution of this semelparous mass flowering is the predator satiation hypothesis which argues that by fruiting at the same time, a population increases the survival rate of their seeds by flooding the area with fruit, so, even if predators eat their fill, seeds will still be left over. By having a flowering cycle longer than the lifespan of the rodent predators, bamboos can regulate animal populations by causing starvation during the period between flowering events. Thus the death of the adult clone is due to resource exhaustion, as it would be more effective for parent plants to devote all resources to creating a large seed crop than to hold back energy for their own regeneration.

Another, the fire cycle hypothesis, argues that periodic flowering followed by death of the adult plants has evolved as a mechanism to create disturbance in the habitat, thus providing the seedlings with a gap in which to grow. This argues that the dead culms create a large fuel load, and also a large target for lightning strikes, increasing the likelihood of wildfire. Because bamboos can be aggressive as early successional plants, the seedlings would be able to outstrip other plants and take over the space left by their parents.

However, both have been disputed for different reasons. The predator satiation hypothesis does not explain why the flowering cycle is 10 times longer than the lifespan of the local rodents, something not predicted. The bamboo fire cycle hypothesis is considered by a few scientists to be unreasonable; they argue that fires only result from humans and there is no natural fire in India. This notion is considered wrong based on distribution of lightning strike data during the dry season throughout India. However, another argument against this is the lack of precedent for any living organism to harness something as unpredictable as lightning strikes to increase its chance of survival as part of natural evolutionary progress.

The mass fruiting also has direct economic and ecological consequences, however. The huge increase in available fruit in the forests often causes a boom in rodent populations, leading to increases in disease and famine in nearby human populations. For example, devastating consequences occur when the Melocanna bambusoides population flowers and fruits once every 30â€“35 years around the Bay of Bengal. The death of the bamboo plants following their fruiting means the local people lose their building material, and the large increase in bamboo fruit leads to a rapid increase in rodent populations. As the number of rodents increases, they consume all available food, including grain fields and stored food, sometimes leading to famine. These rats can also carry dangerous diseases, such as typhus, typhoid, and bubonic plague, which can reach epidemic proportions as the rodents increase in number. The relationship between rat populations and bamboo flowering was examined in a 2009 Nova documentary Rat Attack.

In any case, flowering produces masses of seeds, typically suspended from the ends of the branches. These seeds will give rise to a new generation of plants that may be identical in appearance to those that preceded the flowering, or they may produce new cultivars with different characteristics, such as the presence or absence of striping or other changes in coloration of the culms.

Risk Assessment

Hazard: Wood pieces

Description: Dropping the pieces of wood could cause injury to feet.

Affected People: Visitors or demonstrator

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Place wood away from edges of tables for wood measure. In case of injury, call first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Wood pieces - edges

Description: Any sharp edges of wood could cause splinters.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Do not use any pieces of wood with sharp bits, and smooth them down when possible so can be used in demonstration again. Get first aider or parent to remove splinter and clean the skin. Tell parent to take child to GP if the wound appears infected later.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Bamboo Weapons

Description: Children could be tempted to play with the bamboo (or perhaps any of the other bits of wood) as weapons.

Affected People: All (mainly kids to each other)

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Monitor all pieces of wood and make sure the kids are sensible with them. If kids start misbehaving, don't let them get carried away with the wood. Call a first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

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Turtle Robots

**These turtles want to draw you shapes. ** - Learn the basics of robotics by teaching simple robots to move and draw.

Last initially checked on 2023-02-17 by Emma Crickmore (elc75@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Computer Science

Active (Experiment has working equipment at the time of last update, and is available for events.)

Equipment Needed

- Valiant Roamer Turtle Robots (Currently have 4, one is cracked)
- Valiant Roamer Control Unit (Currently have 1 and sensors)
- Roamer Turtle Cases (I think there's two, one should be used on cracked robot)
- 6V Lantern Batteries (2 per robot) [These are available from some shops (camping ones) but are best got on Amazon or eBay]
- Custom wooden base plates (these are wooden and cover the batteries)
- Obstacles (improvise)

Experiment Explanation

TEACHING THE ROAMER The Roamer moves forward and back, turns left and right, waits and makes sounds. You teach the Roamer to do this by pressing keys on the top of its body. There is a key for each of these functions, and a set of number keys. To enter an instruction press a key, followed by a number. This tells the Roamer how far to move, how much to turn, how long to wait or what sound to make. There are three other function keys: Sense, Two-State Outputs and Stepper Motor.

ROAMER PROGRAMS There are two types of program, the GO Program and Procedures. The GO Program is a list of instructions carried out when you press GO. A Procedure is a list of instructions with a name. Once you have defined the list, its name (e.g. P1) is used like any other instruction. When you enter its name in the GO Program, the Roamer will carry out the whole procedure list.

MEMORY The Roamer has two types of memory, GO Memory and Procedure Memory. The Roamer will remember up to 59 instructions, and its powerful programming facilities enable it to carry out hundreds of actions. When its memory is nearly full the Roamer will sound a warning, similar to the sound you hear when you press CM.

GO MEMORY Instructions in the GO Memory are carried out when you press GO. If you add more instructions after executing the GO Program, they will be added to the GO Program and carried out the next time you press GO. The Roamer waits for two seconds after you press GO before executing the GO Program.

CLEARING THE GO MEMORY Pressing CM then CM clears the GO Memory and allows you to enter a new GO Program. It does not clear the Procedure Memory. The first time you press CM a warning is sounded. Pressing CM a second time clears the GO Memory. If you press by mistake, press another key, or wait 10 seconds. The Roamer will then carry on with its GO Memory intact.

DEMONSTRATION PROGRAM If you press GO after you switch on the Roamer, it will carry out the Demonstration Program. This can be used to show beginners the basic Roamer functions. REMEMBER TO CLEAR THE DEMONSTRATION PROGRAM From THE GO MEMORY BEFORE PROGRAMMING.

FORWARD AND BACK Pressing (forward) or (back) followed by a number from 1 to 99 tells the Roamer to move forward or back that number of units. (See UNITS OF DISTANCE AND TURN). (These examples are illustrated in the style suggested on the programming sheet).

RIGHT AND LEFT TURN Pressing (right) or (left) followed by a number up to 999 turns the Roamer to the right (clockwise) or left (anticlockwise) that number of units. (See UNITS OF DISTANCE AND TURN).

WAIT Pressing (W) followed by a number from 1 to 99 tells the Roamer to be still and quiet for that number of seconds.

MUSIC The Roamer has a programmable sound facility. You need to specify how long each note will last (duration) and how high or low the note will be (pitch). To play a note, press followed by a number from 1 to 8 for its duration, and another number from 1 to 13 for its pitch. If you want a rest (silent note), enter 14 for the pitch.

UNITS The default units are 30cm (one robot length) for movement and 1 degree for turning. They can be changed by pressing (forward) or (right) and then ([]) and a number of cms or degrees.

STOPPING Hold any key to stop the currently executing programme.

CANCELLING pressing (CE) cancels the last instruction from the programme. LOOPS Pressing repeat, (R) followed by a number then ([]) some instructions and a closing ([]) repeats the enclosed instructions as a loop. Conditional loops aren't supported.

PROCEDURES Press (P) followed by a number to define that procedure. Then place instructions inside ([]). To use a procedure in the programme press (P) and its number and the only way to edit or delete is to redefine the procedure. Recursion is not permitted and is implemented by procedures only being able to call procedures of strictly greater number. 99 procedures can be stored.

DEMONSTRATING The robots are very simple to use so can be programmed with a try it approach. The sound feedback tells you what works and what doesn't and people will find out quickly what to do. You may wish to masking tape over some of the buttons, like the note and procedures to prevent them being used and increase the success of random button pressing. The simplest aim is to set up some obstacles and ask them to navigate around the course. With sharpies one could also draw shapes on paper as an alternative. Obviously there are also things to learn. Roamers are procedurly programmed, one can talk about how one might try and solve a problem. A natural way is to break it into sub problems, when setting out the course think of repeatable steps you can build in so they can see they solve some problems a few times. This is where a procedure comes in. This could be something like navigate around a cone and this can be called whenever it's needed to navigate around a cone. Procedures also have other advantages. For instance if we swap all the cones for different obstacles then we only have to change the cone procedure to work for the new obstacle. Bottom up programming - using existing knowledge to solve a new problem. Top down programming - diving a complex problem into smaller sub problems.

CONTROL UNIT We now own one Control Unit, this is in a cardboard box with lots of electronic sensors, I've not yet tested it as I didn't fully realise it was included with a robot I bought. The control unit screws into the depression on the bottom and the cable goes into the battery compartment to link to the robot. You can plug in sensors or two-state outputs (and also motors but we don't have any). In theory the button on top allows you to use these. It introduces some limited conditional elements using the sensor blocks and throwing in several loops lets you use these in more usual ways. Please use and document!

Risk Assessment

Hazard: Battery covers

Description: Batteries may become loose/caught/punctured if improvised covering fails.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Check covering before beginning experiment. Call first aider in the event of accident.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Rain

Description: Batteries may react with rain due to improvised covers.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Don't use in rain. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Roamers

Description: Roamers may fall off table, raised surface and hit a person.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Use on the floor or have barriers on tables. In the event of accident, call a first aider/mechanic.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Roamers

Description: Roamers may be trip hazard if used on floor.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Don't use in thoroughfare and section off area for operation. Call first aider in the event of accident.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

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The Universe is Basically Nothing

Talk about the different forces and particles present in the universe

Last initially checked on 2023-02-19 by Brintha Yasodaran (by277@cam.ac.uk) and double-checked on 2023-02-19 by John Leung (cfl35@cam.ac.uk)

Frequency of use: n/a

Tags

Talk (Lecture to be given at CBS)

Active

Physics

Equipment Needed

- Projector and visualiser
- Slides
- Model of atoms (Ping pong balls on a board)
- Nerf gun w/ foam bullets
- Silk and glass rod
- van de Graaf generator
- Cake tins

Experiment Explanation

Demo 1: Demonstration of Rutherfordâ€™s gold foil experiment. Part 1 is to demonstrate the John Dalton model. A member of the audience (above 12 years old and relatively responsible) will be given a nurf gun with darts acting as alpha particles. They will have a paper figure to shoot at initially to practice their aim. They will then shoot at a model of atoms in gold foil (ping pong balls stuck to a backboard) to observe how the alpha particles just bounce back.

Part 2 involves shooting at a net instead to see how most of the alpha particles pass straight through with only some being deflected/bouncing back.

Demo 2: The second demonstration is to explain how positive charges repel each other, and so how it is anti-intuitive for the nucleus to be an accumulation of positive charge. A brief explanation of the strong force will follow. A glass rod will be rubbed with silk, for a positive charge to accumulate. A balloon will also be rubbed to accumulate a positive charge. The rod and balloon will be brought close to each other to show how they repel one another.

Demo 3: The second demonstration is to explain how negative charges repel each other using a Van de Graaff generator. This will lead into the understanding of electrons being in â€˜shellsâ€™ where they are spaced far apart from each other.

This experiment consists of 2 parts. Part 1 involves a volunteer touching the Van de Graaff generator and their hairs standing on end.

Part 2 involves placing foil cake cases onto the Van de Graaff and showing how the cases repel each other as they all fly off.

Risk Assessment

Hazard: Nerf gun

Description: Volunteer could accidentally or on purpose shoot someone

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Ensure the volunteer is a teenager or adult. Make volunteer practice using gun by shooting at target on wall. Make sure shooting is not in direction of audience. Ensure foam bullets are soft. If someone is shot and badly harmed, call a first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Net and blackboard

Description: Nerf bullets bouncing back from board and hitting someone

Affected People: Bystanders

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: All participants involved made to wear goggles. Audience made to not sit in front few rows.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Glass rod

Description: Being dropped, producing sharp pieces that can cause cuts

Affected People: Bystanders

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Nobody from the audience will be holding the glass rod. Glass rod checked for cracks before use. If glass rod does break, dispose of it carefully. In the event of an accident, call a first aider.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Balloon

Description: Popping and hurting peopleâ€™s ears; or popping in someoneâ€™s hands

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure balloon is not overinflated

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: van de Graaf generator

Description: Giving somebody an electric shock

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Have a grounded discharge electrode that can be used to discharge the VDG before the generator is touched or turned on/off. When an individual is being discharged for the hair-raising demo, discharge them in a controlled manner by making them hold wooden stick until hair falls (+30 seconds longer). Ensure nobody with a heart condition performs the hair raising-experiment. Call first aider in event of accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Cake tins

Description: Flying into someone and hurting them

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Ensure first few rows of audience are not occupied. Call first aider in event of accident.

After Mitigation: Likelihood: 2, Severity: 1, Overall: 2

Risk Assessment Check History

Check 1: 2023-02-19 - Brintha Yasodaran (by277@cam.ac.uk), **Check 2**: 2023-02-19 - John Leung (cfl35@cam.ac.uk)

Urinalysis

nan - Practise diagnosing patients using this simple bedside test - use the dipsticks to analyse "urine" from our patients.

