Animal Cognition

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

Last initially checked on 2024-02-01 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2024-02-14 by Timothy Wong (chw55@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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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 2024-02-15 by Lauren Mason (llm34@cam.ac.uk) and double-checked on 2024-02-15 by Lachlan Rooney (lgmr2@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.
- Get the 2 sheets of paper showing the eye with/without corrective lenses and tape the light boxes in the correct place.
- 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)

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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 2024-02-14 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2024-02-15 by Isobel Gilham (ig419@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 eye’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 you’re in a dark room need bigger pupils to get more light to see things. When you’re in bright light it need to be smaller to stop the light damaging inside your eyes. It’ 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 don’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.

- ‘Red-eye’ 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 it’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 they’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 – 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 it’s dark; this is so it absorbs the maximum amount of light

- In sheep’s eye there’s an iridescent coloured part, called the tapetum lucidum (‘bright carpet’ 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 don’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 friend’s cat/dog. Animal’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 you’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/dissection.

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: Raw tissue

Description: Risk of infection when open wounds are exposed to fluids from the eyeball or if fluids from the tissue are ingested.

**Affected People*: Demonstrator

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

Mitigation: Wear gloves and cover any wounds on the hands with a bandage. Wash hands before and after demonstration.

After Mitigation: Likelihood: 1, Severity: 4, 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 first 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)

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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 2024-02-01 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2024-02-15 by Isobel Gilham (ig419@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 below…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 – 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 – 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

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)

Check 1: 2013-12-25 - Richard “Miffles” Mifsud (rwm41@cam.ac.uk), **Check 2**: 2014-01-01 - Sarah Wiseman (sw628@cam.ac.uk)

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Check 1: 2017-01-13 - Alfred Chia (ac939@cam.ac.uk), **Check 2**: 2017-02-06 - Richard “Miffles” Mifsud (rwm41@cam.ac.uk)

Check 1: 2018-01-29 - Sarah Wiseman (sw628@cam.ac.uk), **Check 2**: 2018-02-02 - Richard “Miffles” Mifsud (rwm41@cam.ac.uk)

Check 1: 2019-01-09 - Amanda Buckingham (abb53@cam.ac.uk), **Check 2**: 2019-01-13 - 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)

Check 1: 2021-01-12 - Richard “Miffles” Mifsud (rwm41@cam.ac.uk), **Check 2**: 2021-01-22 - Polly Hooton (prh43@cam.ac.uk)

Check 1: 2022-02-09 - Jessica Trevelyan (jet81@cam.ac.uk), **Check 2**: 2021-02-09 - Sian Boughton (seb216@cam.ac.uk)

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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 2024-02-15 by Charlotte Marshall (csm69@cam.ac.uk) and double-checked on 2024-02-15 by Isobel Gilham (ig419@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)

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Giant Breadboard

Make circuits using giant components - Explore circuit basics, different components, logic gates, speakers, buzzers and build your own heat alarms and more.

Last initially checked on 2021-01-22 by Polly Hooton (prh43@cam.ac.uk) and double-checked on 2021-01-22 by Grace Exley (gae23@cam.ac.uk)

Tags

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

Computer Science

In development (This experiment doesn't actually exist yet, but might in the future!)

Equipment Needed

- **Electricity needed**
- Giant breadboard
- Selection of wooden components
- Material samples
- 4mm banana plug wires
- Spare banana plugs and components.

Experiment Explanation

This experiment is in the process of being made but hopefully will be useful for a wide range of circuit based experiments. I've bought the following pieces to make up the components. Opamps, transistors, capacitors, motors, solar panel, resistors, logic gates, timers, leds, diodes, thermistors, photoresitors, nickel wire heating element. I'd also like a dynamo for other power input but haven't got this yet and some links to electromag experiment. Idea is playing with circuits and building things. Plus aim could be an adder using logic gates, feedback devices using Opamps, fire alarm using themisotrs, light alarm using photresistors. There'll also be places where you can clip in materials to see how conductive they are, I have some bits of wood, perspex, nickel, and bits we can see how conductive they are. There's also an arduino nano which I've got and will link up if we wanted some really hardcore stuff to do.

