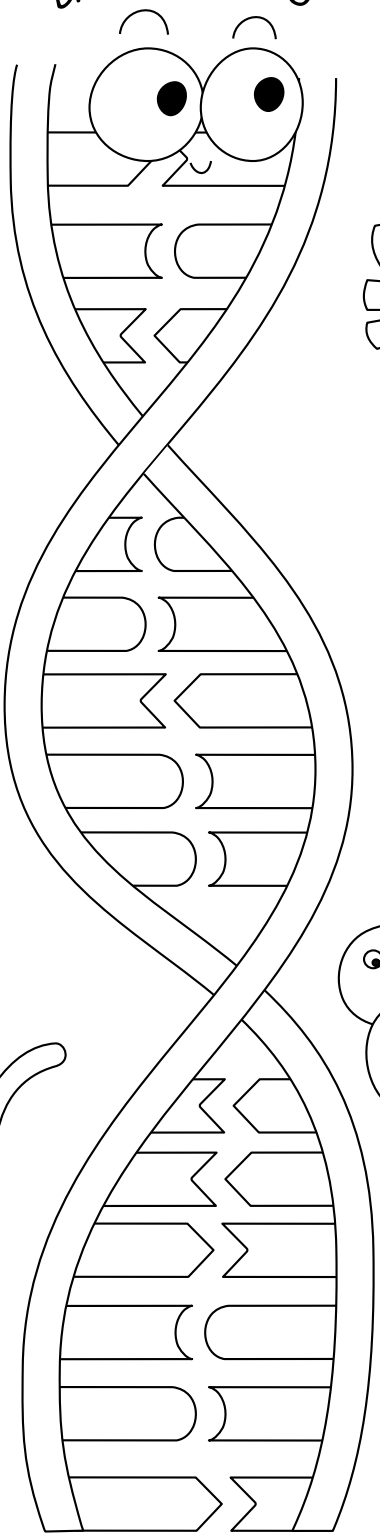
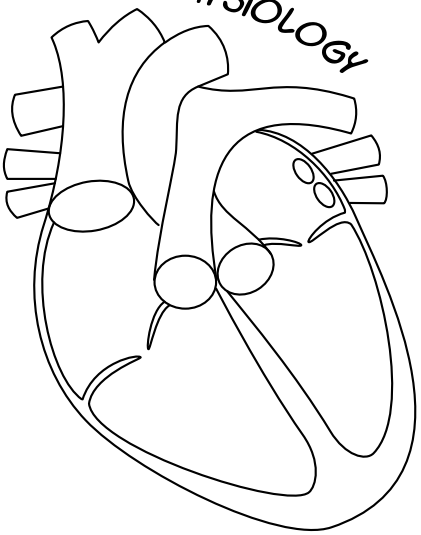
BIOLOGY ONE

BIOMOLECULES

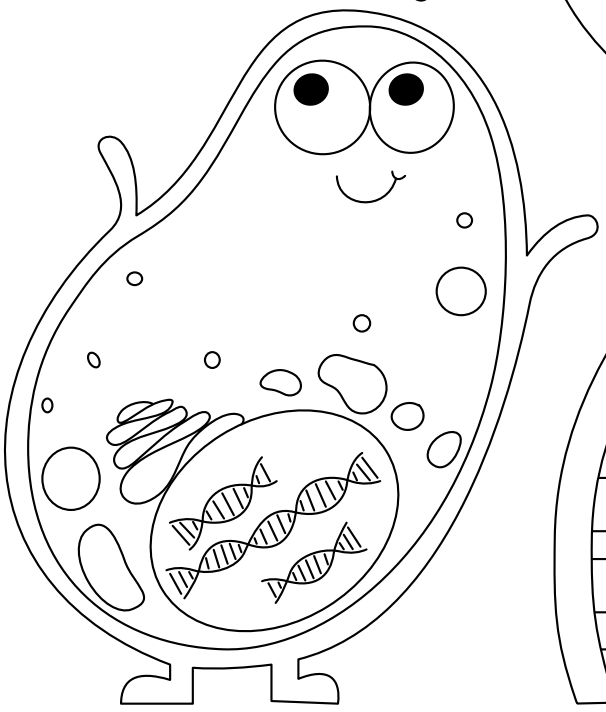


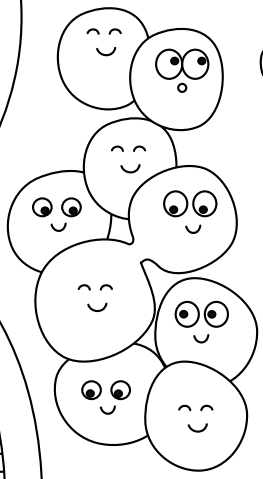
DIVERSITY OF LIFE

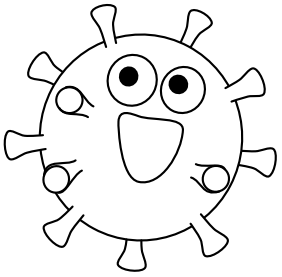
PHYSIOLOGY



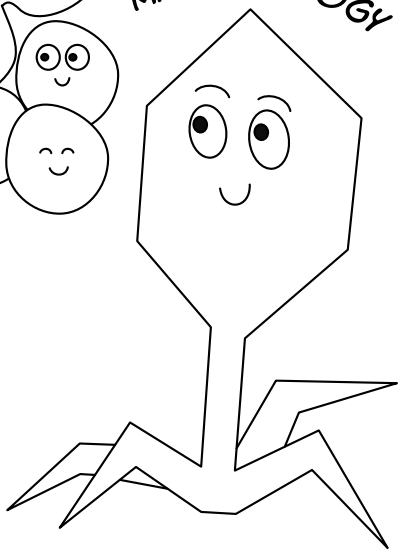
CELLS







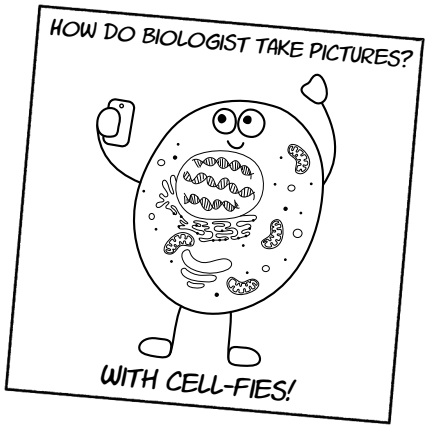
MICROBIOLOGY

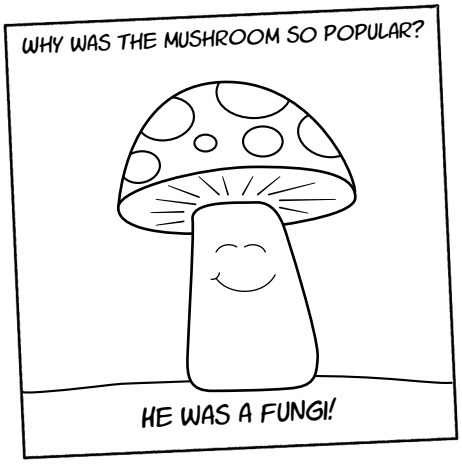


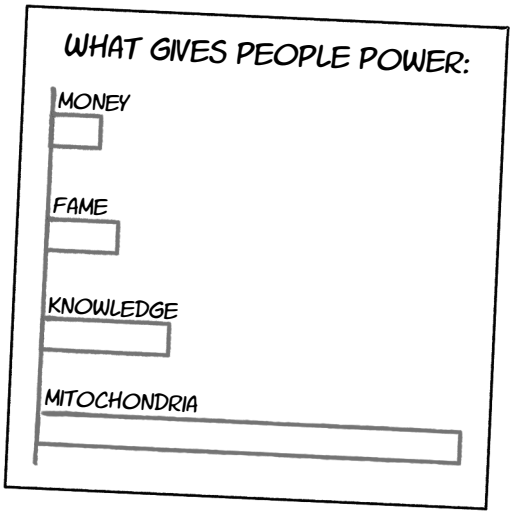
BIOLOGY ONE

~ 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

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

Lesson 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)

Lesson 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

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

Lesson 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

Lesson 16 - Respiration
- 2 Tbsp Yeast
- 2 Balloons
- 2 Water bottles
- Sugar

Lesson 23 - What is Blood?
- 1/3 c measuring cup
- 6 L of water and two containers
- Timer or stopwatch

Lesson 24 - Why We Breathe
- 2 balloons
- Plastic bottle with bottom cut off

Lesson 25 - How Nerves Work
- Ruler

Lesson 37 - 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: Lessons 4, 5, and 6
Living things are made of cells

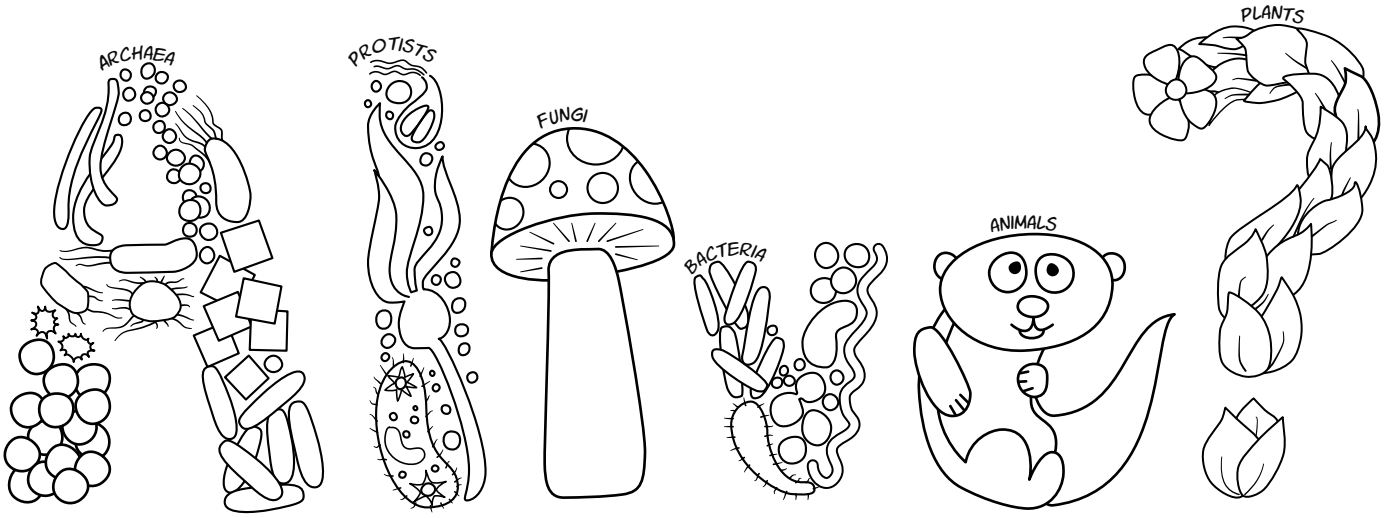
MS-LS1-2: Lessons 3 and 22
The function of a cell as a whole and how the parts of a cell contribute to that function

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

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

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

MS-LS1-8: Lesson 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

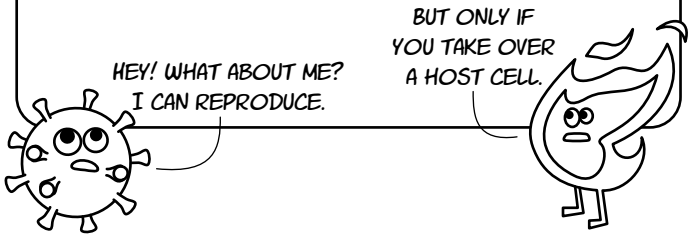
HOMEOSTASIS

GROWTH

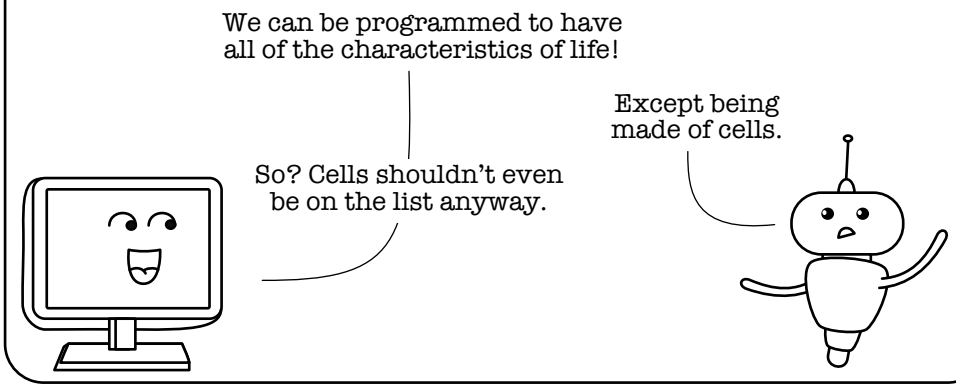
RESPONDS TO STIMULI

MADE OF CELLS

REPRODUCTION



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.

2.

3.

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

1.

2.

3.

What is your opinion?

SCIENCE MOM

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!

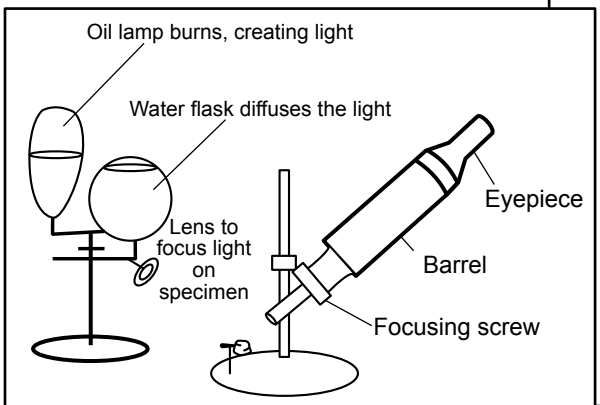
LENS
LENS

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.

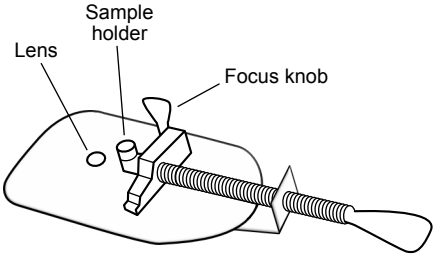
AND LOOK! THERE ARE EVEN CELLS IN FOSSILS!

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.

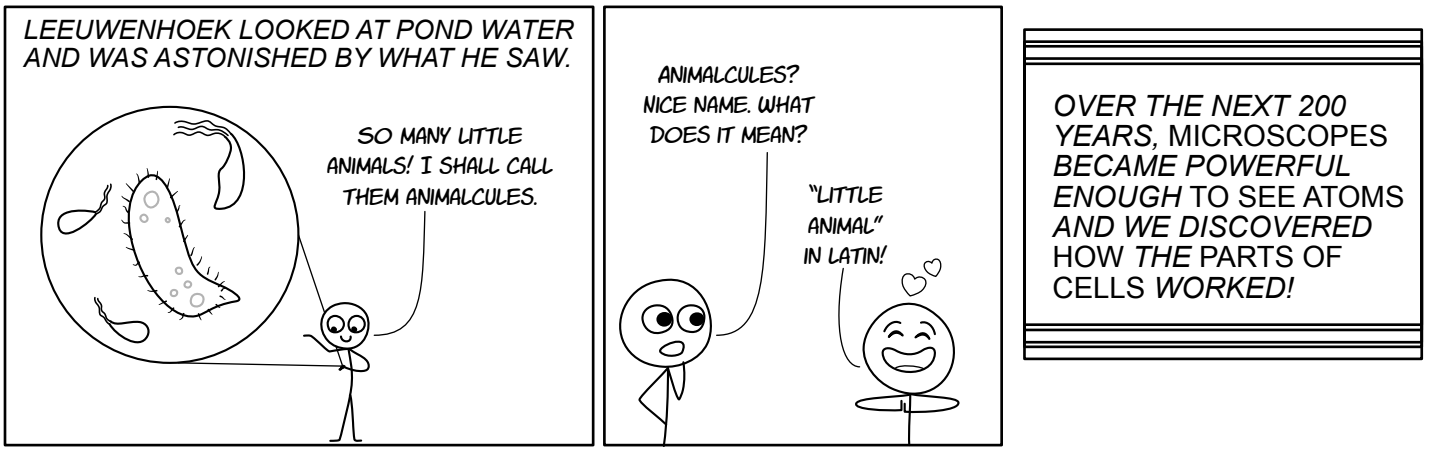
THERE IS ONLY ONE LENS IN THIS MICROSCOPE, BUT THE QUALITY IS SO GOOD I CAN SEE WITH 200 TIMES MAGNIFICATION!

SUPER TINY MICROSCOPE

MY MICROSCOPE HAS BETTER MAGNIFICATION THAN HOOKE'S!

#1

CONTINUED ON NEXT PAGE…



Your notes:

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

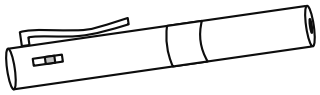
Made of cells or came from cells

NOT made of cells or derived from cells

Hands-on Science Project

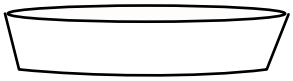
LASER POINTER MICROSCOPE

MATERIALS:


Laser Pointer

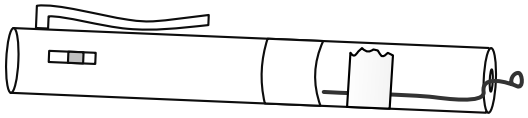

Paperclip


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.

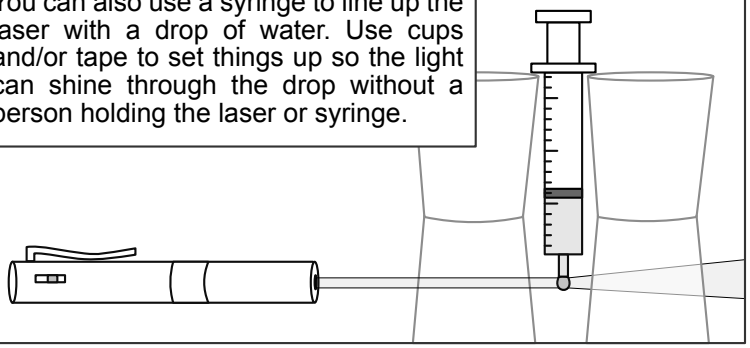
3. Attach the paperclip to the laser pointer with tape so that the loop is directly in the path of the beam.

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 _____.

- ☐ 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.
- ☐ A drop of saliva.
- ☐ Water from a pet's water dish.
- ☐ Water from the tank (not the bowl!) of a toilet.
- ☐ Other: _____

YOUR RESULT:

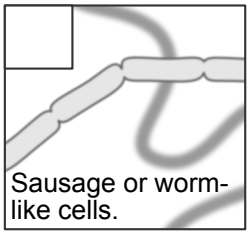
The water with the most observed microbes was _____.

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:

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 _____. This is why they looked so empty. _____ cells contain several important parts or _____ that help them survive. Ribosomes build _____. If the cell has a nucleus, it contains the _____. 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 _____ _____. The liquid inside a cell is called the _____. Not every type of cell will contain all of these parts. There is incredible _____ between different types of cells!

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

Cytoplasm

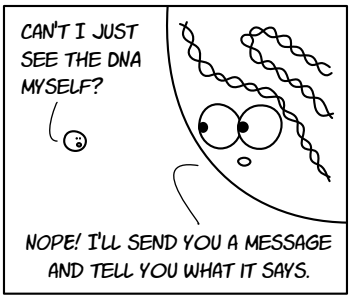
The liquid inside the cell. It's mostly water.

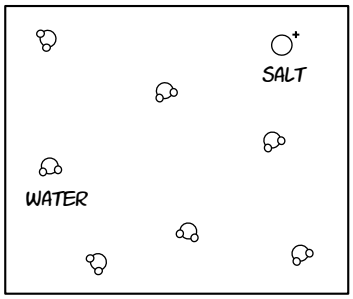
Nucleus

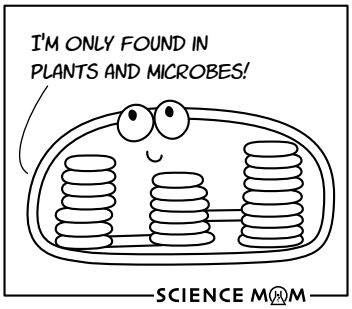
Keeps the DNA separate from the rest of the cell.

Chloroplast

Uses CO_2 and sunlight to create sugars.

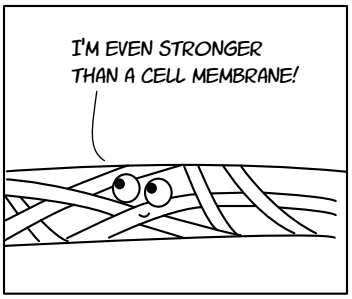






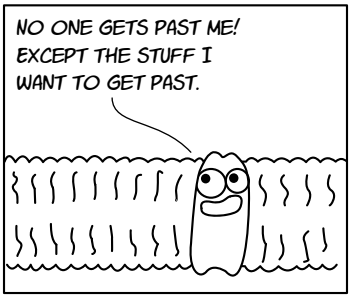
Plasma Membrane

Keeps the cytoplasm inside the cell.



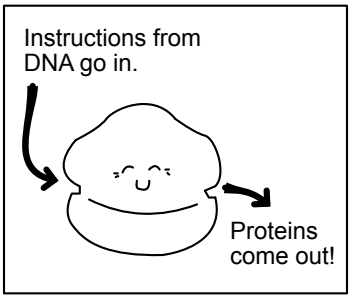
Cell Wall

Keeps the cytoplasm inside the cell.



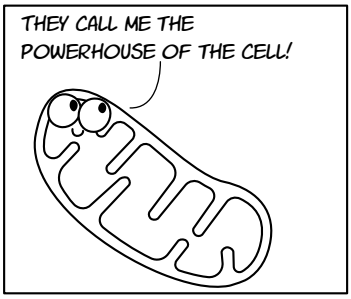
Flagella

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



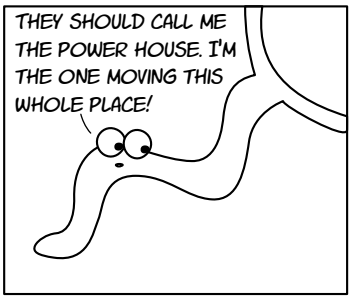
Ribosome

The thing that makes the proteins.



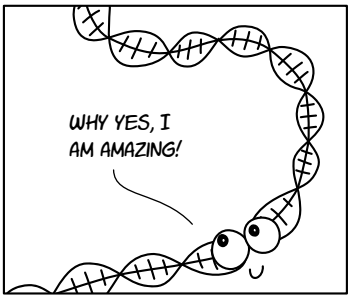
DNA

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

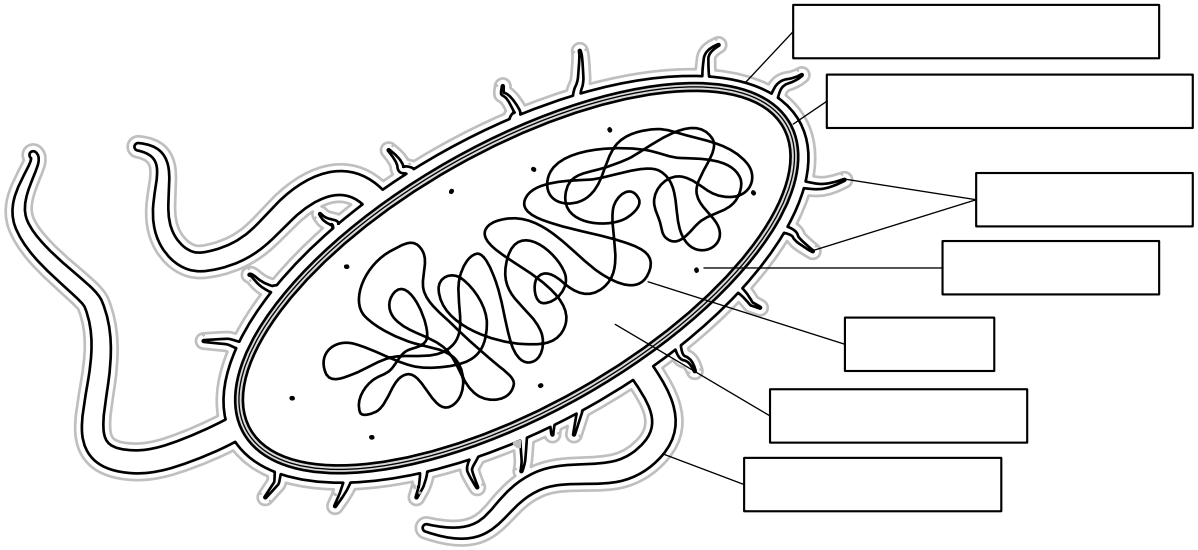


Mitochondria

Uses oxygen and sugar to create energy for the cell.



Prokaryotic Cells



Example: Salmonella
Size: 2-5 Microns long

FILL IN THE LABELS ABOVE USING THESE WORDS:

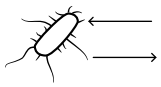
PLASMA MEMBRANE | DNA | CILLIA | CYTOPLASM | CELL WALL | FLAGELLUM | RIBOSOME

Your notes:

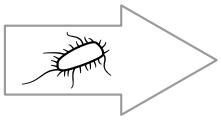
IS SOMETHING AS SMALL AS A SALMONELLA BACTERIUM REALLY *ALIVE*? LET'S CHECK:

METABOLISM ✓

IT EATS FOOD AND PRODUCES WASTE.



RESPONDS TO STIMULI ✓



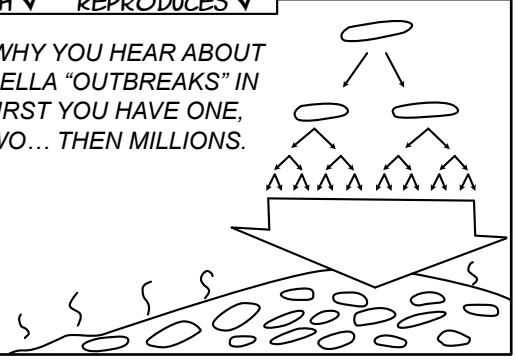
WILL MOVE TOWARD A WETTER AND BETTER ENVIRONMENT

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

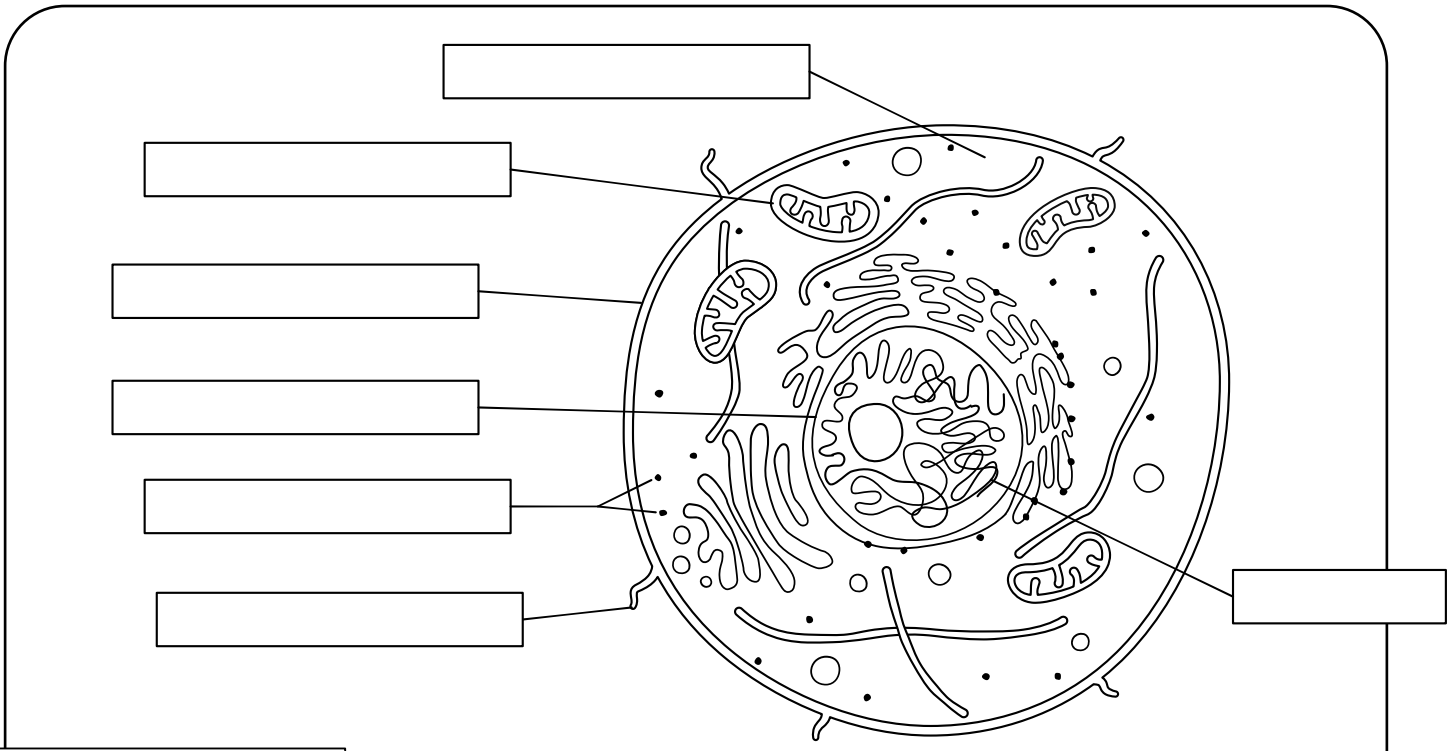
HA HA! THEY'LL NEVER GET RID OF US NOW! TEAM WORK MAKES THE DREAM WORK!

GROWTH ✓ REPRODUCES ✓

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



Eukaryotic Cells



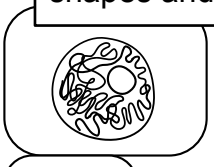
FILL IN THE LABELS ABOVE USING THESE WORDS:

MITOCHONDRIA PLASMA MEMBRANE RIBOSOMES DNA CILLIA NUCLEUS CYTOPLASM

Example: Animal cell
Size: 10-20 Microns long

Your notes:

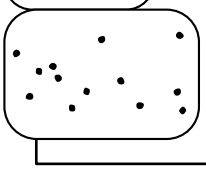
Eukaryotic cells can have incredibly different shapes and parts, but they will always contain:



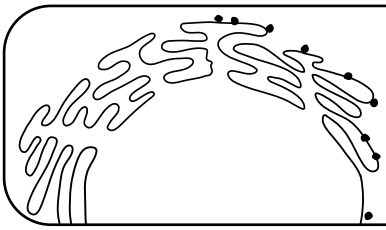
A NUCLEUS which holds the DNA

MITOCHONDRIA which provide energy

MEMBRANE which surrounds the cell



RIBOSOMES which make proteins

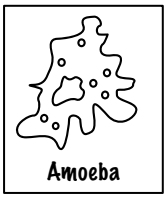


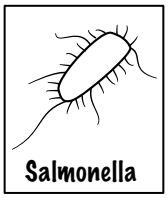
BONUS ORGANELLE!

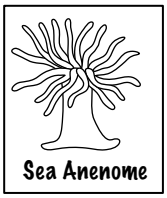
What is the crazy-shaped thing around the nucleus with ribosomes stuck to it? It's called the ***endoplasmic reticulum*** and it helps make proteins. We won't be talking about it more in this class, but of all the organelles, it has one of the coolest names!

Cellular Life

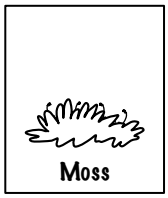
Can you place each of these organisms in their matching category?

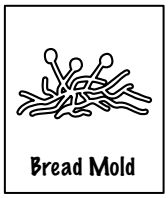

Amoeba


Salmonella


Sea Anenome


Haloquadratum

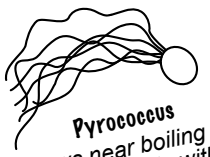

Moss


Bread Mold

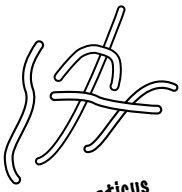
Unicellular

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.

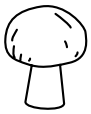
FUNGI


Candida albicans


Bakers Yeast

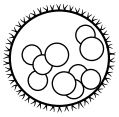

Giant Puffball


Bracket Fungus

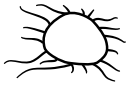

Button mushroom

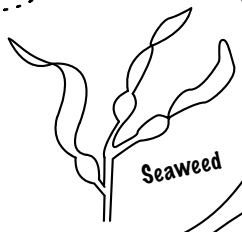
PROTISTS


Malaria

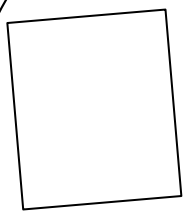

Volvox


Slime mold


Paramecium


Seaweed

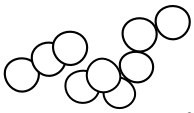
PLANTS




Maple Tree

BACTERIA


Borrelia Burgdofen
(causes lyme disease)

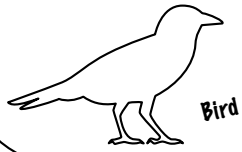

Staphylococcus


Lactobacilis

ANIMALS


Lizard


Octopus


Bird

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);*

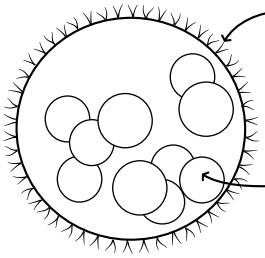
Animal or Plant? *Diploria labyrinthiformis (Brain Coral), Xestospongia muta (Giant barrel sponge), Elysia chlorotica (Emerald Elysia), or Pseudocolochirus violaceus (Sea Apple)*

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

Volvox!

Volvox barberi

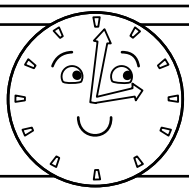
AN ALGAE COLONY MADE OF THOUSANDS OF COOPERATING CELLS!



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!



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?

_____ , _____

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

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

A. True
B. False

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

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

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

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

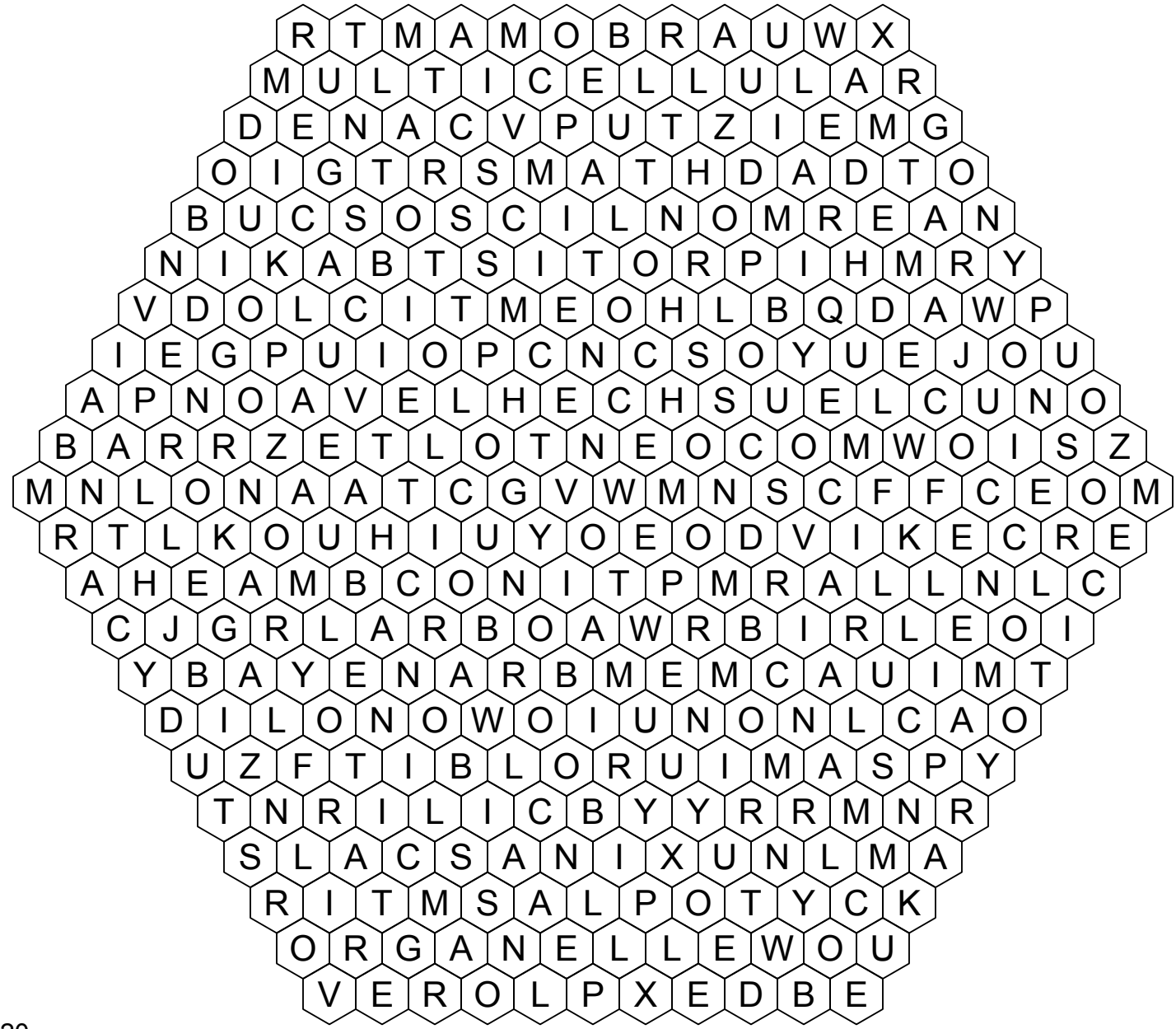
19 Draw a simple bacterial cell. Label the plasma membrane, cell wall, DNA, ribosomes, and flagella.

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

Cellular Word Search

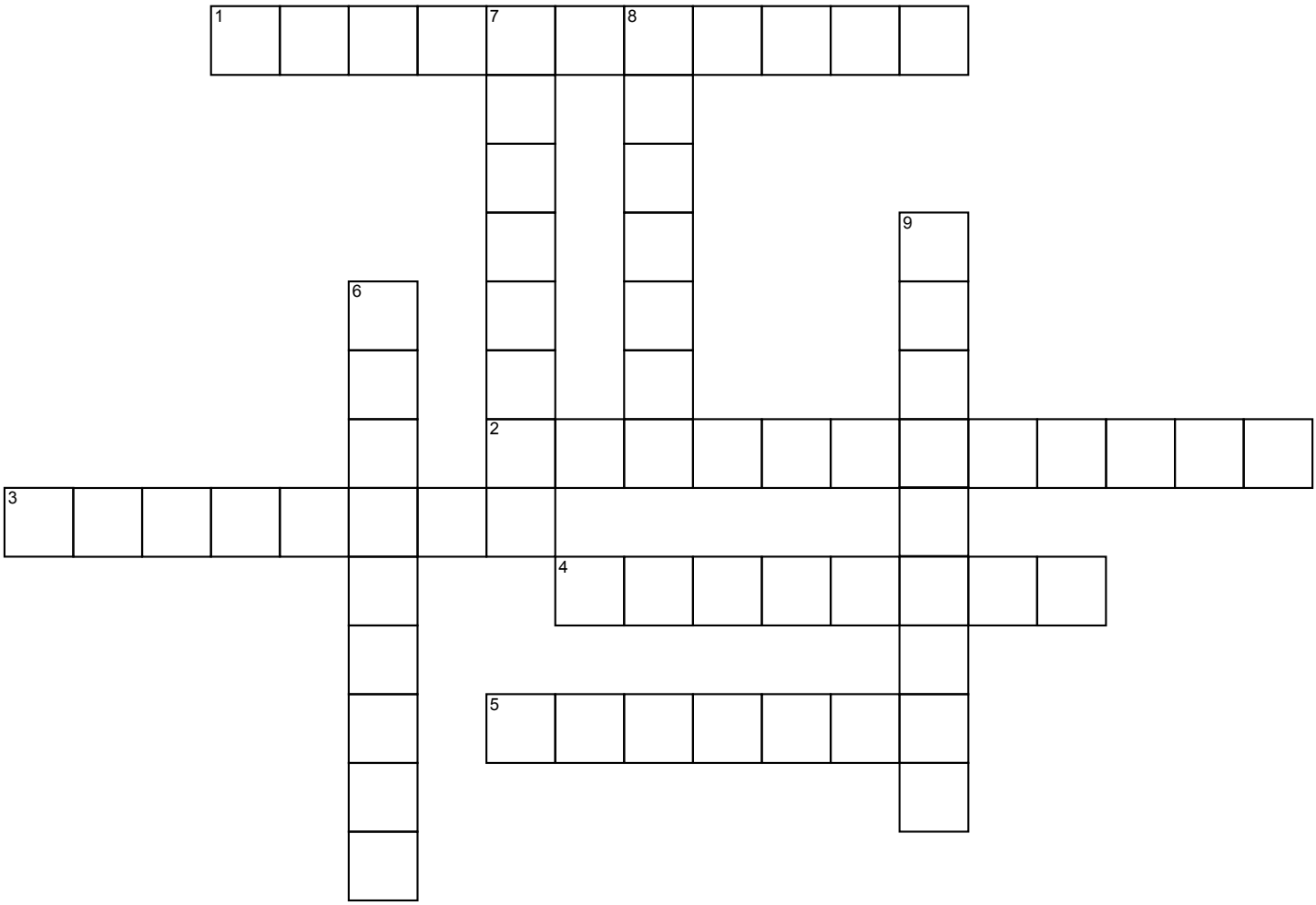
There are a lot of new words to learn when studying biology. Repetition is the best way to learn them, and word games can be part of that! Find each of the hidden words in the word-search. The words can run in any direction: horizontal or diagonal, and the letters might go left to right or right to left!