Last initially checked on 2023-02-10 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-16 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- Urine dipsticks
- Paper towel
- Bin bag
- Large bottles
- 20ml universal containers
- Laminated speech bubbles
- Yellow food colouring
- Sugar
- Powdered milk
- Meat blood (lamb or poultry)
- Water
- Nitrile gloves

Experiment Explanation

In a nutshell: Use urinalysis dipsticks to test the content of artificial urine. Talk about some of the medical conditions that could cause these results (diabetes, urinary tract infection, kidney stones)

How to set up the experiment:

Make up bottles of each urine type:

Normal â€“ water. You can add some yellow food colouring if desired

Diabetes â€“ add some sugar (plus yellow food colouring if desired â€“ only a small drop is required for a full 500ml bottle)

Infection â€“ add a small amount of powdered milk (plus yellow food colouring if desired)

Kidney stones â€“ add a few drops of blood from some fresh meat (e.g. lamb mince)

Pour a sample of each urine type into 20ml containers.

Kids can dip a urinalysis stick into one (or several) samples, place the stick on some paper towel and read off the result against the side of the bottle. You can play a diagnostic matching game, matching the urine samples to the patientâ€™s symptoms and the doctorâ€™s explanation.

Background information:

Urinalysis is a quick, simple and cheap test often used in GP surgeries â€“ many children may have had to provide a wee sample at some point. The results of a dipstick may be all that is required to confirm a diagnosis, or further tests may be carried out (e.g. fasting blood glucose for diabetes, microscopy for infection or imaging for renal stones).

These urine dipsticks test a variety of parameters in addition to the protein, glucose and blood examined here, e.g. bilirubin, a breakdown product of haemoglobin, the presence of which might suggest hepatitis, and urine specific gravity (likely to be abnormal here as weâ€™re just testing water), which can give a measure of dehydration.

Urinary Tract Infections (UTIs) (from Wikipedia)

A urinary tract infection (UTI) is an infection that affects part of the urinary tract. When it affects the lower urinary tract it is known as a simple cystitis (a bladder infection) and when it affects the upper urinary tract it is known as pyelonephritis (a kidney infection). Symptoms from a lower urinary tract include painful urination and either frequent urination or urge to urinate (or both), while those of pyelonephritis include fever and flank pain in addition to the symptoms of a lower UTI. In the elderly and the very young, symptoms may be vague or non specific. The main causal agent of both types is Escherichia coli, however other bacteria, viruses or fungi may rarely be the cause.

Urinary tract infections occur more commonly in women than men, with half of women having at least one infection at some point in their lives. Recurrences are common. Risk factors include female anatomy, sexual intercourse and family history. Pyelonephritis, if it occurs, usually follows a bladder infection but may also result from a blood borne infection. Diagnosis in young healthy women can be based on symptoms alone. In those with vague symptoms, diagnosis can be difficult because bacteria may be present without there being an infection. In complicated cases or if treatment has failed, a urine culture may be useful. In those with frequent infections, low dose antibiotics may be taken as a preventative measure.

In uncomplicated cases, urinary tract infections are easily treated with a short course of antibiotics, although resistance to many of the antibiotics used to treat this condition is increasing. In complicated cases, longer course or intravenous antibiotics may be needed, and if symptoms have not improved in two or three days, further diagnostic testing is needed. In women, urinary tract infections are the most common form of bacterial infection with 10% developing urinary tract infections yearly.

Kidney Stones

A kidney stone, also known as a renal calculus is a solid concretion or crystal aggregation formed in the kidneys from dietary minerals in the urine.

Urinary stones are typically classified by their location in the kidney (nephrolithiasis), ureter (ureterolithiasis), or bladder (cystolithiasis), or by their chemical composition (calcium-containing, struvite, uric acid, or other compounds). About 80% of those with kidney stones are men. Men most commonly experience their first episode between 20-30 years of age, while for women the age at first presentation is somewhat later.

Kidney stones typically leave the body by passage in the urine stream, and many stones are formed and passed without causing symptoms. If stones grow to sufficient size (usually at least 3 millimeters (0.12 in)) they can cause obstruction of the ureter. Ureteral obstruction causes postrenal azotemia and hydronephrosis (distension and dilation of the renal pelvis and calyces), as well as spasm of the ureter. This leads to pain, most commonly felt in the flank (the area between the ribs and hip), lower abdomen, and groin (a condition called renal colic). Renal colic can be associated with nausea, vomiting, fever, blood in the urine, pus in the urine, and painful urination. Renal colic typically comes in waves lasting 20 to 60 minutes, beginning in the flank or lower back and often radiating to the groin or genitals. The diagnosis of kidney stones is made on the basis of information obtained from the history, physical examination, urinalysis, and radiographic studies. Ultrasound examination and blood tests may also aid in the diagnosis.

When a stone causes no symptoms, watchful waiting is a valid option. For symptomatic stones, pain control is usually the first measure, using medications such as nonsteroidal anti-inflammatory drugs (such as ibuprofen). More severe cases may require surgical intervention. For example, some stones can be shattered into smaller fragments using extracorporeal shock wave lithotripsy. Some cases require more invasive forms of surgery. Examples of these are cystoscopic procedures such as laser lithotripsy or percutaneous techniques such as percutaneous nephrolithotomy. Sometimes, a tube (ureteral stent) may be placed in the ureter to bypass the obstruction and alleviate the symptoms, as well as to prevent ureteral stricture after ureteroscopic stone removal.

Diabetes Mellitus

Diabetes mellitus, or simply diabetes, is a group of metabolic diseases in which a person has high blood sugar, either because the pancreas does not produce enough insulin, or because cells do not respond to the insulin that is produced.[2] This high blood sugar produces the classical symptoms of polyuria (frequent urination), polydipsia (increased thirst) and polyphagia (increased hunger). The cause of the polyuria is simply osmotic diuresis â€“ the glucose content of the blood is so high that it cannot all be reabsorbed by the renal tubules and thus glucose is excreted in the urine. This increases osmotic pressure in the tubule, causing retention of water and thus high volumes of urine.

There are three main types of diabetes mellitus (DM).

Type 1 DM results from the body's failure to produce insulin, and currently requires the person to inject insulin or wear an insulin pump. This form was previously referred to as "insulin-dependent diabetes mellitus" (IDDM) or "juvenile diabetes".

Type 2 DM results from insulin resistance, a condition in which cells fail to use insulin properly, sometimes combined with an absolute insulin deficiency. This form was previously referred to as non insulin-dependent diabetes mellitus (NIDDM) or "adult-onset diabetes".

The third main form, gestational diabetes occurs when pregnant women without a previous diagnosis of diabetes develop a high blood glucose level. It may precede development of type 2 DM.

Risk Assessment

Hazard: Spillages

Description: Slip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: All spills should be cleared up immediately. Call a first aider in case of accident.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Powdered milk

Description: Allergen hazard from powdered milk.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Do not allow children to dip fingers in artificial urine, encourage use of gloves, encourage children to wash their hands afterwards.Make sure children know it's milk so if they are allergic they can make sure not to touch it. Alert parents to presence of milk if you are concerned that a child has dipped their fingers in the solution.

Call a first aider in the event of reaction.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Raw meat

Description: Risk of bacterial contamination from uncooked meat blood.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not allow children to dip fingers in artificial urine, encourage use of gloves, encourage children to wash their hands afterwards. Alert parents to presence of raw meat if you are concerned that a child has dipped their fingers in the solution.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Samples

Description: Feeling faint/fainting at sight of experiment.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Be aware that a small percentage of people may feel uneasy or unwell. Stop if someone looks unwell/goes pale. Have a chair nearby light-headed-feeling people, and ask anyone who feels faint to sit down (may be better for them to sit on the floor as people can still faint off chairs). Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2014-01-21 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-26 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-10 - Alisha Burman (arb95@cam.ac.uk), **Check 2**: 2015-01-31 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2016-01-05 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2016-02-12 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2017-02-11 - Fiona Coventry (fiona.coventry@cantab.net), **Check 2**: 2017-02-13 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2018-01-27 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2018-02-07 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2019-01-25 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2019-01-30 - Helen Gildersleeves (hcg31@cam.ac.uk)

Check 1: 2020-01-27 - Samuel Amey (sra44@cam.ac.uk), **Check 2**: 2020-01-27 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2022-01-28 - Sian Boughton (seb216@cam.ac.uk), **Check 2**: 2022-02-09 - Jessica Trevelyan (jet81@cam.ac.uk)

Check 1: 2023-02-10 - Amy Migunda (aom36@cam.ac.uk), **Check 2**: 2023-02-16 - Jamie Barrett (jb2369@cam.ac.uk)

Use of active expression handsets

nan - nan

Last initially checked on 2023-02-18 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Other

Equipment Needed

- **Electricity needed**
- Active Expression voting devices
- Laptop
- USB hub
- Optional extension cable.

Experiment Explanation

An aid to CBS talks. Committee: see how-to guide

Risk Assessment

Hazard: Small parts

Description: Choking on small parts.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Committee to check that the plastic screw on the back cover is not loose when handing out devices. Screws can be tightened using the screwdriver with the devices. Hand devices to the parents of small children, rather than to the child. Call first aider in the event of accident.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Devices

Description: Devices could hurt someone if thrown or dropped on toes (mostly thrown).

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Committee to hand devices to parents of young children/ those they do not believe will behave sensibly. Committee to request the devices back from any group misusing the devices. If necessary, person delivering the talk to tell the audience to put the devices down on the bench when not in use/ until they say so. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Cables

Description: Trip hazard (particularly if using extension lead).

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Set up close to power source, avoid cables crossing walkways and tape down cables. Call first aider in the event of an accident.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2018-02-03 - Fiona Coventry (fiona.coventry@cantab.net), **Check 2**: 2018-02-03 - Andrew Sellek (ads79@cam.ac.uk)

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Check 1: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2023-02-18 - John Leung (cfl35@cam.ac.uk), **Check 2**: 2023-02-18 - Asmita Niyogi (an637@cam.ac.uk)

UV (Fluorescence)

Looking at how materials fluoresce in UV light. - The world looks different when it's lit by UV... see how you can use this type of light to make clothes look extra-bright, find out whether banknotes are real or fake, and revive dead glowsticks.

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Chiara Delpiano Cordeiro (cd796@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Darkroom needed**
- **Electricity needed**
- Short blue box containing:
- Shrouded UV lamp
- White paper
- Washing powder tablets
- Glowsticks
- Highlighters
- Sun cream
- Board covered with glow in the dark paint
- Also useful:
- Banknotes, driving license (anything with UV security markings)

Experiment Explanation

In a nutshell..

Show kids that there's more to light than the colours that they can see- and how this can explain why some ordinary things glow in "black light"

How to set up the equipment

This is best set up on the floor so that you don't look directly at the bulb. Put the lead and switches of the box towards you, with the flat side of the box towards your audience. The experiment is better in a dark corner/ in a dedicated dark room area. See the Risk Assessment for more details, but do thing about avoiding trailing wires in the dark! Also, there should be a power lead for the light box with this kit- please don't pack it with the main box of extension cables! There's lots of extra things in the box- if you keep them in the empty blue box when you're not using them it's easier to find them in the dark/ helps people avoid tripping over them!

What does the box do?

Turn over the box **with both lights switched off**, and show the kids the two bulbs. One is for "ordinary/normal" white light. The other bulb is a UV bulb- a kind of light human eyes can't see. There is a switch for each on the back. Turn it back over as soon as you're done with this to avoid UV directly into people's eyes.

See Risk Assessment for more details, but briefly: this particular UV light is pretty safe- it's not that far into the UV, so isn't as energetic/ dangerous as some other sources. You should hopefully spot that it gives off weak visible light too. It's also fairly weak - but *don't use it while it is facing up* just in case!!

What is light/ UV light?

The light most of us are really familiar with is white light. But that's actually a mixture of different colours. Most of the time we can't tell that, but sometimes we can see these colours split up, like in a rainbow.

Do you know the colours of the rainbow? Ask them to tell you! [Red -> Orange -> Yellow -> Green -> Blue -> Indigo -> Violet (basically purple!)]

It turns out that there are more kinds of light than our eyes can see. Some kinds of light are "redder" than red is - we call that kind of light "infra-red" (there's another CHaOS experiment about this- check it out!). You might have seen images from cameras that can detect this kind of light, perhaps watching animals at night on TV, or police chase criminals with helicopters. At the other end of the rainbow there are other kinds of light that we can't see. These are more blue/ more purple than violet, and we call this kind of light "ultra violet".

It's weird to think that there's kinds of light we can't see, but not all kinds of eyes detect the same light. For example, some people can't tell red and green apart, which is called "colour blindness". Another example: some insects, such as bees, can see UV light. Some types of flowers have extra patterns in UV, so this helps them find the nectar in the middle of a flower! (How cool is that?!)

But what about wavelength/ spectra?

Add this extra level of detail with caution: it can be too much detail to take in if they've never thought about UV/ IR before, and you can overwhelm them. You can come back to this later on once you'rve showed them some of the cool things that glow!

EM Spectrum: we call all the kinds of light (including UV, IR, visible) "electromagnetic radiation". One way of understanding this is to say that all these kinds of light have different sizes of wavelength. There's some charts in the box that you can point at when you explain this. Start with the rainbow: Red light waves are wider/longer than blue light waves. Following on from that, infra-red has longer waves than red light; UV has a shorter waves than blue. If you go further outside that you can see microwaves (that you can cook with) and radio waves (which can hold information. like music). These have a longer wavelength, much longer than infra-red. If you go the other way you get to X-rays- these have smaller waves than UV!

