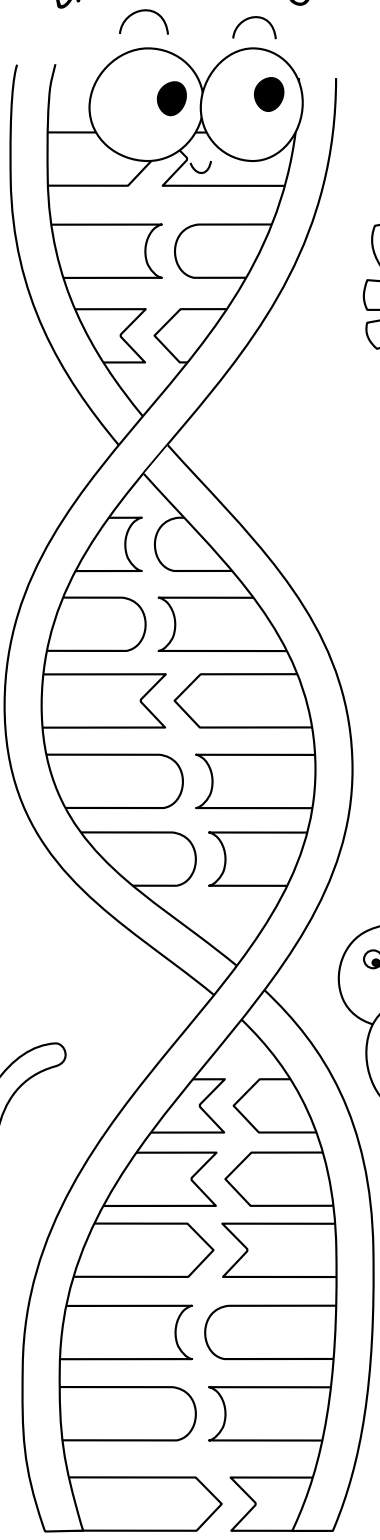
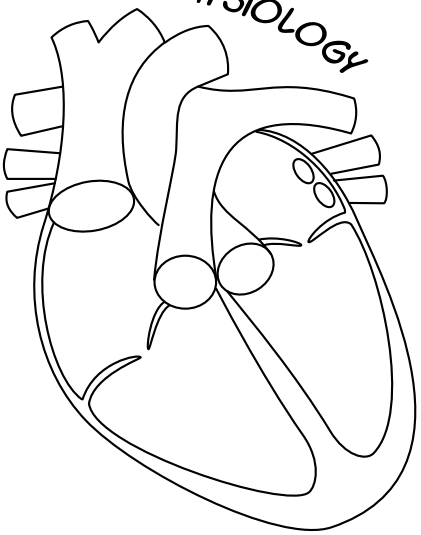
BIOLOGY ONE

BIOMOLECULES

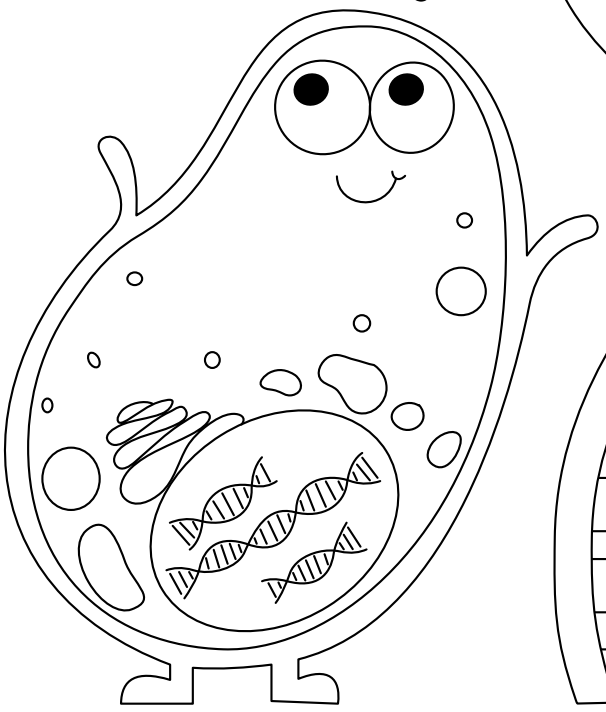


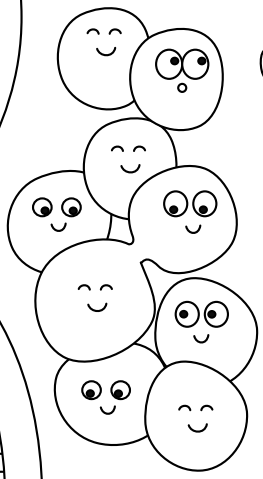
DIVERSITY OF LIFE

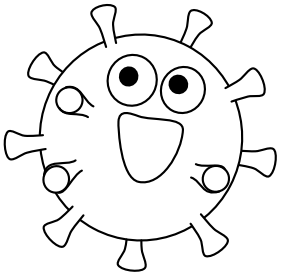
PHYSIOLOGY



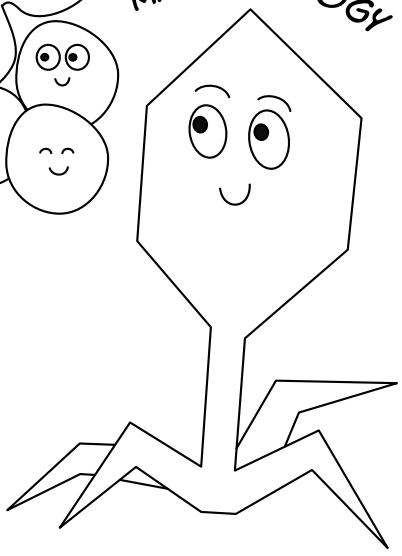
CELLS







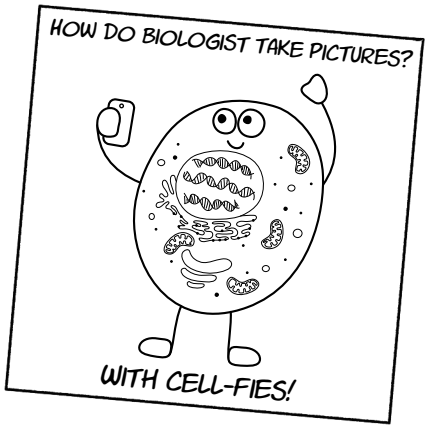
MICROBIOLOGY

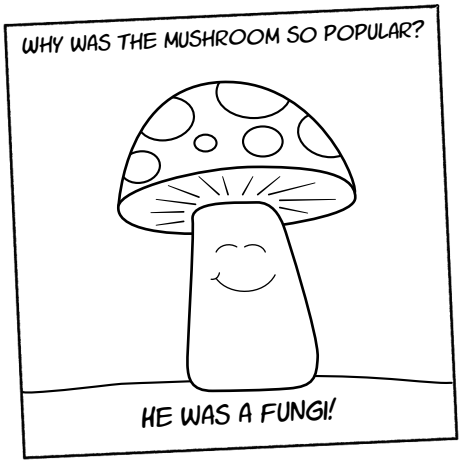


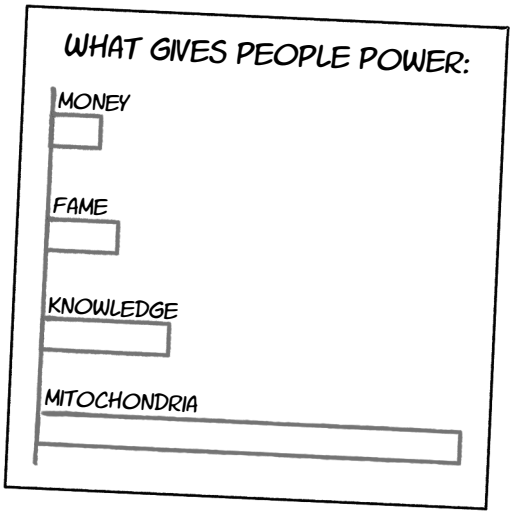
BIOLOGY ONE

~ MICROBIOLOGY ~

There are 5 projects in the course, each listed in bold in this table of contents.
A supply list for all projects and activities can be found on page 5.







Have questions, corrections, or suggestions?
Contact jenny@science.mom or serge@science.mom

Project Supply List

Day 2 - Laser Pointer Microscope
- Laser pointer
- Paper clip or plastic pipette
- Tape
- Water from a stream, pond, or pet water dish

Day 11 - Extract DNA from Fruit
- 2 fresh strawberries (or bananas or other fruit)
- ½ cup warm water
- 1 tsp salt
- Plastic bag or bowl and fork
- 2 tsp concentrated dish soap
- Rubbing alcohol (91%)
- Coffee filter
- Jar or cup
- Meat tenderizer (if using the split pea option)
- Blender (if using the split pea option)

Day 21 - DIY Petri Dishes
- 8 oz boiling water
- 1 bouillon cube
- Cotton swabs
- 4 petri dishes (clean containers with lids)
- 1 Tbsp agar (or 1 packet unflavored gelatin)
- 2 tsp sugar
- Permanent marker

Day 30 - Physiology Art Project
- Several pieces of waxed paper or tracing paper
- Pencil
- Markers
- Brads (paper fastener)

Day 33 - Most Wanted Microbe Art Project
- Copies of the most wanted microbe template
- Pencil
- Markers
- Butter knife (optional)
- Ink and napkin (optional)

Other (optional) Activities

Week 6 - Respiration
- 2 Tbsp Yeast
- 2 Balloons
- 2 Water bottles
- Sugar

Week 8 - What is Blood?
- 1/3 c measuring cup
- 6 L of water and two containers
- Timer or stopwatch

Week 9 - Why We Breathe
- 2 balloons
- Plastic bottle with bottom cut off

Week 9 - How Nerves Work
- Ruler

Week 13 - The Problem with Polio
- 2 dice

How to get the most from this course:

This course can be used in a variety of ways! You can participate passively by just watching the videos, or actively by filling out the notes and completing the projects. You can do the entire course at once or participate in one lesson or section at a time.

For BEST learning, we recommend:

☑ Read the pages that go with each lesson before watching the video. Take 10-15 minutes to see if you can fill in the blanks.

☑ On quiz show days, take the practice quiz before you watch the class!

☑ Complete each of the science activities, and then share your work with a family member or friend.

☑ Download the answer key for the notes, but don't look at the answers until after you give things a try yourself!

Next Generation Science Standards

This class covers the following Next Generation Science Standards. Often referred to as NGSS, they are the United States education standards for science.

MS-LS1-1: Days 4, 5, and 6
Living things are made of cells

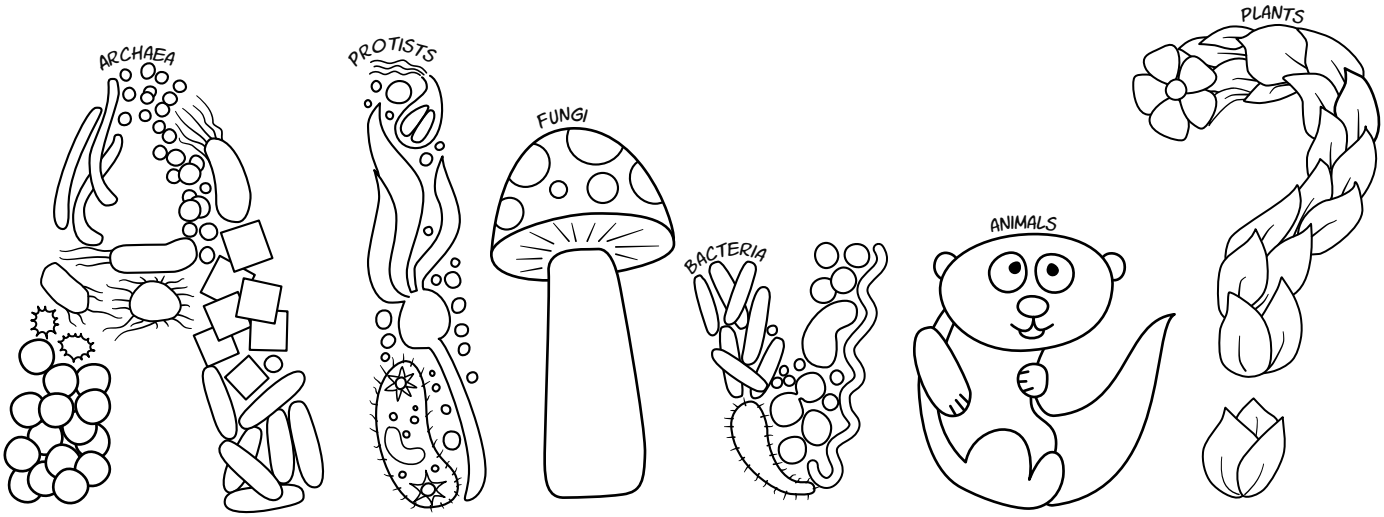
MS-LS1-2: Days 3 and 22
The function of a cell as a whole and how the parts of a cell contribute to that function

MS-LS1-3: Days 22, 23, 24, 25, and *T*
The body is a system of interacting subsystems composed of groups of cells

MS-LS1-6: Days 14, 17, and 18
Photosynthesis and its role in cycling matter and the flow of energy in and out of organisms

MS-LS1-7: Days 14, 15, and 16
How food is rearranged through chemical reactions to form new molecules that support growth and release energy

MS-LS1-8: Day 25
Sensory receptors respond to stimuli by sending messages to the brain



What makes something alive? This is not an easy question to answer! Most definitions agree that living things include all the following qualities or abilities:

METABOLISM

Uses energy!

Metabolism is defined as the chemical processes that occur within a living organism in order to maintain life. Some living things capture energy from digesting food, others use the energy in sunlight.

HOMEOSTASIS

Keep inside conditions stable!

Homeostasis is the ability to regulate internal conditions. It usually involves maintaining a favorable amount of water and/or nutrients and/or temperature.

GROWTH

Gets bigger!

Growth is an increase in cell size and/or in the number of cells. All living things discovered so far have been observed to grow during their lifespan.

RESPONDS TO STIMULI

Reacts to the world around it!

A stimulus is any detectable change in the environment. Living things can react or respond to changes around them.

MADE OF CELLS

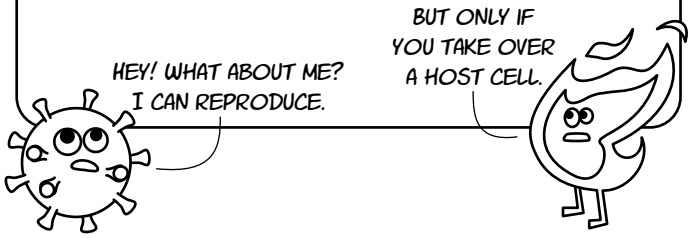
Cells: tiny bags of mostly water!

All things that are commonly agreed to be living are made of cells, which we will be learning more about over the next two weeks.

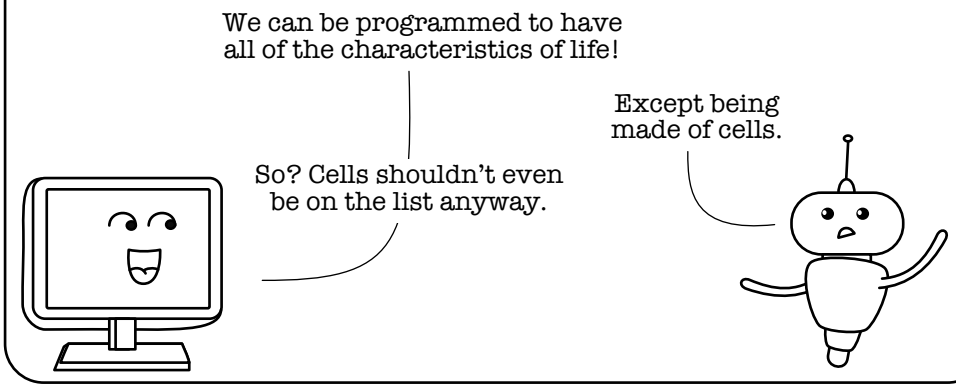
REPRODUCTION

Can make more of itself!

Reproduction is the process of parents creating offspring.



COULD ARTIFICIAL INTELLIGENCE (AI) BE CONSIDERED ALIVE?



The question of whether or not AI is alive is currently being debated, and will be one of the more important questions of the century!

Write down three of the best reasons for each side of the argument and then share your opinion. What do *you* think?

*What are 3 arguments for technology or AI to be considered **alive?***

1. ***Possible answers include:***
   AI can grow and learn as it gets more information.
2. ***Each AI responds to stimulus by executing its programs and altering its output.***
   Each AI is made of distinct bits of code that act together to carry out its objectives,
3. ***and this is similar to individual cells creating a multicellular organism.***
   AI can be programmed to adapt and change.

*What are 3 arguments for technology or AI to be considered **nonliving?***

1. ***Possible answers include:***
   AI do not carry out their own metabolic process (energy conversion process).
2. ***AI do not reproduce in the usual sense.***
   AI is not made up of physical cells.
3. ***AI cannot exhibit the various characteristics of living things (like response to***
   stimuli or adapting and learning) without first being programmed to do so.

What is your opinion?

The Discovery of the Cell

FOR THOUSANDS OF YEARS, PEOPLE KNEW THAT CURVED GLASS MAGNIFIED DETAILS.

I WROTE ABOUT IT WAY BACK IN 160 BCE!

CLAUDIUS PTOLEMY
Famous philosopher

THEN, IN 1590, TWO GLASS MAKERS CREATED THE FIRST COMPOUND MICROSCOPE.

IF WE PUT LENSES ON BOTH SIDES OF A TUBE, THE OBJECTS ON THE OTHER SIDE ARE EXTRA MAGNIFIED!

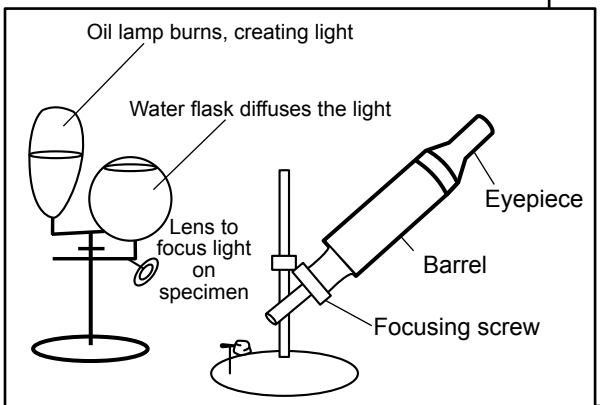
LENS
LENS

WE CAN SEE EVEN MORE! YIPPEE!

HANS & ZACHARIAS JANSSEN
Dutch glassmakers

THE NEXT CENTURY SAW HUNDREDS OF EXPERIMENTS ON IMPROVING THE MAGNIFICATION OF MICROSCOPES AND MANY PUBLICATIONS ABOUT WHAT WAS OBSERVED UNDER THE LENS.

THE MOST FAMOUS OBSERVATIONS WERE MADE BY ROBERT HOOKE…



ROBERT HOOKE'S MICROSCOPE 1665

THIS SPECIMEN OF CORK PLANT IS FULL OF PORES! THEY LOOK LIKE THE PLAIN UNFURNISHED ROOMS OF MONKS.

YOU'RE RIGHT. THEY DO LOOK LIKE EMPTY ROOMS! WHAT WILL YOU CALL THEM?

CELLS.

CELLS? THE SAME NAME FOR EMPTY ROOMS?

WHY NOT? THEY LOOK LIKE HONEYCOMB CELLS TOO.

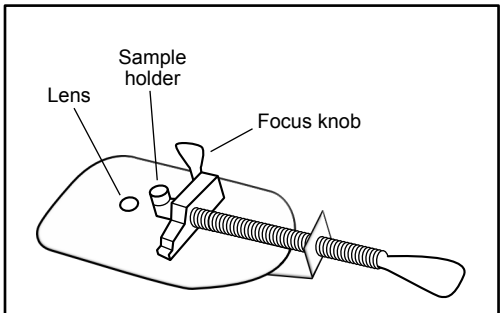
AND LOOK! THERE ARE EVEN CELLS IN FOSSILS!

I THOUGHT FOSSILS WERE JUST ROCKS.

ROCKS THAT USED TO BE ALIVE!

BLIMEY!

…AND DUTCH SCIENTIST ANTON VON LEEUWENHOEK.



LEEUWENHOEK'S MICROSCOPE 1676

I MADE INCREDIBLY TINY LENSES BY MELTING, GRINDING, AND BLOWING GLASS.

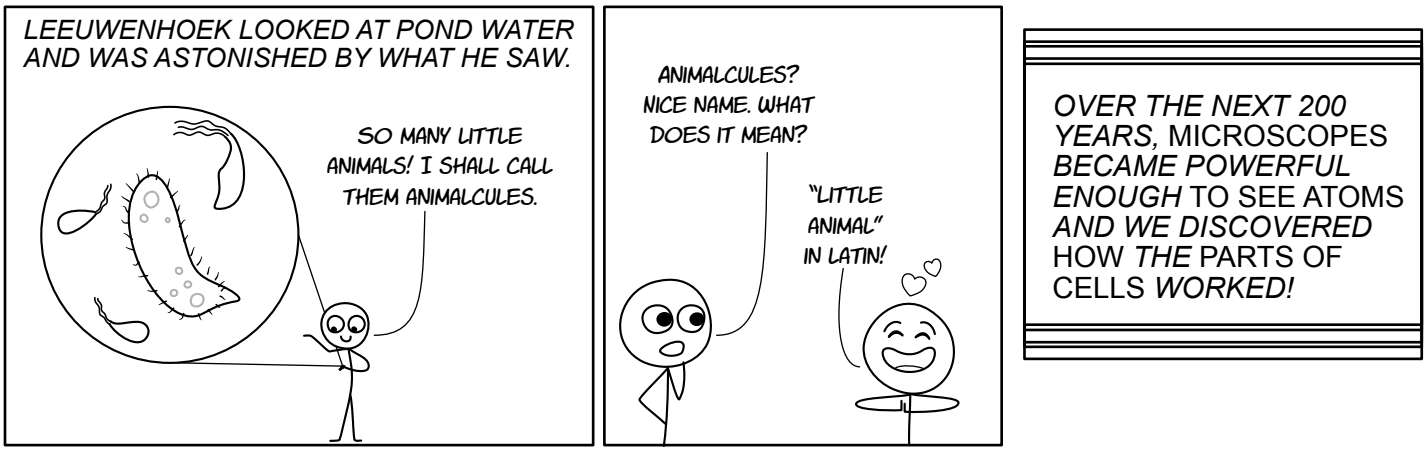
THERE IS ONLY ONE LENS IN THIS MICROSCOPE, BUT THE QUALITY IS SO GOOD I CAN SEE WITH 200 TIMES MAGNIFICATION!

SUPER TINY MICROSCOPE

MY MICROSCOPE HAS BETTER MAGNIFICATION THAN HOOKE'S!

#1

CONTINUED ON NEXT PAGE…



Your notes:

Possible things to note from class would be the discovery of the first ultramicroscope in 1903 which allowed people to see things smaller than the wavelength of light and the invention of the electron microscope in 1938. By 1951, scientists had invented microscopes powerful enough to see individual atoms.

IS IT MADE OF CELLS OR NOT? *Write the words below in the correct oval:*

salt tomato wood cement mold sand cabbage
pepper water onion platypus plastic yogurt grass

Made of cells or came from cells

Tomato, wood, mold, sand, cabbage, pepper, onion, platypus, yogurt, grass

NOT made of cells or derived from cells

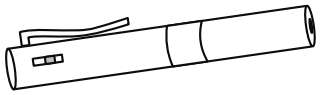
Salt, cement, water, plastic, sand

Note: Sand can be created from both living and non living sources! Beach sand often comes primarily from fragments of coral and shells. Sand in a desert dune is usually created from bits of rock that were eroded by wind.

Hands-on Science Project

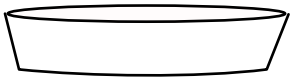
LASER POINTER MICROSCOPE

MATERIALS:


Laser Pointer

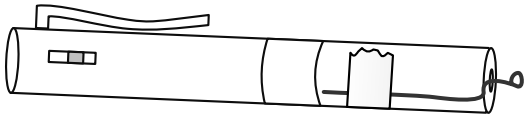

Paperclip


Tape


Water from a pond, dog dish, aquarium, or other source that will have microbial life.

SAFETY WARNING

NEVER POINT A LASER BEAM AT ANYONE'S EYES. LOOKING DIRECTLY AT A LASER BEAM CAN PERMANENTLY DAMAGE YOUR EYES.



1. Straighten out a large paper clip and then bend one end so that it forms a small loop.

2. Test the loop to be sure that It holds a water droplet. When you dip it in water and then lift it out again, a drop of water should stay inside the loop. If the loop does not hold water then bend it again and make it smaller.

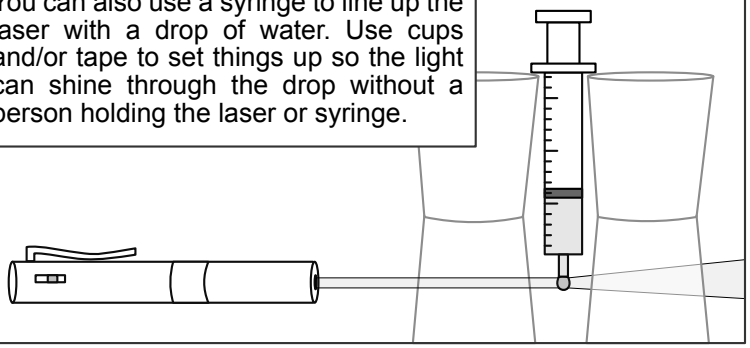
3. Attach the paperclip to the laser pointer with tape so that the loop is directly in the path of the beam.

4. Carefully dip the wire loop into a water source that will have bacteria and other microbial life. Pond water, aquarium water, or water from a pet drinking dish are all good choices.

5. Shine the laser toward a white surface. For best results, conduct this activity in a darkened room.

6. Observe your results and experiment with different sources of water.

AN ALTERNATIVE APPROACH:
You can also use a syringe to line up the laser with a drop of water. Use cups and/or tape to set things up so the light can shine through the drop without a person holding the laser or syringe.



For BEST results

Choose a source of water that is chlorine free and exposed to sunlight.

Observe multiple drops of water from different sources.

Set up the laser in a dark room and shine it on a flat white surface.

Arrange the laser so that no one is touching it. The less it moves, the better you'll see the microbes in the water.

Adjust the distance between the laser and flat white surface to see which distance gives you the best view.

SAFETY TIP

WASH YOUR HANDS AFTER HANDLING SAMPLES OF WATER THAT COULD CONTAIN MICROBES.

Which source of water had the most microbes?

It's time to go exploring! Gather some clean containers or plastic bags and collect water from several sources. If using the paper clip method, be sure to use different paper clips OR to clean your paperclip before testing each sample. If you gather a saliva sample, do NOT put the paperclip in your mouth! Spit into a container and sample the saliva from there. Before you gather your samples, make a prediction about which water will have the most microbes. Then, after observing each sample put a **check mark** by the type of water that had microbes, and a **zero** by water that was microbe-free. Put a **double check mark** by the water that had the MOST microbes. Write NA if you didn't test that type of water.

YOUR PREDICTION:

The water with the most microbes will be ***All predictions are valid! But hopefully you expected outdoor water to contain more microbial life than the water from your kitchen sink.***

- ☐ Water from the kitchen sink.
- ☐ Water from a natural outdoor source that looks clean like a lake or river.
- ☐ Water from a natural outdoor source that looks dirty or scummy like a puddle, swamp, or pond. ***If the water is especially scummy it will block the light of the laser microscope and you won't see anything.***
- ☐ A drop of saliva. ***This one requires a lot of patience to set up because bubbles will interfere with how the light refracts.***
- ☐ Water from a pet's water dish.
- ☐ Water from the tank (not the bowl!) of a toilet. ***Water in the toilet tank may be dirty from water deposits, but because it comes from the same clean water as the kitchen sink and is cycled frequently, it's usually quite clean. Water in the toilet bowl is not!***
- ☐ Other: _____

YOUR RESULT:

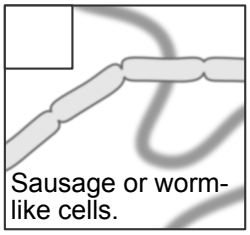
The water with the most observed microbes was _____.

Which of these did you observe using your laser pointer microscope?

Check all that apply.

☐ Clean water with no microbes.

☐ Circular cells that drifted.



☐ Sausage or worm-like cells.

☐ A swimmer! A cell that is moving itself through the water rather than drifting.

☐ Something with a tail or flagella.

Your notes:

Leeuwenhoek observed all of these types of organisms with his small hand-held microscope when he looked in pond water. But this took a lot of patience and time and many samples. It is perfectly fine if you don't see each of these! Just put a check mark by the ones you do observe.

The Parts of a Cell

FILL IN THE BLANKS USING THESE WORDS:

DNA	proteins	living	organelles
plasma membrane	dead	cytoplasm	diversity

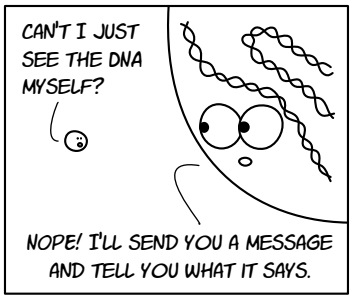
The cells that Robert Hooke saw in the bark of a cork tree were actually ***dead***. This is why they looked so empty. ***Living*** cells contain several important parts or ***organelles*** that help them survive. Ribosomes build ***proteins***. If the cell has a nucleus, it contains the ***DNA***. Mitochondria or chloroplasts are involved in digesting or creating food for the cell, and all of this activity is contained within a cell wall or ***plasma membrane***. The liquid inside a cell is called the ***cytoplasm***. Not every type of cell will contain all of these parts. There is incredible ***diversity*** between different types of cells!

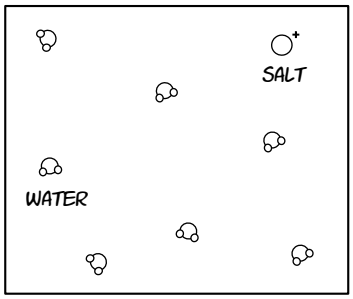
DRAW LINES TO CONNECT THE NAME & DESCRIPTION WITH THE CORRESPONDING PICTURE

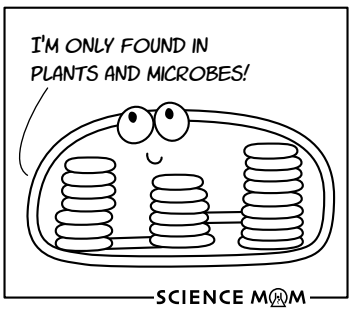
Cytoplasm
The liquid inside the cell. It's mostly water.

Nucleus
Keeps the DNA separate from the rest of the cell.

Chloroplast
Uses CO_2 and sunlight to create sugars.







Plasma Membrane

Keeps the cytoplasm inside the cell.

Cell Wall

Keeps the cytoplasm inside the cell.

Flagella

Helps the cell move. Works like a little paddle or tail to push it through the water.

Ribosome

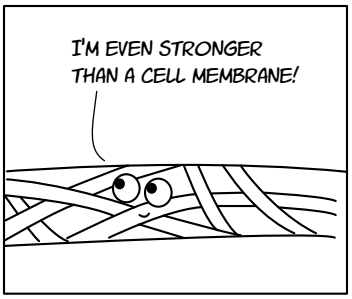
The thing that makes the proteins.

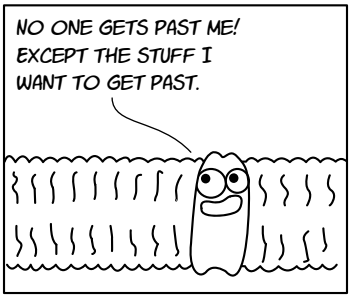
DNA

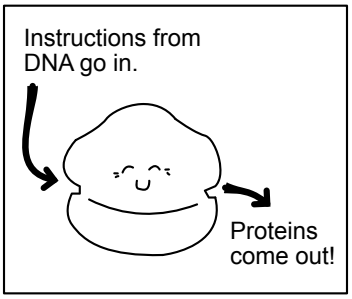
The instructions for making proteins and other stuff for the cell.

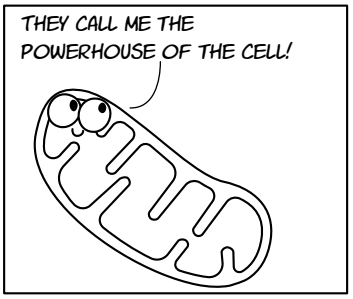
Mitochondria

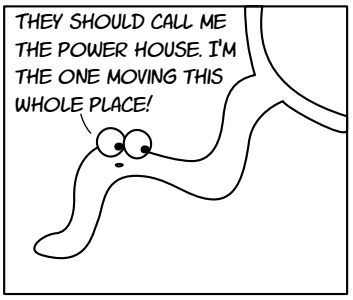
Uses oxygen and sugar to create energy for the cell.

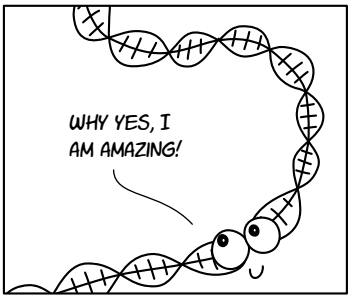




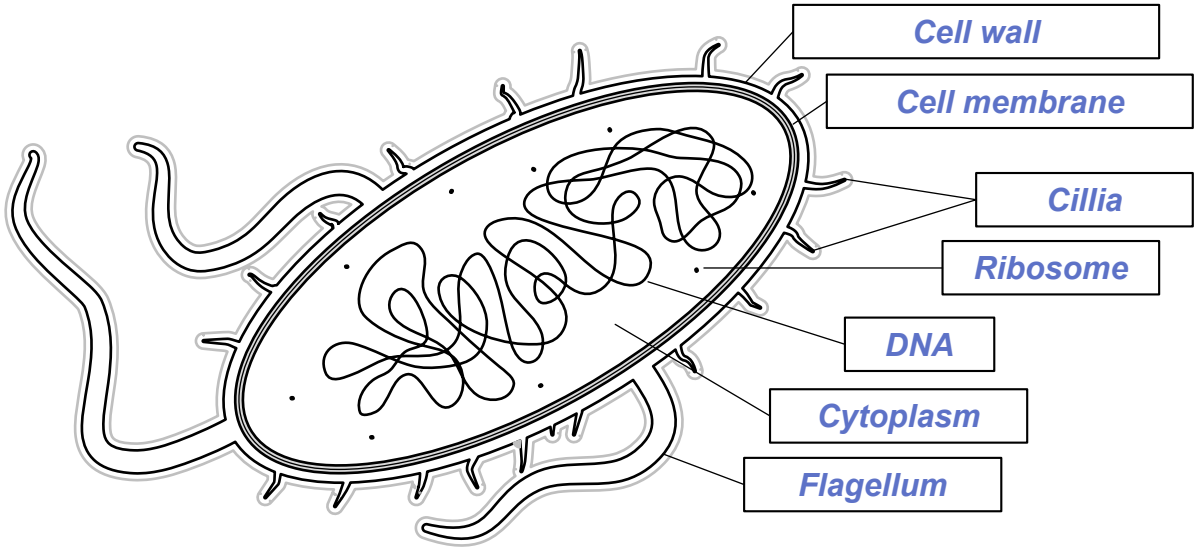








Prokaryotic Cells



FILL IN THE LABELS ABOVE USING THESE WORDS:

PLASMA MEMBRANE | DNA | CILLIA | CYTOPLASM | CELL WALL | FLAGELLUM | RIBOSOME

Example: Salmonella
Size: 2-5 Microns long

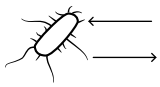
Your notes:

Most prokaryotic cells are 10 to 100 times smaller than eukaryotic cells. They have DNA but it isn't specially wrapped or packaged, it just floats inside the center of the cell. The word prokaryote comes from Greek words meaning "before" and "nut" or "kernel," in reference to the fact that these cells do not have a nucleus. The prokaryotic cells that you hear about most often are bacteria. Some bacteria are beneficial to humans but others (like salmonella) cause disease.

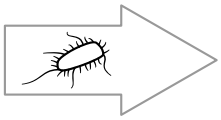
IS SOMETHING AS SMALL AS A SALMONELLA BACTERIUM REALLY *ALIVE*? LET'S CHECK:

METABOLISM ✓

IT EATS FOOD AND PRODUCES WASTE.



RESPONDS TO STIMULI ✓

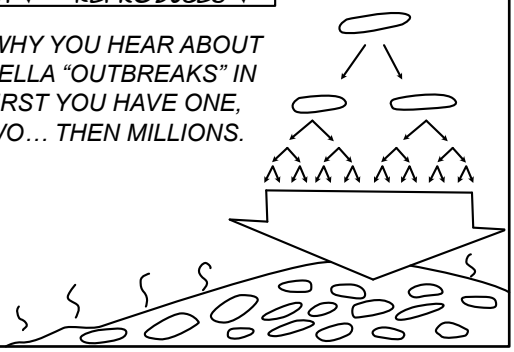


WILL MOVE TOWARD A WETTER AND BETTER ENVIRONMENT

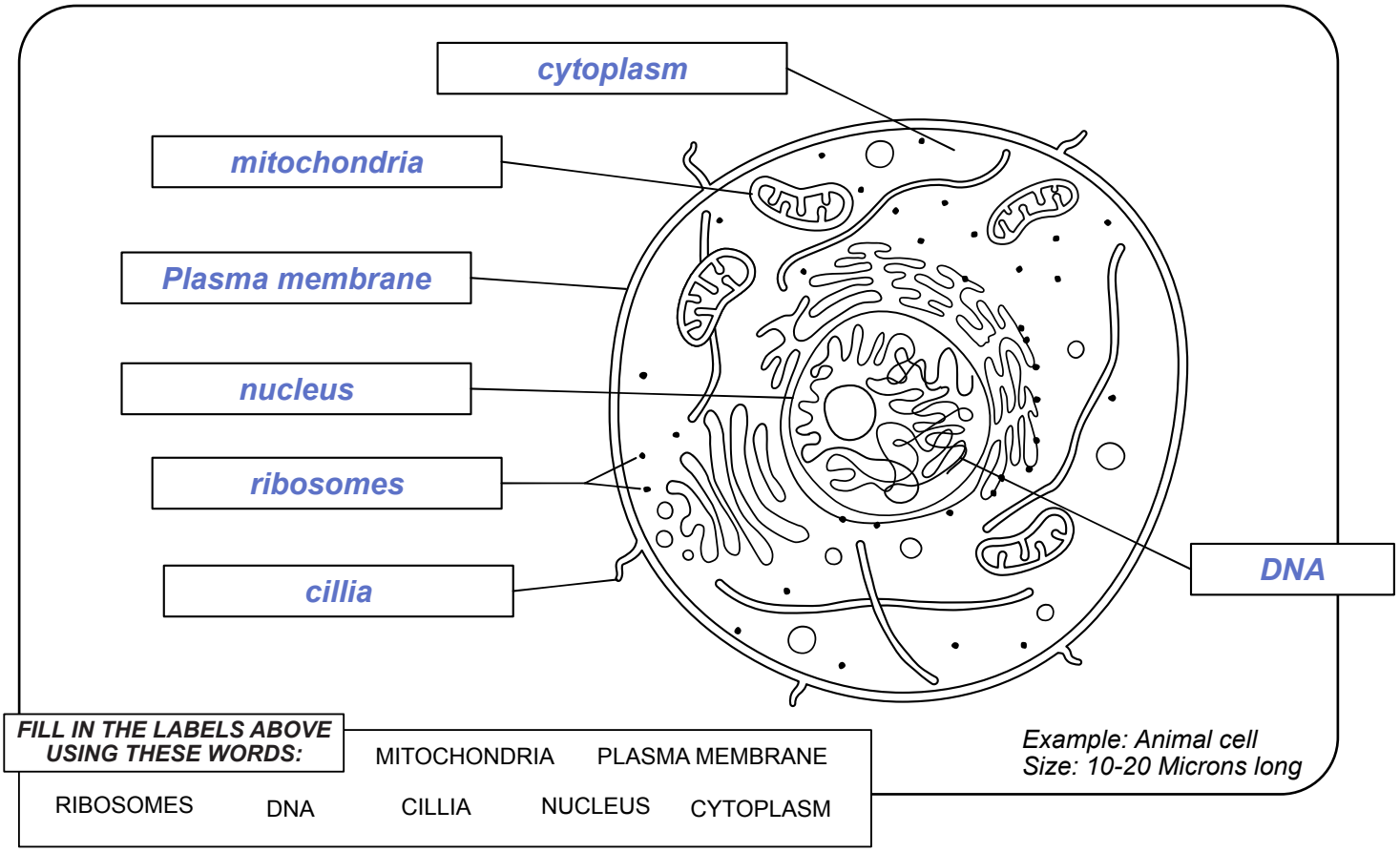
*WHEN IT FINDS A GREAT LOCATION IT FORMS A **BIOFILM**, A COLONY OF CELLS STUCK TOGETHER WITH SLIME.*

GROWTH ✓ REPRODUCES ✓

THIS IS WHY YOU HEAR ABOUT SALMONELLA "OUTBREAKS" IN FOOD. FIRST YOU HAVE ONE, THEN TWO… THEN MILLIONS.



Eukaryotic Cells



FILL IN THE LABELS ABOVE USING THESE WORDS:

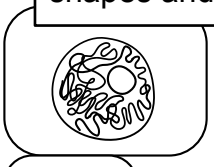
MITOCHONDRIA PLASMA MEMBRANE RIBOSOMES DNA CILLIA NUCLEUS CYTOPLASM

Example: Animal cell
Size: 10-20 Microns long

Your notes:

Eukaryotic cells are much larger and more complex than prokaryotic cells and their DNA is contained in a membrane called a nucleus. Their name comes from the Greek "eu" which means good and "karyon" which means nut or kernel. So Eukaryote literally means "good nut!" They are much more complex than prokaryotic cells.

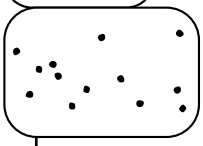
Eukaryotic cells can have incredibly different shapes and parts, but they will always contain:



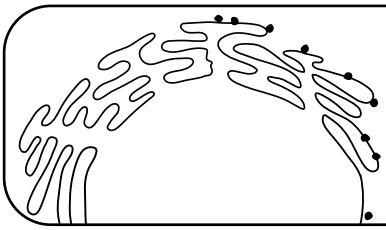
A NUCLEUS which holds the DNA

MITOCHONDRIA which provide energy

MEMBRANE which surrounds the cell



RIBOSOMES which make proteins

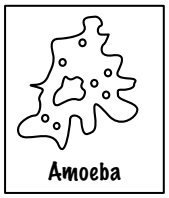


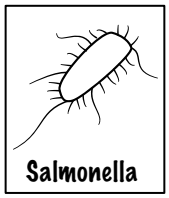
BONUS ORGANELLE!

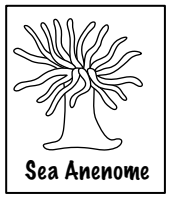
What is the crazy-shaped thing around the nucleus with ribosomes stuck to it? It's called the ***endoplasmic reticulum*** and it helps make proteins. We won't be talking about it more in this class, but of all the organelles, it has one of the coolest names!

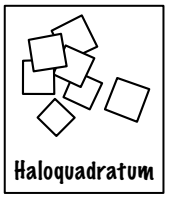
Cellular Life

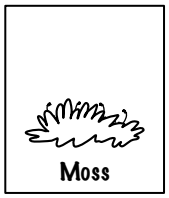
Can you place each of these organisms in their matching category?

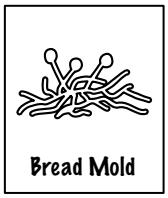

Amoeba


Salmonella


Sea Anenome


Haloquadratum

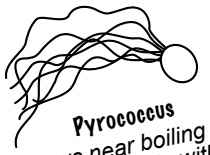

Moss


Bread Mold

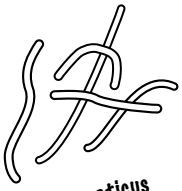
Unicellular

Multicellular

ARCHAEA


Pyrococcus
Grows near boiling hot deep sea vents with no oxygen


Arman
Grows in extremely acidic mine drainage

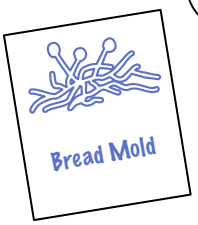

Thermus aquaticus
Heat-loving. Lives in hotsprings.


Haloquadratum

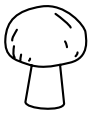
FUNGI


Candida albicans


Bakers Yeast


Bread Mold

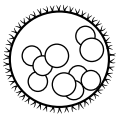

Giant Puffball


Bracket Fungus

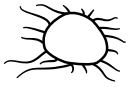
Button mushroom

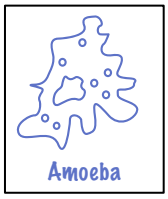
PROTISTS

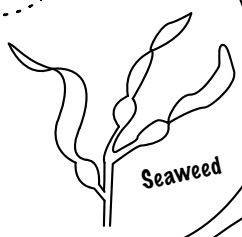

Malaria


Volvox

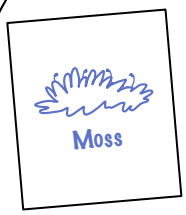

Slime mold

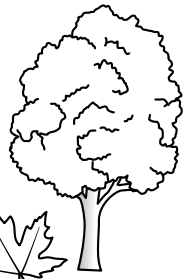

Paramecium


Amoeba


Seaweed

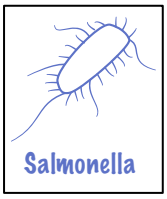
PLANTS

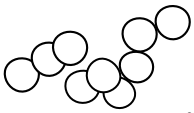

Moss


Maple Tree

BACTERIA


Borrelia Burgdofen
(causes lyme disease)

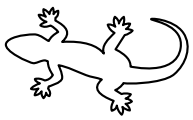

Salmonella

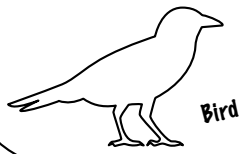

Staphylococcus


Lactobacilis

ANIMALS


Octopus


Lizard


Bird


Sea Anenome

Taxonomy *is the study of classifying groups of organisms based on shared characteristics. Classification systems have changed a lot in recent years thanks to the ability to compare DNA sequences. We'll learn more about taxonomy in Biology 2.*

Five misclassified marvels

Scientists group things into categories to better understand them, but some organisms don't exactly fit! This page is dedicated to five organisms that people often mistake for something else. One is already filled out as an example. Choose 4 more from these lists to fill in the remaining blocks!

Plant or Fungus? *Caloplaca marina (Orange Sea Lichen), Sarcodes sanguina (Snow Flower), Monotropa uniflora (Ghost Pipe), or Clathrus archeri (Octopus Stinkhorn);*

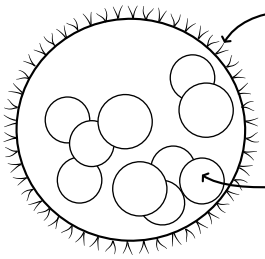
Animal or Plant? *Diploria labyrinthiformis (Brain Coral), Xestospongia muta (Giant barrel sponge), Elysia chlorotica (Emerald Elysia), or Pseudocolochirus violaceus (Sea Apple)*

What in the world? *Caulerpa taxifolia, Acetabularia, and Volvox.*

Volvox!

Volvox barberi

AN ALGAE COLONY MADE OF THOUSANDS OF COOPERATING CELLS!



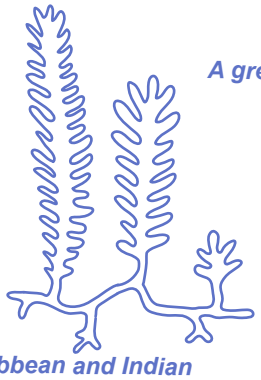
THOUSANDS OF CELLS ARRANGE THEMSELVES SO THAT THEY FORM A SPHERE WITH WITH FLAGELLA FACING OUT.

THE DAUGHTER COLONIES INSIDE HAVE THEIR FLAGELLA FACING TOWARD THE INSIDE AND WILL TURN THEMSELVES INSIDE OUT WHEN THEY GROW UP!

THE FIRST PEOPLE WHO WROTE ABOUT VOLVOX THOUGHT IT WAS A TINY ANIMAL, PERHAPS RELATED TO A JELLYFISH!

Caulerpa taxifolia

The LARGEST known single celled organism!



Can grow more than 30 cm (16 inches) tall!

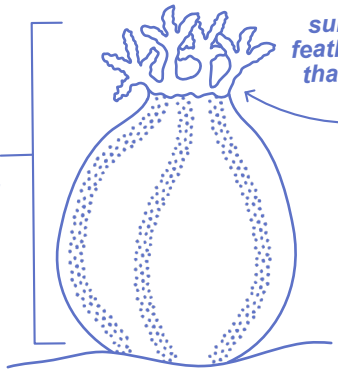
A green seaweed

Is coenocytic (has many nuclei inside one cell)

Native to Caribbean and Indian Ocean. Often considered an invasive species elsewhere.

Psudocolorchirus violaceus

Commonly called "Sea Apple"



Mouth is surrounded by feathery tentacles that gather food

About 20 cm (7 inches) tall.

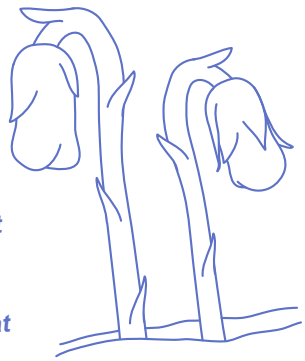
At first glance this looks like a plant, but it can walk slowly on rows of tube feet. Also, if threatened, it can pull in enough seawater to double in size and then escape by floating away on the sea currents!

This animal is closely related to sea cucumbers. It can release a toxin (and it's internal organs!) when stressed.

Monotropa uniflora

Also called Ghost Pipe

This plant is pure white or sometimes pink. It has no chlorophyll and does not perform photosynthesis.

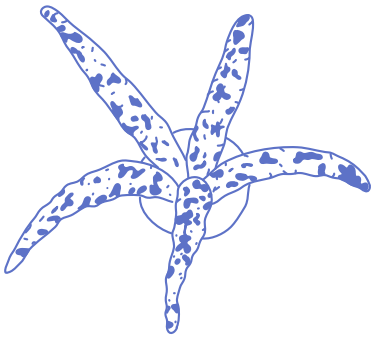


It is a parasite that gets all of it's energy from infecting certain types of fungi that are connected to trees.

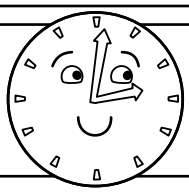
Clathrus archeri

Devil's Fingers or Octopus stinkhorn

This fungus has red "fingers" speckled with black that emerge from a white knob or "egg."



The fungus smells like rotting flesh, which attracts flies. The flies then spread the spores of the fungus to other places.



Quiz Time!

ANSWER THE QUESTIONS TO SEE WHAT YOU LEARNED ABOUT CELLULAR LIFE!

1 Which of these is the best simple definition for the word homeostasis?

- **A.** The ability to regulate internal conditions.
- B. The ability to use energy.
- C. The ability to reproduce.
- D. The ability to respond to a stimulus.

2 What are two characteristics of living things?

Growth, homeostasis, metabolism, made of cells, r esponds to stimuli, reproduction

_____, _____

3 When did humans invent a microscope that can see structures inside a cell that are smaller then the wavelength of light (< 500 nanometers)?

- A. 1665
- B. 1850
- **C.** 1903
- D. 1951

The invention of the ultramicroscope in 1903 allowed scientists to observe particles this small. Richard Zsigmondy, the inventor of the ultramicroscope, later won a Nobel Prize for his research in chemistry.

4 No cell is large enough to be viewed without the help of a microscope.

- A. True
- **B.** False

While most are too small, many can be seen! (egg, certain amoebas and algae, Caulerpa taxifolia and acetabularia)

5 Which type of cell has a nucleus?

- A. Prokaryotic
- **B.** Eukaryotic

6 Fungi are plants, but plants are not fungi.

- A. True
- **B.** False

7 Which domains of life have both single-celled and multi-celled organisms?

- A. Only protists
- B. Archaea and eubacteria
- **C.** Fungi and protists
- D. Only archaea
- E. Only fungi

8 Which of the following are prokaryotic?

- **A.** Bacteria and archaea
- B. Fungi, animals, and plants

9 Protists are which type of cell?

- A. Prokaryotic
- **B.** Eukaryotic

10 A cell can only have one nucleus.

- A. True
- **B.** False

There are many types of multinucleate cells (cells with more than one nucleus) such as muscle cells and the large single-celled Caulerpa taxifolia

11 The average prokaryotic cell is _____ than the average eukaryotic cell.

- A. 2 to 5 times smaller
- **B.** 20 to 100 times smaller
- C. More than 1,000 times smaller

12 Which organelle is responsible for making proteins in the cell?

- A. Mitochondria
- **B.** Ribosome
- C. Plasma membrane
- D. Endoplasmic reticulum

13 Which of the following are made of cells?

- **A.** Wood
- B. Plastic
- **C.** Tomato
- D. Polyester fabric

Plastic and polyester are polymer most often made from petroleum. Although petroleum and other fossil fuels originally came from living things, they have changed through intense pressure and long amounts of time and have no cellular structures remaining.

14 Which organelle uses oxygen and sugar to create energy for the cell?

- **A.** Mitochondria
- B. Chloroplast
- C. Nucleus
- D. Flagella

15 Which of the following statements is true?

- **A.** Some living things are too small to see.
- B. Animals are made of prokaryotic cells.
- C. Fungi contain chloroplasts.
- D. Every cell has a nucleus.