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.

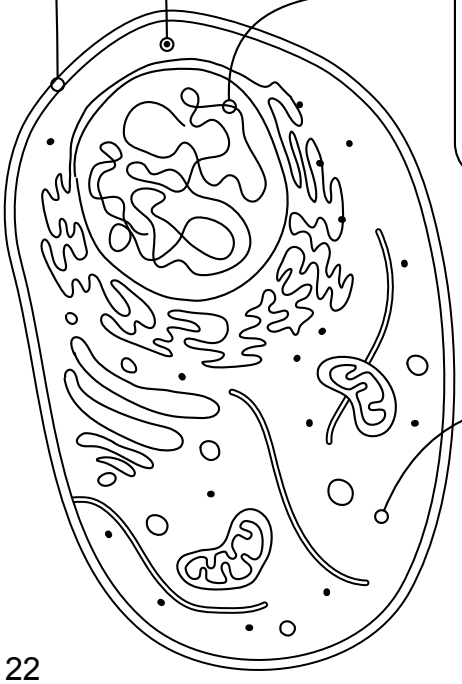
BIOMOLECULES

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

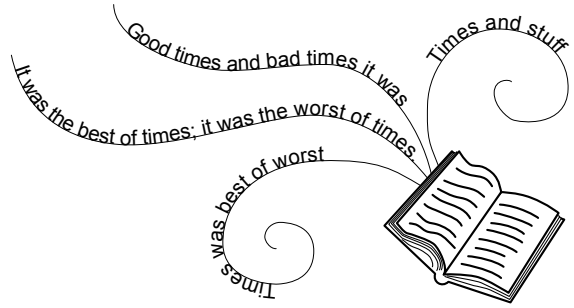


SUGARS

Polymers and Monomers

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

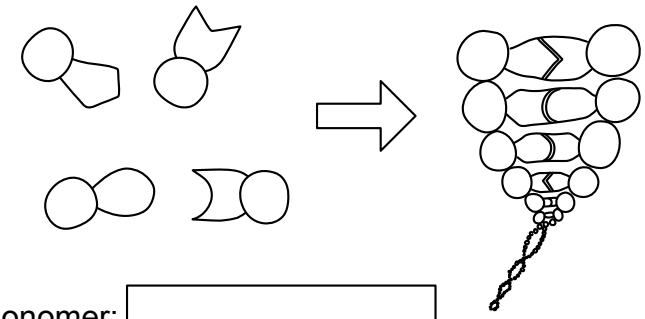
DNA	protein	beads	starch	words	amino acids
stories	HDPE	ethylene	nucleotides	glucose	necklace



Monomer: _____

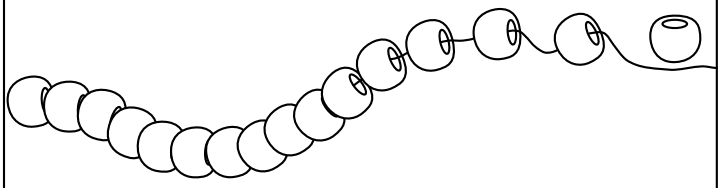
Polymer: _____

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



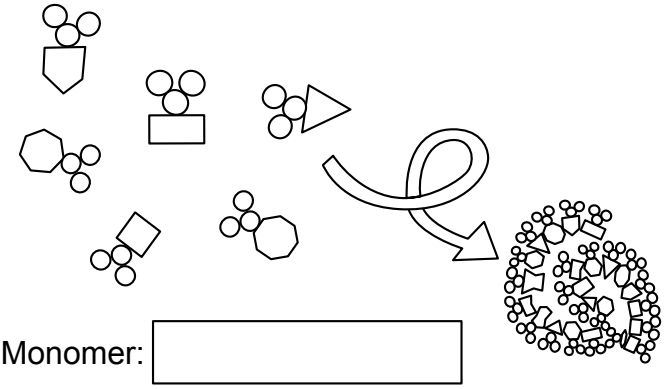
Monomer: _____

Polymer: _____



Monomer: _____

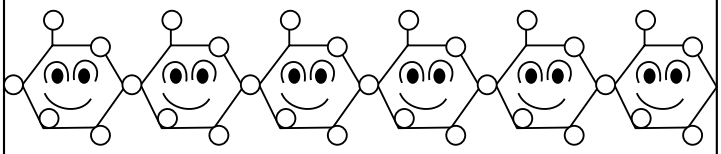
Polymer: _____



Monomer: _____

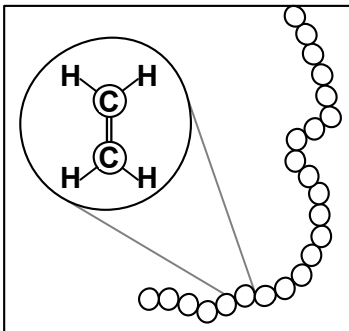
Polymer: _____

Clue: This polymer is used to store energy.

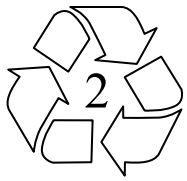


Monomer: _____

Polymer: _____



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



Monomer: _____

Polymer: _____

Osmosis

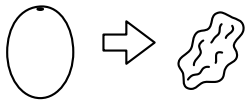
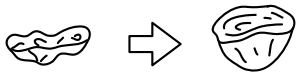
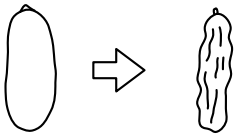
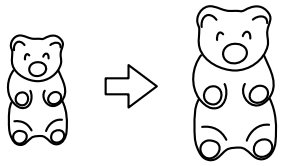
FILL IN THE BLANKS USING THESE WORDS:

osmosis	impermeable	semipermeable

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

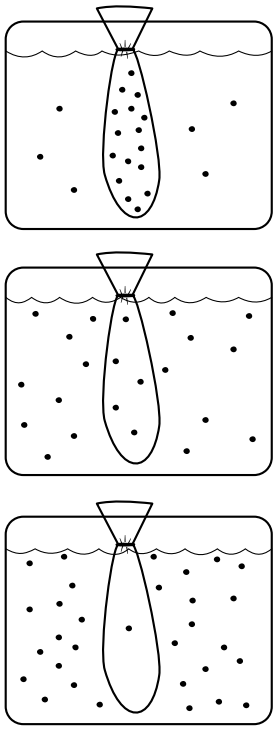
Grape skins, gummy candy, and cell membranes are all semipermeable. They allow water and other small molecules to pass through them. This movement of water or other molecules through a semipermeable membrane is called _____.

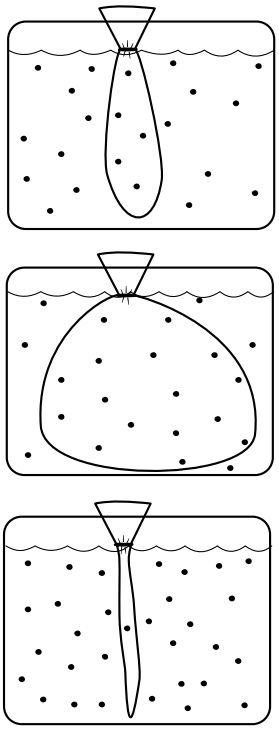
Which examples of osmosis have you seen?

☐ 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.

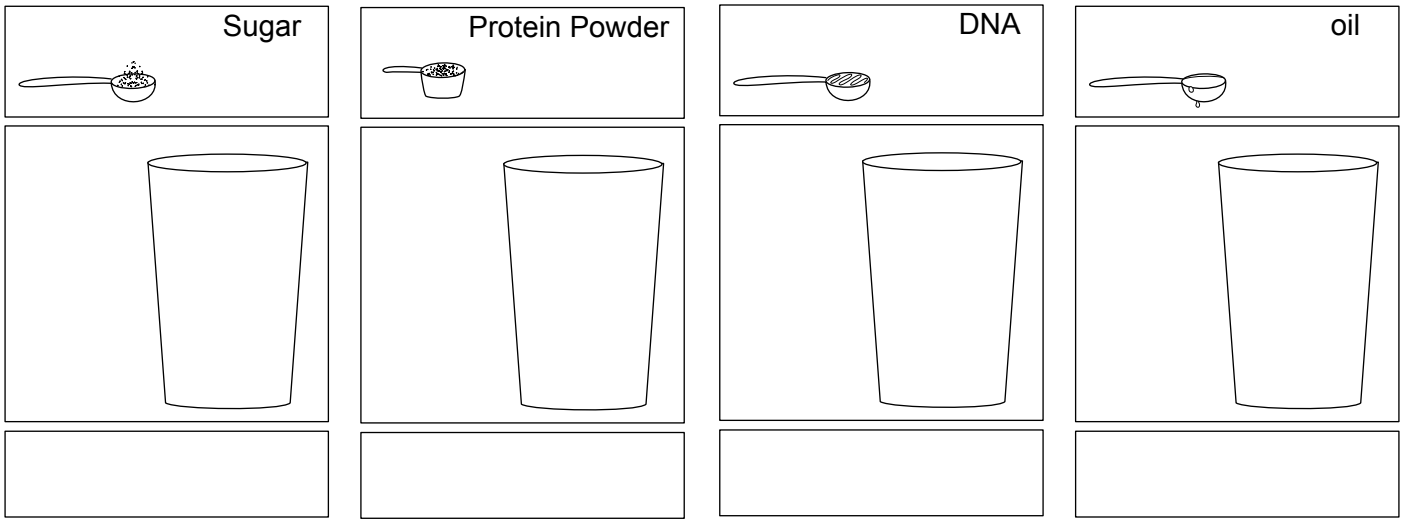
DRAW LINES TO SHOW WHAT WOULD HAPPEN IF A SEMIPERMEABLE BAG WAS PLACED IN ANOTHER CONTAINER CONTAINING A SOLUTION. THE DOTS REPRESENT THE SOLUTE, WHICH CANNOT CROSS THE MEMBRANE.



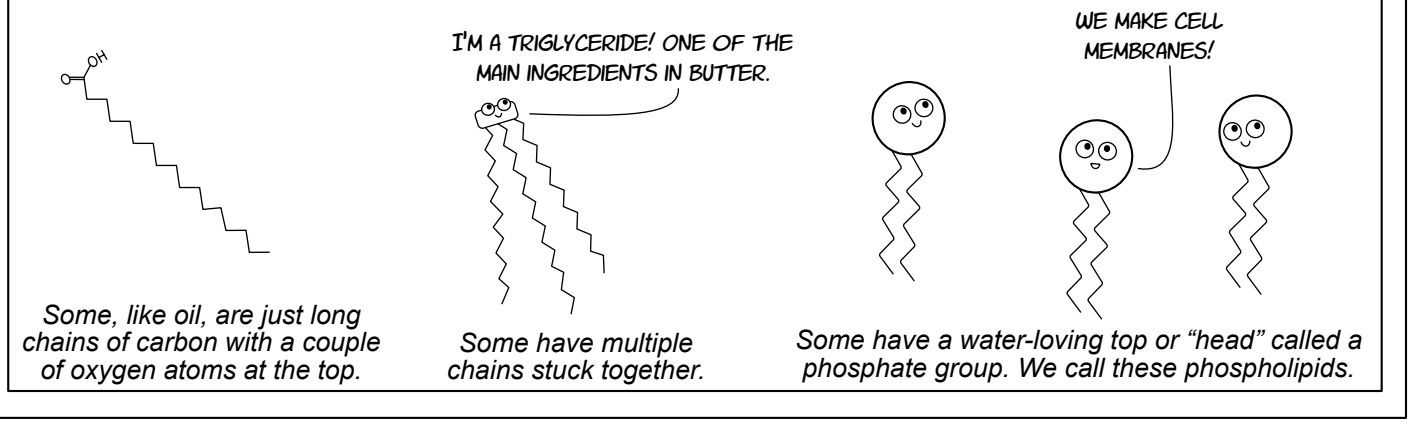


Lipids Make Membranes

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.

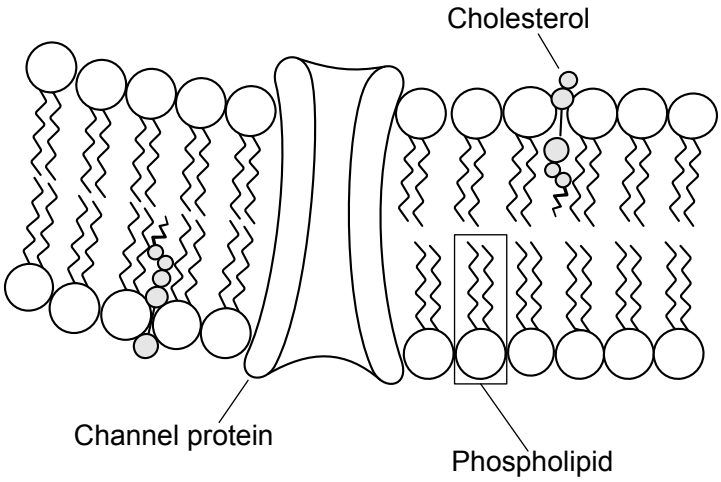
Some have multiple chains stuck together.

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

FILL IN THE BLANKS USING THESE WORDS:

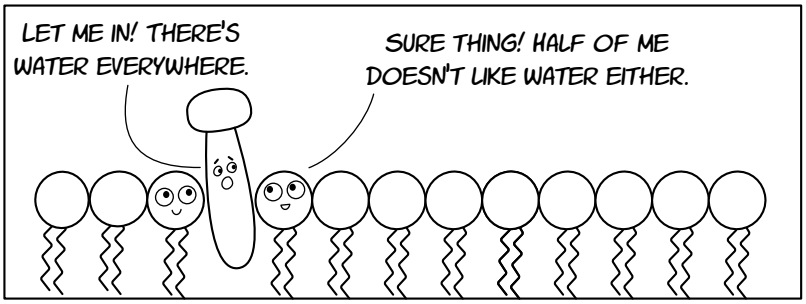
phospholipids	channel	
cholesterol	hydrophobic	hydrophilic

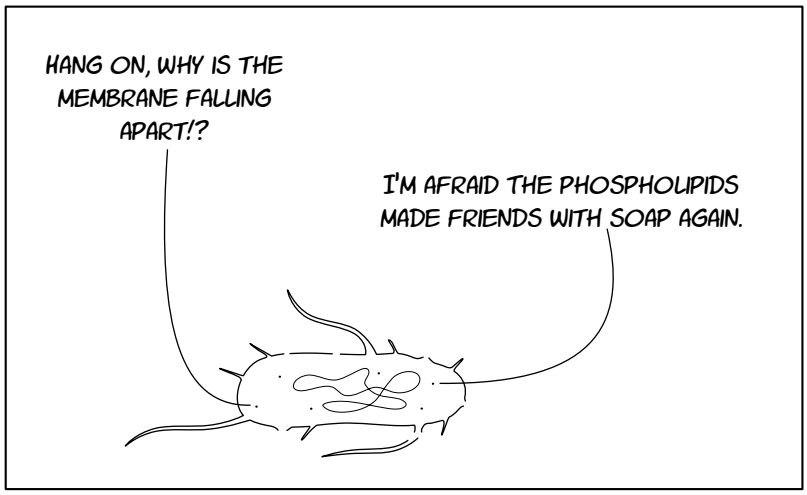
The membranes of animal cells are made of _____. These molecules have a "head" that is _____(attracted to water) and a "tail" that is _____ (repelled by water). _____ molecules stabilize the membrane and _____ proteins can open to allow molecules to pass through and enter the cell.

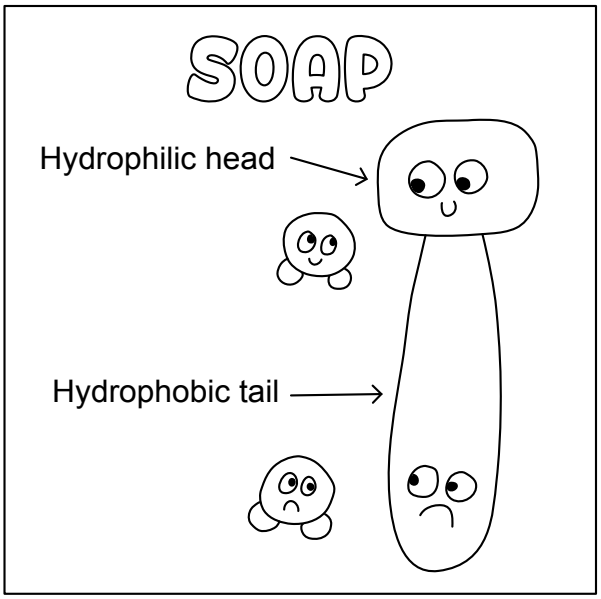


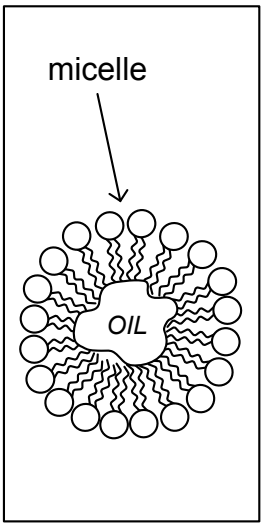
A note about soap

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.







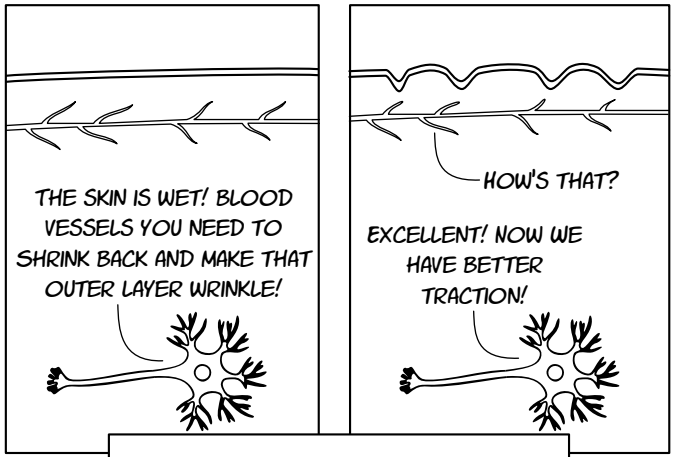


Hand washing doesn't just wash bacteria and other germs down the sink. It also disrupts their cell membranes. If soap damages bacteria, could it damage your cells too? While too much soap can irritate the skin, the outermost layer of skin is an extra-tough layer of lipids and proteins called the stratum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

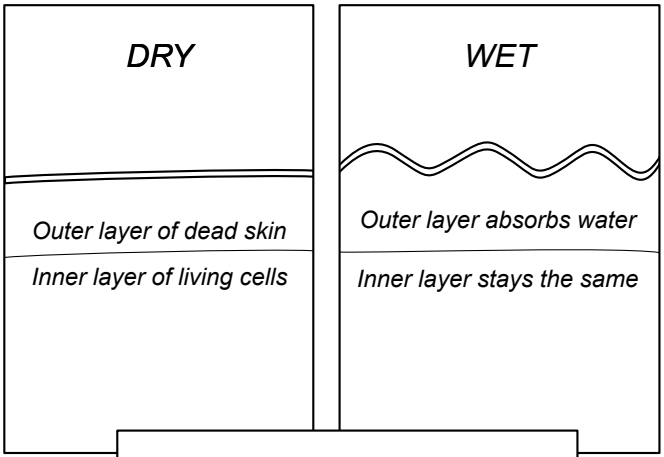
FACT OR FICTION?

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.



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

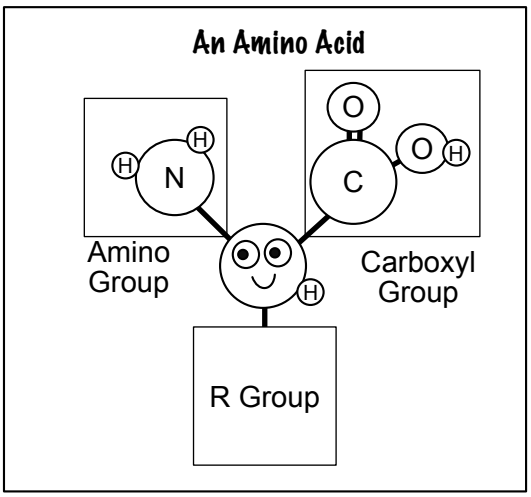


Amino Acids Make Proteins

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

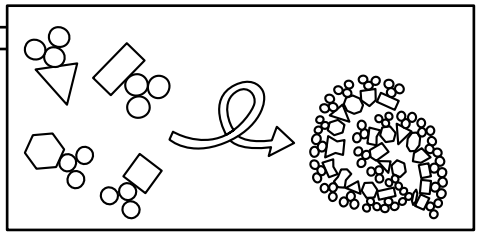
A **receptor** is a protein on the surface of a cell that binds to something specific.

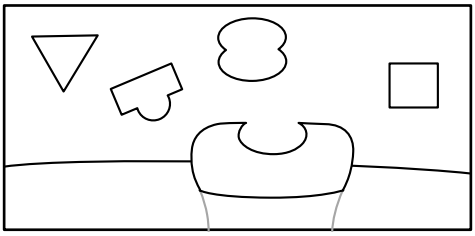
A **protein** is a polymer of amino acids that is folded in a specific way.

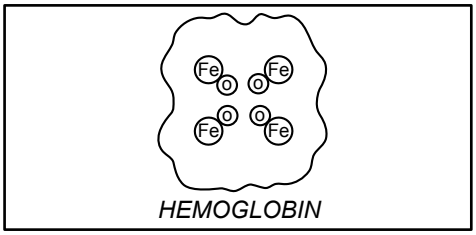
This protein is the most abundant **enzyme** on our planet! It converts carbon dioxide into a small sugar.

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

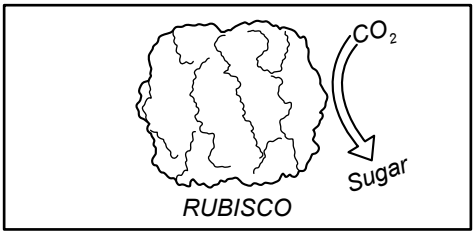
This **structural protein** is used by animals to make strong tissues like hair, nails, claws, and horns.



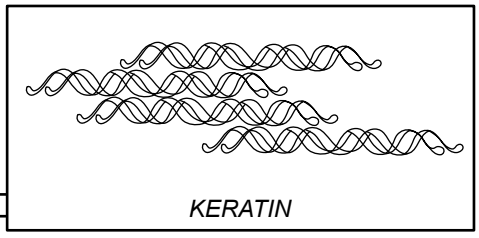




HEMOGLOBIN

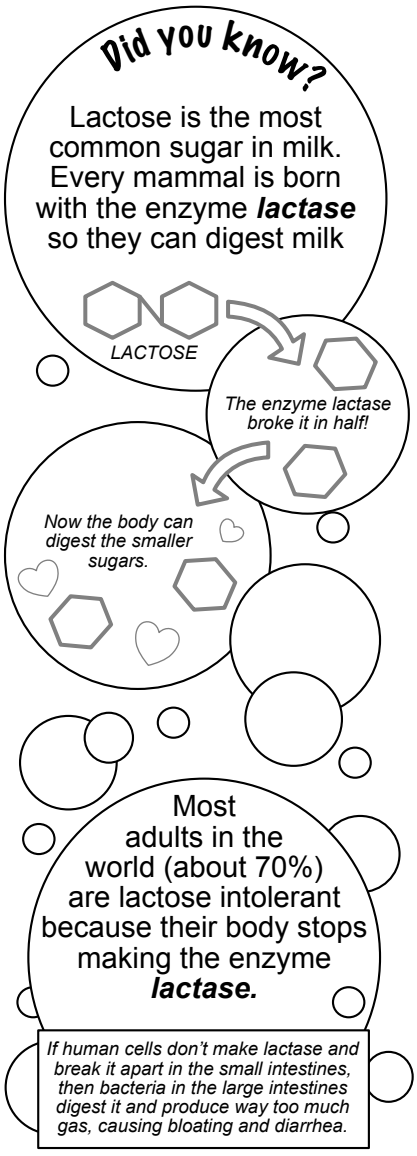


RUBISCO


KERATIN

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

Enzymes are amazing catalysts!



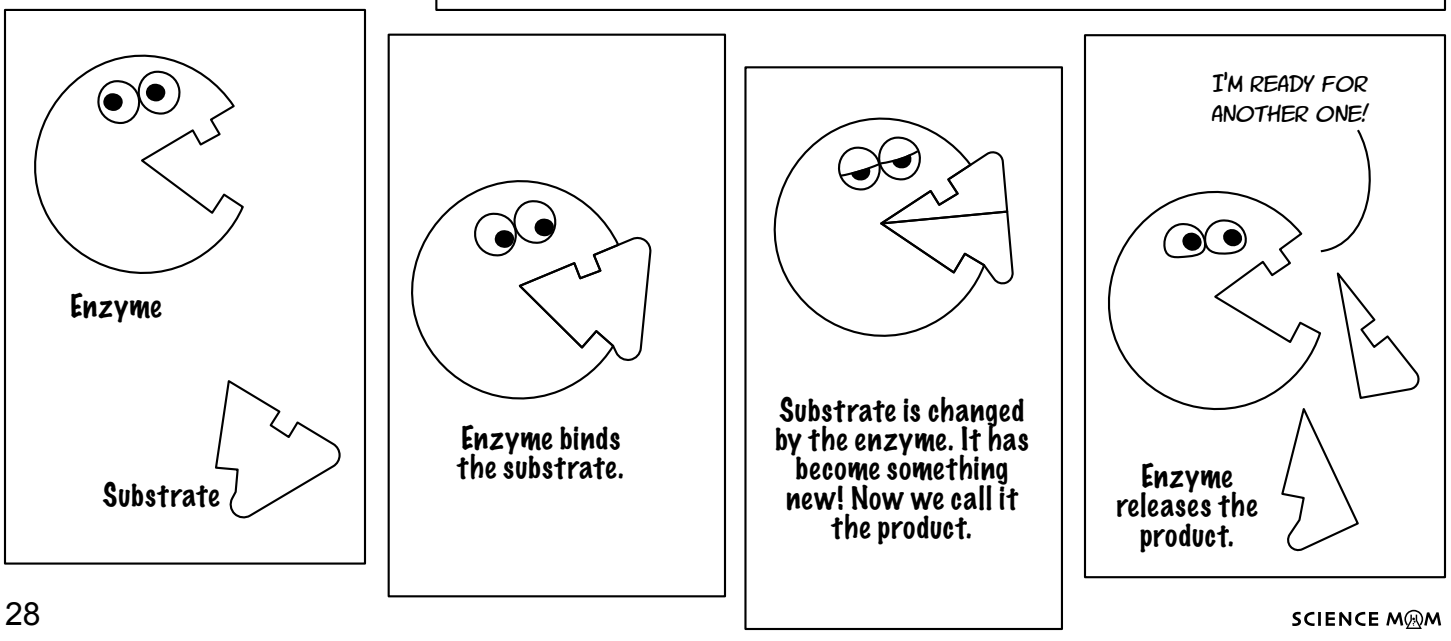
FILL IN THE BLANKS USING THESE WORDS:

sugar lactose substrate catalysts specific protein controlled

A catalyst is something that helps a chemical reaction happen. _____ 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 _____. We call them enzymes.

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

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 _____ by or influenced by enzymes. They're the most important proteins around.



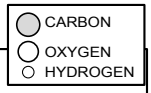
Sugars Store Energy

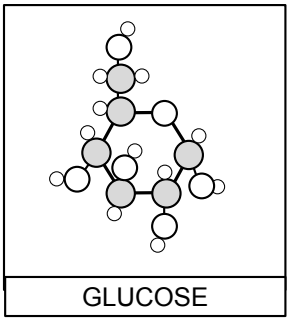
FILL IN THE BLANKS USING THESE WORDS:

molecules	starch	energy	essential	glucose

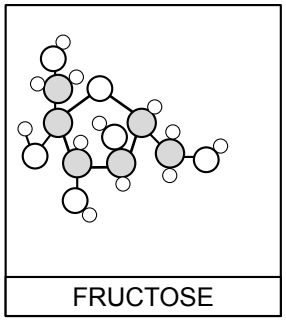
Sugars are _____ made of carbon, oxygen, and hydrogen. The simplest sugars (monomers) have a ring shape and are sometimes drawn as hexagons or pentagons. When simple sugars are linked together to form polymers, they make _____. Sugars can be broken apart by the cell to produce _____. They are an _____ 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 is the primary molecule your cells use for energy.

WRITE DOWN A FACT ABOUT EACH MOLECULE:

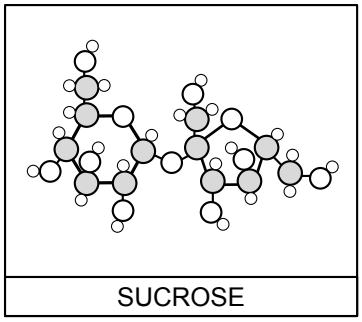




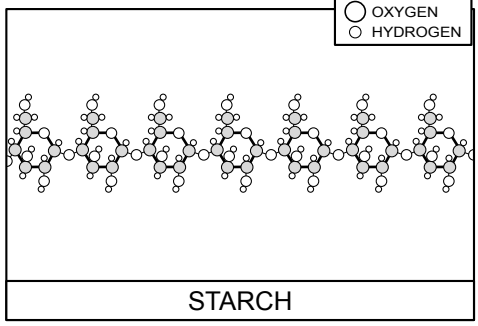
GLUCOSE



FRUCTOSE



SUCROSE



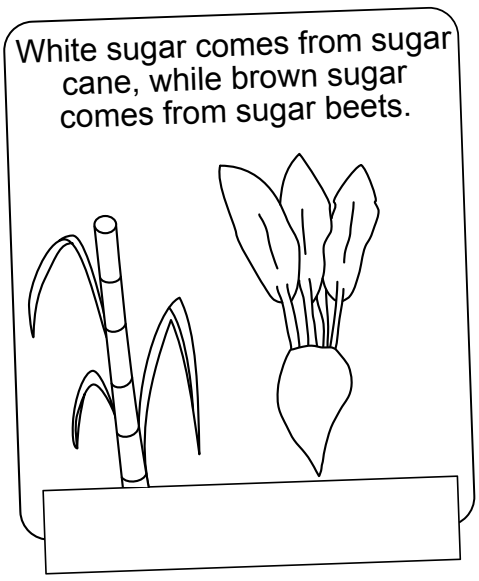
STARCH

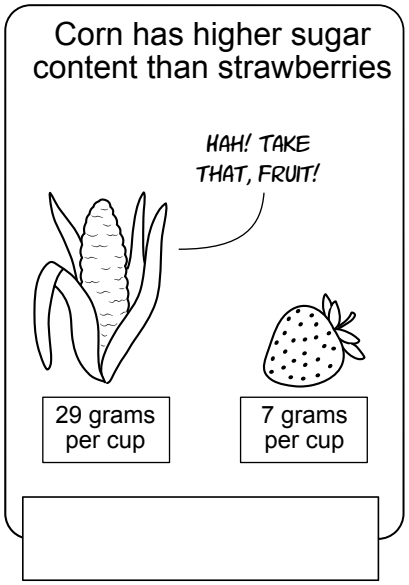
_____ _____ _____ _____

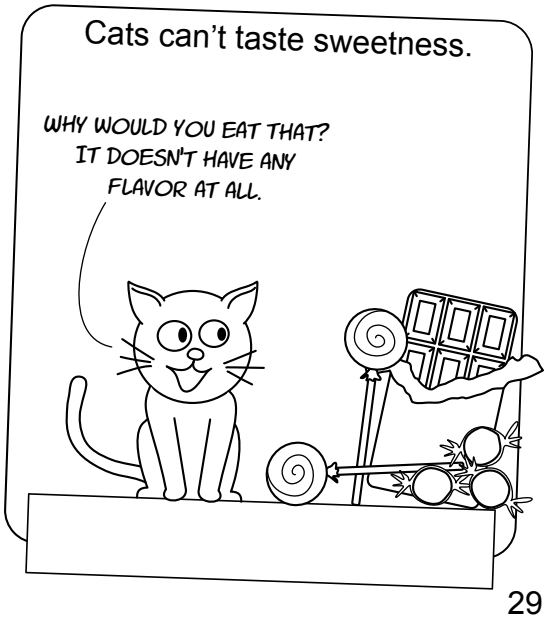
_____ _____ _____ _____

_____ _____ _____ _____

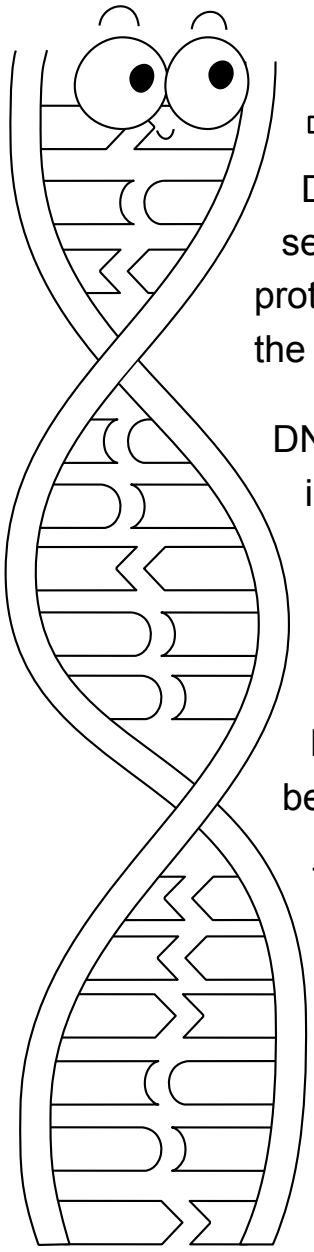
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*







DNA stands for Deoxyribonucleic Acid



FILL IN THE BLANKS USING THESE WORDS:

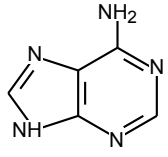
nucleotides | cell | polymer | instructions | molecules | four

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

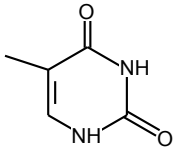
DNA is like a set of _____ for everything that happens in the cell. It is an incredibly long molecule with millions of nucleotides repeating in long sequences. But there are only _____ types of nucleotides in DNA: adenine, thymine, cytosine, and guanine.

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

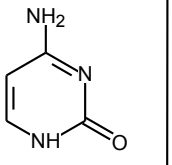
A
Adenine
$C_5H_5N_5$



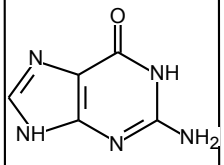
T
Thymine
$C_5H_6N_2O_2$



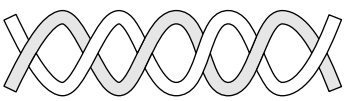
C
Cytosine
$C_5H_5N_3O$



G
Guanine
$C_5H_5N_5O$



SINGLE HELIX



DOUBLE HELIX

CAN YOU FIGURE OUT WHICH BASES PAIR TOGETHER?

_____ *pairs with* _____.

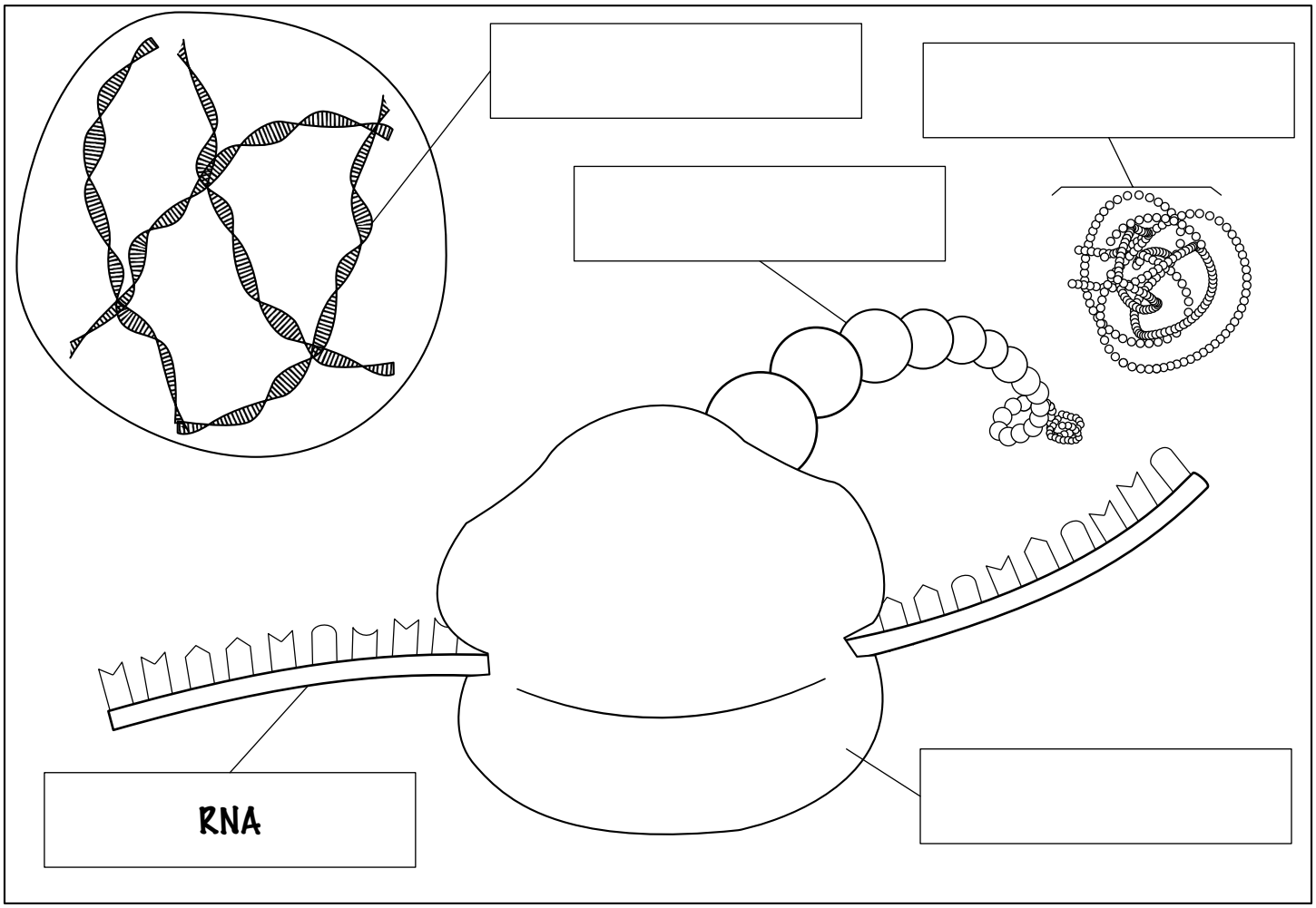
_____ *pairs with* _____.