Energy: Another way of viewing the light is as a stream of particles. We call them photons. They are like small balls travelling at the speed of light. And photons of different colours have different energy. Blue photons have more energy then red ones and ultra-violet ones have even more energy. This if why UV can cause damage to your skin. (You can use analogy with a light and heavy ball. The heavier has more energy and can harm you more if thrown upon you.) It causes damage to the cells (which can cause cancer if it goues really bad). When you get sun burned you have absorbed too much of UV. So wear suncream to prevent this! (And X-rays have even more energy and do not stop on your skin - they can go through your body so you can use them to see what is inside. But they are also more harmful and that is why it is used as little as possible.)

Some things glow if you put them under UV light

Put an object from the box under the UV light. Boring old white paper works- though pretty patterns on driving licenses/ credit cards/ banknotes are a good start if you have them! Either way, this first item should glow! Here's a way of explaining this...

1. Turn on the UV light
2. Place a (fluorescent) object underneath it - it should glow.
3. What's happening? How can we see glowing if we can't see UV?
4. It's fluorescence! (Use this word! Here's a simple explanation- let us know if you have an alternative!)

The object absorbs or takes in light that we can't see- UV light. The object can then change the light from UV to a kind we can see. The energy in the UV light is being converted into a different visible form, and things that do this are called fluorescent.

Wikipedia has a more precise explanation, but it depends on understanding lots of other technical words! *"Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation. It is a form of luminescence. In most cases, the emitted light has a longer wavelength, and therefore lower energy, than the absorbed radiation."* (From http://en.wikipedia.org/wiki/Fluoresce)

Where are UV lights used in everyday life?

In shops, to check if money is fake! (See markings on banknotes)

Ask if they've ever seen notes being checked in shops. You can ask parents if they have a five pound note you can borrow briefly. If you look at the note, there are all kinds of features visible to the eye (metal strip, watermark etc.) but if you put the note under the UV light, you can see extra information, like the value of the note. This is useful in preventing forgery because printing with UV sensitive ink is difficult and expensive. Again, the UV gives the special inks energy so they give out light. Don't forget to give the fiver back

In discos, to make white things look super bright!

You might have seen this!

Fluorescent objects in the box Highlighters:

- Fairly boring in white light, but spectacular under UV. Draw on white paper or non-fluorescent card, on even a smiley face on the back of your hand!

Glowsticks:

- Show them glow sticks in the UV - which will glow. Glow sticks get their energy from a chemical reaction rather than UV, if you give them energy from UV they will still glow though

Tonic water:

- This is probably the brightest fluorescence in the box, so I usually leave it until last. It's quinine that's causing the glow- this compound is more famous for helping to kill malaria parasites when it was added to tonic water. In the past it was in much higher doses than it is now.

Glow in the dark board:

- There is also a board coated with the phosphorescent paint - put it under the UV light for 10 seconds (or more - doesn't do any harm), then turn the light off and let them see how the board carries on glowing. Turn the light back on and invite them to put their hands on the board. Make sure they keep their hands in the same place for at least 10 seconds, and see if they can guess what the board will look like after they take their hands away - the effect will be most long-lasting if you turn the UV light off at almost the same time as they take their hands off the board. Some parents may want to take photos!

For more info on tonic water visit: http://en.wikipedia.org/wiki/Tonic_water

Washing powder:

- Residual powder makes your clothes look whiter by helping balance out the yellower colours of sad old white clothes. **This gets everywhere, need to replace blocks!!**

Phosphorescent things in the box (glow in the dark stars):

- Phosphorescence is very like fluorescence a chemical in the paint absorbs energy from the UV light, but instead of releasing it again in miliseconds, it releases it slowly over minutes.

Glow in the dark paint: tube (not presently available)

- Apparently this stains, so don't open the tube! (There is some phosphorescent paint, this does the same thing as fluorescent dyes but releases the energy much more slowly -> glow in the dark stars etc. NB: this should be well wrapped in plastic (whilst being non-toxic it is very staining) - you can often see it glowing through the container.)

Why is there sunscreen in the box?

- UV light from the sun (not this box, so it's safer than sunlight!) has lots of energy. This damages your skin (or cells, and ultimately, the DNA) when you absorb/ take in too much of this.
- If you use sun screen it can absorb the UV/ block it from reaching your skin, which reduces the damage the sunlight can do
- See this in action: spray a white sheet of paper with a bit of sunscreen. Predict what will happen (should look black). Try it under the light.
- Try drawing with the sunscreen- you can write hidden messages!
- Combine this with highlighter pens- you should be able to block fluorescence.
- Try not to use too much sunscreen -it's pretty expensive...

=============== **Bits of an old explanation- should all be in section above!**

I start off trying to get the idea across, that UV is a colour, but you just can't see it..

What colours are there in a rainbow? -> ROYGBIV..

Have you thought that there might be some other colours that you can't see? If they are older ask them if they have heard of infra red, microwaves, radio waves, X-rays, UV -> they are all colours of light that your eye can't see

Mention that bees can see UV- they seem to get a kick out of this. Some flowers that look plain white to us literally have landing stripes on for bees.

Explain that the tube gives off UV and show them what happens when you put the paper in the UV. This is because when UV hits the paper it gives it some energy, which it can release as blue light...

Do you know what UV does to your skin? normally they don't

What happens to your skin if you stay out in the sun too long -> sunburn -> Due to UV Sun cream

What do you put on to stop you getting sunburnt? -> sun cream

What do you think it does to the UV? -> Stops it

What do you think will happen if we put sun cream on the paper? Quite often they work out that it won't glow

Get them to draw stuff on the paper with the suncream then put it in the UV light -> dark lines. Which I was impressed with the first time I tried it.

It's always more striking if you do the drawing-on-the-paper-with-suncream in the light (take them outside the darkroom) and then bring the paper in... in the darkroom it's harder to see how little difference the suncream makes to visible light. Which I (and lots of parents) think is really cool... sometimes I manage to convince the kids, too. If you've got a group working round the darkroom experiments it's worth being aware what they've already had demonstrated to them, as if they've seen, say, polarised light, they should (OK, might) have some idea about what (you want them to tell you) light is.

Fluorescent things

Get them to play with the highlighter pens (they are much more impressive on paper or cardboard that doesn't glow) Glow sticks get their energy from a chemical reaction rather than UV, if you give them energy from UV they will still glow though Paper money and driving licences (security marking)! Driving licences also have patterns only visible in UV.

Links to IR

This experiment often links well if placed near IR or demonstrated as a pair. You'll find the lights in IR can be too bright to see UV florescence. If separate demonstrations try and place slightly further apart or use the boxes as a screen otherwise switch them off as you move across.

Risk Assessment

Hazard: UV light

Description: Skin/eye damage.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Use LED light, which is less harmful, so much less harmful light. Warn users not to look directly at it. (The old Mercury tube, if used for some reason, is fairly soft UV and was on sale to the general public so the wavelength is at the safer end of the UV spectrum. The experiment is set up so that it is not easy to look directly at the UV light). Avoid prolonged skin exposure. In the event of an accident, call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Electrical cables

Description: Trip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Place wires sensibly (not across middle of room), and put the UV light in a place it is not likely to get trodden on. Tape down if necessary. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Washing powder

Description: Risk of ingestion of washing powder sample, or getting it into eyes.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Washing powder to be kept in a sealed clear plastic tube. Call first aider in event of injury, who may perform an eye wash if trained and confident to do so.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Tube containing mercury.

Description: Tube could break and release mercury. (Mercury tube not used regularly now, but still exists, hence this is still here)

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Tube is inside the light box to protect it. If lamp becomes broken, keep the public well away from the area, and ventilate area where breakage occurred. Take usual precautions for collection of broken glass. Do not use a standard vacuum cleaner for cleaning up dust; instead, pick up pieces/dust with a damp cloth or damp paper towels. Place materials, including the cloth/towels, in a sturdy closed container to avoid generating dust. After you have picked up all that you can, then vacuum the area. Finally, ventilate the room where the breakage occurred.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Sun cream

Description: Some people have an allergic reaction to sun cream. Avoid getting in eyes.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: If children want to put sun cream on their skin, first make sure that they've previously used sun cream without allergic reaction. Call first aider in event of injury, who may perform an eye wash if trained and confident to do so.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Glow stick chemicals

Description: Risk of ingestion of split glow stick - chemicals can cause irritation to skin and eyes and vomiting if ingested.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Don't let children repeatedly play with and bend glowsticks. Make sure anyone in contact with the glow stick washes their hands immediately and clear up spillages before continuing. Call first aider in event of injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2012-01-02 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-03-13 - Anna Kalorkoti (anna.kalorkoti@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

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Vacuum Bazooka

Firing a projectile using a vacuum cleaner and a long tube. - Experiment with launching projectiles using the power of a vacuum cleaner.

Last initially checked on 2023-02-17 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Electricity needed**
- Vacuum cleaner
- PVC Sections
- Joining Pieces
- Small projectile, wrapped in bubble wrap.
- (More projectiles can be made by screwing up paper and wrapping in duct tape, filling balloons with rice and putting in more balloons or using pipe insulation.)

Experiment Explanation

Fire a small, light projectile up to 10m using a Vacuum cleaner and a length of tubing. To fire a projectile place the piece of card over the end closest to the T bend and add the projectile from the other end.

The projectile is accelerated along the tubing by the pressure difference generated by the Vacuum cleaner and shoots out of the end of the tubing. We need the card to create a seal at that end, the card is too big to travel towards the vacuum but the air pressure holds it in place. When we add the projectile we fully seal the tube. The increased air pressure out side the tube pushes the projectile along, accelerating it towards the vacuum cleaner. When it reaches the T junction it continues going straight on, with enough force to knock off the piece of card and fire out. It keeps on going instead of being sucked back because it's gained momentum from the acceleration, and the brief force from the vacuum once it's passed isn't enough to stop it.

Another good intro to this experiment is through what is this (point at vacuum cleaner), what is it for, how does it clean... Eventually you'll make your way onto suction and then you can get people to feel the suction force from the ends of the tube, you'll notice that it's stronger closer to the split junction. If you seal an end using a piece of card it becomes stronger at the other end. This leads on to putting projectiles in with and without the end sealed. Without the seal it won't fire as there's not enough suction, but be careful, as soon as you seal the alternate end it'll fire out.

You may want to talk about why it's not sucked back into the tube, most of the projectiles would actually fit but don't go that way. One thing you could do is extend out of the front of the T bend, this will lead to projectiles being sucked back though which is a bit annoying but may help some groups. You can also talk about turning corners, in a car (most) people slow down to turn, this is because you need to change the direction in which the particles momentum is, this requires a force which we don't have. Similarly running round a corner and why in the 400m there are wide corners, wide corners means a more gradual change in momentum.

____ LOTS OF PARTICLES LOTS OF PARTICLES /----------
LOTS OF PARTICLES|------------| ------------------> Force LOTS OF PARTICLES ----------/ LOTS OF PARTICLES
____ / air escapes here / ________

There are more particle collisions on the left hand side of the ball than the right due to the vacuum cleaner reducing the pressure on the Right hand side.

Particle Theory A good way to start (I think, depends on the age group) is often good to ask what the surroundings are made of, solids liquids gases etc, and introduce the idea of particles (kids, even young ones may have heard of atoms or molecules). You can talk about how particles behave in each state of matter, and then start to focus on the air around you. Many kids will know the names of the gases that make up the atmosphere, so thatâ€™s a nice question to ask, then you can explain that you get lots of these gas particles zooming around, but that you canâ€™t normally feel them. Example, wind blowing you backwards. You can also explain that many, many particles bump into you each second, but because you're used to it you don't notice (and your body has evolved to deal with it, if they're old enough to know about evolution). Maybe make a comparison, such as a bag of flour (1kg) on an area the size of a postage stamp (1cm^2).

Projectiles There are lots of things we can talk about in optimising how the bazooka fires. Swapping to a more powerful vacuum cleaner will increase the muzzle velocity and hence the distance travelled. Why? Because this increases the pressure difference created in the tube. What about swapping the piece of card for a better seal? Well this would be good for increasing the pressure difference but it depends on how easily the projectile can knock it off when it fires out, we lose some energy (and hence speed/distance) by knocking it off. My theory is that this is probably worse. What about changing the angle you hold it at? If they've seen the trebuchets experiment or know some mechanics they may have some ideas about a slightly upwards angle being good for distance. However with the vacuum bazooka we have gravity also playing a roll. Firing directly downwards will obviously increase the muzzle velocity and I doubt firing directly upwards will work. You could do the maths and figure out the optimum yourself before demonstrating and write it here. Projectile weight is another variable, this one should also interact with the above. Demonstrating outside you'll find the crosswind probably means slightly weightier projectiles get blown about less hence fly further. With less wind the lighter the better, unless you're firing downwards from a vantage point. These should be tested on the bazooka and see what happens.

Also see the Vacuums experiment which can be paired with this one.

Risk Assessment

Hazard: Projectile

Description: People being hit, and potentially injured, by the projectile and/or PVC tube. Also possible damage to surroundings.