16 Which organelle is only found in plants or protists?

- **A.** Chloroplasts
- B. Mitochondria

17 Eukaryotic cells are bigger than prokaryotic cells.

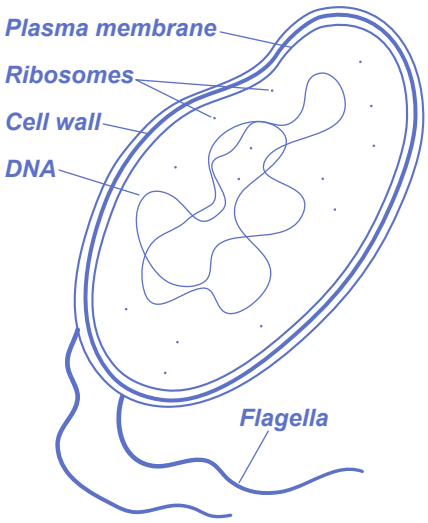
- **A.** True
- B. False

In general, this is true! The average eukaryotic cell is between 10-100 times larger than the average prokaryotic cell. But there are exceptions to every rule. The smallest eukaryotic cell is Ostreococcus, an algae 0.8 micrometers in diameter. The largest prokaryotic cell ever discovered is Thiomargarita namibiensis, which is 100-300 micrometers in diameter. So either answer can be considered correct depending on how you interpret the statement.

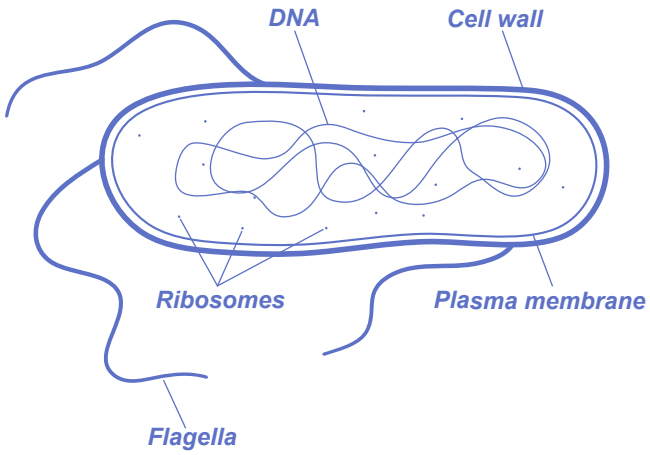
18 Which of these is the best simple definition for the word metabolism?

A. The ability to regulate internal conditions
B. The ability to use energy
C. The ability to reproduce
D. The ability to respond to a stimulus

19 Draw a simple bacterial cell. Label the plasma membrane, cell wall, DNA, ribosomes, and flagella.

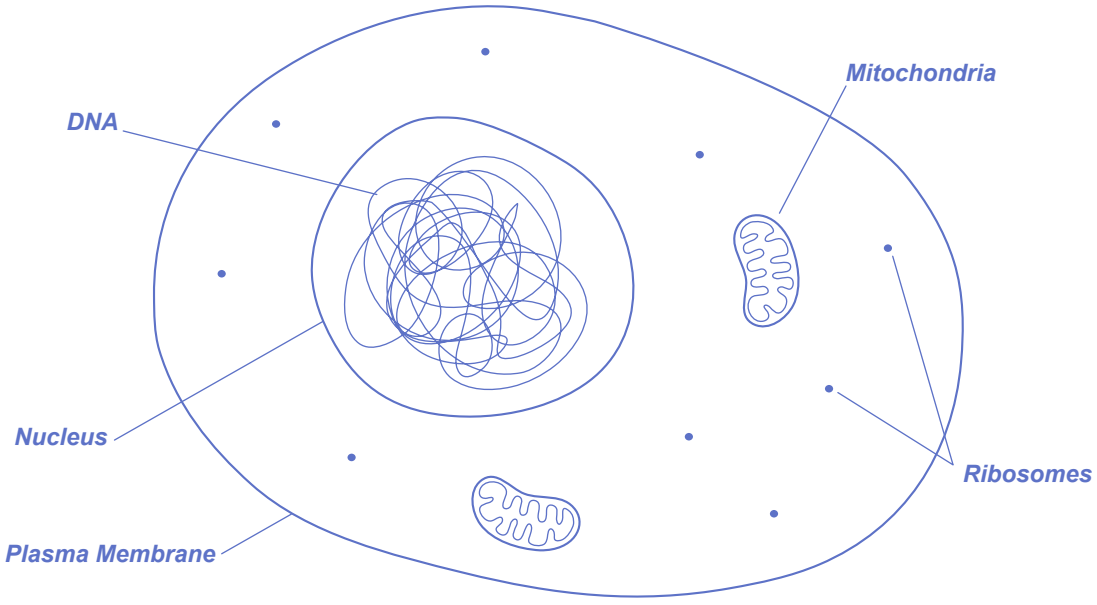


You could draw a GRAM POSITIVE bacterium which has an inner membrane, thin cell wall, and then an outer membrane



You could draw a GRAM NEGATIVE bacterium which has an inner membrane and thick cell wall (no outer membrane). Either choice is just fine!

20 Draw a simple animal cell. Label the plasma membrane, DNA, ribosomes, mitochondria, and nucleus.

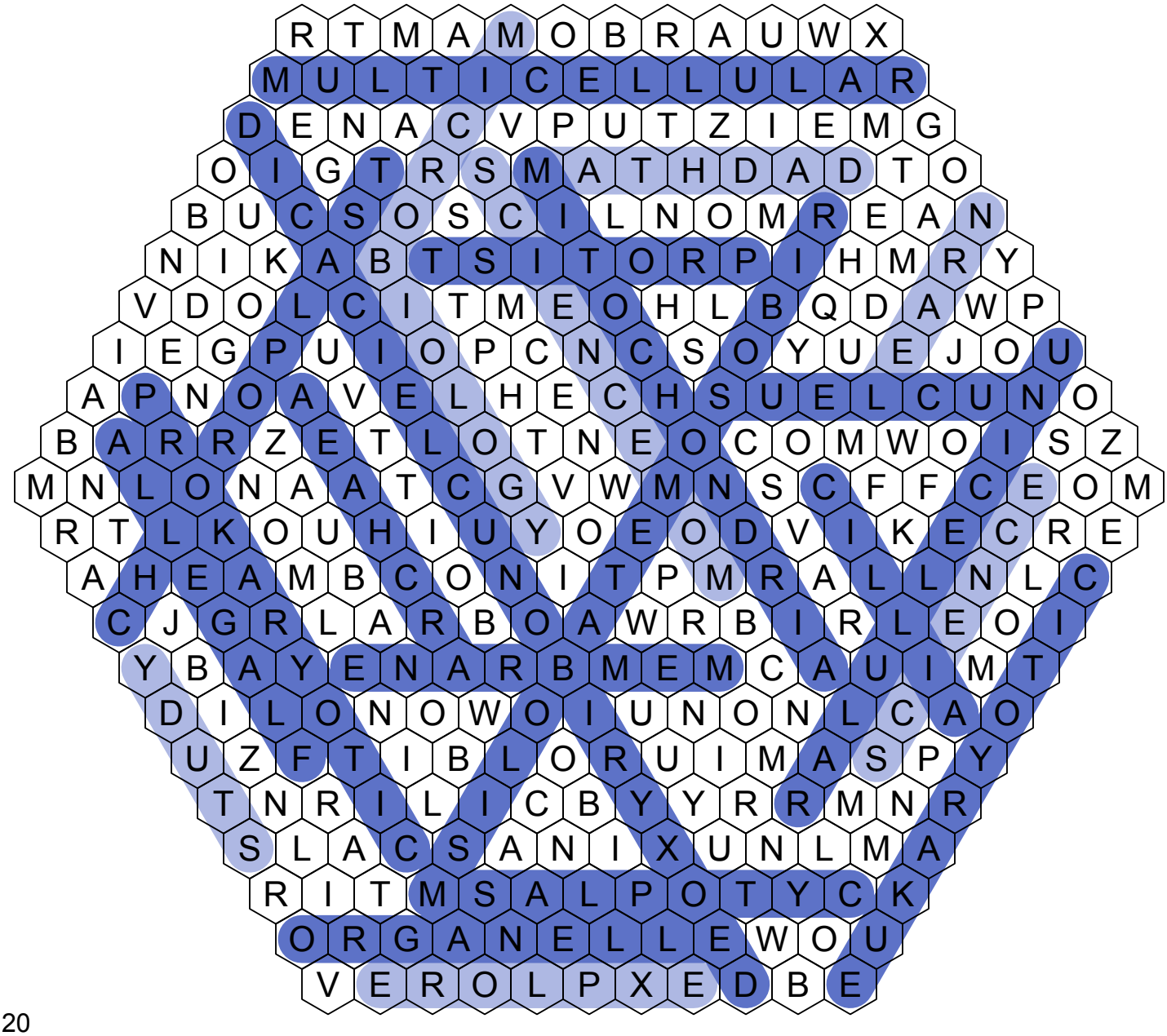


The drawing doesn't need to be fancy or contain more than the 5 items on the list. The goal is to demonstrate a basic understanding of the key cell parts covered in class.

Cellular Word Search

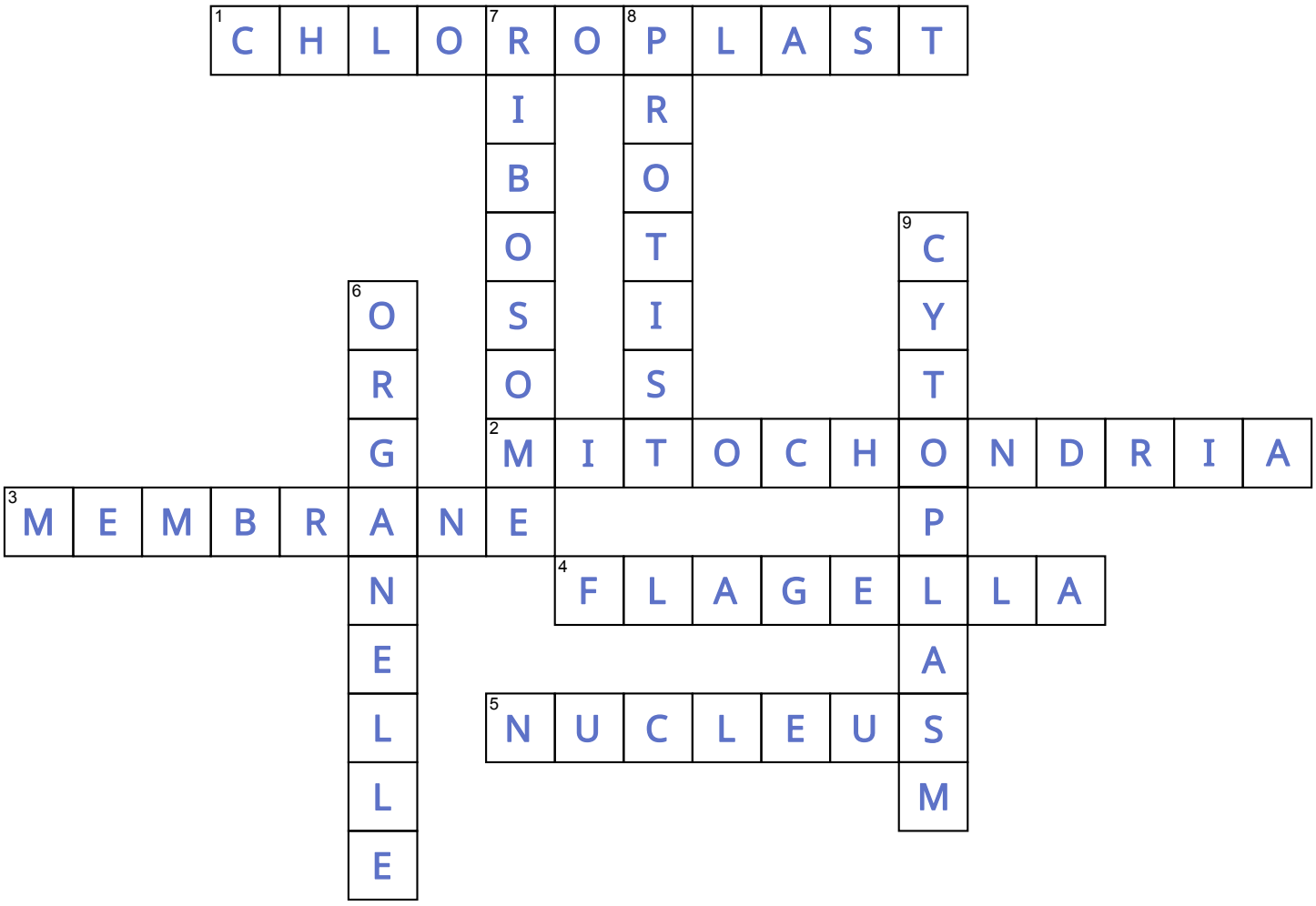
There are a lot of new words to learn when studying biology. Repetition is the best way to learn them, and word games can be part of that! Find each of the hidden words in the word-search. The words can run in any direction: horizontal or diagonal, and the letters might go left to right or right to left!

METABOLISM	NUCLEUS	MULTICELLULAR
MEMBRANE	CHLOROPLAST	EUKARYOTIC
RIBOSOME	FLAGELLA	PROTIST
MITOCHONDRIA	ARCHAEA	CILLIA
DEOXYRIBONUCLEIC ACID	PROKARYOTIC	ORGANELLE
CYTOPLASM	UNICELLULAR	



Biology Crossword

Use the clues below to fill in the crossword puzzle.



Horizontal Words

1. The organelle that performs photosynthesis.
2. The 'powerhouse' of the cell.
3. Keeps the cell intact by surrounding the cell.
4. A tail that some cells use to travel through fluid.
5. The central feature of most plant, fungus, or animal cells.

Vertical Words

6. A structure within a living cell.
7. Organelles that assist the function of DNA, very common throughout the cell.
8. An organism that is eukaryotic but not a fungus, animal, or plant.
9. Contains all of the organelles.

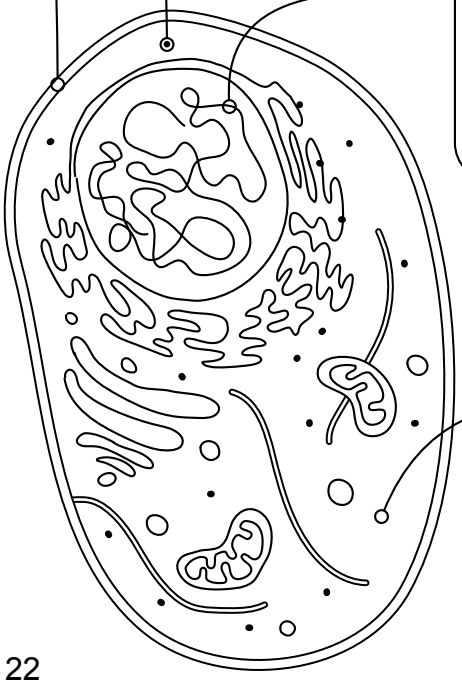
BIOMOLECULES

The molecules that make living things! After completing each topic, return to this page and draw or write a favorite fact you learned about each biomolecule.

LIPIDS

PROTEINS

DNA

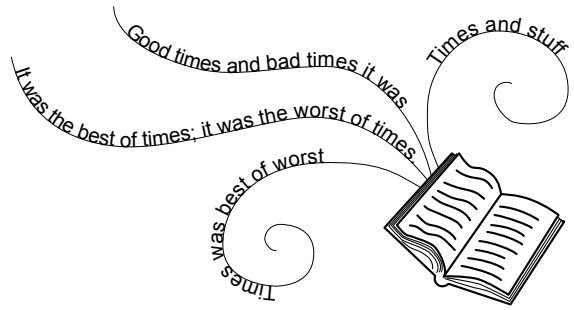


SUGARS

Polymers and Monomers

USE THE WORDS BELOW TO FIILL IN THE BLANKS WITH THE CORRECT MONOMER AND POLYMER FOR EACH PICTURE:

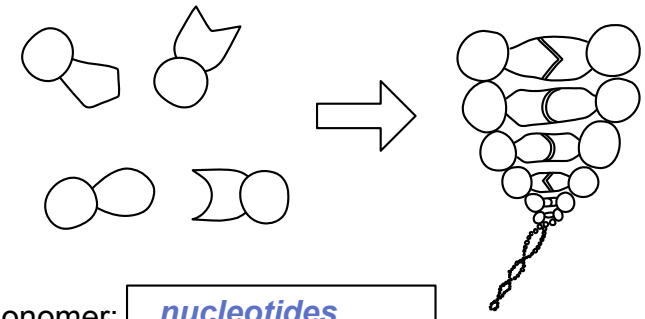
DNA	protein	beads	starch	words	amino acids
stories	HDPE	ethylene	nucleotides	glucose	necklace



Monomer: ***words***

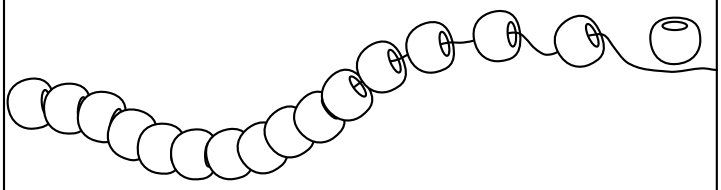
Polymer: ***stories***

Clue: This polymer has the shape of a spiral or helix



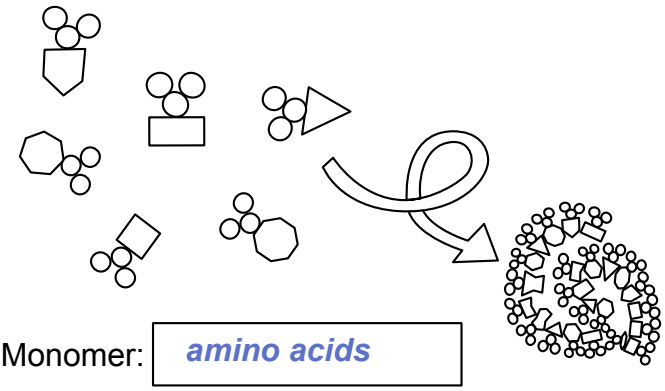
Monomer: ***nucleotides***

Polymer: ***DNA***



Monomer: ***beads***

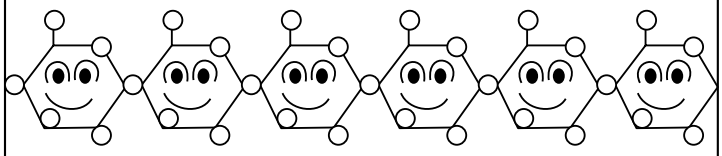
Polymer: ***necklace***



Monomer: ***amino acids***

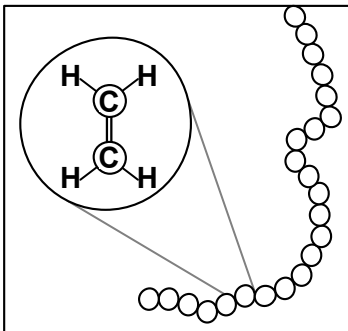
Polymer: ***proteins***

Clue: This polymer is used to store energy.

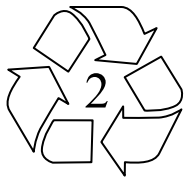


Monomer: ***glucose***

Polymer: ***starch***



Clue: One name for this polymer is High Density Polyethylene. It's one of the more common plastics.



Monomer: ***ethylene***

Polymer: ***HDPE***

Osmosis

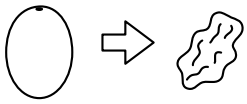
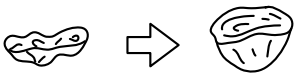
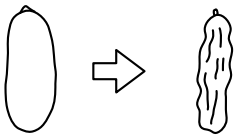
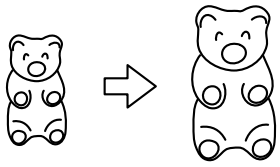
FILL IN THE BLANKS USING THESE WORDS:

osmosis	impermeable	semipermeable

A substance that nothing will pass through is called ___*impermeable*___. You could think of it as a solid steel door. Something that is ___*semipermeable*___ is like a screen door; it lets the air through but keeps the bugs outside.

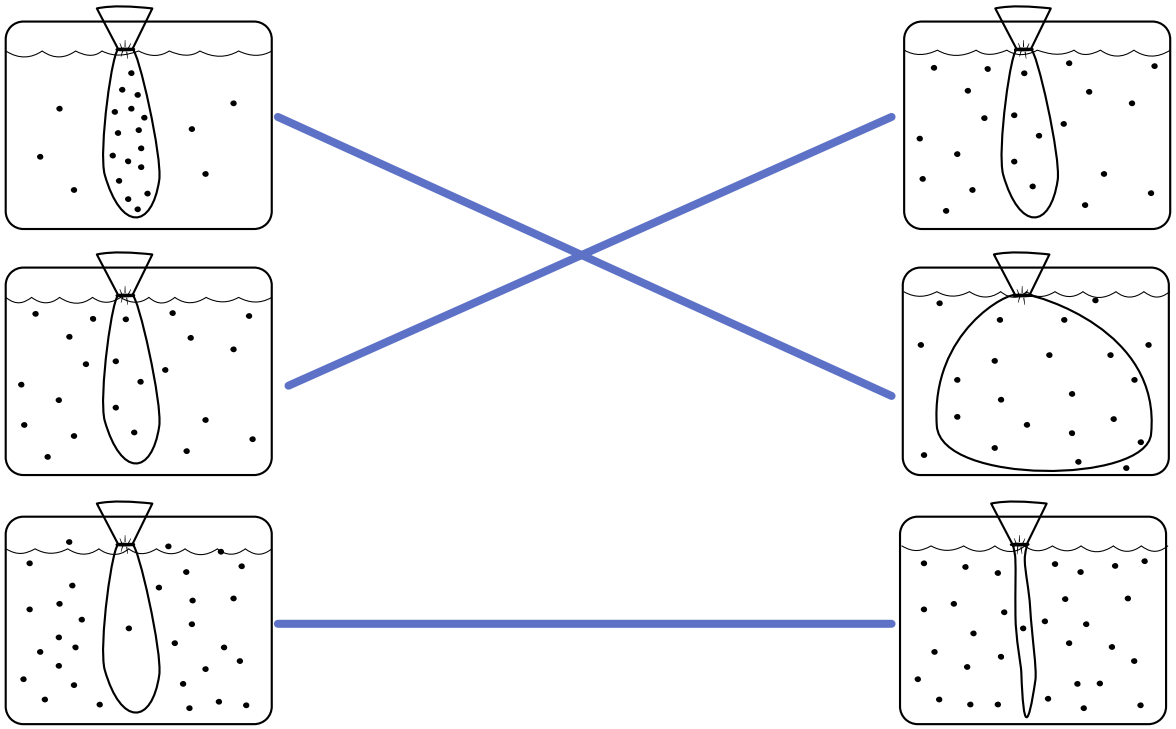
Grape skins, gummy candy, and cell membranes are all semipermeable. They allow water and other small molecules to pass through them. This movement of water or other molecules through a semipermeable membrane is called ___*osmosis*___.

Which examples of osmosis have you seen?

✓	A grape left in the sun shrivels into a raisin.	✓	A dried cranberry soaked in water becomes plump.	✓	A cucumber soaked in brine becomes a pickle.	✓	A gummy bear left in water expands.
							

Why does water move out of a cucumber or into dried fruit? Whenever there is something like salt or sugar (**the solute**) dissolved in water (**the solvent**), water will always move toward the area with a high concentration of solutes.

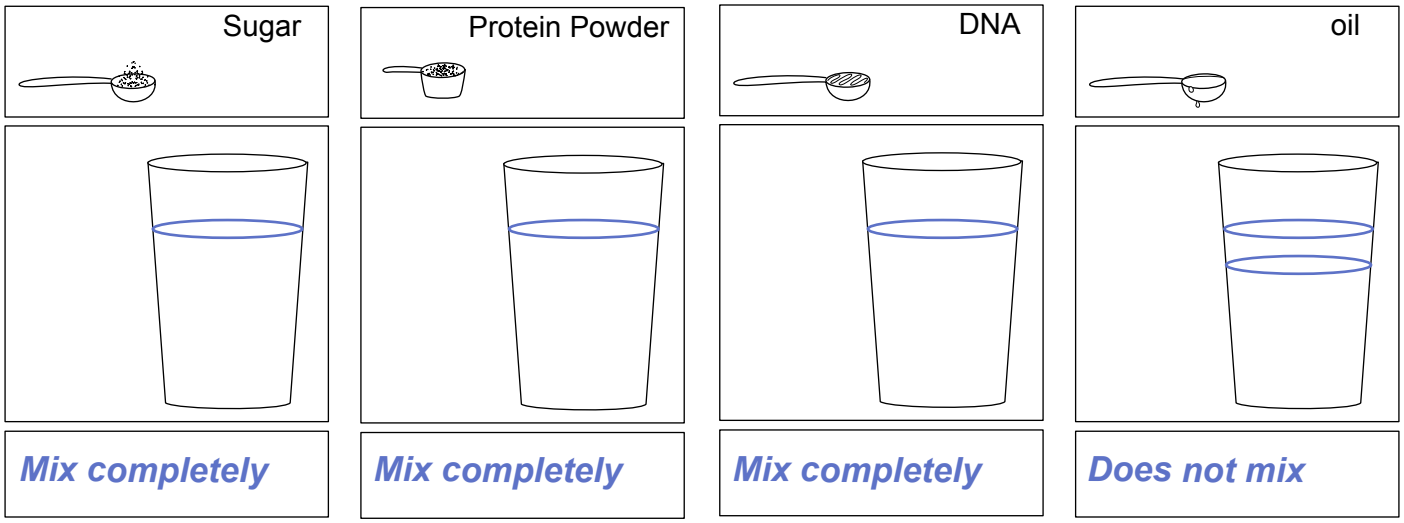
DRAW LINES TO SHOW WHAT WOULD HAPPEN IF A SEMIPERMEABLE BAG WAS PLACED IN ANOTHER CONTAINER CONTAINING A SOLUTION. THE DOTS REPRESENT THE SOLUTE, WHICH CANNOT CROSS THE MEMBRANE.



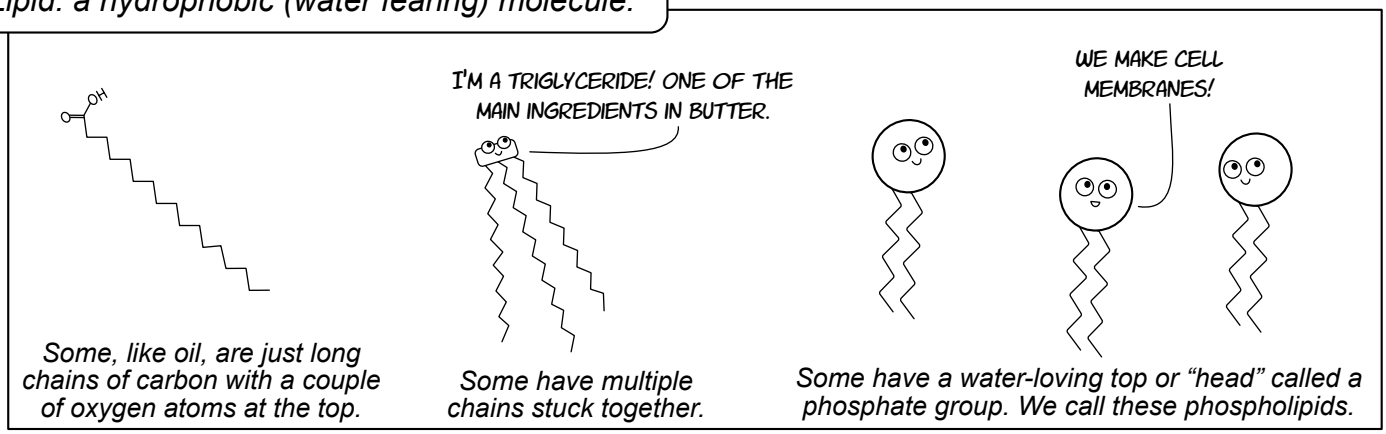
If you had any confusion with this one, count the dots (solute molecules) inside the bag. The number of dots stays the same because the solute does NOT move across the membrane. Only the water moves across.

Lipids Make Membranes

If you mixed a large spoonful of each of the biomolecules into a glass of water, would it mix completely with the water or not? Color in the cup with your prediction.



Lipid: a hydrophobic (water fearing) molecule.



Some, like oil, are just long chains of carbon with a couple of oxygen atoms at the top.

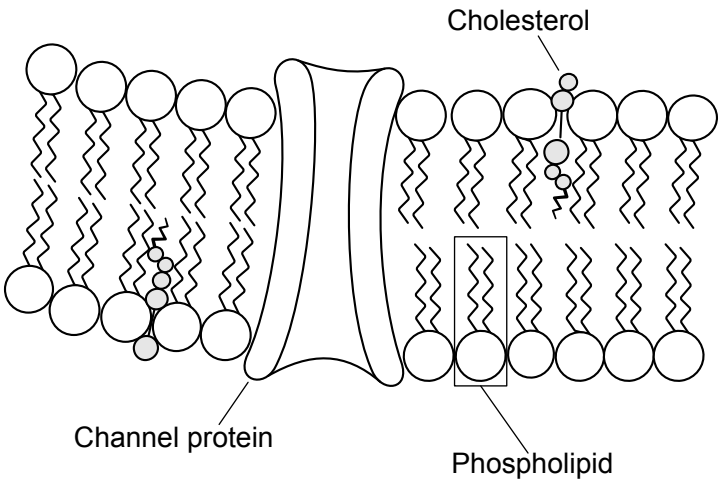
Some have multiple chains stuck together.

Some have a water-loving top or "head" called a phosphate group. We call these phospholipids.

FILL IN THE BLANKS USING THESE WORDS:

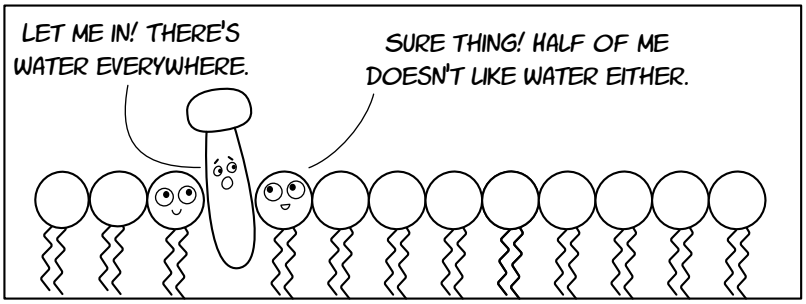
phospholipids	channel	
cholesterol	hydrophobic	hydrophilic

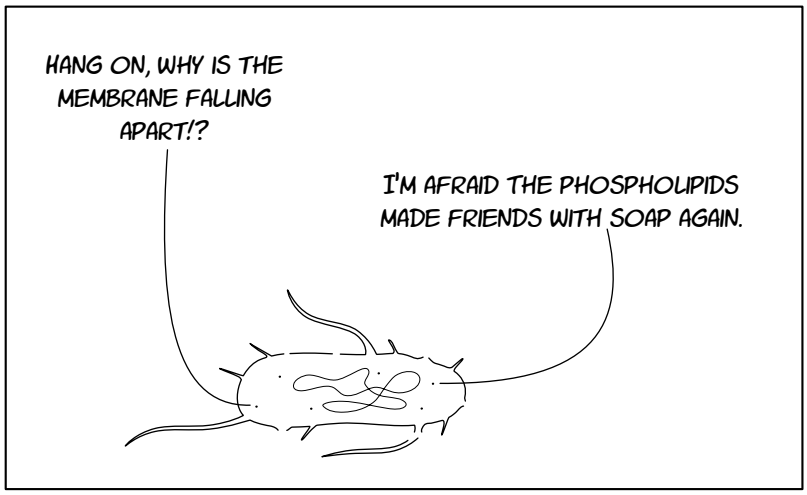
The membranes of animal cells are made of ***phospholipids***. These molecules have a "head" that is ***hydrophilic*** (attracted to water) and a "tail" that is ***hydrophobic*** (repelled by water). ***Cholesterol*** molecules stabilize the membrane and ***channel*** proteins can open to allow molecules to pass through and enter the cell.

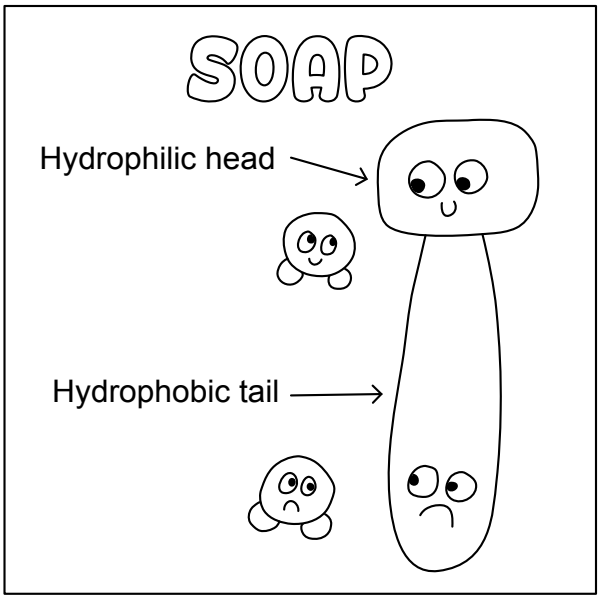


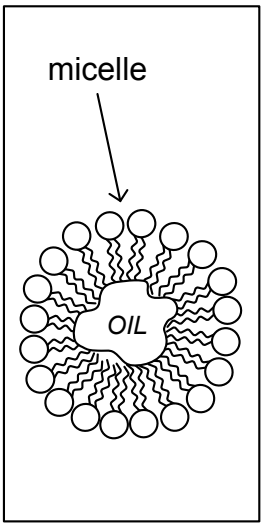
A note about soap

Soap molecules have a very similar structure to phospholipids. They naturally form spheres called *micelles*, and when they come in contact with another membrane (such as a bacteria on your hands) the hydrophobic tails wedge themselves into that membrane, disrupting it and helping it break apart.







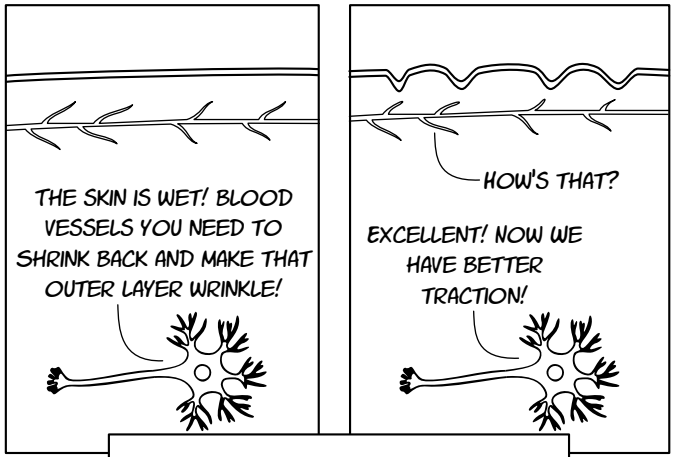


Hand washing doesn't just wash bacteria and other germs down the sink. It also disrupts their cell membranes. If soap damages bacteria, could it damage your cells too? While too much soap can irritate the skin, the outermost layer of skin is an extra-tough layer of lipids and proteins called the stratum corneum which is designed to protect the body and is much tougher than the average germ membrane.

FACT OR FICTION?

Here are two different explanations for why fingers wrinkle in the tub. Which is fact, and which is fiction?

1 It's caused by a sympathetic nervous response (a response that is involuntary and autonomous) to help improve grip and traction in slippery conditions.



FACT

2 It's caused by osmosis. Water travels into the top layer of dead skin, inflating it and causing wrinkles to form.

FICTION

Further reading on finger wrinkling:

***Science gets a grip on wrinkly fingers*, by Becky Summers in the journal Nature (2013)**
https://doi.org/10.1038/nature.2013.12175

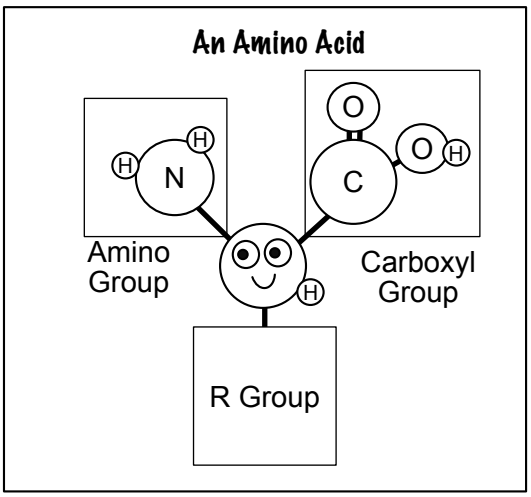
***Ask Smithsonian: Why Do We Get Prune Fingers?* By Alicia Ault, Smithsonian Magazine August 6, 2015.**
https://www.smithsonianmag.com/smithsonian-institution/ask-smithsonian-why-do-we-get-prune-fingers-180956024/

Amino Acids Make Proteins

Proteins are long polymers made of **amino acids**. An amino acid is simply a carbon atom with three attachments: an amino group, a carboxyl group, and a third item that can be anything from hydrogen to an enormously long string of molecules.

While more than 500 amino acids have been observed and described, *only 21 of them are used to make proteins* in eukaryotic cells.* Nine of those amino acids are known as **essential amino acids** because human cells cannot make them. They must come from the food a person eats.

Proteins are polymers of amino acids and can be thousands of units long. They are folded into specific shapes and used for structural support, signaling, and to run the reactions that keep the cell alive.



Match each description with a picture

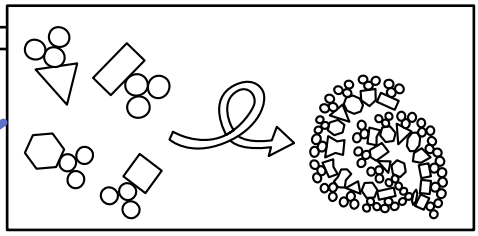
A **receptor** is a protein on the surface of a cell that binds to something specific.

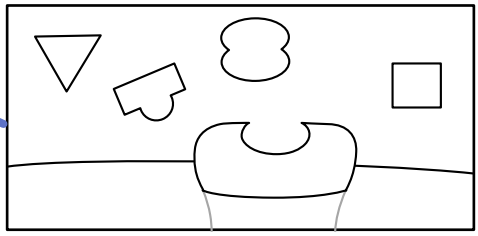
A **protein** is a polymer of amino acids that is folded in a specific way.

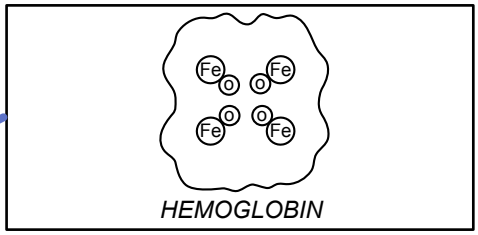
This protein is the most abundant **enzyme** on our planet! It converts carbon dioxide into a small sugar.

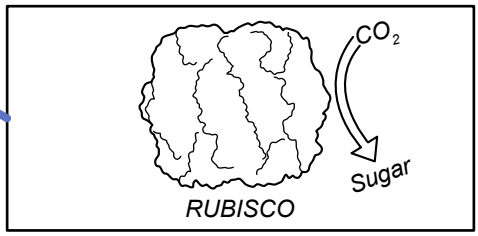
This **globular protein** has a round shape and is used by all mammals and birds to carry oxygen and deliver it to other cells.

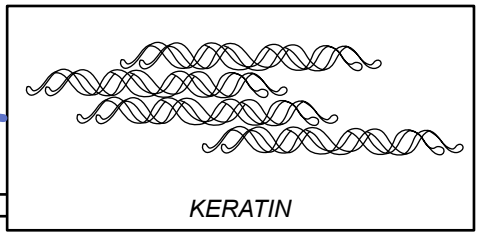
This **structural protein** is used by animals to make strong tissues like hair, nails, claws, and horns.





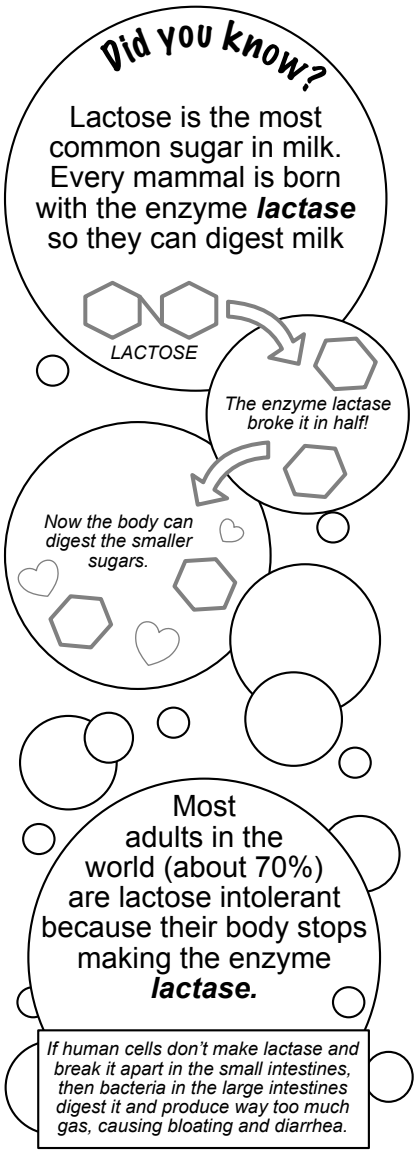






*Some argue that there are only 20 amino acids because they don't include selenocysteine.

Enzymes are amazing catalysts!



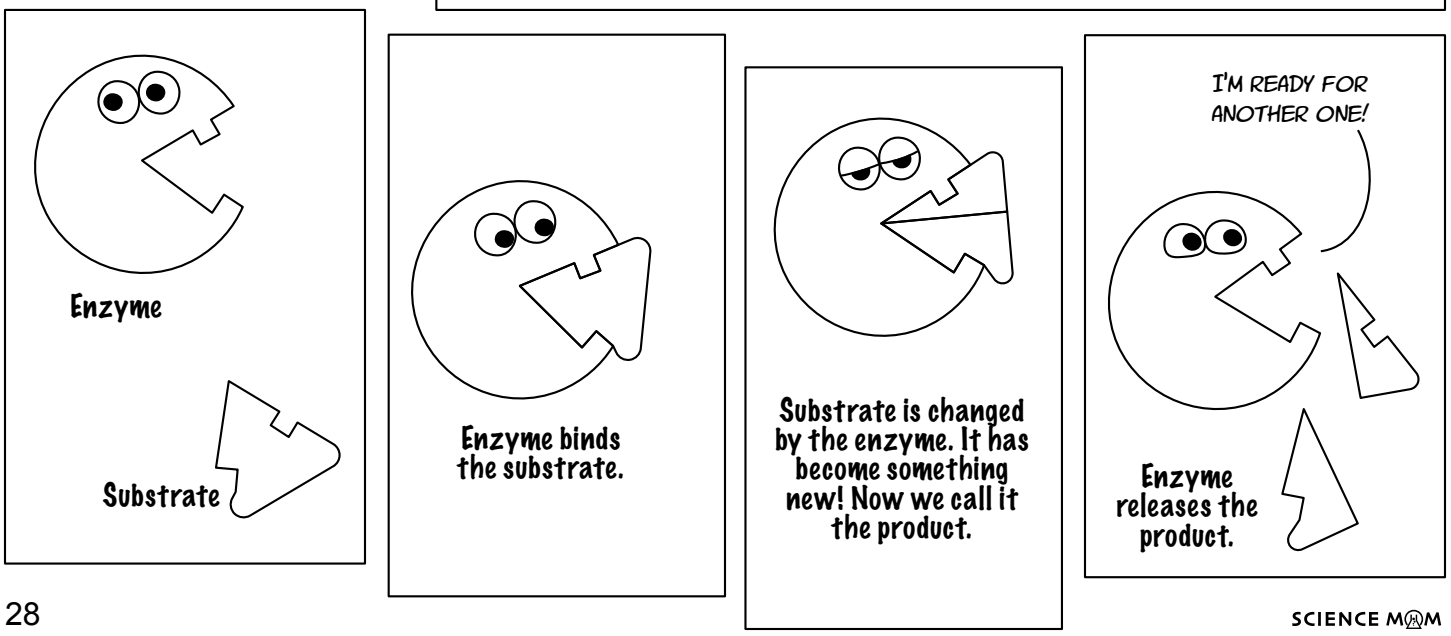
FILL IN THE BLANKS USING THESE WORDS:

sugar lactose substrate catalysts specific protein controlled

A catalyst is something that helps a chemical reaction happen. ***Catalysts*** are not changed during the chemical reaction and they work quickly. Some of the fastest catalysts can cause a million reactions to happen in a single second! In biology, the catalysts which are produced by living things are made from ***protein***. We call them enzymes.

The molecule that will be changed by the enzyme is called the ***substrate***. Different enzymes have different active sites that attach to ***specific*** substrates. One simple example of an enzyme is lactase, a protein that can break apart the ***sugar*** lactose. Someone who does not have this enzyme is no longer able to digest ***lactose***.

Lactose-intolerance can be solved by avoiding lactose sugar, but breathing oxygen also uses enzymes and it's something we can't live without! Almost everything that happens in the cell is ***controlled*** by or influenced by enzymes. They're the most important proteins around.



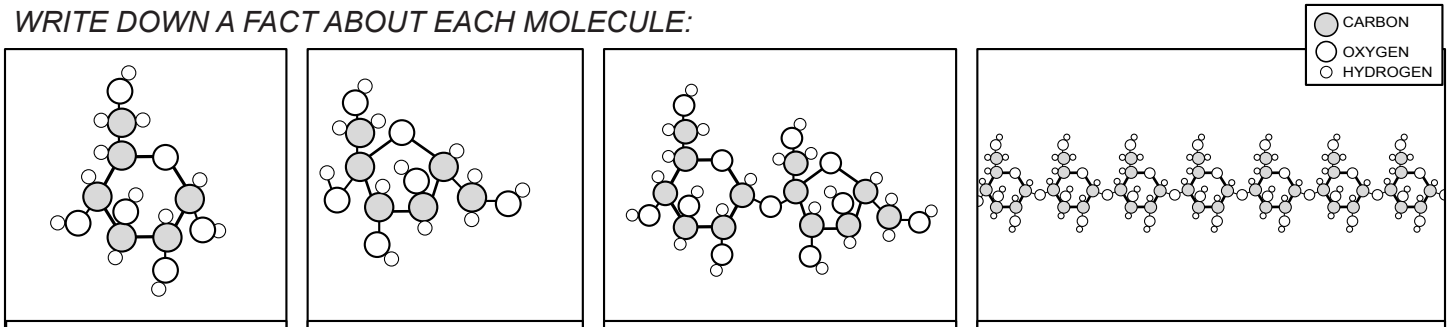
Sugars Store Energy

FILL IN THE BLANKS USING THESE WORDS:

molecules	starch	energy	essential	glucose

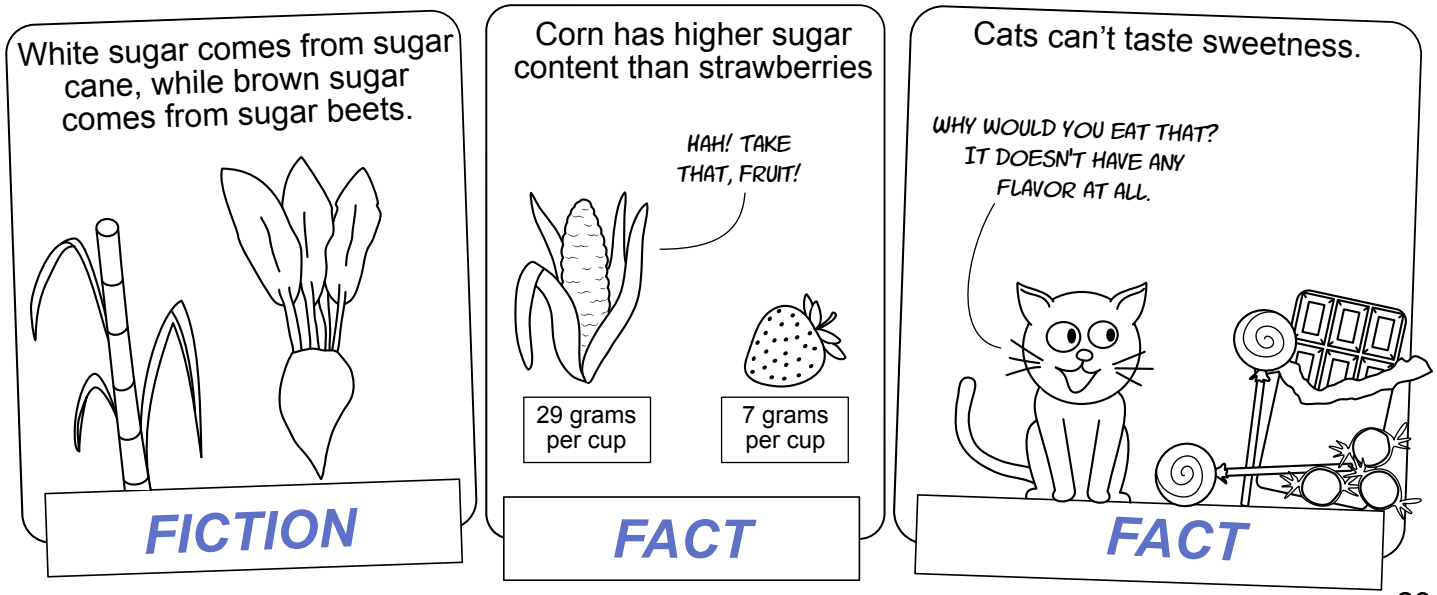
Sugars are ***molecules*** made of carbon, oxygen, and hydrogen. The simplest sugars (monomers) have a ring shape and are sometimes drawn as hexagons or pentagons. When simple sugars are linked together to form polymers, they make ***starch***. Sugars can be broken apart by the cell to produce ***energy***. They are an ***essential*** source of food for many cells. When you eat a meal of protein, fat, or starch, each of those biomolecules will be converted into ***glucose***. Glucose is the primary molecule your cells use for energy.

WRITE DOWN A FACT ABOUT EACH MOLECULE:



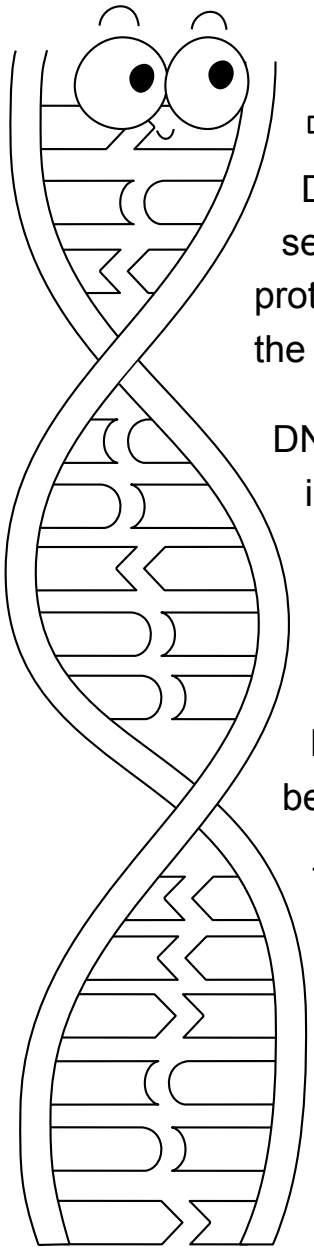
GLUCOSE	FRUCTOSE	SUCROSE	STARCH
Most popular energy source!	***Tastes sweeter than glucose.***	***Also known as table, granulated, or white sugar.***	***Found in potatoes, rice, wheat, pasta, and bread etc.***

ARE THESE FACT OR FICTION? *Write your verdict below each statement:*



 Sugar can be made from both beets or sugar cane. Brown sugar is unrefined (the first product) and white sugar is refined (further processed to remove the molasses)

DNA stands for Deoxyribonucleic Acid



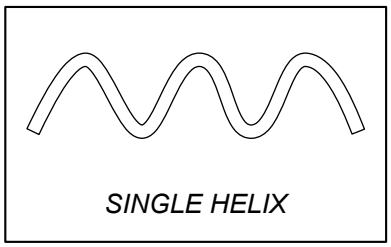
FILL IN THE BLANKS USING THESE WORDS:

nucleotides | cell | polymer | instructions | molecules | four

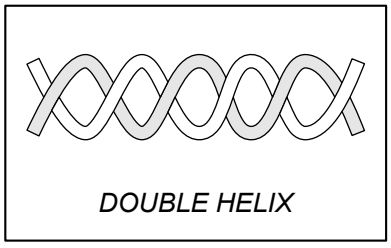
DNA is a ***polymer*** made of nucleotides. The order and sequence of the ***nucleotides*** tell the cell what type of proteins to build and the proteins (especially enzymes) then direct all the growing, eating, and moving in the ***cell***.

DNA is like a set of ***instructions*** for everything that happens in the cell. It is an incredibly long molecule with millions of nucleotides repeating in long sequences. But there are only ***four*** types of nucleotides in DNA: adenine, thymine, cytosine, and guanine.

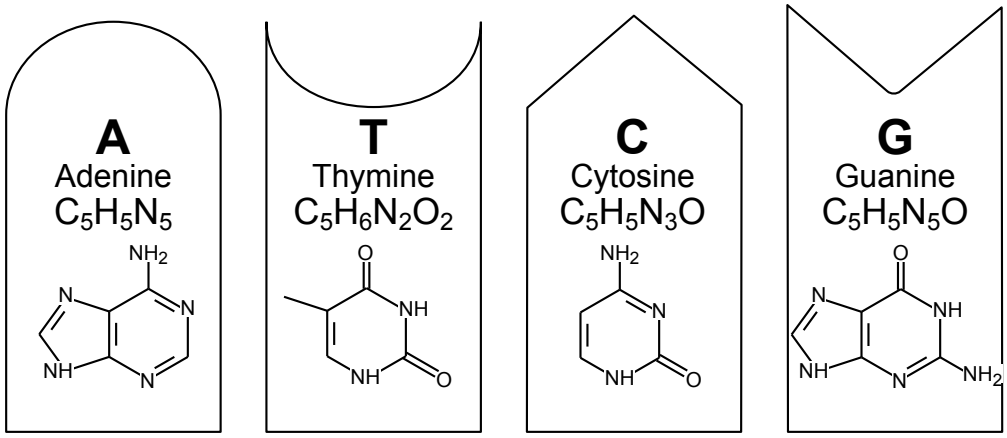
In textbooks, these nucleotides are often represented with little bars between a double helix, but in reality they are small ring-shaped ***molecules*** made of carbon, nitrogen, oxygen, and hydrogen.



SINGLE HELIX



DOUBLE HELIX



CAN YOU FIGURE OUT WHICH BASES PAIR TOGETHER?