The Blueprint for Life

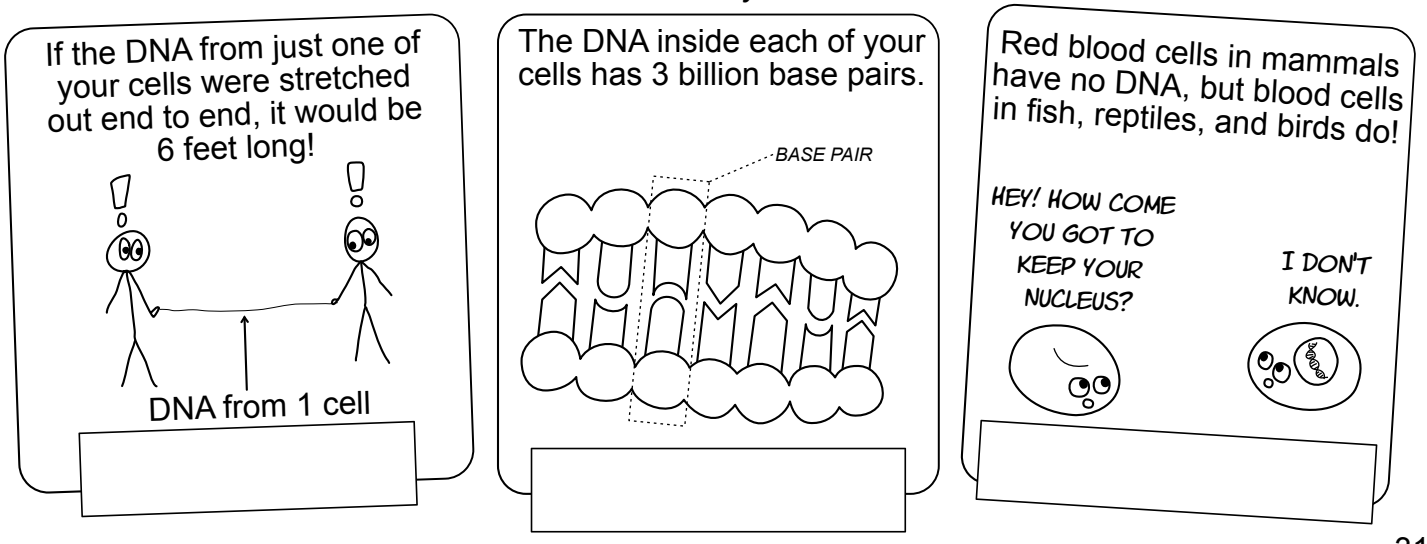
We'll learn more about genetics in Biology 2, but here is a simple overview of how DNA controls protein creation in the cell: the DNA is "transcribed" into a shorter RNA molecule that leaves the nucleus. The RNA is then "read" by a ribosome that matches the nucleotides with the correct amino acids to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

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

RIBOSOME DNA AMINO ACID PROTEIN



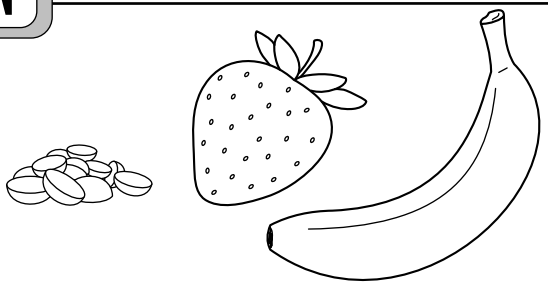
Are these FACT or FICTION? *Write your verdict below each statement:*



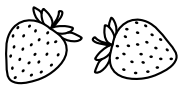
Hands-on Science Project

DNA EXTRACTION

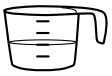
Take Note! This activity can be done with split peas, bananas, OR strawberries. You can choose whichever version is most convenient or try them all and compare them!



OPTION ONE: STRAWBERRY



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



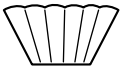
½ cup warm water
(4 ounces)

1 tsp salt
(6 grams)

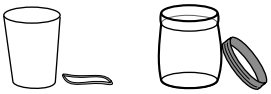
Plastic bag OR a bowl and fork for squishing the strawberry to a pulp.

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.

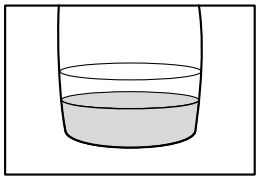
2. Thoroughly squish the strawberries. There should be no chunks or large pieces when you are done.

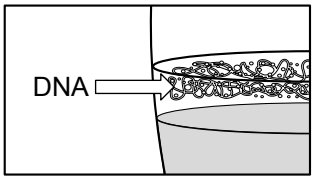
3. Make your extraction solution by mixing together the water, salt, and dish soap. Then add 2 to 3 teaspoons of extraction solution to your squished strawberry and stir gently for one minute.

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.

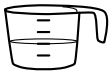
6. Observe and watch for a white foamy substance to form in the rubbing alcohol. This Is your DNA! If desired, you can use a toothpick or fork to lift it out.





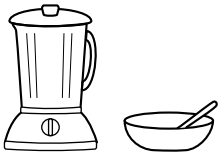
OPTION TWO: BANANA

½ ripe banana, completely frozen and then thawed.



½ cup warm water
(4 ounces)

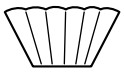
1 tsp salt
(6 grams)



Blender or bowl and fork for pulverizing the banana.

2 tsp concentrated dish soap
(10 ml)

Rubbing alcohol
(91 percent)



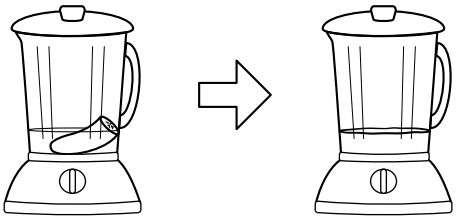
Coffee filter

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

Instructions

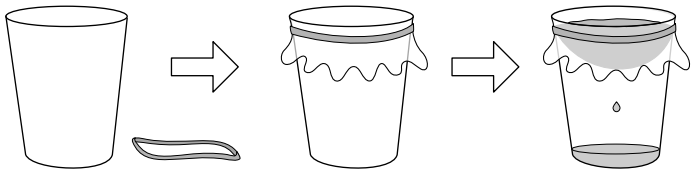
1. Place your rubbing alcohol in the fridge.

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.



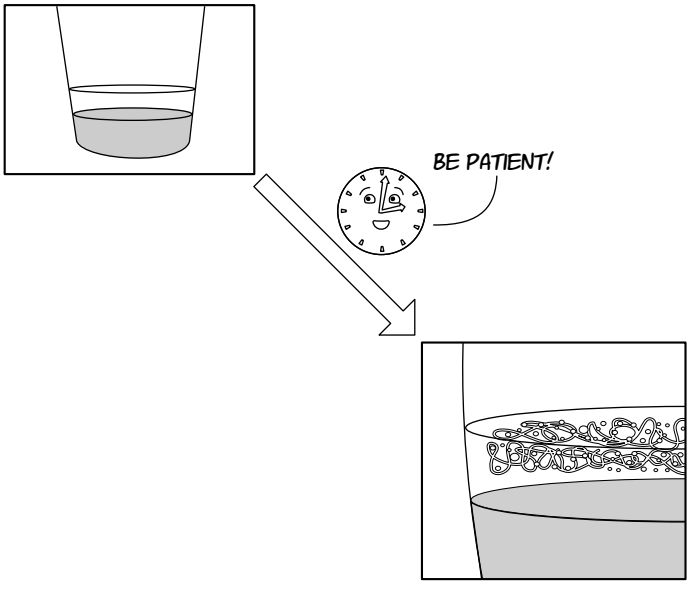
3. Transfer mixture to a cup and add 1 tsp salt and 1 tsp liquid soap.

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.

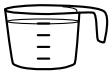
6. Remove the filter and pulp. Tip the cup or jar to the side and slowly add a layer of cold rubbing alcohol on top of the banana juice. The goal is for the amount of rubbing alcohol to be roughly equal in height to the layer of fruit liquid.



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)



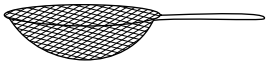
1 cup water
(8 ounces)

1/8 tsp salt
(1.5 grams)

Electric blender

1 tsp concentrated
dish soap *(15 ml)*

Rubbing alcohol
(91 percent)



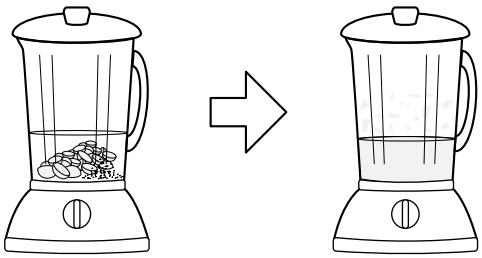
Mesh
strainer

Narrow test tube or
a small clear cup

Meat
tenderizer

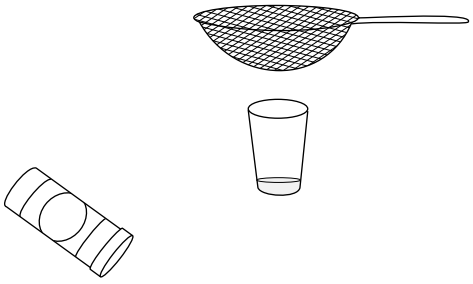
Instructions

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.

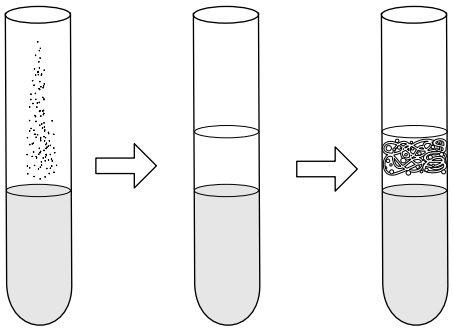
3. Add one tablespoon of soap to the strained split pea juice. Mix slightly and let sit for at least 5 minutes. During this step the soap is dissolving the membranes and releasing the DNA.



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!

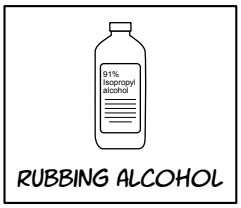


Strawberry vs Banana vs Pea

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?

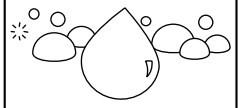
Draw lines to match each ingredient or step with what it's doing:



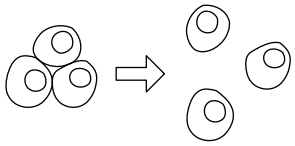
RUBBING ALCOHOL

MASHING OR BLENDING THE FOOD.

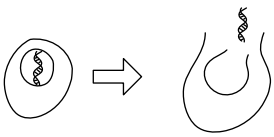
SALT



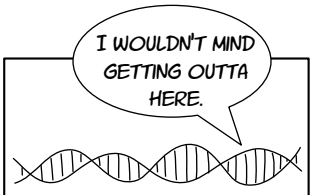
SOAP



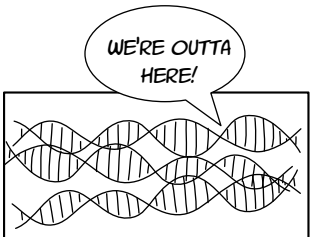
SEPARATES THE CELLS FROM EACH OTHER



BREAKS OPEN THE CELLULAR MEMBRANES



HELPS DNA BE LESS DISSOLVED IN THE WATER



MAKES THE DNA STRANDS CLUMP TOGETHER

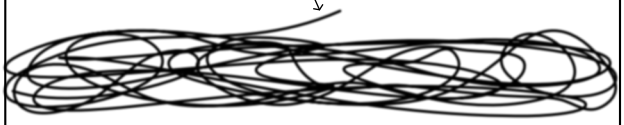
YOUR OBSERVATIONS

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

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

DNA UNDER A LIGHT MICROSCOPE

THIS IS NOT ONE STRAND, IT'S HUNDREDS OF STRANDS CLUMPED TOGETHER, AND WRAPPED AROUND PROTEINS TOO.



CAN ONLY SEE LARGE CLUMPS.
NO DOUBLE HELIX WILL BE VISIBLE.

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**

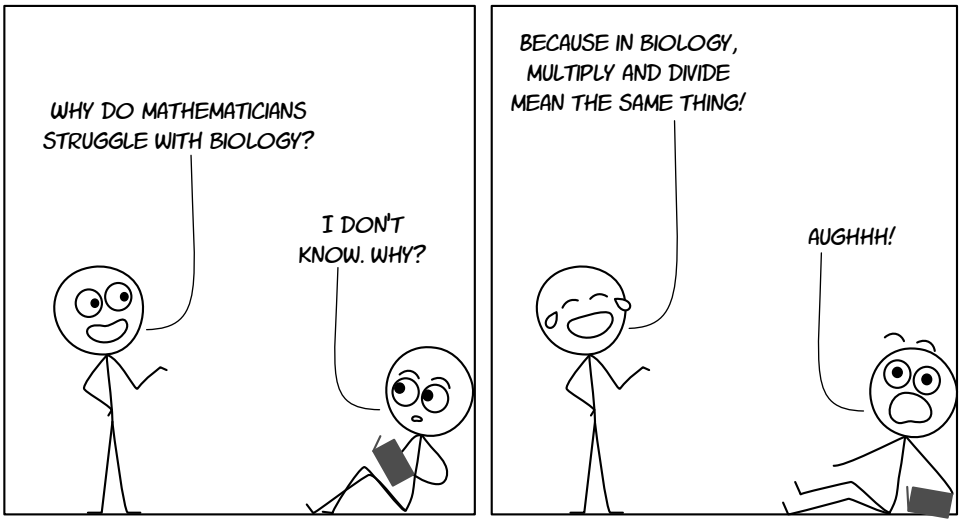
STILL DIFFICULT TO SEE. WE KNOW DNA HAS A DOUBLE HELIX STRUCTURE BECAUSE OF HOW XRAYS DIFFRACT OR BOUNCE OFF THE MOLECULE.

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

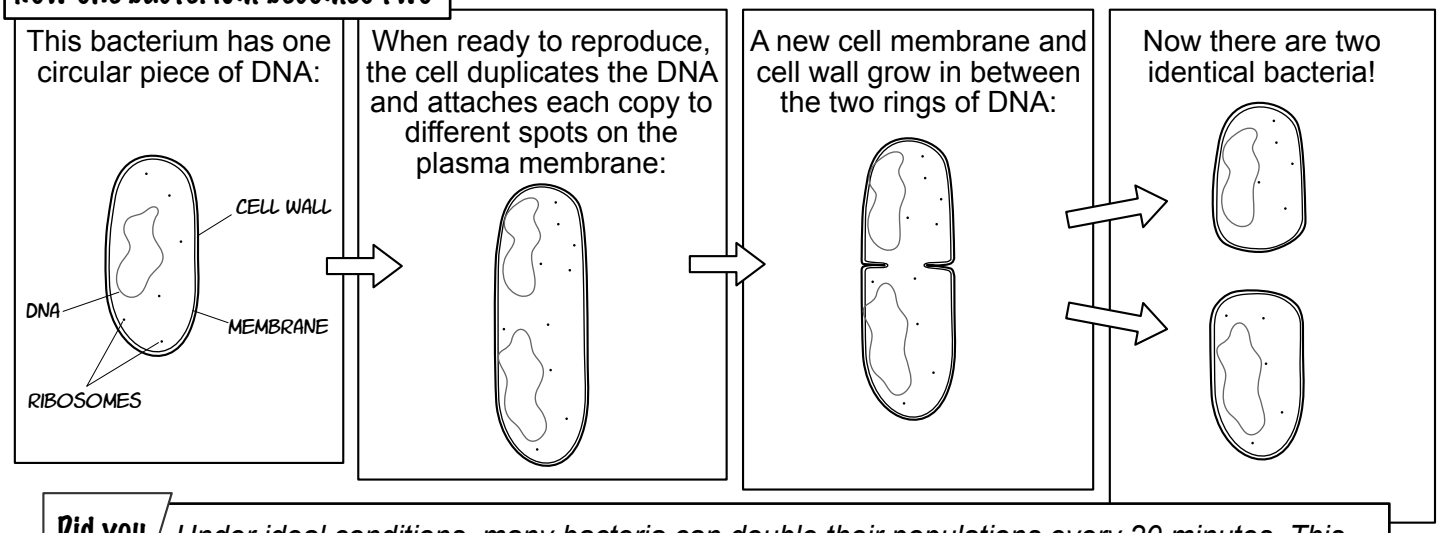
Cell Division

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.

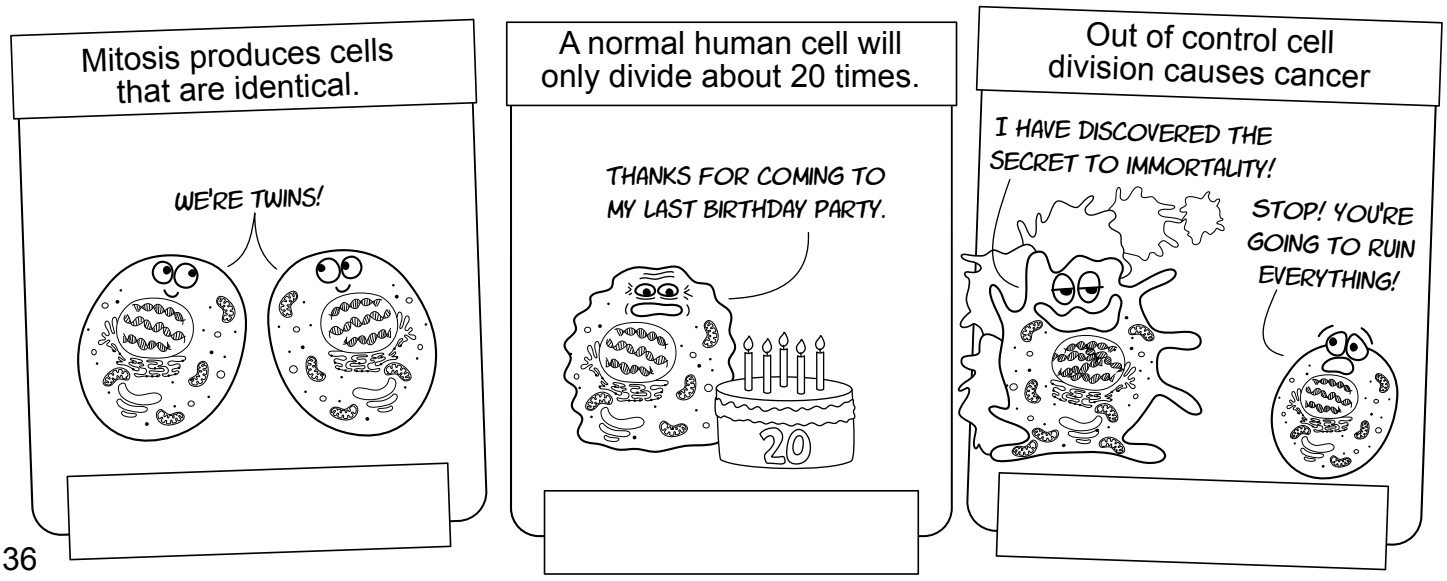


How one bacterium becomes two



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:*



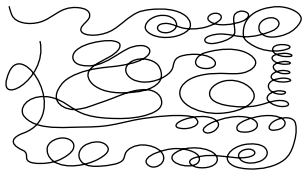
Mitosis

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 _____ itself, it needs to make extra copies of the DNA and separate them. For this step, the DNA is packed tightly with small _____ 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 _____ of the nucleus reforms in each cell and the _____ in the chromosomes unpacks again so it can be used by the cell. This process of cell division is called _____.

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.

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

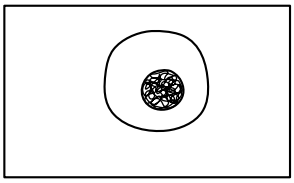
Prophase
The cell prepares to divide by condensing the DNA.

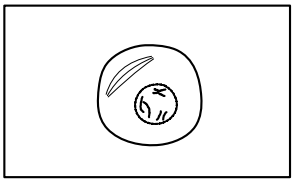
Interphase
The DNA is inside the nucleus, loose and uncondensed. This is the longest phase of the cell cycle.

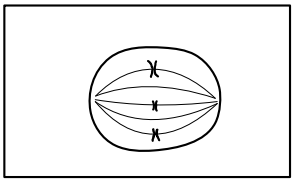
Metaphase
Pairs of tightly packed DNA line up in the center of the cell.

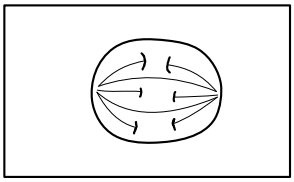
Telophase and Cytokinesis
A nuclear membrane forms around the DNA and a cleavage furrow forms between the two nuclei.

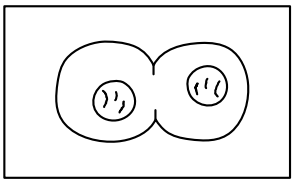
Anaphase
Thin strands called microtubules pull the chromatids apart to opposite ends of the cell.

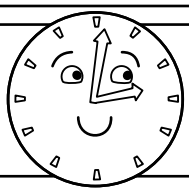












Quiz Time!

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
    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 _____.

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
    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

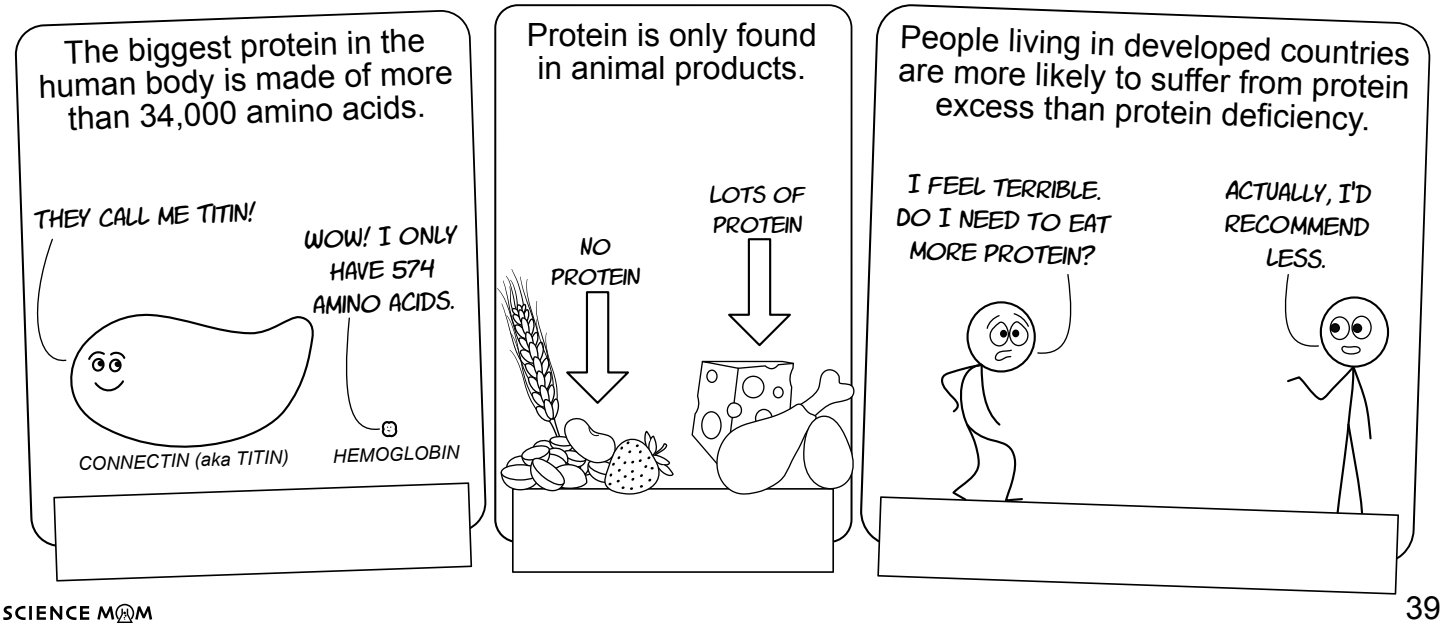
19 Draw a picture of a phospholipid:

20 Draw a picture of a protein molecule:

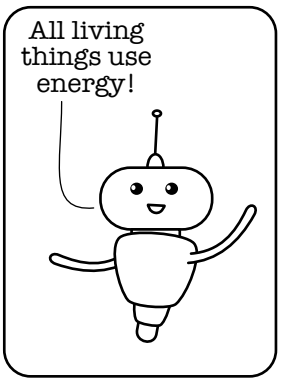
21 Draw a picture of a DNA molecule:

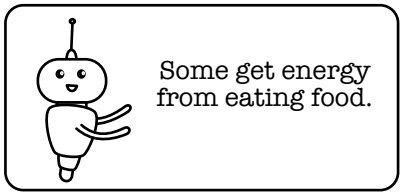
22 Draw a picture of a sugar molecule:

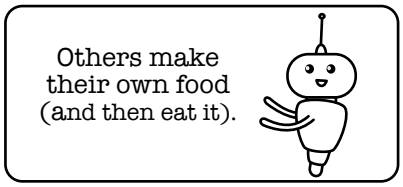
ARE THESE FACT OR FICTI0N? *Write your verdict below each statement:*



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

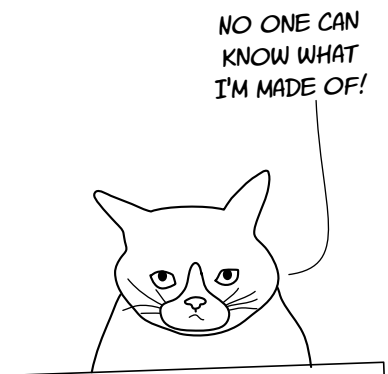

frog

DETRITIVORE - eat decaying things	HERBIVORES - eat plants or algae
worms	

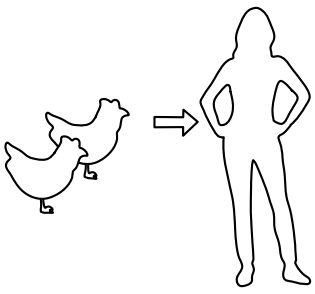
CARNIVORES - eats other animals	OMNIVORES - eat plants and animal matter

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

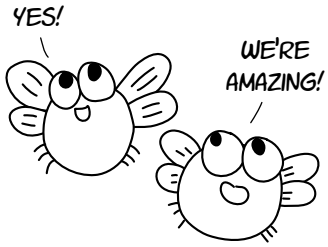
All animals are multicellular consumers made of eukaryotic cells.



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



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

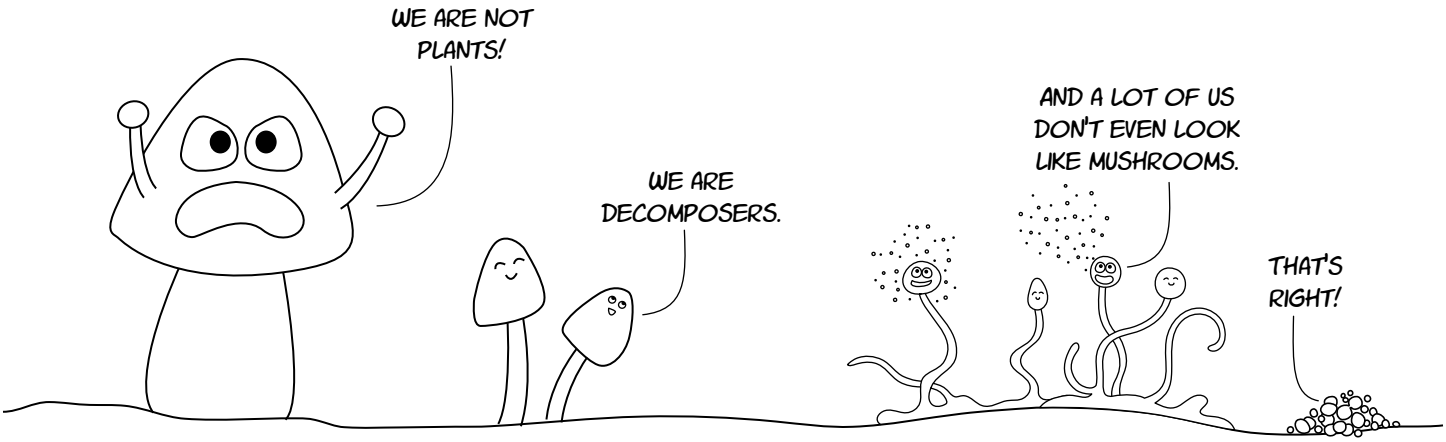


Fabulous Fungi

FILL IN THE BLANKS USING THESE WORDS:

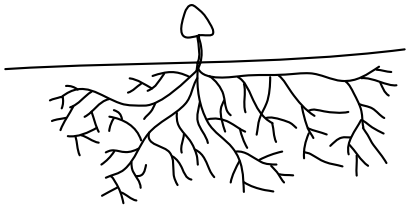
agrees	yeast	trees	organic	infecting
energy	digest	plants	specialize	consumers

All fungi are _____. They get their _____ from eating plant or animal matter. Most fungi are decomposers, meaning they break down _____ matter and _____ 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 _____. Many species _____ in attacking and then _____ living plants or animals. No matter what type of fungus you have, from single-celled _____ to slime molds to mushrooms, every biologist _____ that fungi are not _____!

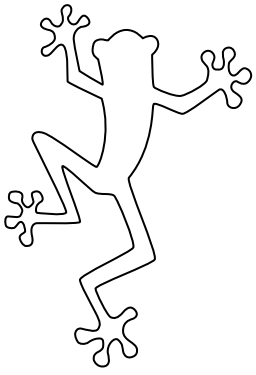


ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

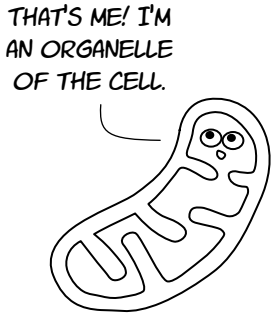
If you see a mushroom on your lawn, most of the mass of that fungus is underground.



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



Fungi cells don't contain mitochondria.



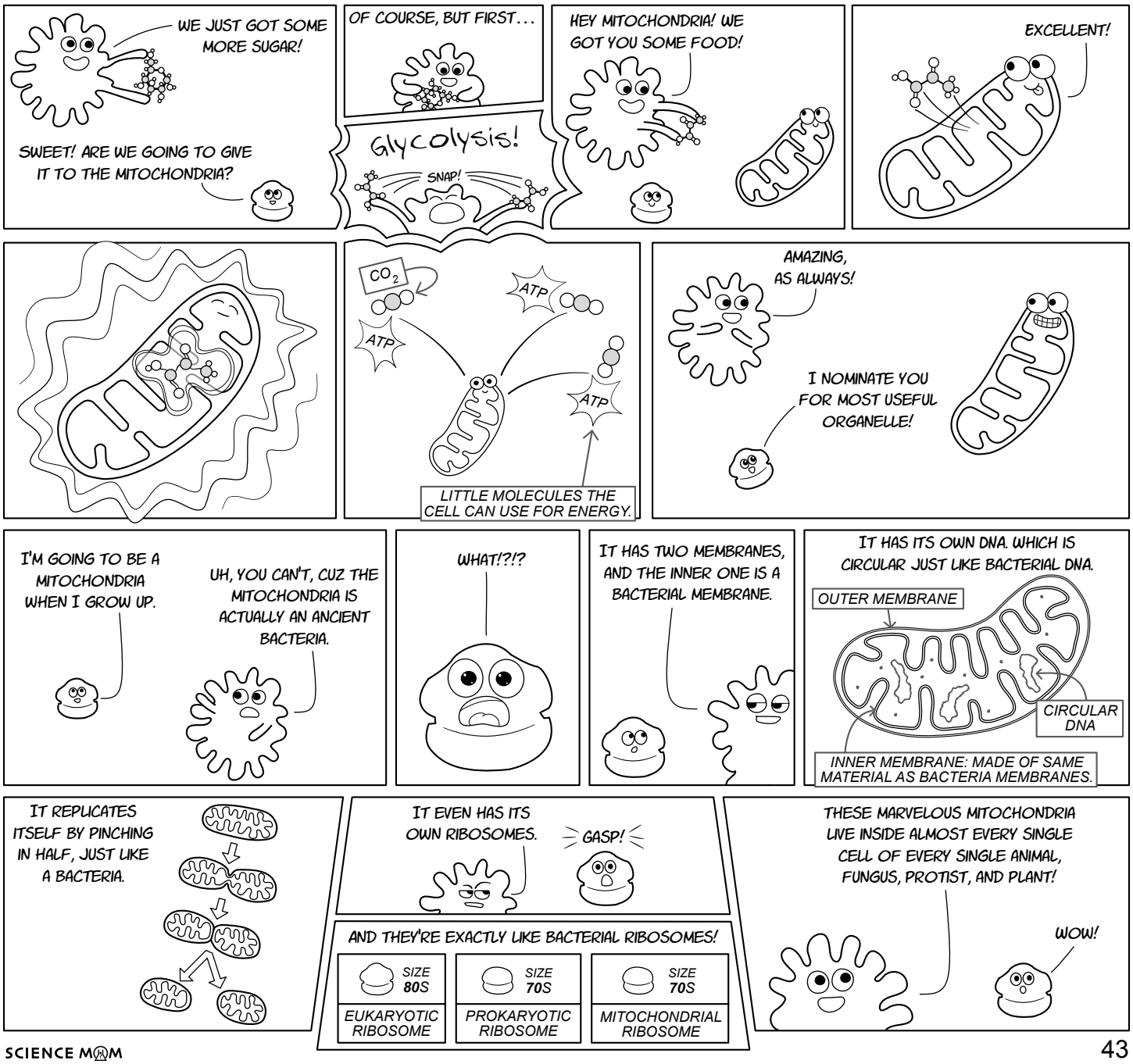
Cellular Respiration

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 _____, one of the most important reactions on the planet! It starts with _____, which is an excellent source of _____. Before the energy can be released, the glucose needs to be split in half. This is called _____. Next the _____ uses oxygen to break the molecules into smaller pieces until they are converted to _____ dioxide and water.

Mitochondria - The MVP with a mysterious past

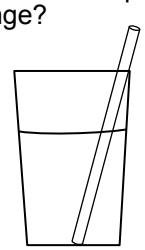


Try these activities to learn more about cellular respiration!

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?

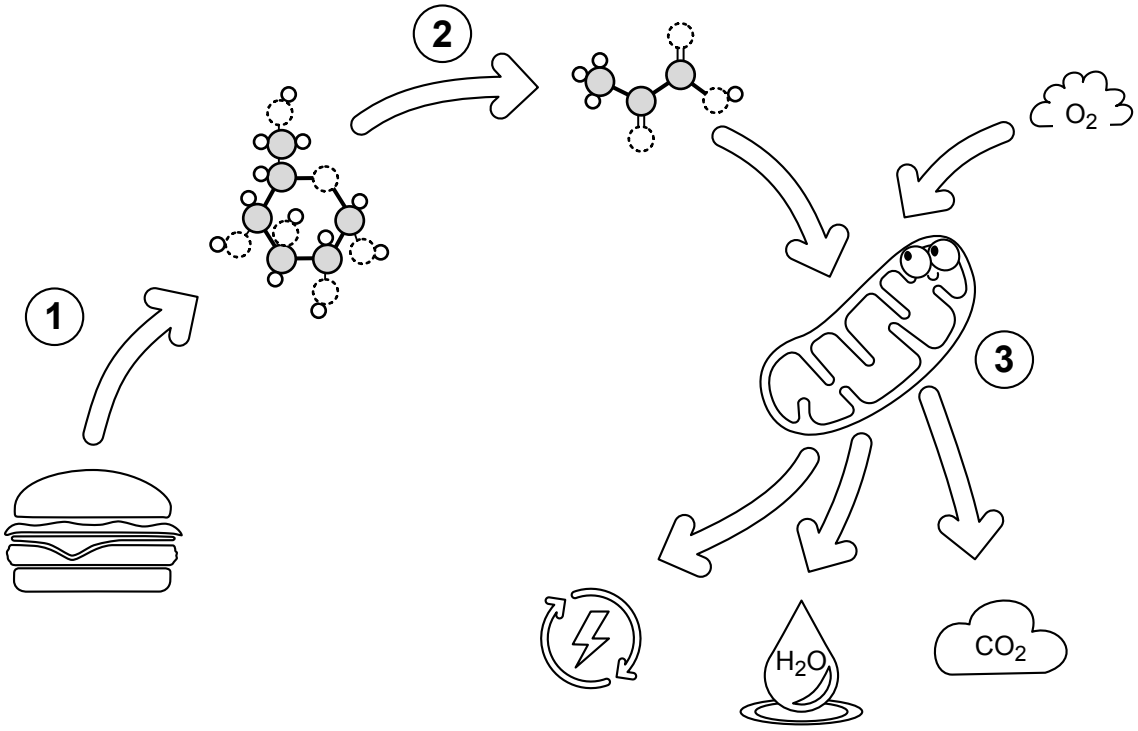
½ water and ½ air

all water

THE EQUATION

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

Glucose | Oxygen | Carbon Dioxide | Water



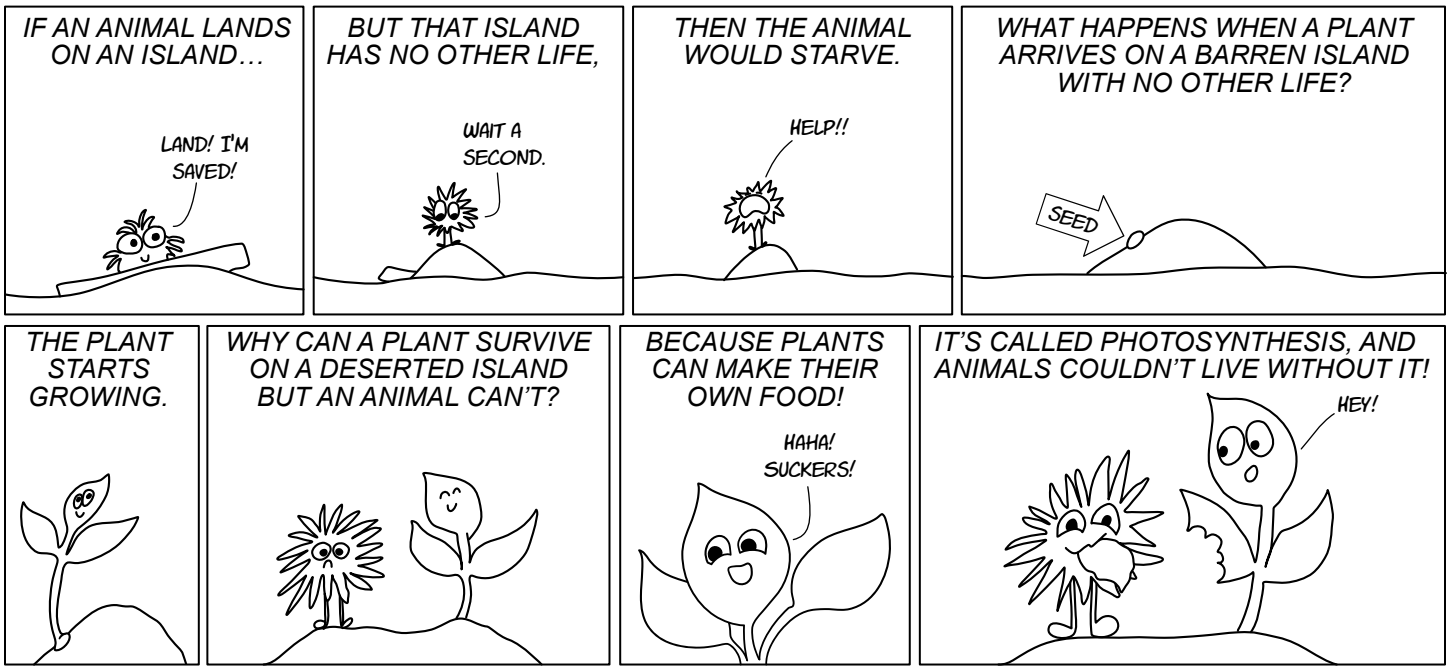
Write the correct number from the diagram in the box with the matching description:

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

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

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?

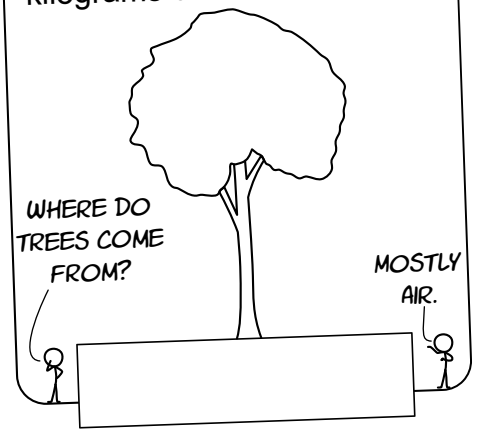
Example: A WOODEN DESK MADE FROM PARTICLEBOARD COMES FROM POPLAR TREES AND PINE TREES.

1. _____ *2.* _____

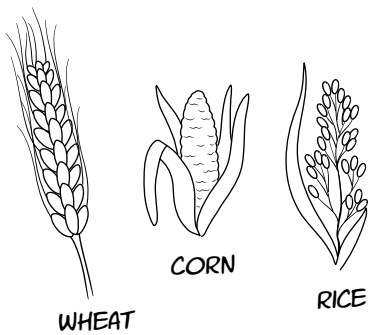
3. _____ *4.* _____

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

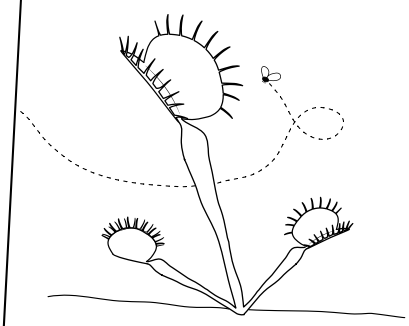
In a tree weighing **100,000** kilograms, approximately *95,000* kilograms came from air and water and *only 5,000* kilograms came from the soil.