Affected People: Mainly persons not part of the experiment

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Demonstrator should maintain control of the direction the bazooka is firing in. If not holding the firing tube the demonstrator should have the projectile, end stop or both in his/her possession at all times to prevent bazooka being fired by anyone else. Bazooka should be sited to allow it to be fired along the room into a wall or (ideally) curtain, such that people who are not involved in the experiment cannot accidentally walk through the area, and so that those that are participating can be excluded from the firing area during firing. Projectile should be composed principally of light-weight packing material or similar (such as bubble wrap). It may be desirable to weight the front end with blu-tack or similar to encourage predictable flight but this should be done with consideration for the total resulting weight. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Hazard: Electrical parts

Description: See electrical parts RA.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Follow electrical parts RA. In the event of an accident, call a first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Electrical cables

Description: Trip hazard.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Place wires sensibly (not across middle of room). Tape down if necessary. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Risk Assessment Check History

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

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Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

Check 1: 2017-01-15 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2017-02-02 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

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Check 1: 2023-02-17 - John Leung (cfl35@cam.ac.uk), **Check 2**: 2023-02-18 - Asmita Niyogi (an637@cam.ac.uk)

Vacuums

Various demonstrations using a vacuum pump. - The idea of a vaccum is very different to what we experience in everyday life, with some surprising consequences!

Last initially checked on 2023-02-05 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-02-05 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Electricity needed**
- Vacuum pump (belongs to Dave)
- Magdeburg hemispheres.

Experiment Explanation

Particle Theory

A good way to start (I think, depends on the age group) is often good to ask what the surroundings are made of, solids liquids gases etc, and introduce the idea of particles (kids, even young ones may have heard of atoms or molecules). You can talk about how particles behave in each state of matter, and then start to focus on the air around you. Many kids will know the names of the gases that make up the atmosphere, so thatâ€™s a nice question to ask, then you can explain that you get lots of these gas particles zooming around, but that you canâ€™t normally feel them. Example, wind blowing you backwards. You can also explain that many, many particles bump into you each second, but because you're used to it you don't notice (and your body has evolved to deal with it, if they're old enough to know about evolution). Maybe make a comparison, such as a bag of flour (1kg) on an area the size of a postage stamp (1cm^2).

Note - the next two sections are included for info only, as we don't have the equipment to do them

Weighing Air

Does air weigh anything? Most kids (and adults!) will answer no to this question when asked it straight off, it links in quite nicely with the hot air balloon experiment where we argue that it floats because some air gets forced out of the bottom of the balloon making it lighter. Have a discussion about the difficulties in weighing air. A good analogy is a swimming pool; if you try to lift someone in the pool they feel much lighter than in the air. There may be a plastic pint glass on a piece of string in the box; so if you have a bucket of water you can test the weight of a glass when it is:

1. Empty, hanging above the water.
2. Full, hanging above the water.
3. Full, hanging in the water.

Get a volunteer to say heavy/light in each case. This should get across the idea that when you weigh something the surroundings matter. Now you can measure the weight of air itself. Take the plastic Vacuum chamber and put it on the scales. You can tare them to zero if you want, but this leaves you with a confusing negative mass measurement. Attach on the tube and then get someone to read the mass off, make sure no-one is touching it/leaning on the table too hard! Turn on the pump and (hopefully) they should see the mass go down by around 10g. (be very clear about what the pump is doing...lots of kids will be confused and think it's pumping air in rather than out!) Talk about how heavy this is, try weighing a marker pen/bunch of keys for comparison. So air really does weigh something!

Expanding balloon

Put a partly inflated balloon into the chamber. Evacuate the air from the chamber and see the balloon expand. Open the tap and it will shrink again (and if you do it too fast, it will shred into lots of pieces to the amusement of all).

Talk about why this happens. No air can get in or out of the balloon, there are always the same number of particles inside it. Can talk about particles bashing against the inside and the outside of the rubber, when you remove them from the outside the balloon can expand more easily. You can even use a child tapping the palm of your hand on either side to demonstrate the point that if the tapping on one side gets taken away your hand moves. For a cheap "urgh!"; what would happen if I put you into a Vacuum chamber?

End of non-experiment section

How strong is the Vacuum?

The other two experiments will have got across the idea that a Vacuum sucks things. Can talk about how this links in to Vacuum cleaners, which use pressure differences to suck up dirt (this is probably the only place they will have heard the word Vacuum before). Don't let them try to pull the lid off the plastic chamber (though they can put fingers on the end of the tap to feel the sucking effect!), but we have a metal Vacuum chamber that they can pull at hard! Evacuate it and let everyone have a go at pulling it apart. Can talk about the fact that you're fighting to pull against the millions and millions of air particles all bashing against the outside pushing it together.

Vacuum Bazooka

This leads nicely into the Vacuum bazooka experiment, which has a separate explanation/risk assessment (and can't be done in confined spaces!).

Risk Assessment

Hazard: Chamber

Description: The chamber could implode, throwing things out, which could hit spectators.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Use a polycarbonate desiccator as the chamber, as polycarbonate doesn't shatter. Check chambers for damage before using them. Don't put things inside the chamber. Can also use a metal vacuum chamber as this will not implode Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Oil mist

Description: The pump will produce oil mist in the exhaust. Could cause problems for audience and long-term exposure for demonstrator.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: The exhaust from the pump is fitted with an air filter. If someone expresses discomfort (e.g. feels sick/dizzy) stop using the machine. Use outside / in a well ventilated area if possible. In the event of an accident/adverse reaction call a first aider.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Pulling the chambers apart

Description: Risk of falling over when two people trying to separate vacuum chamber by "tug of war" method (especially if unexpectedly successful).

Affected People: Visitors taking part in "tug of war" and anyone close by

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Don't allow "tug of war" in a confined space/area with risk of bumping into sharp objects/other hazards, sometimes best to make both parties sit down first. If group is (showing signs of becoming) over excited best for demonstrator to hold one end of the chamber to maintain control Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-01-14 - Richard Ingham (richardingham@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-01-10 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2014-01-22 - Brett Abram (ba305@cam.ac.uk)

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Check 1: 2016-01-03 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

Check 1: 2017-01-15 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2017-02-02 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2018-01-04 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-02-04 - Esmae Jemima Woods (ejw89@cam.ac.uk)

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Vortices

Make smoke rings and see how they form - Experiments with smoke rings and tornado formation.

Last initially checked on 2023-01-12 by Jamie Barrett (jb2369@cam.ac.uk) and double-checked on 2023-01-13 by Chiara Delpiano Cordeiro (cd796@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **This experiment can take place outdoors**
- **Darkroom needed**
- **Electricity needed**
- 2 Vortex cannons + spares
- Polystyrene Cups
- Power supply for the smoke generator
- Smoke generator
- 2 Water bottles, food dye and vortex tube connectors for bottles
- Canned smoke (for busking/floating)
-
- ---------With Tom W bought for CBS 2021----------
- 4 more bottle connectors
- An airzooka
- 25 silicone bracelets

Experiment Explanation

Overview:

This experiment exhibits vortices, in particular in smoke rings. and vortices in water flowing between 2 bottles.

Basic procedure and explanation:

CARE: Check fire alarm status of the venue - machine shouldn't produce very hot smoke so heat sensor shouldn't be affected however smoke detectors will be. Consider isolating alarms and the risk of doing so in that venue. Alternatively demonstrate outside. In the event that the alarm goes off, switch off power and follow standard fire procedure (as per venue RA). Open windows and doors to ventilate area.

This experiment is about smoke rings, but, to understand why they happen, it's best to start with something simple, like pouring water between two bottles. Have you ever noticed what water does when it goes down a plughole? Does it just go straight down? With any luck, your audience will have already noticed that it doesn't, but it's still useful to show them a simple vortex in action using the pair of bottles connected by a plastic connector. The water can't just go straight through (because air needs to go the other way), so it forms a vortex and thus air can go straight up through the middle. If you use a lot of water then you'll be able to see the air bubbles coming up followed by a jet of water.

One experiment you can do is compare two of these bottle setups. Add about 500ml of water to each bottle, the exact amount doesn't matter, however, you'll need the same in each to make it fair and if you add too much water then you'll struggle to get the vortex to form. I found 1L of water required a lot of swirling to get the vortex to form and people may think you're putting in energy to help it go down. You could always try and show this isn't the case by shaking one up and down to give it 'energy' but not help the flow. Then have a race as to which bottle will empty first, turn both bottles over and give one a swirl to encourage the vortex to form. The vortex should be noticeably faster. You may notice that the undisturbed bottle also forms a vortex eventually,

So far the cores of our vortices (whirlpools) have been roughly straight lines. It's possible to make a vortex the core of which bends back on itself in a circle. You can spin your hand in the air at this point - this demonstrates how awkward the thing is to describe without a real example! Fortunately, we have one - since air is a fluid, like water, we can make a ring of vortex in it. If we use smoke, we'll even be able to see it. This is what the smoke machine is for. Using the smoke machine plug in and hit the button, it has around 3 minute warm up time and high output so only switch it on for a couple of seconds. The vortex cannon should show some good smoke rings. You can also feel the force if you fire it at someone, try not to let people get carried away in a fight, this shows we can transmit force through the air. By stacking the polystyrene cups in a pyramid kids can try to knock them over from a set distance. See how far away this can be done, and note how slowly the ring moves. The smoke shows us this travelling. The sides of the hole in the vortex cannon slow down the smokey air near the sides more than that in the middle, and making a twisting movement all of the way round. This makes a ring of vortex - can you see how it's rotating?

Using a vortex like this we can transmit forces through a fluid over much longer distance than without. See how far you can knock down the cups from, do you think you could easily blow them over from this distance otherwise using just the air? Even if you had a hair drier or a fan to push lots of air it'd probably dissipate over the distance. The moving vortex ring carries the spinning fluid and like a wheel of a car lessens the friction and allows the inner fluid to travel long distances with little loss of mass and kinetic energy.

You can talk about how the smoke machine works. It pulls in the fluid from the tank and heats it causing it to vaporise and form a cloud. The fluid is a mixture of water and glycol or glycerine. You can then talk along the lines of phases of matter and the transition from liquid to gas. You can talk about why we can see the smoke but the normal gases in the air are transparent. This is because the sheer number of water droplets making up the smoke. Normally light is scattered slightly by gases in the air but because there's not that many molecules we can't really see it. The sheer number in the smoke means it's scattered a lot after only a short distance, hence why we can see it. It's a white colour as it scatters all wavelength equally. It's slightly grey because of some of the absorption from the other parts. (I think this is true at least.)

Other things to talk about:

Pipe smokers can make smoke rings, as can volcanos! You can also see air in water rings from dolphins and scuba divers.

Vortices in air occur in weather systems. Tornados are a particularly vivid example, but there are big, slow vortices as big as whole countries above us in the sky all of the time, determining the direction of the wind.

Eddy shedding and flag ripples are also interesting (apparently) but I don't know anything about them.

Test with another shaped opening by sticking a piece of card over the front of the airzooka, even if you try and do a square you'll find you either form nothing or still get a ring, this is the only stable solution. (If we break an airzooka it could be worth hot knifing it to form a permanent square zooka)

The ring is stable as air in the centre of the vortex is moving faster than the air at the edges, this causes a twisting motion. This shape is stable as fast air is at a lower pressure so in relation to the stationary air at higher pressure there's a force keeping it in a ring. When it slows the pressure difference decreases and the ring expands as the pressure in the ring increases.

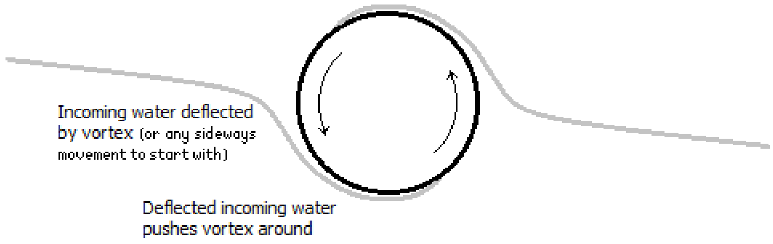
If you touch the ring it breaks as it's a big disruption to the stability.

You can attempt to get them to interfere and can see some repelling (not sure why it happens though) they can theoretically merge or destroy too but hard to do. The best way to get them to merge seems to be having two people stand next to each other and both fire forwards and slightly together at the same speed. You need the rings to meet along the same plane and spinning in the same direction to interfere constructively.

There's also no net movement of air, think about what this would do to the pressure, air just rotates around the vortex. The smoke is highlighting the forward flow: were we to fill the room with smoke and fire clean air vortices, we'd see reversed motion of smokey air. To try and demo this I have some silicone bracelets, if you imagine these are the smoke ring and then try and roll them along your wrist you'll see that the bracelet spins as it moves.

Apparently, you can generate smoke rings by shaking an incense stick. You can also do this at home with a coke bottle, a balloon (or small cardboard box) and an incense stick.

In future, we could add a simple plug hole demo to this. Just a waterproof slope with a plug installed and a bucket underneath. You should then be able to disprove some common myths about plugs always draining (counter)clockwise in the northern hemisphere by just doing it a few times. The direction is influenced by the initial angular momentum that gets imparted into the system



Risk Assessment

Hazard: Water

Description: Spilt water could be a slip hazard

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clear up spills promptly. Make sure the bottles are firmly connected before inverting. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Water

Description: Spilt water could be dangerous if there is electrical equipment nearby.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 4, Overall: 12

Mitigation: Clear up spills promptly. Isolate electrical equipment from the mains if it may have been affected. Try not to spin the water bottles close to the smoke machine, for example. In the event of an accident call a first aider. Switch off power supply to any equipment causing injury. See electrical RA

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Cups

Description: Knocked over cups could be a trip hazard

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Pick up cups if scattered everywhere. Don't let people run around. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 4

Hazard: Canned smoke

Description: Canned smoke is flammable.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Ensure it's kept away from naked flames, do not allow the build-up of too much smoke in an unventilated area (e.g. the darkroom tent!). In case of fire, follow standard procedures for fire (see venue RA).