Adenine *pairs with* ***Thymine***.

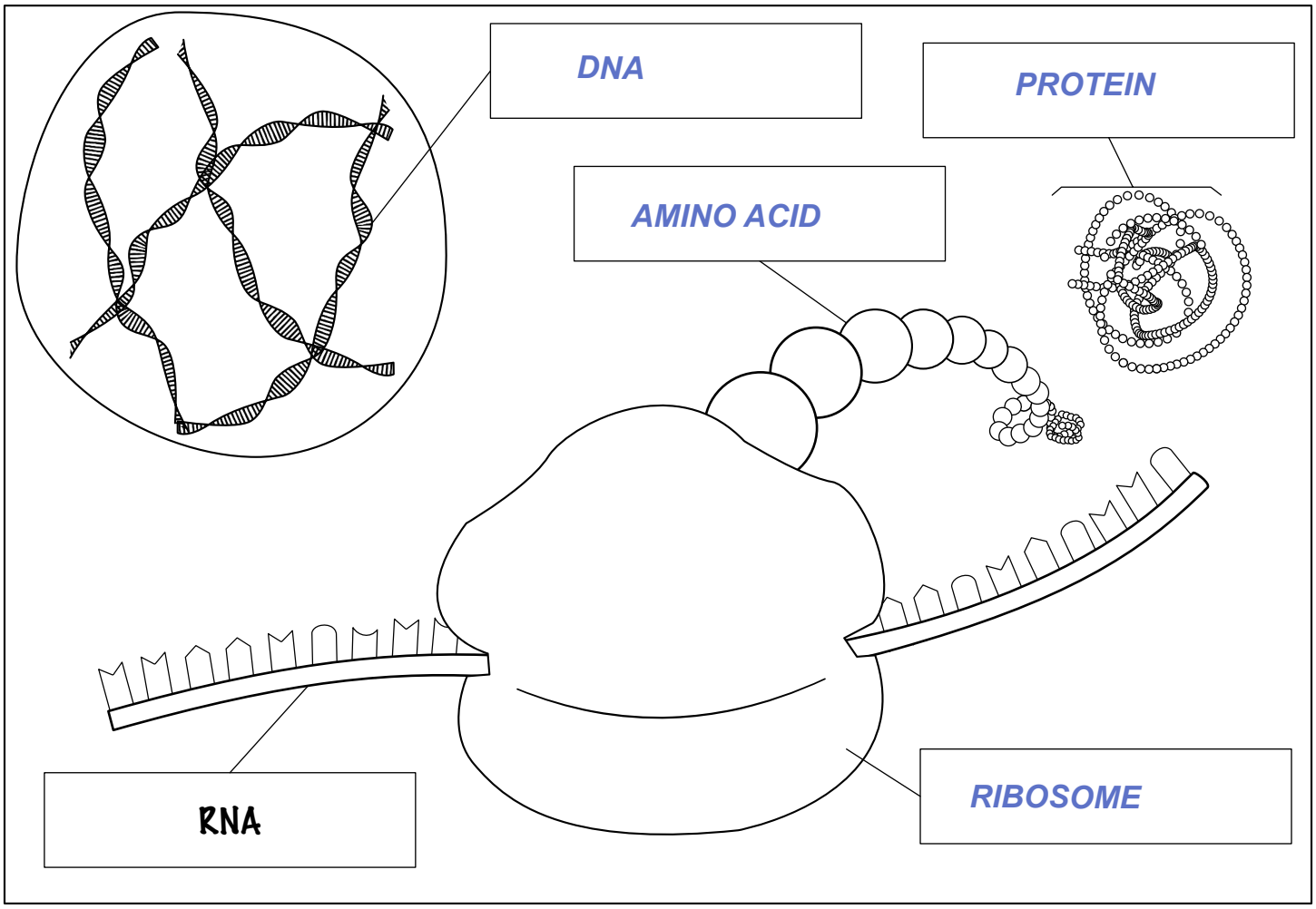
Cytosine *pairs with* ***Guanine***.

The Blueprint for Life

We'll learn more about genetics in Biology 2, but here is a simple overview of how DNA controls protein creation in the cell: the DNA is "transcribed" into a shorter RNA molecule that leaves the nucleus. The RNA is then "read" by a ribosome that matches the nucleotides with the correct amino acids to build a protein.

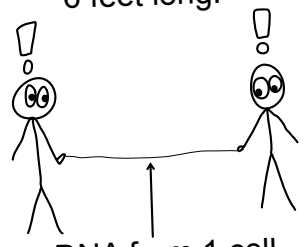
Use the following words to label each box in the drawing below:

RIBOSOME DNA AMINO ACID PROTEIN



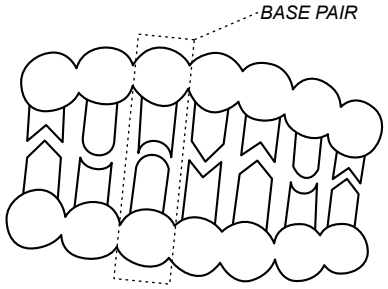
Are these FACT or FICTION? *Write your verdict below each statement:*

If the DNA from just one of your cells were stretched out end to end, it would be 6 feet long!



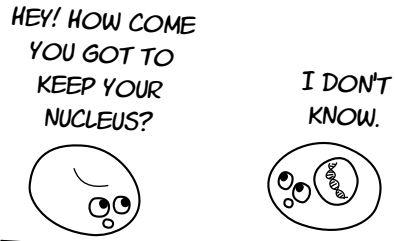
FACT

The DNA inside each of your cells has 3 billion base pairs.



FACT

Red blood cells in mammals have no DNA, but blood cells in fish, reptiles, and birds do!

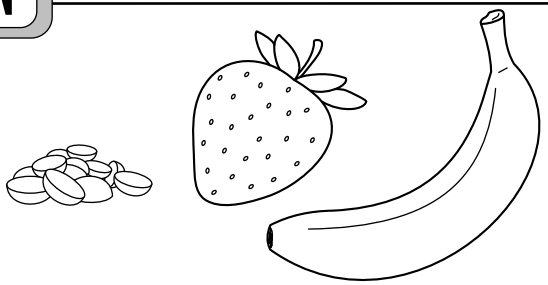


FACT

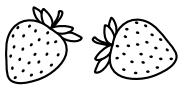
Hands-on Science Project

DNA EXTRACTION

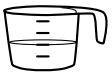
Take Note! This activity can be done with split peas, bananas, OR strawberries. You can choose whichever version is most convenient or try them all and compare them!



OPTION ONE: STRAWBERRY



2 or 3 fresh strawberries
(frozen can be used if they have been completely thawed)



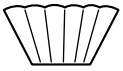
½ cup warm water
(4 ounces)

1 tsp salt
(6 grams)

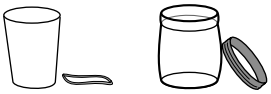
Plastic bag OR a bowl and fork for squishing the strawberry to a pulp.

2 tsp concentrated dish soap
(10 ml)

Rubbing alcohol
(91 percent)



Coffee filter



Cup or glass jar and a rubber band or ring for securing the coffee filter

Instructions

1. Place your rubbing alcohol in the fridge.

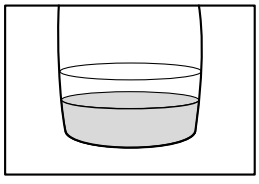
2. Thoroughly squish the strawberries. There should be no chunks or large pieces when you are done.

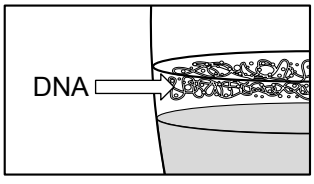
3. Make your extraction solution by mixing together the water, salt, and dish soap. Then add 2 to 3 teaspoons of extraction solution to your squished strawberry and stir gently for one minute.

4. Pour the strawberry mixture into a coffee filter and let sit for 5 minutes. VERY GENTLY close the tops of the coffee filter and press to extract more liquid. Be careful not to press too hard. If the coffee filter breaks you will need to strain the liquid again.

5. Take the rubbing alcohol out from the fridge and carefully pour a layer on top of the fruit liquid. The goal is for the amount of rubbing alcohol to be roughly equal in height to the layer of fruit liquid.

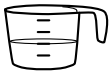
6. Observe and watch for a white foamy substance to form in the rubbing alcohol. This Is your DNA! If desired, you can use a toothpick or fork to lift it out.





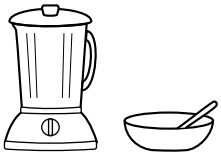
OPTION TWO: BANANA

½ ripe banana, completely frozen and then thawed.



½ cup warm water
(4 ounces)

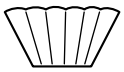
1 tsp salt
(6 grams)



Blender or bowl and fork for pulverizing the banana.

2 tsp concentrated dish soap
(10 ml)

Rubbing alcohol
(91 percent)



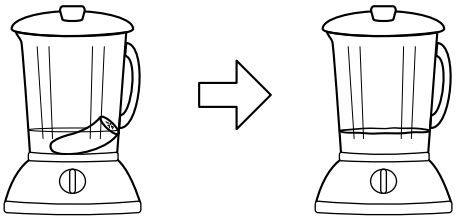
Coffee filter

Cup or glass jar and a rubber band or ring for securing the coffee filter

Instructions

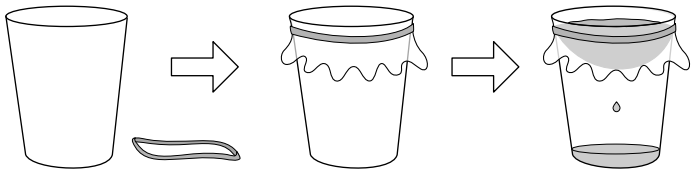
1. Place your rubbing alcohol in the fridge.

2. Add ½ cup warm water and ½ frozen-but-then-thawed banana to a blender. Freezing and then thawing the banana helps the cells to break open more easily and results in better yields of DNA. Blend for 30 seconds. If not using a blender, be sure to mash the banana until it is *completely* smooth.



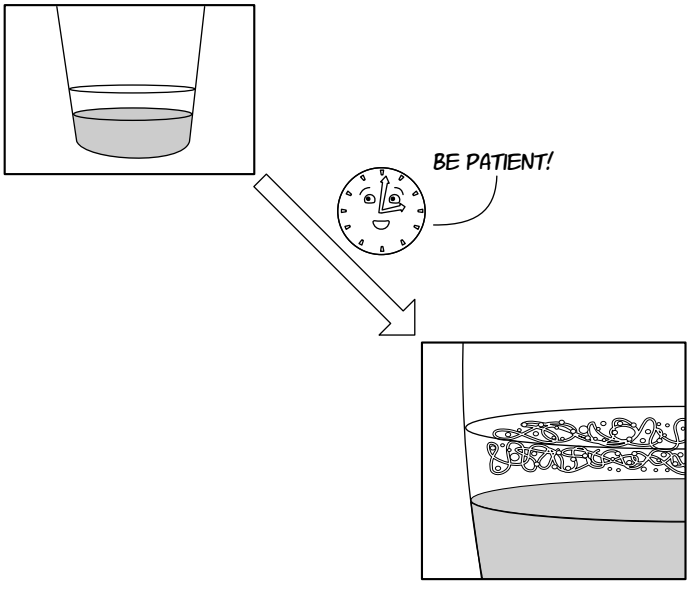
3. Transfer mixture to a cup and add 1 tsp salt and 1 tsp liquid soap.

4. Mix gently. (You don't want the mixture to become frothy or full of suds and soap bubbles.)



5. Place a coffee filter over a cup or jar and pour the banana mixture into a coffee filter. Let sit for 10 minutes. Water, DNA, and other small cell parts will drain through the filter into the jar.

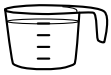
6. Remove the filter and pulp. Tip the cup or jar to the side and slowly add a layer of cold rubbing alcohol on top of the banana juice. The goal is for the amount of rubbing alcohol to be roughly equal in height to the layer of fruit liquid.



7. Observe and watch for a white foamy substance to form in the rubbing alcohol. This is the DNA strands sticking together. Don't worry if you don't see anything in the first minute or two. The process may take up to 10 minutes. The DNA will look like a white strands floating in the rubbing alcohol layer.

OPTION THREE: SPLIT PEAS

½ cup of split peas
(100 ml)



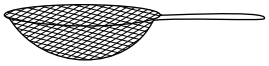
1 cup water
(8 ounces)

1/8 tsp salt
(1.5 grams)

Electric blender

1 tsp concentrated
dish soap *(15 ml)*

Rubbing alcohol
(91 percent)



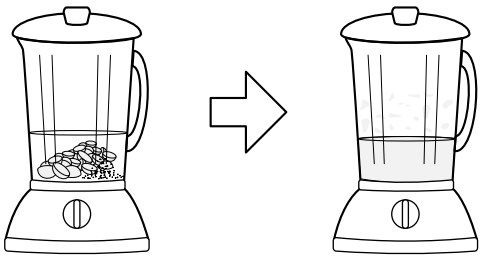
Mesh
strainer

Narrow test tube or
a small clear cup

Meat
tenderizer

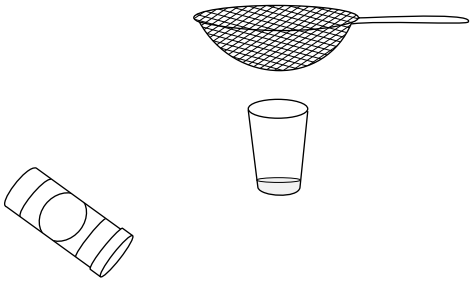
Instructions

1. Add the water, split peas, and salt to the blender. Check to make sure the lid to the blender is on securely. Blend on high speed for 25 seconds.



2. Pour the pea mixture through a strainer and collect the juice.

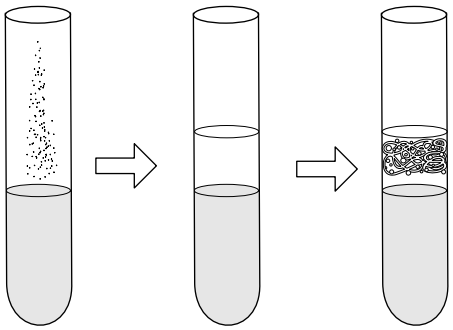
3. Add one tablespoon of soap to the strained split pea juice. Mix slightly and let sit for at least 5 minutes. During this step the soap is dissolving the membranes and releasing the DNA.



4. Pour the juice into a test tube or other narrow container. Add a small pinch of meat tenderizer and mix very gently. The meat tenderizer enzymes help separate the DNA from other proteins so that it will clump together in the next step. Do not shake or stir. Too much motion will cause meat tenderizer to break down the DNA.

5. Very gently add a layer of rubbing alcohol above the split pea mixture.

6. Observe the container for several minutes. You should see a cloudy, white layer form in the rubbing alcohol layer. This is the DNA!

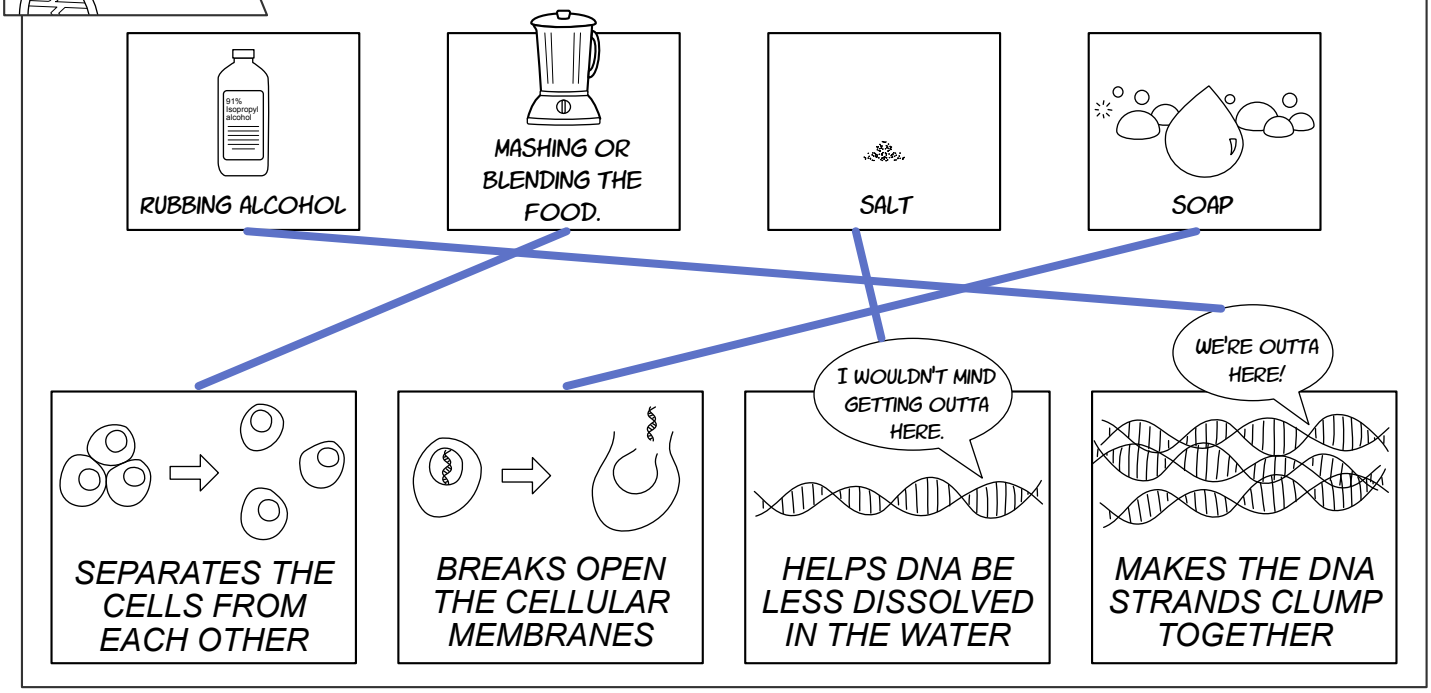


Strawberry vs Banana vs Pea

Of the three variations, DNA extraction from strawberries is the easiest because strawberries naturally contain enzymes called pectinases and cellulases. Once the strawberry is squished, these enzymes start breaking down the cell walls and membranes, releasing the DNA into the mixture. Strawberry extraction typically yields good results even if the rubbing alcohol is warm or the mixture isn't mashed thoroughly. Bananas and peas, on the other hand, can be more challenging because they do not contain enzymes that will help break apart the cells. If you don't see DNA in the first attempt, try again and follow the instructions more carefully.

How does it work?

Draw lines to match each ingredient or step with what it's doing:



YOUR OBSERVATIONS

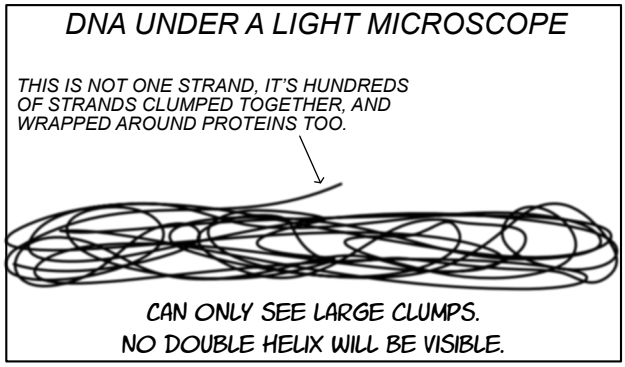
Did your DNA precipitate (clump together) in the layer of rubbing alcohol?

Hopefully it did!

What advice would you give another person who was trying this science activity?

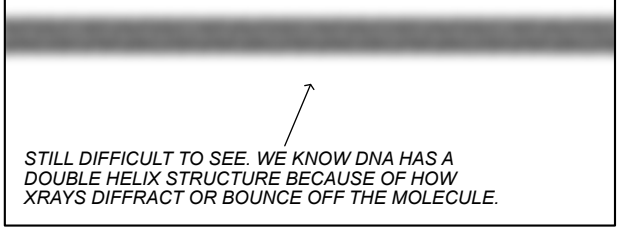
Don't give up if it doesn't work the first time! Be patient and wait a few more minutes if you don't see DNA. Sometimes it takes a little while to precipitate.

DNA UNDER A LIGHT MICROSCOPE



DNA is actually very difficult to see under a microscope because it's a VERY thin molecule (only 2 nanometers across!) and it's quite fragile. Electron microscopes (which can see objects as small as 2 nm) will cause a single strand to break apart.

*DNA UNDER AN ELECTRON MICROSCOPE**

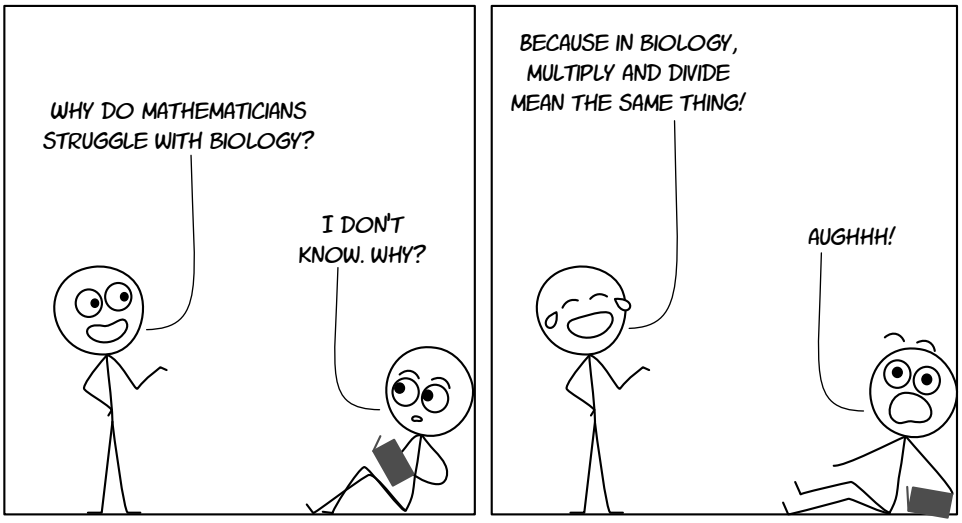


**Artistic interpretation of an image by Enzo di Fabrizio published in the journal Nanoletters in 2012.*

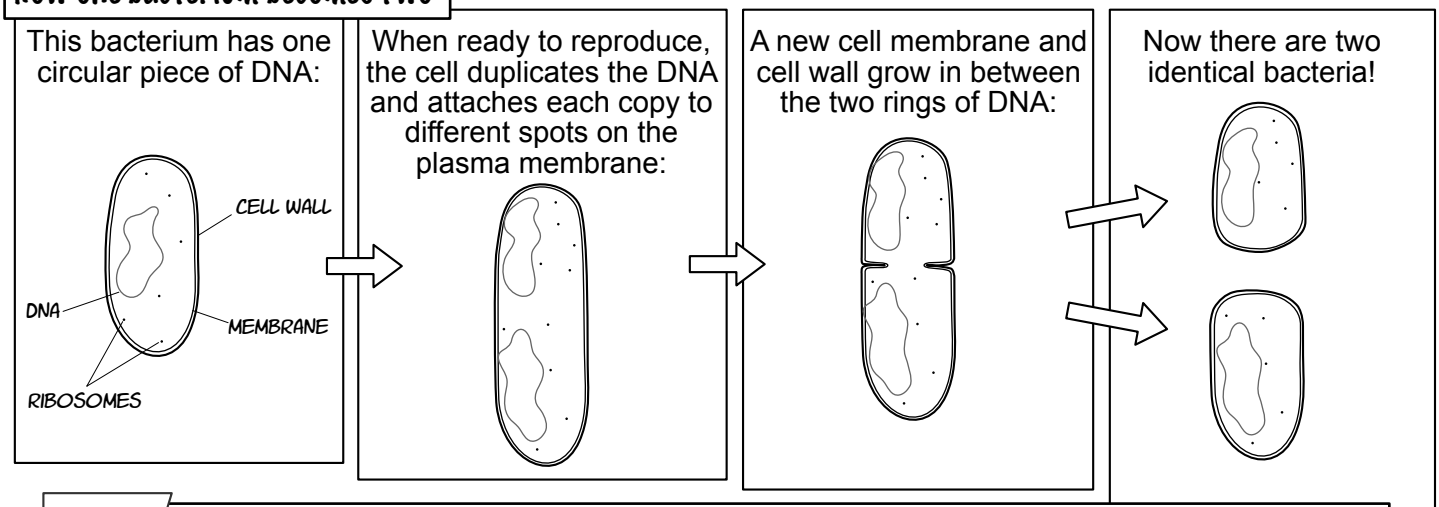
Cell Division

Growing is one of the primary characteristics of living things. A newborn baby likely has around 30 billion cells. When fully grown, that same person is estimated to have more than *30 trillion* cells. As they grew from infant to adult, their body made trillions of new cells using **cell division**.

It's called cell division because under the microscope, it often looks like a cell is being "divided in half" to produce two new cells. But cell division can also be referred to as cells multiplying or reproducing.

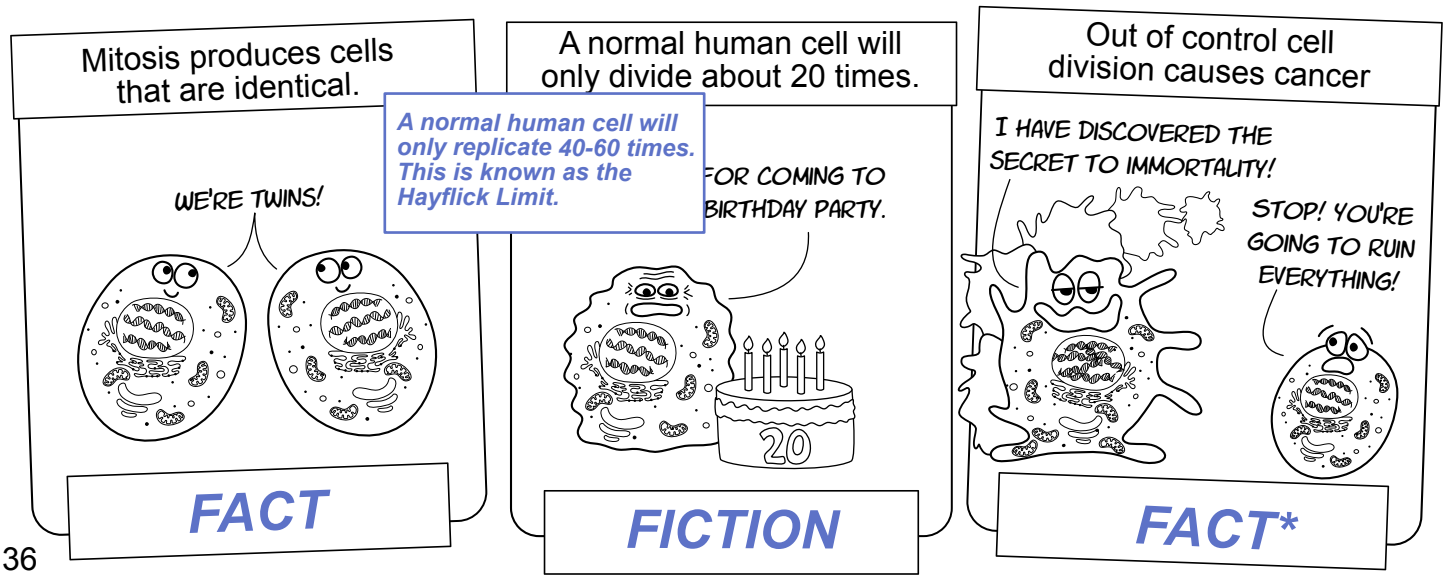


How one bacterium becomes two



Did you know? *Under ideal conditions, many bacteria can double their populations every 20 minutes. This means that in 8 hours, JUST ONE bacterium could multiply to produce 16 MILLION bacteria!*

Are these FACT or FICTION? *Write your verdict below each statement:*



**A cascade of mutations need to occur in the same cell for it to become cancerous. But once it is cancerous it will grow and replicate at an abnormally rapid rate.*

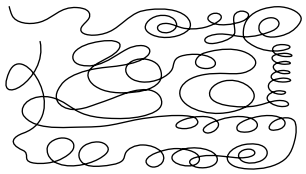
Mitosis

FILL IN THE BLANKS USING THESE WORDS:

replicate DNA proteins membrane mitosis

DNA in the cell is usually loose and "unwound" so that the information it contains can be "read" and used. But when the cell gets ready to ***replicate*** itself, it needs to make extra copies of the DNA and separate them. For this step, the DNA is packed tightly with small ***proteins*** and each strand or chromosome is clearly visible. Next, the chromosomes line up and then split apart and move to opposite ends of the cell. Then the center of the cell pinches together until the cell splits into two and the membranes close. The ***membrane*** of the nucleus reforms in each cell and the ***DNA*** in the chromosomes unpacks again so it can be used by the cell. This process of cell division is called ***mitosis***.

A STRAND OF DNA IS USUALLY LOOSE AND "UNWOUND" SO IT CAN BE USED BY THE CELL.

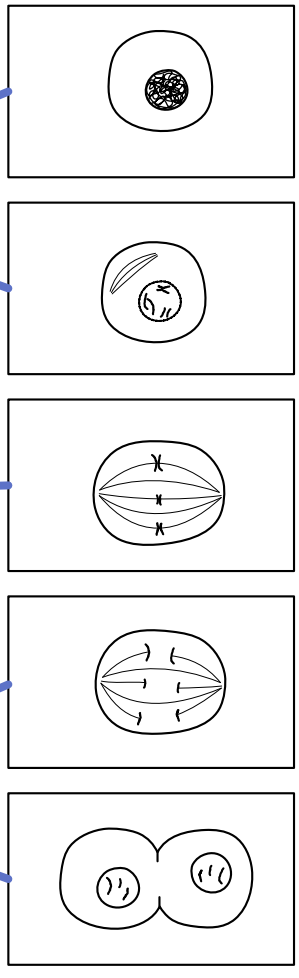


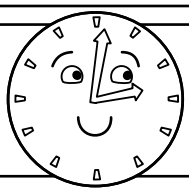
DURING CELL DIVISION THE DNA CONDENSES TO FORM TIGHTLY-PACKED CHROMATIDS.

SAME STRAND AS ABOVE! NOW IT'S JUST PACKED TOGETHER.

Draw lines to match each image of mitosis with the correct name and description:

Prophase	*The cell prepares to divide by condensing the DNA.*
Interphase	*The DNA is inside the nucleus, loose and uncondensed. This is the longest phase of the cell cycle.*
Metaphase	*Pairs of tightly packed DNA line up in the center of the cell.*
Telophase and Cytokinesis	*A nuclear membrane forms around the DNA and a cleavage furrow forms between the two nuclei.*
Anaphase	*Thin strands called microtubules pull the chromatids apart to opposite ends of the cell.*





Quiz Time!

ANSWER THE QUESTIONS TO SEE WHAT YOU LEARNED ABOUT BIOMOLECULES!

1. DNA is a polymer made of which monomer?
   A. Amino acids
   B. Nucleotides
   C. Sugars
   D. Phospholipids

2. A substance that will allow some molecules to pass but not others is best described as:
   A. Impermeable
   B. Semipermeable

3. During osmosis, water will flow from an area with a _____ concentration of solute to an area with a _____ concentration of solute.
   A. Higher, lower
   B. Lower, higher

4. A raisin placed in warm water will:
   A. Shrink
   B. Swell
   C. Stay the same size

5. Membranes of animal cells are made of:
   A. Protein
   B. DNA
   C. Phospholipids
   D. Amino Acids

6. Something that mixes well with water is described as being _____.
   A. Hydrophobic
   B. Hydrophilic

7. Lipids are classified as being _____.
   A. Hydrophobic
   B. Hydrophilic

8. What is cholesterol's role in a cell membrane?
   A. It stabilizes the membrane and keeps it from falling apart.
   B. It allows molecules to pass from one side of the membrane to the other.
   C. Most of the membrane is made of cholesterol.

9. Just like a phospholipid, soap has a _____ head and a _____ tail.
   A. Hydrophobic, hydrophilic
   B. Hydrophilic, hydrophobic

10. True or False: Soap molecules will naturally form tiny spheres when they are mixed with water.
    A. True — *They are called micelles*
    B. False

11. Proteins are polymers made of which monomer?
    A. Amino acids
    B. Nucleotides
    C. Sugars
    D. Phospholipids

12. The most abundant enzyme on the planet is:
    A. Hemoglobin
    B. Rubisco
    C. Keratin
    D. Receptor proteins

13. Something that helps a chemical reaction happen more quickly is called a _____.
    Enzyme or Catalyst
    Both are correct.

14. An enzyme binds to a _____.
    A. Catalyst
    B. Substrate
    C. Sugar
    D. Phospholipid

15. True or False: All enzymes are catalysts but not all catalysts are enzymes.
    A. True — *There are many elements and compounds that can catalyze a reaction without being changed by the reaction.*
    B. False

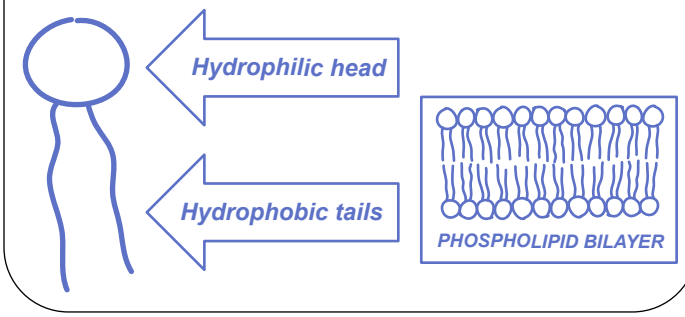
16. Starch is a polymer made of which monomer?
    A. Amino acids
    B. Nucleotides
    C. Sugars
    D. Phospholipids

17. How many different types of nucleotides are used to make DNA?
    A. 4
    B. 5
    C. 21
    D. More than a million

18. True or False: Guanine pairs with cytosine.
    A. True
    B. False

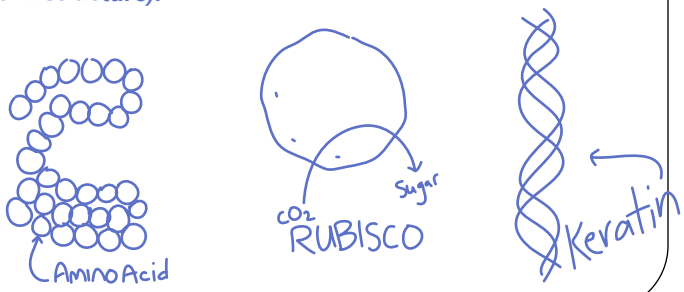
19 Draw a picture of a phospholipid:

Your drawing can be super simple (circle with two lines) or detailed. The main idea is that the tails are hydrophobic (water fearing) and the top or head is hydrophilic (water loving). If you want, you could also include a picture of a phospholipid bilayer or cell membrane.



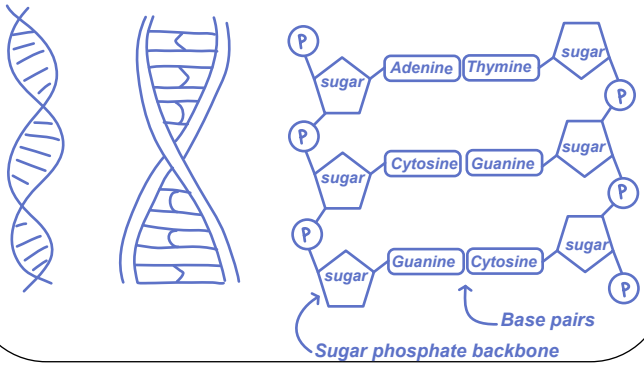
20 Draw a picture of a protein molecule:

The main concept is that a protein is a long chain of units that has then been folded. Circles can be used to represent the amino acids (simplest representation), or specific proteins that were mentioned in class could be used such as Rubisco (large round molecule), hemoglobin (circular with 4 iron atoms), or keratin or collagen (both with a triple helix structure).



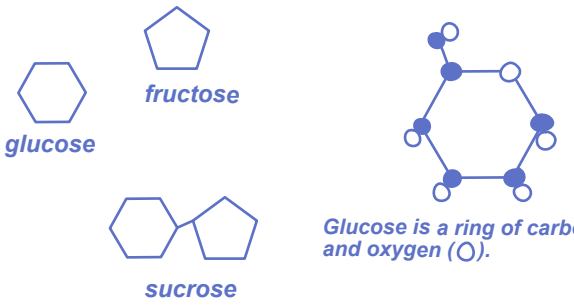
21 Draw a picture of a DNA molecule:

The main concept is that DNA is a double helix made of nucleotides that link together. The drawing can be very simple (just lines to represent the nucleotides and backbone of the helix) or more complex.

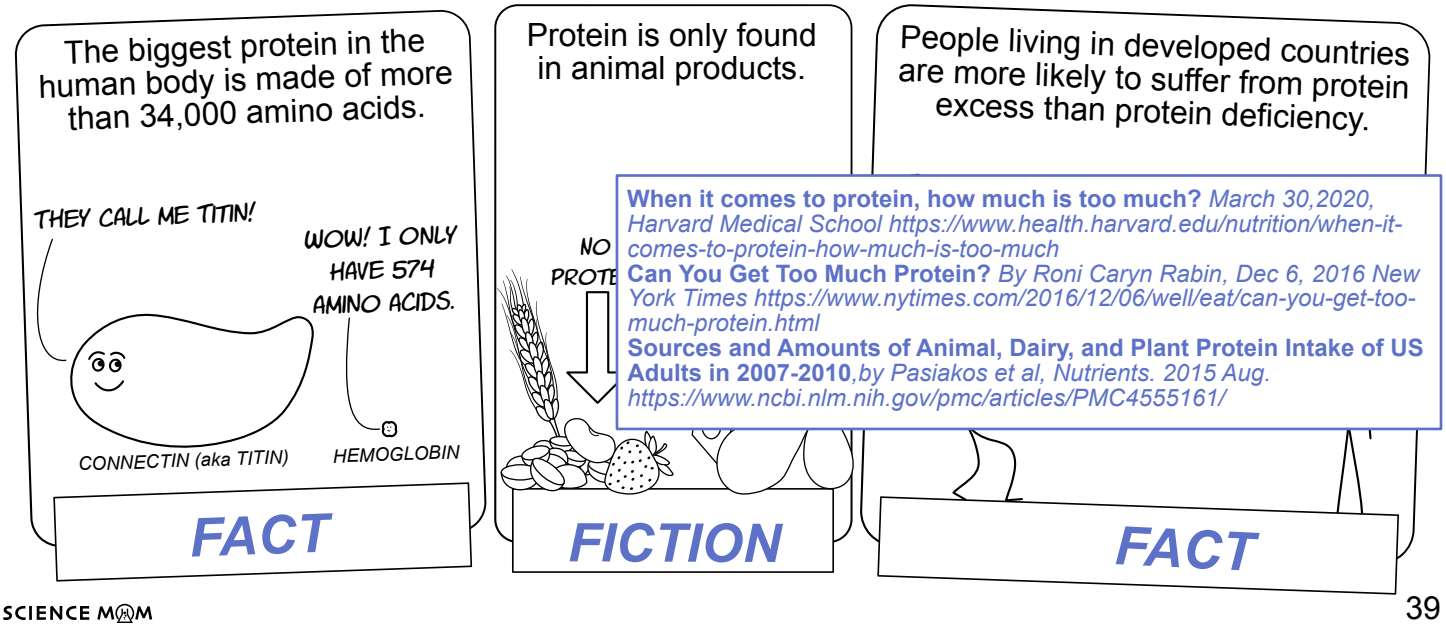


22 Draw a picture of a sugar molecule:

The main concept is that sugars are ring-shaped molecules. Anything with a hexagon or pentagon shape could represent a sugar! Bonus points for remembering that they are made of carbon, oxygen, and hydrogen!

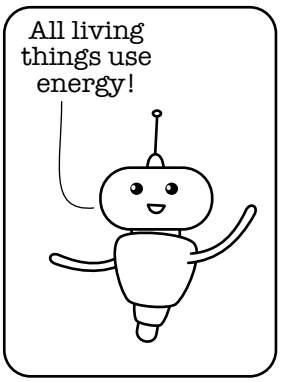


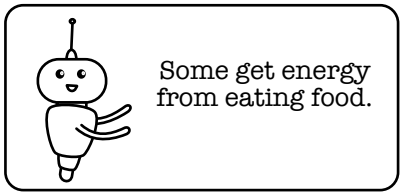
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

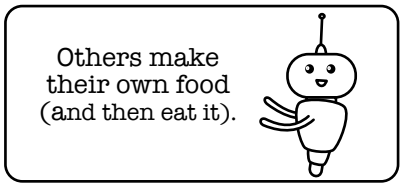


When it comes to protein, how much is too much? *March 30,2020, Harvard Medical School https://www.health.harvard.edu/nutrition/when-it-comes-to-protein-how-much-is-too-much*
Can You Get Too Much Protein? *By Roni Caryn Rabin, Dec 6, 2016 New York Times https://www.nytimes.com/2016/12/06/well/eat/can-you-get-too-much-protein.html*
Sources and Amounts of Animal, Dairy, and Plant Protein Intake of US Adults in 2007-2010,*by Pasiakos et al, Nutrients. 2015 Aug. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4555161/*

Where does the energy come from?







One of the most important questions to ask about a living thing organism is ***where*** and ***how*** it gets its energy. The graphic on page 16 divides life into single-celled and multi-celled categories. Another way to divide living things is to look at whether they ***can*** *make their own food* (**autotroph**) or ***cannot*** *make their own food* (**heterotroph**).

Autotroph

WE HAVE CREATURES THAT CAN DO BOTH! SOME MAKE THEIR OWN FOOD AND OTHERS CONSUME FOOD THAT SOMEONE ELSE MADE.

PLANTS

Fern
A plant that doesn't have flowers

Tulip
A flowering plant

Brown Algae
Also called kelp

PROTISTS

Cyanobacteria
Photosynthetic

Methanogens
Can make its own food without sunlight

Halobacterium
Photosynthetic salt-loving archaea

Sulfolobus
Can do both using sulfur!

Heterotroph

HOW COME NONE OF US GET TO GO ABOVE THAT DOTTED LINE?

Dodder
a parasitic plant!

Amoeba
Eats other cells

Acidophilus
Used to make yogurt

Ferroglobus
Can eat iron and hydrogen gas

THERE'S A REASON THEY CALL US THE CONSUMERS.

Streptococcus
Can cause pneumonia

BACTERIA

Thermus aquaticus
Grows in hot springs

ANIMALS

FUNGI

ARCHAEA

Amazing Animals

All animals get their energy from eating food. Can you write the name for each animal in the box that matches its diet? For example, worms eat rotting bits of leaves or decaying animal matter, so they are detritivores.


worm


ladybug


snail


sponge


cow


blue whale


koala


giraffe


raccoon


tiger


spider


bear


shark


axolotl


tadpole


frog

With the general names of "worm" and "sponge" and "snail," there are multiple right answers because different species have different dietary preferences.

DETRITIVORE - eat decaying things

worms
Snails and slugs
Sea sponge

HERBIVORES - eat plants or algae

Adult ladybug (a few species are strictly herbivorous as adults)
Snails and slugs
Cow
Koala
Giraffe
Bear (Panda) *Tadpoles*

CARNIVORES - eats other animals

Worms
Most ladybug larva are carnivores
Snails and slugs
Sea sponge
Blue whale
Tiger
Spider
Shark
Frog

OMNIVORES - eat plants and animal matter

Worms *Raccoon* *Bear* *Sea sponge*
Most ladybug adults are omnivores
Snails and slugs *Tadpole* *Frog*
Axolotl (larva eat algae, adults eat invertebrates)

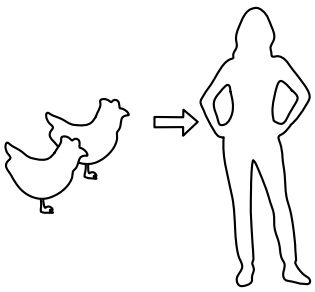
** There are several species of **spider**, such as Bagheera kiplingi, that have mostly herbivorous diets.*

ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

All animals are multicellular consumers made of eukaryotic cells.
This is the definition of an animal.

FACT

On Earth, there are twice as many chickens as human beings.



FICTION

Of the 1.5 million named and described species on Earth, more than 1 million are insects.

Estimating the total number of named species is challenging because new species are being described every day and scientists estimate that we have only described and named a very small percentage of bacteria and archaea. But of the described and named species, the vast majority are insects! For more on species biodiversity, see a 2017 article from the University of Chicago: https://phys.org/news/2017-08-biodiversity-earth.html

FACT

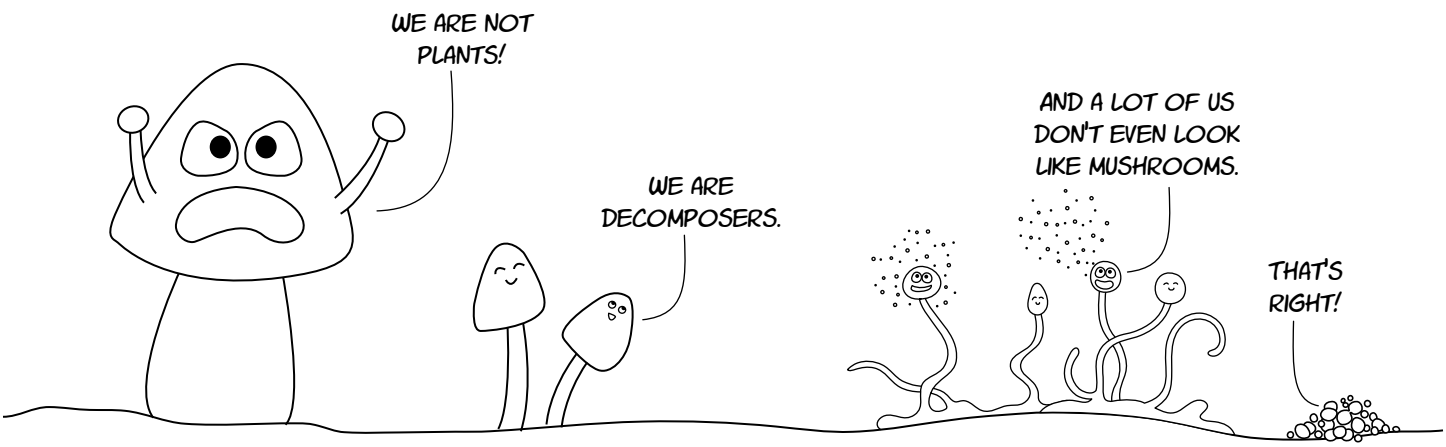
There are an estimated 23 BILLION chickens, which is almost 3 times as many people. For more on how numerous chickens are, see a 2018 article by the Royal Society: "The broiler chicken as a signal of a human reconfigured biosphere. https://royalsocietypublishing.org/doi/10.1098/rsos.180325

Fabulous Fungi

FILL IN THE BLANKS USING THESE WORDS:

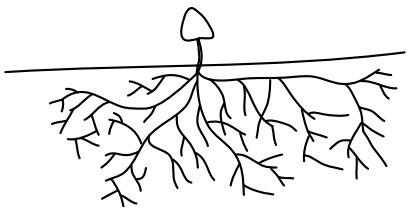
agrees	yeast	trees	organic	infecting
energy	digest	plants	specialize	consumers

All fungi are ***consumers***. They get their ***energy*** from eating plant or animal matter. Most fungi are decomposers, meaning they break down ***organic*** matter and ***digest*** things like dead wood, leaves, or old food that is left in the fridge too long. But that doesn't mean we only find fungi living on rotten food or dead ***trees***. Many species ***specialize*** in attacking and then ***infecting*** living plants or animals. No matter what type of fungus you have, from single-celled ***yeast*** to slime molds to mushrooms, every biologist ***agrees*** that fungi are not ***plants***!



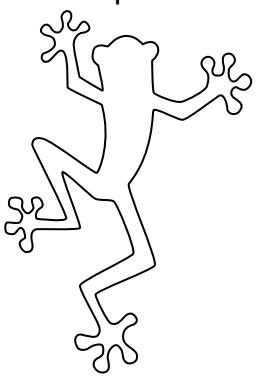
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

If you see a mushroom on your lawn, most of the mass of that fungus is underground.



FACT

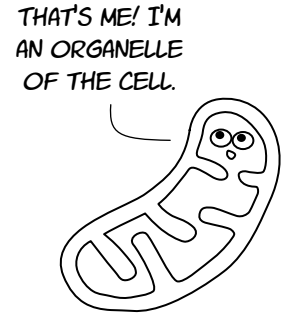
The chytrid fungus has caused the extinction of several species of frogs.



FACT

Fungi cells don't contain mitochondria.

Mitochondria are found in all animal, plant, and fungi cells.



FICTION

For one example of underground mass of fungi being more than above ground, see "Strange but True: The Largest Organism on Earth Is a Fungus, 2007 Scientific American https://www.scientificamerican.com/article/strange-but-true-largest-organism-is-fungus/

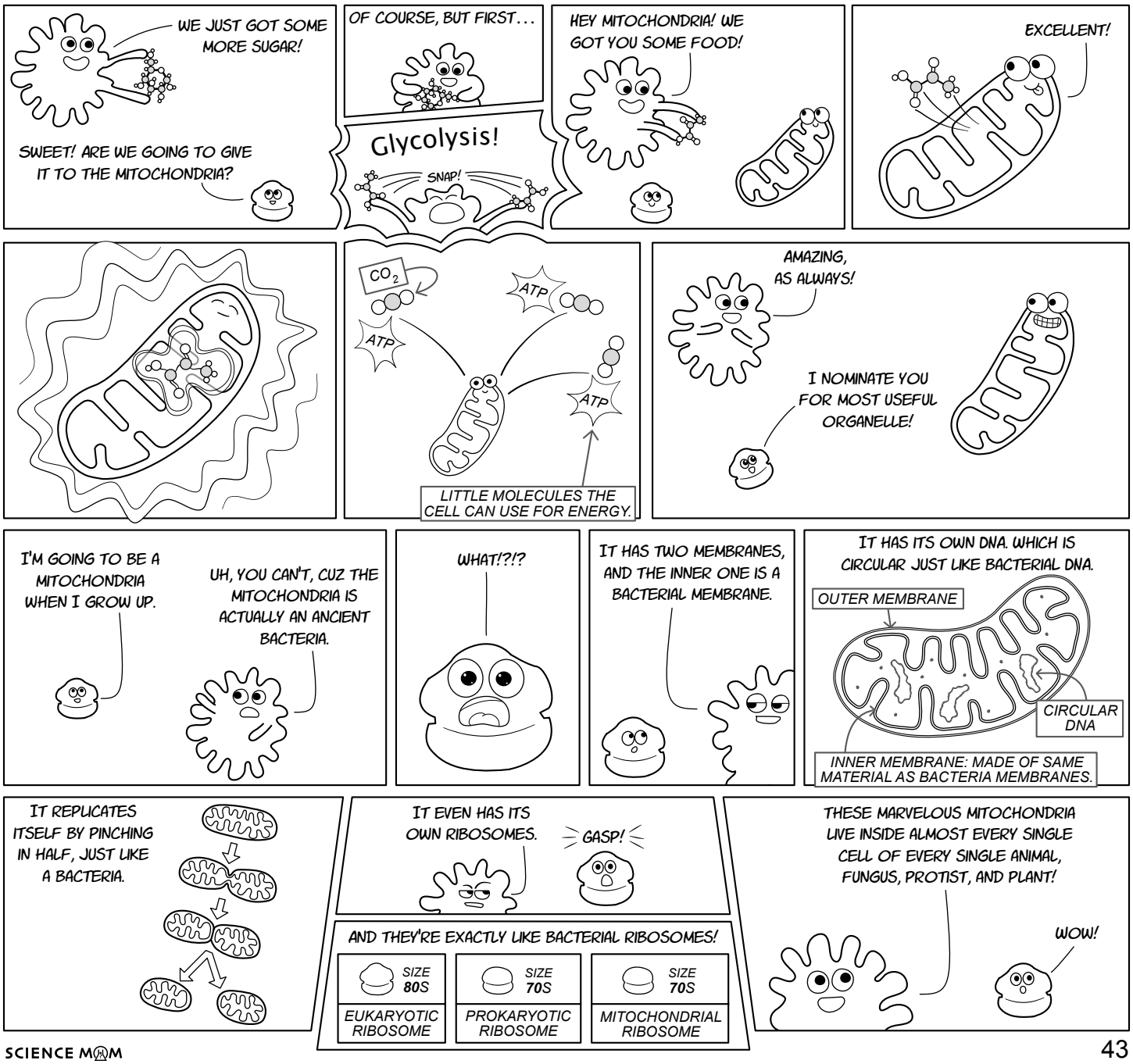
Cellular Respiration

FILL IN THE BLANKS USING THESE WORDS:

energy	glucose	glycolysis
carbon	respiration	mitochondria

Animals and fungi get their energy from food, but how do they do it? The answer is cellular ___respiration___, one of the most important reactions on the planet! It starts with ___glucose___, which is an excellent source of ___energy___. Before the energy can be released, the glucose needs to be split in half. This is called ___glycolysis___. Next the ___mitochondria___ uses oxygen to break the molecules into smaller pieces until they are converted to ___carbon___ dioxide and water.

Mitochondria - The MVP with a Mysterious Past

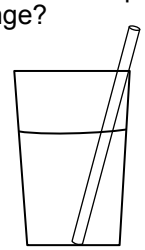


Try these activities to learn more about cellular respiration!

CARBON BREATH?

Each time you exhale, you breath out carbon dioxide, or CO2. Carbon dioxide changes the pH of cabbage juice, making it more acidic. Take a straw and blow bubbles into water that has been boiled with purple cabbage. Do you see a color change?

CONTROL
(NO TREATMENT)



CUP WITH STRAW
(TREATED WITH AIR FROM LUNGS)

WITH OR WITHOUT AIR?

Measure the amount of carbon dioxide that baker's yeast produces in a bottle that is full of water vs one with half water and half air. Add 2 TBS yeast and 2 TBS sugar to both bottles. Then add water to fill them half full, cover the opening of the bottle and shake. Next, fill one bottle completely full of water and cover both with balloons. Which bottle produces more carbon dioxide gas?