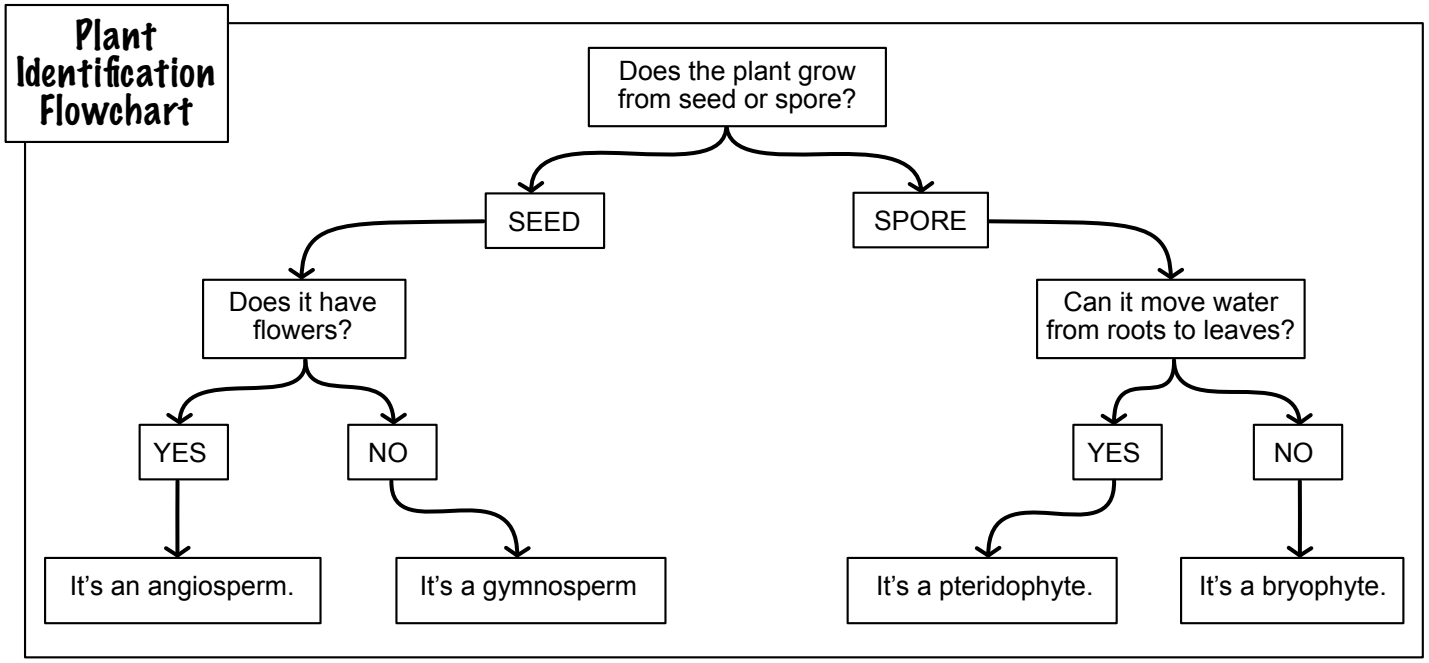
Approximately 90% of the world's food energy is provided by just 15 plants.



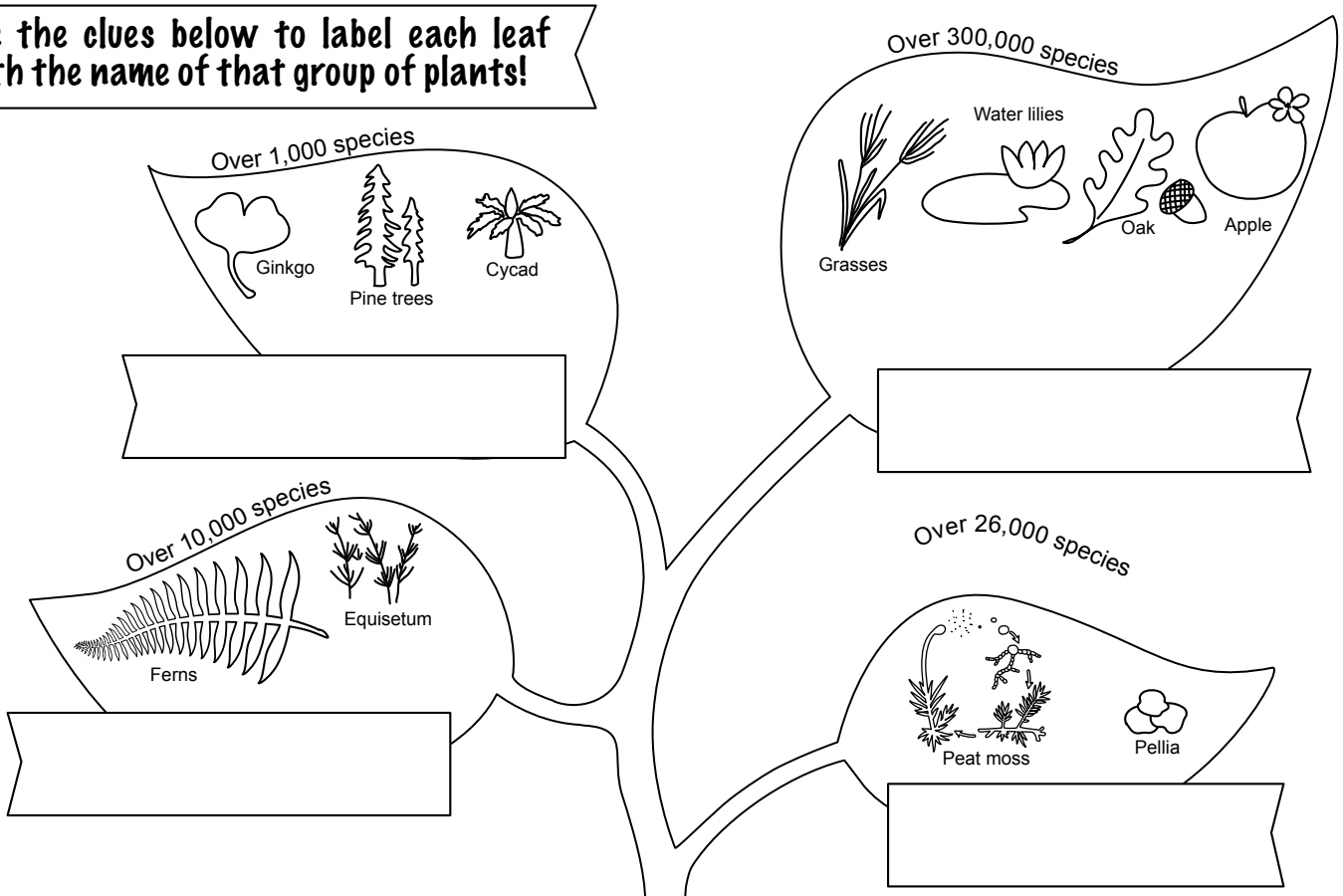
Carnivorous plants don't perform photosynthesis.



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 _____ by capturing _____ _____ in the atmosphere and converting it into _____ molecules. During the reactions of photosynthesis, water is split and oxygen gas is released from the plant. Photosynthesis is powered by _____ _____. It can't happen without sunlight!

In plants and many algae, photosynthesis takes place in an organelle called the _____.

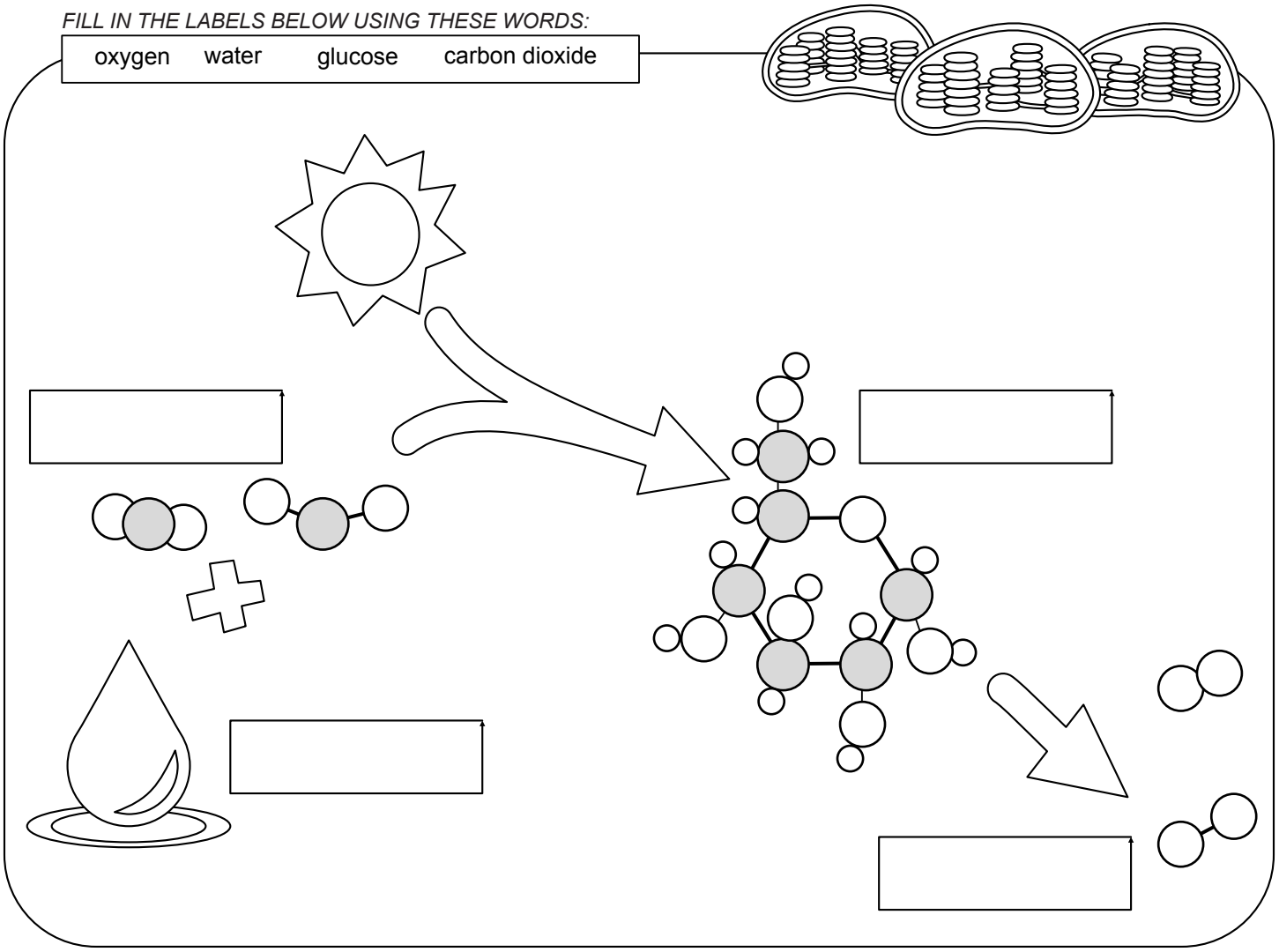
THE EQUATION

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

Water | Carbon Dioxide | Glucose | Oxygen

FILL IN THE LABELS BELOW USING THESE WORDS:

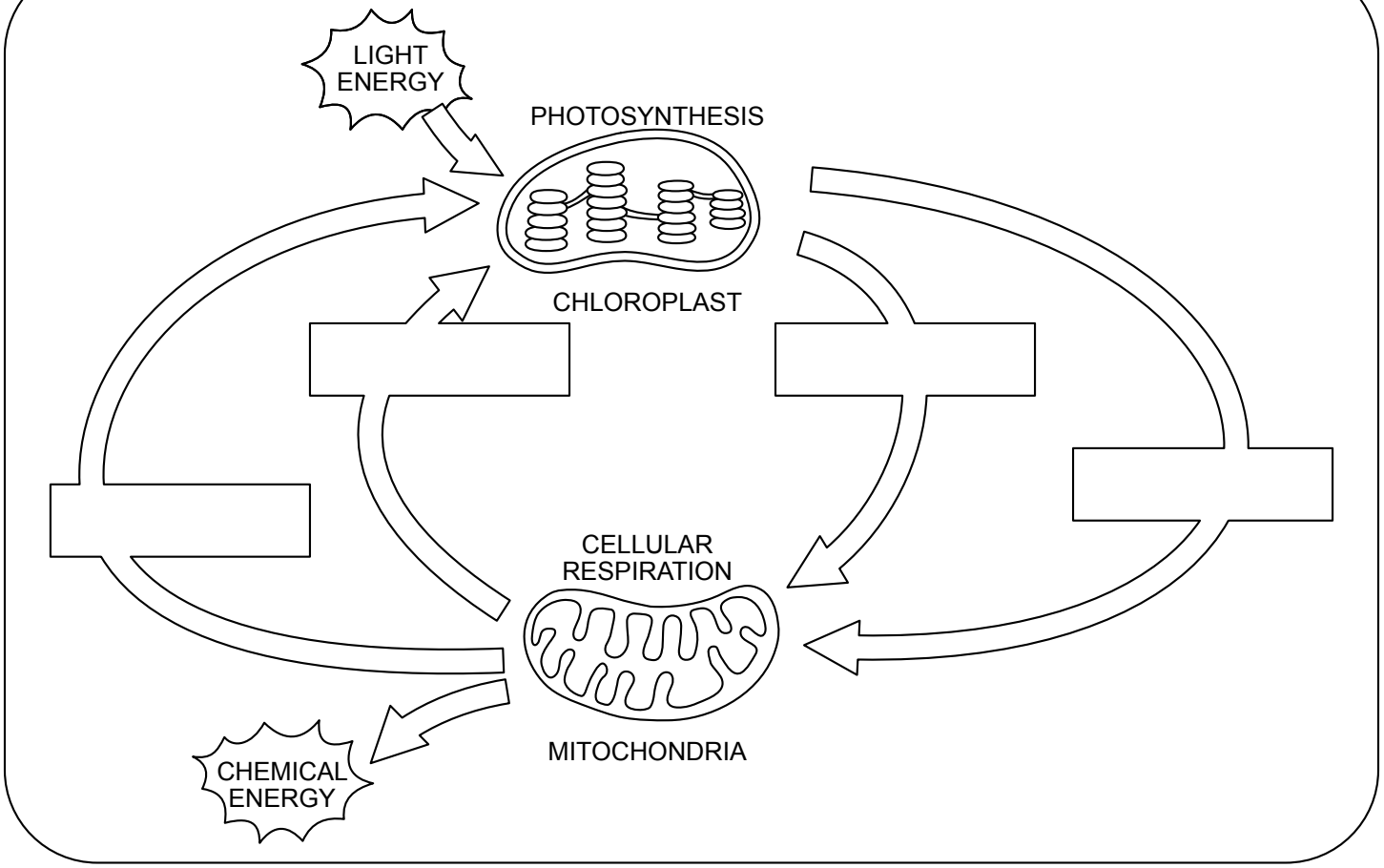
oxygen	water	glucose	carbon dioxide



The Cycle of Photosynthesis and Respiration

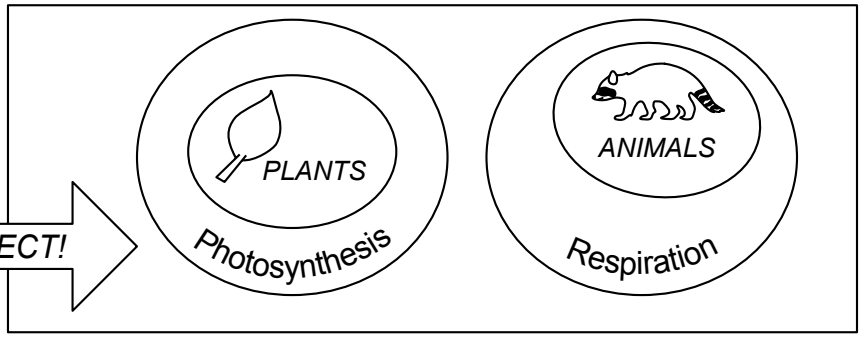
FILL IN THE LABELS BELOW USING THESE WORDS:

oxygen water glucose carbon dioxide



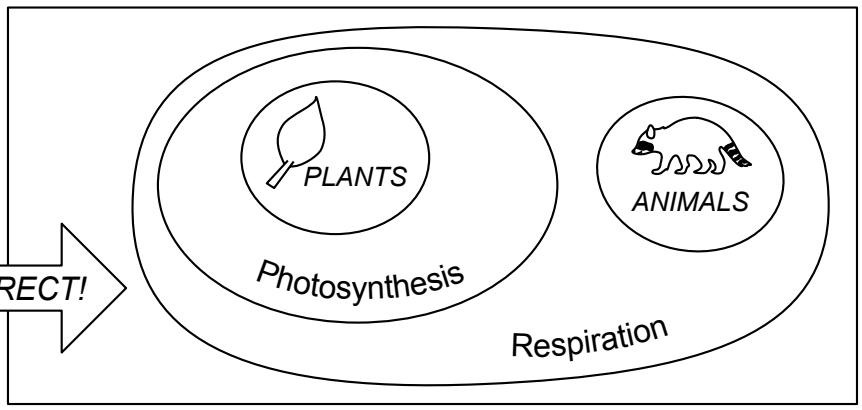
Some people think that plants only do photosynthesis and that animals only do respiration. If this were true, a Venn diagram of these organisms and their energy pathways would look like this:

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!



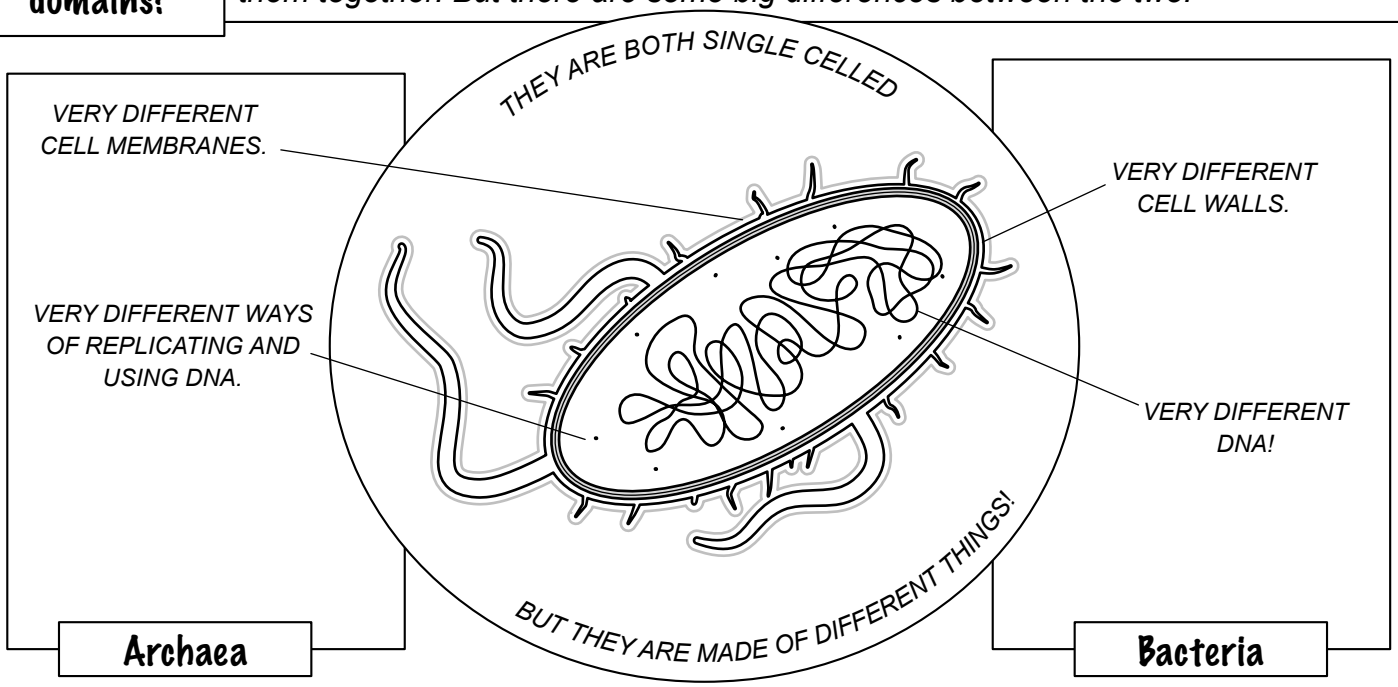
Prolific Prokaryotes

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!

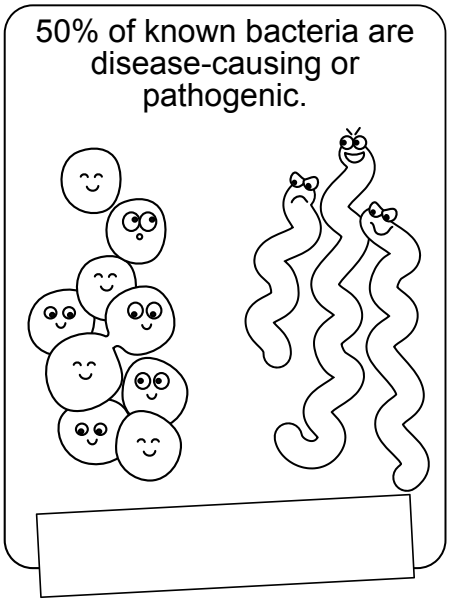
In terms of how they get energy and use it, prokaryotes are the most diverse and well distributed organisms on Earth. They are everywhere from deep sea vents to salt flats, glaciers, soil, and inside of you!

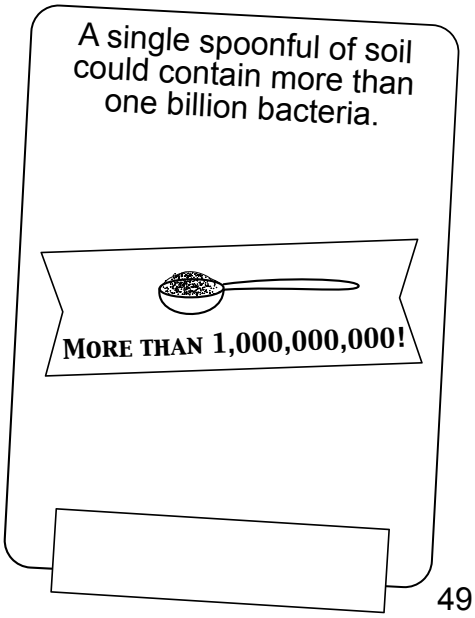
Why two domains?

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:*

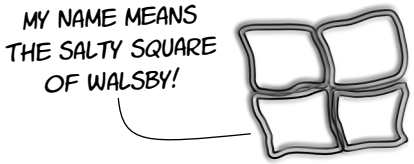




Mixed up Microbes

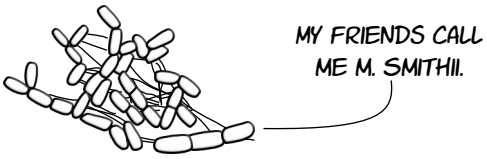
Draw lines to match each microbe with the correct habitat?

Haloquadratum walsbyi



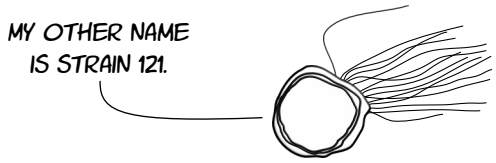
FOOD: Carbon containing compounds
ENERGY SOURCE: food OR light
OXYGEN? Yes please!
SPECIAL SKILLS: Can live in SUPER salty water. Has little bubbles (vesicles) to help it float.

Methanobrevibacter smithii



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

Geogemma barossii

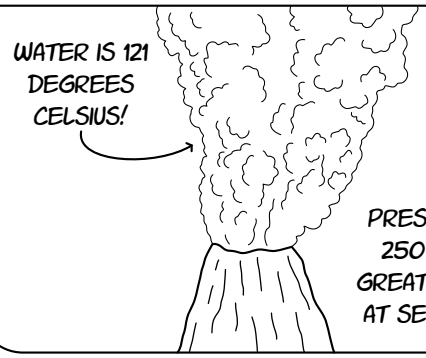


FOOD: Iron and Hydrogen gas!
ENERGY SOURCE: food
OXYGEN? No thanks.
SPECIAL SKILLS: Can live in total darkness and survive being autoclaved.

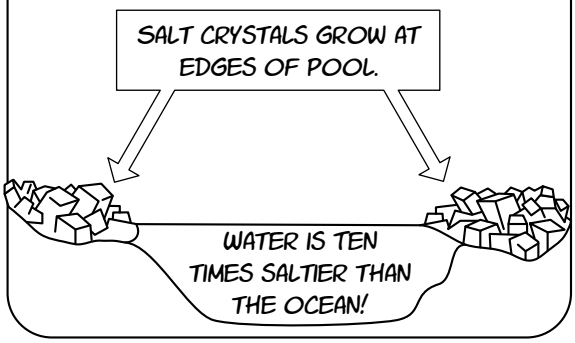
Deinococcus radia

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."

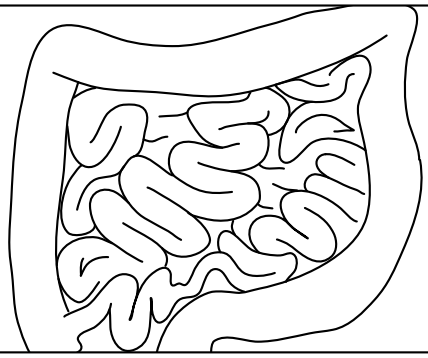
DEEP SEA VENT



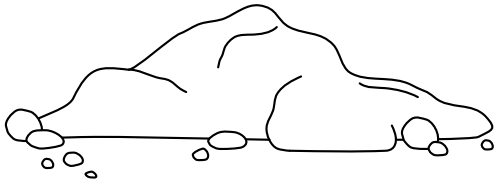
SALTY BRINE POOL



AN ANIMAL'S INTESTINES



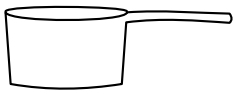
DIRT



Hands-on Science Project

HOMEMADE PETRI DISHES

MATERIALS:

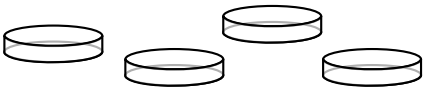


Stove and a pot for boiling water

8 ounces water

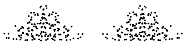
1 bouillon cube
or 1 tsp bullion granules

Cotton swabs



4 petri dishes or other clear and clean containers with lids

1 Tbsp agar
or 1 packet unflavored gelatin



2 Tsp sugar

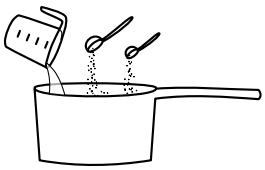
Permanent marker

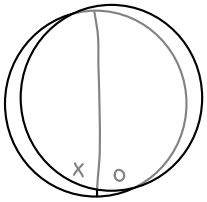
1. Prepare the Petri Dishes

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.

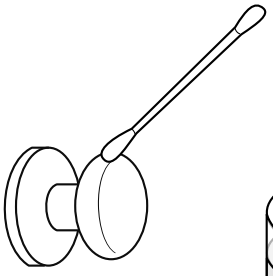
3. Once the solution has cooled somewhat, carefully pour it into the petri dishes so that each dish is about half full. Cover the dishes and let them cool completely without being disturbed. The dishes can be cultured after they are cool, or they can be placed in the fridge for a day before taking samples.

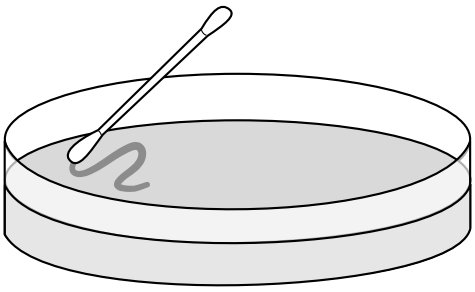




For BEST results

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





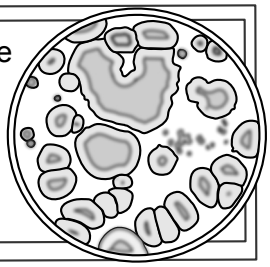
2. Collect samples and swab the plates!

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:

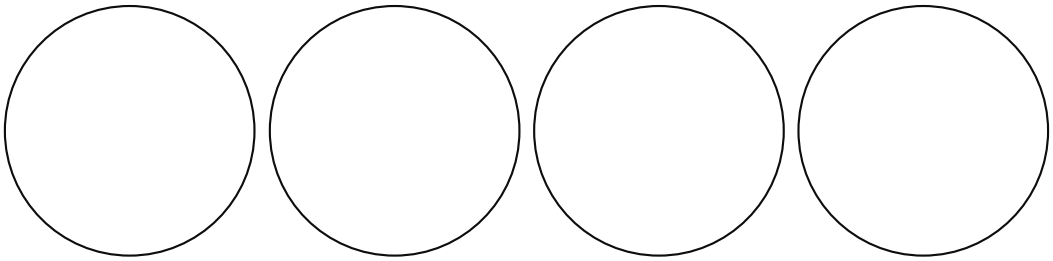
Observations:

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.

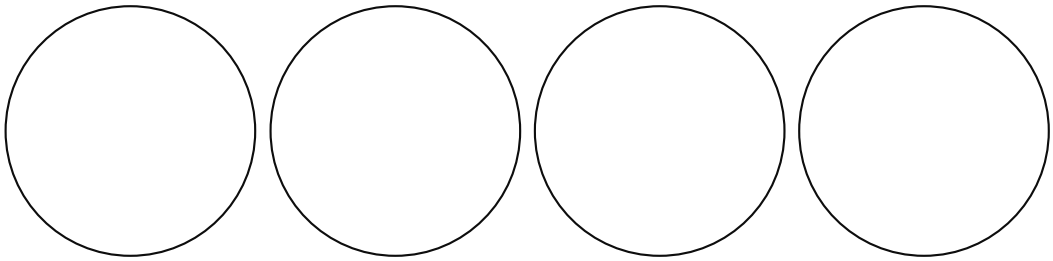
**The fastest/best growth will happen between 21° and 32° C (70° and 90 °F) If temperatures get above about 40 °C or 105 °F, then you will start to see less growth on the plates. It is not recommended to let your plates get above 32° C or 90° F.*

Observations:



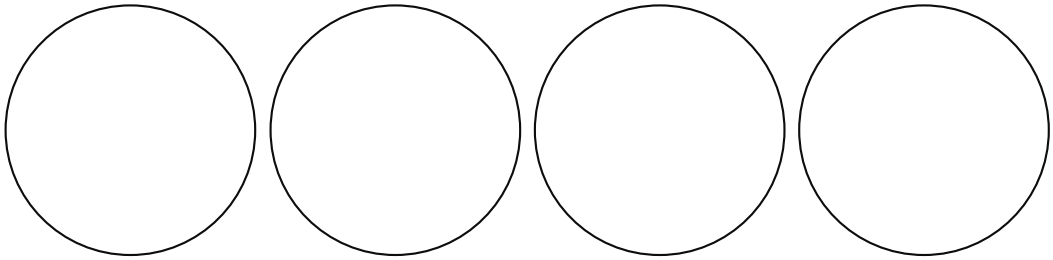
DATE:

Observations:

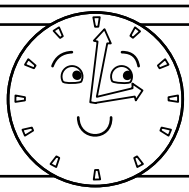


DATE:

Observations:



DATE:



Quiz Time!

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

1. Omnivores are heterotrophs.
   A. True
   B. False

2. The chloroplasts in fungi cells are white instead of green.
   A. True
   B. False

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

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

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

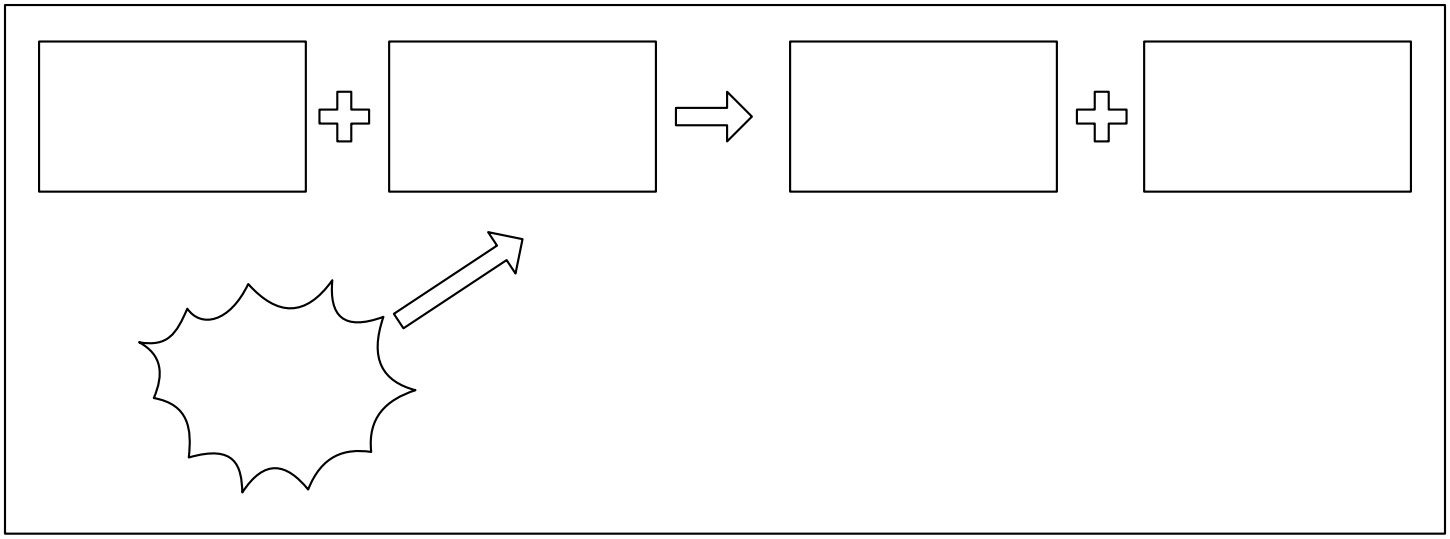
14. What is the scientific name for a flowering plant?
    A. Gymnosperm
    B. Angiosperm
    C. Bryophyte
    D. Pteridophyte

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

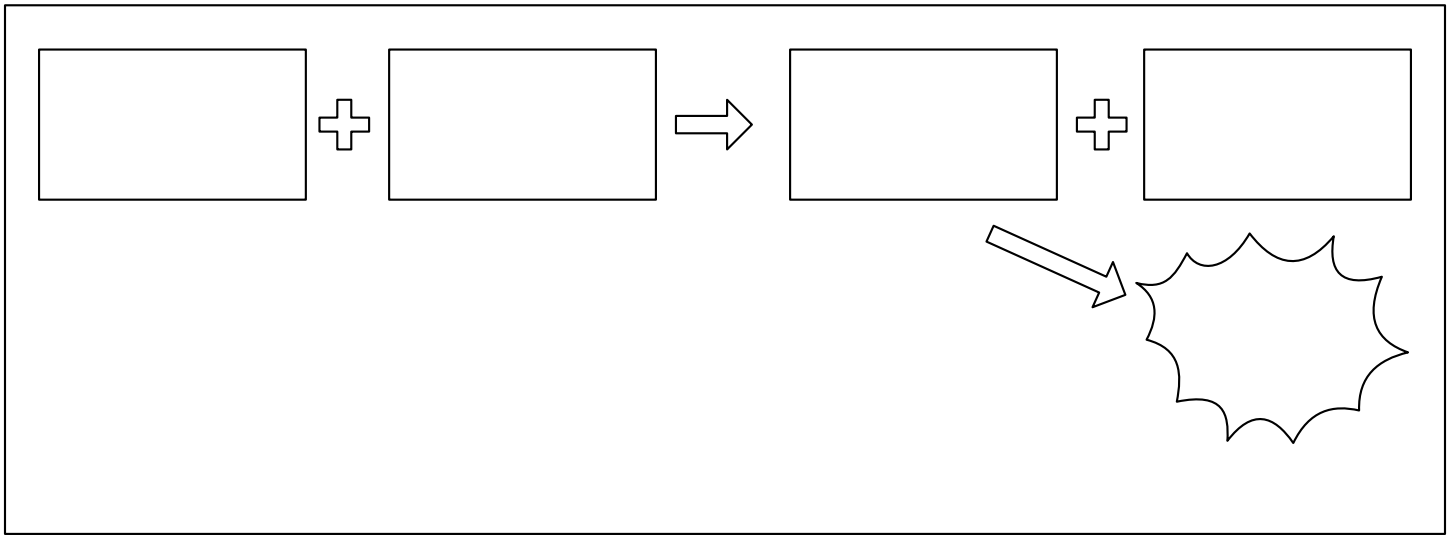
16. Most bacteria cause diseases.
    A. True
    B. False

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

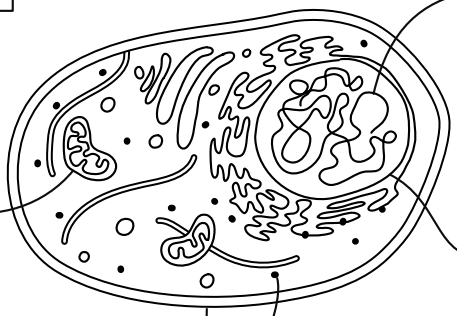
ONLY PHOTOSYNTHESIS	PHOTOSYNTHESIS AND CELLULAR RESPIRATION	ONLY CELLULAR RESPIRATION

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



Makes little snacks the cell can use for energy

The instructions for making things

Keeps the instructions safe!

Keeps the insides inside and the outsides outside.

Makes the things that the instructions tell it to make.

Inside an animal CELL there will be

		9				5		4

to help make

1							

SOBRIMOES

ROPESTIN

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

		6

located inside the

			2			

AND

USCLUNE

7									10		

that generate chemical

8		11			

CHIMTOONDARI

GEERNY

SCIENCE MOM

All of it is surrounded by the

		A							A	N	
1	2		4	5	6	7	8		9	10	11

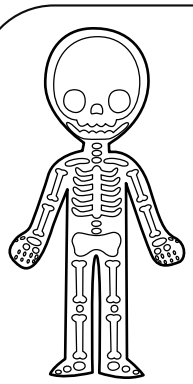
Body Systems

FILL IN THE BLANKS USING THESE WORDS:

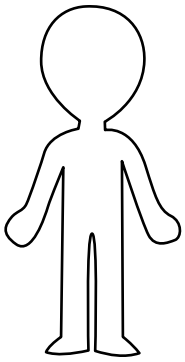
systems
cells
organs
perform
body

Animals are made of _____, 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 _____ a certain task are called systems or _____. The human _____ has many different _____. In the next lessons, we will take a closer look at five of them: the circulatory, respiratory, nervous, digestive, and immune systems.

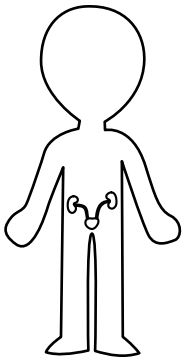
Match the system with the correct description.



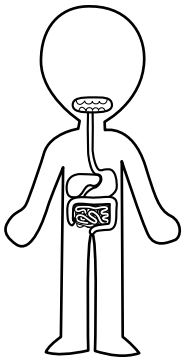
Muscular/ Skeletal



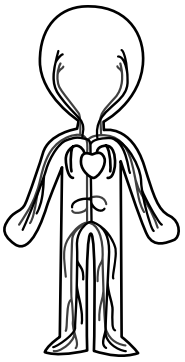
Integumentary



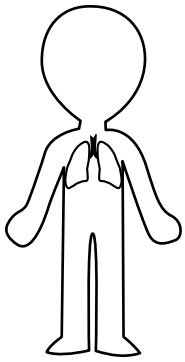
Urinary



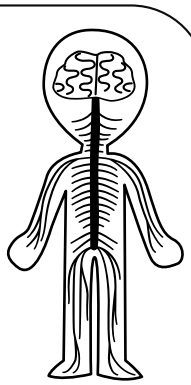
Digestive



Circulatory



Respiratory



Nervous

Moderates body temperature, makes vitamin D, and senses surroundings through touch!

Delivers oxygen, removes carbon dioxide, and protects the body from infection

Provides information, senses, memory, and feeling.

Provides nutrients and changes the food we eat into food that our cells can use.

Provides structure, stability, form, and movement.

Cleans the blood and removes all the waste.

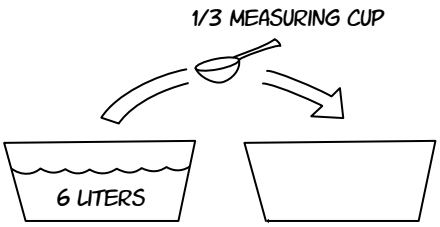
All about breathing, works with the circulatory system to oxygenate the blood.

The circulatory system

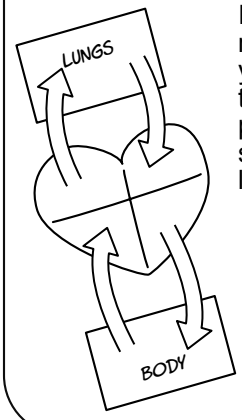
Try these activities to learn more about your circulatory system!