Evacuate area, use fire extinguisher only if safe to do so, call fire brigade.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Smoke machines

Description: Smoke machines are hot during operation and can cause burns if touched or may cause damage to other things.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Move using the yoke (hanging bracket) if necessary. Place on a heat resistant surface. Let it cool down periodically. If burns occur run under tepid water. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Hazard: Smoke

Description: Smoke/haze can cause irritation to the lungs and problems for asthmatics.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 4, Overall: 16

Mitigation: Minimise time machine is on for. Use in a well-ventilated area. Swap demonstrators on the experiment if required and warn spectators. Avoid breathing in the fumes. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Smoke

Description: Excess smoke can affect visibility, increasing the likelihood of other accidents (falls, burns, etc.)

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Do not run the machine for extended periods of time. If smoke becomes too thick increase ventilation and cease demonstrating. Switch off power and call first aider in case of injury. In very poor visibility evacuate as if there were a fire (as per venue RA) opening windows and doors were possible to ventilate area.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2018-01-04 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-02-04 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2019-02-05 - Josh Garfinkel (jlg70@cam.ac.uk), **Check 2**: 2019-02-05 - Conor Cafolla (ctc43@cam.ac.uk)

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Check 1: 2021-01-20 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2021-01-20 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-09 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-09 - Peter Methley (pm631@cam.ac.uk)

Check 1: 2023-01-12 - Jamie Barrett (jb2369@cam.ac.uk), **Check 2**: 2023-01-13 - Chiara Delpiano Cordeiro (cd796@cam.ac.uk)

Water Fibre Optics

Constraining light in a stream of water, making it work like an optical fibre. - Find out what happens when light is trapped inside a stream of water. Make a beam of light bend round corners and see how fibre optics are helping to change the world!

Last initially checked on 2023-02-18 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Darkroom

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **Darkroom needed**
- Large bucket
- Lemonade bottle with a hole drilled in it
- Torch (the more powerful the better)
- Optical Fibre Christmas Tree
- 1m length of 3mm Optical Fibre
- Glass Bowl (Steal from Oli+Pyrex)
- Spoon

Experiment Explanation

Borrowed from Dave's Naked Scientists explanation:
http://www.thenakedscientists.com/HTML/content/kitchenscience/exp/water-fibre-optics/

In a nutshell

A stream of water is used to bend light and demonstrate how fibre optics work.

What to do

1. With the bottle empty, ask where they expect the light to go when the torch is switched on. Most will say in a straight line. Show them they are correct - it's useful to have a wall to point the torch at.
2. Put your finger over the hole and fill the bottle up with water.
3. Shine the torch through the bottle at the back of the hole.
4. Remove your finger from the hole and move it down the stream of water, showing how the light no longer travels in a straight line.

If you can, put a short straw into the hole - you'll get a smoother flow of water than just through the hole alone.

You should notice a spot of light on your hand while it is in the stream of water even though it must have gone around a corner to get there. It tends to work best when the water comes out quite slowly.

What you need to know during the experiment

To understand what is going on here it helps to do another experiment. Fill a transparent bowl with water, put something in the bowl and then look upwards at the bottom of water.

If you look at the bowl from the top you can see the spoon at the bottom.

Looking upwards in the bowl of water you see a reflection of the spoon from the surface of the water. The water is behaving like a mirror.

So light will reflect really well off the inside surface of water at a relatively small angle.

This means that if you shine the light into a tube of water whenever it meets the side it is reflected so the light stays within the water until it hits your hand lighting it up. This happens even if the water goes around a corner.

We say there is total internal reflection if no light is refracted.

Want to know more?

Why do you get such a good reflection from the surface of the water?

Light goes more slowly in water than in air and whenever light changes materials and the speed changes it will be bent (refracted). When it moves from a slow material (like water) to a faster one (like air) it is bent towards the surface.

Optical Fibres

If instead of making the tube out of water you use very very pure glass and pull it to a thin flexible fibre, when you shine light in at one end it will come out of the other. By getting the right design of fibre the light can travel through up to 50Â km of fibre and still be detectable. You can then send signals through the fibre by flashing the light on and off again a bit like morse code, and if you can flash the light very fast you can transfer huge amounts of information. Speeds of data transfer can now reach 1.125 Terrabits per second (2016) down a long-distance optical fibre connection (http://www.ucl.ac.uk/news/news-articles/0116/110216-fastest-data-rate-record). Because they are so good at transmitting data optic fibres move most of the data around the world (internet traffic, phone calls etc.) and you are almost certainly reading this via one.

If you make the tube out of plastic rather than glass it is more flexible and safer, and you can use it to make the artificial Christmas trees with the tiny pin pricks of light.

In the box there's also a length of optical fibre which can be used to show exactly how they work, but be careful with it as it is fragile. Optical fibres have become very common and cheap and many products use them, some artificial Christmas trees use them so the end glows. Some have side glow as well, this happens when there isn't total internal reflection and some light is still refracted.

Risk Assessment

Hazard: Water

Description: There is quite a lot of water involved, so if a surface is vulnerable to getting slippery when wet it could be a slip hazard.

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Clear up any spills. Use wet floor sign if necessary. It may be worth laying down newspaper in the area around the bucket. Try to do the experiment so as to minimize the amount of water getting on the floor in the first instance. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Bucket of water

Description: If using the large bucket of water, note that it is very heavy to carry - could cause back issues and/or is susceptible to drop and spill water everywhere, leading to the risks described above.

Affected People: Demonstrator

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Take care when carrying the large bucket of water, and seek assistance if necessary. If it is too heavy, only fill it as much as you need to fill the lemonade bottle. Use standard lifting techniques (e.g. lift with your knees, not your back) when carrying heavy objects. Clear any spills either as a result of outright dropping the bucket, or from water sloshing out during transfer of bucket. In the event of an accident call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Torch

Description: Electric shock risk with water.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Torch should run on a low voltage (<12 V). Electrical torch to be well insulated from water - protect bodywork and bulb area. Take care not to drop the torch in the water. Turn off torch if in contact with the water. Call a first aider in the event of an accident.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Optical fibre

Description: Optical fibre could smash, creating glass shards and cutting people.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Careful handling of the fibre and not to allow children to play with it. Clear up any broken fibre quickly and dispose of it appropriately. Close the experiment if the fibre smashes. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Torch Shone into eyes

Description: Torch shone into eyes may dazzle people or be damaging to eyes.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Do not shine torch near people's faces and warn children/visitors not to do so if they are using it. Using an LED torch - as these are typically low power and do not pose a risk to sight - would be desirable if possible, though natural aversion should be sufficient in most cases to avoid damage. In the event of a person being dazzled by lights, switch off lights and get them to sit down until they have recovered. Check they are ok before letting them walk around in case they walk into something!

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-01-14 - Richard Ingham (richardingham@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-02-13 - Nunu Tao (nmt26@cam.ac.uk), **Check 2**: 2014-02-16 - Benjamin Lai (bl337@cam.ac.uk)

Check 1: 2015-01-05 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-25 - Tom Comerford (tafc2@cam.ac.uk)

Check 1: 2016-01-04 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

Check 1: 2017-01-15 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2017-02-02 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2018-02-03 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2018-02-04 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2019-02-03 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2019-02-05 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2020-01-30 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2020-01-30 - Beatrix Huissoon (beh37@cam.ac.uk)

Check 1: 2021-01-20 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2021-01-20 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-09 - Maggie Goulden (mcg58@cam.ac.uk), **Check 2**: 2022-02-09 - Margaret Johncock (mllyj2@cam.ac.uk)

Check 1: 2023-02-18 - Peter Methley (pm631@cam.ac.uk), **Check 2**: 2023-02-18 - Asmita Niyogi (an637@cam.ac.uk)

Water rockets

Launching lemonade bottle water rockets with a foot pump. - Try not to get wet as you fire water-powered rockets into the air. Who can shoot it the highest?

Last initially checked on 2023-02-18 by Andrew Sellek (ads79@cam.ac.uk) and double-checked on 2023-02-18 by Peter Methley (pm631@cam.ac.uk).

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Physics

Equipment Needed

- **This experiment can take place outdoors**
- Pump.
- Bung with hole or with valve.
- Rope
- Launching base.
- A selection of lemonade (or other fizzy drink) bottles
- Lots of water in a large container.
- Preferably another bucket for filling the container.
- *The box also includes some of Dave's 'professional' water rockets, but we currently do not have the right pump for them and these bottles will hurt more if they hit people! For now, the 2L drinks bottles and the old launcher works better*

Experiment Explanation

Setup

Set up the rope running from the launch area to a higher point (raising the launch area, e.g. blocks, can keep the rope above head height) - run the rope through the tube attached to the bottle. Jam the bung in the bottle and get kids to pump until the rocket launches up the rope. Hopefully it should come back down to somewhere you can grab it. Keep people out of the area where the rope is so that they don't get hit by the rocket or walk into the rope!

As a further point - it can very occasionally be done without the guide rope pointing vertically upwards, or without a guide rope at all. This is suitable in large sports halls or outside only. Here care needs to be taken that a large enough area is cordoned off so that it does not hit anyone when it returns to Earth. If a guide rope is not being used, it can still be helpful to attach a rope to the rocket, in order to limit its range (such as to avoid hitting people) or to aid retrieval.

Explanation

Water rockets are great fun. Everyone wants a go, from 3 to 13 - and the teenagers and adults too, if they are brave enough to admit it. The does mean that you'll always have a queue and so an interactive discussion is difficult to achieve: on the upside, they'll be back for another try. I always try to remember the faces to keep a line of questioning going from launch to launch. I question them before every launch on a couple of points and while questioning I always keep their rocket in my hand, it keeps their attention and stops a rocket from flying up your ass.

As a first question I always ask: "So how do you think it works?" Which is always a good starter and that gives you your level. If it's not a terribly bad explanation, generally I don't try and correct it or improve it and I let them launch their rockets. Each time they come back a couple more questions maybe a little demo. They very rarely listen to the children ahead of them, which is kind of stupid, but there you go.

Then I suppose I start to refine their understanding of how it works and try and get them to experiment. Trying the bottle, full, empty; the bung in hard, or soft - you have to fiddle this one as it is difficult to control. Indeed you have to fiddle the empty bottle too, you want it to go about 5 feet and catch it, otherwise it can go almost as high as with water.

You've got a couple of lines of questioning. Pressure is always a good one. You can relate it to the pump. As a kid I could never pump up my bicycle tyres, because I didn't push the plunger very far. That sort of inspires me down this line. You can put your thumb over the valve and get them to push down on the plunger, the further they push down the harder it gets. When they let go the air may push it up a little. So that's your basis for explaining what pressure is, how you raise the pressure in the bottle and how it pushes the bung out. Don't use density.

Older kids and adults may talk about molecules. When your talking about molecules you can raise the concept of molecules inside the bottle hitting the inside of the bottle. I quote how fast an air molecule moves, about 500 ms-1, so even though it's light it packs a punch. I crush the bottle, put the bung in and then pump some air in. The bottle comes back to its original state, so the air molecules hitting the wall have pushed it back into shape. Then invite an assistant to squeeze the bottle, it's soft, but as you pump more air in it gets harder and harder, because those air molecules are pushing back at you. It's not a way people generally see the world so it's kind of a fun thing to do.

As part of fully explaining how it works you need the water there to push the rocket up. Every reaction has an opposite but equal reaction. I put the question: "when you lean on a wall and push on it, does it push you back?" All ages generally say no. So on to the demo, lean forward and get an assistant to push on your hand as your wall; "Now, I'm pushing against him and he's pushing against me and I'm going nowhere, what do you suppose happens if he's stops pushing against me." Your assistant stops pushing and you pretend to fly forward. "So if you're pushing against a wall, it must be pushing back."

The more water you've got in the bottle the harder the air pushes it down and the bottle up. So the more water the higher it goes. Sometimes getting them to imagine throwing a tennis ball versus a boulder can help.

Next is the energy. Where is the energy stored? This can lead on nicely to all sorts of questions about conservation of energy and what forms of energy are being converted from launch to launch. So the more air the higher it goes.

There seems to be a catch 22 situation. Of course it means there is an optimum and this is an important scientific concept in itself. Remember the heavier it is the lower it goes as well. This is all worth expanding on, especially with adults and at this point I may sweeten the pill by saying that on tour "we" settled down to try and work out what the optimum amount of water is, four sides of maths later we still hadn't solved it. The mathematics of how these bottles launch is more complicated than NASA rockets as the thrust changes over time.

The next bit is the bung. This is what really makes it go high or low. "If I push in the bung really hard will it go higher, lower, or not make a difference?"

I even ask the tots questions. I push some air into the bottle and say, "What are these?" Bubbles. "What's in a bubble?" Air, relate to blowing a balloon, what is in a blow? Indeed what's air?

These are just some of the themes I question on and there are plenty more so you shouldn't get bored. Remember, be a bastard hold that bottle 'til you've got some science into, or out of, them.

Practicalities

Let them fill their bottles some way away, though you may want another bucket to make your own adjustments to the amount in the bottle. The area around the launch site gets very wet, so move on occasionally. Stay away from roads, people and roofs. Keep the queue back and make sure the rocket isn't angled towards their, or your, face. Bottles may get stuck in trees, that's half the fun.

