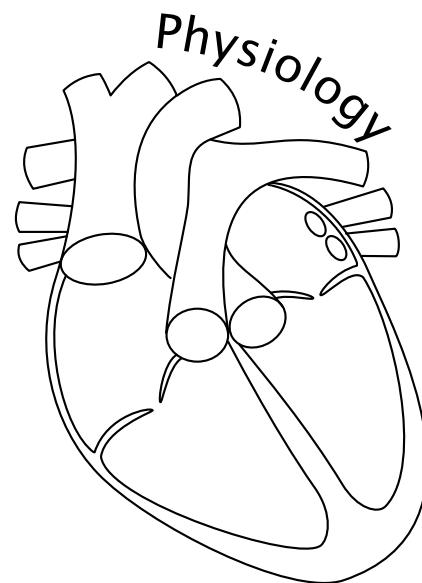
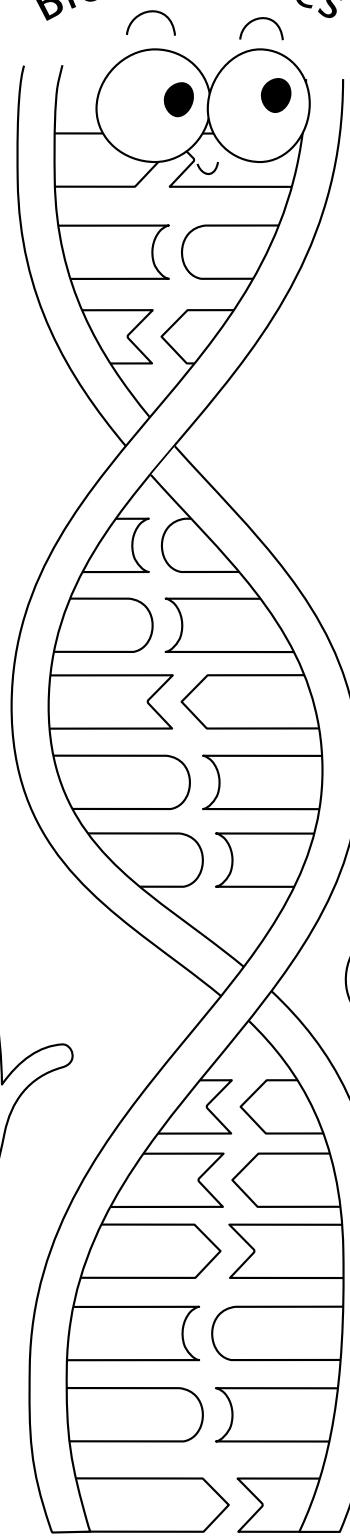