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



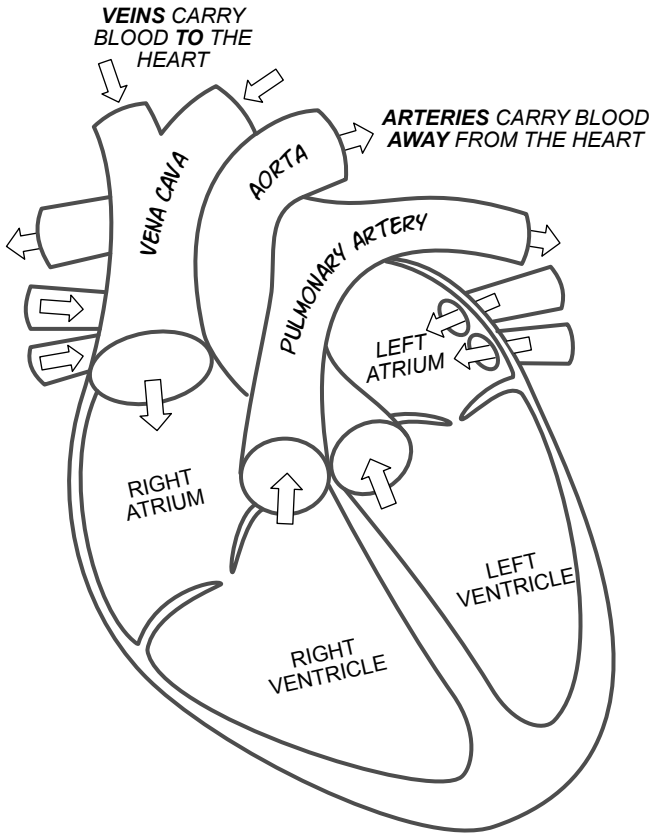
It can be simple or realistic. But however you make it, be sure to include both the pulmonary and systemic circulation loops.

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:*



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.

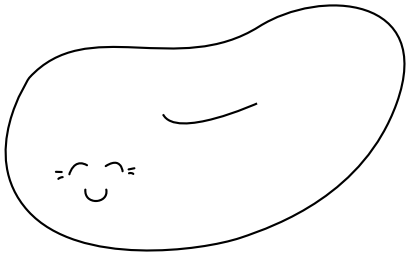
Pulse points are where arteries are close enough to the skin that you can feel the pulse of your heart beating. Which of these could you feel?

- 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

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.

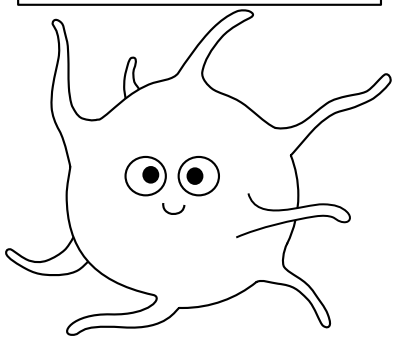
What is blood made of?

Red Blood Cell
Also known as: Erythrocyte



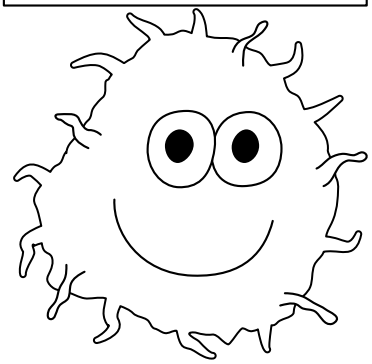
The most common cell in the human body. There are 250 million of these in just one drop of blood! They are full of a protein called hemoglobin that carries oxygen. The hemoglobin is what makes them red.

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



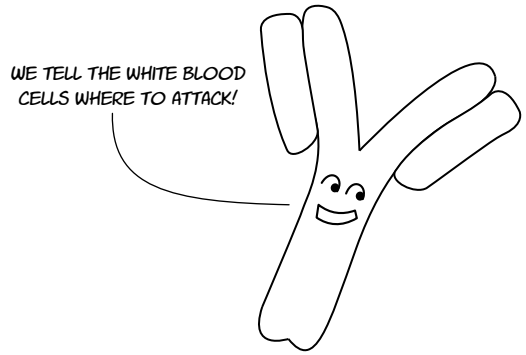
There are a lot of different types of white blood cells. This one is a macrophage and it's really good at eating things like other cells!

Plasma
The liquid that holds the blood cells

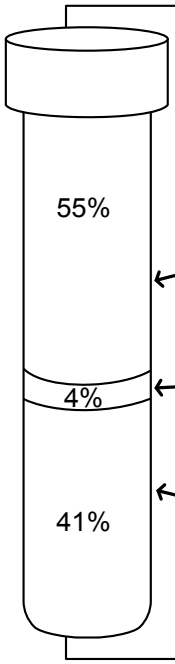
The liquid part of the blood. It is mostly water (95%) but also contains important things like hormones, blood sugar, and dissolved carbon dioxide.

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

Antibodies
Small proteins



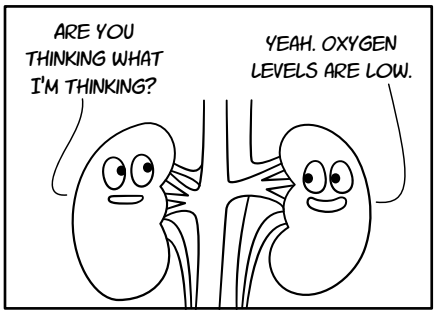
Your notes:

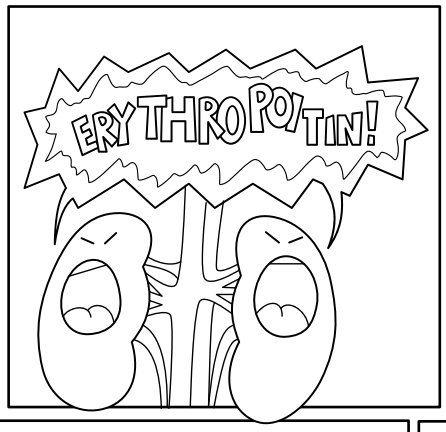


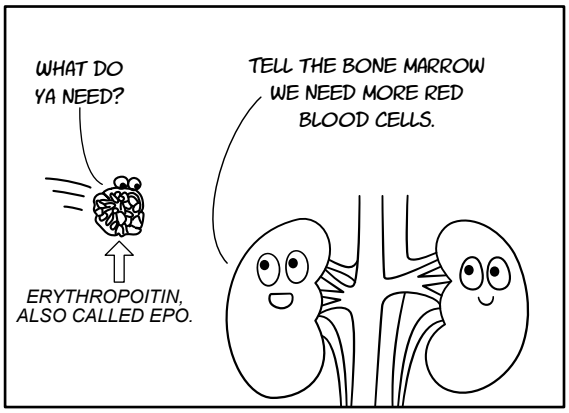
This vial contained a sample of blood that was centrifuged (spun around fast to separate it into layers.) Can you label the layers correctly? One is red blood cells, one is plasma, and the other is white blood cells and platelets.

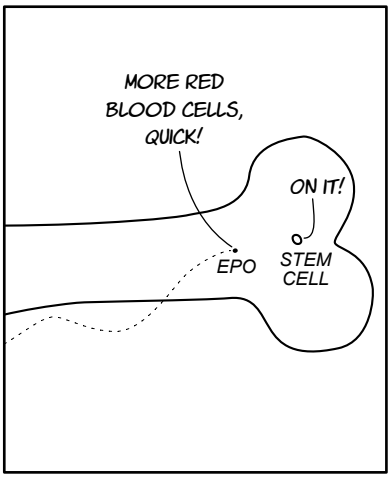
The Life of a Red Blood Cell

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

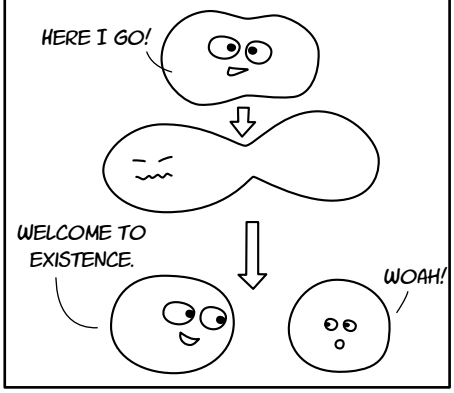




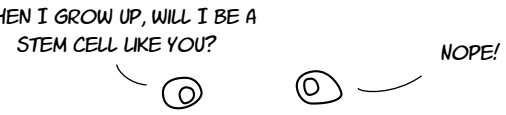


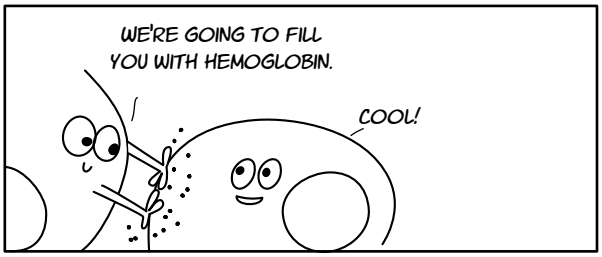


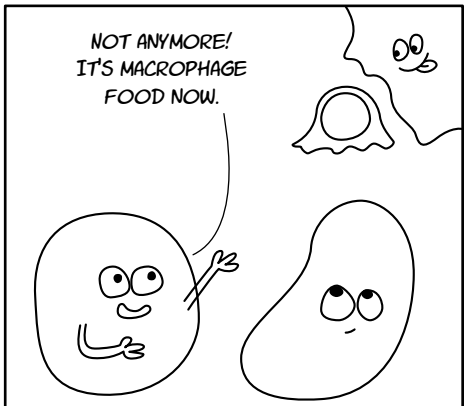
A stem cell in the bone marrow divides, creating a new cell.

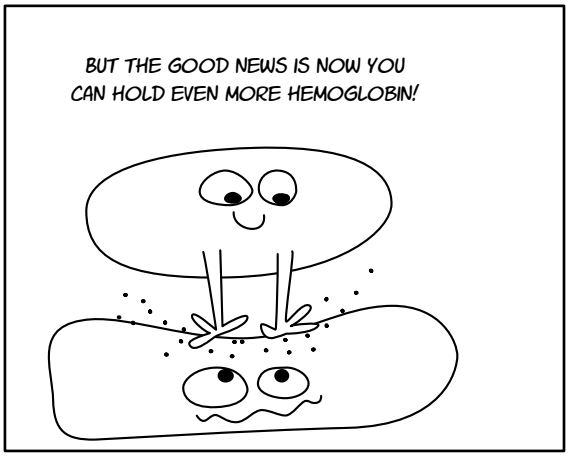


The new cell stays in the bone marrow for several days, undergoing several changes.

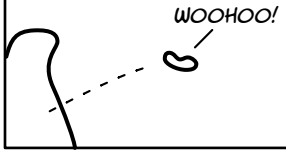




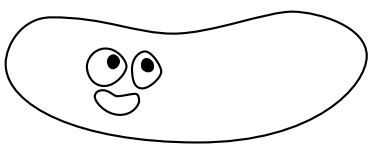




With the nucleus removed, the cell is now a reticulocyte - a brand new red blood cell. It's officially ready to leave the bone marrow and begin carrying oxygen.



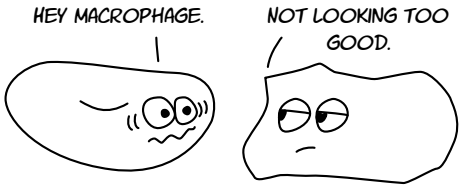
It circulates through the entire body approximately every 60 seconds, bringing oxygen to other cells.



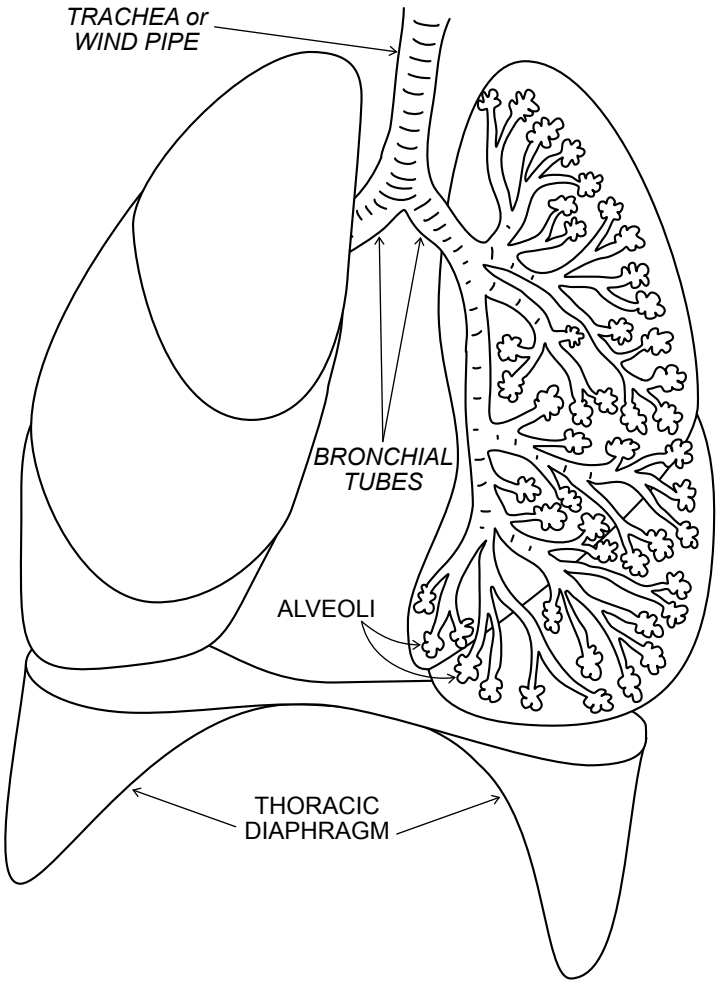
After 120 days, the RBC starts to get a little worn out from so much travel… and is eaten by a macrophage.

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

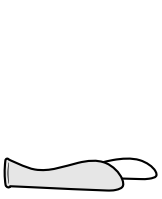
Breathing is the process of exchanging _____. Every animal needs to absorb _____ and get rid of _____, but they do it in very different ways! Human beings have two _____ and a diaphragm that helps the lungs expand and take in oxygen. Inside the lungs are small sacks called _____ where oxygen is passed into the blood. Fish use _____ to breathe. Worms and amphibians breathe through their _____, 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?

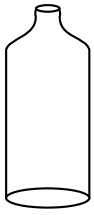
Hiccups are caused by the muscle that separates the lungs and heart from the abdomen: the thoracic diaphragm. When the diaphragm spasms it causes air to suddenly rush past the vocal chords and into the lungs. This is what produces the hiccup sound. Hiccups can be caused by many different things and severe 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:

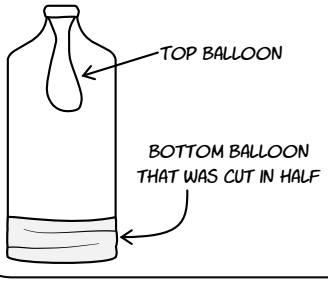


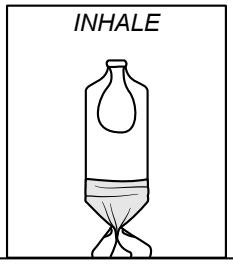
2 BALLOONS

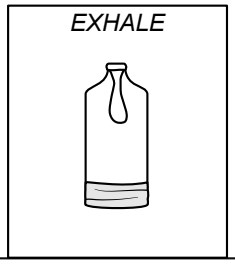


PLASTIC BOTTLE WITH BOTTOM CUT OFF

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.

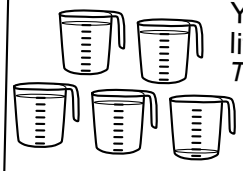






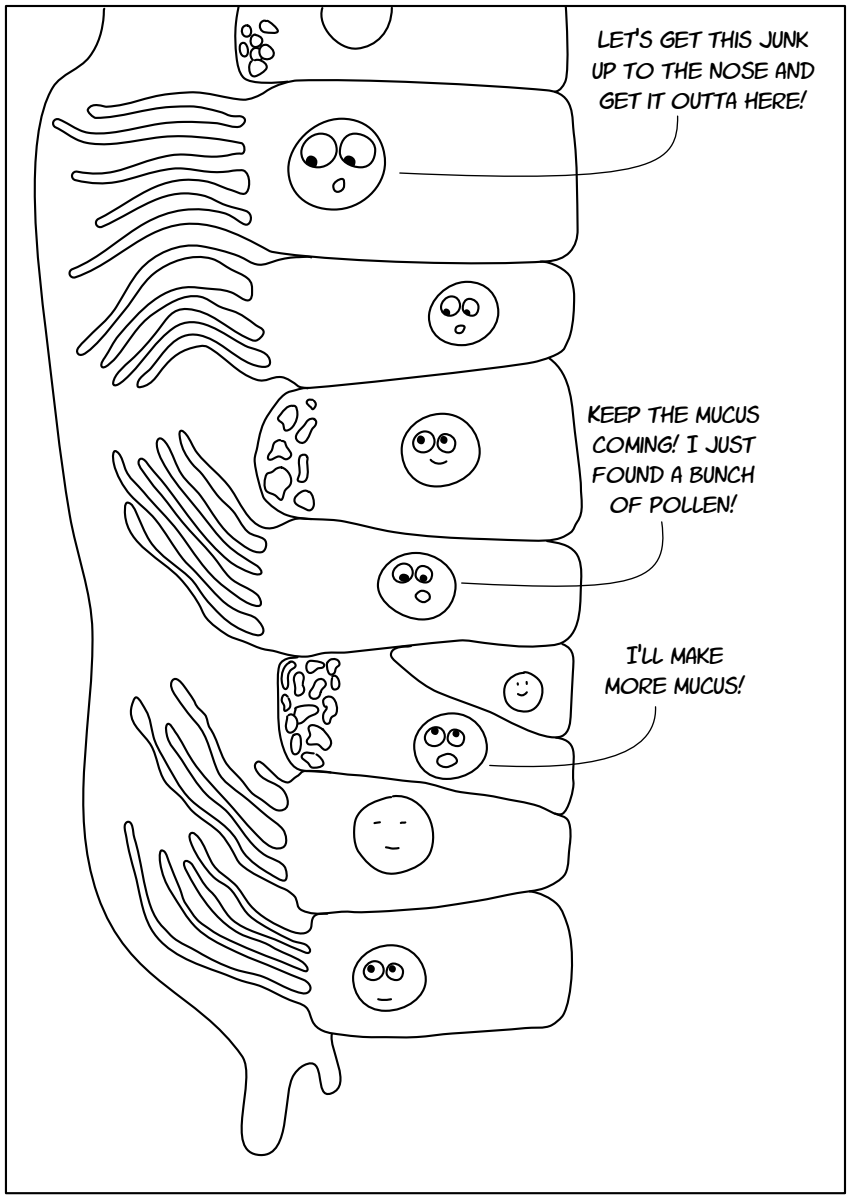
Did you know?

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!



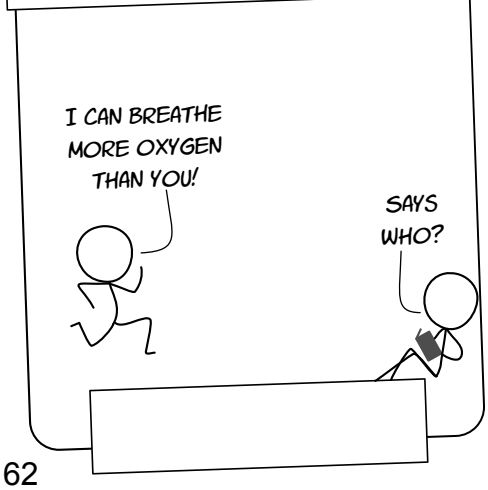
Your body makes about 1 liter of snot every day. *That's more than 33 ounces!*

Your notes:

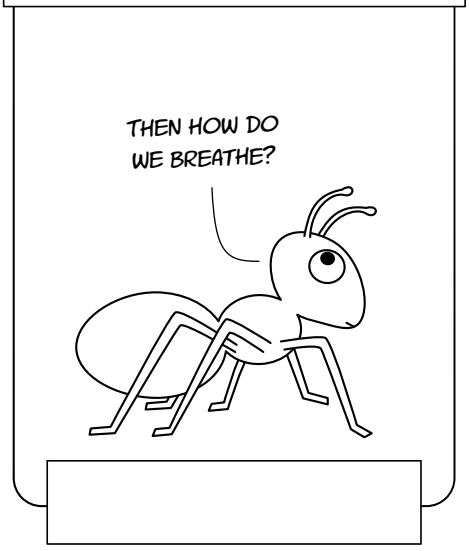


ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

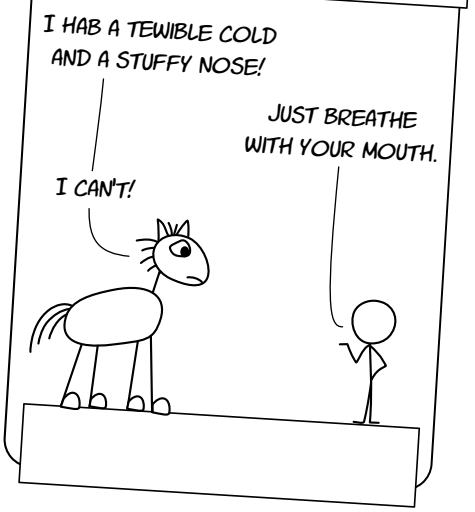
Aerobic exercise like running improves lung capacity by making the lungs larger.



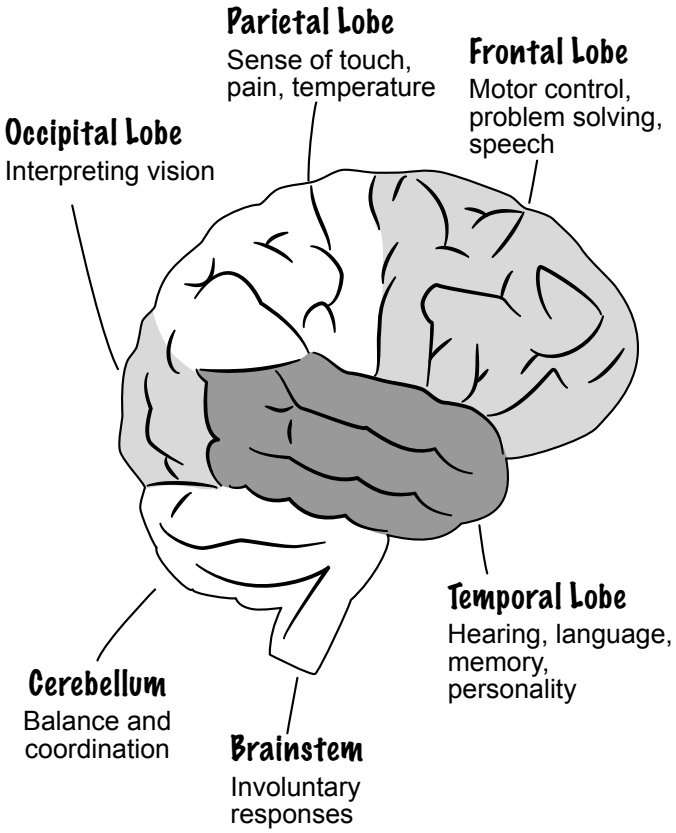
Insects have no lungs.



Horses can only breathe through their noses.



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 _____ that transmit signals between different parts of the body. These neurons also help us to _____ and _____ information. The central nervous system consists of the brain and the _____ _____. The _____ nervous system carries sensory and motor information between the central nervous system and the organs and limbs while also helping to regulate _____ 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

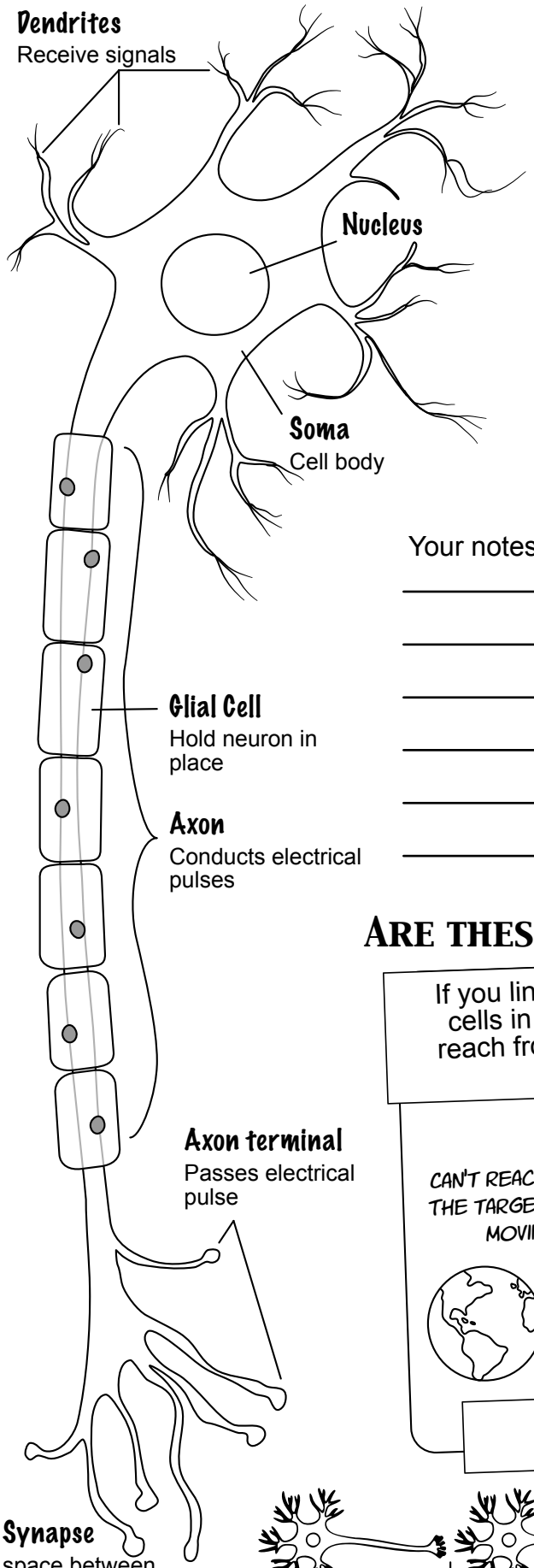
Try the experiment 10 times and then average your results:

Reaction Time: _____

Your average reaction time is how long it took for your body to react, which included your nerve cells sending the VISUAL signal to your brain, your brain cells deciding or THINKING about what to do, 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



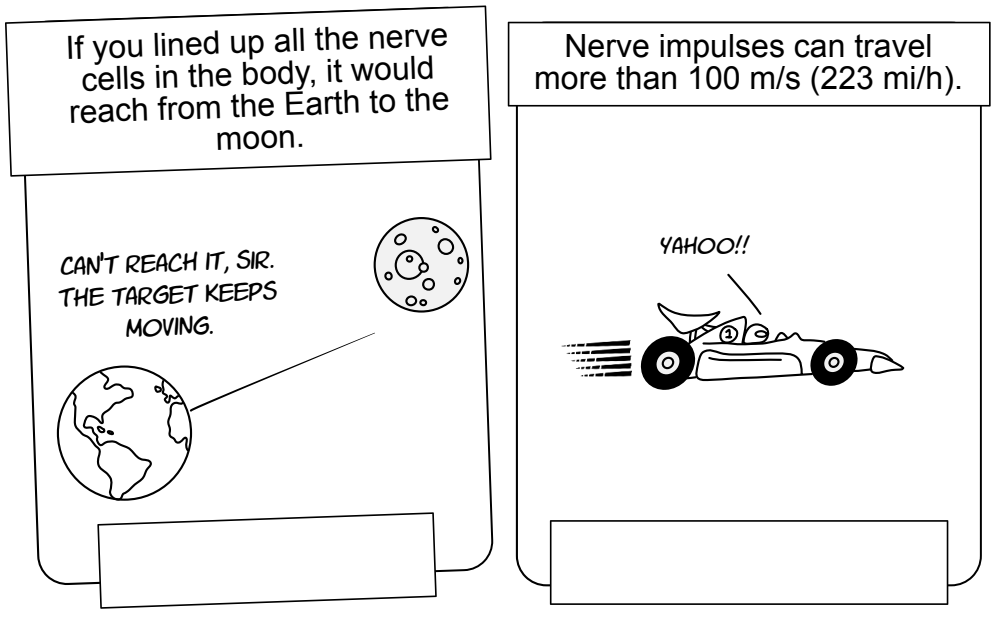
Neurons are specialized cells that transmit chemical and electrical signals throughout the body. The brain is built entirely of neurons and **glial cells** (cells that provide structure and support for neurons).

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.

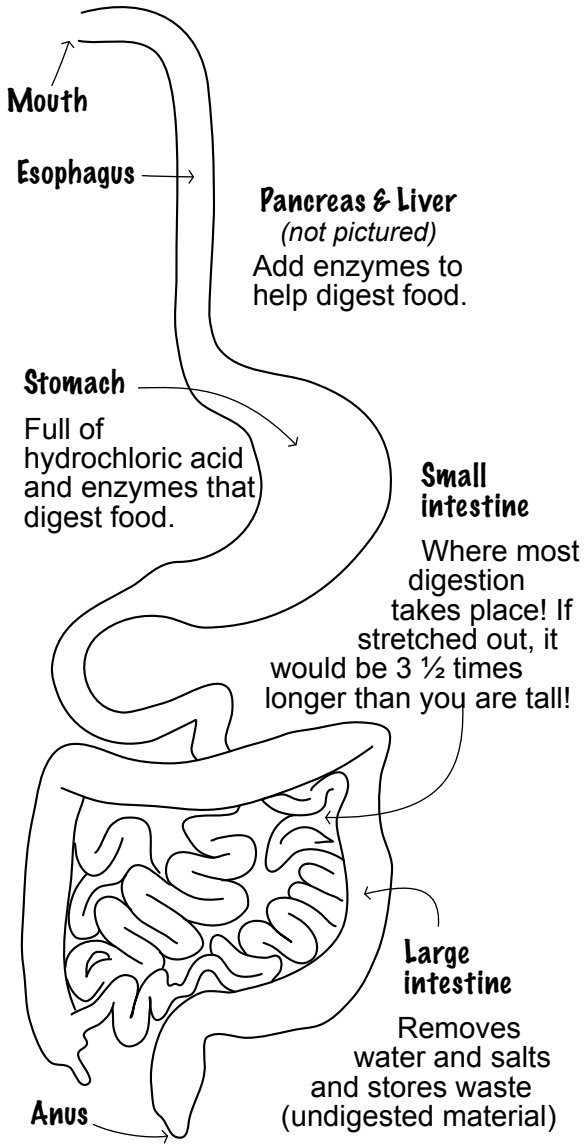
The gap between neurons is called a **synapse**. Nerve impulses are relayed from the axon terminal of one neuron to a dendrite of the neighboring neuron by a chemical substance called a **neurotransmitter** that is passed across the synapse.

Your notes:

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



The Digestive System



FILL IN THE BLANKS USING THESE WORDS:

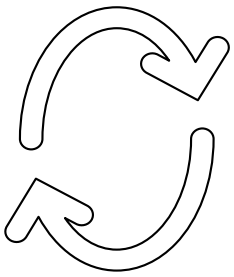
nutrients	protect	signal	repair
lining	bacteria	tract	hormones

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

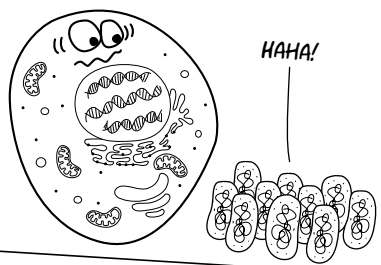
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

A platypus doesn't have a stomach.

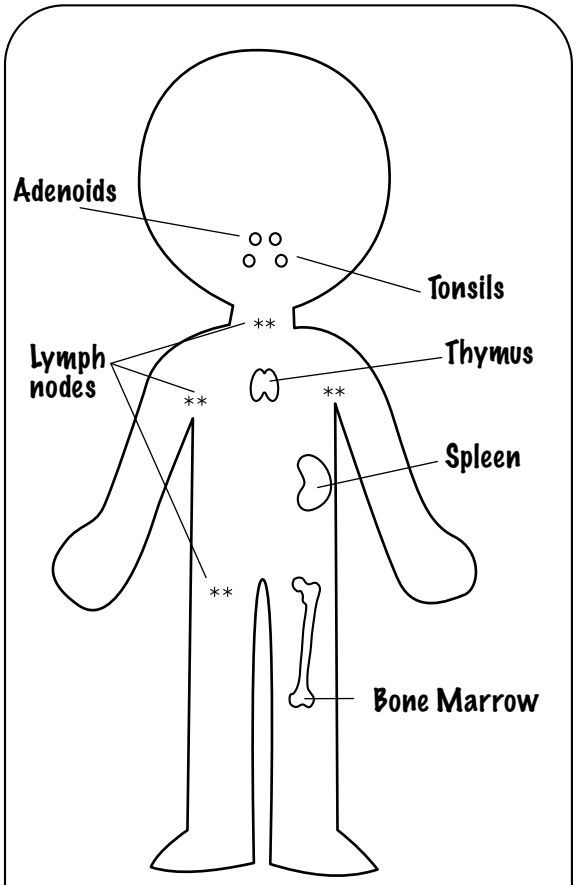
You can't swallow food while hanging upside down because gravity is required for swallowing.



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



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

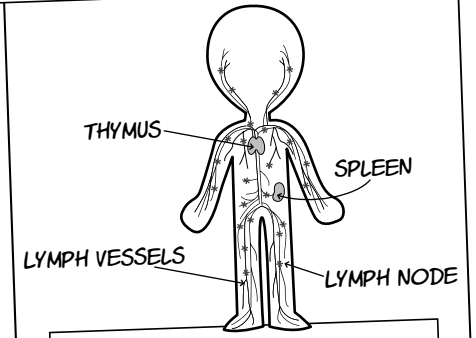
The immune system protects the body from outside invaders like bacteria, viruses, fungi, and toxins. Microorganisms that can make us sick are called _____ (or germs). When pathogens invade and multiply, we call this an _____.

The body's action to fight off the pathogens is called an _____ _____. The first time the pathogen is detected and destroyed is called the _____ immune response. When the same pathogen is encountered again, this triggers the _____ 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 _____ cells are able to recognize and remember specific pathogens.

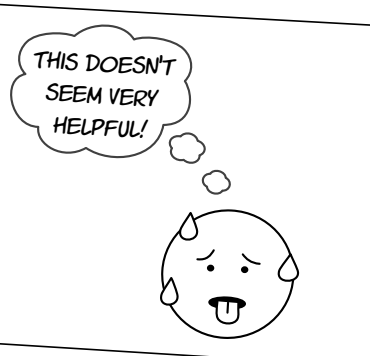
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*

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



You can never catch the same cold twice.

A fever helps your body fight an infection.



Match each organ with its description.

Filters the blood, removing damaged blood cells. If it is surgically removed then the body becomes more prone to infection.

Located at the back of the throat. This is often surgically removed because of swelling and infection.

This starts shrinking in childhood and has often disappeared entirely by the time a person becomes an adult.

Adenoid

Tonsil

Thymus

Lymph nodes

Spleen

Bone marrow

These are the shape and size of peas. They are located throughout the body and store lymphocytes.

This body part produces all the body's blood cells.

This organ is shaped like a thyme leaf. It is located near the heart and helps make white blood cells.

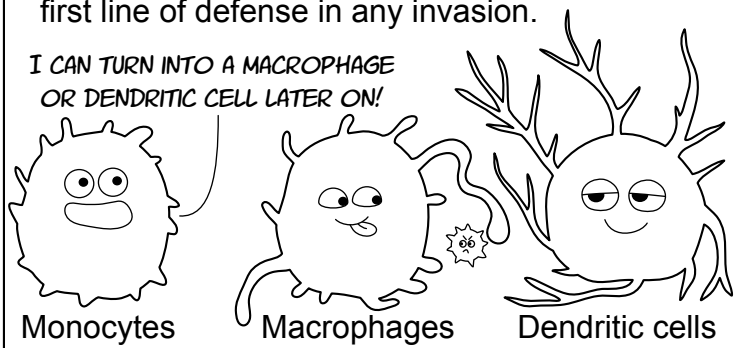
Your notes:

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

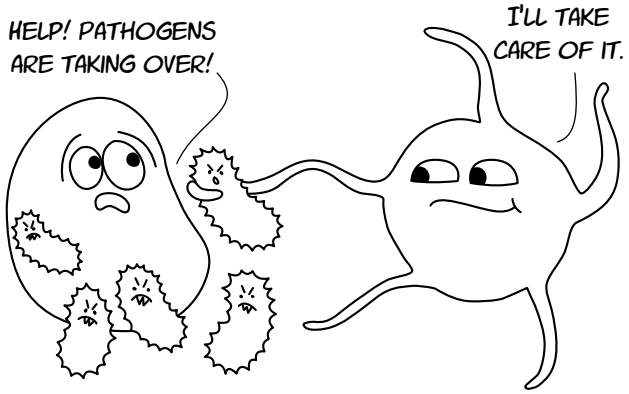
These general-purpose fighter cells engulf and dissolve invading microorganisms. They are the first line of defense in any invasion.



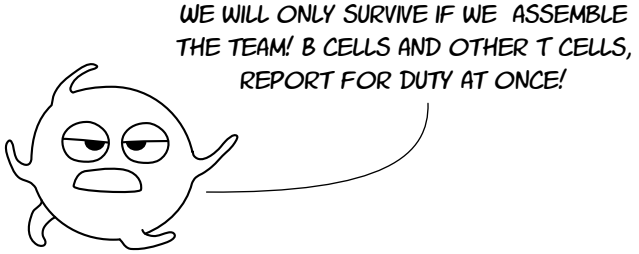
Monocytes Macrophages Dendritic cells

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:



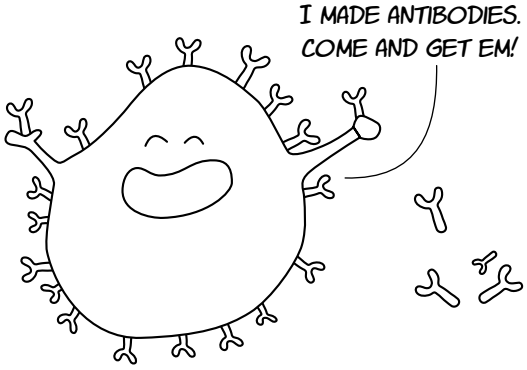
Killer T cells find infected cells using an antibody and kill the infected cells by injecting a cytotoxin.



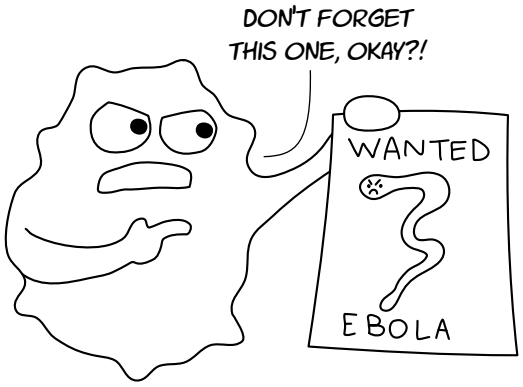
Helper T cells coordinate the attack by giving chemical instructions to the other cells of the immune system.

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.