Risk Assessment

Hazard: Power from dynamo/battery/power supply

Description: Electric shock

Affected People: All

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

Mitigation: Limit power supply to minimise danger

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

Hazard: Heating element

Description: Burns

Affected People: All

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

Mitigation: Keep power low and prevent children from touching the heating element. If a burn occurs run it under cold water for an appropriate amount of time.

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

Hazard: Wooden components

Description: Splinters

Affected People: All

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

Mitigation: Sand it down if splintery.

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

Hazard: Capacitors and other components

Description: Exploding causing parts to fly around and hit people.

Affected People: All

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

Mitigation: Don't use excessive voltage/current. Check health of components before using.

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

Hazard: Candle flame

Description: Setting things alight, or setting off fire alarms

Affected People: All

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

Mitigation: Supervise candle while lit, don't use near flammable things, watch people's hair.

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

Risk Assessment Check History

Check 1: 2018-10-02 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2019-12-12 - Matthew Le Maitre (msl54@cam.ac.uk)

Check 1: 2019-01-01 - Thomas Webster (tw432@alumni.cam.ac.uk), **Check 2**: 2018-12-12 - Matthew Le Maitre

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Check 1: 2020-01-27 - Polly Hooton (prh43@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)

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 2024-01-01 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2024-01-30 by Andrew Marriott.

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)

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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 2024-01-09 by Jessica Trevelyan (jet81@cam.ac.uk) and double-checked on 2024-30-01 by Lucy Bland (lb831@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 won'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, let'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 it...

First Pulley

Put it on to the pulley that looks like the first picture in figure 1 (I know the diagram isn'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 don't mistakenly count it – 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 (don't worry if they don'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 don'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).

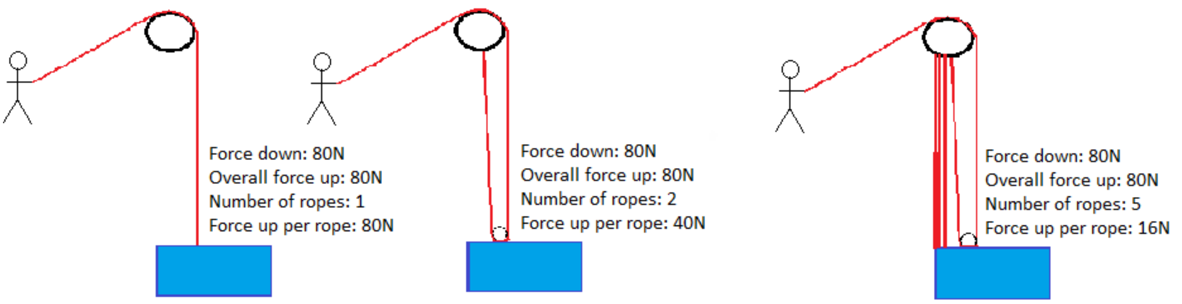
Closing Comments

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 – this is incorrect as very heavy things you couldn't pull). The answer is three – 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:



Pulley 1 **Pulley 2** **Pulley 3**

Figure 2:

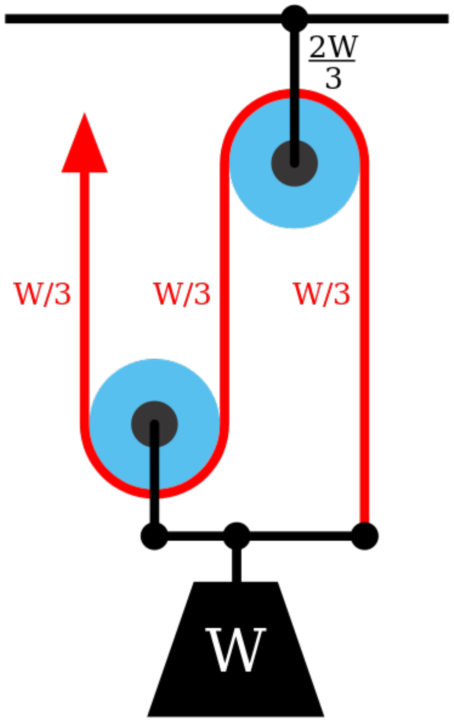
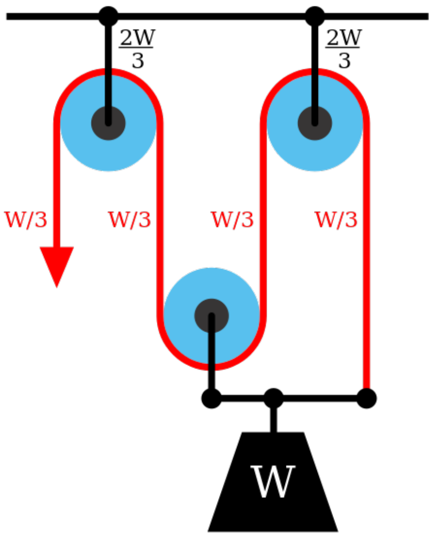


Figure 3:



Risk Assessment

Hazard: Pulleys

Description: Finger trap in pulley blocks / entanglement of ropes.

Affected People: All

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

Mitigation: Ask children to hold on to the ends of ropes when pulling. Their hands should not come close to the pulleys. 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: 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.

Ask a committee member to check that the frame is set up correctly every time after assembly.

Call first aider if required.

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

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: 2, Overall: 4

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: 2, Overall: 2

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: 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: 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

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Mini-beasts

A variety of sea life and freshwater animals observed using microscopes - nan

Last initially checked on 2024-02-15 by Chiara Delpiano-Cordeiro (cd796@cam.ac.uk) and double-checked on

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 – 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 'pseudopod') 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 – they engulf food in their membrane.

f. Volvox – these are made of numerous cells each with 2 flagellae all interconnected and arranged in a sphere (filled with glycoproteins) – all the cells swim together in a coordinated way. Can see daughter colonies developing inside. Found in ponds, ditches and shallow puddles.

g. Daphnia – 'water fleas' (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 – 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

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Pond Life

A selection of organisms from a local pond or rock pool - nan

Last initially checked on 2024-02-01 by Margaret Johncock (mllyj2@cam.ac.uk) and doubled checked on 2024-02-15 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**
- 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: "We're losing our ponds, rivers and streams at a rapid rate. The loss or degradation of these places – to development, drainage and intensive farming – 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 – the best natural garden pest controllers!" "Your pond needn'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

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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Check 1: 2015-01-11 - Arporn Wangwiwatsin (Koi) (aw584@cantab.net), **Check 2**: 2015-01-23 - Kym Neil (kym.e.neil@gmail.com)

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Check 1: 2019-01-20 - Matt Worssam (mdw47@cam.ac.uk), **Check 2**: 2019-01-27 - Polly Hooton (prh43@cam.ac.uk)

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Reversible Flow

Turn syrup one way, then the other, and see that it gets back where it started.

Last initially checked on 2024-02-15 by Lauren Mason (llm34@cam.ac.uk) and double-checked on 2024-02-15 by 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

- 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 90°). 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. (see: scallop theorem/hydrodynamic starvation)

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. For a more detailed explanation, a low Reynolds number means the inertia of the fluid is negligible compared to the viscous forces.

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)

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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 2023-12-23 by Lauren Mason (llm34@cam.ac.uk) and double-checked on 2024-01-06 by Lauren Mason (lb831@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.)