# BIOLOGY ONE

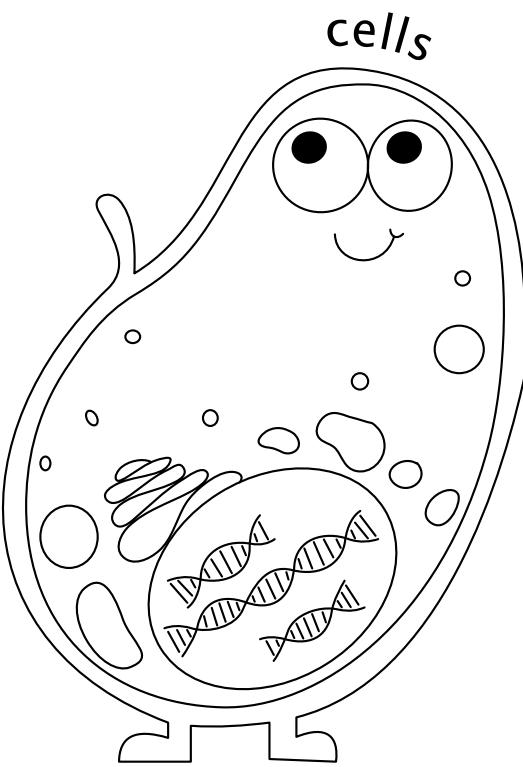


Diversity of life

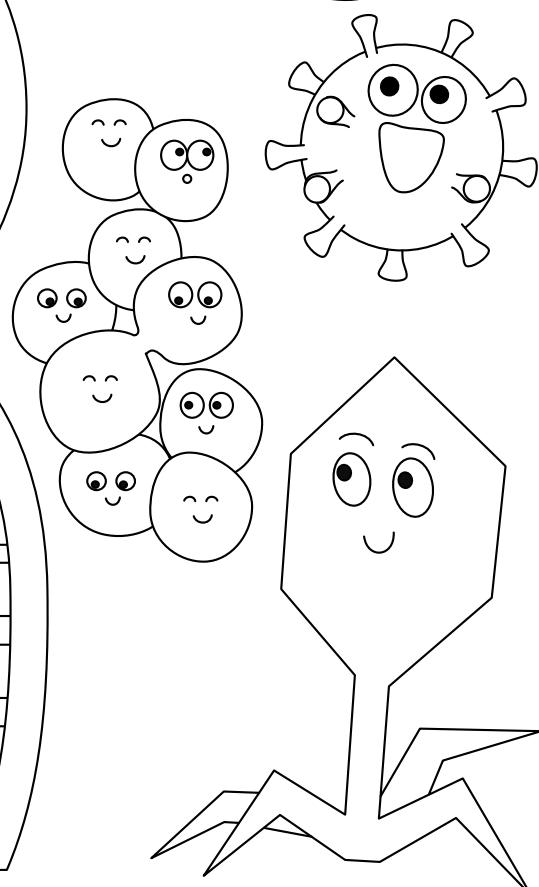
Biomolecules



Physiology



cells



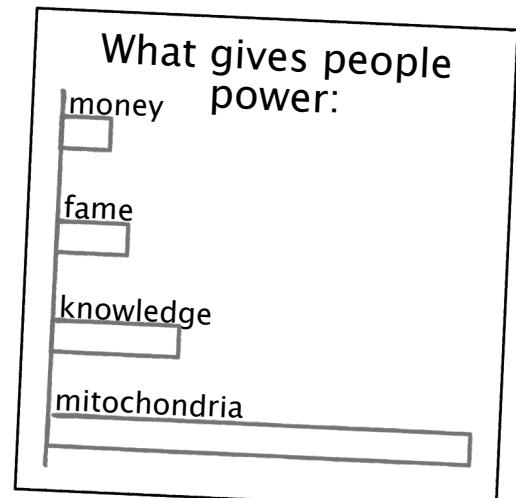
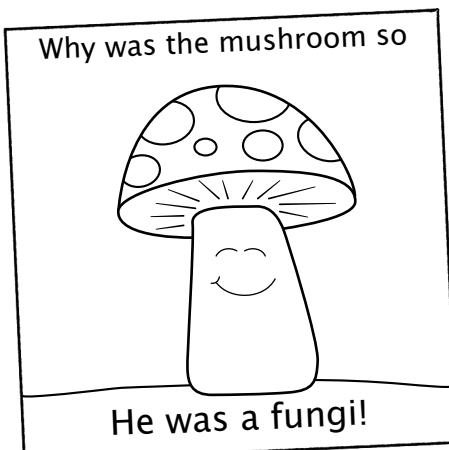
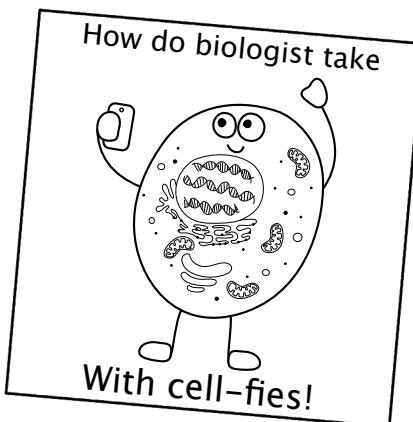
# BIOLOGY ONE