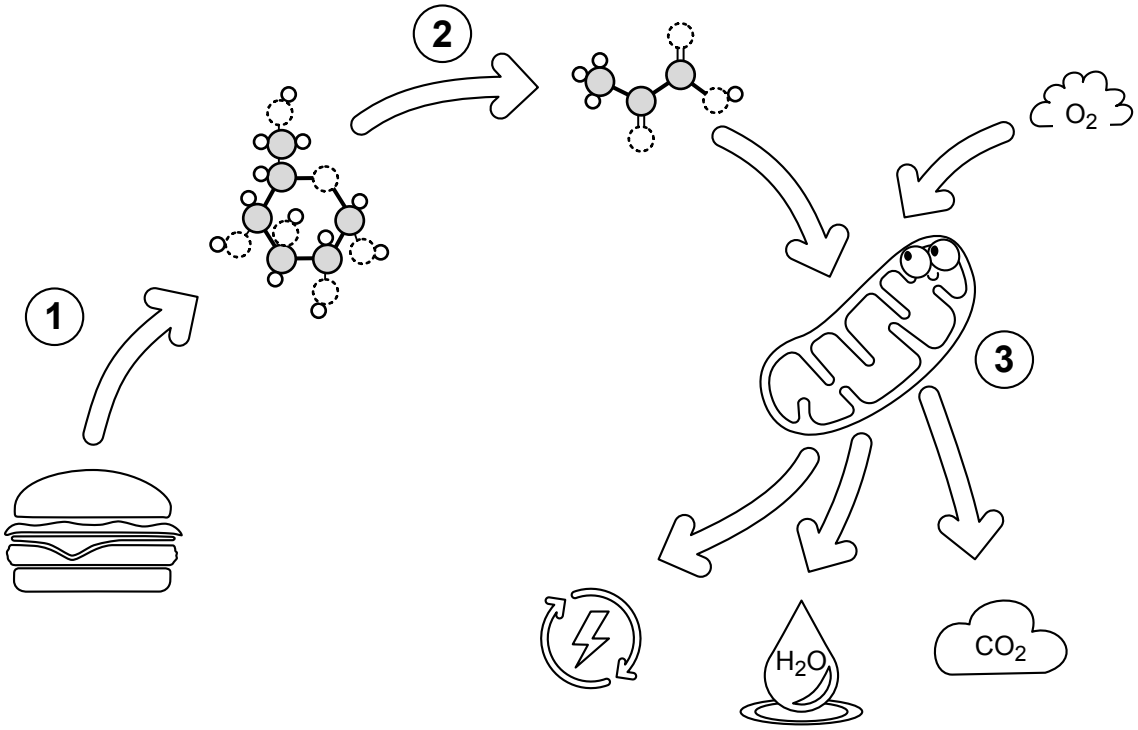
½ water and ½ air

all water

THE EQUATION

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O +$ Chemical Energy

Glucose | Oxygen | Carbon Dioxide | Water



Write the correct number from the diagram in the box with the matching description:

3

The mitochondria uses oxygen to break the molecules down even more. This series of reactions produces carbon dioxide, water, and energy.

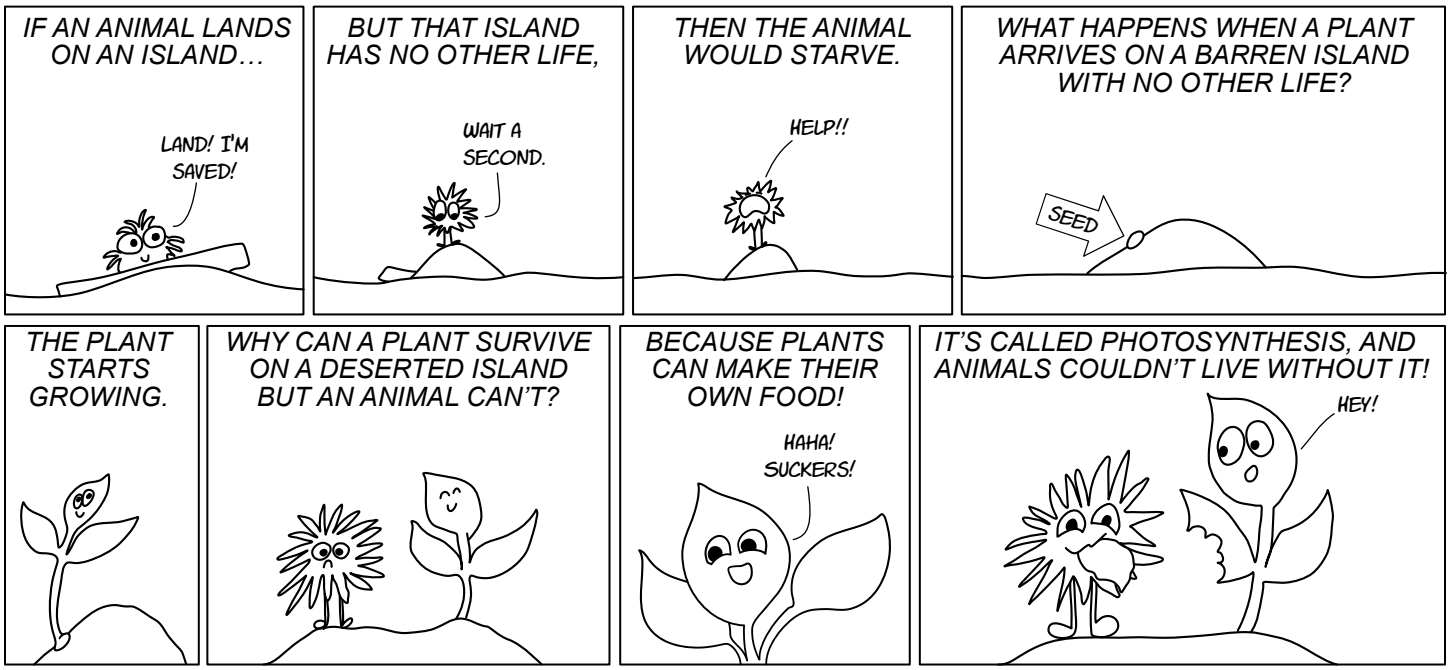
2

Glucose enters the cell and is broken down in the cytoplasm into smaller molecules. This is called glycolysis.

1

The body digests food into the sugar glucose. Then the glucose is released into the blood stream.

Phenomenal Plants



What plants are you using?

We depend on plants for more than food! Can you find FOUR THINGS in your home that come from plants? As a bonus challenge, can you figure out which specific plants they came from?

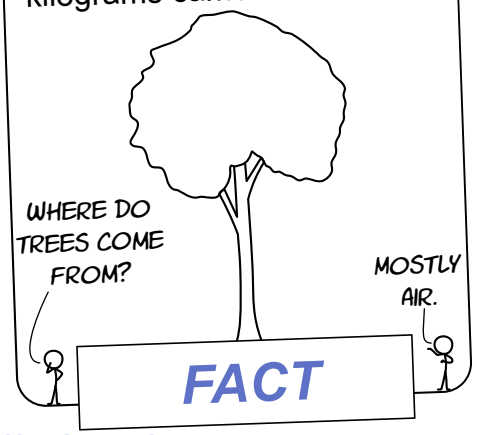
Example: A WOODEN DESK MADE FROM PARTICLEBOARD COMES FROM POPLAR TREES AND PINE TREES.

There are many possible answers for this activity. If someone doesn't know where to look, you could suggest they open their fridge or start reading ingredient labels on household products.

1. ***Lotion with shea butter (from shea tree)***
2. ***Wooden cooking spoon, possibly made of bamboo***
3. ***Breakfast cereal made from flour which comes from wheat and oats.***
4. ***Some types of chewing gum are made of chicle that comes from juice of sapodilla tree***

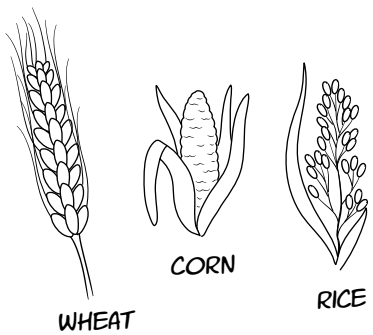
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

In a tree weighing **100,000** kilograms, approximately *95,000* kilograms came from air and water and *only 5,000* kilograms came from the soil.



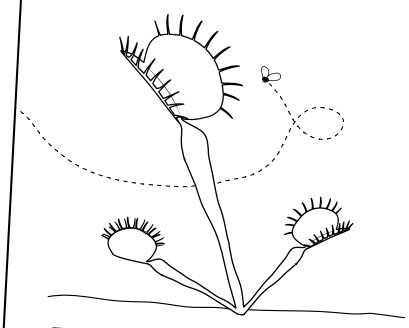
FACT

Approximately 90% of the world's food energy is provided by just 15 plants.



FACT*

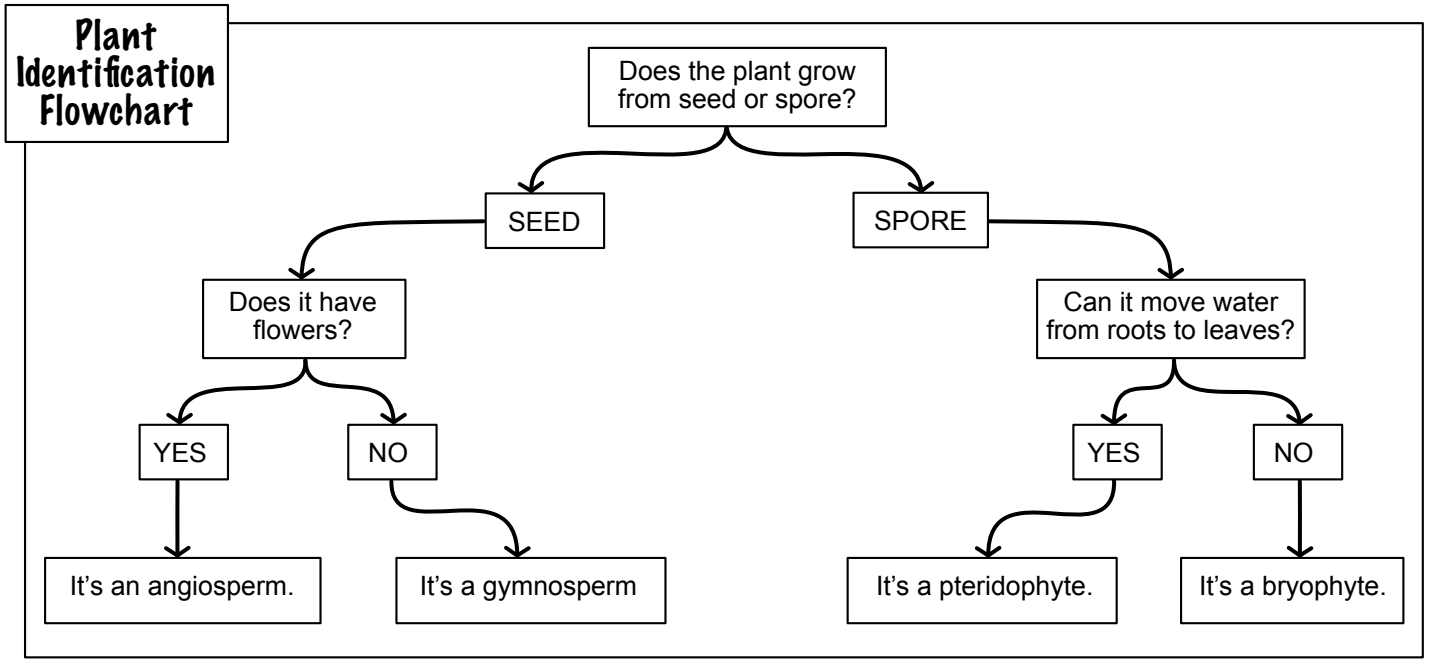
Carnivorous plants don't perform photosynthesis.



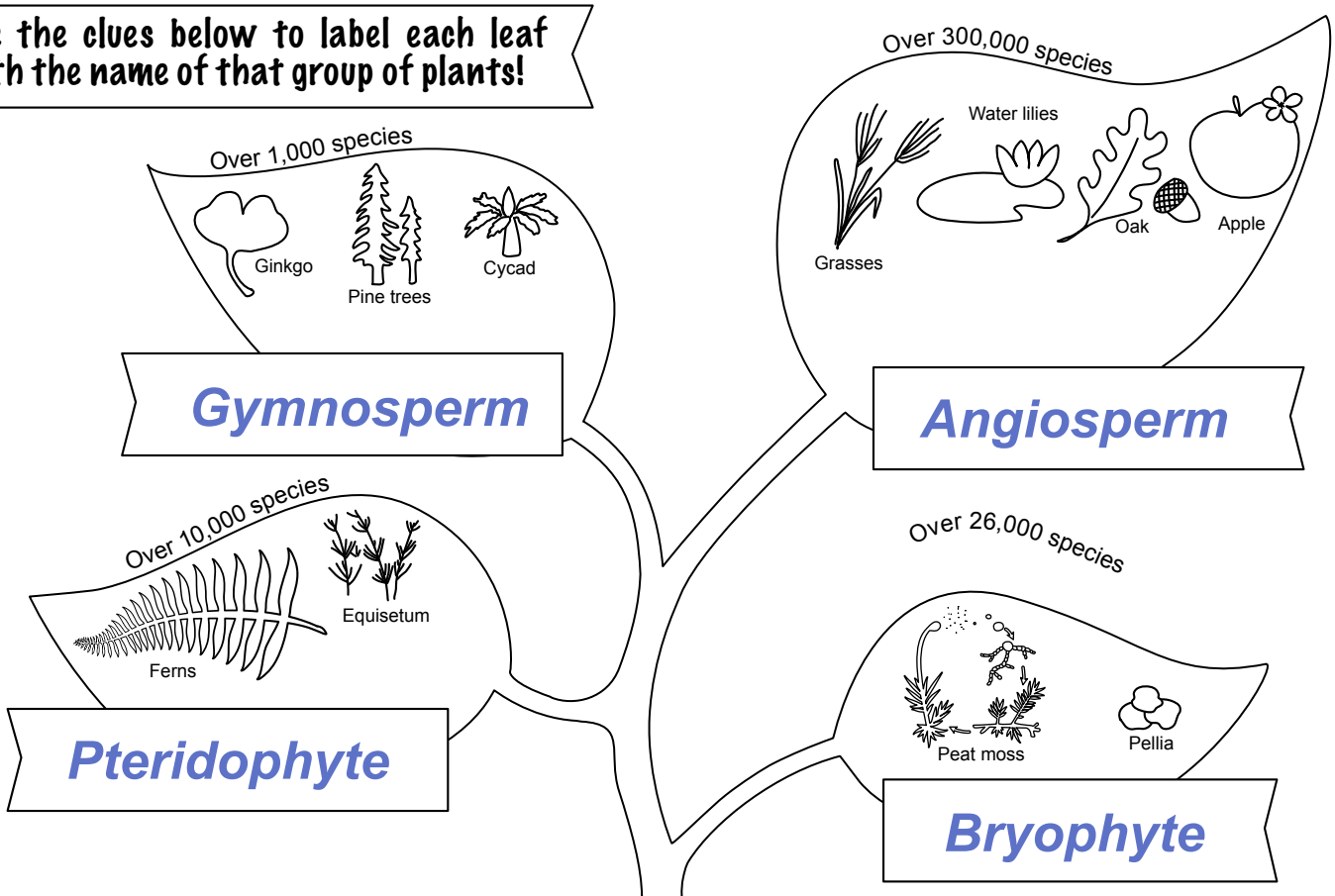
FICTION

**Numbers will vary depending on the source (some say 15 plants provide 90%, others that 12 plants provide 75%…), but there is widespread agreement that the three largest STAPLE CROPS (wheat, corn, and rice) provide MORE THAN HALF of the energy needs for the human population.*

Plant Identification Flowchart



Use the clues below to label each leaf with the name of that group of plants!



Angiosperms
(an-gee-oh-sperms)
More than 94% of plant species are in this group!

Pteridophyte
(teh-rid-uh-fite)
Reproduce with spores but are larger than the other spore plants.

Bryophytes
(bry-oh-fite)
Reproduce with spores! Most live in very wet areas.

Gymnosperms
(gymn-no-sperms)
Many have cones and needles instead of leaves.

PHOTOSYNTHESIS

FILL IN THE BLANKS USING THESE WORDS:

carbon	sugar	light	energy
food	chloroplast	dioxide	

Plants, algae, and cyanobacteria are all able to make their own ___*food*___ by capturing ___*carbon*___ ___*dioxide*___ in the atmosphere and converting it into ___*sugar*___ molecules. During the reactions of photosynthesis, water is split and oxygen gas is released from the plant. Photosynthesis is powered by ___*light*___ ___*energy*___. It can't happen without sunlight!

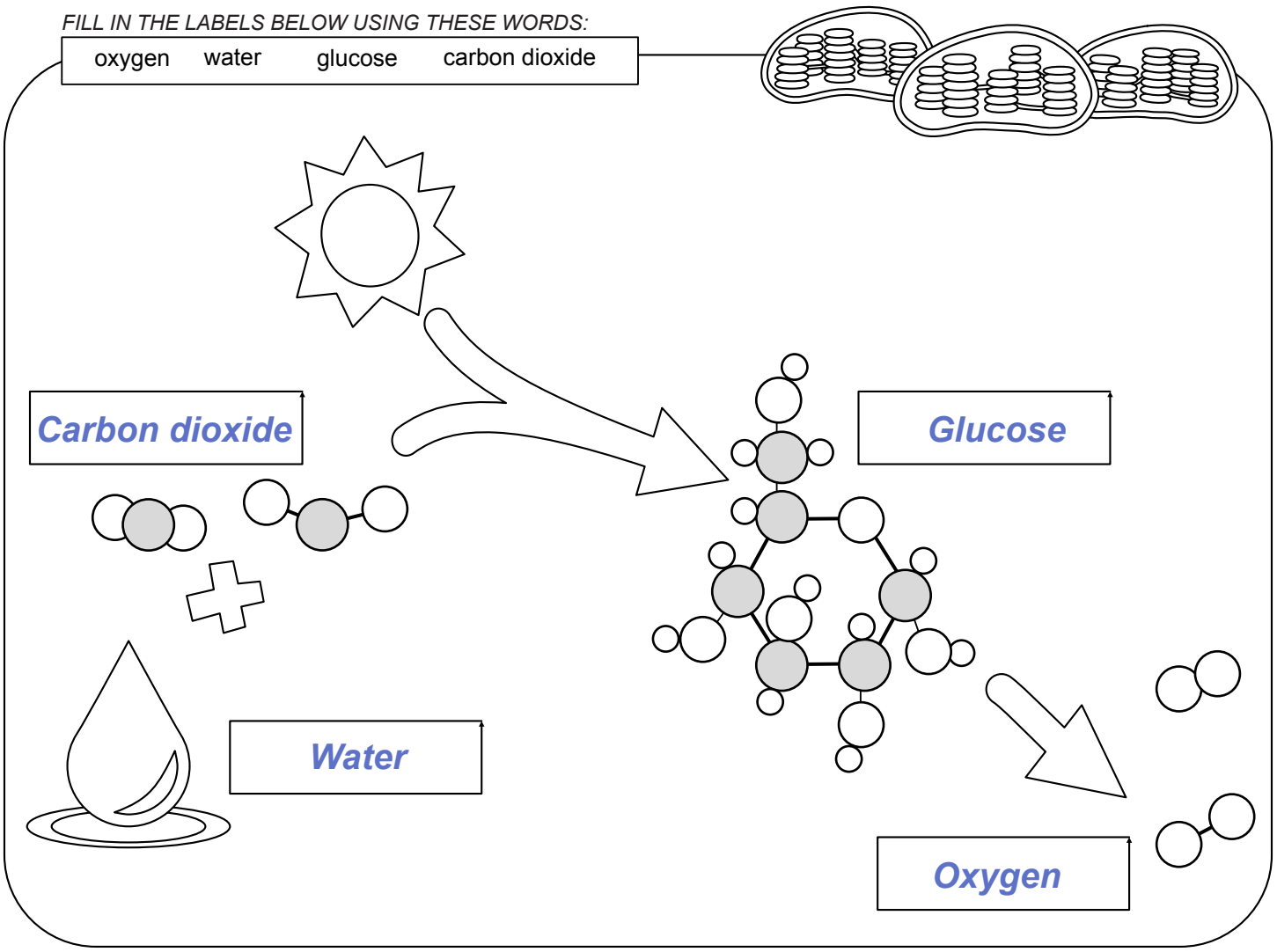
In plants and many algae, photosynthesis takes place in an organelle called the ___*chloroplast*___.

THE EQUATION

$$\text{Light Energy} + \underset{\text{Water}}{6H_2O} + \underset{\text{Carbon Dioxide}}{6CO_2} \rightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

FILL IN THE LABELS BELOW USING THESE WORDS:

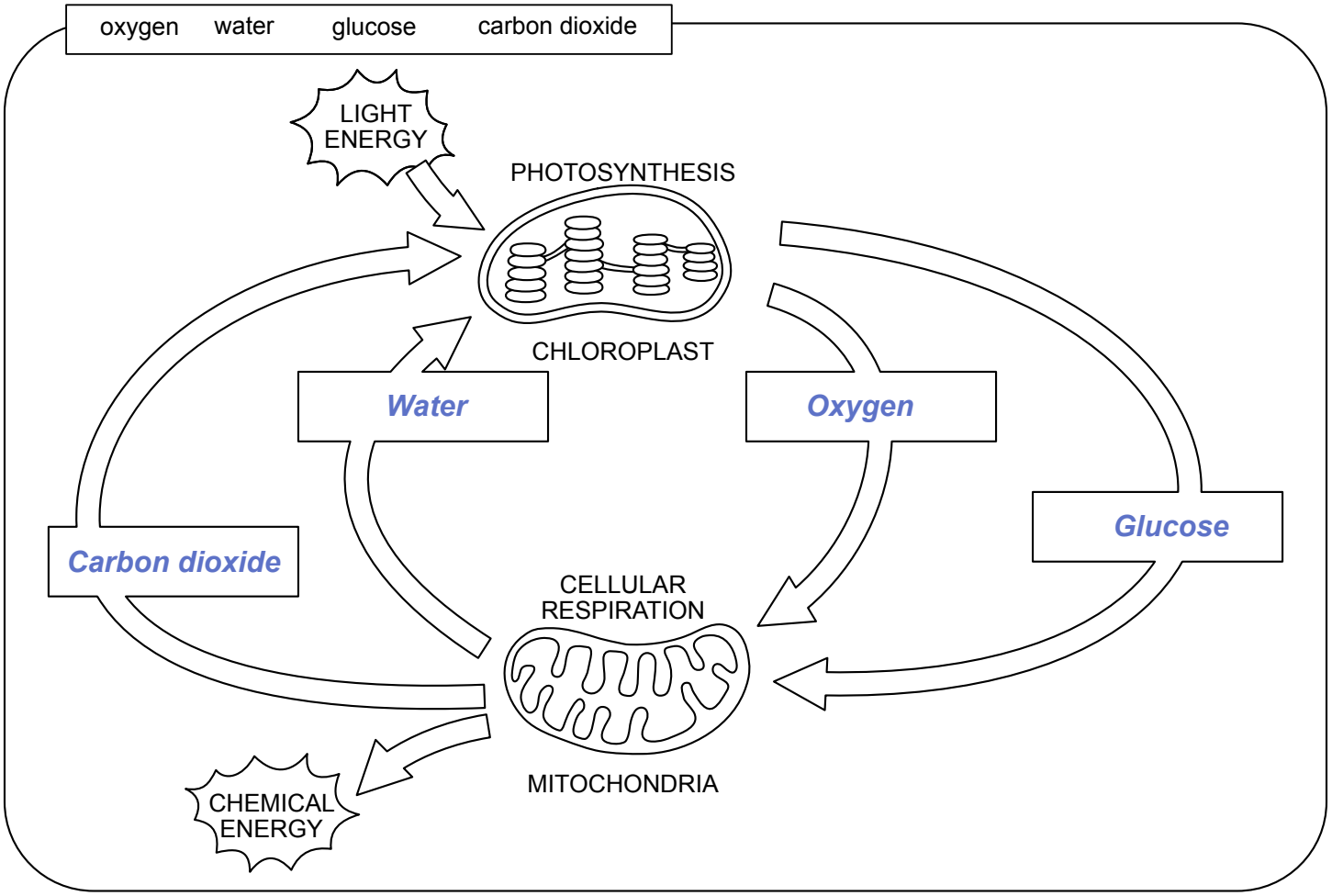
oxygen	water	glucose	carbon dioxide



The Cycle of Photosynthesis and Respiration

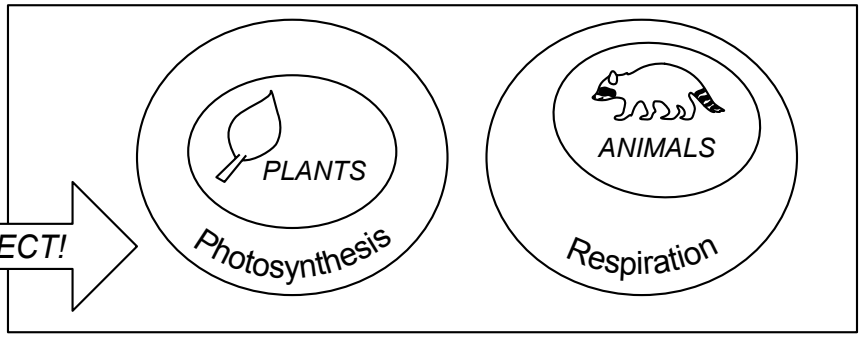
FILL IN THE LABELS BELOW USING THESE WORDS:

oxygen water glucose carbon dioxide



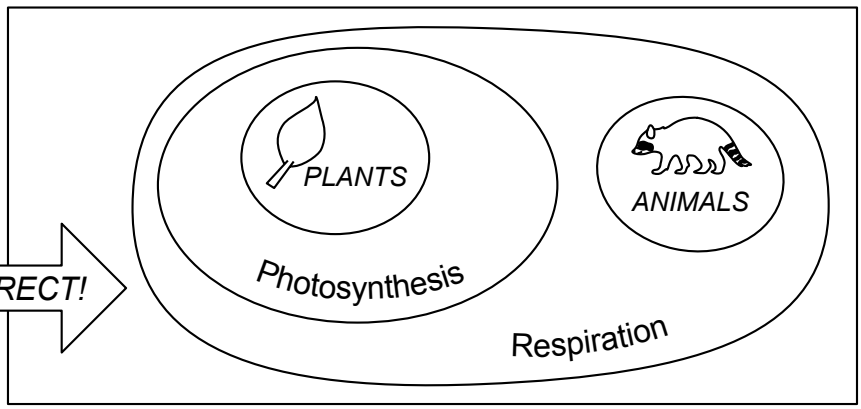
Some people think that plants only do photosynthesis and that animals only do respiration. If this were true, a Venn diagram of these organisms and their energy pathways would look like this:

INCORRECT!



A plant that could do photosynthesis but not respiration would quickly starve to death. Plant cells need to perform respiration to survive. In reality, a Venn diagram for the energy pathways of plants and animals looks something like this:

CORRECT!



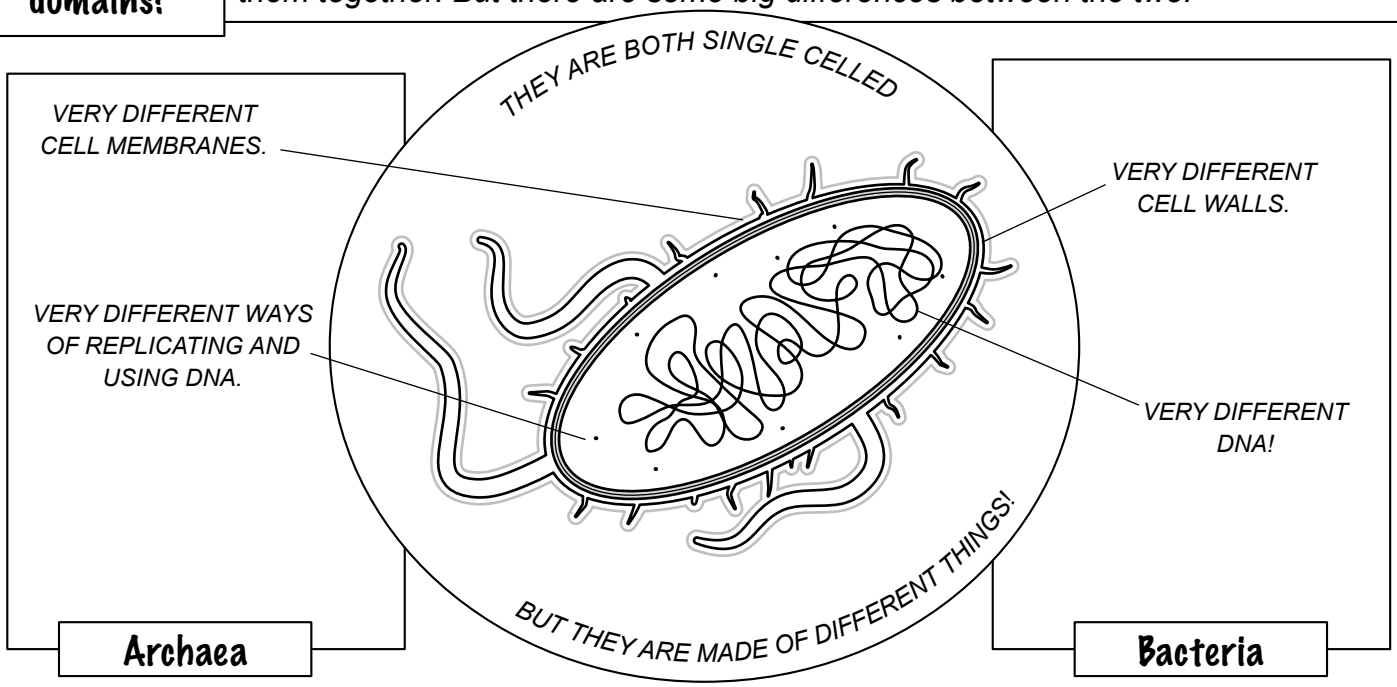
Prolific Prokaryotes

Plants use energy from sunlight to create glucose. They then use respiration to break down some of those sugars for energy. Animals and fungi get energy from eating sugars that were made by other plants or animals. But in the archaea and bacteria domains, there are single-celled organisms that can get energy from ammonia, metal ions, sulfur, or even hydrogen gas! There are also cells that use sunlight as an energy source but do not perform photosynthesis. “Extremophiles” live in locations where no other thing can survive!

In terms of how they get energy and use it, prokaryotes are the most diverse and well distributed organisms on Earth. They are everywhere from deep sea vents to salt flats, glaciers, soil, and inside of you!

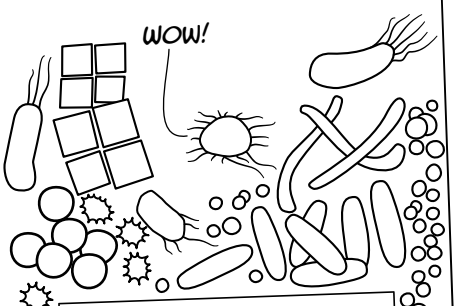
Why two domains?

Archaea and Bacteria are both prokaryotes, so some classification systems group them together. But there are some big differences between the two!



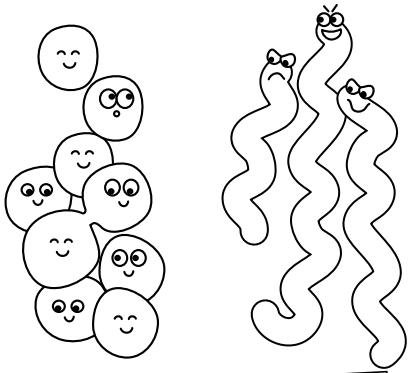
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

Despite being some of the most numerous organisms on the planet, no parasitic or disease-causing archaea have ever been found.



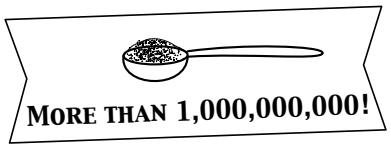
FACT

50% of known bacteria are disease-causing or pathogenic.



FICTION!

A single spoonful of soil could contain more than one billion bacteria.



FACT

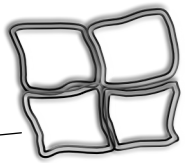
The vast majority of bacteria are neutral or beneficial to human health. Of the estimated one trillion microbial species on Earth, only 1,400 cause diseases in humans. That’s less than one in a billion. Further reading: Balloux, F., van Dorp, L. Q&A: What are pathogens, and what have they done to and for us?. BMC Biol 15, 91 (2017). https://doi.org/10.1186/s12915-017-0433-z

Mixed up Microbes

Draw lines to match each microbe with the correct habitat?

Haloquadratum walsbyi

MY NAME MEANS THE SALTY SQUARE OF WALSBY!



FOOD: Carbon containing compounds
ENERGY SOURCE: food OR light
OXYGEN? Yes please!
SPECIAL SKILLS: Can live in SUPER salty water. Has little bubbles (vesicles) to help it float.

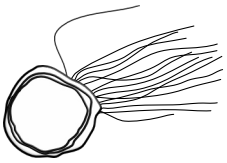
Methanobrevibacter smithii

MY FRIENDS CALL ME M. SMITHII.

FOOD: Hydrogen gas & carbon dioxide
ENERGY SOURCE: food
OXYGEN? No way!
SPECIAL SKILLS: Can make methane. Thrives in oxygen-free (anoxic) environments.

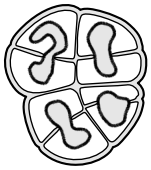
Geogemma barossii

MY OTHER NAME IS STRAIN 121.



FOOD: Iron and Hydrogen gas!
ENERGY SOURCE: food
OXYGEN? No thanks.
SPECIAL SKILLS: Can live in total darkness and survive being autoclaved.

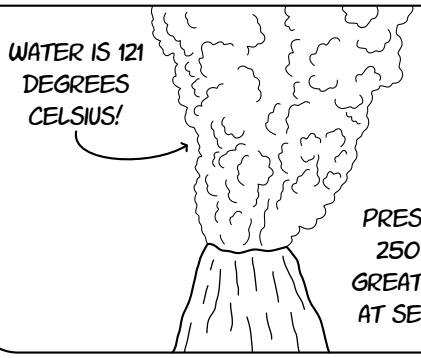
Deinococcus radia



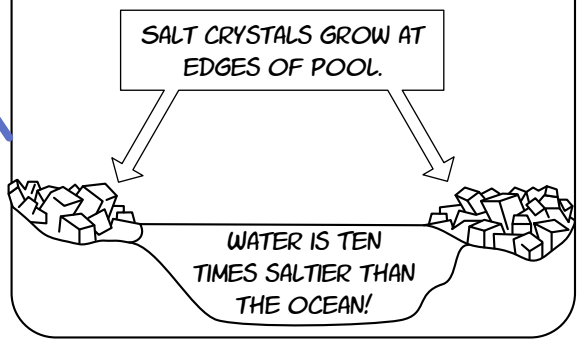
I SURVIVED 3 YEARS IN OUTER SPACE!

FOOD: Carbon containing compounds
ENERGY SOURCE: food
OXYGEN? Yes, please!
SPECIAL SKILLS: Can withstand 1,000 times the amount of radiation fatal to a human. Once given the nickname of "Conan the Bacterium."

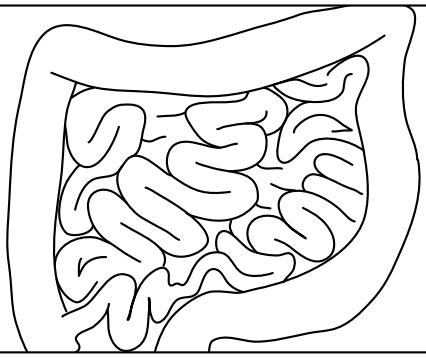
DEEP SEA VENT



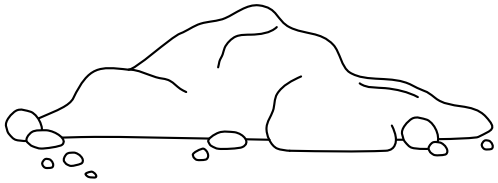
SALTY BRINE POOL



AN ANIMAL'S INTESTINES



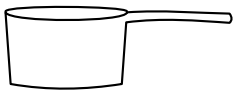
DIRT



Hands-on Science Project

HOMEMADE PETRI DISHES

MATERIALS:

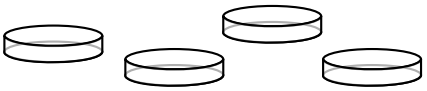


Stove and a pot for boiling water

8 ounces water

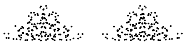
1 bouillon cube
or 1 tsp bullion granules

Cotton swabs



4 petri dishes or other clear and clean containers with lids

1 Tbsp agar
or 1 packet unflavored gelatin



2 Tsp sugar

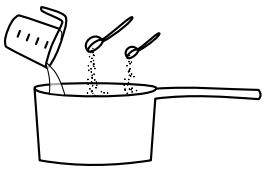
Permanent marker

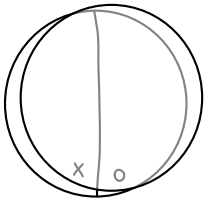
1. Prepare the Petri Dishes

1. Heat the water to a full boil in a saucepan and add the agar, stirring until it is completely dissolved. Add the bouillon and sugar and stir until dissolved. Cover and let cool for 2-3 minutes.

2. Use a permanent marker to draw an line on the bottom of your petri dish or other clear container. Label the sections of the dish. I recommend using an x and o so that you do not have to write backwards. The labels should be visible when you look at the top of the dish.

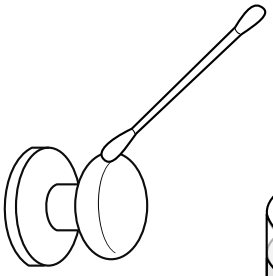
3. Once the solution has cooled somewhat, carefully pour it into the petri dishes so that each dish is about half full. Cover the dishes and let them cool completely without being disturbed. The dishes can be cultured after they are cool, or they can be placed in the fridge for a day before taking samples.

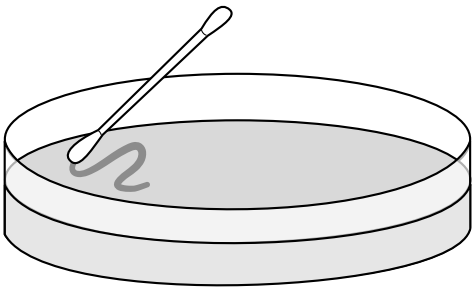




For BEST results

Watch the instructional video before you collect samples. Then decide what you want to investigate! Include a ***control*** as part of your experiment.





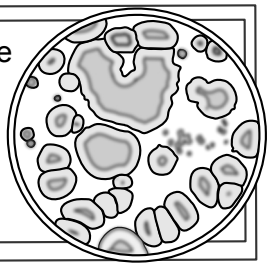
2. Collect samples and swab the plates!

1. To collect a sample, take a cotton swab and rub it on the surface you are sampling. For best results, twirl the swab to get contact with the entire swab. It can also help to get the swab slightly damp with clean water before collecting your sample.

2. Use the swab to very gently trace a squiggle line over one half of the petri dish. Be sure to use a new swab for each surface your test.

SAFETY WARNING

While many bacteria and fungi that may grow on a petri dish are harmless, there is the possibility of growing pathogenic (disease-causing) bacteria and fungi. *DO NOT REMOVE THE LID OR TOUCH THE SAMPLES ONCE YOUR COLONIES START TO GROW!* When you have concluded your experiment, either disinfect the dishes or seal them in a closed container and throw them away. In the case of accidental exposure to the colonies, promptly use disinfectants such as rubbing alcohol to clean the area.



SUBSTITUTIONS

The main goal of this experiment is to appreciate how **ubiquitous** microorganisms are. There are fungi spores, bacteria, archaea, and viruses around us ALL the time. Once they have the ideal environment, their populations can grow at an incredible rate. This is why we store food in refrigerators! If you do not have all the ingredients for this experiment, don't worry. There are several substitutions you can try:

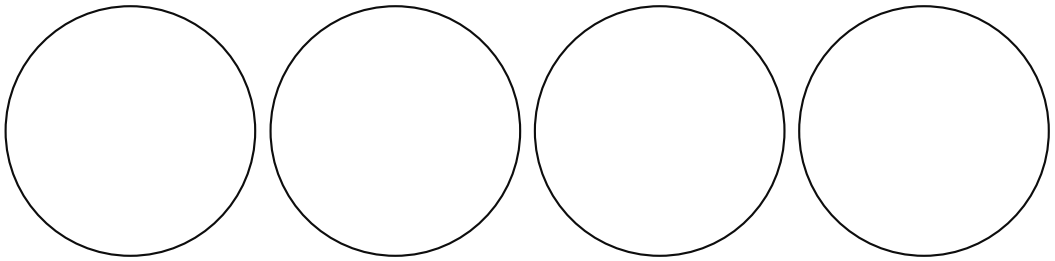
If you do not have **agar**, you can substitute a similar amount of unflavored gelatin. Some bacteria can cause the gelatin to dissolve and it can melt if it is stored above 95° F. But in general, it works as well as agar.

If you do not have **petri dishes**, you can substitute a clear container or jar that has been thoroughly cleaned. It is essential that the container has a lid!

If you do not have **cotton swabs** you can use a damp paper towel.

If you want to try an **alternative experiment**, you can place four pieces of bread into separate ziplock bags. Try to keep one piece of bread as clean and uncontaminated as possible. Deliberately contaminate the second and third by coughing on them or wiping them over a doorknob or by adding a spoonful of dirty water. Be sure each of the first three pieces of bread are moist. Dehydrate the fourth by toasting it lightly in a toaster and letting it cool before placing it in the bag. Seal all bags and record observations over a period of 2 weeks.

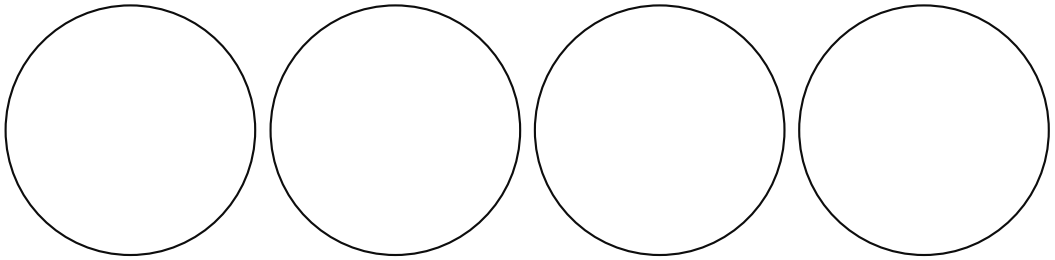
Observations:



DATE:

Data gathered here can vary enormously. Hopefully you will observe different colors and shapes in different colonies. If your control dish also has colonies, don't be too discouraged. Without a laminar hood to ensure sterile conditions it is very difficult to make a plate with no bacteria or fungal spores.

Observations:

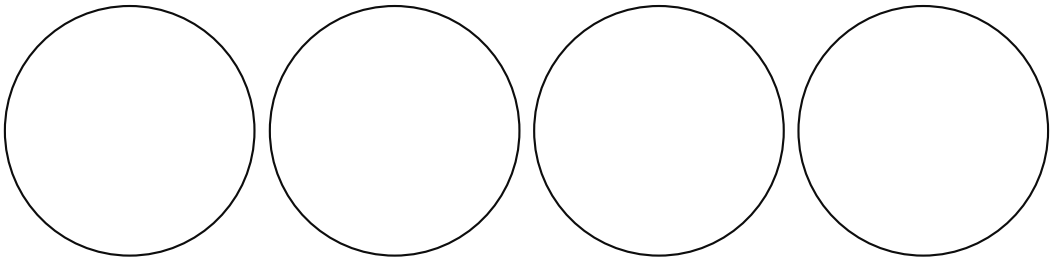


DATE:

When to record data? How fast your colonies grow depends very strongly on the temperature. The warmer it is, the faster they will grow.* You should record what the plates look like immediately after gathering samples and then check them twice a day after that. Make your next observation whenever you first see visible signs of colonies. Then repeat every 24-48 hours afterwards. Be sure to record the date when you make your observations.

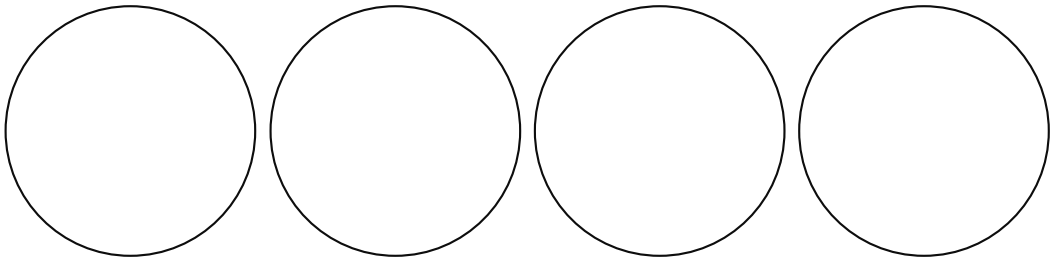
**The fastest/best growth will happen between 21° and 32° C (70° and 90 °F) If temperatures get above about 40 °C or 105 °F, then you will start to see less growth on the plates. It is not recommended to let your plates get above 32° C or 90° F.*

Observations:



DATE:

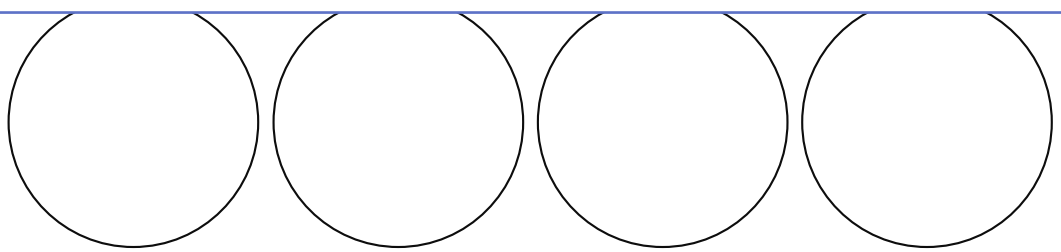
Observations:



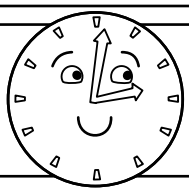
DATE:

If your temperatures are warm and you have full colonies growing into each other after 3 observations and you area now ready to clean up the experiment, you do not need to keep your trays around for 2 additional observations. The experiment goals and results should influence your decisions more than the number of circles on a worksheet. Conversely, if you have cooler temperatures and slower growth, feel free to add another series of observations on another piece of paper.

Observations:



DATE:



Quiz Time!

ANSWER THE QUESTIONS TO SEE WHAT YOU LEARNED ABOUT THE DIVERSITY OF LIFE!

1. Omnivores are heterotrophs.
   - A. True *So are carnivores and herbivores.*
   - B. False

2. The chloroplasts in fungi cells are white instead of green.
   - A. True
   - B. False *Fungi do not have chloroplasts! They are not plants.*

3. Most plant species fall into which of the following groups?
   - A. Angiosperms
   - B. Ferns
   - C. Mosses
   - D. Gymnosperms

4. What part of the cell contains the DNA?
   - A. Ribosome
   - B. Nucleus
   - C. Plasma membrane
   - D. Cytoplasm

5. Which organelle(s) came about when a cell incorporated a bacteria?
   - A. Nucleus
   - B. Chloroplast
   - C. Ribosome
   - D. Mitochondria

   For more on endosymbiosis check out https://askabiologist.asu.edu/explore/cells-living-in-cells and https://www.molbiolcell.org/doi/full/10.1091/mbc.e16-07-0509

6. What products are created by cellular respiration?
   - A. Oxygen
   - B. Carbon Dioxide
   - C. Water
   - D. Glucose

7. Which groups of living things contain both autotrophs and heterotrophs
   - A. Plants
   - B. Animals
   - C. Fungi
   - D. Protists
   - E. Bacteria
   - F. Archaea

   Note that although there are no known photosynthetic archaea, there are archaea that use light as an energy source. There are also archaea that can capture CO_2 and create sugars from non-organic carbon, but they do this with a different chemical process (one that does not produce oxygen).

8. A visible mushroom is only a small part of a fungus. Most of the mass is underground.
   - A. True
   - B. False

9. In cellular respiration…
   - A. Water is used to create oxygen.
   - B. Oxygen is used to create water.

10. Most of the mass of a tree comes from
    - A. Soil and water
    - B. Water and air
    - C. Air and soil

11. In photosynthesis….
    - A. Carbon dioxide is used to create glucose.
    - B. Glucose is used to create carbon dioxide.

12. There are bacteria and fungi spores floating in the air.
    - A. True
    - B. False

13. Which group of organisms is the most diverse and numerous on the planet?
    - A. Prokaryotes
    - B. Plants
    - C. Animals
    - D. Fungus
    - E. Protists

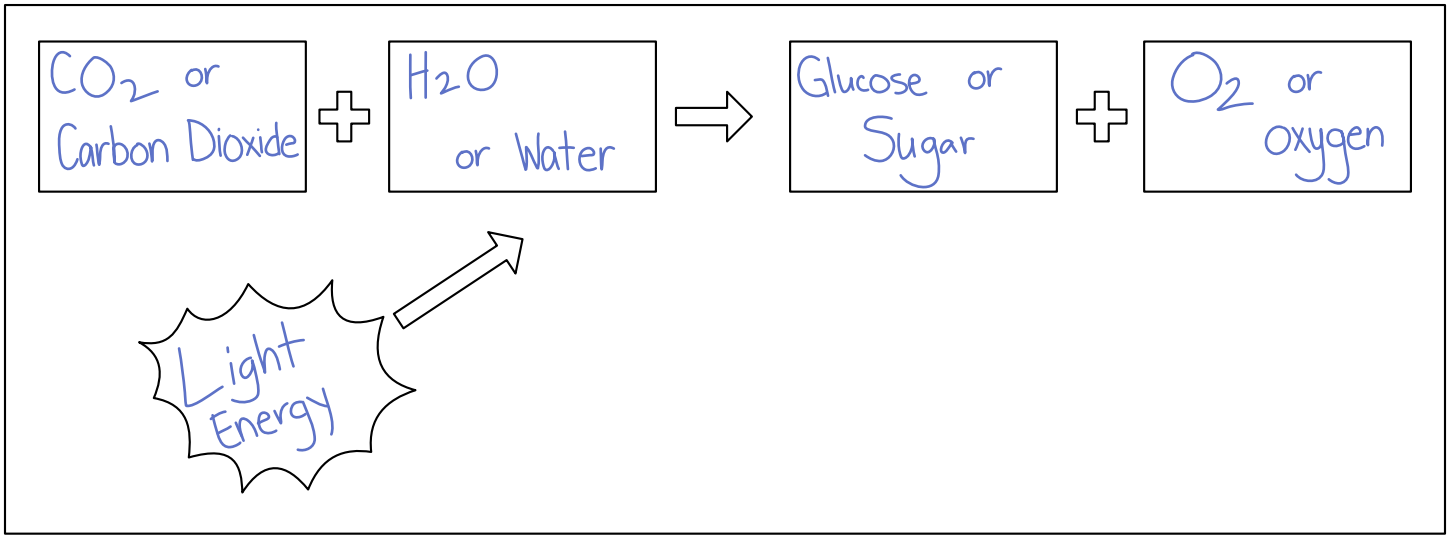
14. What is the scientific name for a flowering plant?
    - A. Gymnosperm
    - B. Angiosperm
    - C. Bryophyte
    - D. Pteridophyte

15. Which energy pathway(s) do plants perform?
    - A. Photosynthesis only
    - B. Respiration only
    - C. Respiration and photosynthesis

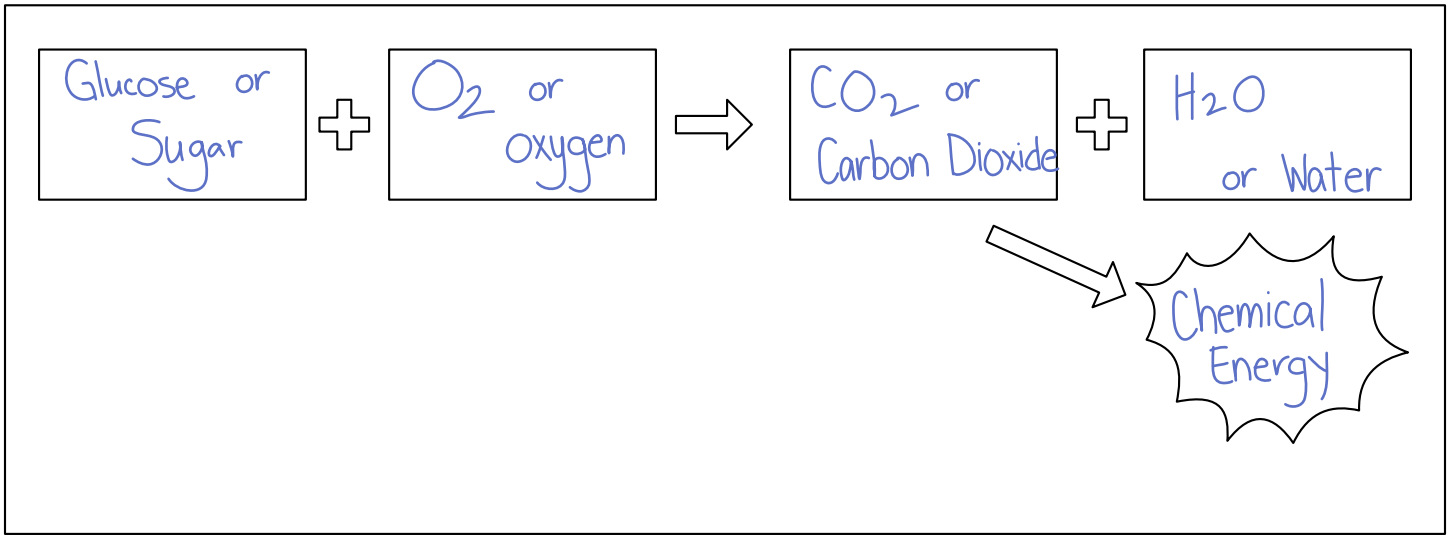
16. Most bacteria cause diseases.
    - A. True
    - B. False

17. Which energy pathway(s) do animals perform?
    - A. Photosynthesis only
    - B. Respiration only
    - C. Respiration and photosynthesis

18 The drawing below represents the reaction of photosynthesis. Label each box , including the type of energy used.



19 The drawing below represents respiration. Label each box , including the type of energy produced.



20 Write the name of each organism or group of organisms in the correct box according to whether it performs photosynthesis, respiration, or both processes:

PINE TREE, MUSHROOM, BACTERIA, GRASS, MOLD, FERN, MARMOSET, MOSS, ARCHAEA, ANIMAL

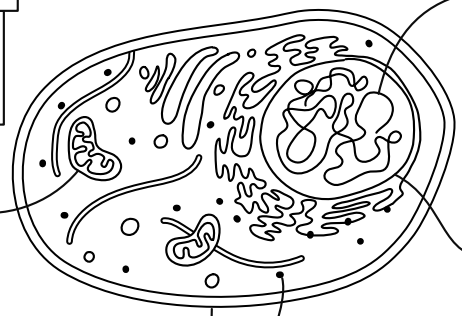
ONLY PHOTOSYNTHESIS	PHOTOSYNTHESIS AND CELLULAR RESPIRATION	ONLY CELLULAR RESPIRATION
Some species of archaea	*Pine tree*	*Mushroom*
Some species of bacteria	*Bacteria (Green and purple non-sulphur bacteria)*	*Various species of bacteria*
	Archaea (halobacterium salinarum)	*Mold*
	Grass	*Marmoset*
	Fern	*Various species of archaea*
	Moss	*Animal*

Cell Systems

A cell is made of several different parts which each have their own job or function. Can you match the names of each cell part with its corresponding description?