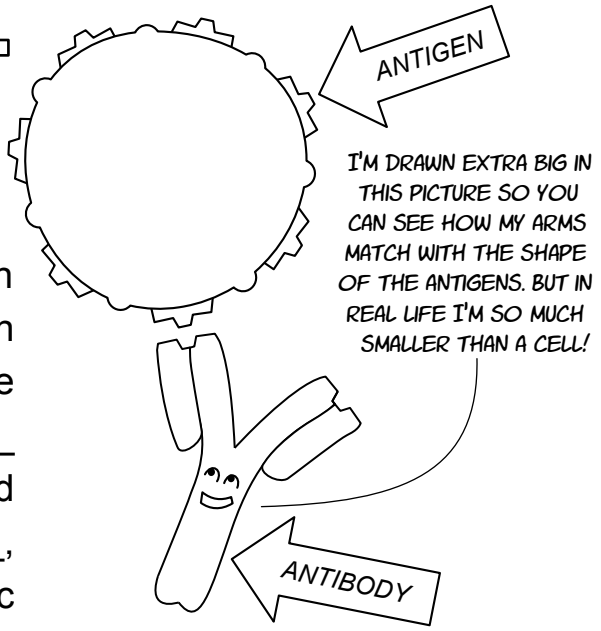
Your notes:

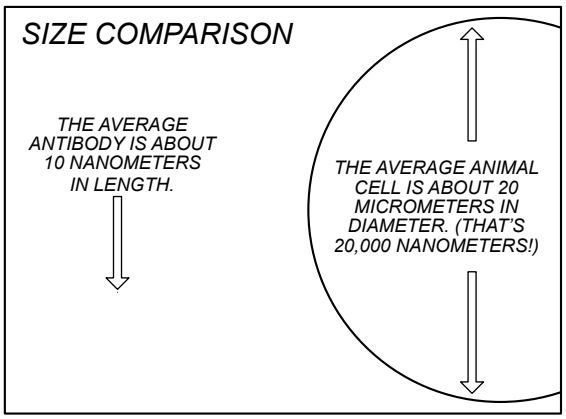
Antibodies & Antigens

FILL IN THE BLANKS USING THESE WORDS:

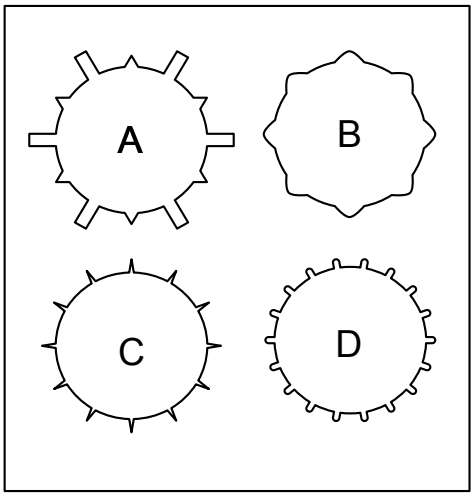
bind	pathogens	specific
inactivate	antibodies	antigens

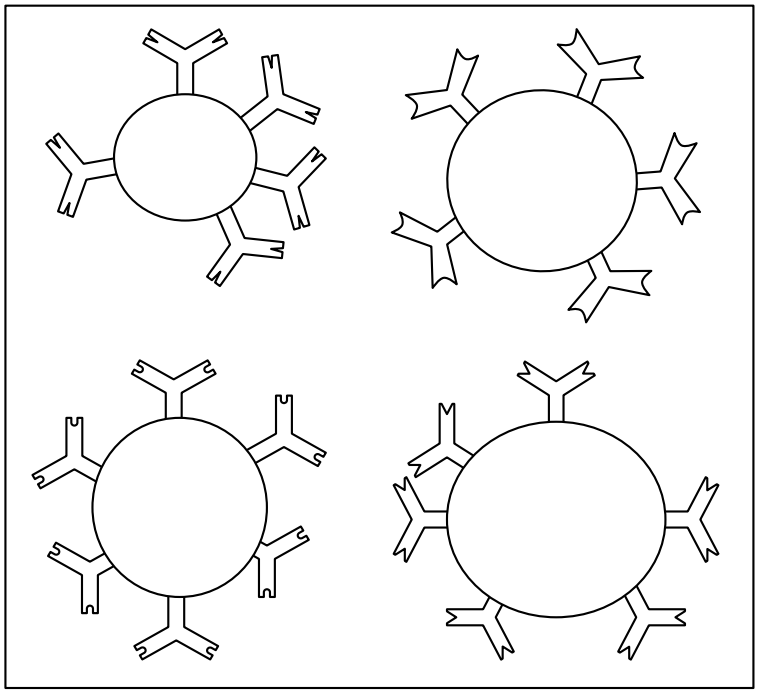
All cells have molecules on their cell surface membranes called _____ that can trigger an immune response. Our bodies are able to distinguish between its own antigens and foreign antigens. When the body recognizes a foreign antigen, it starts an immune response because cells with foreign antigens could be _____ and cause disease. Special white blood cells called B lymphocytes (B cells) release _____, which are proteins that will _____ to a specific antigen. The antibodies have a shape that is _____ 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 _____ the pathogen and signal white blood cells to come attack.



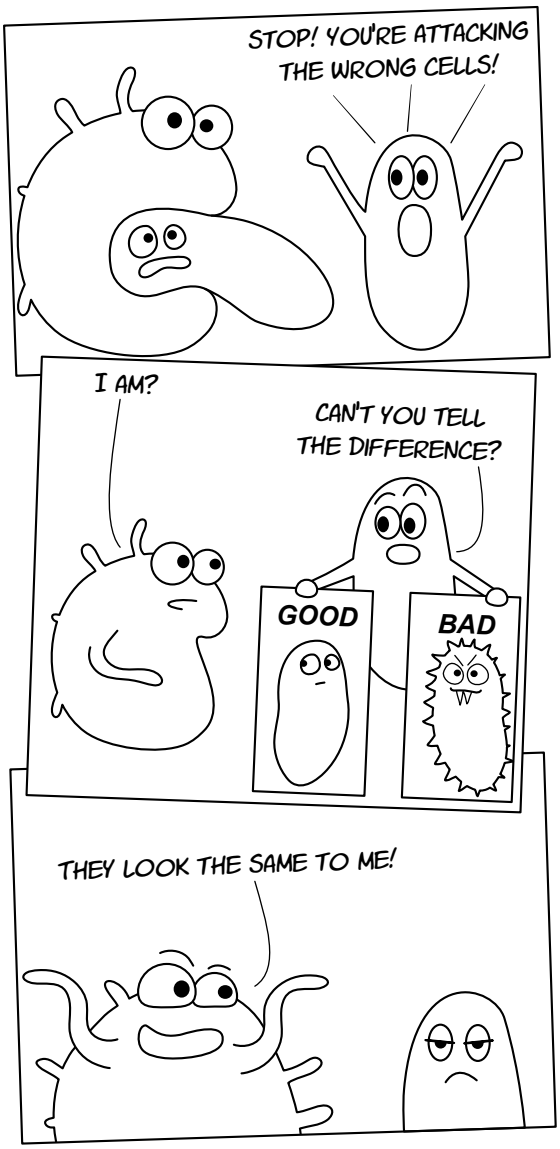


Four different pathogens are pictured below, each with different antigens on their cell surface. Match each pathogen with the antibodies that will bind to it.





Autoimmune & Allergies



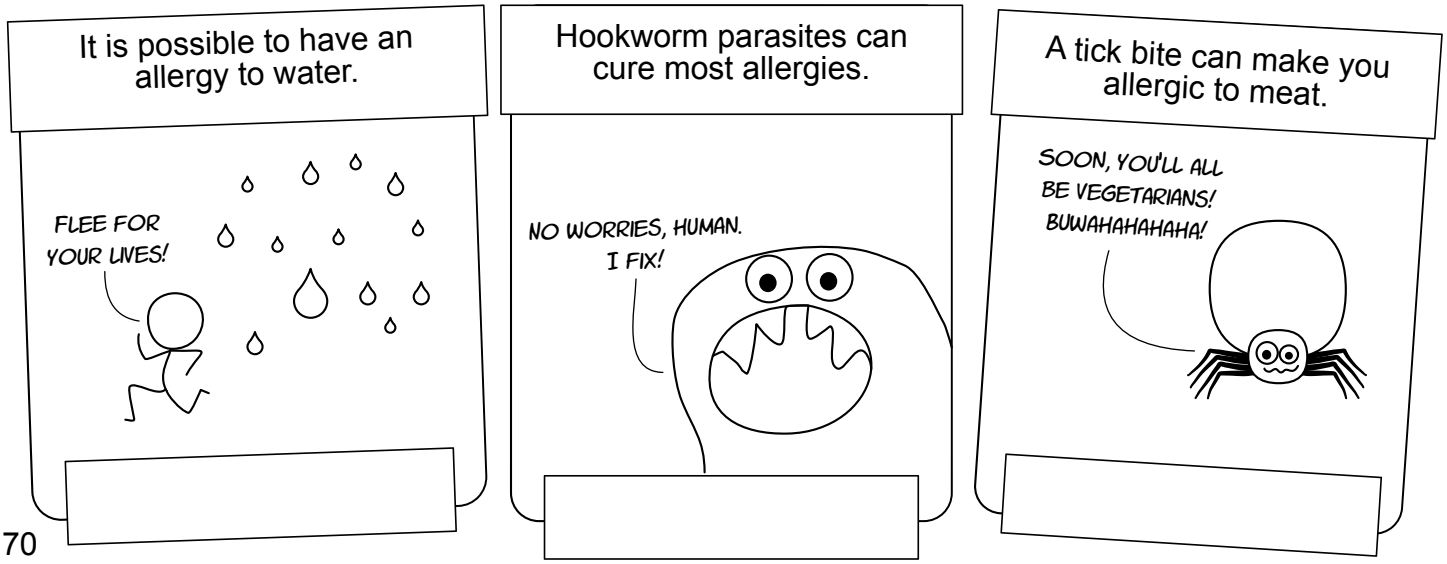
FILL IN THE BLANKS USING THESE WORDS:

nerve	autoimmune	allergies
connective	pancreas	allergen

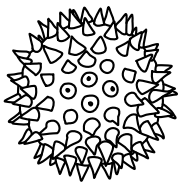
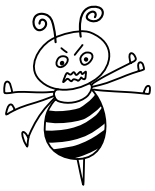
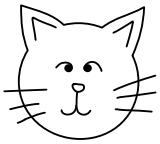
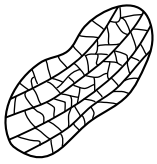
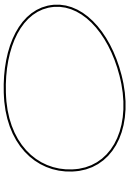
When the immune system develops antibodies for the body's own cells or tissues and begins to attack them, this causes an _____ disorder. There are several different types: Rheumatoid arthritis is caused when the immune system attacks the _____ tissue around the joints. Multiple sclerosis is the result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

_____ are another example of the immune system attacking the "wrong" thing. During an allergic reaction, the body responds to a foreign substance or _____ 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:*



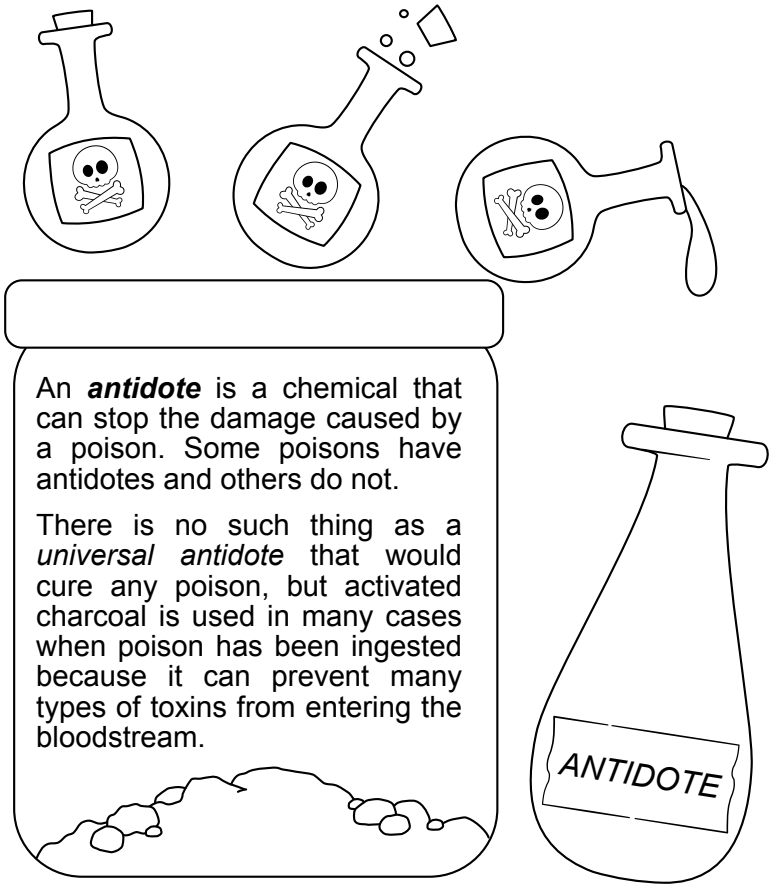
Can you match each fact with it's corresponding picture(s)?

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.	 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?

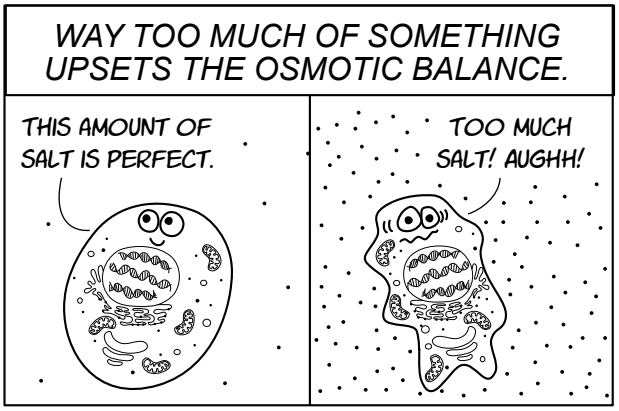
Because they cause something to go wrong with the cell!

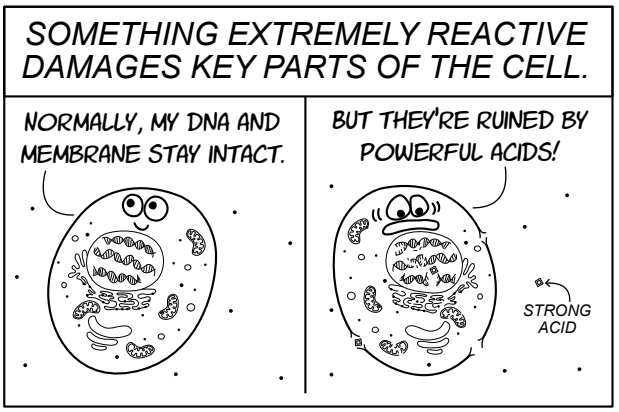
The cell exists in a state of balance where the different parts are working together in harmony. If one thing stops working, it can upset the entire system. Poisons and toxins exist in virtually every category of molecule or compound: there are poisonous elements, toxic proteins, dangerous minerals, 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!



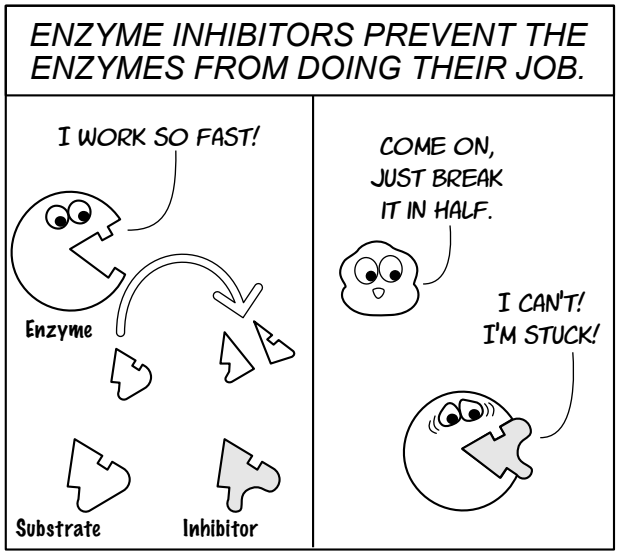
An ***antidote*** is a chemical that can stop the damage caused by a poison. Some poisons have antidotes and others do not.

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.

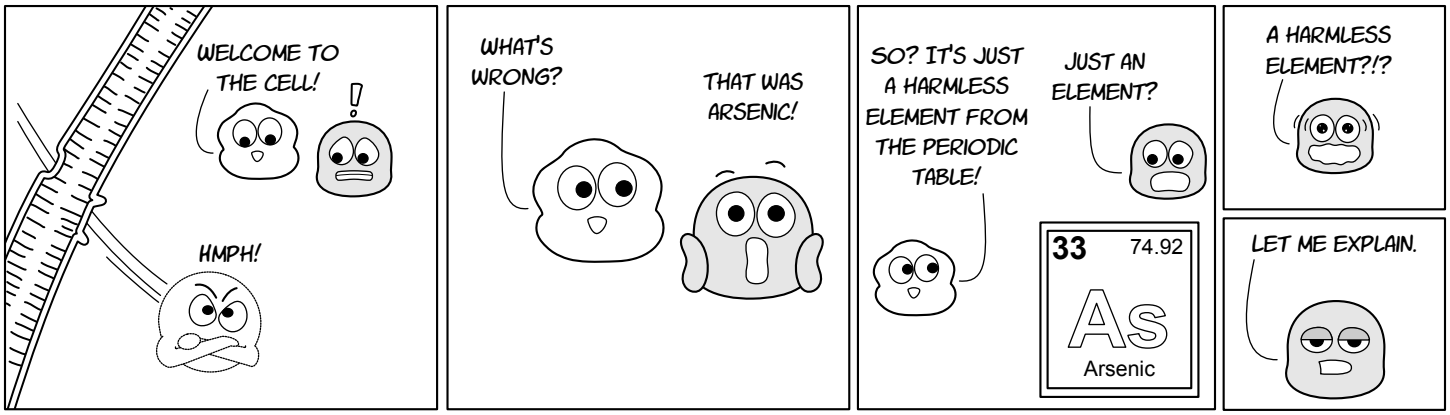


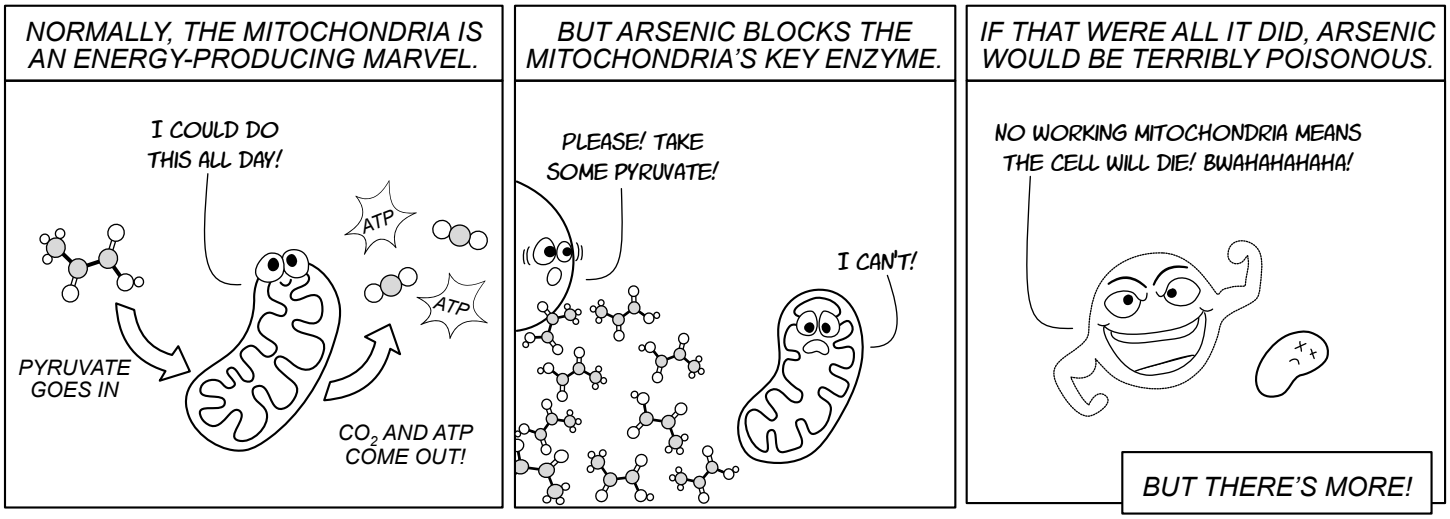


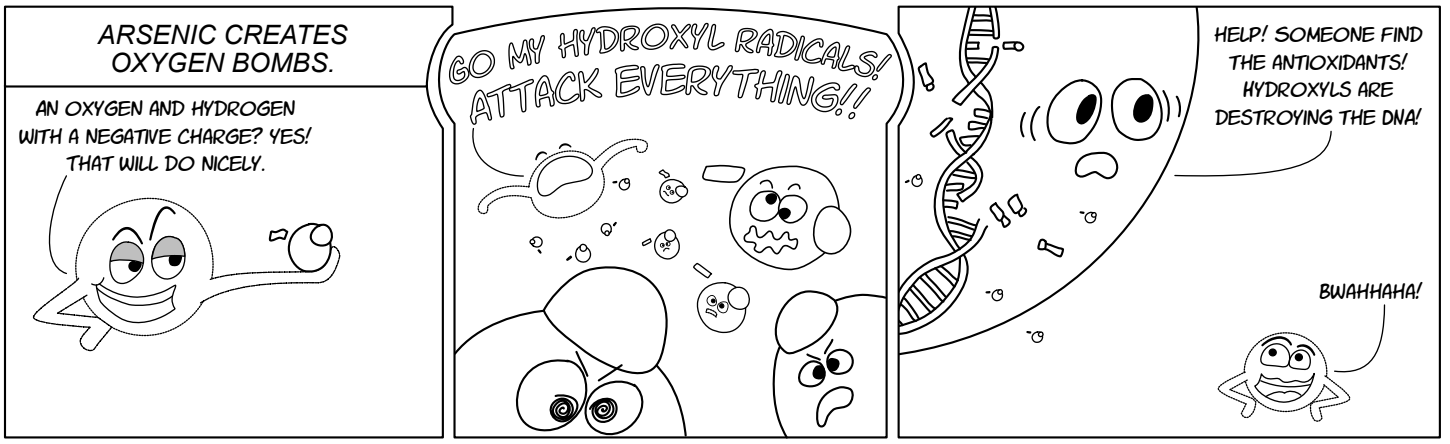
Your notes:

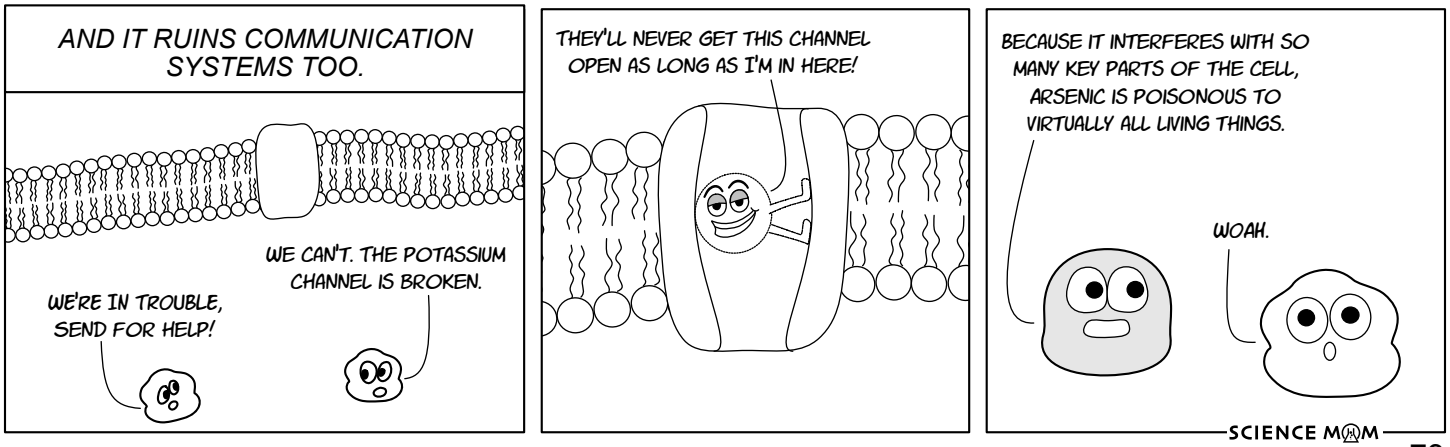


Awful Arsenic – a poisonous element



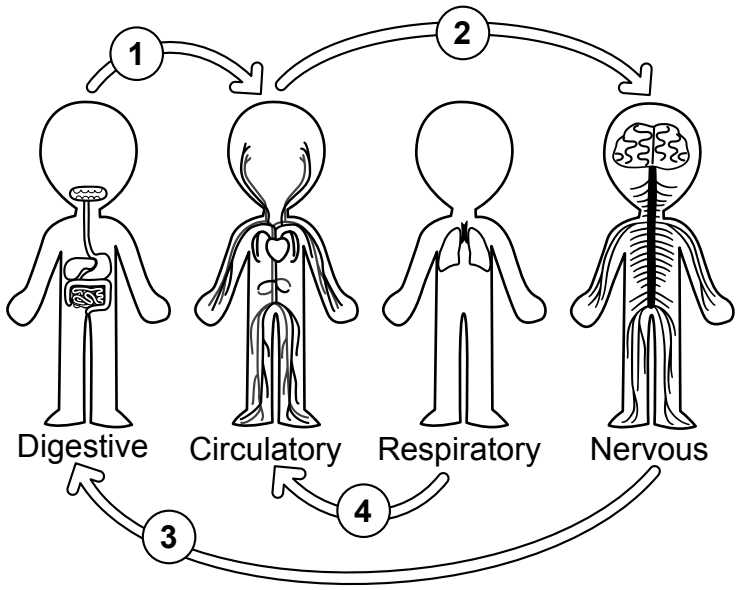






Interdependent Systems

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



1 *The digestive system impacts the circulatory system by:* _____

_____

2 *The circulatory system impacts the nervous system by:* _____

_____

3 *The nervous system impacts the digestive system by:* _____

_____

4 *The respiratory system impacts the circulatory system by:* _____

_____

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

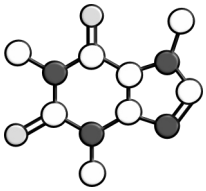
The most poisonous toxin known. It blocks the receptors on nerve cells. Symptoms of poisoning include difficulty breathing and muscle weakness. It is so effective at paralysis that it is used in medical and cosmetic applications (botox injections).

FOXGLOVE

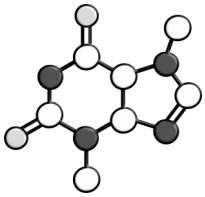
This plant contains cardiac glycosides, compounds that disable sodium-potassium ion pumps on cell membranes. They especially impact heart cells but also impact the nervous and gastrointestinal systems, causing, nausea, vomiting, and diarrhea.

HEMOTOXINS FROM A RATTLESNAKE

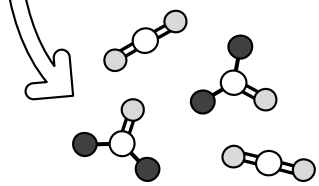
Rattlesnake venom contains an enzyme that destroys a protein in red blood cells, causing them to break open. This results in bruising and internal bleeding.The venom also has other compounds that prevent clotting and reduce platelets.



CAFFEINE

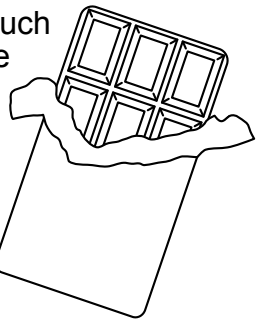


THEOBROMINE



SMALLER MOLECULES (CARBON DIOXIDE AND UREA)

WHY NO CHOCOLATE FOR DOGS?

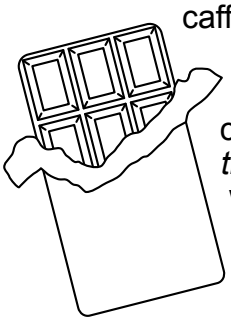


Caffeine and theobromine are found in many foods such as chocolate. They block certain **receptors** in the nervous system, producing a stimulating effect that makes people feel more alert and awake.

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.

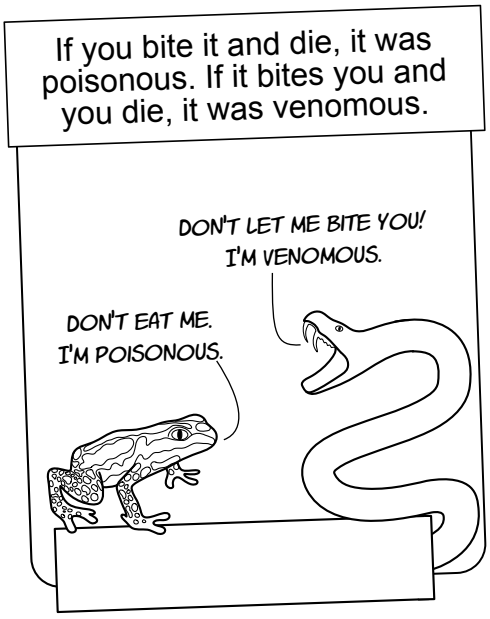


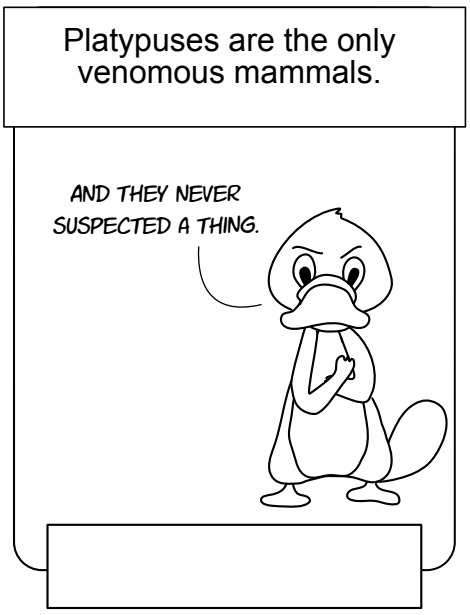
But because a human body has **enzymes** that can break caffeine down quickly, a person would need to eat *more than 700 regular-sized (1.5 oz) chocolate bars* before they would experience theobromine toxicity.

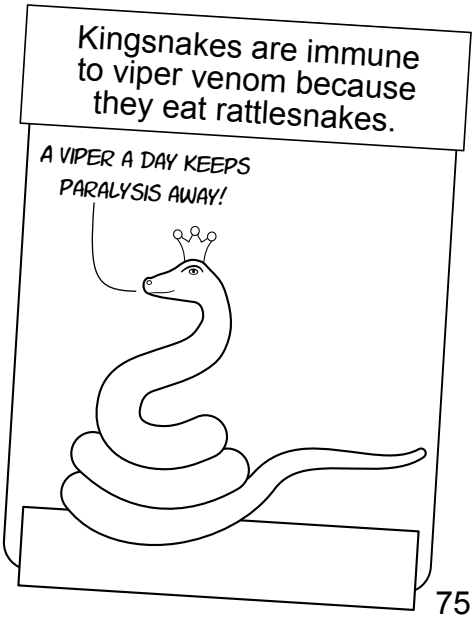
A dog, bear, or cat, on the other hand, can become poisoned from a small amount. All because of the difference between their **enzymes** and how they work.

Your notes:

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

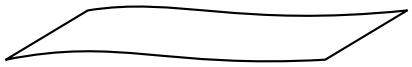






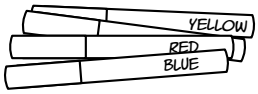
Physiology ART PROJECT

MATERIALS:

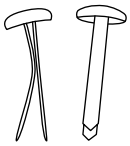


Several pieces of waxed paper, parchment paper, or tracing paper

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.

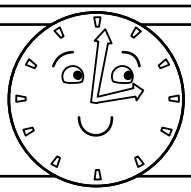
2. One at a time, place a piece of the transparent paper over the 5 templates of the body systems we covered in class. (Templates can be found in the appendix.) Trace each body system with pencil and then outline it with markers and color in the parts.

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

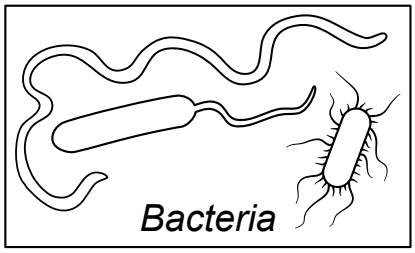
13 The largest organ of the body is the:
- A. Skin
- B. Heart
- C. Brain
- D. Pancreas

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

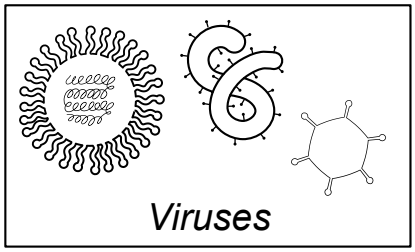
Pathogen: A microorganism that can cause disease

Match each family of pathogens with their description:



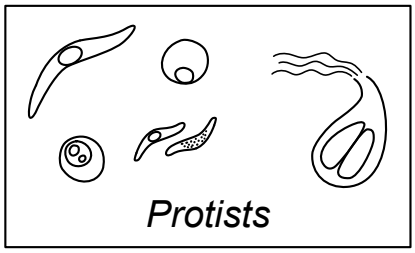
Bacteria

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.



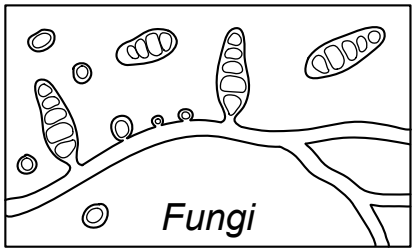
Viruses

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



Protists

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.

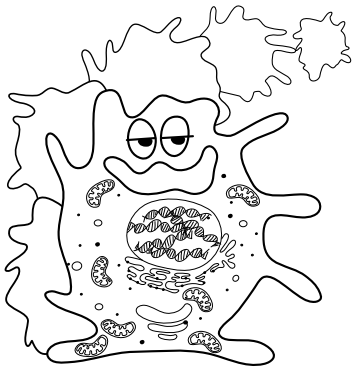


Fungi

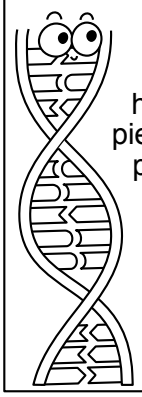
These pathogens can be difficult to treat because their cells are eukaryotic. The most deadly pathogen in this family is spread by mosquitos.

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

What about diseases that are NOT caused by pathogens?

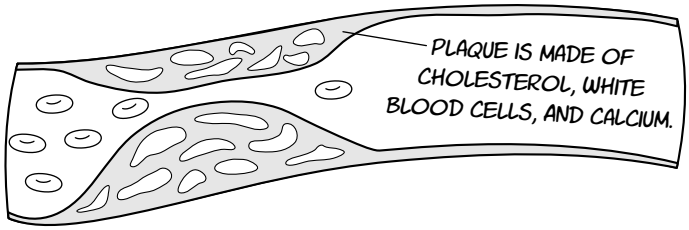


Cancer is caused by uncontrolled cell growth. When the body's own cells mutate and become malignant, they invade and grow in tissues where they shouldn't, causing pain and death. Some types of cancer are strongly genetic, others can be caused by things that damage DNA, such as radiation. But others are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

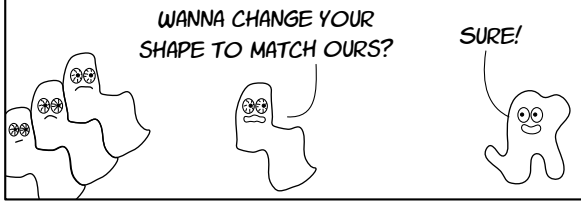


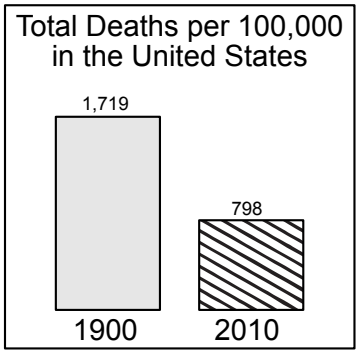
Genetic Diseases like sickle cell anemia or hemophilia are caused by pieces of DNA that cause a problem with an important protein. There are no pathogens involved in most genetic diseases. We'll learn more about them in Biology 2.

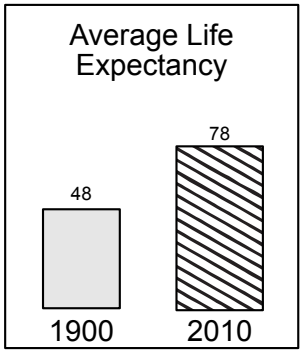
Heart Disease is the leading cause of death in developed countries. It is caused by a buildup of plaque in the arteries that stops the flow of blood through the heart. Diet, exercise, and genetics all play a role in heart disease, but infections do as well. Scientists are researching how certain bacteria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



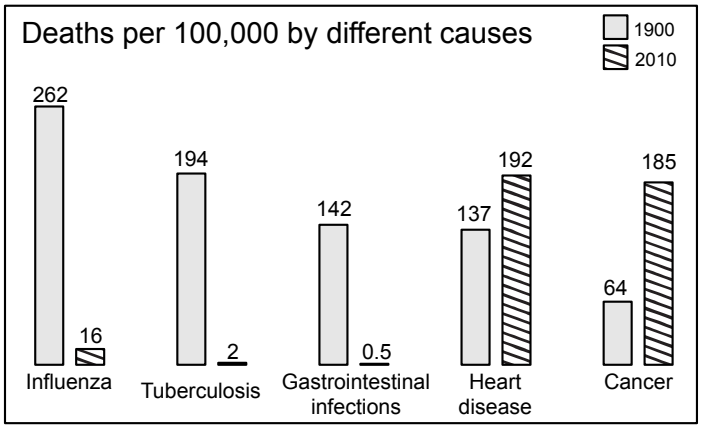
Prion Diseases like mad cow disease are caused by proteins that are folded differently. Their amino acid sequence is identical to the normal proteins found in the brain and nerves. But somehow, these infectious proteins cause the normal proteins to change shape and then cluster together, destroying nervous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







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



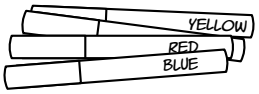
Data for the graphs was adapted from a 2012 article from the New England Journal of Medicine titled *The Burden of Disease and the Changing Task of Medicine* by Jones et al. The 2010 data for tuberculosis and gastrointestinal infections was estimated from reports on the Center for Disease Control and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

Most Wanted Microbe ART PROJECT

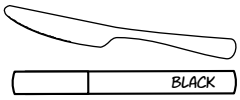
MATERIALS:

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)

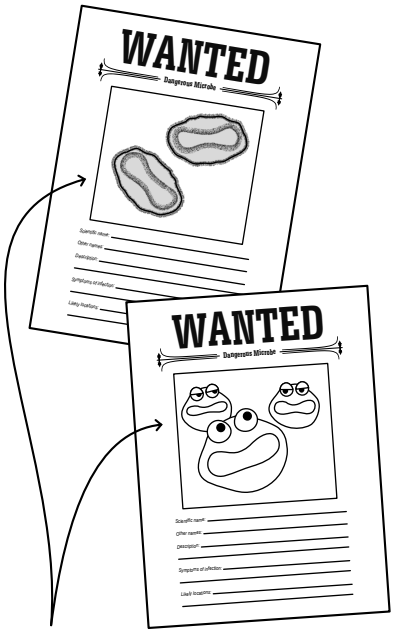
1. (Optional) Weather the paper to make it look old by scraping a knife along the edges and then wiping them with a piece of tissue wet with ink.

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.*

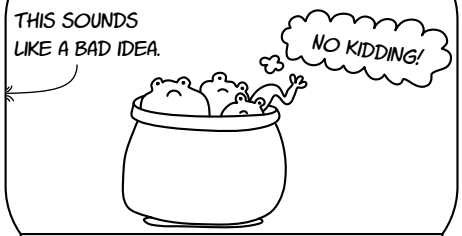
Medicine in the 1700s

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

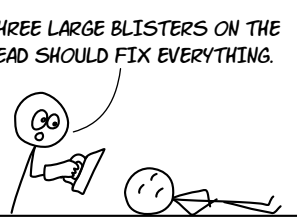
For malaria: Eat the BARK of the CINCHONA Tree.

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

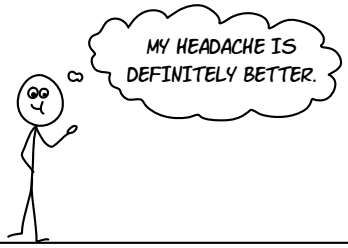


For mental distress, fevers, and many other diseases: PURGING.

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



For headaches: Chew on wintergreen leaves.