## ~ MICROBIOLOGY ~

		Topic	Page(s)
Week 1		<i>Watch the Welcome and Intro videos.</i>	
	Day 1	It's alive! Or is it? <i>Characteristics of living things and why we study biology</i>	6-7
	Day 2	The discovery of the cell <b>Laser Pointer Microscope</b>	8-11
Week 2	Day 3	The Parts of the Cell <i>Meet the organelles. Prokaryotes &amp; Eukaryotes</i>	12-15
	Day 4	Unicellular vs Multicellular life <i>A look at the incredible diversity of cellular life!</i>	16-17
	Day 5	Cell Quiz Show <i>Practice Quiz 1</i>	18-19
		Science Vocabulary Crossword and Word Search	20-21
Week 3	Day 6	Biomolecules <i>The molecules that make living things</i>	22-23
	Day 7	Osmosis! <i>All about cell membranes and why we salt our food</i>	24-26
	Day 8	Proteins and Enzymes <i>A deeper look at enzymes and cell proteins</i>	27-28
Week 4	Day 9	Sugars and Carbohydrates <i>The main source of energy</i>	29
	Day 10	DNA <i>The instructions for the cell</i>	30-31
	Day 11	<b>Extract DNA from fruit</b> <i>Hands on science project</i>	32-35
Week 5	Day 12	Mitosis and cell division <i>How one cell becomes two</i>	36-37
	Day 13	Biomolecules Quiz Show <i>Practice Quiz 2</i>	38-39
	Day 14	Where does energy come from? <i>Eating vs making food</i>	40

*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.*

		<b>Topic</b>	<b>Page(s)</b>
Week 6	Day 15	Animals & Fungi <i>Diversity of the consumers</i>	41-42
	Day 16	Cellular Respiration <i>Making energy in the mitochondria</i>	43-44
	Day 17	Plants <i>The big producers</i>	45-46
Week 7	Day 18	Photosynthesis <i>Making sugars in the chloroplast</i>	47-48
	Day 19	The Single-Celled Archaea <i>The most diverse groups of all</i>	49-50
	Day 20	<b>DIY Petri Dishes</b> <i>Culture your own microorganisms</i>	51-53
Week 8	Day 21	Diversity of Life Quiz Show <i>Practice Quiz 3</i>	54-55
	Day 22	Systems of the human body <i>The body is made of different systems of cells</i>	56-57
	Day 23	What is blood? <i>Introduction to circulatory system and different blood cells</i>	58-60
Week 9	Day 24	Why we need to breathe <i>An introduction to the respiratory system</i>	61-62
	Day 25	How nerves work <i>Introduction to the nervous system and the longest cells!</i>	63-64
	Day 26	There's more of us than you! <i>Introduction to the digestive system and the microbiome</i>	65



		Topic	Page(s)
Week 10	Day 27	The Immune System <i>An introduction to the body's most fascinating system</i>	66-68
	Day 28	How Antibodies Work <i>The basic defenses and fighters against infections</i>	69
	Day 29	You're Allergic to What? <i>How a misbehaving immune system causes allergies</i>	70-71
Week 11	Day 30	What makes things poisonous? <i>What happens when things go wrong in the cell</i>	72-75
	Day 31	<b>Physiology Art</b> <i>Hands on science project</i>	76
	Day 32	Physiology Quiz Show <i>Practice Quiz 4</i>	77
Week 12	Day 33	<b>Most Wanted Microbes</b> <i>An overview of viruses, fungi, bacteria, and parasites</i>	78-80
	Day 34	Pre-industrial Medicine <i>A look at common 16<sup>th</sup> century treatments</i>	81-82
	Day 35	Scurvy and Trials <i>The evolution of modern medicine</i>	83-85
Week 13	Day 36	The Story of Smallpox <i>How a deadly disease led to the first vaccine</i>	86-89
	Day 37	The Problem with Polio <i>An exercise in understanding and comparing risk</i>	90-91
	Day 38	Elementary Epidemiology <i>Lessons from looking at diseases in large populations</i>	92-95
Week 14	Day 39	Penicillin & the Discovery of Antibiotics <i>How a moldy dish led to medicine</i>	96-97
	Day 40	MRSA and antibiotic resistance <i>How overuse of a good tool is breeding superbugs</i>	98-99
	Day 41	<i>Final Quiz Show</i> <i>And a showcase of Most Wanted Microbe art from students.</i>	100
Appendix		Suggested Microbe List	101
		Most Wanted Microbe Template	102
		Body System Templates	103-106