The Cell

DNA
nucleus
mitochondria
ribosome
membrane



Mitochondria

Makes little snacks the cell can use for energy

"Energy snacks" is a very informal nickname for ATP

DNA

The instructions for making things

Nucleus

Keeps the instructions safe!

Membrane

Keeps the insides inside and the outsides outside.

Ribosome

Makes the things that the instructions tell it to make.

Inside an animal CELL there will be

R	I	B	O	S	O	M	E	S
		9				5		4

SOBRIMOES

to help make

P	R	O	T	E	I	N	S
1							

ROPESTIN

CAN YOU REARRANGE THE LETTERS TO REVEAL THE PART OF THE CELL?

D	N	A
		6

AND

located inside the

N	U	C	L	E	U	S
			2			

USCLUNE

M	I	T	O	C	H	O	N	D	R	I	A
7									10		

CHIMTOONDARI

that generate chemical

E	N	E	R	G	Y
8		11			

GEERNY

SCIENCE MOM

All of it is surrounded by the

P	L	A	S	M	A
1	2		4	5	6

M	E	M	B	R	A	N	E
7	8		9	10			11

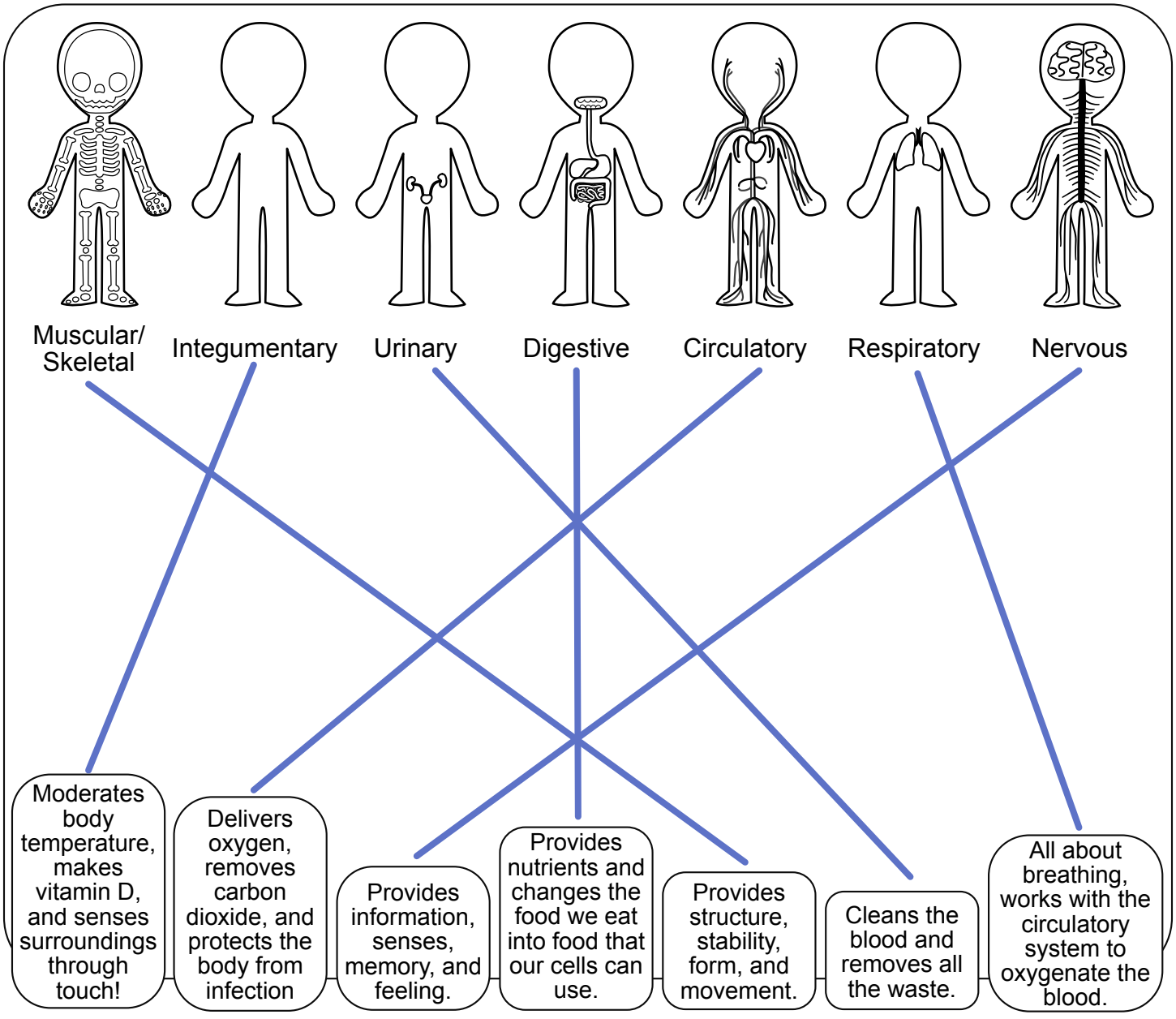
Body Systems

FILL IN THE BLANKS USING THESE WORDS:

systems
cells
organs
perform
body

Animals are made of ___*cells*___, but not all of the cells in an animal are the same! They have different shapes and do different things. Groups of cells that work together to ___*perform*___ a certain task are called systems or ___*organs*___. The human ___*body*___ has many different ___*systems*___. In the next lessons, we will take a closer look at five of them: the circulatory, respiratory, nervous, digestive, and immune systems.

Match the system with the correct description.

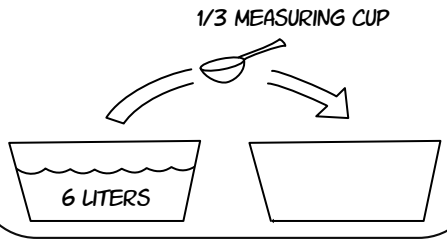


The circulatory system

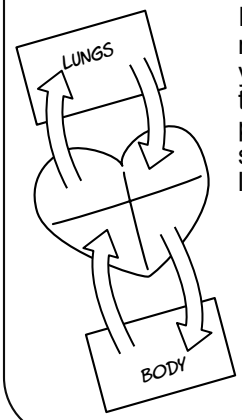
Try these activities to learn more about your circulatory system!

RACE THE PUMP

The average adult heart pumps about 6 liters of blood each minute when at rest. How much water can you move in a minute? Fill up a container and give it a try!



MAKE A MODEL



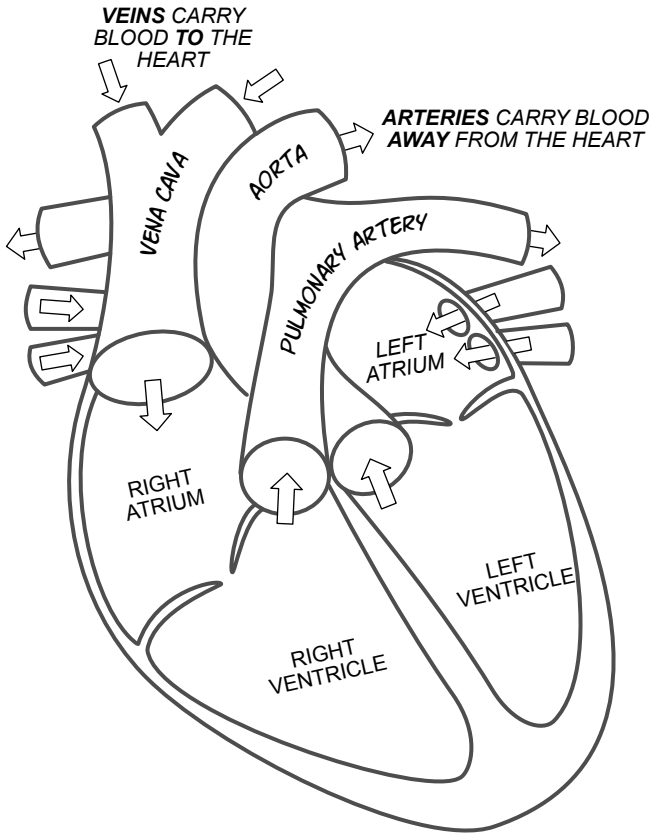
It can be simple or realistic. But however you make it, be sure to include both the pulmonary and systemic circulation loops.

ON THE CLOCK

Count your pulse at rest. How many heartbeats in one minute?

Then do 30 jumping jacks or some other type of exercise and count your pulse again. How did it change?

Pulse at rest:	*Pulse after exercise:*
75	160



Ever notice how your heartbeat sounds “ba-buh” “ba-buh” with two beats? That’s because it’s pumping two systems or loops!

The smaller loop runs from the heart to the lungs and back again. It’s called **pulmonary circulation**, and its purpose is to oxygenate the blood.

The larger loop is called **systemic circulation**. This is when the heart pumps blood out the aorta and to the entire rest of the body.

The heart has 4 chambers, and each chamber receives or sends blood from one of these loops.

FIND YOUR PULSE.

Pulse points are where arteries are close enough to the skin that you can feel the pulse of your heart beating. Which of these could you feel?

- Brachial artery: upper arm, near elbow ☑ Y ☐ N
- Carotid artery: either side of neck ☑ Y ☐ N
- Dorsalis pedis artery: top of foot ☐ Y ☑ N
- Radial artery: inside wrist below thumb ☑ Y ☐ N
- Temporal artery: in front of ear ☑ Y ☐ N

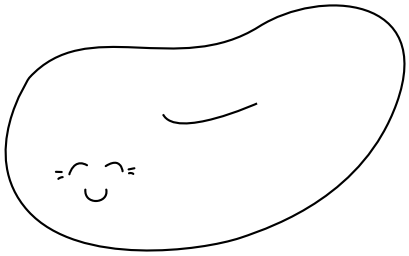
Some of these are easier to find than others! It’s perfectly fine if you aren’t able to feel all of them.

If you lay down on your back and place one hand over your navel, you might feel the pulse of your aorta in your abdomen! It isn’t close to the surface like the other pulse points, but it’s a lot bigger than the others.

Your maximum heart rate is 220 beats per minute minus your age. The American Heart Association recommends 30 minutes of daily exercise that increases the heart rate to 50% - 85% of the maximum heart rate.

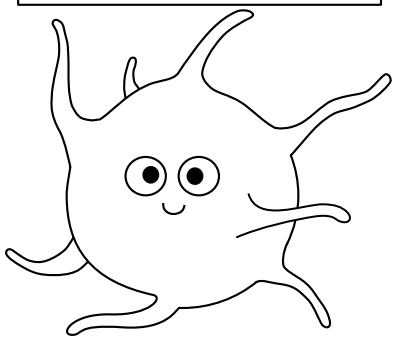
What is blood made of?

Red Blood Cell
Also known as: Erythrocyte



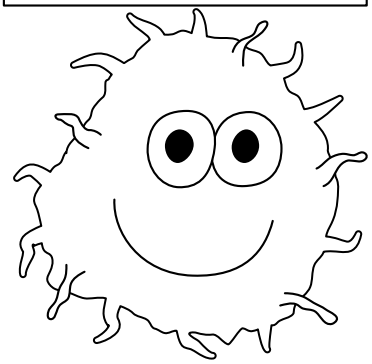
The most common cell in the human body. There are 250 million of these in just one drop of blood! They are full of a protein called hemoglobin that carries oxygen. The hemoglobin is what makes them red.

Platelet
Also known as: Thrombocyte



Platelets prevent bleeding! These tiny cell fragments form clots when needed. They help the blood stay in the circulatory system.

White Blood Cell
Also known as: Leukocyte



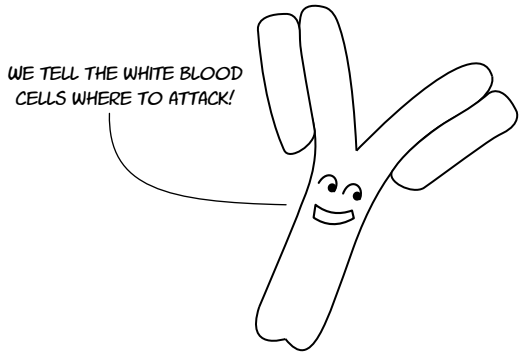
There are a lot of different types of white blood cells. This one is a macrophage and it's really good at eating things like other cells!

Plasma
The liquid that holds the blood cells

The liquid part of the blood. It is mostly water (95%) but also contains important things like hormones, blood sugar, and dissolved carbon dioxide.

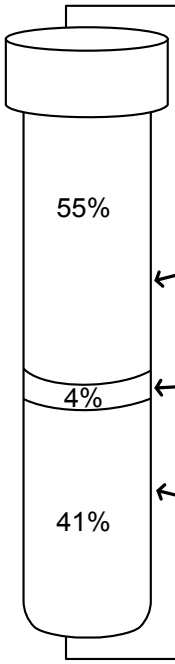
Cool fact: blood plasma isn't red. It's yellow!

Antibodies
Small proteins



Your notes:

"Cyte" means cell and is used as a suffix in the names of many cells! Blood needs to have the right ratio of plasma, cells, and platelets to work correctly and deliver oxygen. Both too few or too many red blood cells can cause serious health problems. The body is always monitoring and adjusting the number of cells in the blood.



This vial contained a sample of blood that was centrifuged (spun around fast to separate it into layers.) Can you label the layers correctly? One is red blood cells, one is plasma, and the other is white blood cells and platelets.

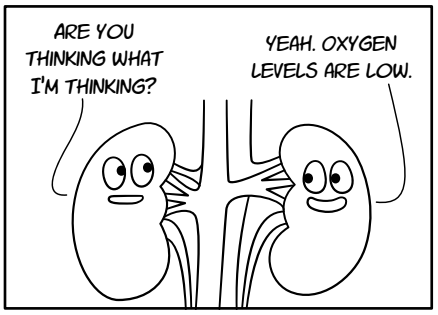
Plasma

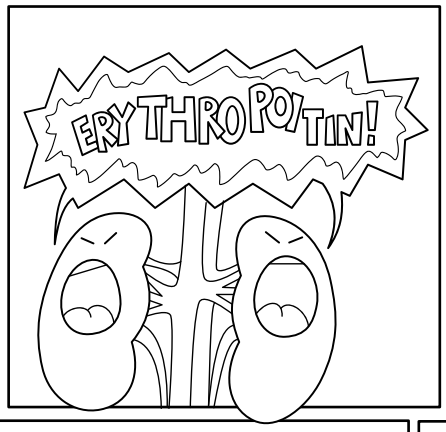
White blood cells and platelets

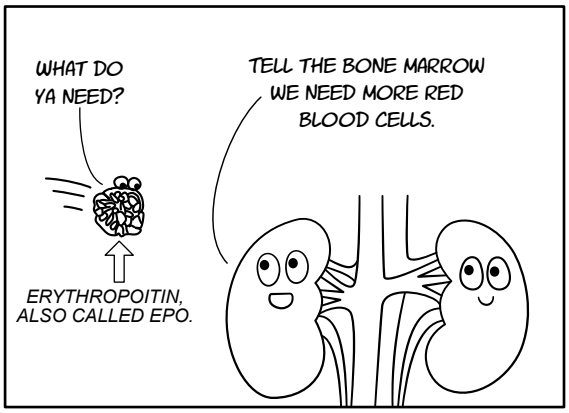
Red blood cells

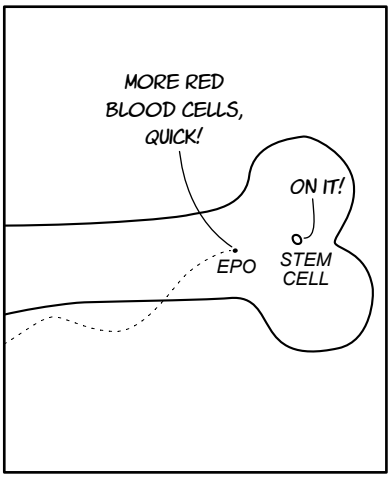
The Life of a Red Blood Cell

The life of a new red blood cell actually starts with a message from the kidneys:

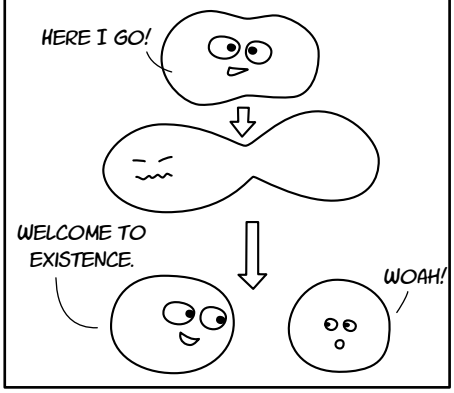




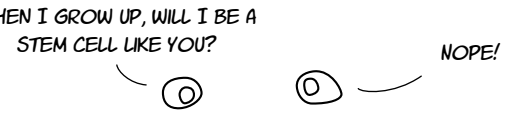


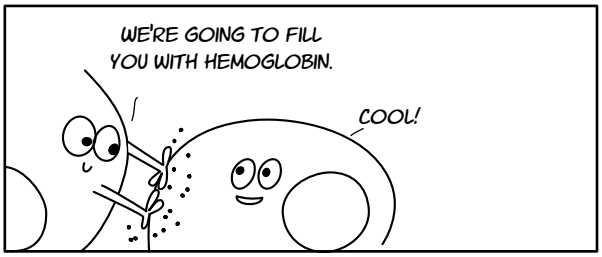


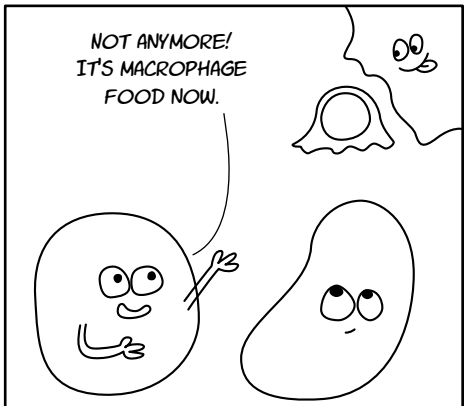
A stem cell in the bone marrow divides, creating a new cell.

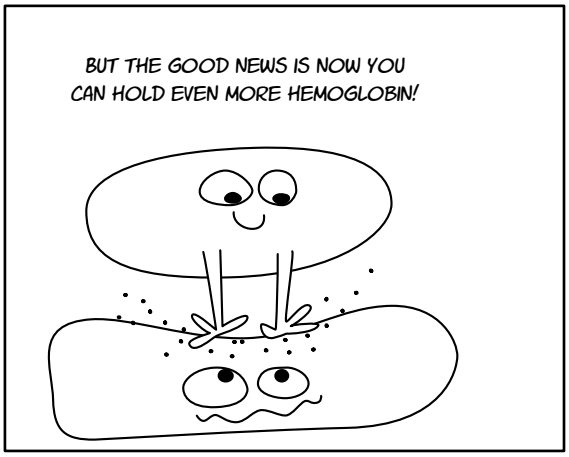


The new cell stays in the bone marrow for several days, undergoing several changes.

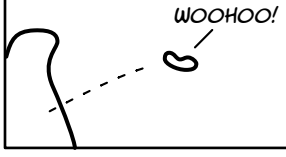




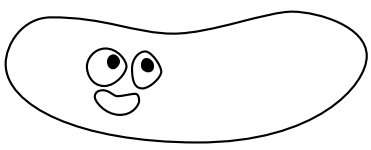




With the nucleus removed, the cell is now a reticulocyte - a brand new red blood cell. It's officially ready to leave the bone marrow and begin carrying oxygen.



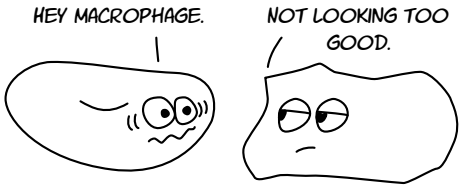
It circulates through the entire body approximately every 60 seconds, bringing oxygen to other cells.



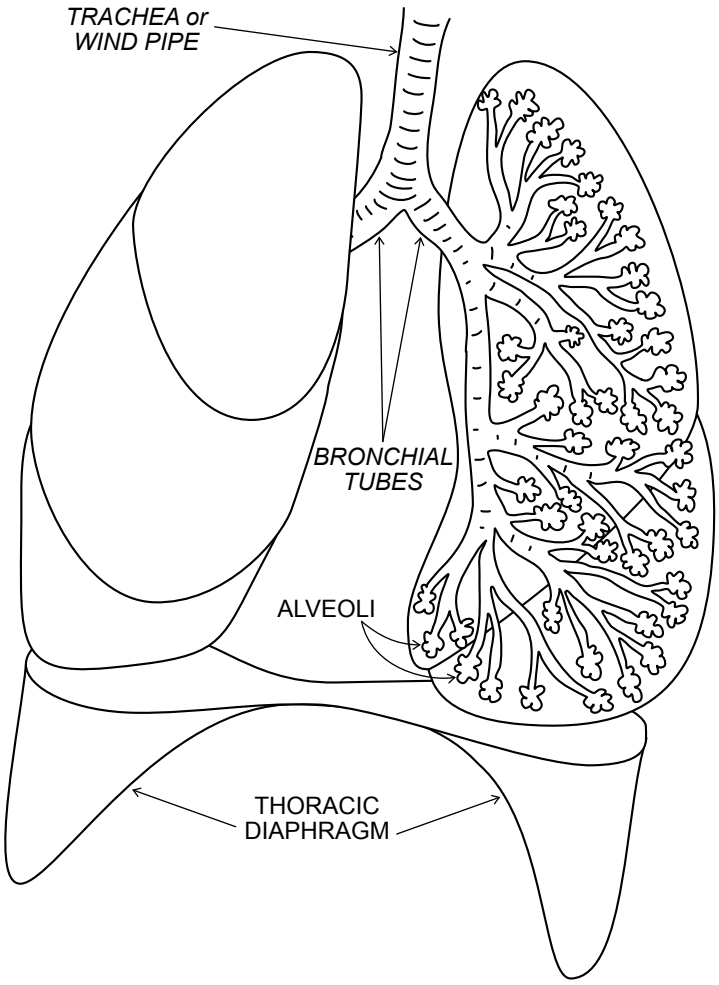
After 120 days, the RBC starts to get a little worn out from so much travel… and is eaten by a macrophage.

CHECKPOINT

Pause here to enter the liver.



The Respiratory System



FILL IN THE BLANKS USING THESE WORDS:

carbon dioxide	lungs	gills		
gases	oxygen	alveoli	skin	

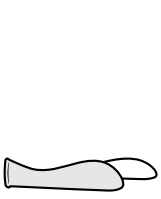
Breathing is the process of exchanging ___gases___. Every animal needs to absorb ___oxygen___ and get rid of ___carbon dioxide___, but they do it in very different ways! Human beings have two ___lungs___ and a diaphragm that helps the lungs expand and take in oxygen. Inside the lungs are small sacks called ___alveoli___ where oxygen is passed into the blood. Fish use ___gills___ to breathe. Worms and amphibians breathe through their ___skin___, and birds have extra air sacs around their lungs that make them more efficient. Air only flows one direction through bird lungs, allowing them to take in oxygen with each exhale and inhale!

Just a hiccup?

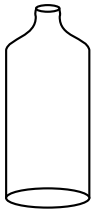
Hiccups are caused by the muscle that separates the lungs and heart from the abdomen: the thoracic diaphragm. When the diaphragm spasms it causes air to suddenly rush past the vocal chords and into the lungs. This is what produces the hiccup sound. Hiccups can be caused by many different things and severe chronic hiccups (lasting more than 2 days!) are not well understood. Whether you experience hiccups frequently or hardly ever, one thing is certain: you use your diaphragm every day and would have a hard time breathing without it!

Make a model lung!

SUPPLIES:

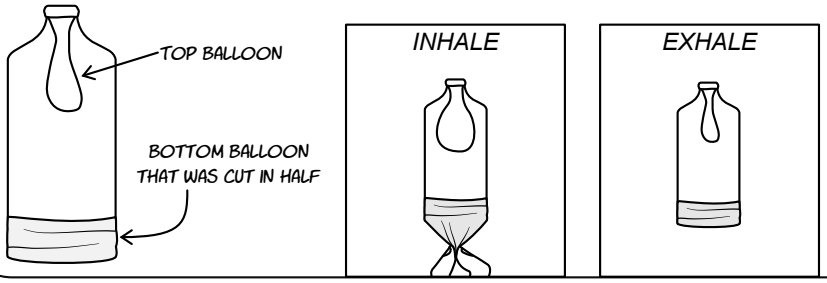


2 BALLOONS



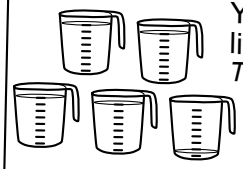
PLASTIC BOTTLE WITH BOTTOM CUT OFF

Place one balloon on the top of the bottle and carefully push the body of the balloon into the water bottle. Cut off the top of the other balloon and stretch it over the bottom of the bottle so that it is flat. The bottom balloon represents the thoracic diaphragm. Pull down on the bottom balloon to inflate or "inhale" the lung and release it to "exhale" the lung.



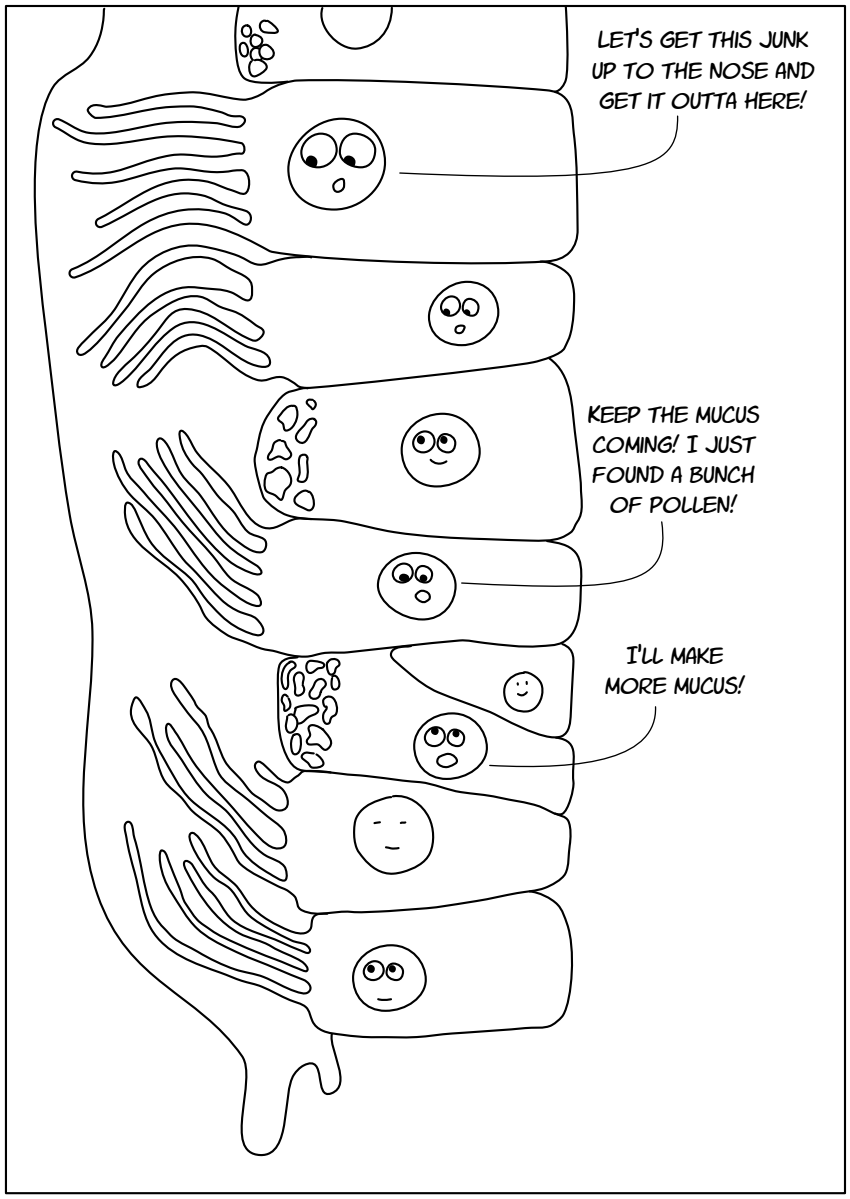
Did you know?

The cells on the inside of your lungs are coated in mucous! The outer layer of cells are called lung epithelial cells and they have long cilia that wave constantly, pushing any dust, pollen, or bacteria spores up and OUT of the lungs. The mucous is either swallowed (sent into the acidic stomach) or it comes out your nose!



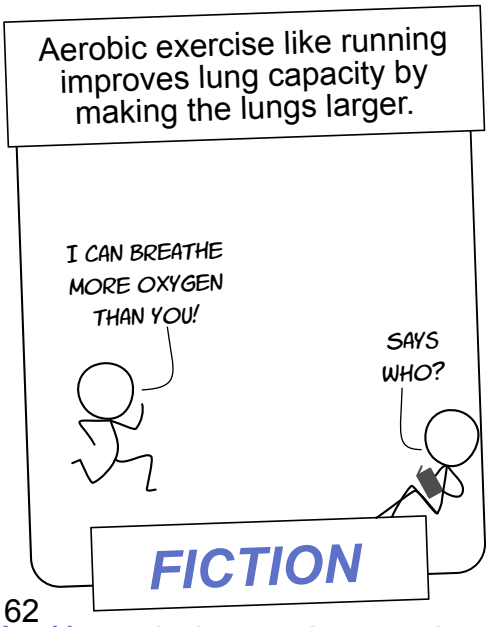
Your body makes about 1 liter of snot every day. *That's more than 33 ounces!*

Your notes:

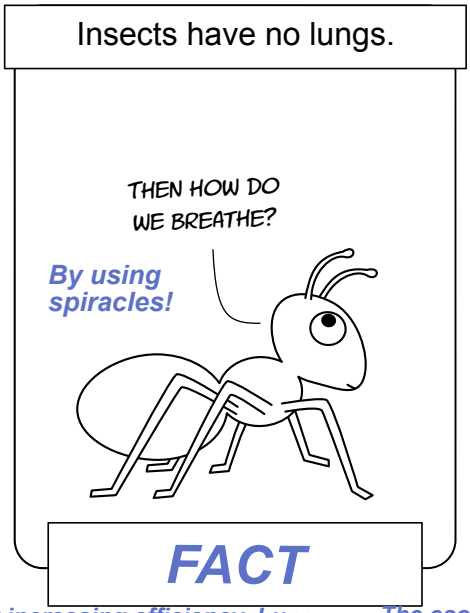


ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

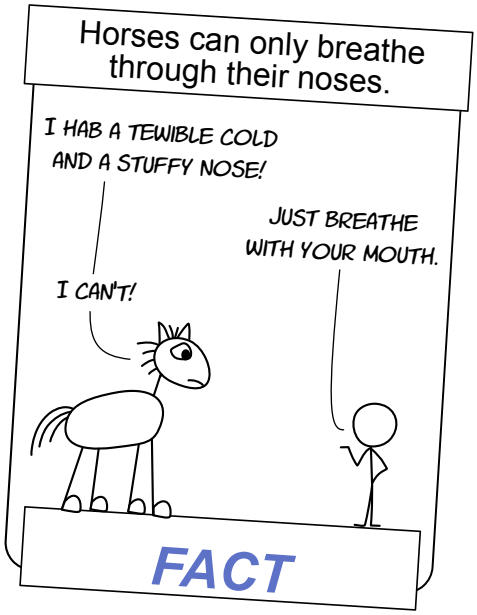
Aerobic exercise like running improves lung capacity by making the lungs larger.



Insects have no lungs.



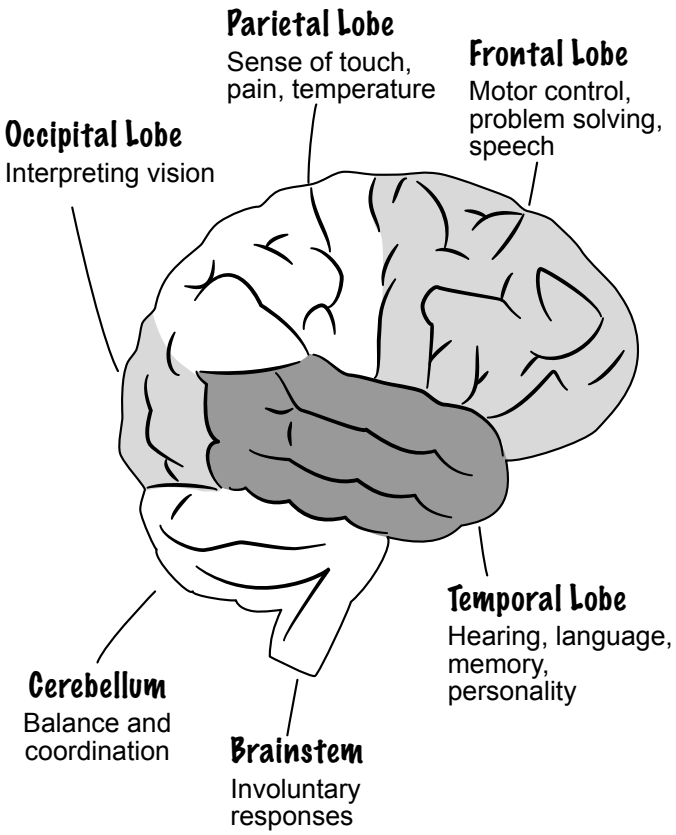
Horses can only breathe through their noses.



Aerobic exercise improves lung capacity by increasing efficiency. Lung size does not change. For further reading see: https://www.scientificamerican.com/article/if-a-persons-lung-size-ca/

The esophagus and windpipe being completely separated in horses allows for more efficient grazing. Horses don't have to stop breathing to swallow. Humans do.

The Nervous System



FILL IN THE BLANKS USING THESE WORDS:

spinal cord	involuntary	neurons
store	peripheral	sense

The nervous system is a network of cells called ***neurons*** that transmit signals between different parts of the body. These neurons also help us to ***sense*** and ***store*** information. The central nervous system consists of the brain and the ***spinal cord***. The ***peripheral*** nervous system carries sensory and motor information between the central nervous system and the organs and limbs while also helping to regulate ***involuntary*** body functions like heartbeat and breathing.

Try this activity to learn more about your nervous system!

TIME YOUR REFLEXES!

A partner holds a ruler vertically just above your outstretched fingers and drops it without warning. Try to catch it before it falls too far! Use the distance it fell to measure your reaction time using the table below.

Distance	Time
2 in (~5 cm)	0.10 s
4 in (~10 cm)	0.14 s
6 in (~15 cm)	0.17 s
8 in (~20 cm)	0.20 s
10 in (~25.5 cm)	0.23 s
12 in (~30.5 cm)	0.25 s
15 in (~38 cm)	0.28 s
20 in (~51 cm)	0.32 s
25 in (~63.5 cm)	0.36 s
30 in (~76 cm)	0.39 s
35 in (~89 cm)	0.43 s

Try the experiment 10 times and then average your results:

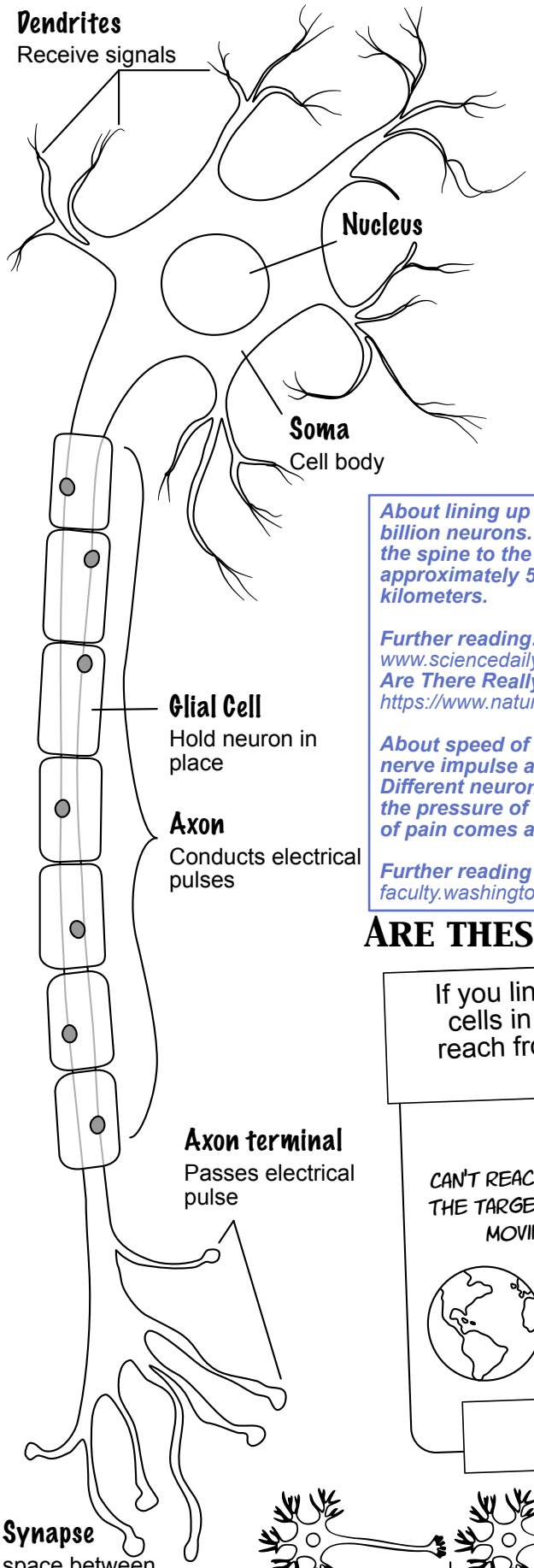
Reaction

A reaction time of zero is luck, not skill! It takes time for the nerve signals to travel from your eyes to your brain to your fingers. Although it is possible for a person to very rarely get a reaction time of zero if they start closing their fingers before the ruler is dropped, an average of 10 attempts will always have a longer time than zero!

Your aver
took for y
your nerv
signal to y
deciding
and your brain sending the MOVEMENT signal to the muscles in your hand.

Would it be possible to have a reaction time of zero seconds?

YES NO



Neurons are specialized cells that transmit chemical and electrical signals throughout the body. The brain is built entirely of neurons and **glial cells** (cells that provide structure and support for neurons).

Neurons have the usual organelles, but they also have special structures for sending electrical signals. **Dendrites** are a branching structure with a large surface area for receiving signals. **Axons** are long tubes that carry an electrical signal from the dendrite to the far end of the cell where the signal is passed out of the **axon terminal** to the next neuron.

The gap between neurons is called a **synapse**. Nerve impulses are relayed from the axon terminal of one neuron to a dendrite of the neighboring neuron by a chemical substance called a **neurotransmitter** that is passed across the synapse.

About lining up nerve cells and their total length: ***The human brain has an estimated 86 billion neurons. The longest neuron in the body is a cell that reaches from the base of the spine to the foot. The total length of the nerve fiber network in the brain alone is approximately 500,000 kilometers. The distance from the Earth to the Moon is 384,400 kilometers.***

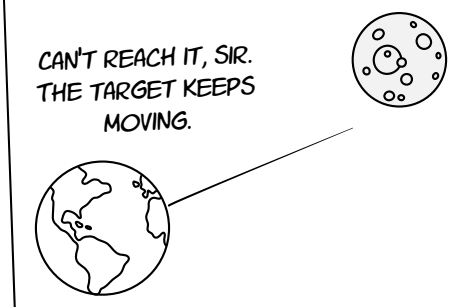
Further reading: Navigation System of Brain Cells Decoded, *2017. https://www.sciencedaily.com/releases/2017/10/171025105041.htm)*
Are There Really as Many Neurons in the Human Brain as Stars in the Milky Way? *https://www.nature.com/scitable/blog/brain-metrics/are_there_really_as_many/*

About speed of nerve impulses: ***The Guinness Book of World Records lists the fastest nerve impulse at 288 kilometers per hour, based on research by Stevens et al in 1966. Different neurons have different rates of signaling. This is why if you stub a toe you feel the pressure of hitting your toe immediately (or almost immediately) but the sensation of pain comes a second or two later.***

Further reading about how nerves work on Neuroscience for Kids: *http://faculty.washington.edu/chudler/ap.html*

ARE THESE FACT OR FICTION? *Write your verdict below:*

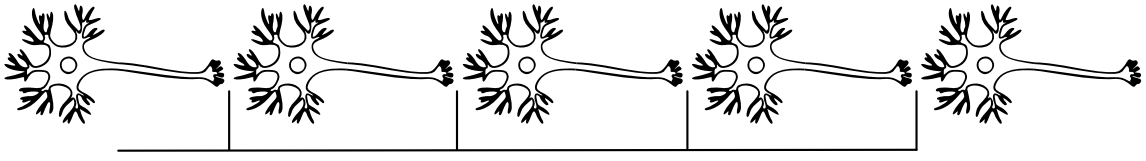
If you lined up all the nerve cells in the body, it would reach from the Earth to the moon.



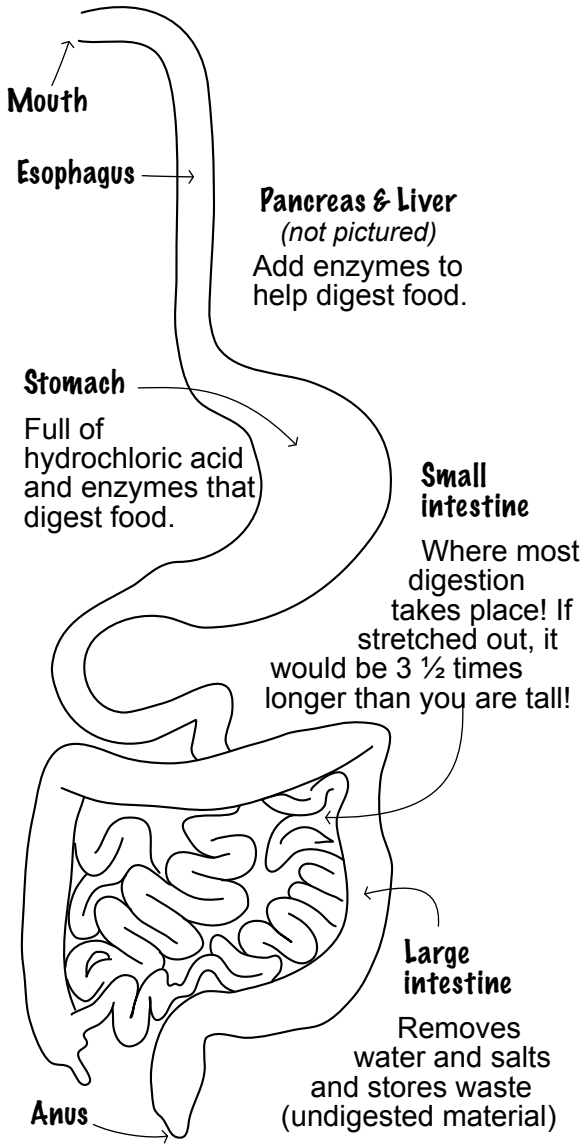
FACT

Nerve impulses can travel more than 100 m/s (223 mi/h).

FACT



The Digestive System



FILL IN THE BLANKS USING THESE WORDS:

nutrients	protect	signal	repair
lining	bacteria	tract	hormones

The main part of the digestive system is called the gastrointestinal tract or GI ___*tract*___. It moves food from one part to another by contracting muscles. Enzymes, ___*hormones*___, and other substances are released that help the body digest the food and ___*signal*___ to the brain when we are hungry or full. ___*Nutrients*___ are broken down into molecules small enough to pass through the ___*lining*___ of the gut so they can enter the bloodstream. The digested nutrients are used or stored for energy, growth, and ___*repair*___. But the food we eat doesn't just feed us! Our digestive system is home to trillions of ___*bacteria*___ as well as archaea, fungi, protists, and viruses. These microbes are called our human microbiome. They help us digest our food and ___*protect*___ us from disease.

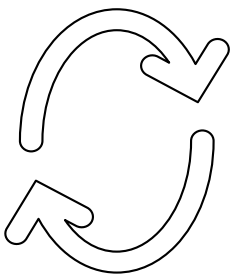
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

A platypus doesn't have a stomach.

FACT

Echidnas and many fish don't have stomachs either.

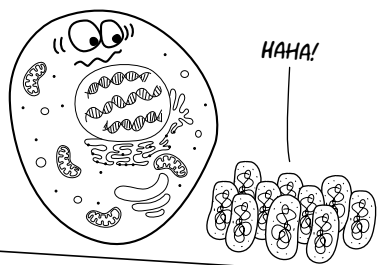
You can't swallow food while hanging upside down because gravity is required for swallowing.



FICTION

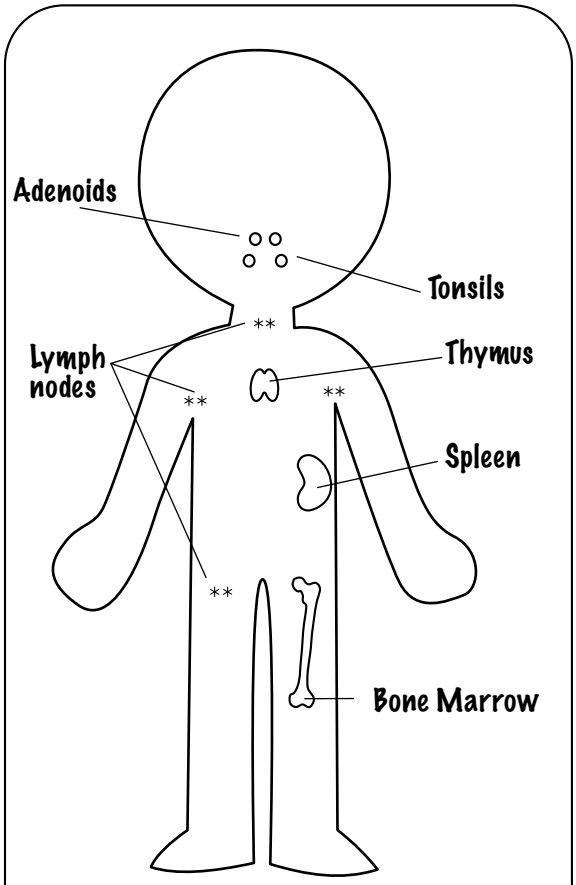
If this were true, astronauts wouldn't be able to swallow!

There are more prokaryotic cells inside your body than human cells.



FACT

The Immune System



The immune system is made of several different organs as well as cells that circulate in both the blood and a specialized system of vessels called the lymphatic system.

FILL IN THE BLANKS USING THESE WORDS:

pathogens	infection	immune response
primary	secondary	memory

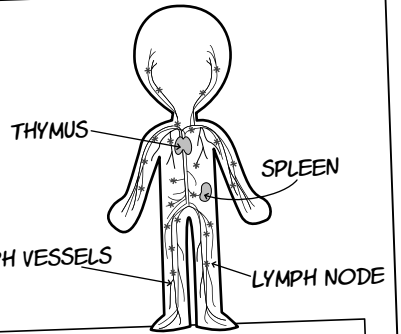
The immune system protects the body from outside invaders like bacteria, viruses, fungi, and toxins. Microorganisms that can make us sick are called ***pathogens*** (or germs). When pathogens invade and multiply, we call this an ***infection***.

The body's action to fight off the pathogens is called an ***immune response***. The first time the pathogen is detected and destroyed is called the ***primary*** immune response. When the same pathogen is encountered again, this triggers the ***secondary*** immune response.

White blood cells (leukocytes) do most of the work of finding pathogens and distinguishing them from the body's own cells. Long-lived white blood cells called ***memory*** cells are able to recognize and remember specific pathogens.

ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

The lymph system collects excess fluid from the rest of the organs in the body.



FACT

You can never catch the same cold twice.

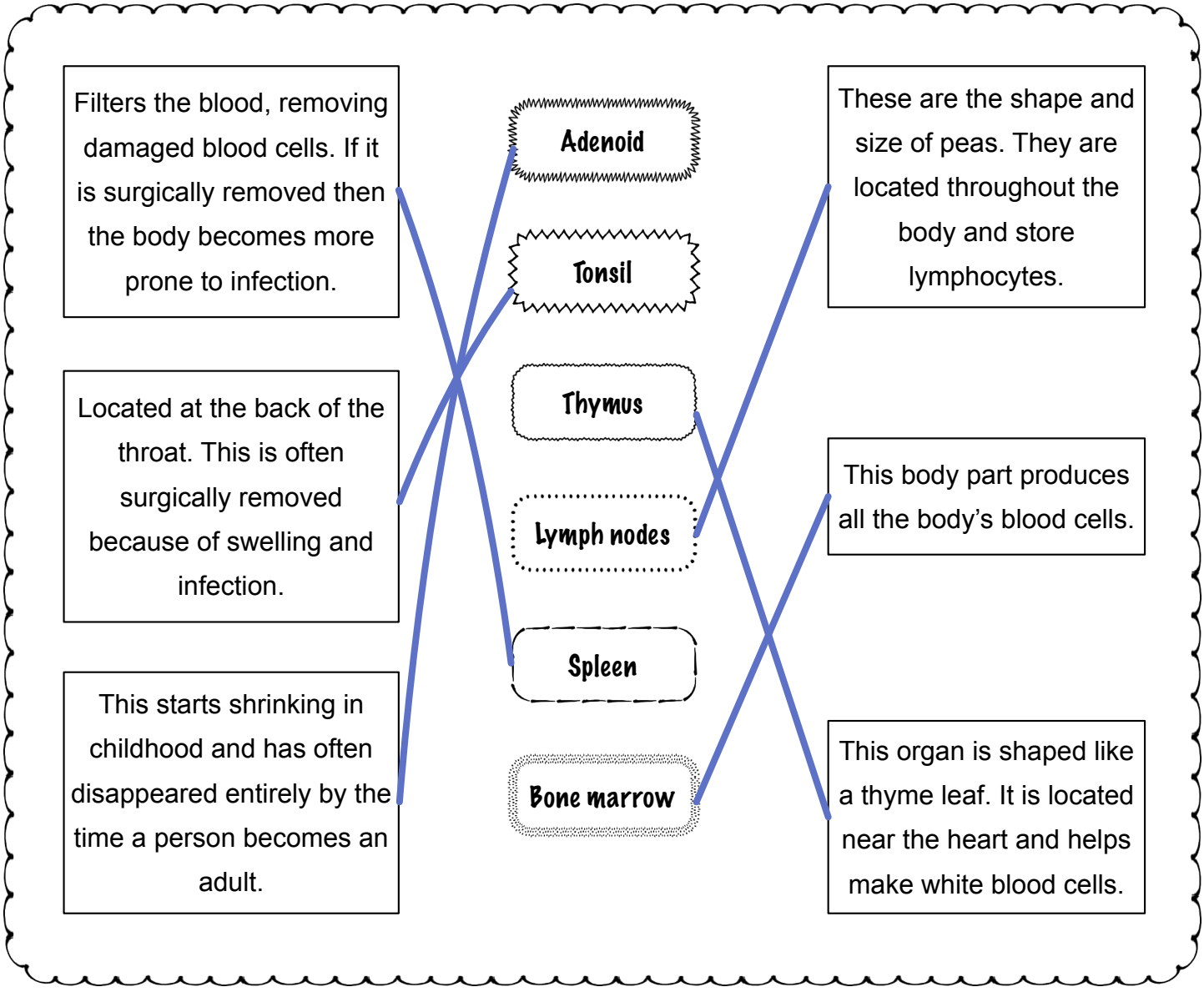
FICTION*

A fever helps your body fight an infection.

FACT

****If your immune system is working properly, you have immunity to bacteria or viruses that have previously made you sick and will not become sick when exposed to them again. However, some viruses and bacteria can mutate and you may not have immunity to new strains or variants. Having a "cold" refers to an upper respiratory infection caused by hundreds of different viruses. Just because you have had one cold does not mean you will never get another one, because the next "can cause a cold" virus you're exposed to will likely be different!***
Also, the strength of your immune system can be weakened by illness or stress. If you are immunocompromised, a pathogen you previously had could still make you sick.

Match each organ with its description.