If you're launching along a rope, you can engineer your setup so that most of the water goes back into the bucket on launch. This will save you some walking!

The more taut the rope is, the less friction the rocket will experience and the further it will go, so tie it to something strong and tie it tight!

Risk Assessment

Hazard: Bottle (projectile), epsecially if flown without rope

Description: Hitting people with the bottle

Affected People: All

Before Mitigation: Likelihood: 5, Severity: 3, Overall: 15

Mitigation: Keep people away from the rope (which the rocket travels on) by blocking off any area where the rope is below head height with chairs, hazard tape or similar. Make sure the person launching the rocket doesn't lean into its path (try to keep the pump as far away from the rocket as the hose will allow - we have lengthened the hose to make this job easier). Also locate the experiment sensibly, bearing in mind walkways that people will want to use in the venue, roads etc and wind direction.

If done without a guide rope, cordon off sufficiently large area to ensure it lands within it. Check prevalent wind direction as well by test firing the rocket before people come.

Wait until the surrounding area is fully clear before launching.

If using the rope to limit range, the areas in which the rocket might land (accounting for prevalent wind direction and lean of the launch stand) must still be cordoned off as there are two hazards - both from the rocket falling on someone and the trip hazard due to the rope.

It is the responsibility of the demonstrator to ensure that the area is clear and there is no chance of the rocket straying into the path of anyone.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Bottle (pressurised)

Description: Bottle exploding; debris might cause small cuts or fall on people.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Check bottle for cracks and other damage before use. Any damaged bottles should be cut or marked to show they cannot be used if they cannot be disposed of immediately. Only use 2L "fizzy drink" bottles (Coke, Fanta, etc.) not bottles for still drinks which are not (always) suitable for pressurising. In the event of an accident call a first aider.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Rope

Description: Walking into/tripping on the rope which the rocket travels on

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 2, Overall: 8

Mitigation: Area is fenced off to prevent people from getting too near the bottle, ensuring people do not get too close to the rope as well. Keep rope ends tucked away and off the ground if possible.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Hazard: Water

Description: There is quite a lot of water involved, which presents a slip hazard.

Affected People: All

Before Mitigation: Likelihood: 5, Severity: 2, Overall: 10

Mitigation: Do the experiment outside on a surface that can take water. If done indoors or on a surface which can get slippery, keep a mop close to hand and cordon off the area.

Call a first aider in the case of an injury.

After Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Risk Assessment Check History

Check 1: 2011-12-30 - Mark Durkee (mark.durkee@cantab.net), **Check 2**: 2012-01-14 - Richard Ingham (richardingham@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-20 - Richard Hall (rjh216@cam.ac.uk)

Check 1: 2014-01-17 - Zephyr Penoyre (jp576@cam.ac.uk), **Check 2**: 2014-01-23 - Vamsee Bheemireddy (vrb23@cam.ac.uk)

Check 1: 2015-01-05 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-25 - Tom Comerford (tafc2@cam.ac.uk)

Check 1: 2016-01-04 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2016-01-17 - Frances Victoria Western (fvw22@cam.ac.uk)

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Check 1: 2018-01-12 - Josh Garfinkel (jlg70@cam.ac.uk), **Check 2**: 2018-02-04 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

Check 1: 2019-02-03 - Conor Cafolla (ctc43@cam.ac.uk), **Check 2**: 2019-02-05 - Josh Garfinkel (jlg70@cam.ac.uk)

Check 1: 2020-01-10 - Esmae Jemima Woods (ejw89@cam.ac.uk), **Check 2**: 2020-01-20 - Beatrix Huissoon (beh37@cam.ac.uk)

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Check 1: 2021-01-07 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-07 - Lucy Hart (ljfh2@cam.ac.uk)

Check 1: 2022-02-09 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-09 - Margaret Johncock (mllyj2@cam.ac.uk)

Check 1: 2023-01-12 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2023-02-18 - Peter Methley (pm631@cam.ac.uk)

Waves at Boundaries (PLUS only)

A few demos of transmission/reflection of waves at boundaries - nan

Last initially checked on 2023-01-29 by John Leung (cfl35@cam.ac.uk) and double-checked on 2023-01-29 by Joshua Wu (jw2311@cam.ac.uk)

Tags

Active (Experiment has equipment that needs to be fixed)

Demo only (Demonstration type experiments and lectures, not suitable for assignment for standard events.)

Physics

Equipment Needed

- Oil and pyrex experiment (+ maybe lenses)
- Wave machine (requires tape, skewers, and small masses [e.g. jelly babies, plasticine balls])

Experiment Explanation

A few demos on the effects that boundaries have on propagating waves, the general theme being 'waves cross boundaries easily if the properties on either side match'. This demonstration is kept in its own box inside Oil and Pyrex, because that is what it will most commonly be used alongside.

Wave machine: Good for going over wave basics and the concept of wave impedance (how much force it takes to create a certain response from the moving object). Make by stretching gaffer between two tables, and evenly space skewers along it (it helps to mark the skewers' midpoints in advance). Stick another layer of tape on the top to secure the skewers, and put weights on their ends. The heavier and further away the weights are, the higher the impedance and the slower the wave will be.

You can play with skewer spacing and weight positions to vary the impedance and create boundaries. You should be able to reflect a wave of one of these boundaries, and the difference in wave speed should be noticeable. Note that the tape will stretch, and will need tightening every so often

The rest of the experiment is basically just Oil+Pyrex, and oven shelf.

Risk Assessment

Hazard: Skewers

Description: Ends of skewers could be sharp (could stab/cut people)

Affected People: All

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Don't set up in a high-traffic area (where people might walk through it), and make sure people don't lean in close. Ends of skewers have plastic on to reduce pointiness. Call a first aider in the case of an injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Swallowing sweets/marshmallows

Description: Audience could try to eat them, which is unsanitary.

Affected People: Public

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Keep an eye on children, and mention not to eat the sweets or Plasticine In the event that something is eaten, warn parents/relevant adult to take the child to the GP if ill.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Oil and Pyrex

Description: Assorted risks due to Oil and Pyrex demonstration.

Affected People: -

Before Mitigation: Likelihood: -, Severity: -, Overall: -

Mitigation: See separate RA for Oil and Pyrex. Follow procedures in Oil and Pyrex.

After Mitigation: Likelihood: -, Severity: -, Overall: -

Risk Assessment Check History

Check 1: 2017-02-12 - Tom Comerford (tafc2@cam.ac.uk), **Check 2**: 2017-02-12 - Thomas Webster (tw432@alumni.cam.ac.uk)

Check 1: 2018-02-06 - Jared Jeyaretnam (jaj55@alumni.cam.ac.uk), **Check 2**: 2018-02-07 - Fiona Coventry (fiona.coventry@cantab.net)

Check 1: 2019-01-07 - Josh Garfinkel (jlg70@cam.ac.uk), **Check 2**: 2019-01-27 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2019-12-28 - Lucy Hart (ljfh2@cam.ac.uk), **Check 2**: 2020-01-19 - Esmae Jemima Woods (ejw89@cam.ac.uk)

Check 1: 2021-01-21 - Polly Hooton (prh43@cam.ac.uk), **Check 2**: 2021-01-22 - Grace Exley (gae23@cam.ac.uk)

Check 1: 2022-02-09 - Andrew Sellek (ads79@cam.ac.uk), **Check 2**: 2022-02-09 - Maggie Goulden (mcg58@cam.ac.uk)

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CBS Talk 2023 - When Your Salad Finds You Tasty

CBS Talk about carnivorous plants

Last initially checked on 2023-02-19 by Isaac Howell (ih393@cam.ac.uk) and double-checked on 2023-02-19 by John Leung (cfl35@cam.ac.uk)

Frequency of use: n/a

Tags

Talk (Lecture to be given at CBS)

Active

Biology

Equipment Needed

- Projector and visualiser
- Slides
- Plant samples
- Interactive models of carnivorous plants

Talk outline

The aim is to try and involve the audience in moving the talk forward throughout, treat the talk as a â€˜call and responseâ€™ exercise. Each section will begin with a question and the content will be framed as answer to the question.

Begin and ask audience about their ideas about plants, ask about examples, known properties.

Ask audience about what they know about requirements for plants to grow (light, water, nutrients etc)

Change the subject to specialised plants (cacti for retaining water, etc) then introduce carnivory as a specialisation.

Talk about the variety of ways plants can trap animals (With practical demonstrations)

Talk about how these traits can arise from â€˜normal plantsâ€™

Questions

Risk Assessment

Hazard: Moving model of Venus Flytrap

Description: It closes quite quickly when activated, and can pinch a finger

Affected People: Demonstrator / Bystanders

Before Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Mitigation: Demonstrator be aware of this risk, and not let audience come near, or use it

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Model of sundew/pitcher plant

Description: Large model, can hurt people nearby, or break into sharp pieces when dropped

Affected People: Demonstrator / Bystanders

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Demonstrator should not put the model anywhere near the edge of the table, be careful not to wave hands near it

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Live carnivorous plant specimens

Description: Potential adverse reaction if touched, could trap finger

Affected People: Demonstrator / Bystanders

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Only the speaker (experienced with these specimens) should handle them, do not let any audience members near them

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2023-02-19 - Isaac Howell (ih393@cam.ac.uk), **Check 2**: 2023-02-19 - John Leung (cfl35@cam.ac.uk)

X-Rays

A collection of X-rays and other forms of medical diagnostic imagery. - Have you ever had an X-ray? Have you ever wondered how they work? Take a look at our collection of exciting X-rays and MRI scans, test your anatomical knowledge and diagnostic skills and find out about the physics behind the images.

Last initially checked on 2023-01-22 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2023-01-22 by Jamie Barrett (jb2369@cam.ac.uk)

Tags

Standard (A standard CHaOS experiment, useable for all hands-on events.)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Medicine

Equipment Needed

- **Electricity needed**
- X-ray light box.
- Collection of X-rays and MRIs.
- Kettle lead with 'right-angled' end that fits.
- Torch.

Experiment Explanation

- General - What is it? Do they know when are they taken (when someone might have a fracture) and where? Asking whether they know anyone who's had one or had a plaster cast can be a good way to start.

How do X-rays work? You can talk about the production of X rays to older kids - it involves very high voltages across metal, releasing photons which travel along and get stopped by things which are dense and/or which have high molecular mass (this is why calcium shows up, and explains blood being somewhat radioopaque because of its iron content - you can see blood in the heart, and you can also visualise it on CT scans, which are just X-rays taken at loads of different levels and cunningly put together). The X-ray film starts white and becomes black where the photons hits it, therefore non-dense things, e.g. gas, look black on film and dense things, e.g. metal, stay looking white.

Smaller kids will appreciate something a bit like light which can go through softer things eg. skin but not harder things eg bone, metal implants. Likening it to a shadow can be useful. Of course then explaining a barium enema can be tricky, but you could describe it as "special liquid which can be seen on X rays".

Basically, you can go through the X-rays however you like and develop your own spiel. Here are some ideas:

- Ask lots of questions, get them to work out what everything is for themselves (our skeleton can help with this). If they're young it will probably take them half an hour to work out what they're looking at.
- What are bones for? (support, locomotion, protection - see Skeleton explanation)
- Skull X-ray - why do we have big spaces in our skull? (decrease weight)
- why do some of the teeth look different? (fillings - can talk about x-rays not passing through metal)
- Chest X-ray - identify the bones (ribs, clavicles, spine)
- Identify the organs (big spaces are air-filled lungs, the thing in the middle is the heart - they're always amazed by how low and central it is)
- But X-rays go through soft bits? What is the heart made of? How can we see it on the X-ray? Do bones have metal in them? (calcium - they usually know this or will get it with prompts about why you should drink milk to keep your bones strong)
- What is the heart full of? Does blood have metal in it then? (iron - they may not know this).
- Hand and foot X-rays - did they know they have so many bones in their foot/hand? Get them to feel the bones in their palm. Compare their hands to Boris if he's nearby.
- Angiograms/enemas - can talk about using contrast (dense liquids) to highlight structures we wouldn't normally be able to see.

MRI images

- First point - these images were donated by a committee member, so they are not anonymised as all the radiographs (which are teaching images) are. This is fine - you just might need to know as we have in the past had members of the public tell us off for using identifiable images, but it's ok as we do have full permission!
- Compare with X-rays e.g. can see soft tissues - when might this be useful?
- How does it work? The machine contains an extremely strong magnet. This makes all the water molecules in your body line up in the same direction they may have played with compasses in magnetic fields at school). The machine then fires radio waves at the body. This knocks all the little spinning water molecules slightly out of line, but a different amount out of line depending on the type of tissue it's in. When the radio wave is turned off, the molecules all flick back to where they were in the magnetic field, releasing energy in different amounts depending on how out of line they were earlier. This energy release is captured by sensors and turned into an image.