Have questions, corrections, or suggestions?  
 Contact [jenny@science.mom](mailto:jenny@science.mom) or [serge@science.mom](mailto:serge@science.mom)

# Project Supply List

## Day 2 - Laser Pointer Microscope

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

## Day 11 - Extract DNA from Fruit

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

## Day 21 - DIY Petri Dishes

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

## Day 30 - Physiology Art Project

- Several pieces of waxed paper or tracing paper
- Pencil
- Markers
- Brads (paper fastener)

## Day 33 - Most Wanted Microbe Art Project

- Copies of the most wanted microbe template
- Pencil
- Markers
- Butter knife (optional)
- Ink and napkin (optional)

## Other (optional) Activities

### Week 6 - Respiration

- 2 Tbsp Yeast
- 2 Balloons
- 2 Water bottles
- Sugar

### Week 8 - What is Blood?

- 1/3 c measuring cup
- 6 L of water and two containers
- Timer or stopwatch

### Week 9 - Why We Breathe

- 2 balloons
- Plastic bottle with bottom cut off

### Week 9 - How Nerves Work

- Ruler

### Week 13 - The Problem with Polio

- 2 dice

## How to get the most from this course:

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

For BEST learning, we recommend:

- ✓ Read the pages that go with each lesson before watching the video. Take 10-15 minutes to see if you can fill in the blanks.
- ✓ On quiz show days, take the practice quiz before you watch the class!
- ✓ Complete each of the science activities, and then share your work with a family member or friend.
- ✓ Download the answer key for the notes, but don't look at the answers until after you give things a try yourself!

## Next Generation Science Standards

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

### MS-LS1-1: Days 4, 5, and 6

*Living things are made of cells*

### MS-LS1-2: Days 3 and 22

*The function of a cell as a whole and how the parts of a cell contribute to that function*

### MS-LS1-3: Days 22, 23, 24, 25, and 7

*The body is a system of interacting subsystems composed of groups of cells*

### MS-LS1-6: Days 14, 17, and 18

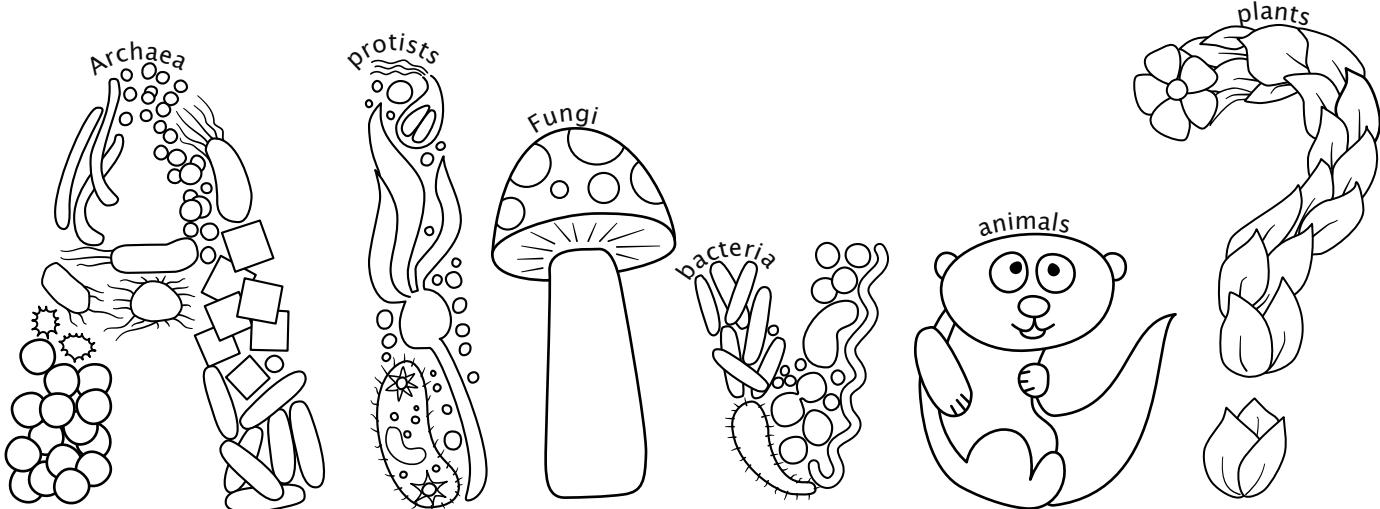
*Photosynthesis and its role in cycling matter and the flow of energy in and out of organisms*