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

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? What's the difference between the water and the jam? Answer: Jam is sticky, but water isn't. When the jar of the water rolls down, the water doesn'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 doesn'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 you'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 Newton's second law to explain how mass doesn't affect acceleration under gravity. It seems odd that the inertial mass term in Newton's second law happens to be the gravitational mass. Einstein used this empirical fact in his 'Equivalence Principle' 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 isn'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? What's the difference between the water and the jam? Answer: Jam is sticky, but water isn'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, isn't 'stuck' 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 doesn'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 you'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 isn'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 = (½)mv^2 RKE = (½)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)

Check 1: 2014-01-26 - Zephyr Penoyre (jp576@cam.ac.uk), **Check 2**: 2015-01-22 - Tom Comerford (tafc2@cam.ac.uk)

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Check 1: 2016-12-29 - Andrei Ruskuc (ar720@cam.ac.uk), **Check 2**: 2017-02-01 - Matthew Le Maitre (msl54@cam.ac.uk)

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Check 1: 2018-01-29 - Benjamin Akrill (bja32@alumni.cam.ac.uk), **Check 2**: 2018-02-09 - Matthew Le Maitre (msl54@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 2024-03-13 by Lauren Mason (llm34@cam.ac.uk) and double-checked on 2024-03-13 by John Leung (cfl35@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. For older groups you may want to spend more time on identification and comparison, if so see the section below.

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.

Identification

If you want to do this in detail then you really need to turn the board over between demos. In schools asking the previous gorup to shuffle the bones back to a pile then flip it over quickly during changeover.

Start by taking wild guesses. Expect some terrible (hopefully joke) guesses to start with. If something is ridiculous then try and rule it out straight away, there are some really obvious facts you can use to help: - Size: by laying out the spine you can find an approximate length of animal. If they can identify the skull you can figure its head size. If they can find some leg bones you can figure out how tall it was. These are all rough measurements, and we dont know if this animal was fully grown or not however should rule put some guesses. For example, Duck, Girrafe, Pidgeon, Elephant. - Wings/Beak: This sheep doesnt have any. If children are instant its a bird ask them to find the wing bones and compare to a chicken. - Similarity to us: You can probably use this as a catch-all to eliminate most non-mamals. E.g., Shark, Fish, etc.

From this you are hopefully at the point where we're looking at mammals. You can now do some more detailed investigation eliminating other (closer) guesses: - Toes: This sheep has two. Rules out Human and various primates. This animal has hooves so is an ungulate, in fact we can say it is an even-toed ungulate (vs. an odd toed one) - Eyes: The sheep has side eyes, suggesting its a prey animal. - Teeth: Herbivore. The sharp teeth at the front may cause some confusion, but ask them to think if those teeth would rip meat from a carcass. - Collarbone: Some mammals have these (e.g., primates, felines) and others dont (e.g., canines, ungulates)

At this point we are down to an (even-toed) ungulate and contextually probably a ruminant, usong the size info the only real candidates left are sheep, goat, deer or a baby of some other type. At this point the details get more subtle hwoever things to look for are: - Deer will have some horn base formation. The horn base is also more pointy in goats. This skeleton has a cueved short horn base, offering the (easiest to see) evidence it is a sheep, although without a goat for comparison its hard to confirm.

For a long while CHaOS was uncertain wether the skeleton was that of a sheep or a goat until we got some more experienced veterinary opinions. More nuanced features include: - Humerous and scapula is slightly different between goats and sheep. - The trachea is a different shape. - See this paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0178543 While it may seem weird there's not a lot of information on this if you think from the perspective of a vet sheeo and goats are easy to distinguish externally (wool). The main research comes from zooarcheologists who can only use bone information, and even they have contextual clues beyond the bones.

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)

Check 1: 2024-03-13- Lauren Mason (llm34@cam.ac.uk), **Check 2**: 2024-03-13 - John Leung (cfl35@cam.ac.uk)

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 2024-02-01 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2024-02-14 by Andrew Marriott (asm206@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 cups, 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 there'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)

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Check 1: 2014-12-27 - Joseph Hooton (jh795@cam.ac.uk), **Check 2**: 2015-01-02 - Holly Davis (hd308@cam.ac.uk)

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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 2024-02-01 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2024-02-15 by Isobel Gilham (ig419@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) – 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 isn'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 'circulatory systems' 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 don'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 'xylem' and 'phloem'.