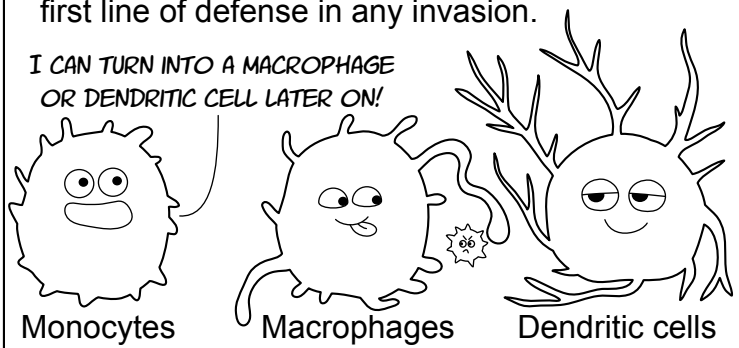
Your notes:

The White Blood Cells

There are several different types of white blood cells or leukocytes. Below are some of the body's key defenders:

Phagocytes

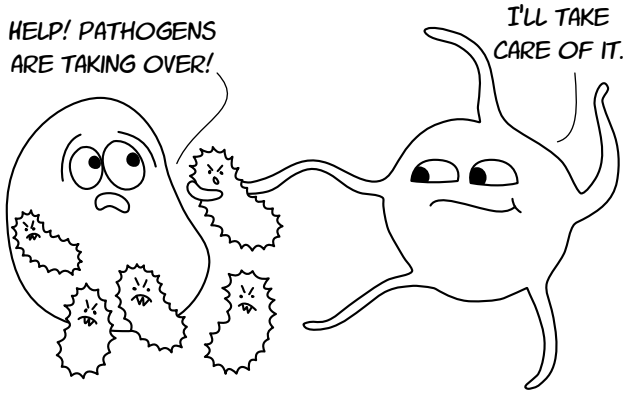
These general-purpose fighter cells engulf and dissolve invading microorganisms. They are the first line of defense in any invasion.



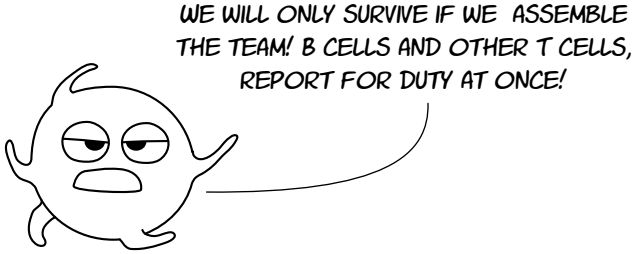
Monocytes Macrophages Dendritic cells

T lymphocytes or T cells

These specialized cells can only fight one type of pathogen, but they are experts at taking them out. They come in two types:



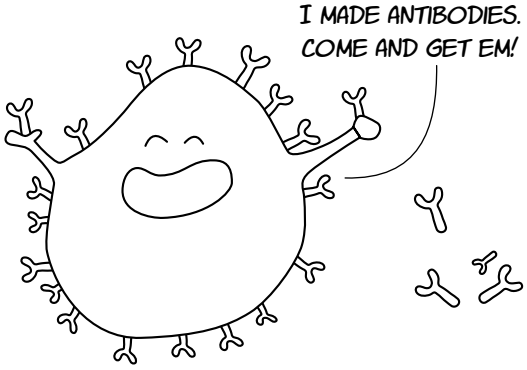
Killer T cells find infected cells using an antibody and kill the infected cells by injecting a cytotoxin.



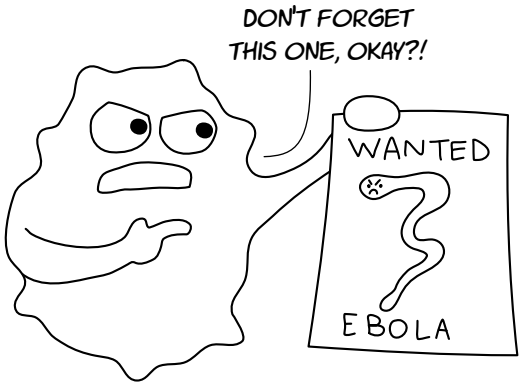
Helper T cells coordinate the attack by giving chemical instructions to the other cells of the immune system.

B lymphocytes or B cells

These cells don't attack pathogens directly. They work behind the scenes.



Plasma B cells make antibodies with special receptors that lock onto pathogenic cells and mark them for destruction.



Memory B cells are permanent sentries that can recognize a specific pathogen and quickly jump start the body's immune response.

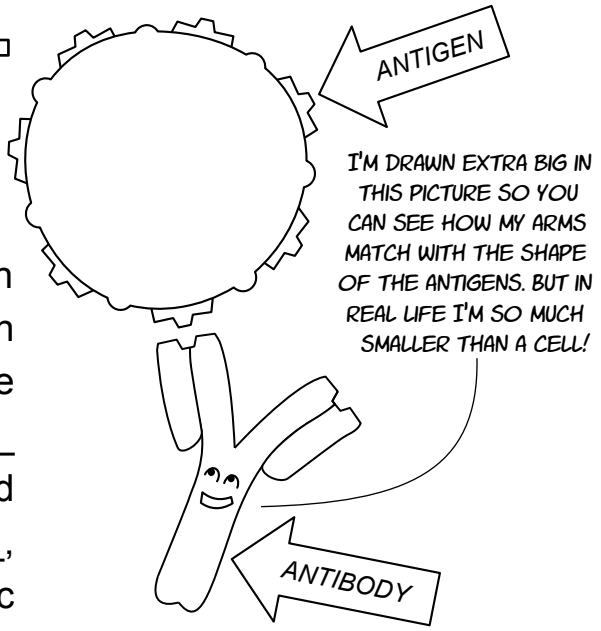
Your notes:

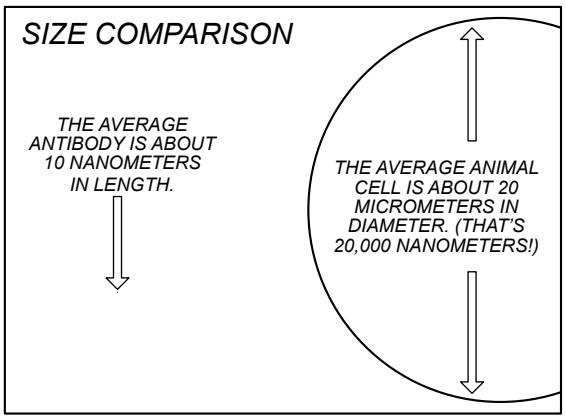
Antibodies & Antigens

FILL IN THE BLANKS USING THESE WORDS:

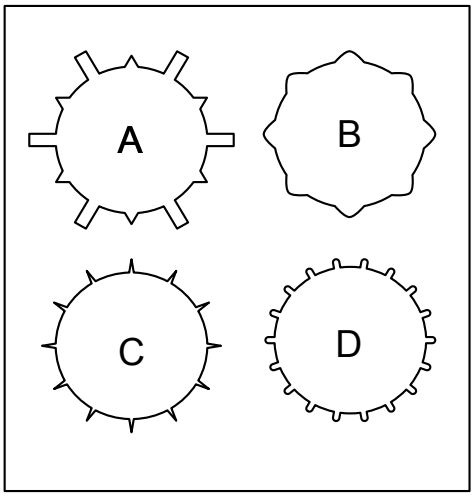
bind	pathogens	specific
inactivate	antibodies	antigens

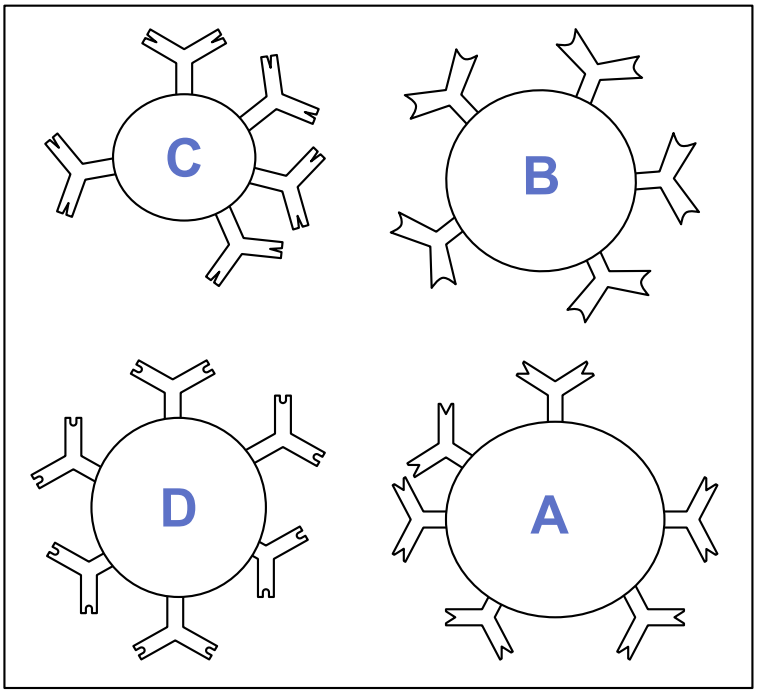
All cells have molecules on their cell surface membranes called ***antigens*** that can trigger an immune response. Our bodies are able to distinguish between its own antigens and foreign antigens. When the body recognizes a foreign antigen, it starts an immune response because cells with foreign antigens could be ***pathogens*** and cause disease. Special white blood cells called B lymphocytes (B cells) release ***antibodies***, which are proteins that will ***bind*** to a specific antigen. The antibodies have a shape that is ***specific*** to a particular antigen, so binding is only possible between those molecules, much like a door can only be opened by keys of a specific shape. When antibodies latch onto the antigens on the surface of the pathogen, they help to ***inactivate*** the pathogen and signal white blood cells to come attack.



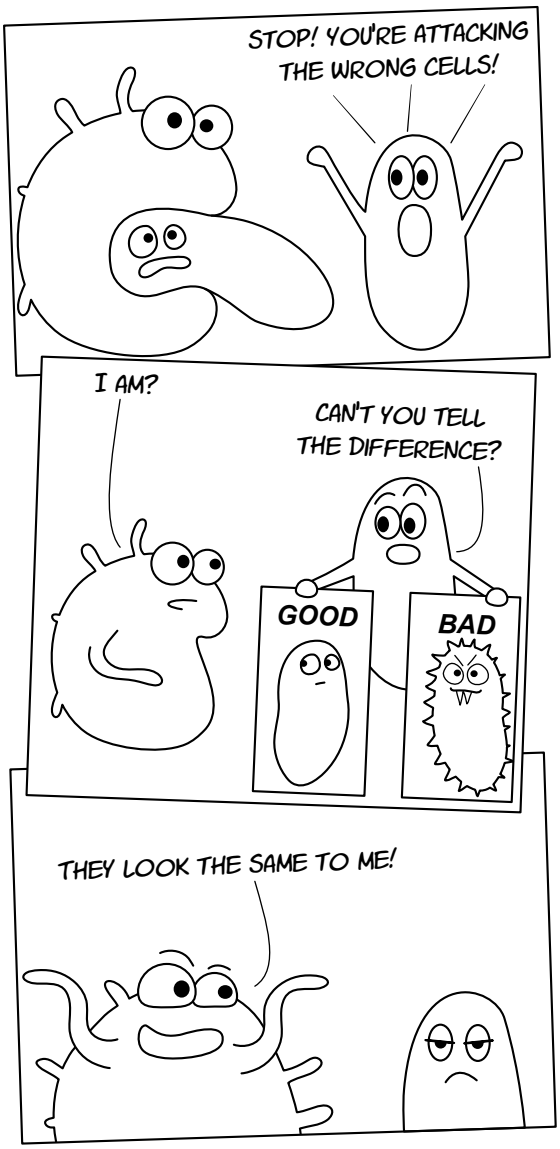


Four different pathogens are pictured below, each with different antigens on their cell surface. Match each pathogen with the antibodies that will bind to it.





Autoimmune & Allergies



FILL IN THE BLANKS USING THESE WORDS:

nerve	autoimmune	allergies
connective	pancreas	allergen

When the immune system develops antibodies for the body's own cells or tissues and begins to attack them, this causes an ___*autoimmune*___ disorder. There are several different types: Rheumatoid arthritis is caused when the immune system attacks the ___*connective*___ tissue around the joints. Multiple sclerosis is the result of the immune system attacking the myelin coating of ___*nerve*___ cells. Type 1 diabetes is caused by antibodies destroying cells in the ___*pancreas*___ that produce insulin.

___*Allergies*___ are another example of the immune system attacking the "wrong" thing. During an allergic reaction, the body responds to a foreign substance or ___*allergen*___ by producing histamines that fight infection. This causes inflammation. In a severe allergic reaction, the inflammation can be life threatening and cause anaphylactic shock.

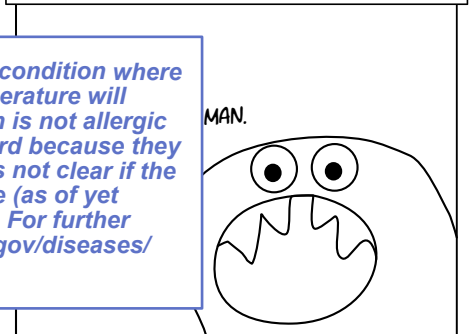
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

It is possible to have an allergy to water.

Aquagenic urticaria is an extremely rare condition where exposure of the skin to water of any temperature will cause a rash. A person with this condition is not allergic to water in the traditional sense of the word because they can still drink water with no ill effects. It is not clear if the rash is in response to water itself or some (as of yet unknown) allergen dissolved in the water. For further reading see https://rarediseases.info.nih.gov/diseases/10901/aquagenic-urticaria

FACT*

Hookworm parasites can cure most allergies.



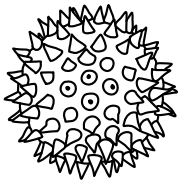
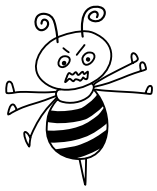
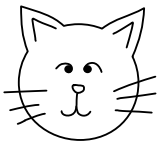
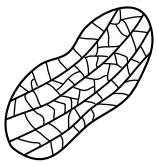
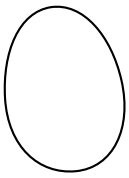
FICTION**

A tick bite can make you allergic to meat.

FACT

There is some evidence that hookworm parasites suppress the immune system and scientists were hopeful they could be a cure for autoimmune diseases. But controlled trials showed no significant effect. See https://www.npr.org/sections/goatsandsoda/2016/08/12/489619045/could-worms-in-your-gut-cure-your-allergies

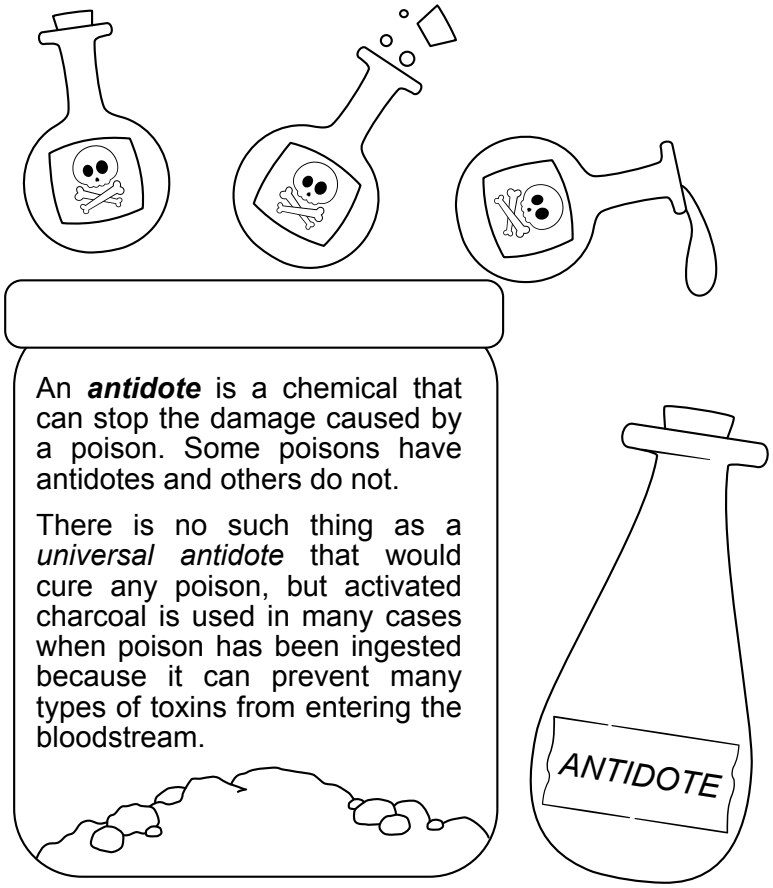
Can you match each fact with it's corresponding picture(s)?

High humidity in your home will make it more likely to encounter this allergen		 Pollen
These animals eat flakes of human skin, mold, and cotton fibers. Proteins from their shells and feces are common allergens.		 Dust mites
Hay fever, with symptoms of a runny nose, swollen eyes, and sneezing, is often caused by exposure to these things.	*Hay fever is commonly caused by pollen, but it can also be caused by dust mites or mold.*	 Mold
Approximately 5% of the population has a severe allergy to the venom of this animal.		 Bees
This is one of the most common food allergies and can be very severe.		 Cats
Allergies to this animal are not caused by hair! They are caused by proteins in the saliva and skin.		 Peanuts
If you have an allergy to this food you also need to be careful about eating mayonnaise, marshmallows, and some types of pasta.		 Eggs

Why are Poisonous Things Poisonous?

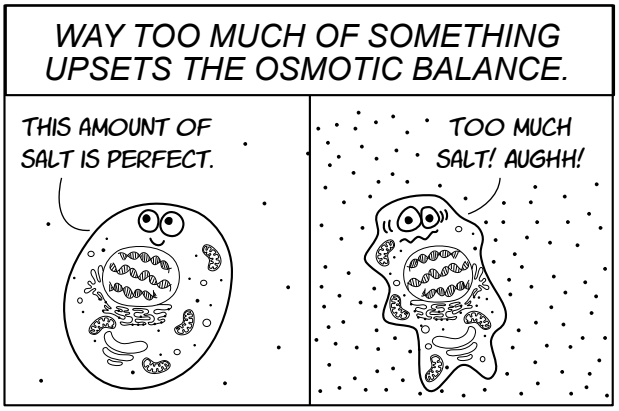
Because they cause something to go wrong with the cell!

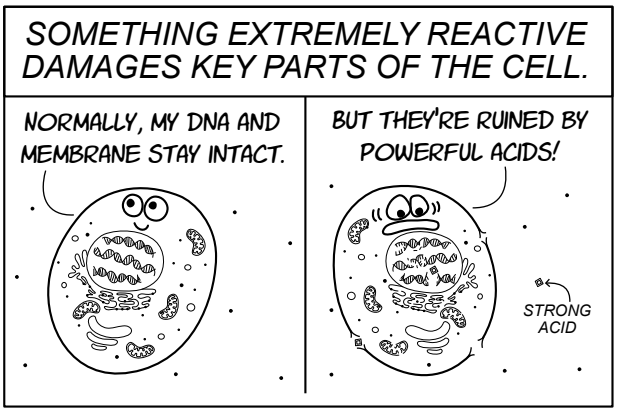
The cell exists in a state of balance where the different parts are working together in harmony. If one thing stops working, it can upset the entire system. Poisons and toxins exist in virtually every category of molecule or compound: there are poisonous elements, toxic proteins, dangerous minerals, and small alkaloids (nitrogen-containing molecules made by plants). But the most important question when talking about poisons is the DOSE. Anything can become toxic if there is too much of it!



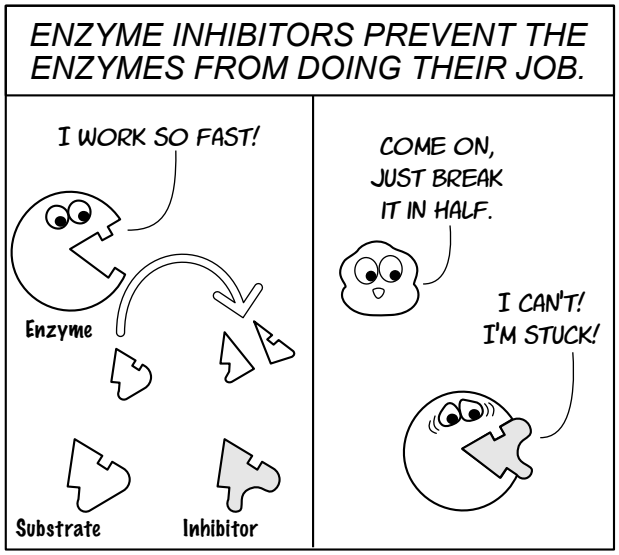
An ***antidote*** is a chemical that can stop the damage caused by a poison. Some poisons have antidotes and others do not.

There is no such thing as a *universal antidote* that would cure any poison, but activated charcoal is used in many cases when poison has been ingested because it can prevent many types of toxins from entering the bloodstream.

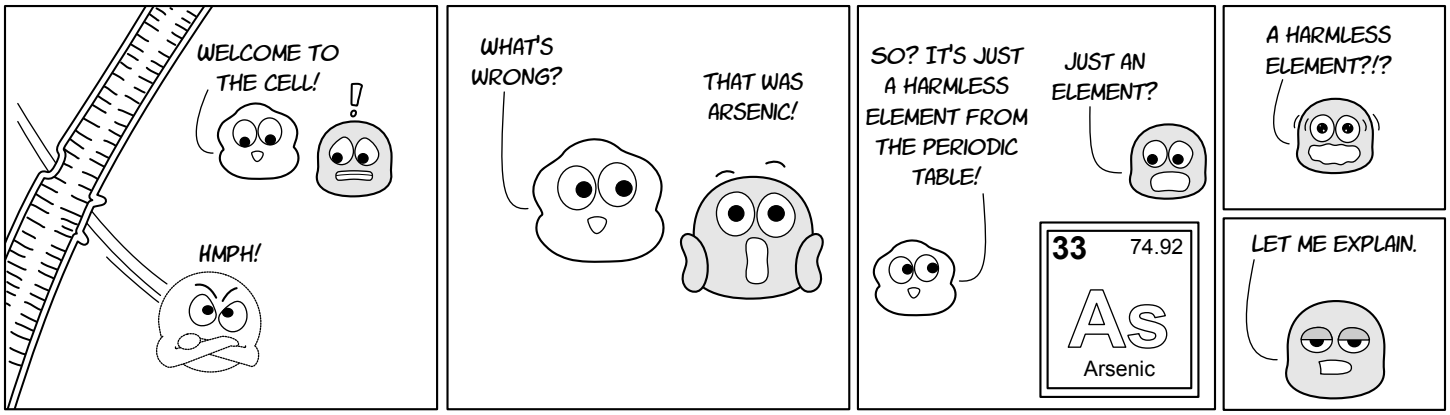


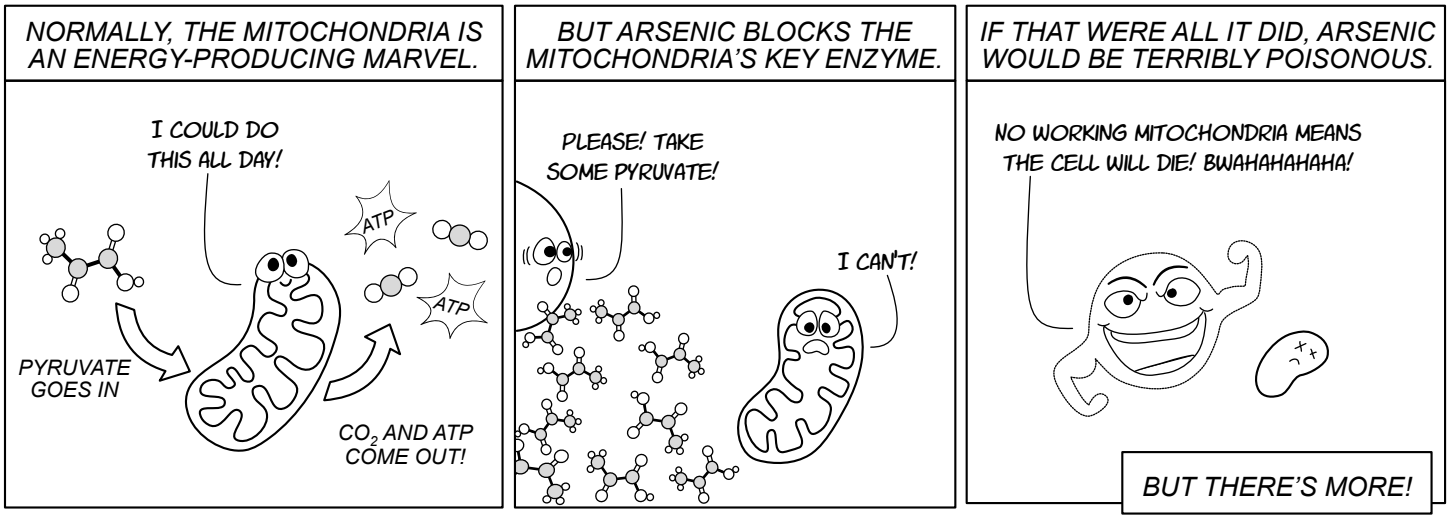


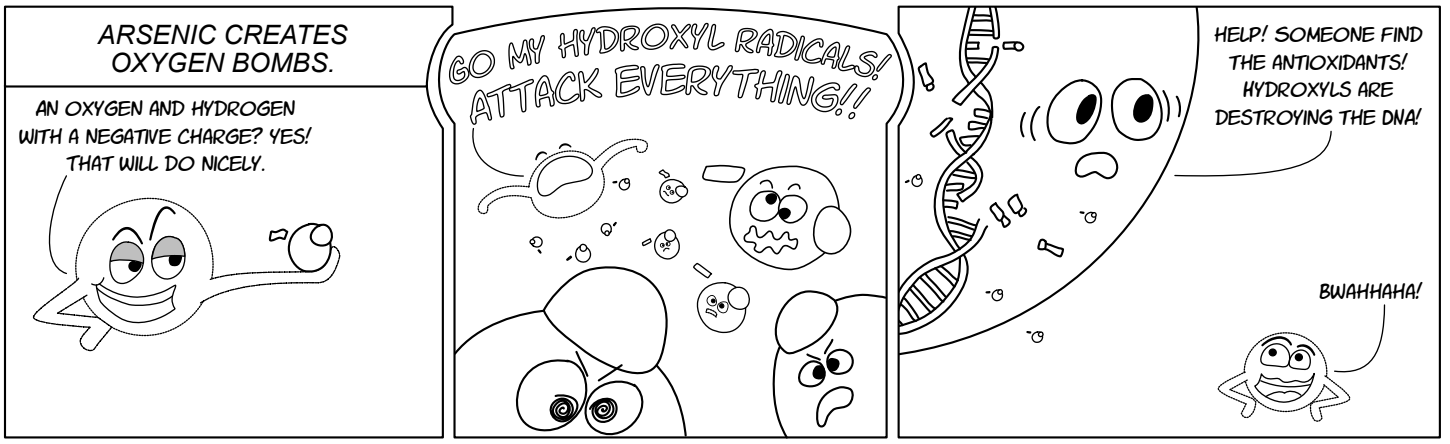
Your notes:

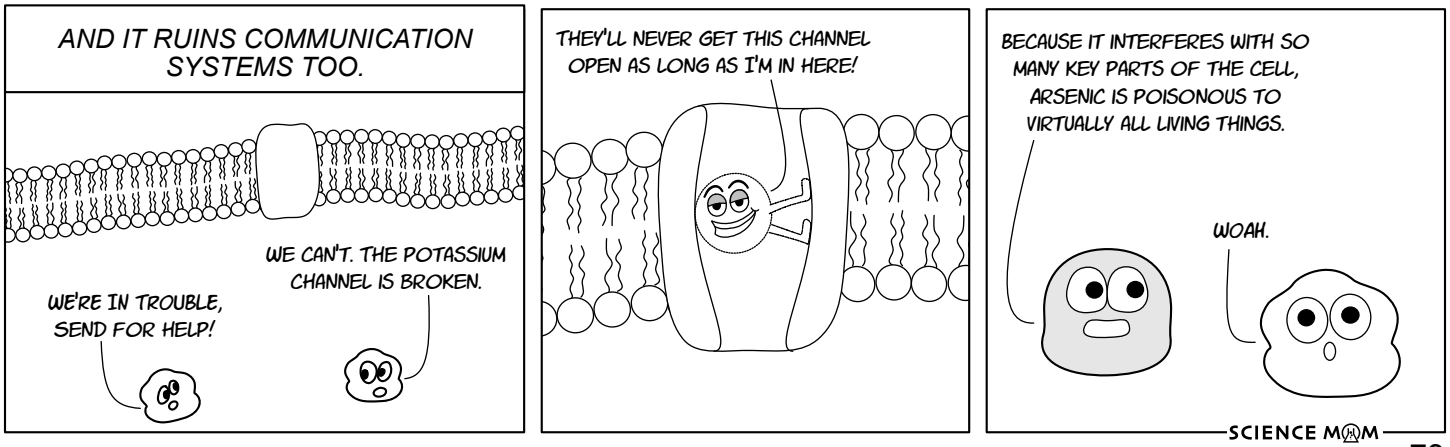


Awful Arsenic – a poisonous element



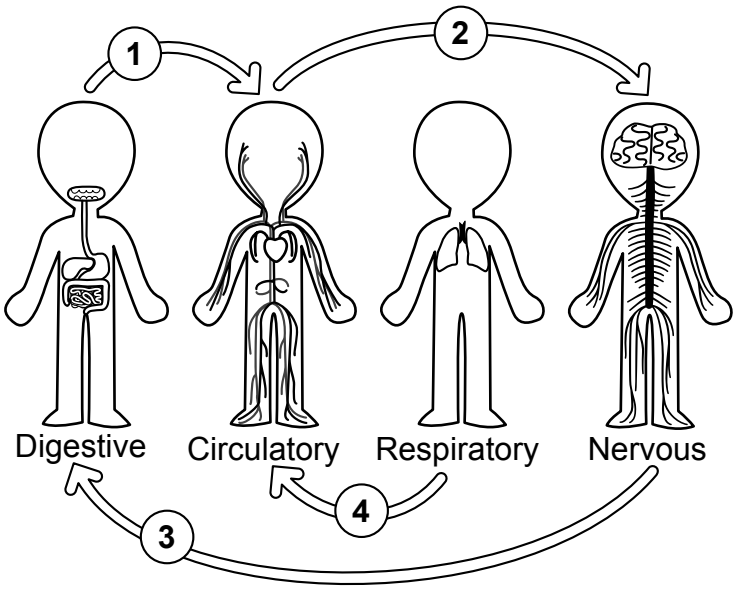






Interdependent Systems

The body's systems interact with and depend on each other. Describe how one system influences another in the list below:



There are multiple correct answers. For example, a different response for #3 could be that nerves allow the movement of tongue and mouth to chew and swallow food.

1 *The digestive system impacts the circulatory system by:* ***passing nutrients like sugar, salts, and vitamins into the blood stream so they can circulate throughout the body.***

2 *The circulatory system impacts the nervous system by:* ***delivering oxygen to the brain.***

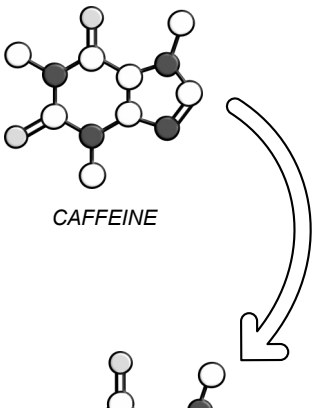
3 *The nervous system impacts the digestive system by:* ***controlling the muscles that move food through the gastrointestinal tract.***

4 *The respiratory system impacts the circulatory system by:* ***delivering oxygen to the blood cells.***

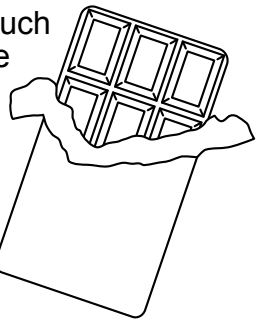
Which system was poisoned?

Use clues from the toxin's description to decide which system is going to be most affected. Then write the name of that system in the box below the toxin.

BOTULINUM TOXIN	***FOXGLOVE***	***HEMOTOXINS FROM A RATTLESNAKE***
The most poisonous toxin known. It blocks the receptors on nerve cells. Symptoms of poisoning include difficulty breathing and muscle weakness. It is so effective at paralysis that it is used in medical and cosmetic applications (botox injections).	*This plant contains cardiac glycosides, compounds that disable sodium-potassium ion pumps on cell membranes. They especially impact heart cells but also impact the nervous and gastrointestinal systems, causing, nausea, vomiting, and diarrhea.*	*Rattlesnake venom contains an enzyme that destroys a protein in red blood cells, causing them to break open. This results in bruising and internal bleeding.The venom also has other compounds that prevent clotting and reduce platelets.*
Nervous system	***Circulatory system And Nervous system***	***Circulatory system***



WHY NO CHOCOLATE FOR DOGS?

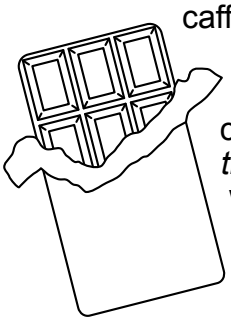


Caffeine and theobromine are found in many foods such as chocolate. They block certain **receptors** in the nervous system, producing a stimulating effect that makes people feel more alert and awake.

When people eat chocolate, **enzymes** in their body break down the caffeine and theobromine into smaller molecules. Within a few hours, all of the stimulants have been **metabolized** by being converted into different molecules.

Dogs, bears, and cats have slightly different enzymes in their cells and instead of digesting or metabolizing theobromine in two to three hours, it takes them almost twenty! This is why chocolate is poisonous to dogs, cats, and bears.

Could chocolate also be poisonous to humans if they ate too much of it? Of course! *Anything* can cause poisoning if the dose is too high. A caffeine or theobromine overdose can cause irregular heartbeat and seizures in any mammal.



But because a human body has **enzymes** that can break caffeine down quickly, a person would need to eat *more than 700 regular-sized (1.5 oz) chocolate bars* before they would experience theobromine toxicity.

A dog, bear, or cat, on the other hand, can become poisoned from a small amount. All because of the difference between their **enzymes** and how they work.

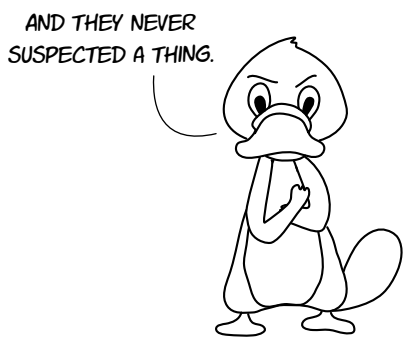
Your notes:

ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

If you bite it and die, it was poisonous. If it bites you and you die, it was venomous.

FACT

Platypuses are the only venomous mammals.



FICTION*

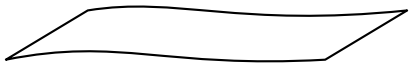
Kingsnakes are immune to viper venom because they eat rattlesnakes.

FICTION

**The platypus is the most venomous mammal, but other venomous mammals include several species of shrews, slow lorises (a small nocturnal primate), and vampire bats (the anticoagulant in their saliva technically counts as a venom).*

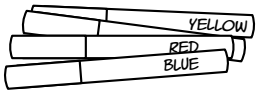
Physiology ART PROJECT

MATERIALS:

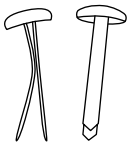


Several pieces of waxed paper, parchment paper, or tracing paper

Pencil



Markers



Paper Fastener (also called brads)

1. Cut seven pieces of transparent paper to be approximately the same size as a regular piece of paper.

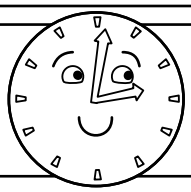
2. One at a time, place a piece of the transparent paper over the 5 templates of the body systems we covered in class. (Templates can be found in the appendix.) Trace each body system with pencil and then outline it with markers and color in the parts.

3. After tracing all 5 body systems on different pieces of transparent paper, trace two additional outlines. One is for a bonus system (you could do the skeletal, muscular, urinary, reproductive, or integumentary system). The other is for coloring in to look like a person. Feel free to add hair and clothes that extend beyond the body outline.

4. Stack the seven pieces of waxed paper together so that the dots above the outlines are all aligned. Carefully puncture the dots and fit the paper fastener through the hole, opening the wings so that the pieces are fixed together.

5. Line the body outlines up and then trim the paper in a smaller oval or rectangular shape (optional).

6. Hold your physiology art up to the window and experiment with rotating different pieces in and out to see how the view changes and how different organs overlap.



Quiz Time!

ANSWER THE QUESTIONS TO SEE WHAT YOU LEARNED ABOUT PHYSIOLOGY!

1. Which body system is responsible for cleaning the blood and removing waste?
   A. Integumentary system
   B. Urinary system
   C. Nervous system
   D. Digestive system

2. The flow of blood between the heart and the lungs is called:
   A. Limbic circulation
   B. Pulmonary circulation
   C. Systemic circulation
   D. Aortic circulation

3. The most numerous type of cell of the body is a
   A. Red blood cell
   B. White blood cell
   C. Bone marrow cell
   D. Skin cell

4. Where is the Carotid artery located?
   A. Behind the knee
   B. The belly button
   C. The neck
   D. The wrist

5. _____ are the component of blood that prevents bleeding.
   A. Plasma
   B. Red blood cells
   C. White blood cells
   D. Platelets

6. How long does a typical red blood cell circulate?
   A. 7 days
   B. 36 days
   C. 120 days
   D. 365 days

7. Where does most our digestion take place?
   A. Stomach
   B. Small intestine
   C. Large intestine
   D. Liver
   E. Pancreas

8. The center of the nervous system is in the:
   A. Brain
   B. Spine
   C. Heart

9. Which system of the body is the liver in?
   A. Circulatory system
   B. Respiratory system
   C. Digestive system
   D. Urinary system

10. Select all of the functions below that are carried out by the integumentary system of the body.
    A. Sensing via touch
    B. Cleaning the blood
    C. Storing memories
    D. Providing protection
    E. Breaking down nutrients

11. The ribcage is part of which system of the body?
    A. Respiratory system
    B. Digestive system
    C. Skeletal system
    D. Nervous system

12. What connects muscle to bone?
    A. Ligaments
    B. Cartilage
    C. Tendons

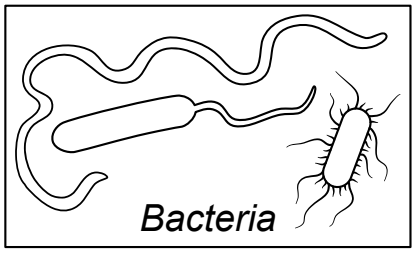
13. The largest organ of the body is the:
    A. Skin
    B. Heart
    C. Brain
    D. Pancreas

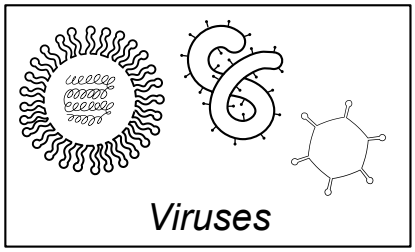
14. Approximately how many times does a person breath each day?
    A. 230
    B. 2,300
    C. 23,000
    D. 230,000

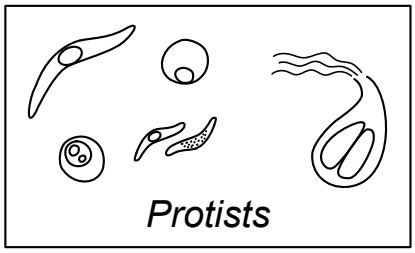
15. The smallest type of blood vessels are called:
    A. Arteries
    B. Veins
    C. Capillaries

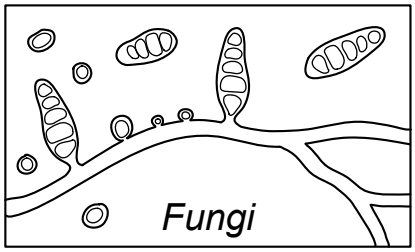
Pathogen: A microorganism that can cause disease

Match each family of pathogens with their description:









The genetic information of this pathogen is covered with a structure known as a capsule or envelope. It has no ribosomes or true cellular structure and cannot reproduce on its own.

Some of these single-celled prokaryotic cells produce toxins that are poisonous to their host. Famous examples include Tuberculosis, E-coli, and Salmonella.

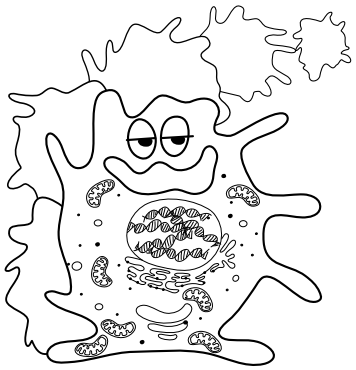
Most of these pathogens are not deadly but several species cause persistent and annoying infections such as ringworm, athletes' foot, toenail fungus, and yeast infections.

These pathogens can be difficult to treat because their cells are eukaryotic. The most deadly pathogen in this family is spread by mosquitos.

If you could prevent two species of pathogens from causing any further disease, which two would you choose and why?

There are no incorrect answers to this question since it's asking for an opinion, but hopefully students will consider the impact of some of the most deadly and disruptive diseases in modern times such as: Malaria, Tuberculosis, Influenza, Ebola, or Coronaviruses (all of them from common cold variants to SARS, MERS, and COVID).

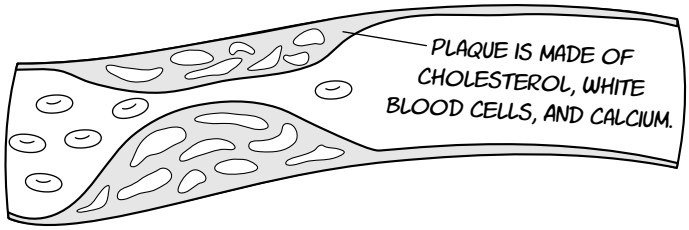
What about diseases that are NOT caused by pathogens?



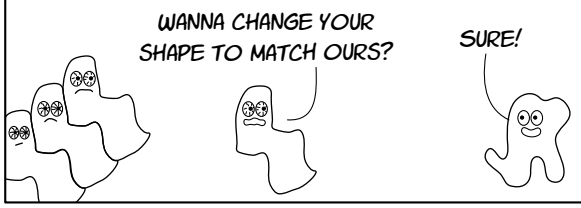
Cancer is caused by uncontrolled cell growth. When the body's own cells mutate and become malignant, they invade and grow in tissues where they shouldn't, causing pain and death. Some types of cancer are strongly genetic, others can be caused by things that damage DNA, such as radiation. But others are caused by *viruses.*

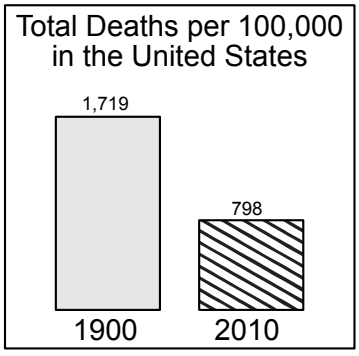
Genetic Diseases like sickle cell anemia or hemophilia are caused by pieces of DNA that cause a problem with an important protein. There are no pathogens involved in most genetic diseases. We'll learn more about them in Biology 2.

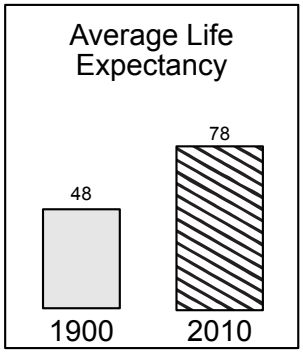
Heart Disease is the leading cause of death in developed countries. It is caused by a buildup of plaque in the arteries that stops the flow of blood through the heart. Diet, exercise, and genetics all play a role in heart disease, but infections do as well. Scientists are researching how certain bacteria and viruses contribute to the formation of heart disease.

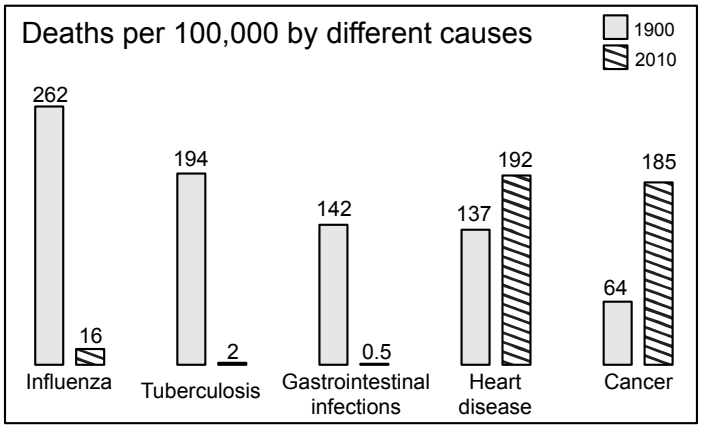


Prion Diseases like mad cow disease are caused by proteins that are folded differently. Their amino acid sequence is identical to the normal proteins found in the brain and nerves. But somehow, these infectious proteins cause the normal proteins to change shape and then cluster together, destroying nervous tissue.









Between 1900 and 2010 the number of deaths and causes of deaths have changed dramatically. What do you think explains these changes?

Life expectancy was increased by the development of germ theory and subsequent improvement to health care. Large scale access to clean water, vaccines, and antibiotics reduced deaths from many infectious diseases. Longer lives then made it more likely for the heart to wear out or for the body's cells to become cancerous. People are now much more likely to die of diseases associated with old age.

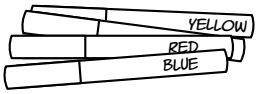
Data for the graphs was adapted from a 2012 article from the New England Journal of Medicine titled *The Burden of Disease and the Changing Task of Medicine* by Jones et al. The 2010 data for tuberculosis and gastrointestinal infections was estimated from reports on the Center for Disease Control and World Health Organization websites.

Most Wanted Microbe ART PROJECT

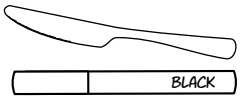
MATERIALS:

Several copies of the most wanted microbe templates (located in the appendix)


Pencil



Markers, colored pencils, crayons, or paint.



Knife and ink for weathering the edges (optional)

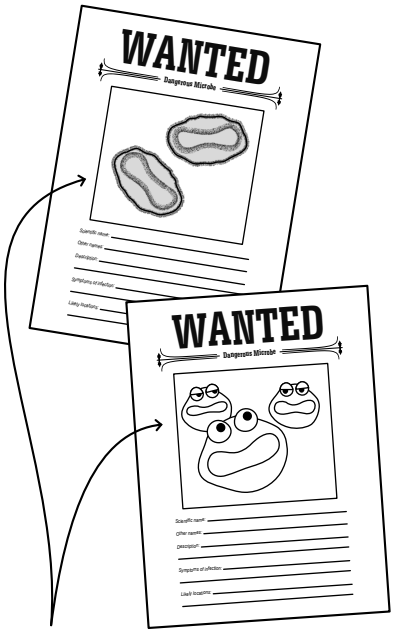
1. (Optional) Weather the paper to make it look old by scraping a knife along the edges and then wiping them with a piece of tissue wet with ink.

2. Select four microbes to study for the creation of your most wanted microbe posters. You can select them from the suggested microbes list in the appendix, or find your own. Make sure you have at least 1 virus and at least 1 bacteria.

3. Find photos of the microbe and make notes of key features. Record the official name of the organism as well as names for the disease the microbe causes. Make notes on a piece of scratch paper or computer as you do research, and then fill out the poster.

4. Draw a "wanted portrait" for your microbe. It can be realistic or cartooned, but whichever approach you choose, be sure to highlight key features of the microorganism.

5. Share your artwork with a friend and tell them something you learned!



NOTE HOW BOTH THE REALISTIC AND CARTOON VERSIONS OF SMALLPOX HAVE OVAL-SHAPED VIRUSES WITH RELATIVELY SMOOTH SURFACES AND DUMBBELL-SHAPED VIRAL CORES.

What's in a name?

*The name of the microorganism is often different than the name of the disease it causes. For example, **chicken pox** is caused by the **varicella-zoster virus** (VZV) which has an official name of "Human alphaherpesvirus 3."*

When a person is first infected with this virus, they will become ill with chickenpox. A case of chickenpox usually involves a headache, fever, fatigue, and an itchy rash of small fluid-filled blisters.

*After that initial infection, the virus lies dormant in the nerve cells. Decades later, when the chickenpox survivor is old, or their immune system is stressed, the virus can reactivate to cause **shingles**, a painful patch of blisters over the skin of one dermatome (an area of skin supplied by similar nerves). Shingles and chickenpox are two different diseases caused by the same virus.*

Medicine in the 1700s

Three hundred years ago, people didn't believe that diseases were caused by germs. They thought illnesses came from an **imbalance of fluids** in the body or from breathing smelly air (called **miasma**). If a person got really sick during the early 1700s and called a doctor, these are some of the treatments that could have been prescribed. Write "helped" under treatments that could help someone recover and "hurt" under treatments that would have made the person's condition worse:

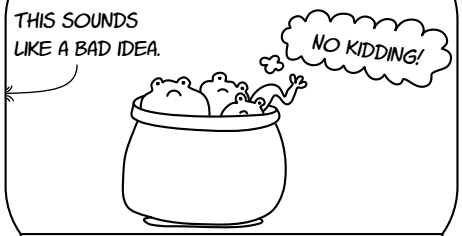
For fevers, abdominal pain, seizures, and almost every ailment: BLOODLETTING

Hurt

For malaria: Eat the BARK of the CINCHONA Tree.

Helped

For smallpox: Burn a POT OF TOADS and then eat their remains.



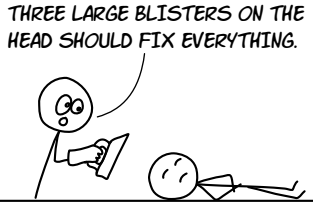
Hurt*

**This was an actual remedy recommended in 17th century America. See https://colonialnorthamerica.library.harvard.edu/spotlight/cna/feature/medicine-in-colonial-north-america*

For mental distress, fevers, and many other diseases: PURGING.

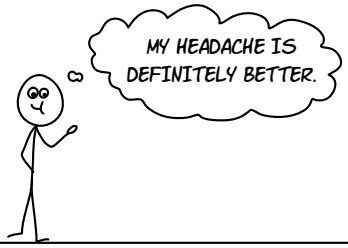
Hurt

For unconsciousness or severe fevers: BURN the skin with a red-hot iron to produce large BLISTERS.



Hurt

For headaches: Chew on wintergreen leaves.



Helped**

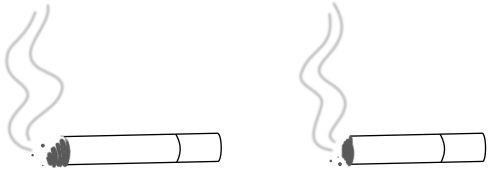
***Wintergreen leaves contain aspirin, a chemical that has an anti-inflammatory and pain-reducing effects.*

The bloodletting, purging, and blistering were traditions that dated back to ancient Greece. They did not help people recover from illness, yet thousands of physicians and healers prescribed these treatments for hundreds of years! Why do you think this happened? How could so many people have caused the body pain and stress when they were trying to help it heal?

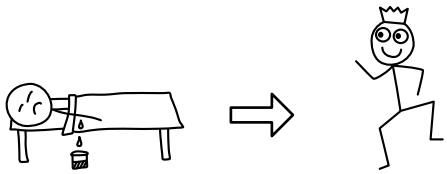
Your Thoughts: ***It's often difficult for people to admit that an idea or belief they have is wrong, and correlation can be easily confused for causation. If someone lost consciousness and was burned with an iron to make large blisters on their head and then they recovered, their 16th century doctor would say they recovered BECAUSE of the blisters, when actually they would have recovered anyway.The blisters correlated with the recovery, but they did not cause it. Until people applied statistics to medicine, it was often difficult to tell what really worked and what didn't.***

Anecdote vs. Research

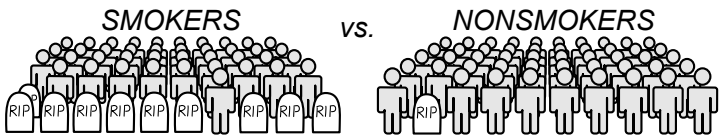
***Anecdotes** are stories. They are often memorable and repeatable, but when people base conclusions on an anecdote (one person's experience) rather than **qualitative research** (many people's experiences with precise parameters and analysis), their conclusions are often wrong. Compare these two examples of anecdotes and studies which came to opposite conclusions. Which conclusion would you trust and why?*



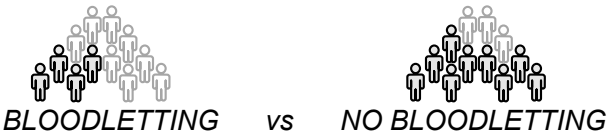
***Anecdote 1:** Great Aunt Jeanne smoked two cigarettes every day and lived to be 122 years old.*
***Conclusion:** Smoking cigarettes makes people live longer.*



***Anecdote 2:** King Louis was sick with a terrible case of pneumonia. The doctor drained 3 pints of his blood and the next day he began to recover.*
***Conclusion:** Bloodletting cures pneumonia.*



***Study 1:** 200,000 people were tracked for 5 years. Half smoked daily, and half did not smoke. 103 of the smokers got lung cancer during the study but only 9 nonsmokers became ill with lung cancer.*
***Conclusion:** Smoking cigarettes increases the risk of getting lung cancer.*



***Study 2:** 36 patients sick with pneumonia were treated with bloodletting, while 33 similar patients receive no bloodletting. Less than half of the bled group survived while 3/4 of the others recovered.*
***Conclusion:** Bloodletting decreases the likelihood of recovering from pneumonia.*

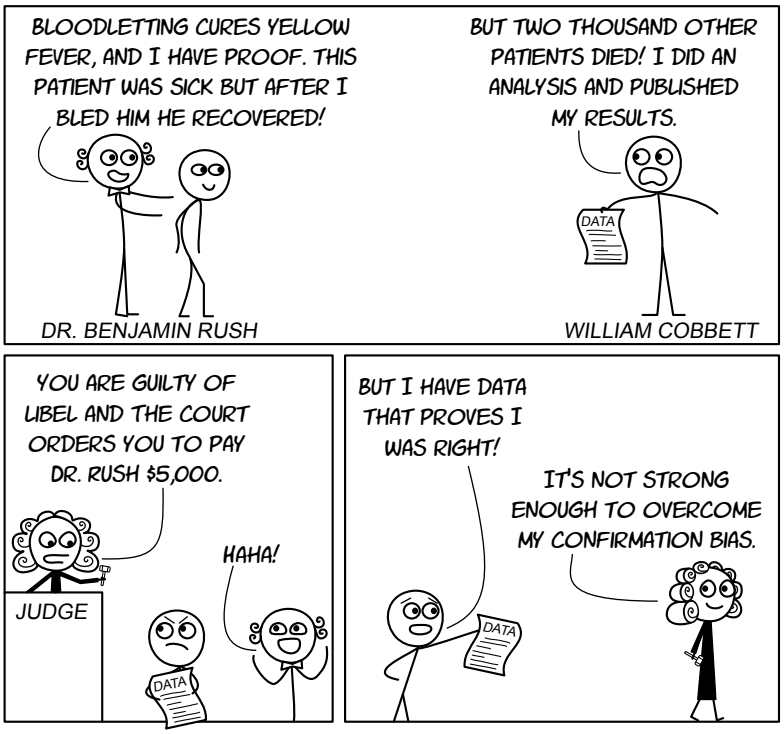
Your Thoughts: *I would trust the study because there are more people involved and greater evidence about the effects.*

Most people today agree that smoking causes health risks and that losing a large amount of blood is harmful. But what if you had always been told the opposite? Would you still choose to trust the study over the anecdote?