### MS-LS1-7: Days 14, 15, and 16

*How food is rearranged through chemical reactions to form new molecules that support growth and release energy*

### MS-LS1-8: Day 25

*Sensory receptors respond to stimuli by sending messages to the brain*



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

### METABOLISM

**Uses energy!**

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

### HOMEOSTASIS

**Keep inside conditions stable!**

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

### GROWTH

**Gets bigger!**

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

### RESPONDS TO STIMULI

**Reacts to the world around it!**

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

### MADE OF CELLS

**Cells: tiny bags of mostly water!**

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

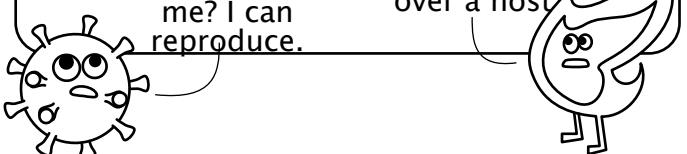
### REPRODUCTION

**Can make more of itself!**

**Reproduction is the process of parents creating offspring.**

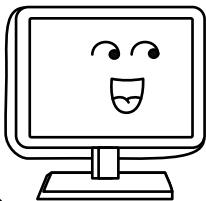
Hey! What about me? I can reproduce.

But only if you take over a host



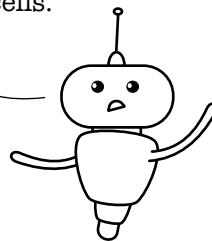
## COULD ARTIFICIAL INTELLIGENCE (AI) BE CONSIDERED ALIVE?

We can be programmed to have all of the characteristics of life!



So? Cells shouldn't even be on the list anyway.

Except being made of cells.



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

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

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

1, Possible answers include:

AI can grow and learn as it gets more information.

2, Each AI responds to stimulus by executing its programs and altering its output.

3, Each AI is made of distinct bits of code that act together to carry out its objectives, and this is similar to individual cells creating a multicellular organism.

AI can be programmed to adapt and change.

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

1, Possible answers include:

AI do not carry out their own metabolic process (energy conversion process).

2, AI do not reproduce in the usual sense.

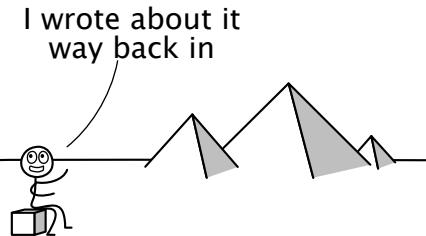
AI is not made up of physical cells.

3, AI cannot exhibit the various characteristics of living things (like response to stimuli or adapting and learning) without first being programmed to do so.

What is your opinion?

# THE DISCOVERY OF THE CELL

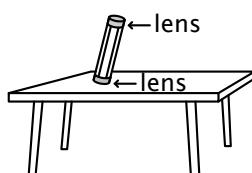
FOR THOUSANDS OF YEARS,  
PEOPLE KNEW THAT CURVED  
GLASS MAGNIFIED DETAILS.