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 – 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).

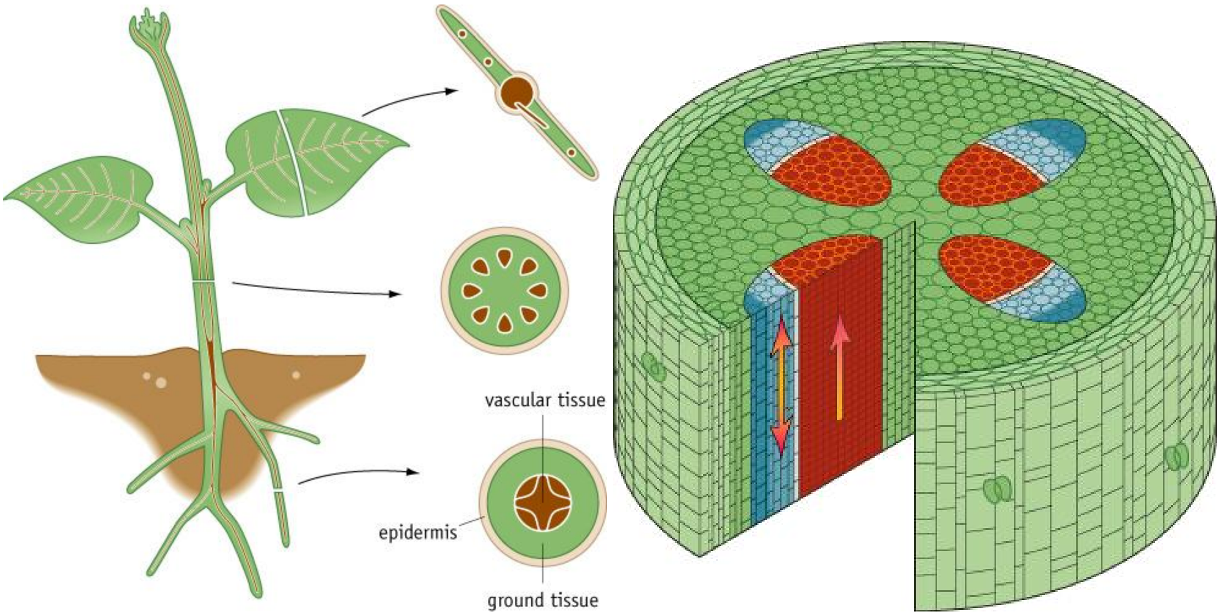
I would then start with the analogy of circulatory systems in humans, get the children to find their veins, ask if they know why they are important – for transporting important things like sugars for energy around the body – talk about how when they eat food and it gets digested in the stomach, those 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 – 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 they'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 'veins' 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 – 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 can't then escape the petals, so the colour stays there and create our coloured flowers.

If someone asks about multicoloured flowers – 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 – 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)

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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 2024-02-14 by Margaret Johncock (mllyj2@cam.ac.uk) and double-checked on 2024-02-15 by Isobel Gilham (ig419@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 – ask if they have ever eaten bread (hopefully a 'yes' but this should get them engaged with you as it's a simple question that they don't have to struggle to think about). - Ask if they know what goes into bread; you'll probably get told that it is made from flour. Some may tell you about water and yeast. - Ask them whether they'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 (it'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 isn't much oxygen so the yeast can't breathe oxygen to allow them to produce energy like we do. Instead they use 'fermentation' 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 don't encourage it), but stress that it'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 'conveyor-belt' system where you set one up with a group but show them the previous group'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. Possible risk of mould in very old flour that can also cause allergies if breathed in.

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. Check manufacture date of flour before event and ensure that flour used is not too old. 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 don'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: 2017-02-08 - Alfred Chia (ac939@cam.ac.uk), **Check 2**: 2017-02-09 - Matt Worssam (mdw47@cam.ac.uk)

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