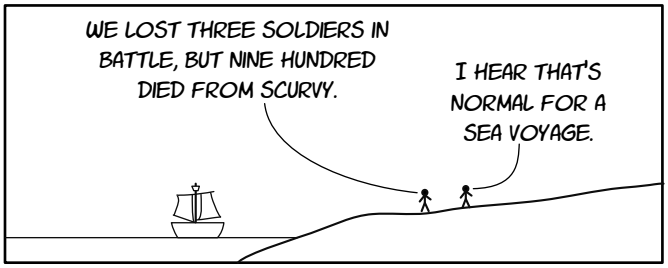
In 1799, the famous doctor Benjamin Rush filed a lawsuit against William Cobbett because Cobbett had published articles saying that bloodletting caused increased death. The court ordered Cobbett to pay Rush $5,000 (which would be equivalent to almost $150,000 today) because Cobbett's articles about bloodletting were hurting the doctor's reputation.

Why didn't Benjamin Rush or the judge and jury in the trial recognize that bloodletting was casing harm? Two words: *confirmation bias.*

Confirmation Bias is the tendency to interpret new evidence as confirmation of one's existing beliefs or theories.



Scurvy and a clinical trial



WHO GOT IT: ***Sailors on long voyages & poor people in the middle of winter.***

SYMPTOMS: ***Bleeding gums, weakness, aches, swollen joints, exhaustion***

MORTALITY: ***Up to 50% of sailors died on extended voyages***

16TH & 17TH CENTURY IDEAS ABOUT THE CAUSE OF SCURVY:

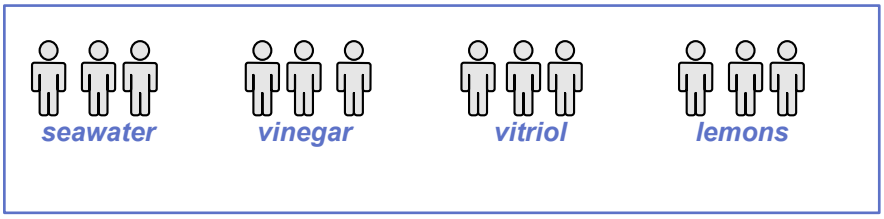
- *Scurvy is the result of damp air and cooking in copper pans.*
- Scurvy comes from laziness
- Any who eats food spoiled by rats will become ill with
- Survey is owing to a total lack of fresh vegetable food and greens.
- The disease comes from acute depression and homesickness.
- Scurvy is the result of too much exercise.
- Scurvy is the result of too little exercise.
- *Breathing too much sea air will bring scurvy.*
- Scurvy comes from eating too
- Anywhere with filth and poor morals, scurvy will follow.
- The illness results from excessively cold and damp weather.

Cures for Scurvy:

Seawater *Vitriol*
Vinegar *Lemons*

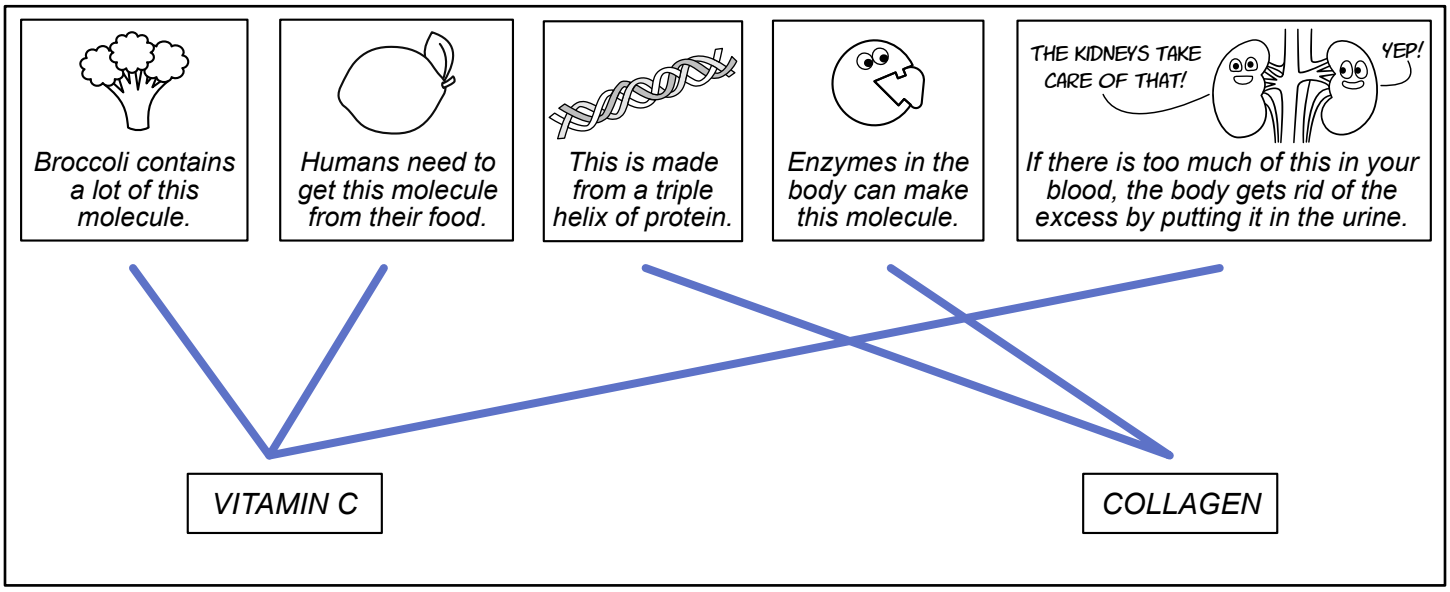
In the 16th and 17th centuries, shipowners and governments expected half of their sailors to die from scurvy on any long voyage. The disease was incredibly painful, common, and problematic. People generally agreed that it had *something* to do with diet, but there was no agreement on a cure. If you were a doctor on a ship with 12 sailors sick with scurvy and your medical book listed four treatments, how would you find out which one worked? Write or draw your plan to help the sailors in the box below:

Example answer: To test the theory that scurvy is caused by diet, we need to try the four different diets. We know that the standard sailing diet gives most sailors scurvy, so we will divide the 12 sick sailors into 4 groups of 3 people each. Each of the other groups would incorporate one of the four proposed cures into their diet, but otherwise, they would try to keep things the same so that the only difference between the groups is their diets. Then carefully monitor the health of the sailors to see if the diets make a meaningful difference. If one group of sailors recovers sooner from scurvy, then that diet should be studied further in a larger group to see if it really is a cure.

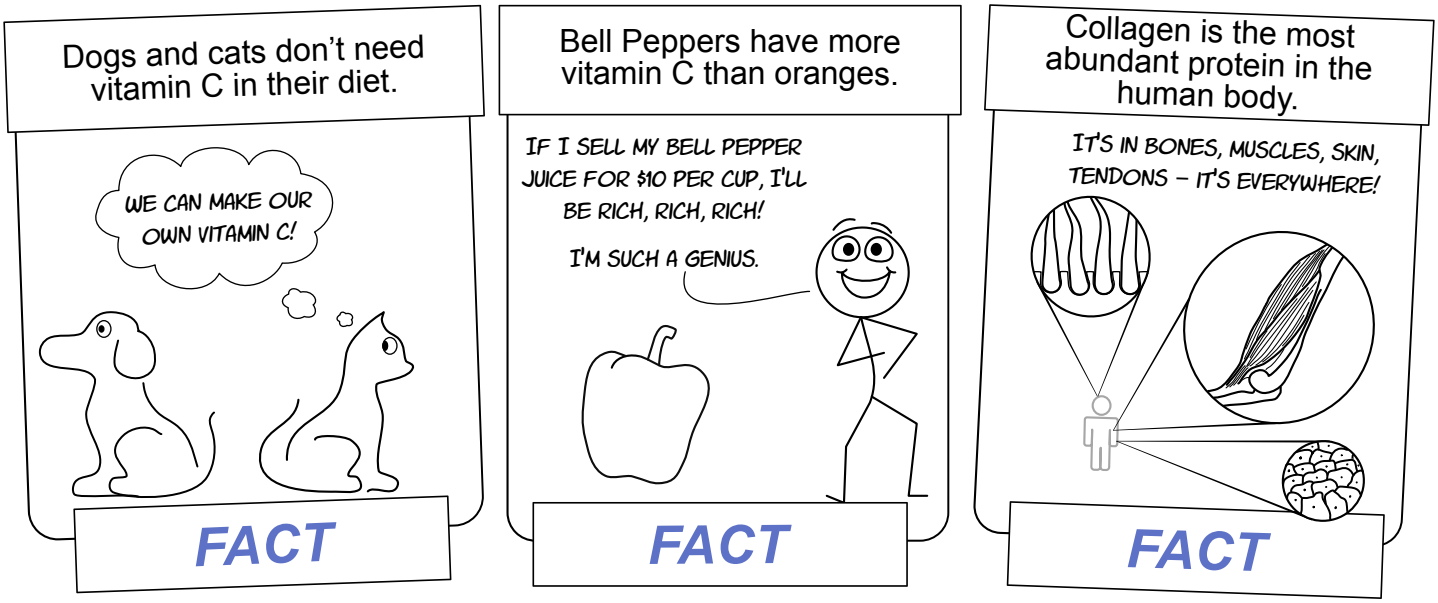


This example doesn't include a control group (people on regular sailor diet). But there should definitely be bonus points for including a control group in the experimental design!

Which of these facts describe vitamin C and which describe collagen? Match each with the correct molecule.



ARE THESE FACT OR FICTION? *Write your verdict below each statement:*



FILL IN THE BLANKS USING THESE WORDS:

cabbage trial lemons clinical scurvy oranges

The knowledge that scurvy could be cured by eating foods such as citrus, ***cabbage***, and leafy greens was discovered and forgotten multiple times. James Lind performed what is considered to be the first ***clinical trial*** when he treated a group of twelve soldiers for ***scurvy*** and observed that those who ate ***lemons*** and ***oranges*** recovered the fastest. Although Lind formed half-hearted conclusions and didn't realize the importance of his discovery, his approach of conducting a careful study to test if a treatment was effective was an essential step forward for scientific progress.

The Scientific Method in Medicine

How do you know if a medicine works to heal a disease? If someone sick with yellow fever eats pineapple and recovers three days later, did the pineapple cure them or would they have gotten better then anyway? With a sample size of one, there's often no way to know. We can learn much more by designing an experiment using the scientific method. Ideally, there should be:

- **A control group** that does not receive the treatment.
- **Similar conditions** between each of the groups being studied.
- **Randomized** group assignments to minimize bias or complicating factors.
- **A placebo**, a treatment that has no effect.
- **Double blind** conditions where the people administering the study do not know which of the participants are receiving the placebo and which are receiving the treatment being studied.

Why are these qualities an important part of discovering whether a treatment is effective? Write your answer for each in its corresponding box:

CONTROL GROUP

The control group provides someone to compare the outcomes against. The control group lets you compare whether the treatment is better than no treatment.

RANDOMIZED

If the test groups are not randomized, then they might be stacked in such a way that you can't draw any conclusions. If one group gets all the healthy people to start with, then that group will probably have more healthy people in the end whether the treatment is effective or not.

PLACEBO

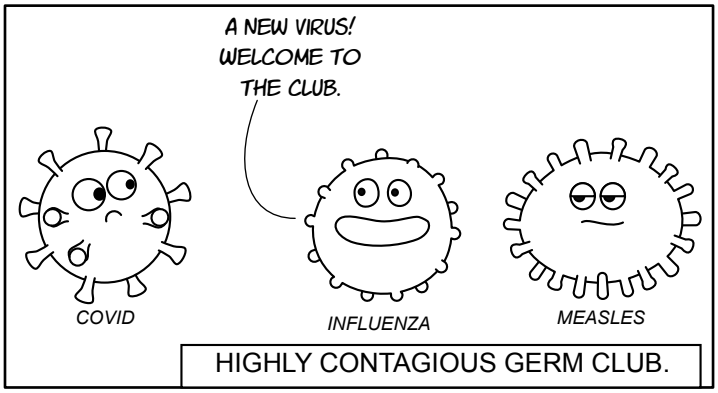
Usually, any treatment is better than no treatment because it influences a person's attitude and expectations, which then have a measurable effect on health. If a treatment doesn't outperform a placebo, then you can conclude it is not very effective.

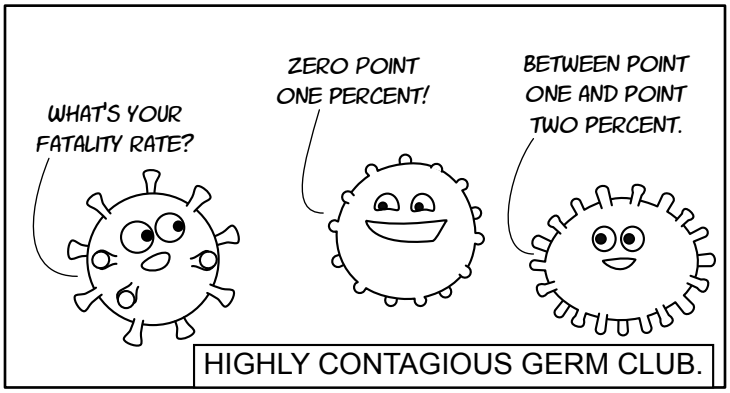
DOUBLE BLIND

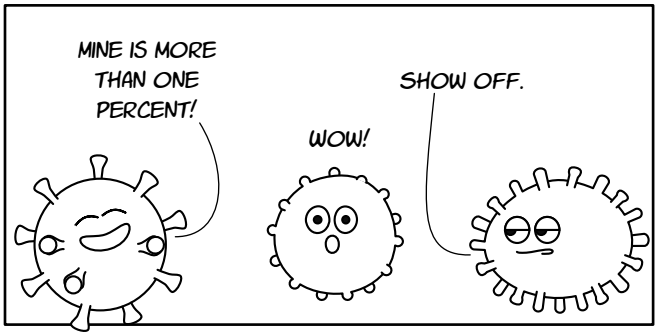
Whenever possible, the doctor should not know which patients are getting a placebo because the doctor might then unconsciously convey their expectations to the patients or they might interpret the outcomes in a way that agrees with their expectations. That can taint the results.

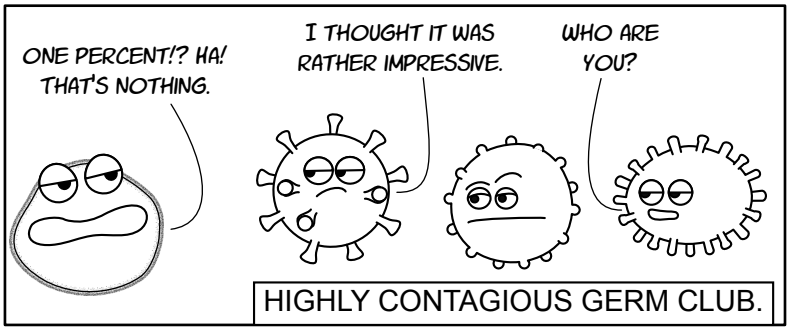
The highest possible standard of medical testing is a randomized, placebo controlled, double-blind clinical trial.

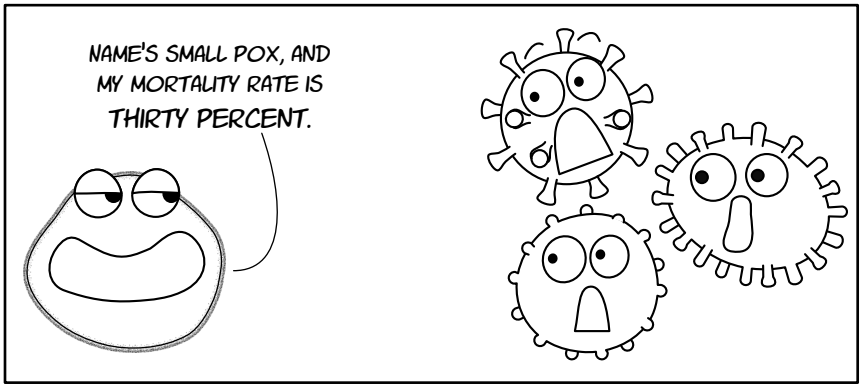
Small Pox & The Germ Club

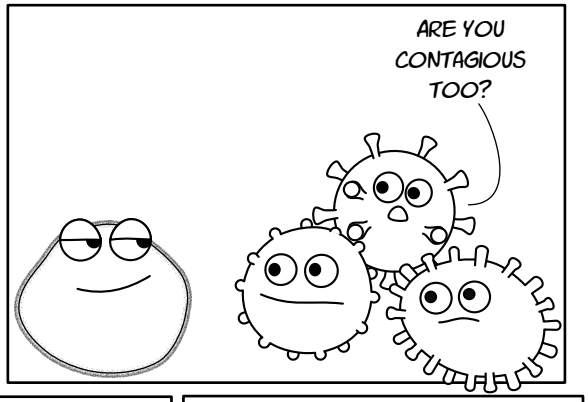


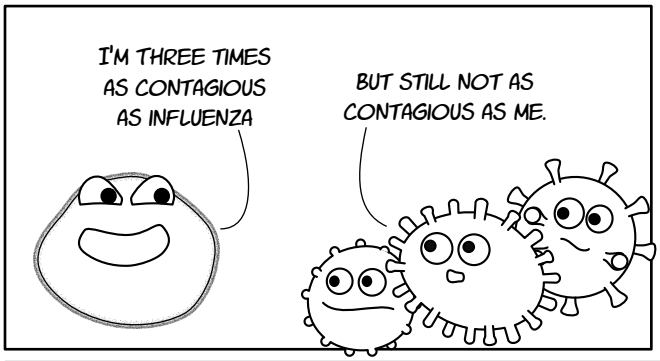


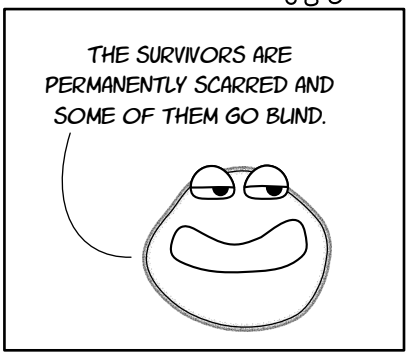


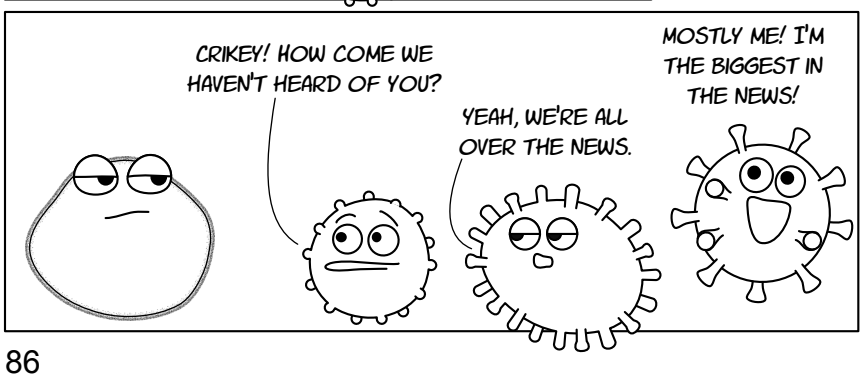


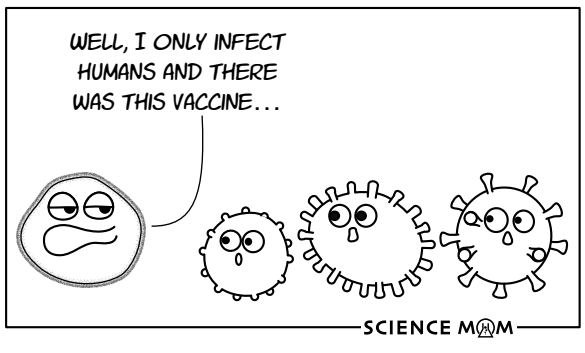






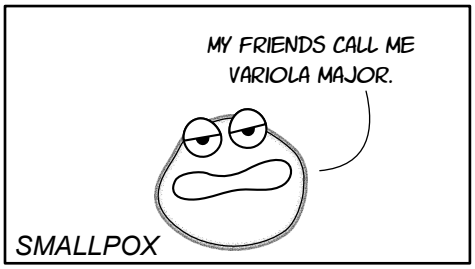


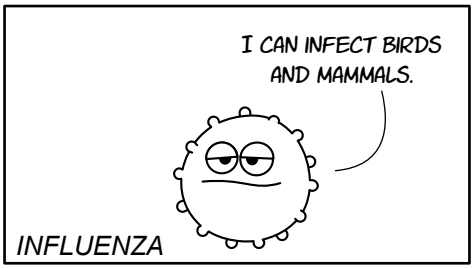


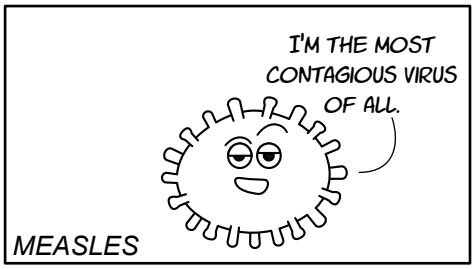


The Pox: A Fearsome Disease

WRITE DOWN THE MAIN CHARACTERISTICS OF EACH DISEASE:







HOW IT SPREADS: **Airborne or scab contact**

R_0:* **5-7**

MORTALITY: **30%**

SYMPTOMS: **Raised welts or scabs in mouth, throat, and all over skin, fever,**

**For more about R_0, see page 89.*

HOW IT SPREADS: **Airborne**

R_0: **1-2**

MORTALITY: **0.01%**

SYMPTOMS: **Fever, cough, sore throat**

HOW IT SPREADS: **Airborne, touching surface**

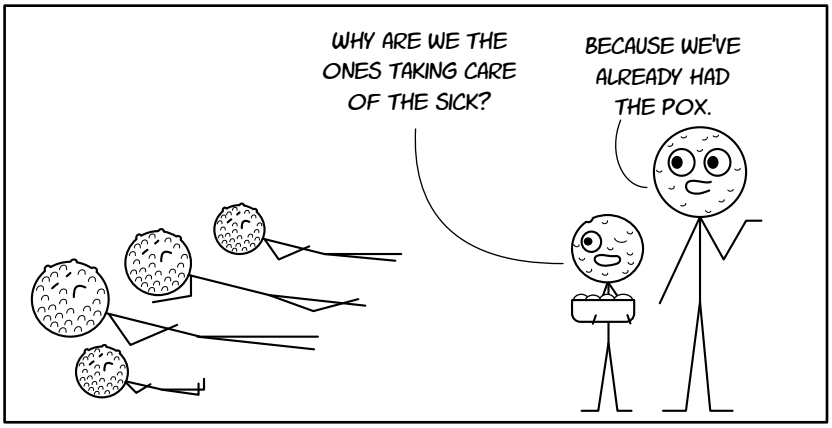
R_0: **12-18**

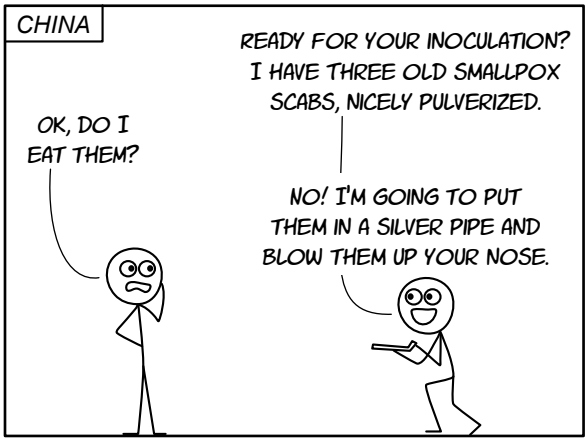
MORTALITY: **0.012%**

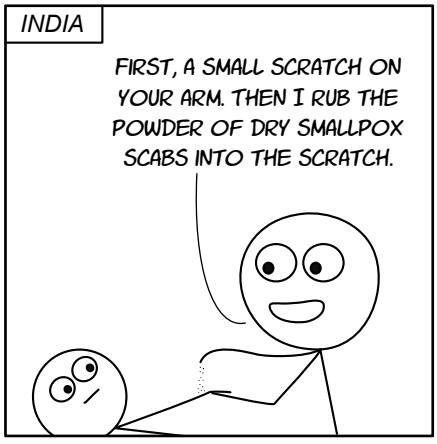
SYMPTOMS: **Aches, white dots or pustules on skin, sneezing, fever**

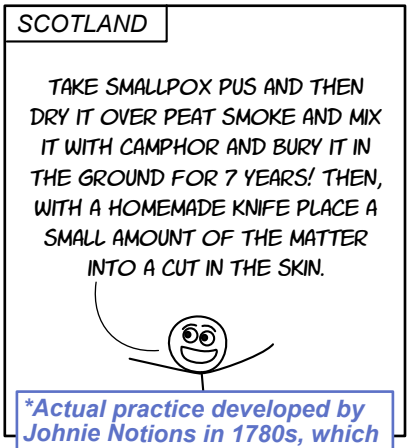
For thousands of years smallpox terrorized communities all around the world, killing 20 to 60% of the population each time it struck. Although the disease was brutal, there was one bright side: IF SOMEONE SURVIVED SMALLPOX, THEY NEVER GOT SICK FROM IT AGAIN.

This remarkable fact led to the invention of *variolation,* which was independently discovered and practiced for centuries in China, India, and Africa before being adopted in Europe and the Americas.









***Actual practice developed by Johnie Notions in 1780s, which was surprisingly effective.**

VARIATIONS IN VARIOLATION The approach varied from country to country, b[illegible] prevented a more serious illness. These [illegible]eadly as catching smallpox "naturally."

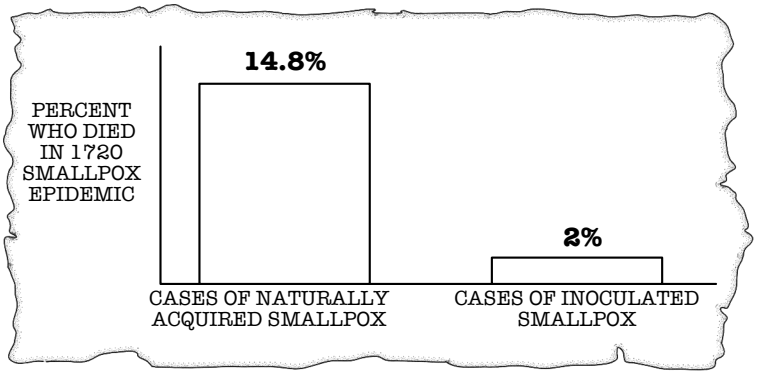
For further reading on different variolation techniques, see THE ORIGINS OF INOCULATION by Arther Boylston, published in the Journal of the Royal Society of Medicine. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3407399/

The 1721 Outbreak

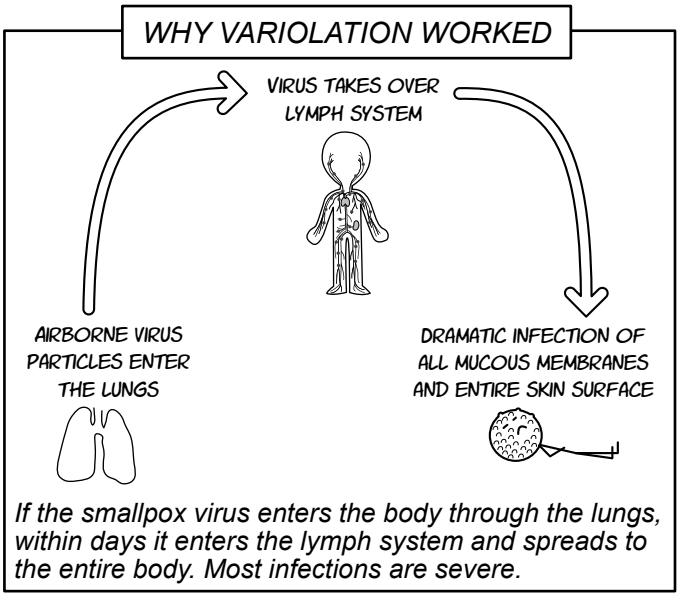
In the summer of 1721, a ship arrived at Boston with a sailor who had symptoms of smallpox. Despite the best efforts to quarantine, the disease began to spread. There had been a previous smallpox epidemic in 1703, but everyone under the age of 18 hadn't been around in 1703. They lacked immunity. A doctor named Cotton Mather who had heard about variolation started inoculating volunteers with dried pus from smallpox scabs.

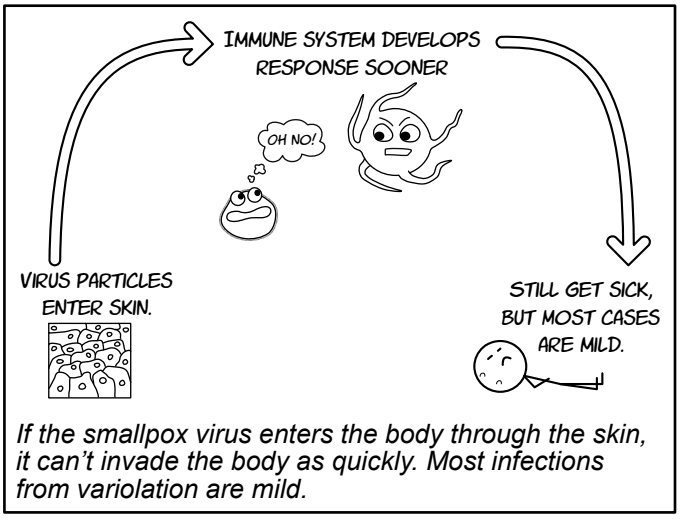
The variolation effort was extremely controversial. Some who were opposed said it would spread smallpox faster and cause the outbreak to become worse. Others thought it was morally wrong.

In November, someone opposed to the variolation effort threw a bomb into the home of Dr. Mather. Fortunately, it didn't go off. Mather later published data about the effect of variolation:

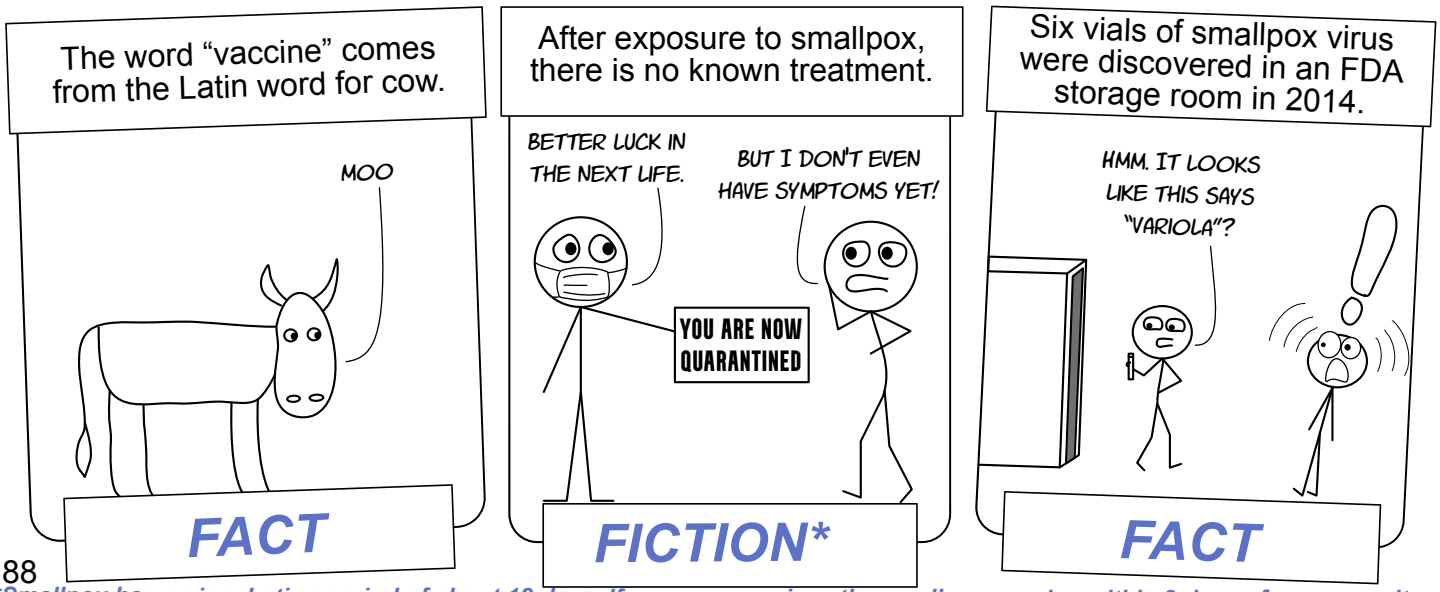


Mather's publication had a dramatic impact on the rate of variolation in both America and Europe. The increased inoculations resulted in fewer outbreaks of smallpox.



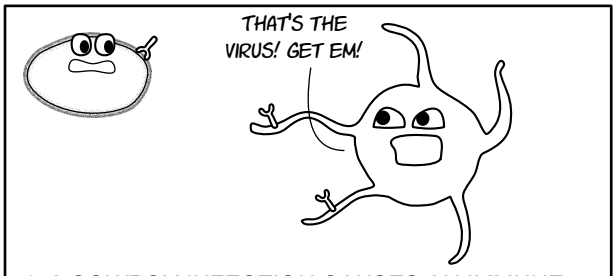


ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

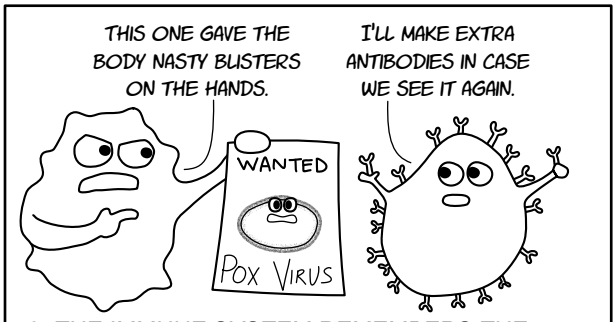


**Smallpox has an incubation period of about 12 days. If a person receives the smallpox vaccine within 2 days of exposure, it dramatically improves their chances of survival and may even prevent them from becoming symptomatic. When Janet Parker contracted smallpox in England in 1978, more than 500 people were vaccinated and quarantined, which prevented an outbreak.*

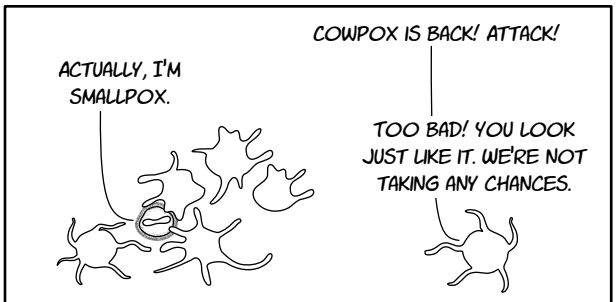
A pox on the pox



1. A COWPOX INFECTION CAUSES AN IMMUNE RESPONSE. THE BODY DEVELOPS ANTIBODIES.



2. THE IMMUNE SYSTEM REMEMBERS THE EXPERIENCE AND PREPARES TOOLS TO FIGHT BACK IN CASE IT MEETS COWPOX AGAIN.



3. THE ANTIBODIES AND "MEMORY" OF COWPOX ALSO PREVENTS INFECTION FROM SMALLPOX.

People who worked with cows and became sick with cowpox also never got sick with smallpox. In 1796, a doctor in England named Edward Jenner investigated this phenomenon with several unethical experiments. He took pus from the sore of a milk maid who had cow pox and inoculated a young boy with cowpox. Over the next few years he exposed the boy to smallpox multiple times. The boy never got sick.

Jenner called the cowpox inoculation a "vaccination" and it soon replaced variolations from smallpox scabs because it had a lower risk of death.

In the 1900s, scientists developed a safer version that used the vaccinia virus and started a global smallpox vaccination program. The disease did not go quietly. From 1900-1978, smallpox killed 300 MILLION people. Since 1978, there have been zero deaths.

The only smallpox viruses in the world today exist in laboratories in Atlanta, USA, and Novosibirsk, Russia.

How big is 300 million? Write down a country (or select a combination of countries) that has 300,000,000 people:

91% of the population of the United States

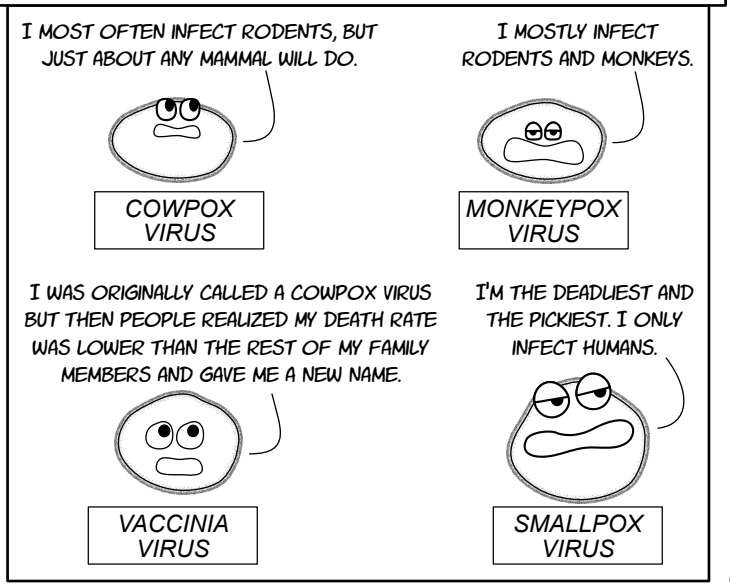
The combined populations of the UK, Ireland, France, Spain, Germany, Switzerland, Denmark, Sweden, Finland, and Norway.

The population of Brazil, Colombia, and most of Argentina.

20% of the population of China

Your notes:

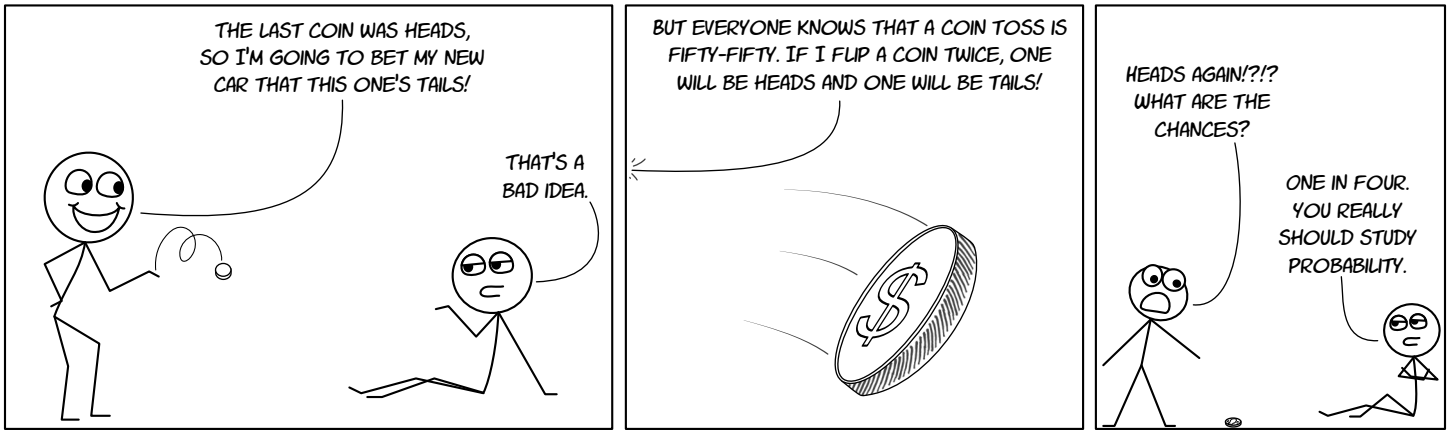
POXVIRUSES: viruses so similar that exposure to one gives you immunity to the entire family (for a while)



Understanding Risks

To understand diseases and their treatments, it's important to be able to understand and compare risks. If a coin is tossed in the air, there is a 50% chance of it landing with the face showing (heads) and a 50% chance of it landing with the other side showing (tails).

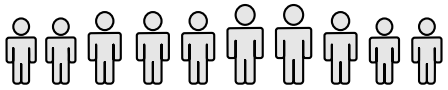
Although the chances of each outcome are 50/50, if you flip a coin ten times you will not necessarily get 5 heads and 5 tails! You could get 4 heads and 6 tails, or 8 heads and 2 tails, or even ten heads or ten tails. But if you spend a few hours flipping coins and tabulating the results, *on average,* half of the flips will result in heads and half of the flips will result in tails.



The average mortality rate from a smallpox epidemic was 30%. But it varied dramatically depending on the age of the population, how many in the population has previously had smallpox, whether there had been variolation or vaccinations, and how effective the quarantines were. Then, for the individuals infected, the initial viral load, strength of their immune system, whether they had someone take care of them while they were sick, and dozens of other factors all came together to influence the outcome.

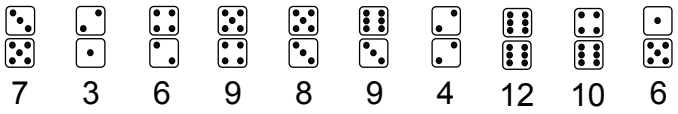
Keeping all of this in mind, it is still a useful exercise to use dice to compare the average outcomes for the various approaches to smallpox. Find two dice and then roll them to predict the outcomes for a group of ten people. Read the example below and then roll your own dice and fill in the scenarios on the following page.

1 Smallpox outbreak

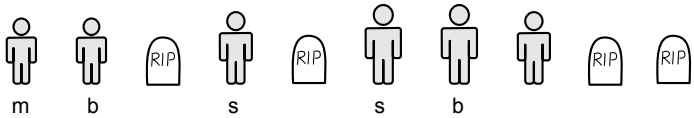


# rolled:	Smallpox outbreak outcome:
2,12	Healthy. Not exposed during outbreak
3,4,11	Survived but now blind
6,8,10	Died
5,7	Survived with moderate scarring
9	Survived with severe scarring

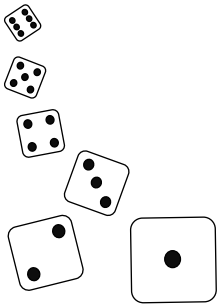
If you rolled the following numbers:



Then the outcome for group 1 would be:



4 dead, 2 blind, 2 severely scarred, 1 moderately scarred, and 1 healthy.



On page 91 where the instructions say "Two 2s in a row," that means the first 2 is treated as an even number. Only a second 2 produces the "two 2s in a row" effect. A sequence of five 2s would produce the following:

Smallpox Scenarios

Roll a pair of dice ten times for each group to show probable outcomes for each scenario.
Did you see more or less variation between the groups than you expected?

Answers can vary considerably but should show a dramatic difference in severe outcomes with Smallpox being most severe and Vaccinia being least.

1 Smallpox outbreak

SMALLPOX CAUSED BY VARIOLA MAJOR HAD A MORTALITY RATE BETWEEN 20-60%, BUT WAS AS HIGH AS 90% FOR INFANTS.

# rolled:	Smallpox outbreak outcome:
2,12	Healthy. Not exposed during outbreak
3,4,11	Survived but now blind
6,8,10	Died
5,7	Survived with moderate scarring
9	Survived with severe scarring

Group 1 ***2 dead, 2 blind, 1 severely scarred, 4 moderately scarred, and 1 healthy.***	Group 2 ***5 dead, 2 blind, 1 severely scarred, 1 moderately scarred, and 1 healthy.***
Group 3 ***2 dead, 2 blind, 1 severely scarred, 5 moderately scarred, and 0 healthy.***	Group 4 ***5 dead, 2 blind, 3 severely scarred, 0 moderately scarred, and 0 healthy.***

Smallpox total for 40 people: 14 dead, 8 blind, 6 severely scarred, 10 moderately scarred, and 2 healthy.

2 Cowpox inoculation

ALTHOUGH THIS WAS MUCH SAFER, SOME RIDICULED THE IDEA AND SAID PEOPLE WOULD TURN INTO COWS IF THEY EXPOSED THEMSELVES TO COWPOX.

# rolled:	Cowpox inoculation outcome:
Roll 9, then roll a 10	Died
Even number	Mild symptoms of cowpox, now immune from smallpox
Odd number	Moderate to severely sick with cowpox but recovered, now immune from smallpox

Group 1 ***0 dead, 3 moderate symptoms, 7 with mild symptoms***	Group 2 ***0 dead, 5 moderate symptoms, 5 with mild symptoms***
Group 3 ***0 dead, 8 moderate symptoms, 2 with mild symptoms***	Group 4 ***0 dead, 0 moderate symptoms, 10 with mild symptoms***

Cowpox inoculation total for 40 people: 0 dead, 16 with moderate symptoms and 24 with mild symptoms.

****Note: I tried rolling dice until I came up with a 9 that was immediately followed by a 10 and it took me 45 rolls the first time I tried, 20 rolls the second time, 59 the third and 155 times on the fourth try. On average, the chance of rolling a 9 and then a 10 is 1 out of 108 rolls, which is similar to the estimated 1% death rate from cowpox inoculation.***

3

THE VACCINIA VIRUS IS SIMILAR TO COWPOX BUT HAS A LOWER DEATH RATE. BECAUSE IT IS A LIVE VIRUS (NOT PIECES OF A VIRUS) PEOPLE WERE CONTAGIOUS FOR A WHILE AFTER GETTING IT.

# rolled:	Vaccinia vaccine outcome:
Four 2s in a row	Died
Two 2s in a row	Allergic reaction or other adverse reaction
Even number	Mild symptoms (sore arm some fatigue), now immune from smallpox
Odd number	Moderate symptoms (very sore arm, fever, fatigue), now immune from smallpox

Group 1 ***0 dead, 5 moderate symptoms, 5 with mild symptoms***	Group 2 ***0 dead, 8 moderate symptoms, 2 with mild symptoms***
Group 3 ***0 dead, 1 moderate symptoms, 9 with mild symptoms***	Group 4 ***0 dead, 6 moderate symptoms, 4 with mild symptoms***

Vaccinia inoculation total: 0 dead, 20 moderate symptoms, 24 mild.

****Deaths from vaccinia virus (the smallpox vaccine) are very rare, occurring between 0.25 to 1 out of every MILLION vaccinations. This does not mean the deaths are inconsequential. If a population of 8 billion were vaccinated for smallpox, up to 8,000 people could die as a result of the vaccine. But if there were a global outbreak of smallpox, the virus would be expected to kill over TWO BILLION people and the catastrophe of those deaths would cause further death as supply chains, healthcare, and food distribution collapsed. Many countries maintain vaccinia vaccines so they could be used in the event of a smallpox outbreak.***

The Problem of Polio

Humans have practiced different traditions of inoculating against smallpox for thousands of years. Given how deadly smallpox is, few would argue that it would be best for that disease to take its "natural course" and kill between 20-80% of the population with each outbreak.

Most infectious diseases have much lower mortality rates than smallpox. Let's consider polio, a disease caused by a poliovirus that only infects human beings. Use two dice to roll outcomes for four groups of ten people:

4 Polio Outbreak

95-99% of infected people have *NO symptoms*. They feel completely healthy and do not know that they are spreading the virus to other people.

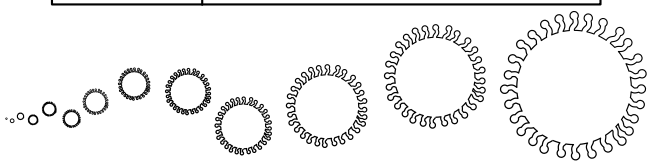
4-5% have minor symptoms of fever, headache, nausea, vomiting, and muscle weakness.

1-2% develop severe muscle pain and stiffness in the neck and back, but make a full recovery.

Less than 1% are paralyzed.

# rolled:	Polio outbreak outcome:
Roll a 7 three times in a row	Mild symptoms
3 doubles in a row	Paralyzed with permanent nerve damage.
5 doubles in a row	Severely paralyzed. Need to be inside an iron lung in order to breathe.
All other rolls	No symptoms

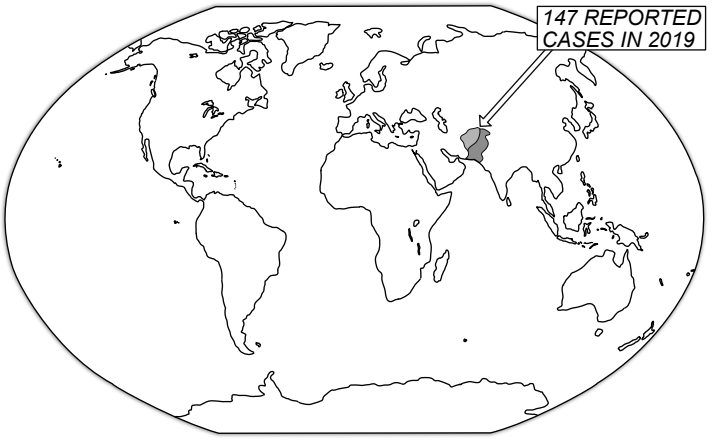
10 with no symptoms	*10 with no symptoms*
9 no symptoms, 1 paralyzed	*10 with no symptoms*



Less than 1 percent is a small number, but polio is highly contagious. Infected individuals who have symptoms will actively spread the virus for 7-10 days *before they have symptoms* and then for up to 6 weeks afterward.

A disease as contagious as polio can easily infect the majority of a population. On average, 1 out of every 200 people exposed to polio will have permanent paralysis (usually in the legs, but sometimes in most of the body) and roughly 1 in 2,000 will die. Using those probabilities, answer question one:

In the 1952 outbreak in the United States, 57,628 cases of polio were reported. Of those that became ill, 3,145 died and 21,269 were paralyzed.



In 2019, Afghanistan and Pakistan are the only two countries where cases of polio occurred.

① If a polio outbreak occurred in a country of 400 million people who had no immunity to the disease, and every person was exposed to the virus, how many people would be expected to become paralyzed for life? How many would be expected to die from the outbreak?

2 million would be paralyzed for life, and 200,000 would die. (Divide 400 million by 200 and 2,000 to get those numbers.)

② If 400 million people with no exposure to polio were vaccinated against the disease and there was a 1 in a 1,000,000 risk of complications from the vaccine, how many would be expected to experience complications? If 50% of those with a severe complication died, how many would be expected to die as a result of the vaccination program?

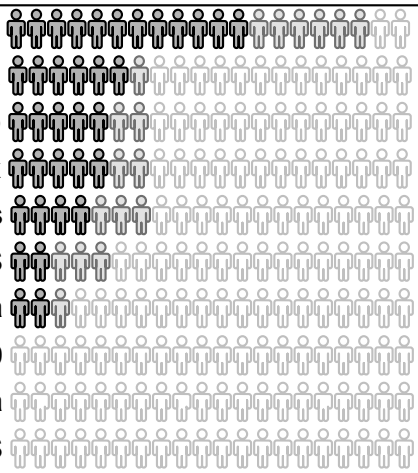
400 would experience complications while 200 would die. (Divide 400 million by 1 million and then divide the result in half.)

Elementary Epidemiology

Epidemiology is the study of what affects the health of a population, especially how diseases behave. To understand public health it's important to be familiar with the following terms and ideas:

R_0 Basic Reproduction Number

EXPECTED NUMBER OF PEOPLE A DISEASE WILL INFECT



Measles	12 - 18
Rubella	6-7
Polio	5-7
Smallpox	5-7
Mumps	4-7
SARS	4-7
1918 Influenza	2-3
COVID-19	2 - 2.5
Ebola	1.5 - 2.4
MERS	0.3 - 0.8

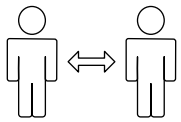
Use these numbers to fill in the last three diseases in the graphic.

THE BASIC REPRODUCTION NUMBER IS ALSO CALLED "R ZERO" OR "R NAUGHT." IT IS THE EXPECTED NUMBER OF PEOPLE THAT ONE PERSON WOULD INFECT IF THE POPULATION HAD NO IMMUNITY TO THE DISEASE. IF R_0 IS GREATER THAN 1, THEN THE DISEASE WILL SPREAD IN THE POPULATION. IF THE R_0 IS LESS THAN 1, THE DISEASE WILL NOT SPREAD.

THE HIGHER THE R_0, THE MORE CONTAGIOUS THE DISEASE.

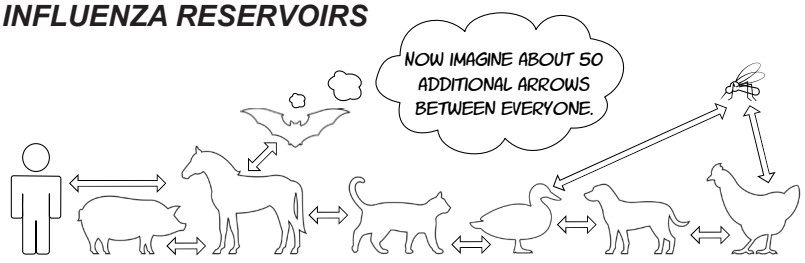
Natural Reservoir or Disease Reservoir

MEASLES RESERVOIR



Only infects humans

INFLUENZA RESERVOIRS



Infects multiple species (zoonotic)

A RESERVOIR IS THE SPECIFIC PLACE WHERE A PATHOGEN NATURALLY LIVES AND REPRODUCES. SOME DISEASES HAVE MULTIPLE SPECIES OF ANIMALS THAT SERVE AS HOSTS OR RESERVOIRS. OTHER PATHOGENS, LIKE CHOLERA AND GIARDIA, CAN BE FREE-LIVING IN WATER SOURCES LIKE RIVERS.