CLAUDIUS PTOLEMY  
Famous philosopher

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

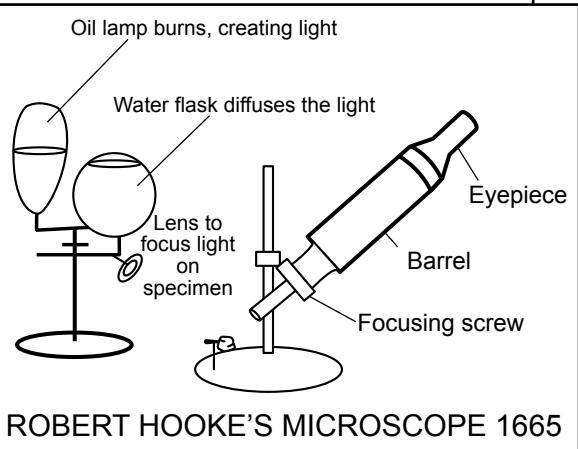
If we put lenses on both  
sides of a tube, the  
objects on the other side



HANS & ZACHARIAS JANSSEN  
Dutch glassmakers

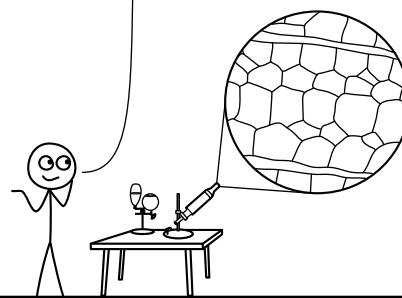
THE NEXT CENTURY  
SAW HUNDREDS OF  
EXPERIMENTS ON  
IMPROVING THE  
MAGNIFICATION  
OF MICROSCOPES  
AND MANY  
PUBLICATIONS  
ABOUT WHAT WAS  
OBSERVED UNDER  
THE LENS.

THE MOST FAMOUS OBSERVATIONS  
WERE MADE BY ROBERT HOOKE...

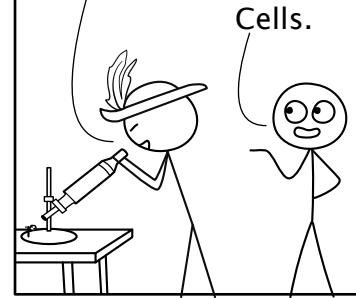


ROBERT HOOKE'S MICROSCOPE 1665

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  
Cells.



Cells? The  
same name  
for empty  
rooms?

Why not? They  
look like  
honeycomb cells

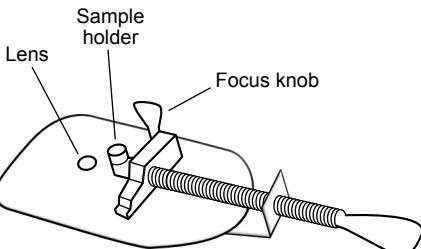
And look!  
There are  
even cells in

I thought  
fossils were  
just rocks.

Rocks that  
used to be  
alive!

Blime  
y!

...AND DUTCH SCIENTIST ANTON VON LEEUWENHOEK.

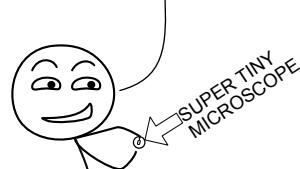


LEEUWENHOEK'S MICROSCOPE 1676

I made  
incredibly tiny  
lenses by  
melting,  
grinding, and



There is only one  
lens in this  
microscope, but  
the quality is so  
good I can see with

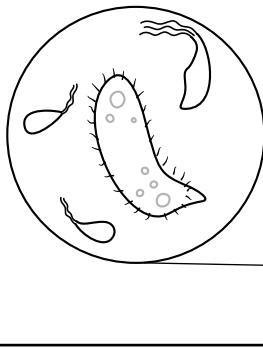


My microscope  
has better  
magnification  
than Hooke's!



CONTINUED ON NEXT PAGE...

LEEUWENHOEK LOOKED AT POND WATER AND WAS ASTONISHED BY WHAT HE SAW.



So many little animals! I shall call them animalcules.

Animalcules? Nice name. What does it

"Little animal" in

OVER THE NEXT 200 YEARS, MICROSCOPES BECAME POWERFUL ENOUGH TO SEE ATOMS AND WE DISCOVERED HOW THE PARTS OF CELLS WORKED!