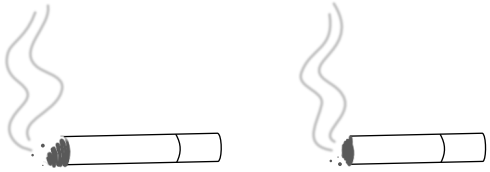


The bloodletting, purging, and blistering were traditions that dated back to ancient Greece. They did not help people recover from illness, yet thousands of physicians and healers prescribed these treatments for hundreds of years! Why do you think this happened? How could so many people have caused the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

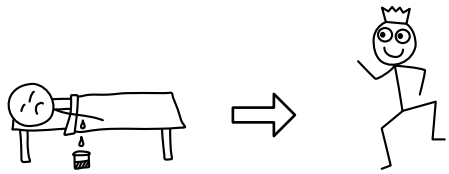
Your Thoughts: _____

Anecdote vs. Research

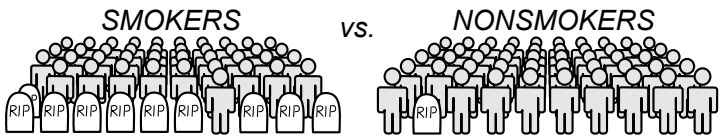
***Anecdotes** are stories. They are often memorable and repeatable, but when people base conclusions on an anecdote (one person's experience) rather than **qualitative research** (many people's experiences with precise parameters and analysis), their conclusions are often wrong. Compare these two examples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



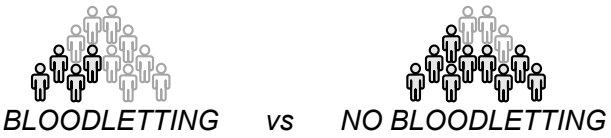
***Anecdote 1:** Great Aunt Jeanne smoked two cigarettes every day and lived to be 122 years old.*
***Conclusion:** Smoking cigarettes makes people live longer.*



***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: _____

_____

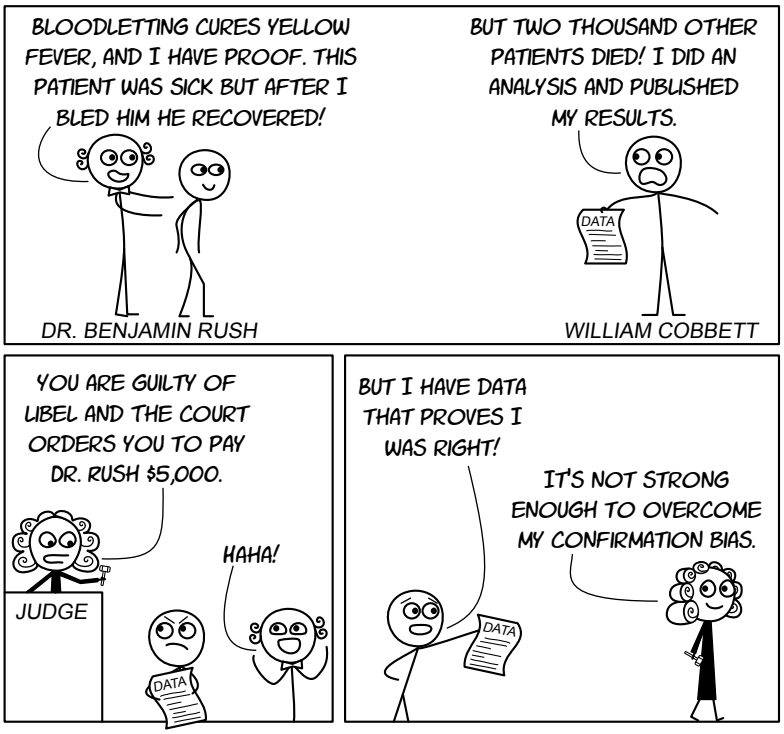
_____

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?

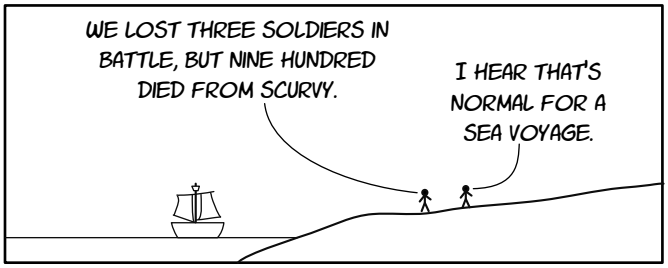
In 1799, the famous doctor Benjamin Rush filed a lawsuit against William Cobbett because Cobbett had published articles saying that bloodletting caused increased death. The court ordered Cobbett to pay Rush $5,000 (which would be equivalent to almost $150,000 today) because Cobbett's articles about bloodletting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

_____

SYMPTOMS: _____

_____

MORTALITY: _____

_____

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.

Scurvy comes from eating too

Breathing too much sea air will bring scurvy.

Anywhere with filth and poor morals, scurvy will follow.

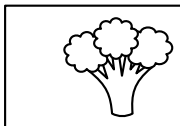
The illness results from excessively cold and damp weather.

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:

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

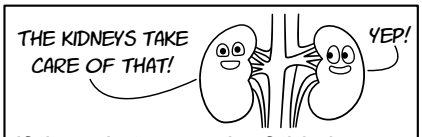


Broccoli contains a lot of this molecule.

Humans need to get this molecule from their food.

This is made from a triple helix of protein.

Enzymes in the body can make this molecule.

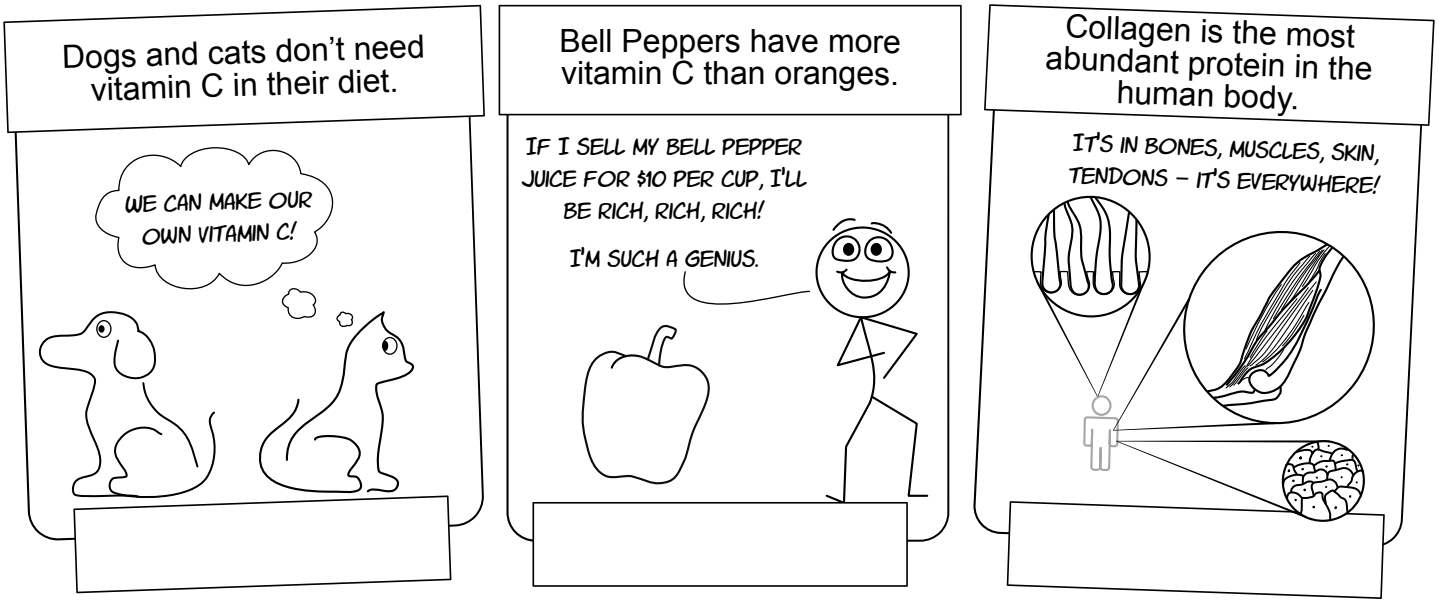


If there is too much of this in your blood, the body gets rid of the excess by putting it in the urine.

VITAMIN C

COLLAGEN

ARE THESE FACT OR FICTI0N? *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, _____, and leafy greens was discovered and forgotten multiple times. James Lind performed what is considered to be the first _____ _____ when he treated a group of twelve soldiers for _____ and observed that those who ate _____ and _____ 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

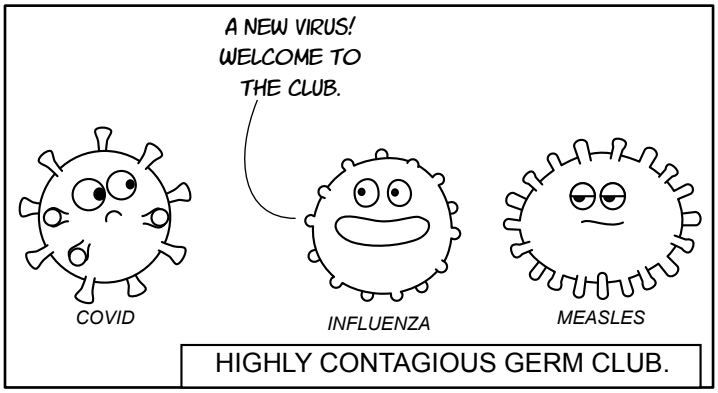
RANDOMIZED

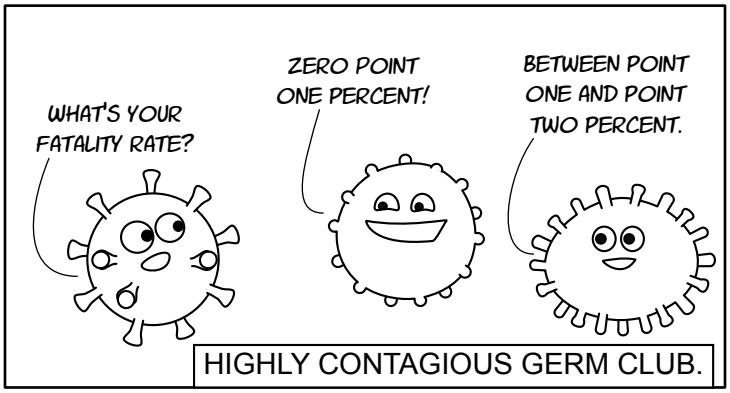
PLACEBO

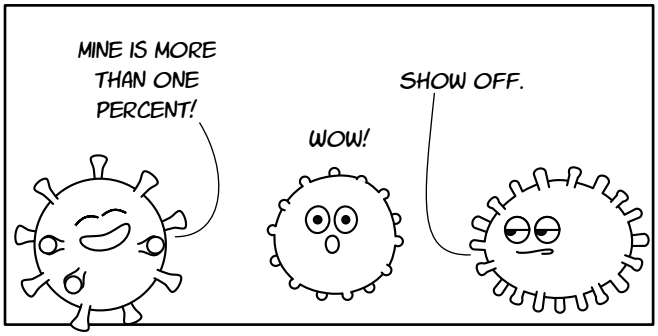
DOUBLE BLIND

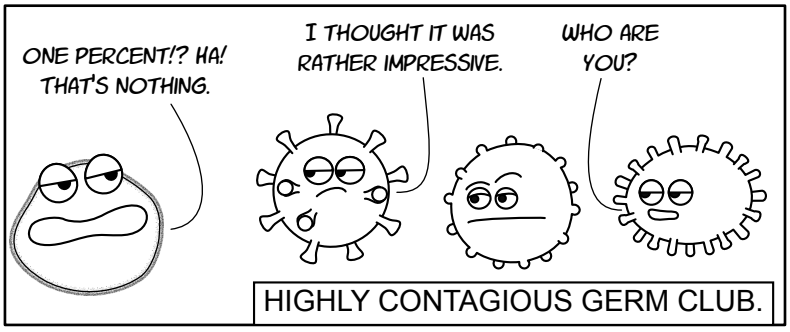
The highest possible standard of medical testing is a randomized, placebo controlled, double-blind clinical trial.

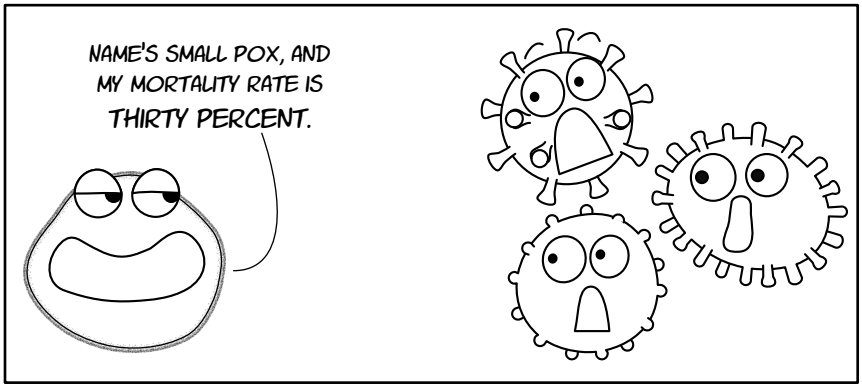
Small Pox & The Germ Club

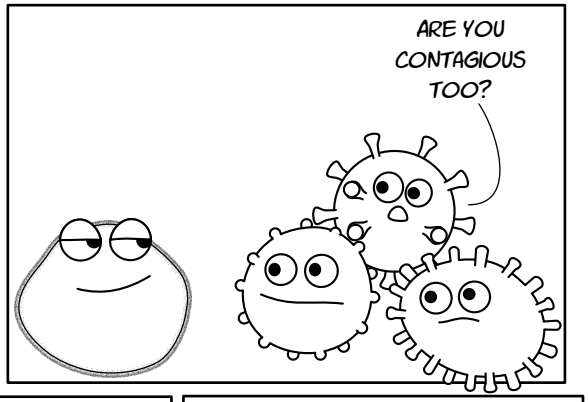


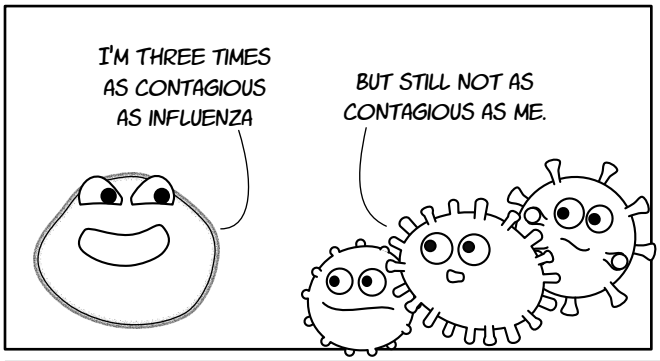


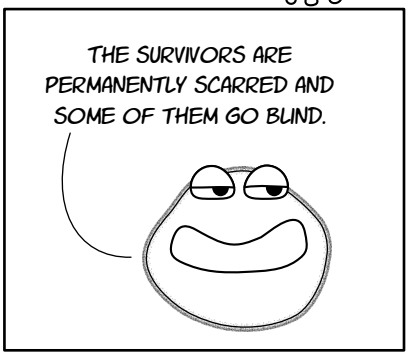


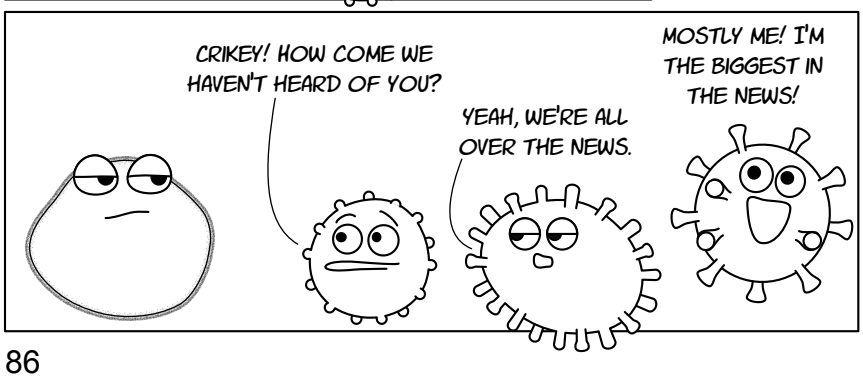


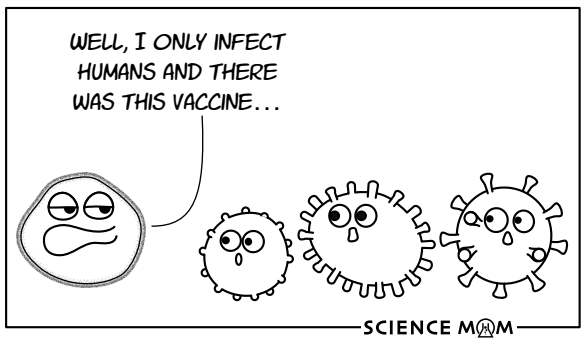






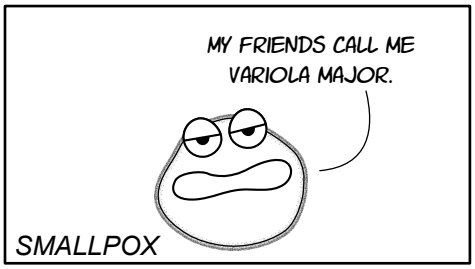






The Pox: A Fearsome Disease

WRITE DOWN THE MAIN CHARACTERISTICS OF EACH DISEASE:



SMALLPOX

HOW IT SPREADS: _____

_____

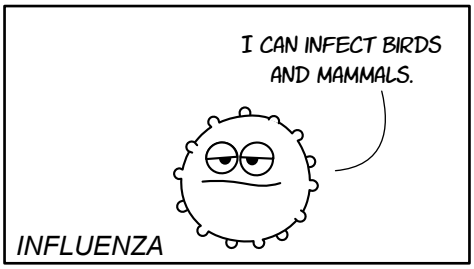
*R_0:** _____

MORTALITY: _____

SYMPTOMS: _____

_____

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



INFLUENZA

HOW IT SPREADS: _____

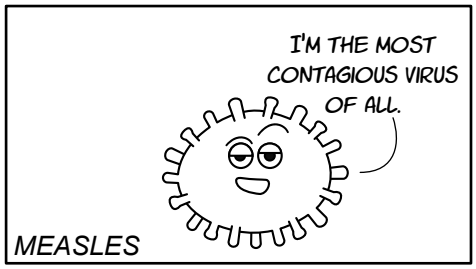
_____

R_0: _____

MORTALITY: _____

SYMPTOMS: _____

_____



MEASLES

HOW IT SPREADS: _____

_____

R_0: _____

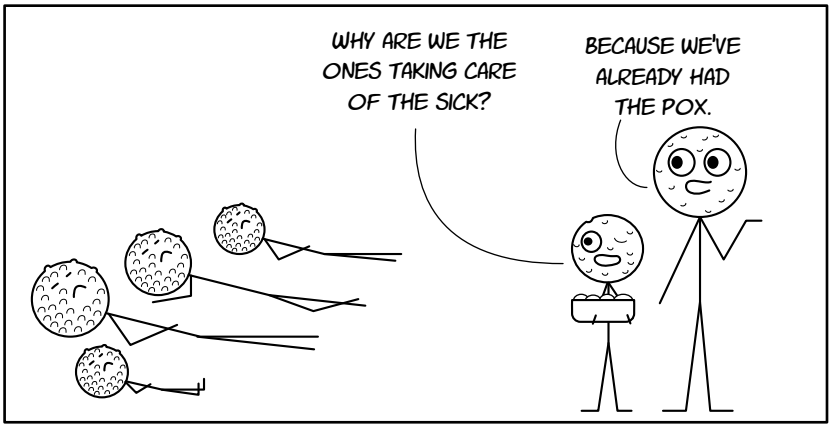
MORTALITY: _____

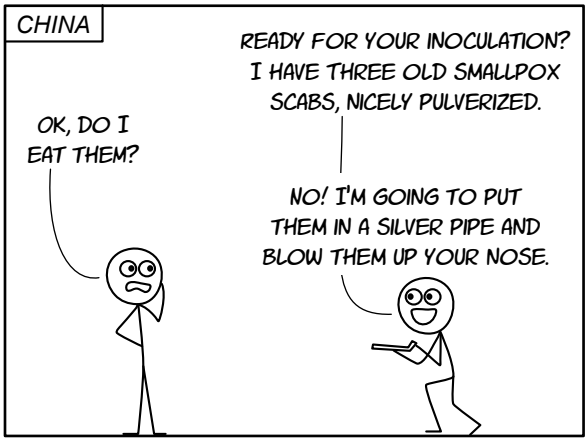
SYMPTOMS: _____

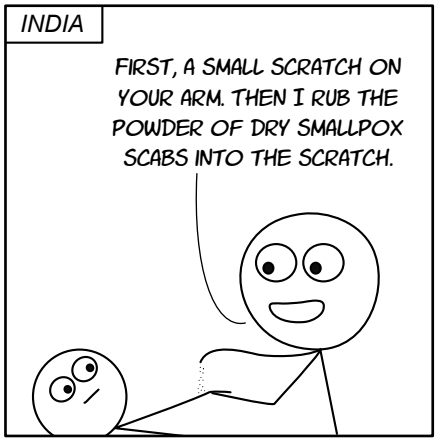
_____

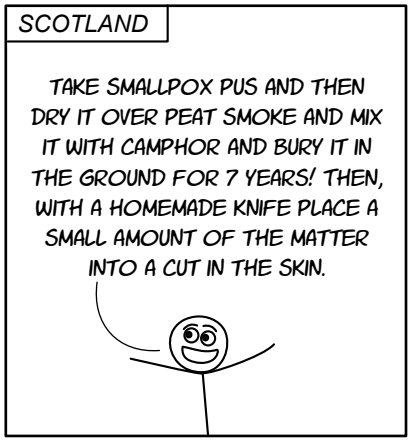
For thousands of years smallpox terrorized communities all around the world, killing 20 to 60% of the population each time it struck. Although the disease was brutal, there was one bright side: IF SOMEONE SURVIVED SMALLPOX, THEY NEVER GOT SICK FROM IT AGAIN.

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.









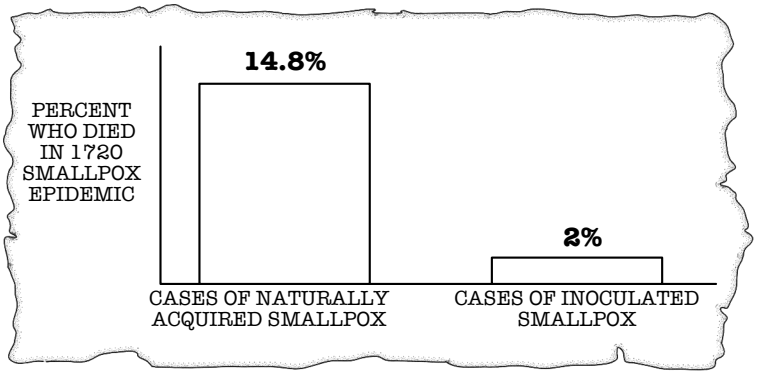
VARIATIONS IN VARIOLATION The approach varied from country to country, but the basic idea remained the same: inoculating a person with a small dose of the disease prevented a more serious illness. These early variolations could be deadly, but they weren't nearly as deadly as catching smallpox "naturally."

The 1721 Outbreak

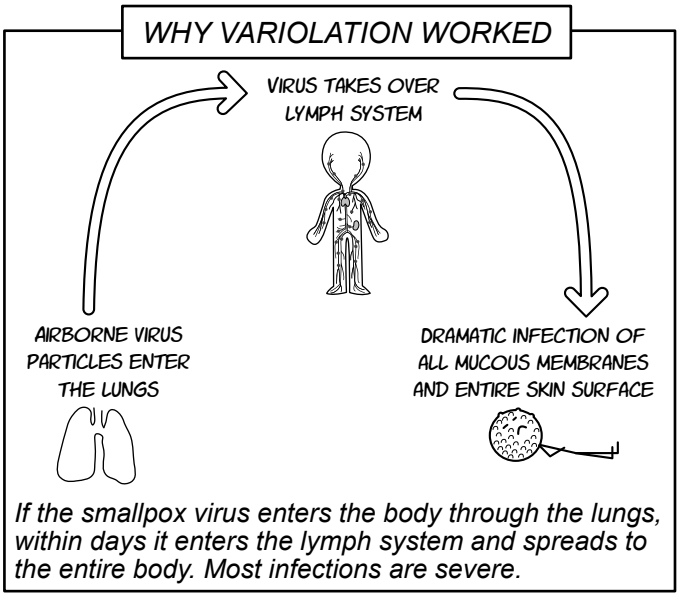
In the summer of 1721, a ship arrived at Boston with a sailor who had symptoms of smallpox. Despite the best efforts to quarantine, the disease began to spread. There had been a previous smallpox epidemic in 1703, but everyone under the age of 18 hadn't been around in 1703. They lacked immunity. A doctor 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.

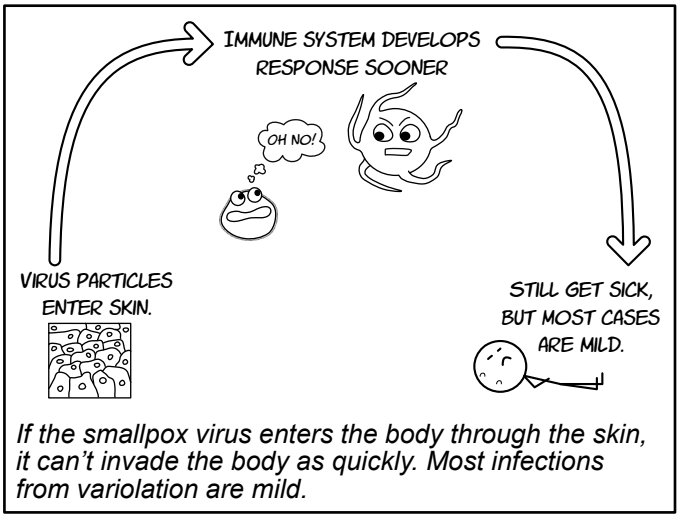
In November, someone opposed to the variolation effort threw a bomb into the home of Dr. Mather. Fortunately, it didn't go off. Mather later published data about the effect of variolation:



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.

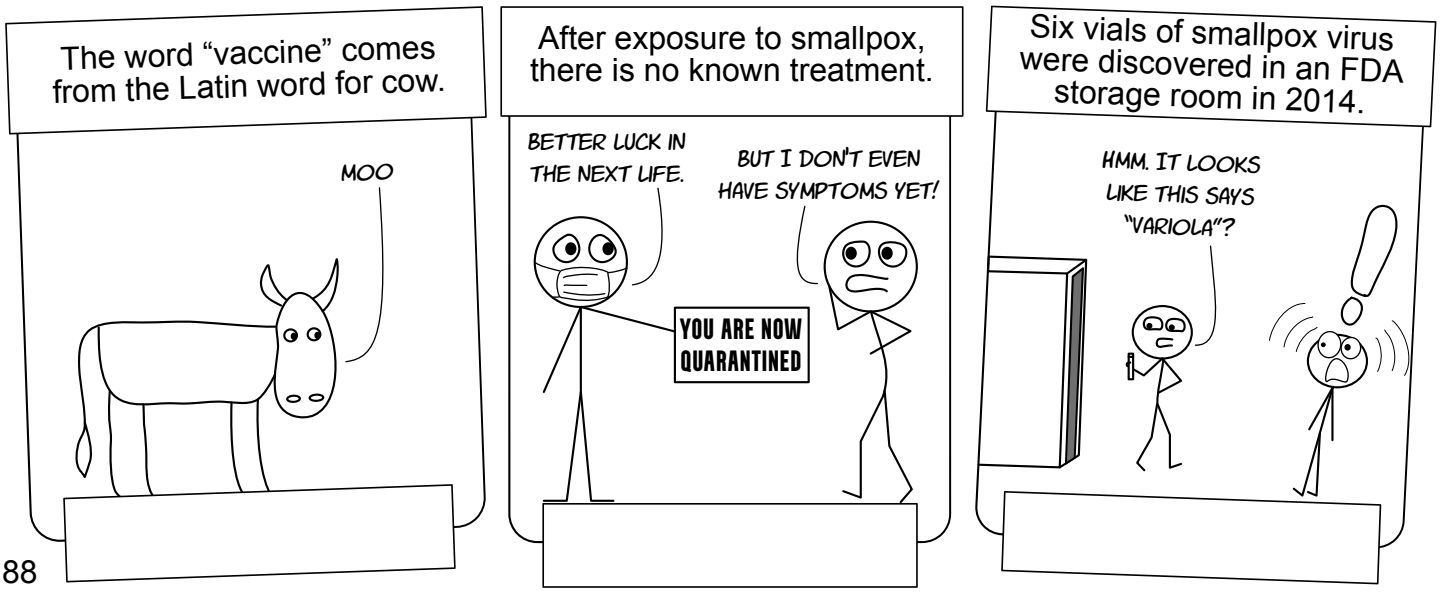


If the smallpox virus enters the body through the lungs, within days it enters the lymph system and spreads to the entire body. Most infections are severe.

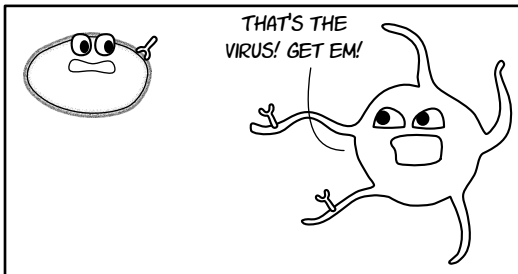


If the smallpox virus enters the body through the skin, it can't invade the body as quickly. Most infections from variolation are mild.

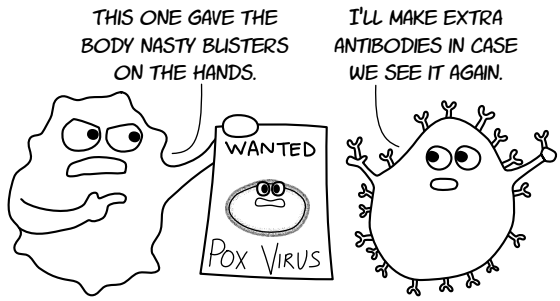
ARE THESE FACT OR FICTION? *Write your verdict below each statement:*



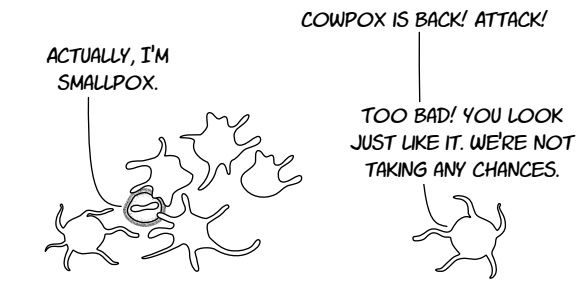
A pox on the pox



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.

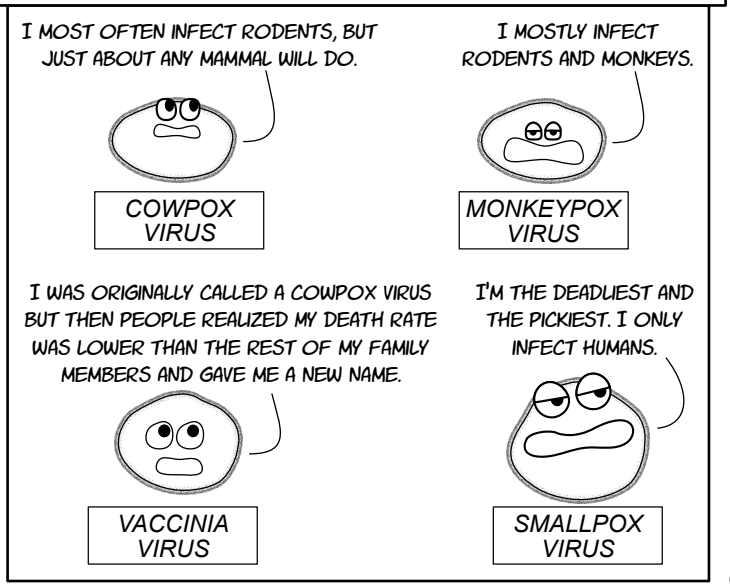
In the 1900s, scientists developed a safer version that used the vaccinia virus and started a global smallpox vaccination program. The disease did not go quietly. From 1900-1978, smallpox killed 300 MILLION people. Since 1978, there have been zero deaths.

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:

Your notes:

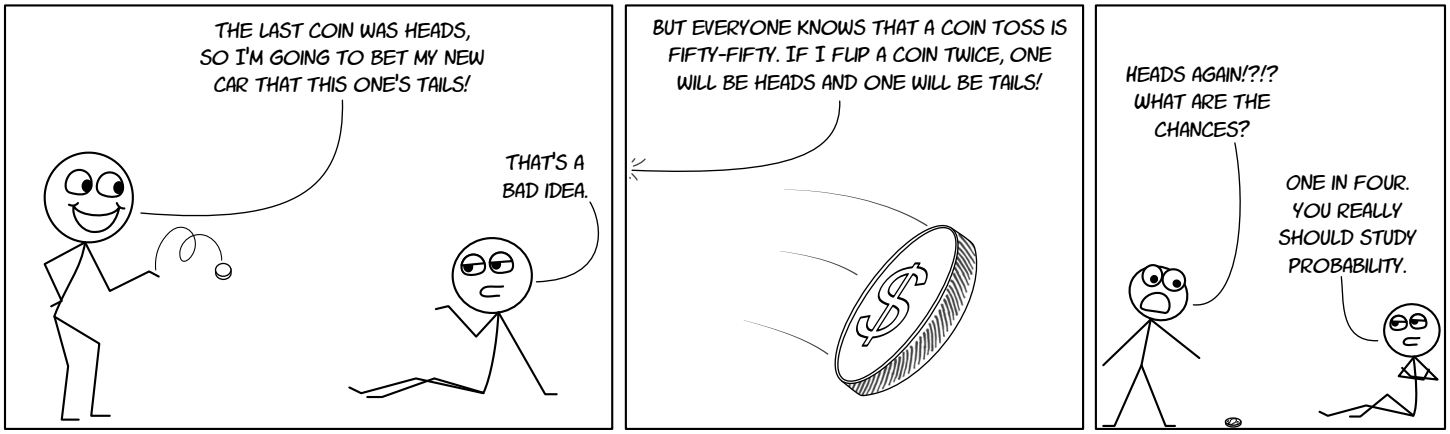
POXVIRUSES: viruses so similar that exposure to one gives you immunity to the entire family (for a while)



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).

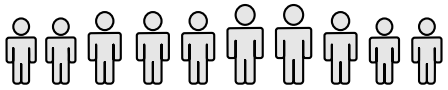
Although the chances of each outcome are 50/50, if you flip a coin ten times you will not necessarily get 5 heads and 5 tails! You could get 4 heads and 6 tails, or 8 heads and 2 tails, or even ten heads or ten tails. But if you spend a few hours flipping coins and tabulating the results, *on average,*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

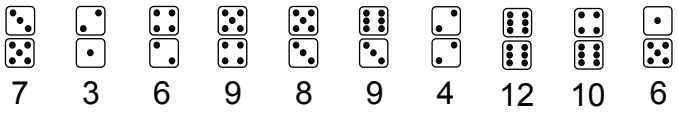
Keeping all of this in mind, it is still a useful exercise to use dice to compare the average outcomes for the various approaches to smallpox. Find two dice and then roll them to predict the outcomes for a group of ten people. Read the example below and then roll your own dice and fill in the scenarios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

1 Smallpox outbreak

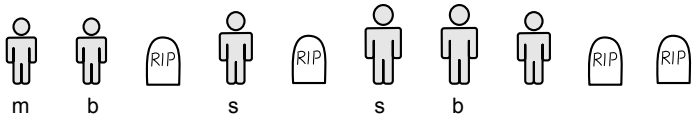


# rolled:	Smallpox outbreak outcome:
2,12	Healthy. Not exposed during outbreak
3,4,11	Survived but now blind
6,8,10	Died
5,7	Survived with moderate scarring
9	Survived with severe scarring

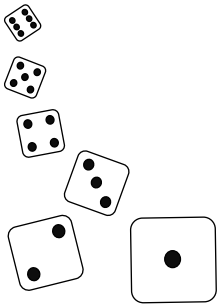
If you rolled the following numbers:



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?

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	Group 2
Group 3	Group 4

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	Group 2
Group 3	Group 4

3 Vaccinia Vaccine

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	Group 2
Group 3	Group 4

**Estimated mortality rates were gathered from the WHO and CDC websites and then translated into paired-dice roll probabilities.*

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

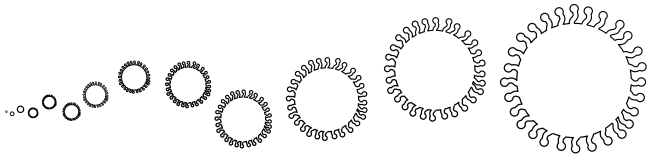
95-99% of infected people have *NO symptoms*. They feel completely healthy and do not know that they are spreading the virus to other people.

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.

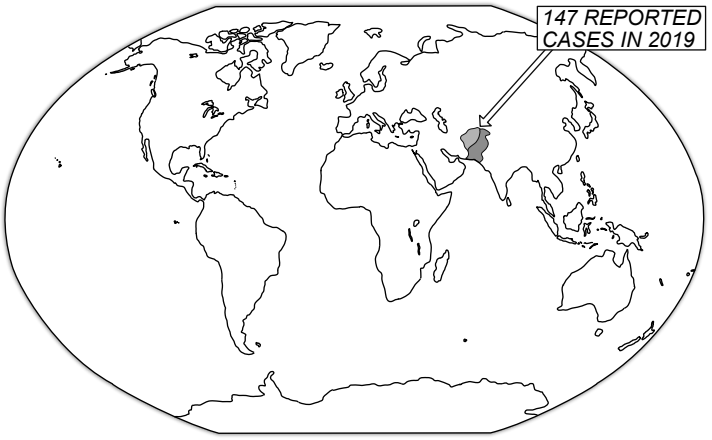
# rolled:	Polio outbreak outcome:
Roll a 7 three times in a row	Mild symptoms
3 doubles in a row	Paralyzed with permanent nerve damage.
5 doubles in a row	Severely paralyzed. Need to be inside an iron lung in order to breathe.
All other rolls	No symptoms



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?

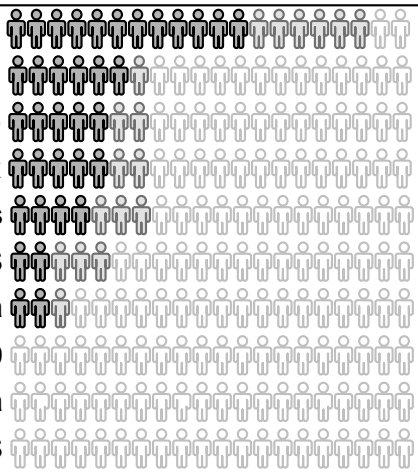
② If 400 million people with no exposure to polio were vaccinated against the disease and there was a 1 in a 1,000,000 risk of complications from the vaccine, how many would be expected to experience complications? If 50% of those with a severe complication died, how many would be expected to die as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

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

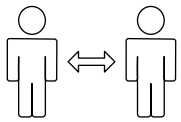
Use these numbers to fill in the last three diseases in the graphic.

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.

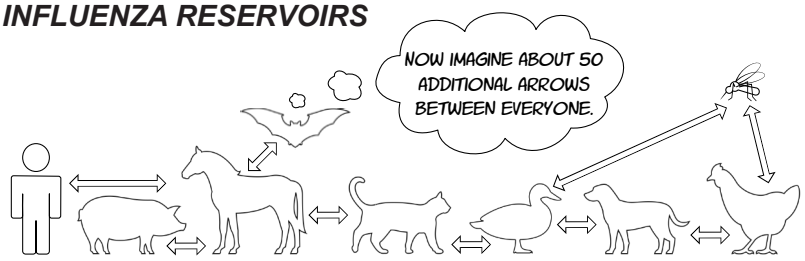
Natural Reservoir or Disease Reservoir

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 _____is more than twice as contagious as polio.

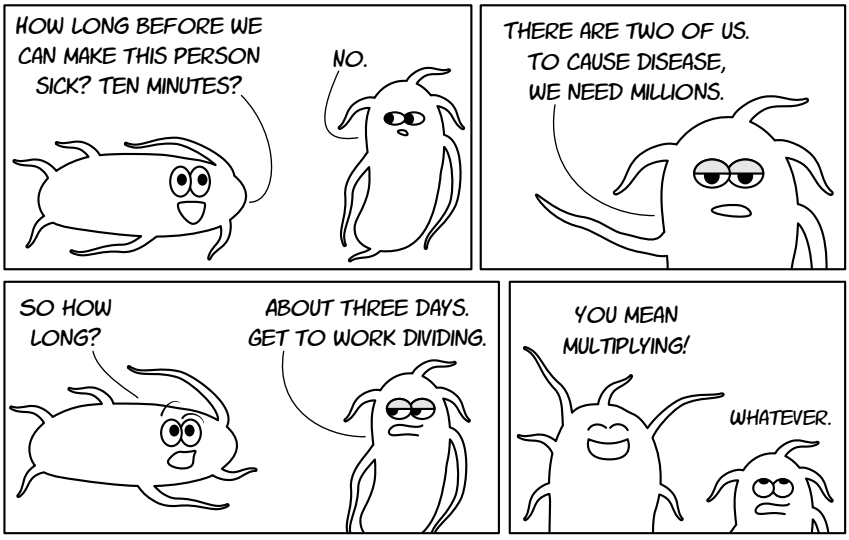
A carrier or vector can transmit a disease from one _____ to another.

WHY ARE DISEASES WITH MORE RESERVOIRS HARDER TO CONTAIN?

_____

_____

Incubation Period



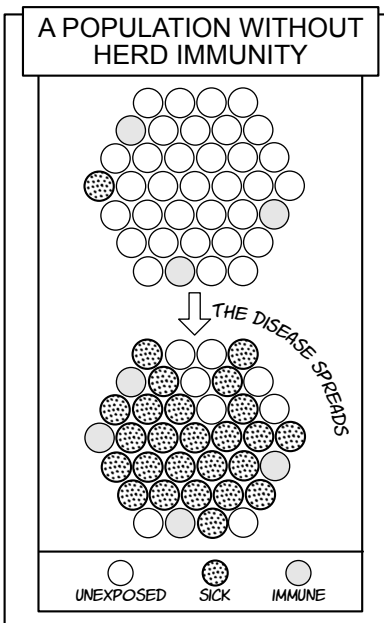
THE INCUBATION PERIOD IS THE AMOUNT OF TIME BETWEEN EXPOSURE AND THE FIRST SYMPTOMS OF ILLNESS. SOME BACTERIA THAT CAUSE FOOD POISONING HAVE AN INCUBATION PERIOD OF JUST A FEW HOURS. THE RABIES VIRUS HAS A LONG INCUBATION PERIOD THAT CAN BE BETWEEN 2 TO 12 MONTHS!