IN GENERAL, PATHOGENS WITH MULTIPLE RESERVOIRS ARE MORE DIFFICULT TO CONTROL OR ERADICATE.

USE THE ABOVE INFORMATION ABOUT R_0 AND RESERVOIRS TO COMPLETE THE FOLLOWING SENTENCES:

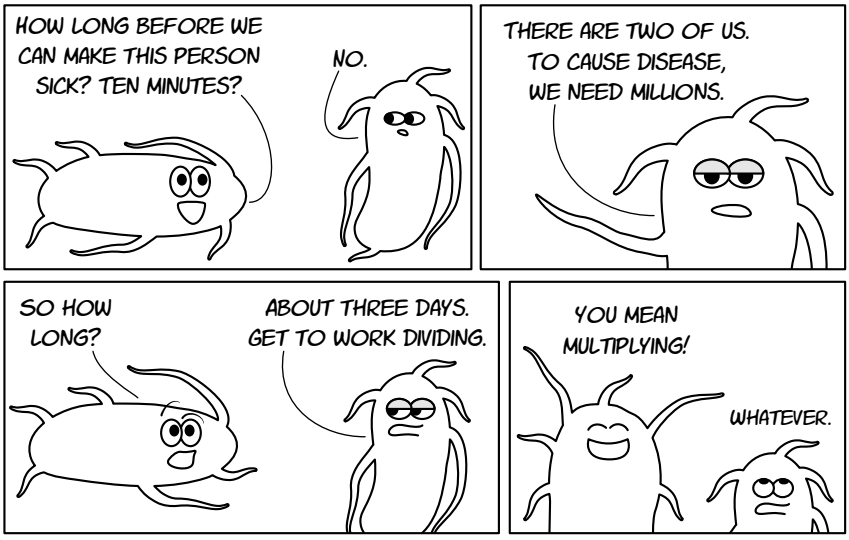
The disease of ***measles*** is more than twice as contagious as polio.

A carrier or vector can transmit a disease from one ***reservoir*** to another.

WHY ARE DISEASES WITH MORE RESERVOIRS HARDER TO CONTAIN?

There are more species that can transmit the disease which makes contact tracing and quarantining more difficult or impossible.

Incubation Period



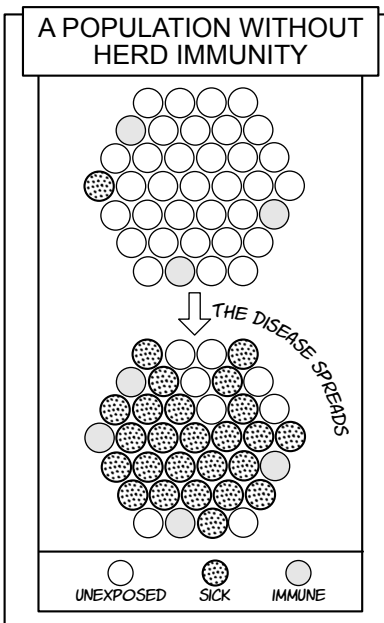
THE INCUBATION PERIOD IS THE AMOUNT OF TIME BETWEEN EXPOSURE AND THE FIRST SYMPTOMS OF ILLNESS. SOME BACTERIA THAT CAUSE FOOD POISONING HAVE AN INCUBATION PERIOD OF JUST A FEW HOURS. THE RABIES VIRUS HAS A LONG INCUBATION PERIOD THAT CAN BE BETWEEN 2 TO 12 MONTHS!

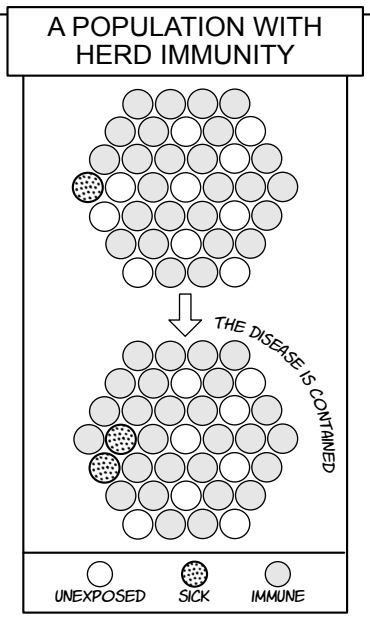
MOST VIRUSES HAVE INCUBATION PERIODS BETWEEN 2 TO 14 DAYS. THE AMOUNT OF PATHOGEN (OR VIRAL LOAD) IN THE INITIAL EXPOSURE HAS A BIG EFFECT ON THE INCUBATION PERIOD.

Herd Immunity

A PATHOGEN NEEDS TO LIVE INSIDE ITS HOST OR NATURAL RESERVOIR. WHEN A HEALTHY IMMUNE SYSTEM DEVELOPS AN EFFECTIVE IMMUNE RESPONSE, IT GETS RID OF THE PATHOGEN. THE VIRUS OR BACTERIA CAN ONLY CONTINUE TO CAUSE DISEASE IF IT TRANSFERS TO A NEW RESERVOIR OR HOST.

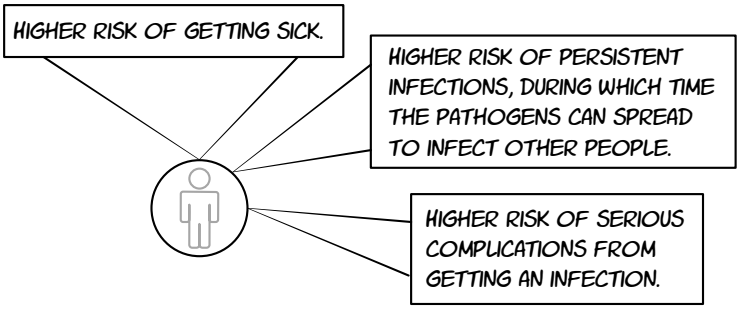
WHEN A HIGH ENOUGH PERCENTAGE OF THE POPULATION HAS IMMUNITY TO A DISEASE, THEN THE PATHOGEN CANNOT EFFECTIVELY TRANSFER THROUGH THE POPULATION. THIS IS CALLED HERD IMMUNITY. THE HIGHER THE PROPORTION OF IMMUNE INDIVIDUALS, THE SMALLER THE CHANCE OF THE DISEASE FINDING NEW HOSTS TO INFECT.





Immunocompromised

Some people are at greater risk from pathogens because their immune system cannot effectively respond to infections. This is known as being immunocompromised. It can be caused by disease, malnutrition, genetic disorders, or certain medicines like those that treat cancer or support an organ transplant.



THE VARICELLA VIRUS, WHICH CAUSES CHICKENPOX, HAS THE ABILITY TO HIDE. A PERSON WHO HAD CHICKENPOX AS A CHILD STILL HAS THE VIRUS INSIDE THEM, EVEN THOUGH IT ISN'T CAUSING ANY SYMPTOMS. IF THEIR IMMUNE SYSTEM IS COMPROMISED, THE VIRUS WILL RE-EMERGE AND CAUSE SHINGLES. IT CAN THEN SPREAD AND CAUSE CHICKENPOX IN OTHER PEOPLE.

IN A LARGE POPULATION OF PEOPLE, OTHER VIRUSES ARE ABLE TO "HIDE" BY INFECTING PEOPLE WHO ARE IMMUNOCOMPROMISED. WHEN THE IMMUNE SYSTEM IS WEAKENED BY ILLNESS OR OTHER FACTORS, IT IS UNABLE TO ERADICATE DISEASES.

THOUGHT EXPERIMENT ONE: Working together, the entire human race decides that they will end the influenza virus through voluntary self-isolation. Every human being in the entire world will self-isolate for 3 weeks. They will each stay inside a room with plenty of food and water (and a bathroom) and will have no direct contact with any other person. Obviously, the logistics of such a plan could never work, but – *assuming that it did work* – what would happen? Could this approach eradicate influenza? Could it eradicate the measles? Why or why not?

Because the measles is a virus that ONLY infects human beings, this approach could eradicate measles IF measures had been taken first to be sure that all immunocompromised people were safe from the virus.

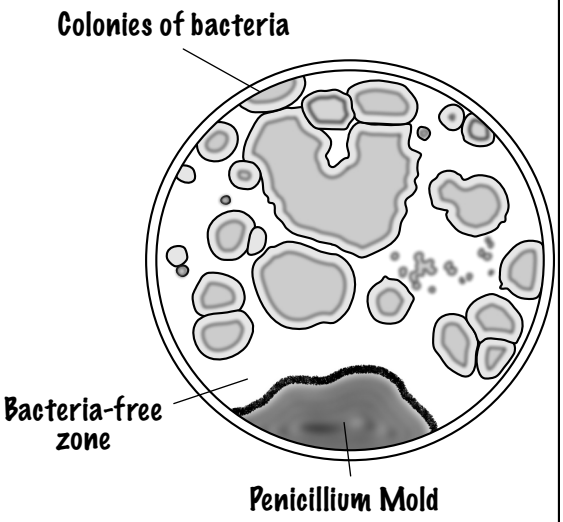
This approach would not work for influenza because the virus also infects wild birds, bats, and a variety of other animals including pigs and horses. While human beings were quarantining and their immune systems were overcoming the virus, influenza could easily be replicating in a herd of pigs or a flock of birds. Then when a person came into contact with those animals (or a vector such as a mosquito carried it from them to a person), the virus could easily spread through the human population again.

THOUGHT EXPERIMENT TWO: Smallpox is back. Every person on the planet has been exposed and the now much smaller human population forms two countries named A and B. Leader A declares that because every person in their country is a smallpox survivor, they have herd immunity and have overcome the disease. Normal life will resume and they will have no further outbreaks. Leader B declares that every effort will be put toward a country-wide vaccination program using the cowpox or varicella virus because this is the only way to eradicate the disease. The two countries will have no physical contact with each other for the next 200 years. Which is expected to happen if each country follows their leader's advice?

Country A will have few to no smallpox outbreaks for several years after every person is exposed. But soon someone who was born after the "apoxalypse" will pull an old blanket out of a chest or clean out a closet where dirty bedding had been stored. These chance encounters with the virus (which can last for decades outside of a host) will cause outbreaks where smallpox infects most people young enough to have been born without immunity. Without any effort at variolation or vaccination, smallpox will regularly kill between 20 to 80% of each rising generation. Outbreaks will become a regular part of life as each new generation pays the price to obtain herd immunity.

Country B could eliminate smallpox with a combination of contact tracing, vaccination, and careful quarantine or destruction of any materials that came into contact with smallpox pus or scabs.

The Discovery of Penicillin



Drawing of petri dish with penicillin mold growing and ring of bacteria-free space around it.

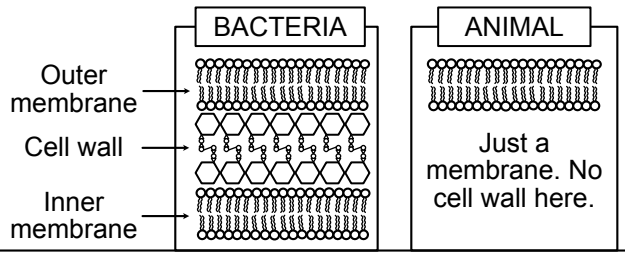
FILL IN THE BLANKS USING THESE WORDS:

secreting	mold	penicillin
mechanism	treatment	petri

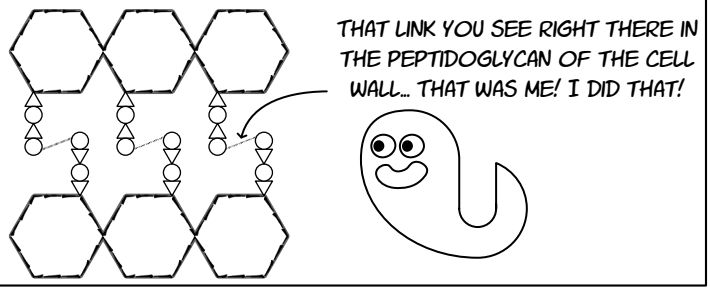
In 1928, Dr. Alexander Flemming returned from a two-week vacation and saw a ***petri*** dish that had accidentally been left out of an incubator. Some ***mold*** had contaminated the dish of Staphylococcus bacteria, and the mold was surrounded by a zone of bacteria-free gel. Flemming's investigation showed that the mold was ***secreting*** a substance that inhibited the growth of staph bacteria. This substance was ***penicillin***. Later scientists were able to discover the ***mechanism*** by which penicillin functioned and find different types of mold that could produce enough penicillin to create a viable ***treatment*** for bacterial infections.

Attack the Cell Wall – how penicillin works

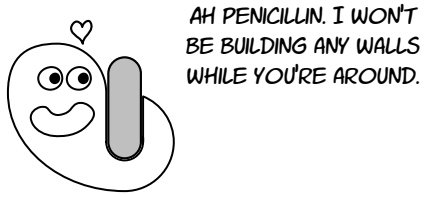
Bacteria have a cell wall. Animal cells do not. Below, we can see the outer cover of the cells.



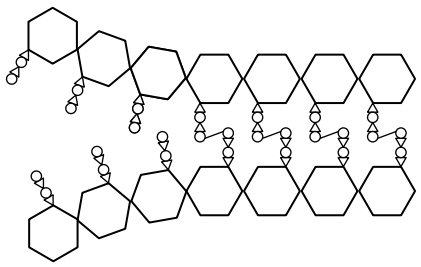
One of the most important steps in making the cell wall is done by an enzyme called transpeptidase.



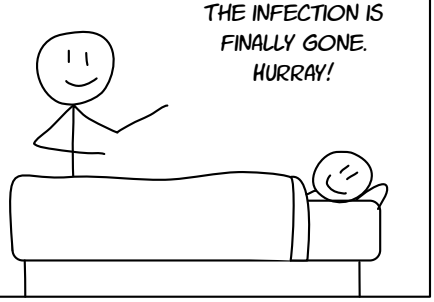
Penicillin is a small molecule that blocks the enzyme transpeptidase.



Without transpeptidase, the bacterium can't grow or reproduce.



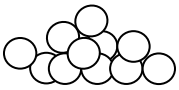
The cell dies.



*Which of these cells or microbes would be harmed by penicillin and which would not? Draw lines to the likely outcome for each.**

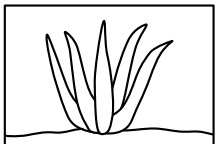
Borrelia burgdorferi
A bacteria with a cell wall made of peptidoglycan

Ebola Virus
RNA surrounded by membrane that was stolen from host cell. Studded with glycoproteins.

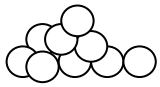


Staphylococcus
A bacteria with a cell wall made of peptidoglycan.

Entamoeba hystolytica
A eukaryotic cell that has no cell wall.



Aloe Vera
A plant with cell walls made of cellulose.



Staphylococcus
Same bacteria as before, but this one has an enzyme that can digest penicillin.

Penicillin damages the cell and/or stops the infection.

Penicillin has no effect on the cell and/or does not stop the infection.

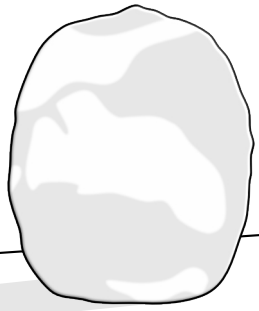
**An important disclaimer that in real life, medicine and treatments can be quite complex. This exercise is not intended to prescribe or recommend treatment. See a doctor if you are sick.*

What happens to your microbiome when you take an antibiotic?

The antibiotic kills many of the beneficial bacteria in your gut that help with digestion. This is why diarrhea and nausea are a common side-effect of antibiotics, and why many doctors recommend taking a probiotic or eating foods like yogurt, kimchi, or kombacha while on an antibiotic. The lack of a healthy microbiome can make a person more susceptible to fungal infections.

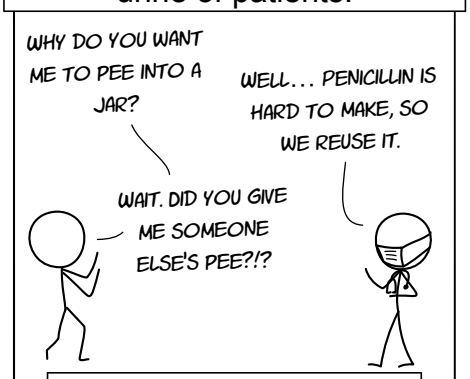
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

The best strain of penicillin came from a moldy cantaloupe.



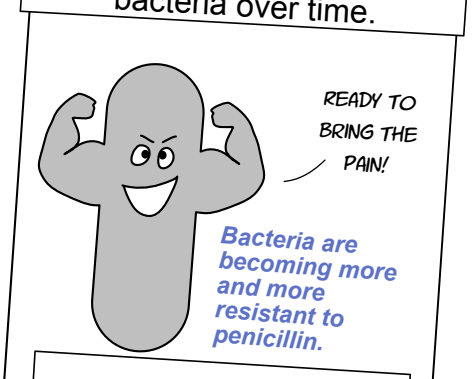
FACT

To get enough penicillin, doctors used to collect the urine of patients.



FACT*

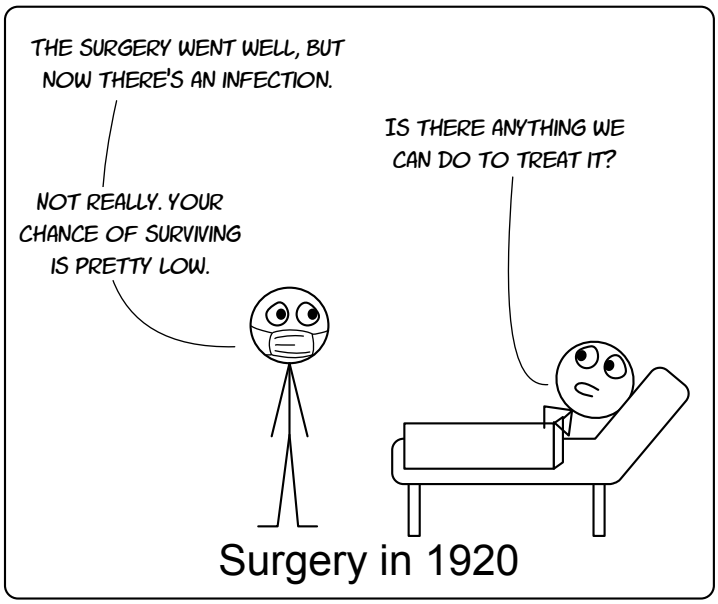
Penicillin is becoming even more effective against bacteria over time.

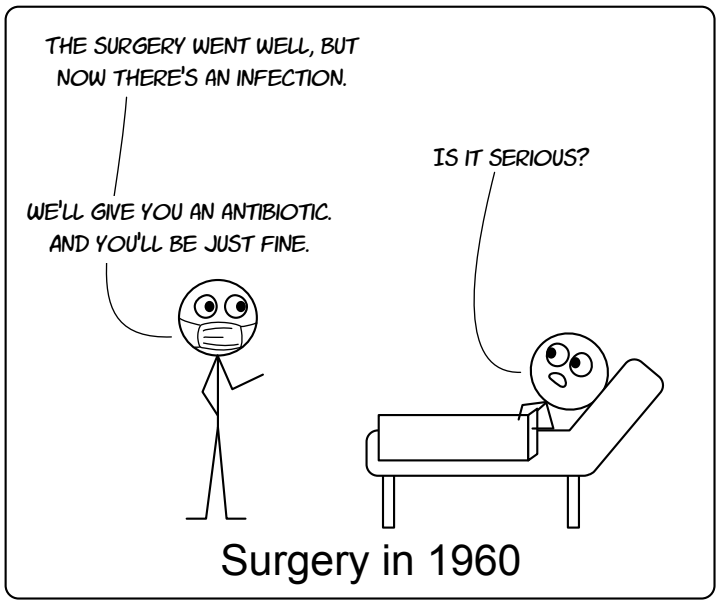


FICTION

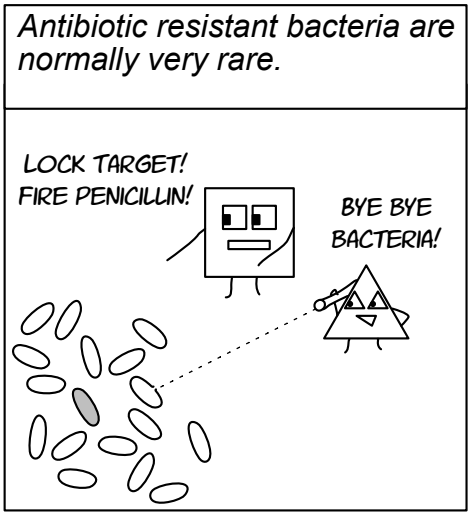
This is not done any more because we have cheap and efficient ways to produce penicillin. But initially, it was very hard to make. Since most of the antibiotic was excreted in the urine within an hour or two of taking it, scientists used to extract it from urine in order to reuse it. See https://www.smithsonianmag.com/smart-news/we-used-recycle-drugs-patients-urine-180953789/

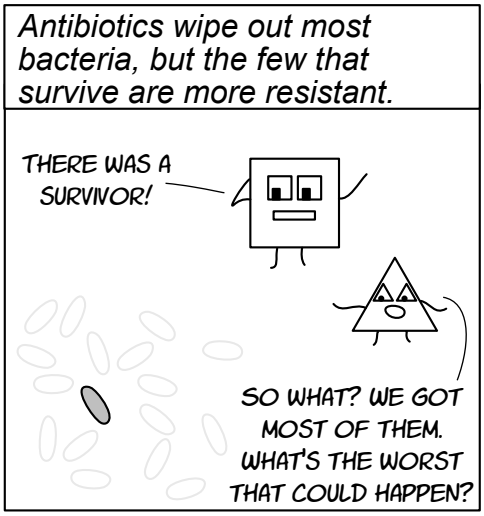
Antibiotics Fight Bacterial Infections

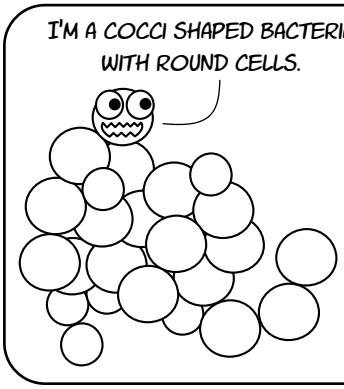




Antibiotics revolutionized the treatment of infectious diseases. At the turn of the 20th century, before antibiotics, the average life expectancy in the US was around 47 years. After antibiotics had become widely available, the average life expectancy was 68 – a jump of over twenty years! Before antibiotics, tuberculosis, gastroenteritis, and syphilis were among the leading causes of death. Today those ailments are treated effectively with antibiotics. Things like stepping on a nail, animal bites, or drinking bad water could readily kill a person before the age of antibiotics. It's essential to use antibiotics carefully, so bacteria don't become resistant. This way we will continue to have effective tools for fighting infections.







MRSA stands for **M**ethicillin-**R**esistant **S**taphylococcus **A**ureus, a type of staph bacteria that has developed a strong resistance to several antibiotics. Typically, MRSA causes unpleasant skin infections. However, in vulnerable populations such as people who are in nursing homes or hospitals, MRSA can cause deadly bloodstream infections and pneumonia. In 2017, 20,000 people died from MRSA.

The best way to avoid MRSA is through frequent hand washing with soap and covering wounds in clean, dry bandages.

MRSA - a dangerous superbug

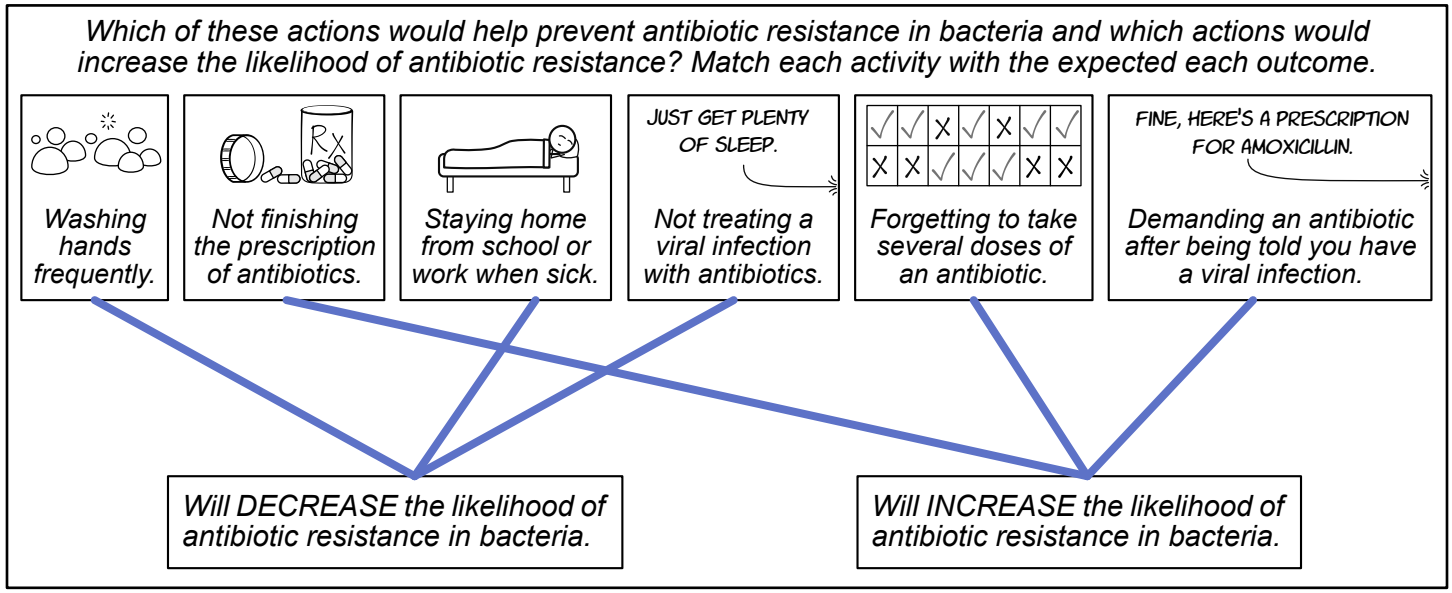
FILL IN THE BLANKS USING THESE WORDS:

antibacterial	bind	inactivates
proteins	resisting	methicillin

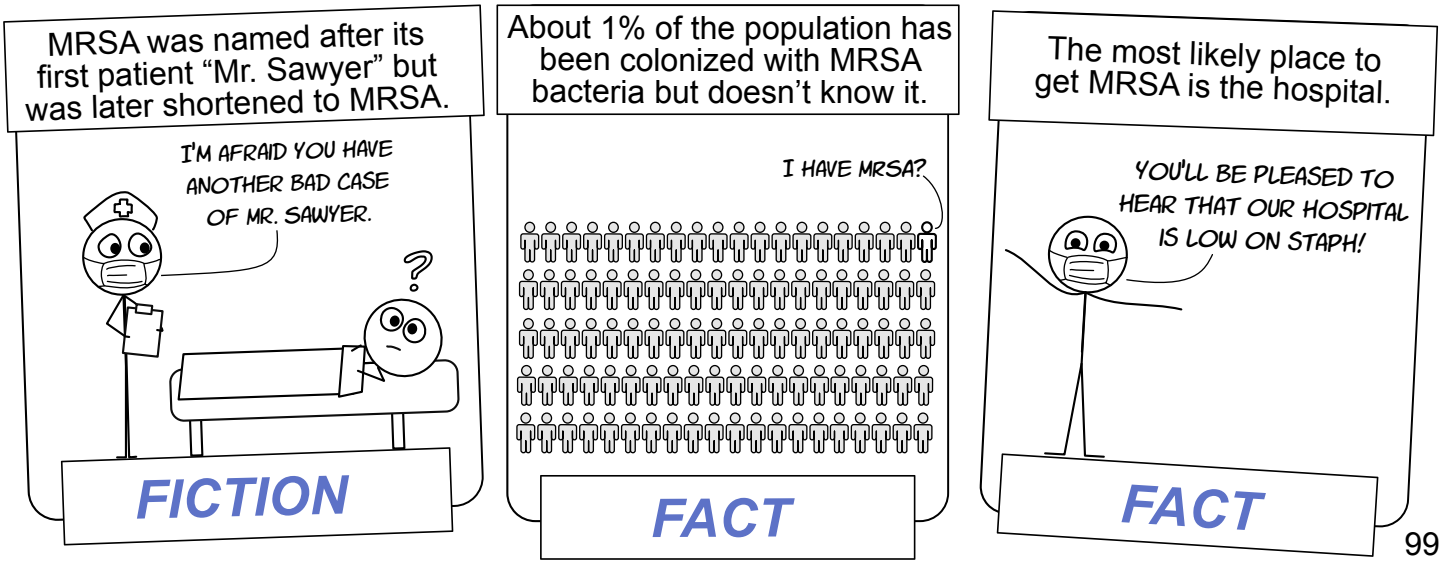
Staphylococcus (staph) is a common bacteria present on many healthy people. MRSA is a strain of staph that has developed a number of methods for ***resisting*** antibiotics like penicillin and ***methicillin***. These bacteria secrete an enzyme that ***inactivates*** the antibiotic. They also have different ***proteins*** in their cell walls that don't ***bind*** to the antibiotic.

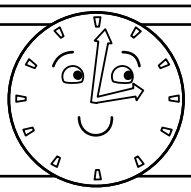
Scientists are in a virtual arms race to come up with new ***antibacterial*** agents before our current antibiotics are no longer effective. But how do bacteria develop resistance to antibiotics? They evolve, which is something we'll learn more about in our next biology class.

Which of these actions would help prevent antibiotic resistance in bacteria and which actions would increase the likelihood of antibiotic resistance? Match each activity with the expected each outcome.



ARE THESE FACT OR FICTION? *Write your verdict below each statement:*





Quiz Time!

CREATE YOUR OWN QUIZ TO REVIEW WHAT YOU LEARNED ABOUT MICROBIOLOGY!

On a separate piece of paper, create a quiz for the microbiology section of the course by writing twenty questions. Consider what some of the most important ideas and concepts are, and invent some essay, multiple choice, and fill-in-the-blank questions that will demonstrate whether someone understands those ideas.

Next, create an answer key for your quiz and then find a family member or friend who is willing to test their skills against the challenging test you just created!

As a bonus activity, create a quiz for the entire course.

Appendix

Suggested Microbe List

A small selection of microbes and the disease(s) they cause

VIRUSES:	***ILLNESS:***
Severe acute respiratory syndrome coronavirus 2	*COVID-19*
Human alphaherpes 3 or varicella-zoster virus	*Chickenpox and shingles*
Human immunodeficiency virus or HIV	*Acquired immunodeficiency syndrome or AIDS*
Mumps orthorubulavirus or MuV	*Mumps*
Zaire ebolavirus or EBOV	*Ebola*
Hepatitis B virus or HBV	*Hepatitis*
Measles morbillivirus	*Measles*
Influenza A, B, or C	*Influenza or the flu*
Rabies lyssavirus	*Rabies*
Dengue virus	*Breakbone fever or Dengue fever*
Variola major	*Smallpox*
Zika virus	*Zika*
Poliovirus	*Polio*
Norovirus	*Stomach bug or 24-hr flu*

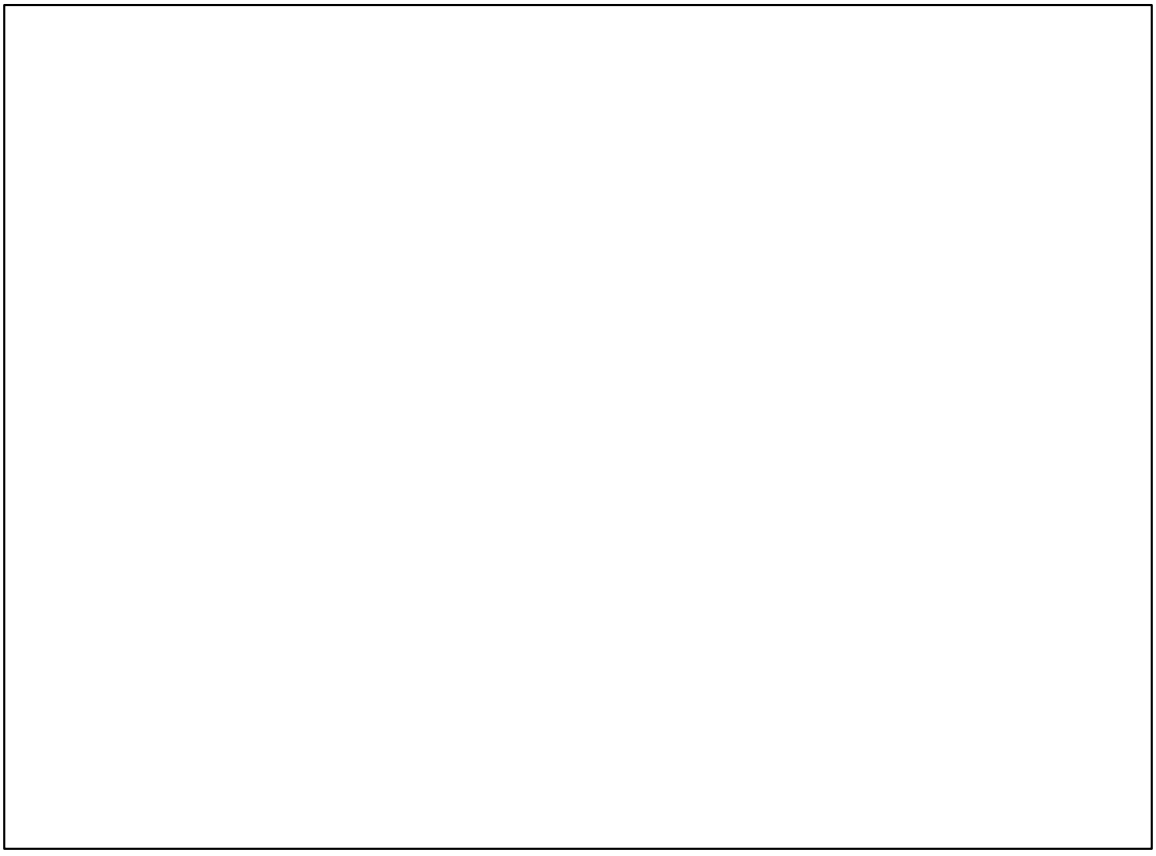
BACTERIA:	***ILLNESS:***
Various species of Group A Streptococcus	*Necrotizing fasciitis (flesh eating disease)*
Corynebacterium diphtheriae	*Diphtheria*
Mycobacterium tuberculosis	*Tuberculosis*
Clostridium botulinum	*Botulism*
Bordetella pertussis	*Whooping Cough or Pertussis*
Borrelia burgdorferi	*Lyme Disease*
Salmonella bongori	*Salmonellosis or Food Poisoning*
Clostridium tetani	*Tetanus or Lockjaw*
Salmonella typhi	*Typhoid Fever*
Bacillus anthracis	*Anthrax*
Vibrio cholerae	*Cholera*
Yersinia pestis	*Bubonic Plague or Black Death*

PROTISTS:	***ILLNESS:***
Plasmodium falciparum	*Malaria*
Entamoeba histolytica	*Amoebic dysentery*
Giardia duodenalis	*Giardia*
Naegleria fowleri *“Brain-eating amoeba”*	*Primary Amoebic Meningoencephalitis (PAM)* *or Naegleriasis*

FUNGI	***ILLNESS:***
Various species from Microsporum and Trichophyton	*Ringworm, Athlete’s foot, Toenail fungus*
Batrachochytrium salamandrivorans	*Chytridiomycosis*
Coccidioides immitis	*Valley Fever*
Claviceps purpurea	*Ergot*
Candida auris	*Can cause serious infections in people with breathing tubes, feeding tubes, or catheters.*

WANTED

Dangerous Microbe



Microbe name: _____

Disease name: _____

Description: _____

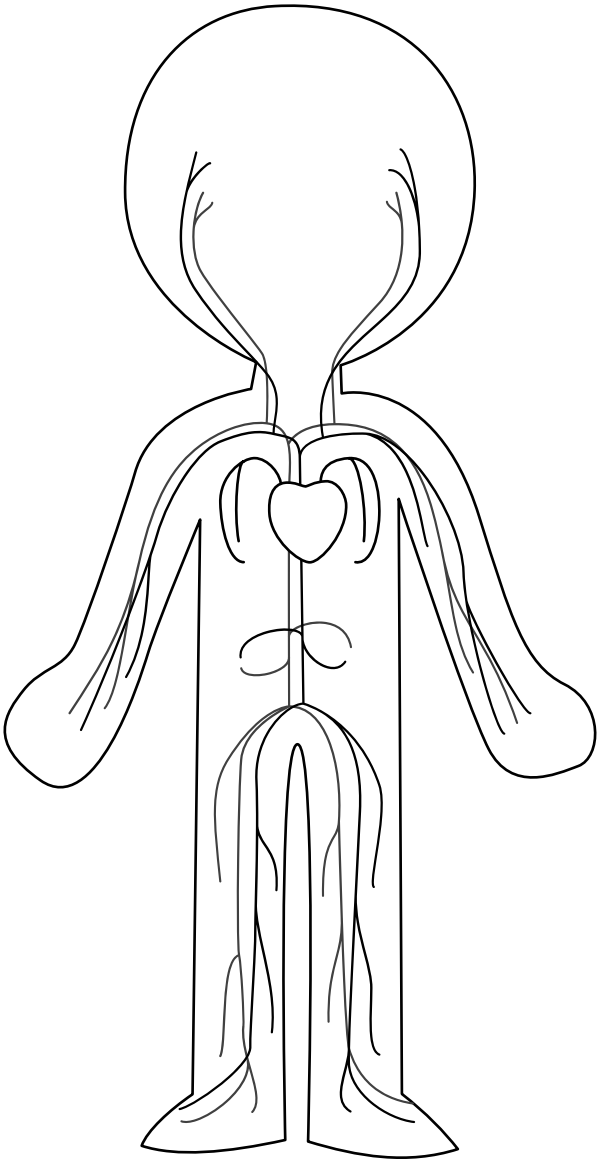
_____

Symptoms of infection: _____

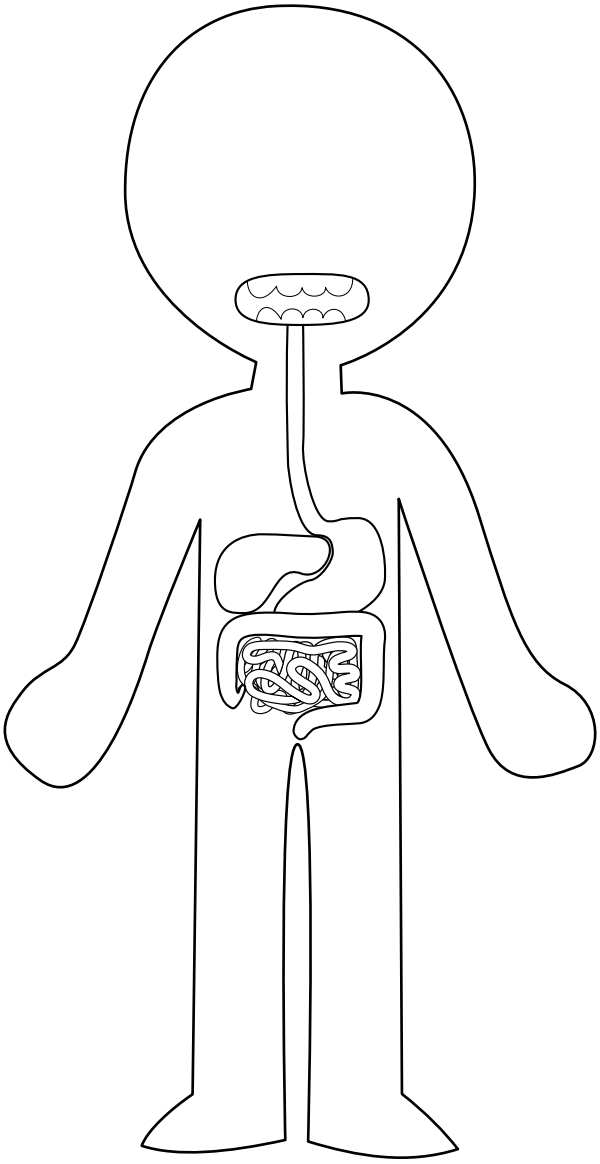
_____

Likely locations: _____

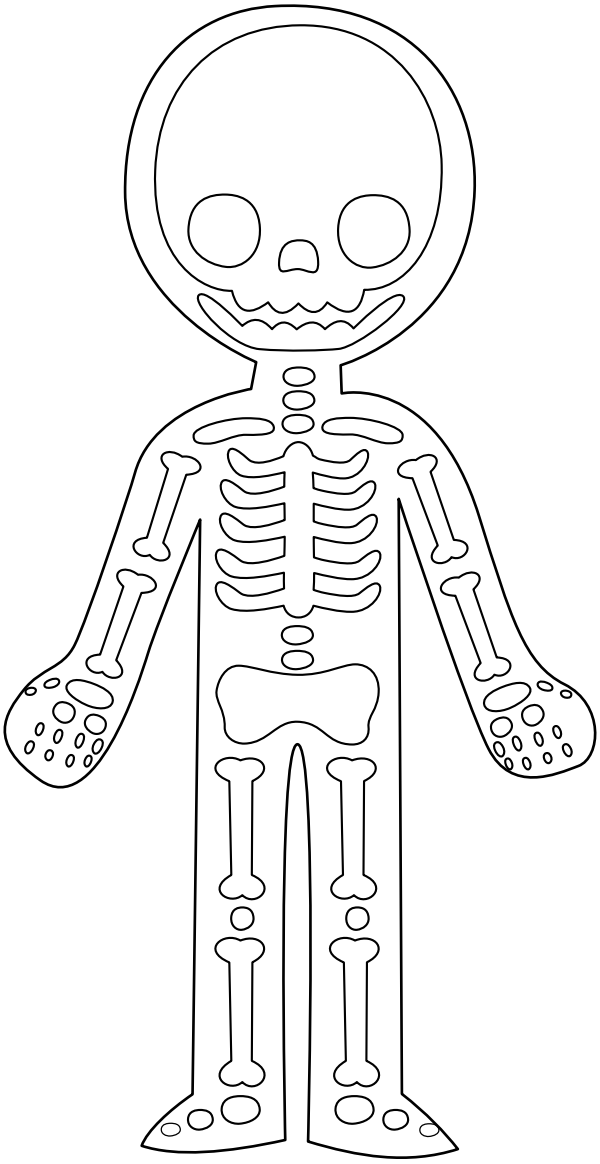
_____



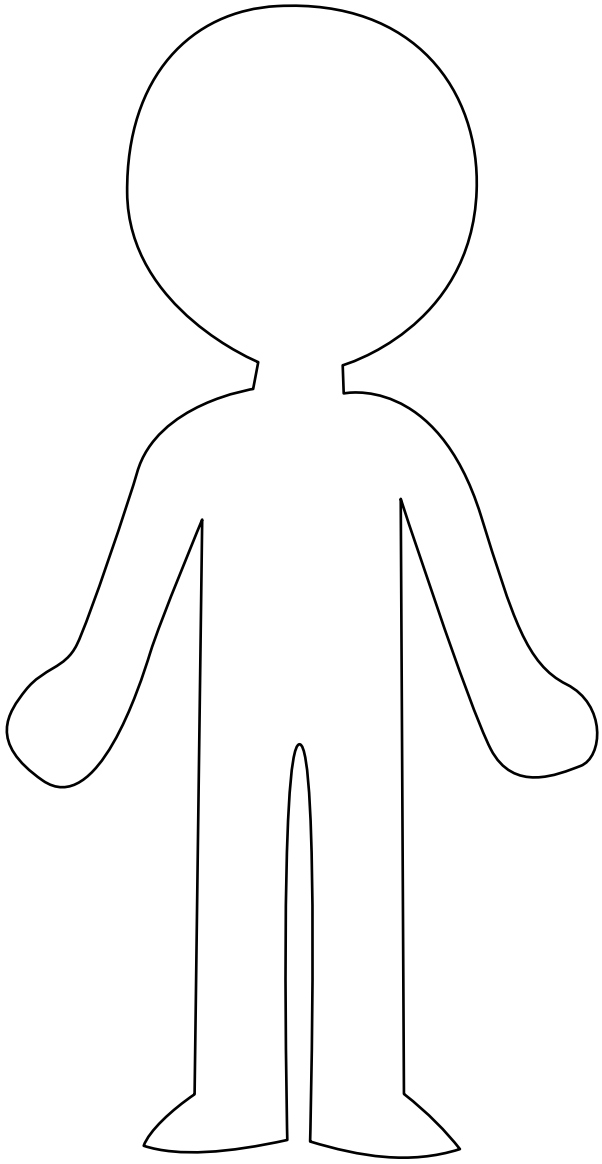
Circulatory



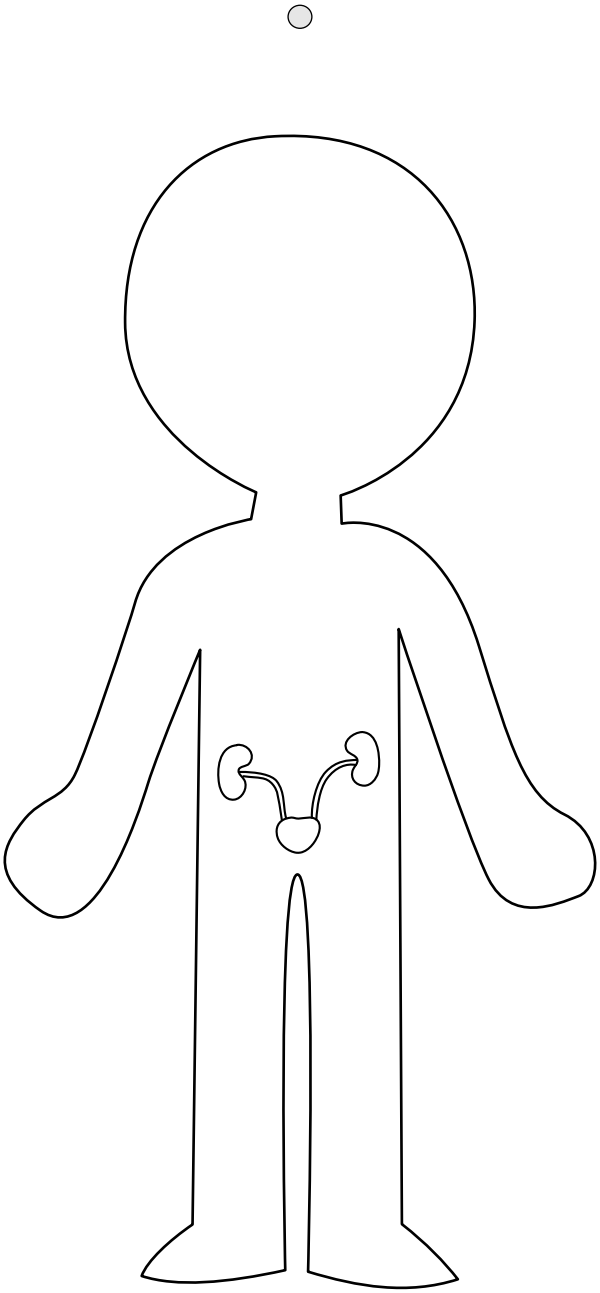
Digestive



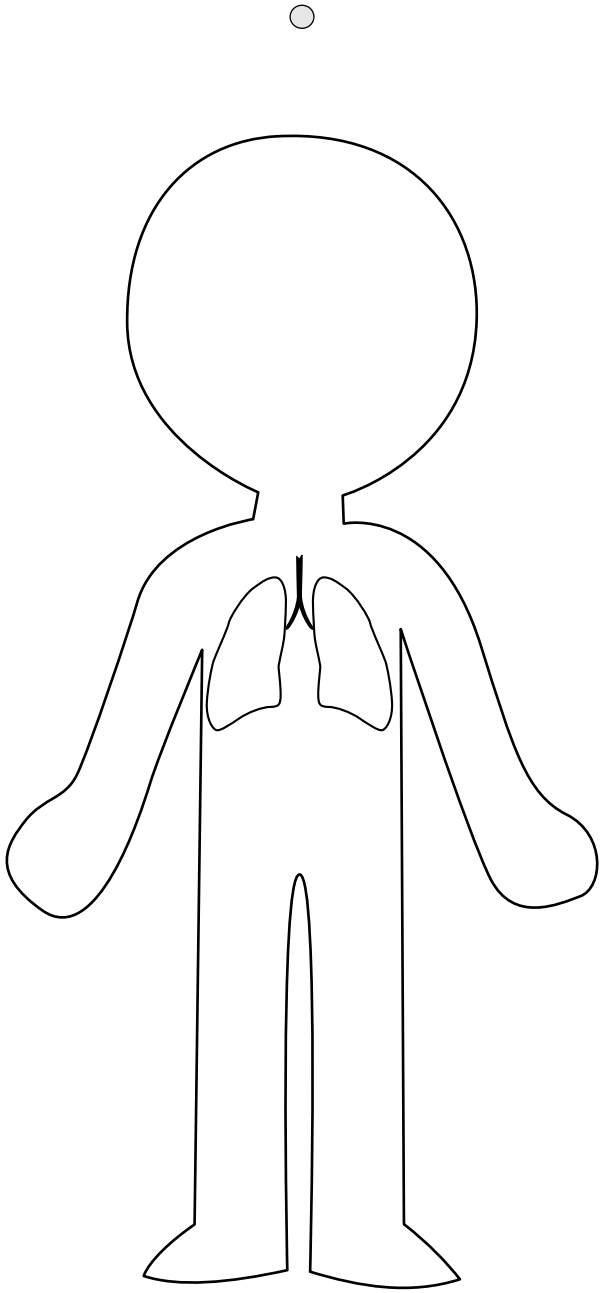
Muscular/
Skeletal



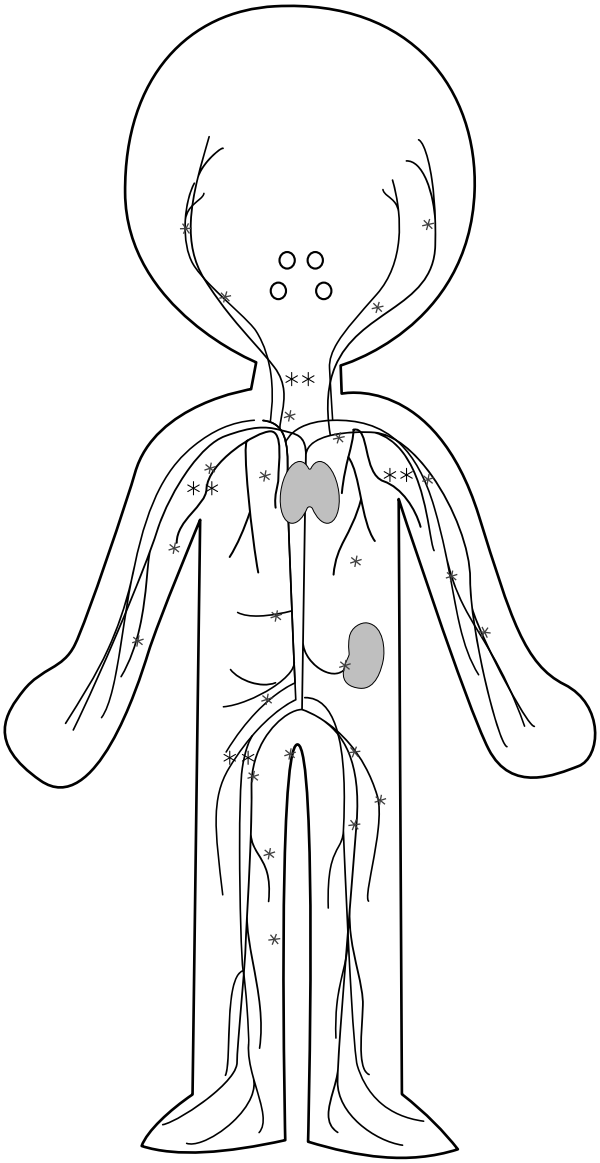
Integumentary



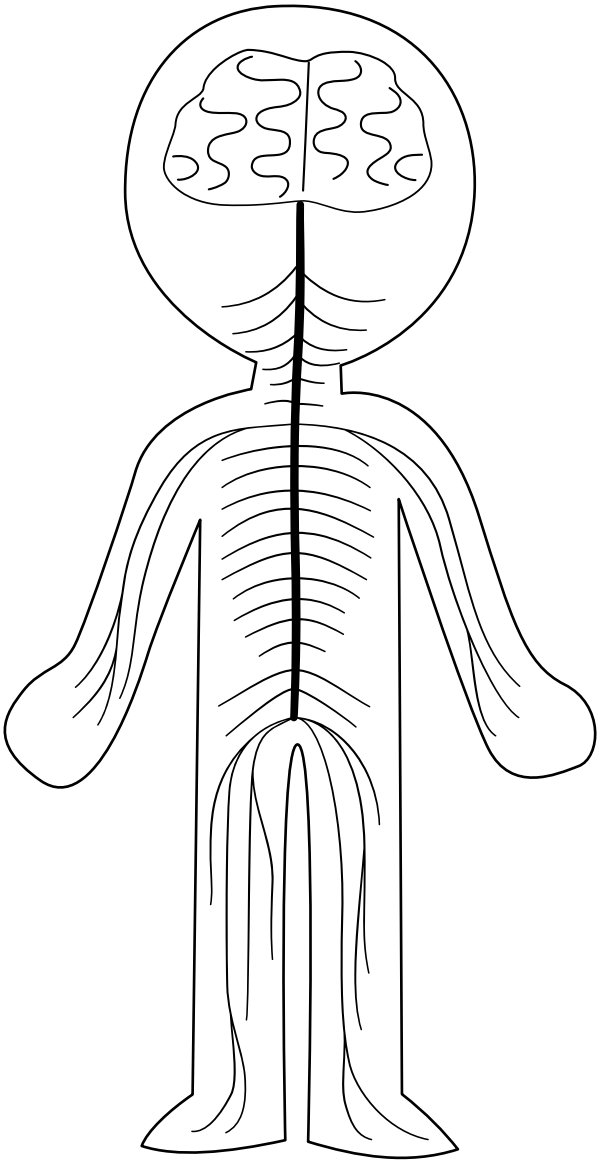
Urinary



Respiratory



Immune



Nervous