Your notes:

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

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

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

Made of cells or came from cells

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

NOT made of cells or derived from cells

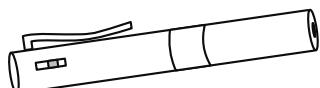
Salt, cement, water, plastic, sand

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

# Hands-on Science Project

## LASER POINTER MICROSCOPE

### MATERIALS:



Laser Pointer



Paperclip



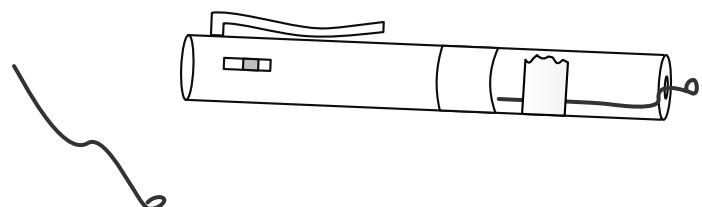
Tape



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

### SAFETY WARNING

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



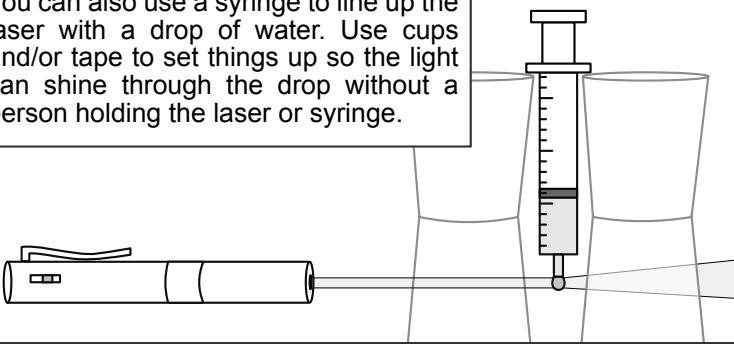
1. Straighten out a large paper clip and then bend one end so that it forms a small loop.
2. Test the loop to be sure that it holds a water droplet. When you dip it in water and then lift it out again, a drop of water should stay inside the loop. If the loop does not hold water then bend it again and make it smaller.
3. Attach the paperclip to the laser pointer with tape so that the loop is directly in the path of the beam.
4. Carefully dip the wire loop into a water source that will have bacteria and other microbial life. Pond water, aquarium water, or water from a pet drinking dish are all good choices.
5. Shine the laser toward a white surface. For best results, conduct this activity in a darkened room.
6. Observe your results and experiment with different sources of water.

### SAFETY TIP

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

### 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.

# WHICH SOURCE OF WATER HAD THE MOST MICROBES?

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

## YOUR PREDICTION:

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

Water from the kitchen sink.

Water from a natural outdoor source that looks clean like a lake or river.

Water from a natural outdoor source that looks dirty or scummy like a puddle, swamp, or pond. *If the water is especially scummy it will block the light of the laser microscope and you won't see anything.*

A drop of saliva. *This one requires a lot of patience to set up because bubbles will interfere with how the light refracts.*

Water from a pet's water dish.

Water from the tank (not the bowl!) of a toilet. *Water in the toilet tank may be dirty from water deposits, but because it comes from the same clean water as the kitchen sink and is cycled frequently, it's usually quite clean. Water in the toilet bowl is not!*

Other: \_\_\_\_\_

## YOUR RESULT:

The water with the most observed microbes was \_\_\_\_\_.

## WHICH OF THESE DID YOU OBSERVE USING YOUR LASER POINTER MICROSCOPE?

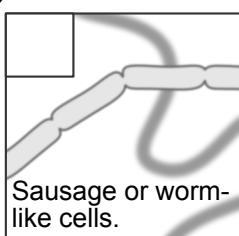
Check all that apply.