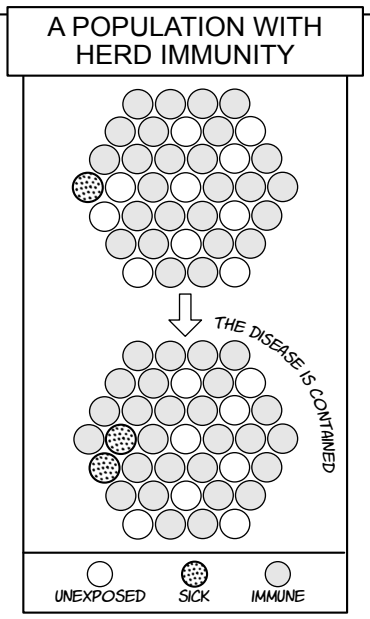
MOST VIRUSES HAVE INCUBATION PERIODS BETWEEN 2 TO 14 DAYS. THE AMOUNT OF PATHOGEN (OR VIRAL LOAD) IN THE INITIAL EXPOSURE HAS A BIG EFFECT ON THE INCUBATION PERIOD.

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.

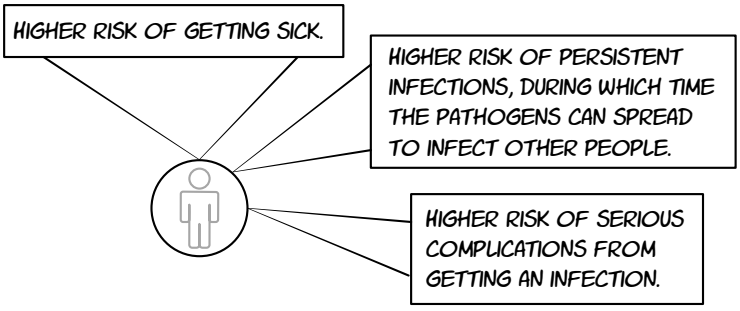
WHEN A HIGH ENOUGH PERCENTAGE OF THE POPULATION HAS IMMUNITY TO A DISEASE, THEN THE PATHOGEN CANNOT EFFECTIVELY TRANSFER THROUGH THE POPULATION. THIS IS CALLED HERD IMMUNITY. THE HIGHER THE PROPORTION OF IMMUNE INDIVIDUALS, THE SMALLER THE CHANCE OF THE DISEASE FINDING NEW HOSTS TO INFECT.





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.



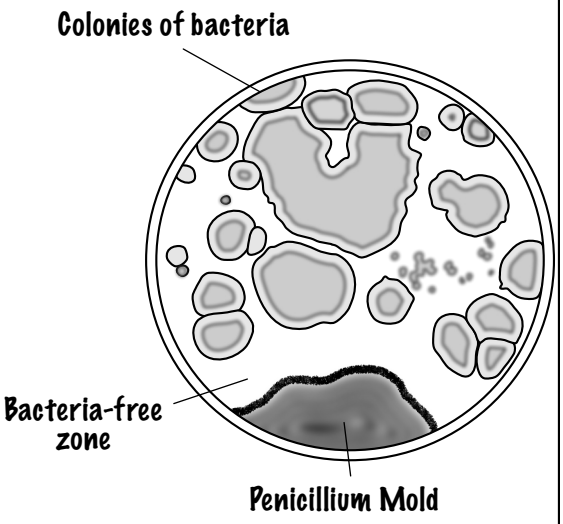
THE VARICELLA VIRUS, WHICH CAUSES CHICKENPOX, HAS THE ABILITY TO HIDE. A PERSON WHO HAD CHICKENPOX AS A CHILD STILL HAS THE VIRUS INSIDE THEM, EVEN THOUGH IT ISN'T CAUSING ANY SYMPTOMS. IF THEIR IMMUNE SYSTEM IS COMPROMISED, THE VIRUS WILL RE-EMERGE AND CAUSE SHINGLES. IT CAN THEN SPREAD AND CAUSE CHICKENPOX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

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?

The Discovery of Penicillin



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

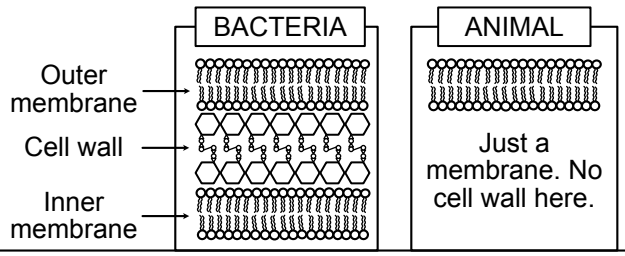
FILL IN THE BLANKS USING THESE WORDS:

secreting	mold	penicillin
mechanism	treatment	petri

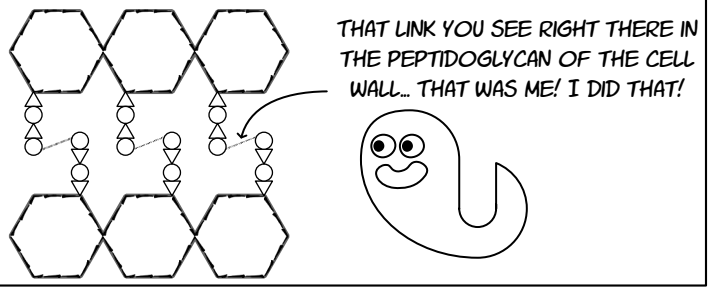
In 1928, Dr. Alexander Flemming returned from a two-week vacation and saw a _____ dish that had accidentally been left out of an incubator. Some _____ had contaminated the dish of Staphylococcus bacteria, and the mold was surrounded by a zone of bacteria-free gel. Flemming's investigation showed that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

Attack the Cell Wall – how penicillin works

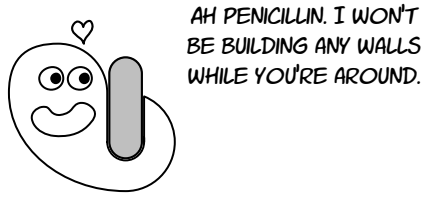
Bacteria have a cell wall. Animal cells do not. Below, we can see the outer cover of the cells.



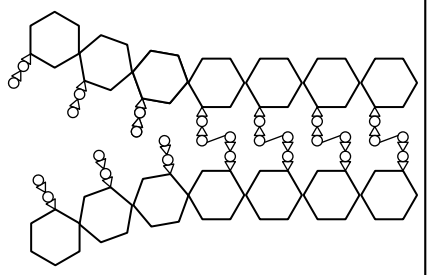
One of the most important steps in making the cell wall is done by an enzyme called transpeptidase.



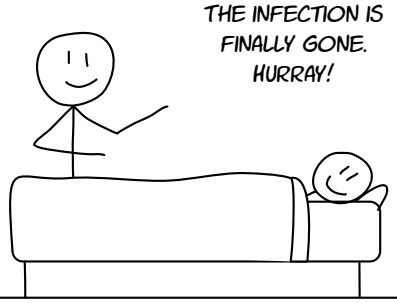
Penicillin is a small molecule that blocks the enzyme transpeptidase.



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



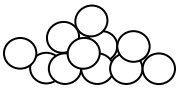
The cell dies.



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

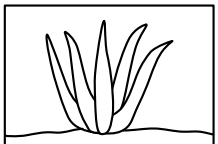
Borrelia burgdorferi
A bacteria with a cell wall made of peptidoglycan

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

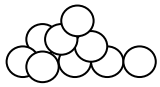


Staphylococcus
A bacteria with a cell wall made of peptidoglycan.

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.

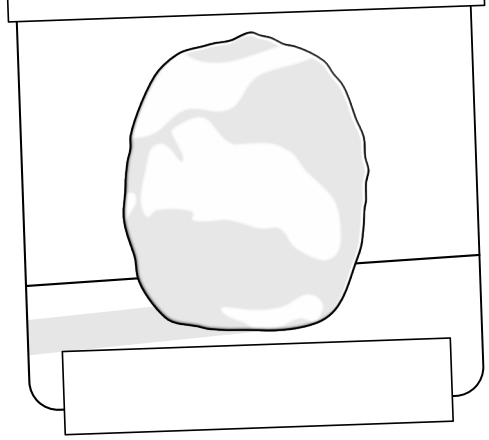
**Penicillin damages the cell and/or stops the infection.*

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.

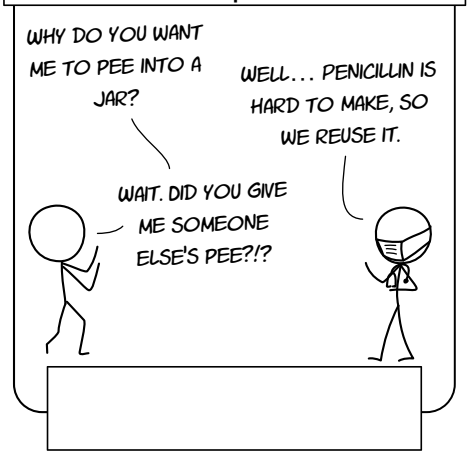
What happens to your microbiome when you take an antibiotic?

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

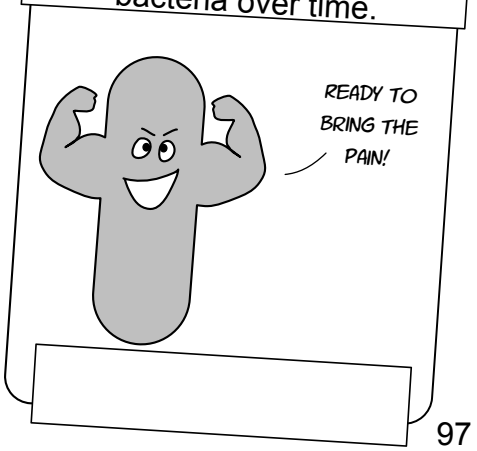
The best strain of penicillin came from a moldy cantaloupe.



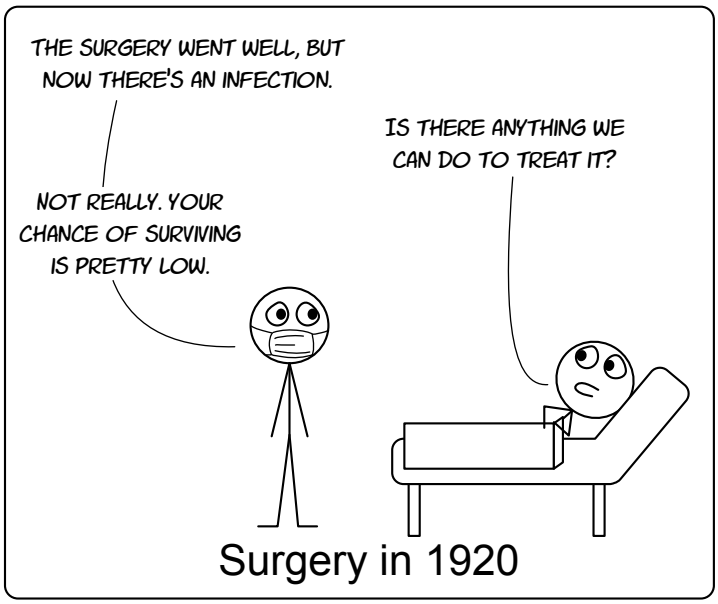
To get enough penicillin, doctors used to collect the urine of patients.

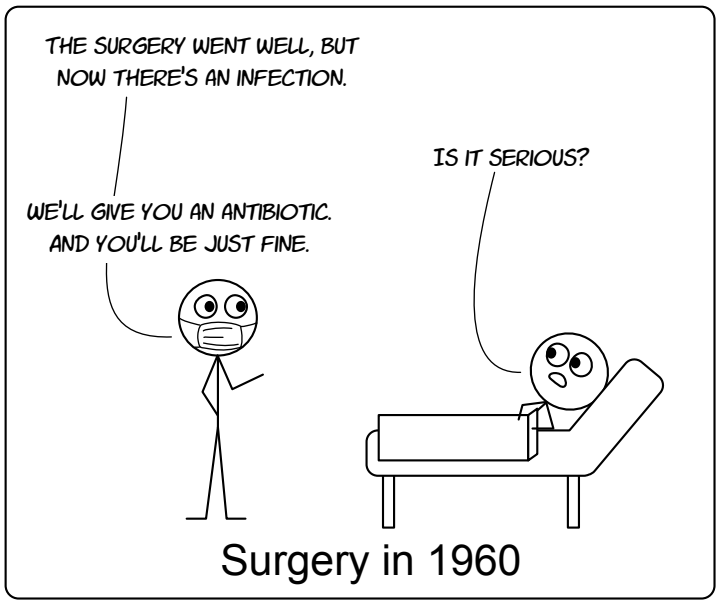


Penicillin is becoming even more effective against bacteria over time.

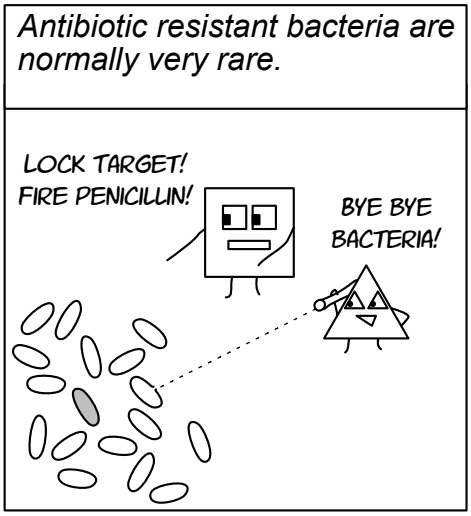


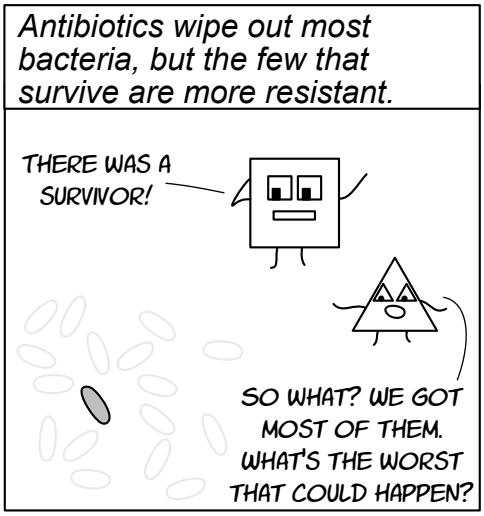
Antibiotics Fight Bacterial Infections

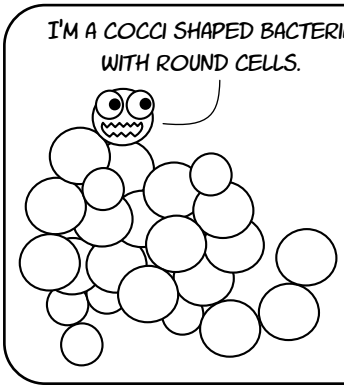




Antibiotics revolutionized the treatment of infectious diseases. At the turn of the 20th century, before antibiotics, the average life expectancy in the US was around 47 years. After antibiotics had become widely available, the average life expectancy was 68 – a jump of over twenty years! Before antibiotics, 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

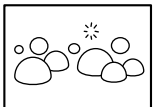
Staphylococcus (staph) is a common bacteria present on many healthy people. MRSA is a strain of staph that has developed a number of methods for _____ antibiotics like penicillin and _____. These bacteria secrete an enzyme that _____ the antibiotic. They also have different _____ in their cell walls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

FILL IN THE BLANKS USING THESE WORDS:

antibacterial	bind	inactivates
proteins	resisting	methicillin

Scientists are in a virtual arms race to come up with new _____ 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.

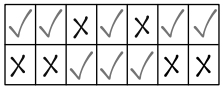


Washing hands frequently.

Not finishing the prescription of antibiotics.

Staying home from school or work when sick.

Not treating a viral infection with antibiotics.



Forgetting to take several doses of an antibiotic.

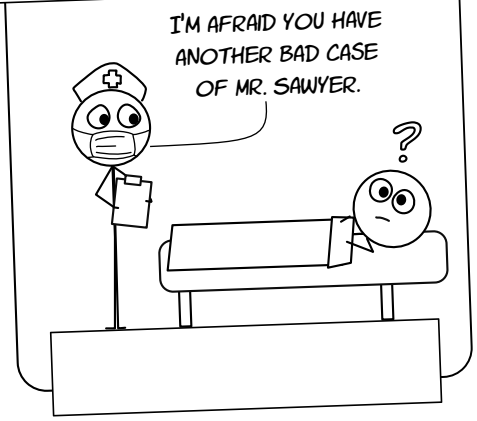
Demanding an antibiotic after being told you have a viral infection.

Will DECREASE the likelihood of antibiotic resistance in bacteria.

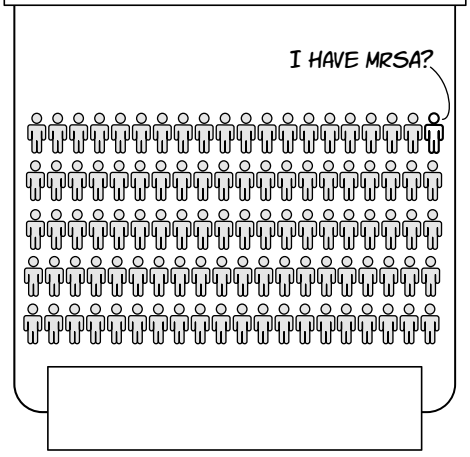
Will INCREASE the likelihood of antibiotic resistance in bacteria.

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

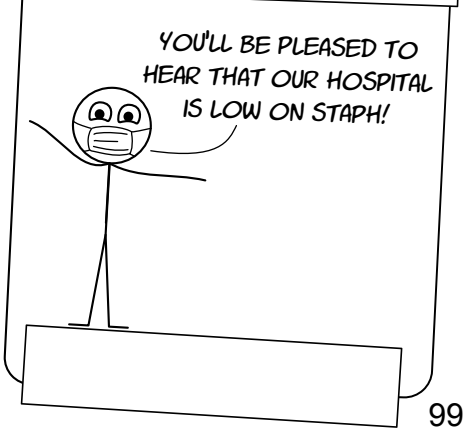
MRSA was named after its first patient "Mr. Sawyer" but was later shortened to MRSA.

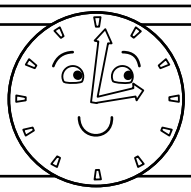


About 1% of the population has been colonized with MRSA bacteria but doesn't know it.



The most likely place to get MRSA is the hospital.





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*

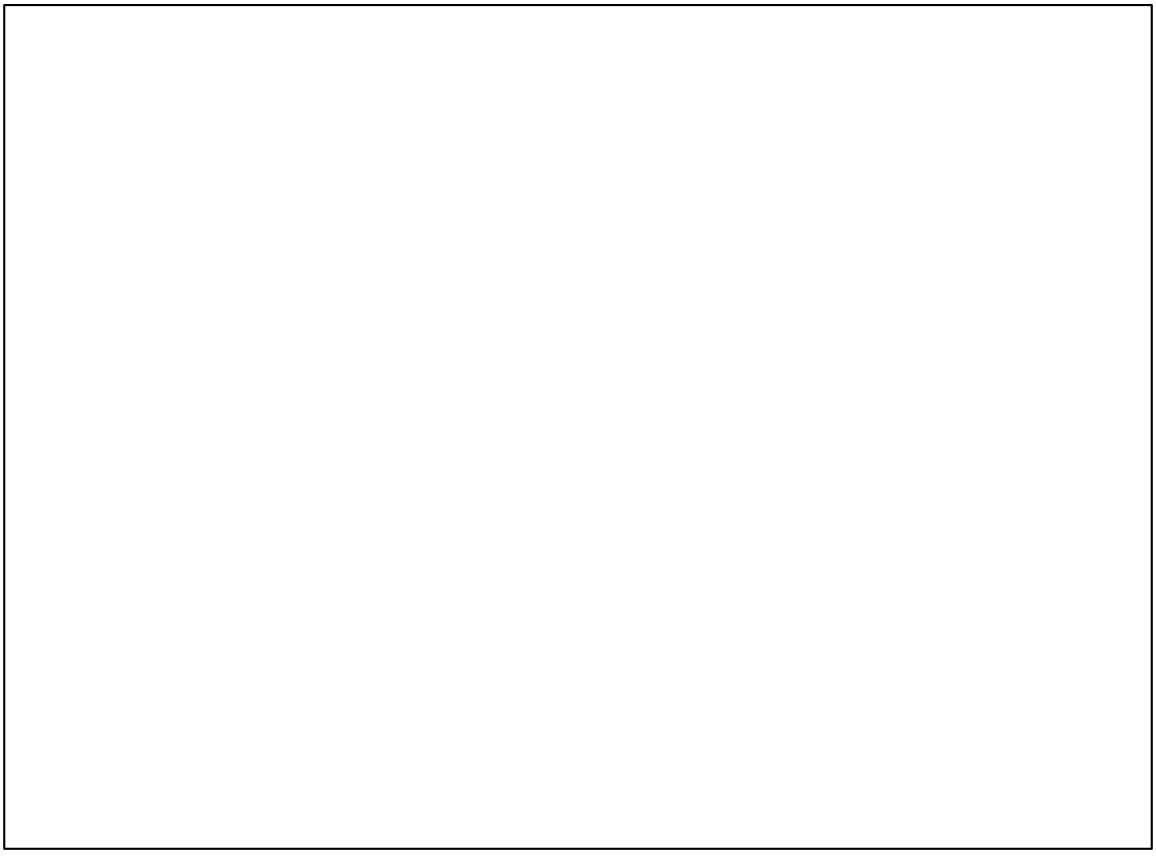
BACTERIA:	***ILLNESS:***
Various species of Group A Streptococcus	*Necrotizing fasciitis (flesh eating disease)*
Corynebacterium diphtheriae	*Diphtheria*
Mycobacterium tuberculosis	*Tuberculosis*
Clostridium botulinum	*Botulism*
Bordetella pertussis	*Whooping Cough or Pertussis*
Borrelia burgdorferi	*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: _____

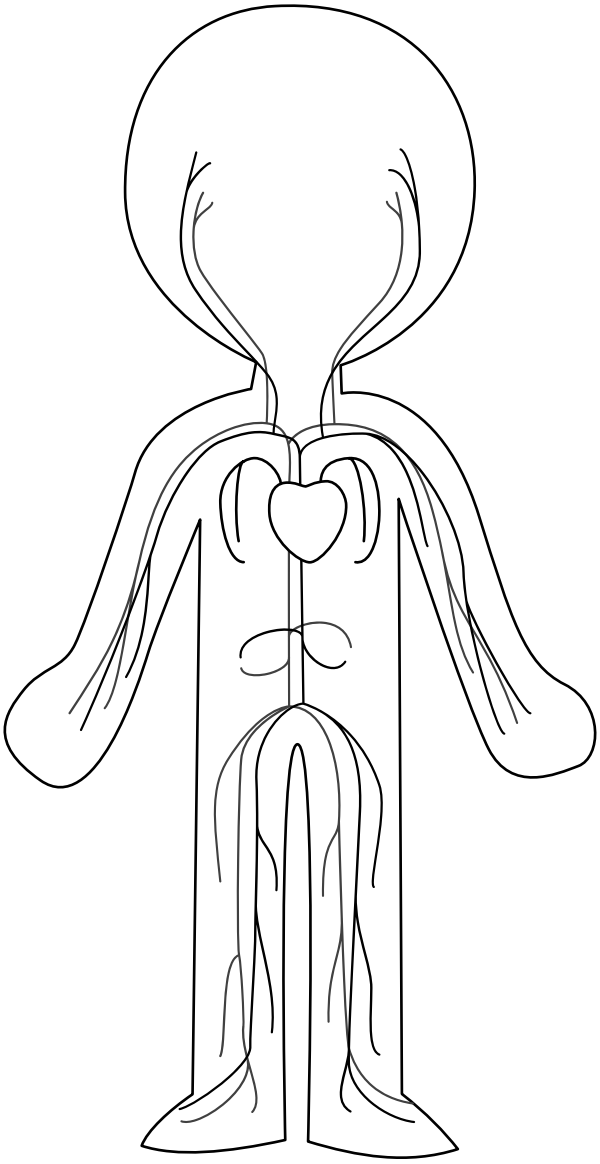
_____

Symptoms of infection: _____

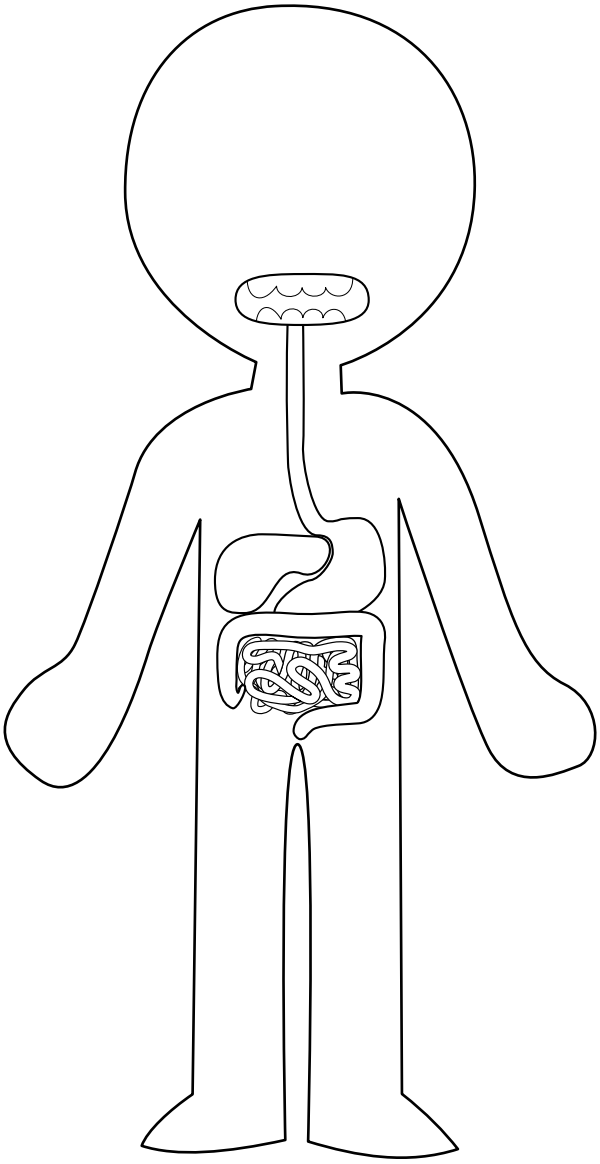
_____

Likely locations: _____

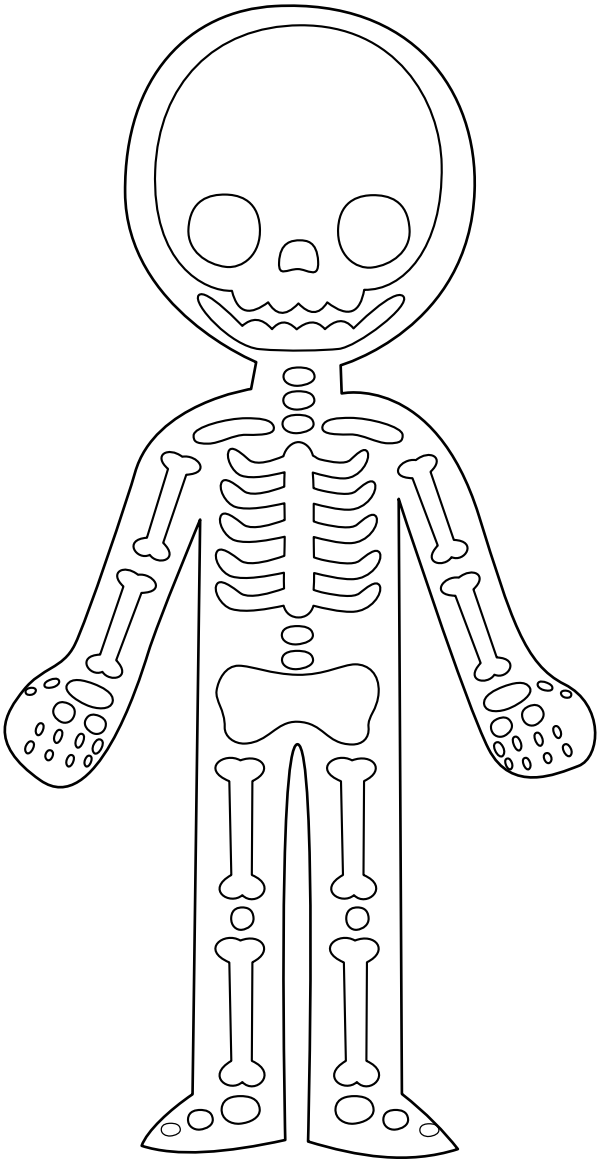
_____



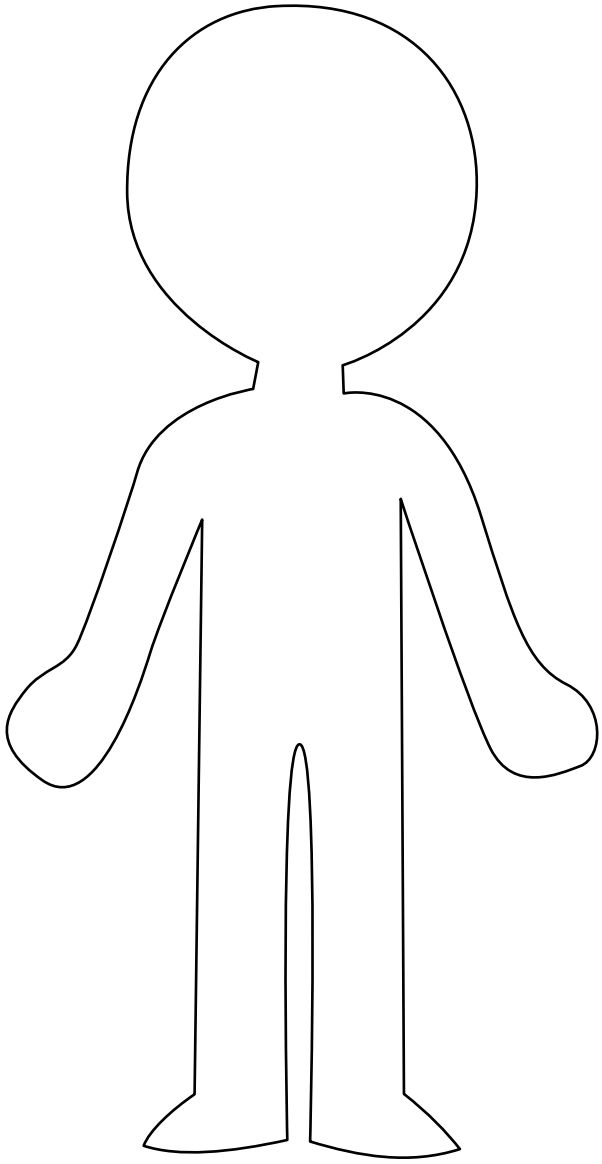
Circulatory



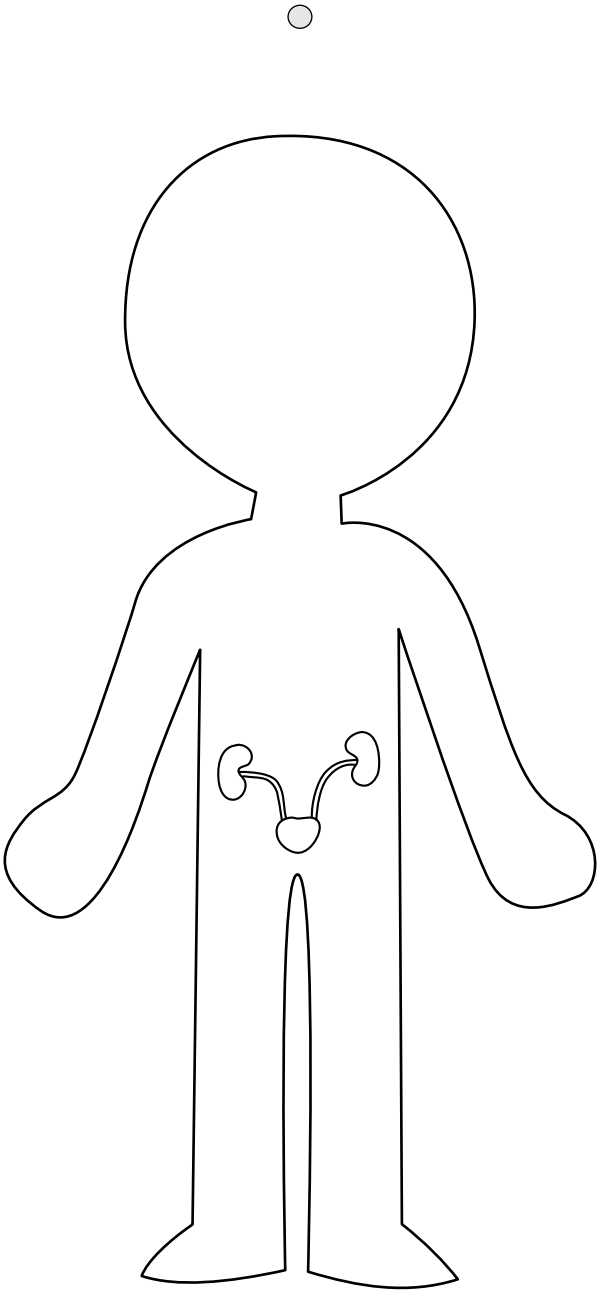
Digestive



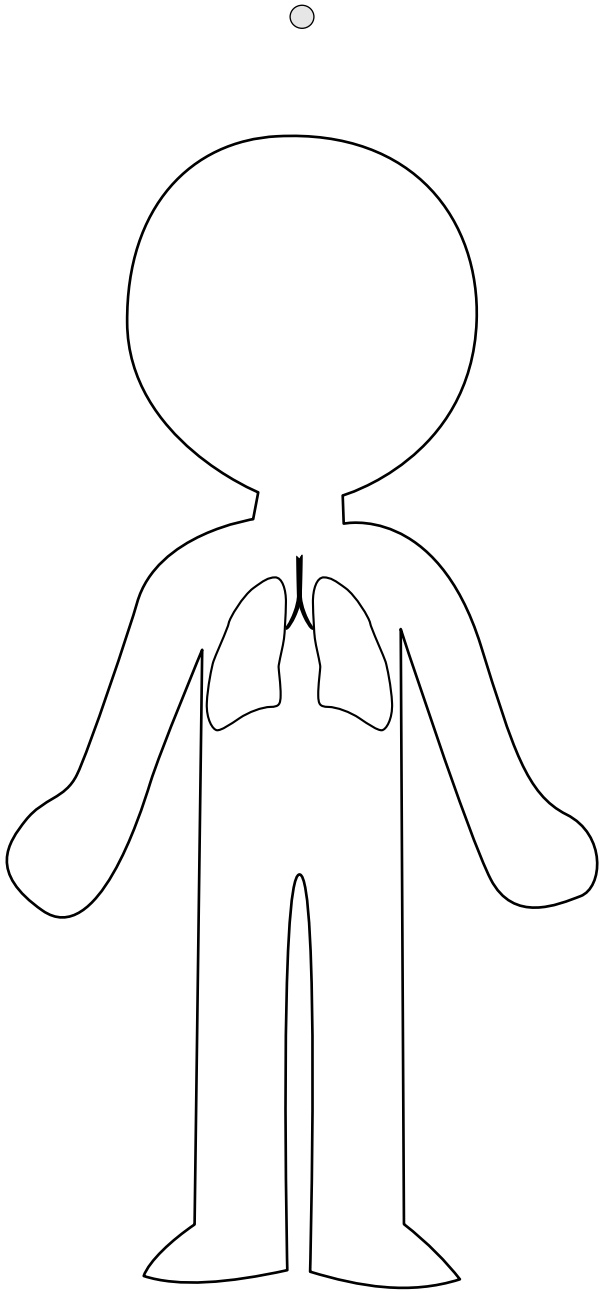
Muscular/
Skeletal



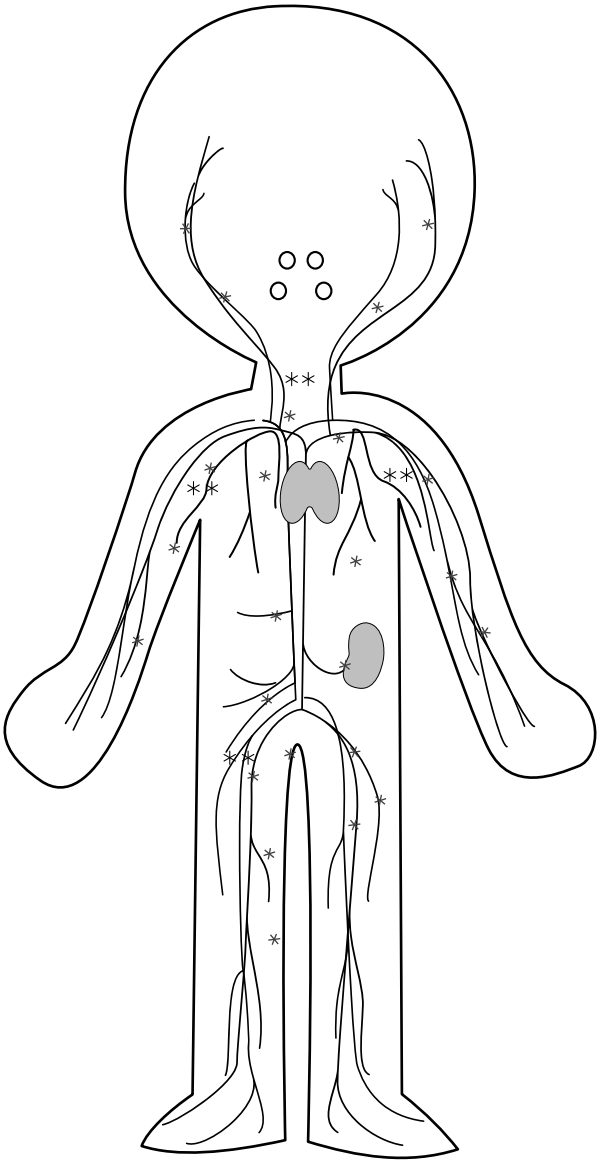
Integumentary



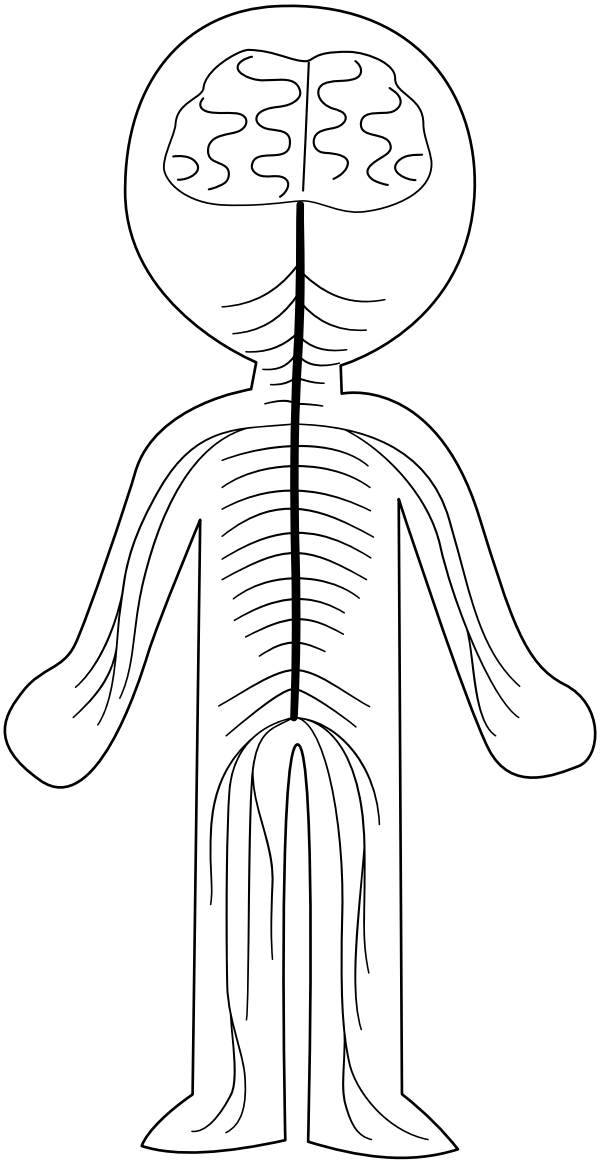
Urinary



Respiratory



Immune



Nervous