List of Radiographs (correct as of December 2020):

Human:

1. Gastrointestinal Tract- double contrast (gas and barium)
2. Gastrointestinal Tract
3. Chest
4. Hands
5. Pinned Femur
6. Dislocated Shoulder
7. Left foot
8. Spinal cord at shoulder level
9. Pelvic Fracture
10. Knee- displaced patella
11. Forearm
12. Skull 2 views- radiodense (bright white) tooth = filling 15: Dislocated Elbow 16: Angiogram Lung 3xMRI of spinal cord

New batch of Animal X-Rays from Queens Veterinary Schools Hospital - these have had patient/owner details cut out and could rip along cutting lines so try to avoid this! (Jennifer's X-rays folder):

1. Dog, fractured right femur, urinary catheter in place
2. Dog, plate used to repair fractured femur
3. Dog, plate has been used to repair the fractured femur, urinary catheter in place
4. Cat, normal cervical spine
5. Dog, normal spine of a dog
6. Dog, normal thorax of a dog
7. Dog, leg extended. normal pelvis
8. Cat, fractured left femur
9. Cat, fractured left femur
10. Cat, internal repair of a fractured femur
11. Cat, domestic shorthair, external fixator on the tibia, rushpin technique on the femur to allow repair without damage to the growth plates
12. Dog, cranial cruciate ligament rupture- soft tissue within the joint, tibia is mildly displaced cranially. Also evidence of osteoarthritis.
13. Dog, TPLO (Tibial Plateau Levelling Osteotomy) used to repair the cranial cruciate ligament rupture
14. Dog, normal stifle for comparison
15. Horse, lateromedial radiograph, front foot and hind foot. Can see the shoes, nails attaching the shoes, phalanges, navicular bone, proximal sesamoids and the start of the metacarpus/metatarsus. Radiopaque hairline marker helps assess the angles within the foot and possibly help diagnose laminitis

Other animal X-rays in this folder (blue stickers):

2. Male dog angiogram - can ask about what the most important organs are (can see these as those with greatest blood supply), contrast these with limbs which have far less blood supply - important in reducing heat loss, and possible because there are no major organs in limbs and most muscles are proximal (meaning the distal limbs are mainly bone and connective tissue, which require very little blood supply)
3. Arteries of the head (dog and sheep) - can ask about why the brain needs such a good blood supply - very important organ with high energy and oxygen demand (one of the few organs which cannot survive any period of hypoxia - neuron cell death begins 4-6 minutes after blood flow stops). It also has many different large arteries going into the brain, as if there was only one and it got damaged/blocked this would cause death as brain tissue cannot survive long without oxygen (about 2-3 minutes). As it is, only a small area of the brain will be damaged - this is what a stroke is - as the other arteries will continue to supply most of the brain.

- Following on for this, can ask why the nose also has high blood supply (esp. clear in sheep) - smell is a vital sense for survival in both sheep (prey) and dogs (predators) and requires energy and oxygen to allow adequate sensitivity for their needs. The nose is also important in cooling blood going to the brain and heating air breathed out through the nose which allows thermoregulation.

9. Dog intestine and pelvis lateral view - black areas in abdomen are gas build up in intestines which is normal

Other Animal X-Rays in black case:

For the exotic ones there's an information sheet which shows which X-ray is which and tells you about the animals. There are pictures of the animals which line up with the X-rays, which is good for young children as they enjoy matching them up. There should be:

- Common marmoset
- European rabbit
- Joey kangaroo
- Pumpkinseed sunfish
- Frontsa cichlid (fish)
- Green tree python
- Western diamondback rattlesnake
- Infant green iguana
- Dwarf crocodile eggs
- Veiled chameleon
- Box turtle with eggs
- Red-tailed hawk
- Turkey vulture
- Leaf Frog

Others:

1. Puppy angiograms x2 dorsoventral and lateral views - same interesting points as dog angiogram, also have epiphysis at joints.
2. Cat Barium Contrast study - shows the presence of megaoesophagus = dilation of the oesophagus which means that most food cannot get to the stomach (instead will be regurgitated, will see weight loss because of this), can feed animals in special chairs that sit them upright like a human so gravity can help food reach the stomach.
3. Bird skull
4. Puppy pelvis - shows left hip displacement and growth plates
5. Dog intestines barium contrast study - shows food in stomach and poo in rectum

Risk Assessment

Hazard: Light box

Description: Electrical hazard from light box.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: See electrical parts RA (attached)

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Light box (fluorescent tube)

Description: Flicker from the fluorescent tube in the light box has the potential to induce seizures in individuals with photosensitive epilepsy.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Discourage demonstrators with epilepsy from choosing this experiment, and the public from staring too closely at the light box for prolonged periods. If they complain of feeling unwell switch the box off and advise them not to look at it further. Switch off the light box if necessary.

Call a first aider in the event of injury.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Hazard: Light box (weight)

Description: Possible risk of light box falling off table onto people.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 2, Overall: 6

Mitigation: Ensure that the light box is not close to the edge of the table and is in a stable position.

Call first aider in case of injury.

After Mitigation: Likelihood: 2, Severity: 2, Overall: 4

Risk Assessment Check History

Check 1: 2012-01-11 - Elizabeth Mooney (erm40@cam.ac.uk), **Check 2**: 2012-01-23 - Ashley Smith (ashley.smith@cantab.net)

Check 1: 2013-01-08 - Ophelia Crawford (oc251@cam.ac.uk), **Check 2**: 2013-01-24 - Jaimie Oldham (jlo40@cam.ac.uk)

Check 1: 2014-01-21 - Catherine Bi (catherine.bi@cantab.net), **Check 2**: 2014-01-27 - Sharmila Walters (sw632@cam.ac.uk)

Check 1: 2015-01-10 - Alisha Burman (arb95@cam.ac.uk), **Check 2**: 2015-02-12 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2016-01-05 - Charlotte Attwood (ca402@cam.ac.uk), **Check 2**: 2016-02-07 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2017-02-11 - Fiona Coventry (fiona.coventry@cantab.net), **Check 2**: 2017-02-12 - Andrew Sellek (ads79@cam.ac.uk)

Check 1: 2018-01-27 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2018-02-07 - Benjamin Akrill (bja32@alumni.cam.ac.uk)

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Check 1: 2023-01-22 - Jessica Trevelyan (jet81@cam.ac.uk), **Check 2**: 2023-01-22 - Jamie Barrett (jb2369@cam.ac.uk)

Xylem

Showing one of the transport systems in plants. - Combine food colouring with water transport in stem and flowers- you can then see where all the water goes!

Last initially checked on 2023-02-15 by Amy Migunda (aom36@cam.ac.uk) and double-checked on 2023-02-18 by Asmita Niyogi (an637@cam.ac.uk)

Tags

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Equipment Needed

- Need
- White carnations or gerberas (other white flowers might work, but these display colours nicely)
- Celery
- Food dyes (green tends to get lots of questions for flowers, red is best for celery)
- Scalpel (for preparation only, not needed in the demonstration)

Experiment Explanation

Xylem vessels in plants

Note: Sainsbury's own green food colouring does NOT work at all with white carnations (suspect all other flowers also). Silver spoon red food colouring doesn't work great with carnations. However the red did work well in celery. This was learnt at Cherry Hinton 2013. For future, we must try fountain pen ink or similar instead.

For single coloured plants: Add food dye to small amounts of water and add the plant stem (cut off a bit to speed up the process) â€“ leave for at least 2 hours, but the longer you leave them the better they look (possibly even overnight)

For multicoloured plants: Add different food dyes to different containers, and use the scalpel to slit the bottom ~5cm of the stem in half. Put the different cut parts in different colours, again leave for several hours (overnight isnâ€™t ideal for these as the cut stems dry out).

Celery: Cut a fresh end on the celery and put the end in red food dye (diluted with water). Leave for a few hours and it should have nicely highlighted the xylem vessels that you can then talk about in relation to the microscope slides.

Single coloured and multicoloured examples (green clearly highlights vessels very well):

Plants have â€˜circulatory systemsâ€™ just like animals

We need our blood vessels (like the veins you can see in your arms) to supply blood to all parts of our body.

Plants also have vessels but they donâ€™t transport blood, instead they transport water or sugar syrup.

Like we have veins to transport blood back to the heart and arteries to transport blood from the heart and around the rest of the body, plants also have two slightly different vessels. These are called â€˜xylemâ€™ and â€˜phloemâ€™.

Xylem vessels (red) bring things up from the roots to the leaves of the plant. Phloem vessels (blue) transport things to the roots from the leaves.

Xylem vessels transport water and anything that dissolves in water (what can you think of that dissolves in water?) This includes the food dye that we have added to the water â€“ and you can see how it has been transported up the stem and into the flower. Cross section through a plant stem

Discussion

If someone asks why the flowers are coloured, I would explain that the plants were able to move the dye colour in the water up into the flower (maybe use absorb, transport for older children).

I would then start with the analogy of circulatory systems in humans, get the children to find their veins, ask if they know why they are important â€“ for transporting important things like sugars for energy around the body â€“ talk about how when they eat food and it gets digested in the stomach, those sugars need to be transported to other parts of the body, for example their legs if they run. Then you explain how plants are no different â€“ they need to move different resources around their body too.

Next ask children where plants get water from (the ground), so how does it get all the way up to the top of the plant, even a really tall tree? Hopefully theyâ€™ll say they suck it up or similar. Then I would either compare it to a straw, if you suck on one end because you want a drink you lift the liquid up and the leaves need to get water, or for older children I might explain the evaporation part in the leaves, and with water continuously evaporating it needs to be replaced and creates a force to draw the water up. Then introduce them to the concept of xylem vessels if that seems appropriate. Explain that plants have specific â€˜veinsâ€™ to transport water.

So, how does the dye get there? I would move on to talk about water, and ask if they know that certain things dissolve in water, like salt or sugar â€“ hence you can get flavoured waters. Our dye is just the same, another molecule that dissolves/mixes with water, so gets carried along too. But it canâ€™t then escape the petals, so the colour stays there and create our coloured flowers.

If someone asks about multicoloured flowers â€“ then you can go back to the veins/arteries analogy and explain how different blood vessels in humans take blood to specific areas, and the same is true for plants.

If it seems appropriate, you can also talk about phloem, that transport things back down to the roots â€“ such as sugars that they make via photosynthesis (roots are underground, no light = no photosynthesis), and how this is similar to blood transporting sugars from our intestines to other parts of the body. At various points in the talk, you have the opportunity to bring in the microscope slides of xylem and phloem vessels (if they are available), doing so can draw more interest, and you can compare the size of what they can see in the celery to the size magnified under the microscope. Keen people/skilled people can create a microscope slide right there and then from the celery and put it under a microscope, although this requires a scalpel to be in the vicinity of the children and can be tricky to get thin enough!

Risk Assessment

Hazard: Scalpel

Description: Possibility of cuts.

Affected People: Demonstrator

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Warn demonstrator of risk, remove scalpel before public arrive. Call first aider in event of cut. If scalpel goes missing, assist demonstrator in finding it and inform committee.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Plant/food colouring

Description: Allergies to plant/ food colourings.

Affected People: All

Before Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Mitigation: Use food colourings easily available in supermarkets (non-toxic etc). Also source plants from consumer supplier. Advise the public not to touch. Call first aider if food colouring goes in eyes. Demonstrator can administer eye wash if trained and confident to do so.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Containing vessel

Description: Breakage of containing vessel resulting in cuts.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: If possible, use a plastic vessel rather than a glass one. Keep containers on a stable surface, away from the edge. Call first aider in case of injury.

After Mitigation: Likelihood: 1, Severity: 2, Overall: 2

Hazard: Water

Description: Spillage of water near power cables.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 4, Overall: 8

Mitigation: Set up experiment away from other power cords, have cloths/towels on hand to clear up spillage. In the event of spillage, ensure any electrical equipment within reasonable radius of the spill is switched off.

After Mitigation: Likelihood: 1, Severity: 4, Overall: 4

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

Check 1: 2013-12-26 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2014-02-02 - Raghd Rostom (rr415@cam.ac.uk)

Check 1: 2015-01-23 - Kym Neil (kym.e.neil@gmail.com), **Check 2**: 2015-01-24 - Chloe Hammond (cjh214@cam.ac.uk)

Check 1: 2016-01-07 - Natalie Cree (nc434@cam.ac.uk), **Check 2**: 2016-02-01 - Charis Watkins (czrw2@cam.ac.uk)

Check 1: 2017-02-09 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2017-02-12 - Fiona Coventry (fiona.coventry@cantab.net)

Check 1: 2018-02-02 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2018-02-07 - Sarah Wiseman (sw628@cam.ac.uk)

Check 1: 2019-01-20 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2019-01-21 - Amanda Buckingham (abb53@cam.ac.uk)

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Check 1: 2021-01-12 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk), **Check 2**: 2021-01-18 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-01-25 - Jessica Trevelyan (jet81@cam.ac.uk), **Check 2**: 2022-01-29 - Margaret Johncock (mllyj2@cam.ac.uk)

Check 1: 2023-02-15 - Amy Migunda (aom36@cam.ac.uk), **Check 2**: 2023-02-18 - Asmita Niyogi (an637@cam.ac.uk)

Yeast & bread making

The idea is to look at how yeast grows and how it relates to bread making. It involves getting the kids to make bread dough. - Like all the best biology experiments, this is hands-on and messy! See what happens when you add living yeast to a bread mix, and don't forget to come back a bit later to see what's happened to your dough!

Last initially checked on 2023-02-18 by Maggie Goulden (mcg58@cam.ac.uk) and double-checked on 2023-02-18 by John Leung (cfl35@cam.ac.uk)

Tags

Biology

Active (Experiment has working equipment at the time of last update, and is available for events.)

CBS only (Non-transportable experiments that tend to be used for CBS only.)

Equipment Needed

- Baker's yeast (a fair amount - we got through 3 of the tins of it last year)
- Flour 80g per child (lots!)
- Sugar (a couple of bags)
- Water (warm - will have to keep getting this from tap)
- Beakers/cups for cultures
- 500 ml plastic drinks bottles
- Balloons
- Trays to do experiment over to contain the mess
- Possibly somewhere for kids to wash hands as it gets a bit messy

Experiment Explanation

Key messages to get across about this experiment:

- Yeast is alive
- It gives off gas (carbon dioxide) when bread rises giving you bubbles in the bread

Suggested demonstration:

- Start with bread â€“ ask if they have ever eaten bread (hopefully a â€˜yesâ€™ but this should get them engaged with you as itâ€™s a simple question that they donâ€™t have to struggle to think about).
- Ask if they know what goes into bread; youâ€™ll probably get told that it is made from flour. Some may tell you about water and yeast.
- Ask them whether theyâ€™ve ever seen bread dough rise. It rises because of bubbles of gas. This gas is made by yeast.
- Show them some yeast and add about half a teaspoonful to some water and sugar in a plastic cup.
- Yeast is alive (itâ€™s a fungus) and when you add water to the dried yeast it starts growing again. Yeast are little round creatures (if the kids are old enough to know what a cell is, they have one cell) and they grow, getting bigger, and then a new yeast buds off the side of the old one.
- Inside bread there isnâ€™t much oxygen so the yeast canâ€™t breathe oxygen to allow them to produce energy like we do. Instead they use â€˜fermentationâ€™ of the sugar that you gave them. This produces a gas called carbon dioxide (and ethanol/alcohol). This gives the bubbles that you get in bread.
- Add flour to the water and yeast mix and get the child to mix them together to form dough.
- Did they notice how the dough went stringy as they kneaded/mixed it? Why is that? Flour contains some proteins that make gluten when water is added, and as you mix the dough these all line up becoming more stretchy. This traps the bubbles of gas made by the yeast so the dough rises.
- Mark the level of the dough on the plastic cup. Tell them to come back and look at it later, but also show them some from earlier that have risen. If parents want to take dough then they can (but donâ€™t encourage it), but stress that itâ€™s not edible because it was made in a lab.
- Ask if they want to see something else? If yes, have a look at the balloon demonstration.
- Put some warm water, sugar and yeast in a 500 ml drinks bottle
- The yeast will use the oxygen in the bottle first, and then start fermenting the sugar to produce carbon dioxide
- This will increase the volume of gas in the bottle and inflate the balloon

- You may need these on a â€˜conveyor-beltâ€™ system where you set one up with a group but show them the previous groupâ€™s one which is hopefully partially inflated.

Use trays as 'workstations' to contain the mess. Throw well-risen dough out after a few hours again to reduce mess.

Risk Assessment

Hazard: Dough

Description: Kids may eat the dough, which is not good, as the kids' hands will not be clean and it is in a lab.

Affected People: Public

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Stop kids eating the dough, and tell parents of small kids it isn't clean. If dough ingested inform parents and advise them to take child to GP if they become ill.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Wet/floury surfaces

Description: Slip hazard.

Affected People: All

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Clear up any spills immediately. Use containment trays for the experiment. Use wet floor sign if necessary. In case of injury call first aider.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Flour/yeast

Description: Possible risk of allergy to flour or yeast, potentially resulting in anaphylactic shock.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Demonstrators with yeast/ flour allergies should not demonstrate this experiment. Demonstrators must ask participants about allergies to flour or yeast before commencing experiment. In case of a reaction, call a first aider.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Plastic, tins etc.

Description: Risk of cuts from broken plastic, yeast tin lids etc.

Affected People: All

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Supervised use only. Demonstrator to dispense yeast and dispose of any broken plastic cups/spoons. In case of injury call first aider.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Balloons, flour

Description: Possible choking hazard if child tries to eat balloon or inhales flour.

Affected People: Public

Before Mitigation: Likelihood: 2, Severity: 5, Overall: 10

Mitigation: Keep only the balloons in use on display and make sure that children donâ€™t eat them, don't let children eat dry flour either and be careful not to knock it over and cause a flurry of flour dust. If child is choking, get parent to encourage child to cough it out and find first aider.

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Risk Assessment Check History

Check 1: 2012-01-17 - Michael Darling (md510@cam.ac.uk), **Check 2**: 2012-01-24 - Alex Davies (ad578@cam.ac.uk)

Check 1: 2012-12-28 - Beatrice Tyrrell (bet23@cam.ac.uk), **Check 2**: 2012-12-30 - Richard "Miffles" Mifsud (rwm41@cam.ac.uk)

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Check 1: 2016-01-07 - Natalie Cree (nc434@cam.ac.uk), **Check 2**: 2016-02-03 - Sarah Wiseman (sw628@cam.ac.uk)

Check 1: 2017-02-08 - Alfred Chia (ac939@cam.ac.uk), **Check 2**: 2017-02-09 - Matt Worssam (mdw47@cam.ac.uk)

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Check 1: 2019-01-24 - Amanda Buckingham (abb53@cam.ac.uk), **Check 2**: 2019-01-27 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2020-01-08 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2020-01-25 - Beatrix Huissoon (beh37@cam.ac.uk)

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You Rock My World: how the history of our planet is set in stone

Find out how rocks record stories from the past - CBS Talk first given by Peter Methley in 2023

Last initially checked on 2023-01-28 by Peter Methley (pm631@cam.ac.uk) and double-checked on 2023-02-18 by John Leung (cfl35@cam.ac.uk)

Frequency of use: n/a

Tags

Talk (Lecture to be given at CBS)

Active (Experiment has working equipment at the time of last update, and is available for events.)

Geology

Equipment Needed

- Collection of copper coins (from Cleaning Coppers)
- Ribbon marked with geological time scale
- Blu-tack to stick up ribbon
- Petrographic microscope with HDMI camera (borrowed from Earth Sciences)
- Selection of rocks and thin sections
- Projector and visualiser

Talk Outline

Introduction: rocks are Earthâ€™s oldest time capsules.

- They are billions of years old!
- They can record what was happening on Earth (Uniformitarianism: by seeing how rocks are created today, we know what processes have created similar rocks in the past)
    - Example of rippled sandstone?

What is a **rock**?

- Usually made of minerals (e.g. quartz; calcite)
- These can take the form of interlocking crystals, sand, mud, shells, etc.
- Some contain fossils: preserved bits of (or traces left by) living things
    - Life is the biggest thing that has changed over Earthâ€™s history

Oldest rocks are **meteorites** (older than Earth!)

- Can tell us how Solar System and planets form
- I might be able to borrow some from the Sedgwick if I ask nicely! Otherwise we have the iron meteorite in Rocks and Fossils
- *Demo*: Volunteer helps to pull out a coloured ribbon to compare age of earth with age of Homo Sapiens
    - Ribbon also has the other events marked? Wind up through talk to see how far weâ€™ve come?

Oldest rock from Earth is (debatably) **Acasta Gneiss** (4 Ga).

- Looks similar to Lewisian Gneiss (oldest rock in UK; 3 Ga) â€“ show under microscope, explain how crystals have grown due to heat and pressure: a metamorphic rock
- Earliest signs of life â€“ stromatolites, bits of organic carbon (made from photosynthesis?)

More convincing fossils in **Gunflint Chert** (2 Ga).

- Persuade Butterfield to let me borrow a slide?
- Life is still single celled, but by now has oxygenated the atmosphere

How do we know **how old** these things are, anyway?

- Find a zircon in biotite â€“ show radiation halo
- These crystals contain uranium â€“ ask audience if they know what uranium does.
- It decays into lead, and the longer you wait the more Pb you get and the less U is left
- *Demo of radioactive decay*:
  - Give everyone (that is responsible enough not to eat it) a coin from Cleaning Coppers. Use a clicker to count the number of coins given out (in zircon we would know this amount from mineral chemistry)
  - Those who do not have a coin represent initial amount of lead in zircon â€“ this is a known quantity from mineral chemistry.
  - Everyone who has a coin stands up â€“ they are uranium atoms.
  - Send an assistant out of the room so they do not know how many cycles we are going to do.
  - Pretend we have waited one half-life. Everyone flips their coin (parents can flip childrenâ€™s coins for them). If they get heads, they have decayed into lead and sit down.
  - Repeat this 2-4 times.
  - The assistant comes back in, and counts the number of people still standing.
  - Have an Excel formula ready to go â€“ we put in the initial number of coins and the number of people still standing and it should let the assistant predict how many half-lives have gone.

Back to rocks, and the story of life.

Ediacaran biota (600 Ma) are the first fossils of multicellular animals

- Discovered by schoolchildren in Charnwood Forest!
- See if I can get hold of a cast.
- Live in the rippled sandstone we saw â€“ imagine ancient beaches.

Then the **Cambrian explosion** (500 Ma) â€“ all the modern groups of animals suddenly appear (+ some v weird ones that are now extinct)

- See if I can get some Burgess Shale from Butterfield.
- Muddy deep sea!

Talk about interpretation of **Carboniferous cyclothems** (310 Ma) (if time)

- Ice ages â†’ low sea level â†’ swamps with plants decaying to form coal
- Ice melts â†’ higher sea level â†’ beaches and deltas

Chalk seas of **Cretaceous** (100 Ma).

- Sea level rise meant that much of continents are covered in shallow layer of water
- Plankton create tiny shells that form the rock (show SEM image)
- Fossils: ammonites, sea urchins, marine reptiles

K-T extinction (66 Ma):

- Layer of iridium and tektites suggests a meteorite impact
- Disappearance of ammonites and dinosaurs from fossil record.
- Explosion in mammal diversity afterwards

Back to **Homo sapiens** (300 ka)

- Fossils appear in Morocco
- Meanwhile, in the UK, boulder clay is being deposited â€“ what could transport giant boulders?
- We also get U-shaped valleys and rock surfaces with â€˜scratchesâ€™ on them from ice
  - Similar to what was seen in polar rocks of Carboniferous
- From weight of oxygen in tiny sea shells (foraminifera) we know that there has actually been about 30 ice ages in the last 2.5 Ma!

Present day: we are currently living in interglacial. If cycle continues then there will be another ice age in 100 ka or so

- But we might have broken it with COâ‚‚ emissions (show hockey stick)
- Life has been influencing Earthâ€™s geochemistry for billions of years (GOE, shells) but we are doing it faster than ever before!
- The â€˜Anthropoceneâ€™ will certainly be an interesting age for future geologists to study!

Risk Assessment

Ribbon Demo

Hazard: Volunteer moving around lecture theatre with ribbon

Description: Slips/trips/falls, especially if they are running or not looking where they're going.

Affected People: Volunteer

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Check area at front of lecture theatre is clear of trip hazards/general mess before the demo starts. Choose a volunteer who seems responsible. Tell them to walk carefully (not run or go up steps) before giving them the ribbon to pull.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Hazard: Ribbon

Description: Trip hazard after it has been unrolled

Affected People: Lecturer, Volunteers

Before Mitigation: Likelihood: 3, Severity: 3, Overall: 9

Mitigation: Attach ribbon to wall at both ends after unrolling. Check that it is still attached before moving around / inviting any volunteers.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Radioactive Decay Demo

Hazard: Coins

Description: Choking hazard if put in mouth

Affected People: Audience

Before Mitigation: Likelihood: 3, Severity: 5, Overall: 15

Mitigation: When giving out coins at the beginning, do not give to very young children who cannot be trusted to not eat them. Even for older children, give their coins to a responsible adult to look after them until the demo happens, and tell the adult to keep an eye on the coin at all times and to take it back after the demo. In case of choking, call a first aider immediately (they should already be on site).

After Mitigation: Likelihood: 1, Severity: 5, Overall: 5

Hazard: Coins

Description: Coins may be dirty and possibly carry diseases.

Affected People: Audience

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: Wash coins before starting. Tell people to wash their hands after touching the coins and before eating.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Flipping coins

Description: If people lose control of coins when flipping them, they might hit other audience members, or they may hurt themselves trying to pick the coins up again.

Affected People: Audience

Before Mitigation: Likelihood: 4, Severity: 3, Overall: 12

Mitigation: Responsible adults can flip coins for their young children. Tell everyone to flip their coins by clasping them in two hands and gently shaking rather than launching the coin into the air.

After Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Demo: Showing Rocks and Slides

Hazard: Rocks and Microscope Slides

Description: Rocks may be heavy and may break to produce dust / sharp edges (especially for fragile microscope slides) if dropped.

Affected People: Lecturer

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: No rocks used should be overly heavy. Lecturer should handle rocks and slides with care and keep over desk so they cannot fall on floor. If breakages do occur, wrap in paper towel and put in bag in safe location.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Hazard: Rocks

Description: Rocks may contain toxic compounds or contamination from previous handlers and cause illness if ingested.

Affected People: Lecturer

Before Mitigation: Likelihood: 2, Severity: 3, Overall: 6

Mitigation: No rocks used should contain overly toxic minerals. Lecturer (and anyone else who has handled the rocks) should wash their hands after touching the rocks and before eating.

After Mitigation: Likelihood: 1, Severity: 3, Overall: 3

Risk Assessment Check History

Check 1: 2023-01-28 - Peter Methley (pm631@cam.ac.uk), **Check 2**: 2023-02-18 - John Leung (cfl35@cam.ac.uk)