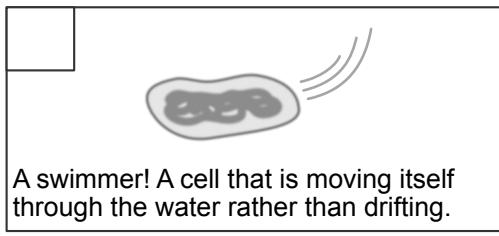
Clean water with no microbes.



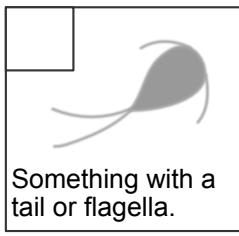
Circular cells that drifted.



Sausage or worm-like cells.



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



Something with a tail or flagella.

Your notes:

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

# The Parts of a Cell

FILL IN THE BLANKS USING THESE WORDS:

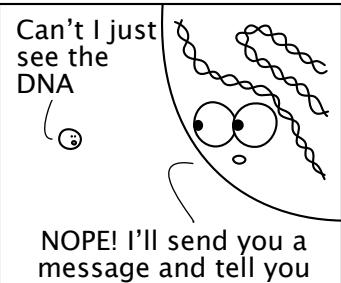
DNA      proteins      living      organelles  
plasma membrane      dead      cytoplasm      diversity

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

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

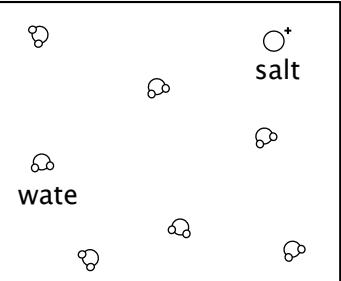
## Cytoplasm

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



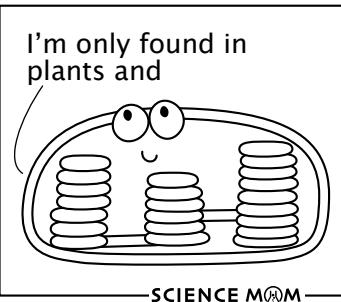
## Nucleus

Keeps the DNA separate from the rest of the cell.



## Chloroplast

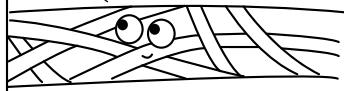
Uses CO<sub>2</sub> and sunlight to create sugars.



### Plasma Membrane

Keeps the cytoplasm inside the cell.

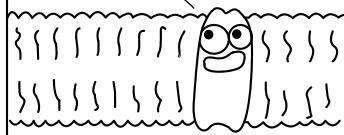
I'm even stronger than a cell



### Cell Wall

Keeps the cytoplasm inside the cell.

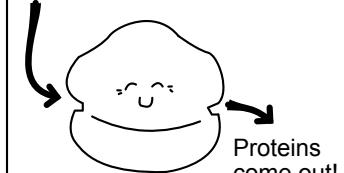
No one gets past me!  
Except the stuff I want to get past.



### Flagella

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

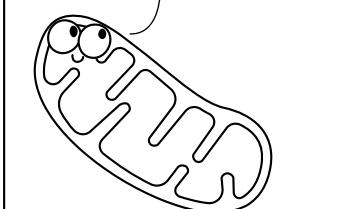
Instructions from DNA go in.



### Ribosome

The thing that makes the proteins.

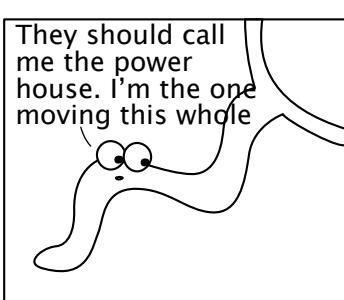
They call me the powerhouse of the



### DNA

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

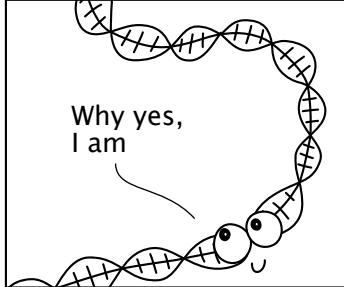
They should call me the power house. I'm the one moving this whole



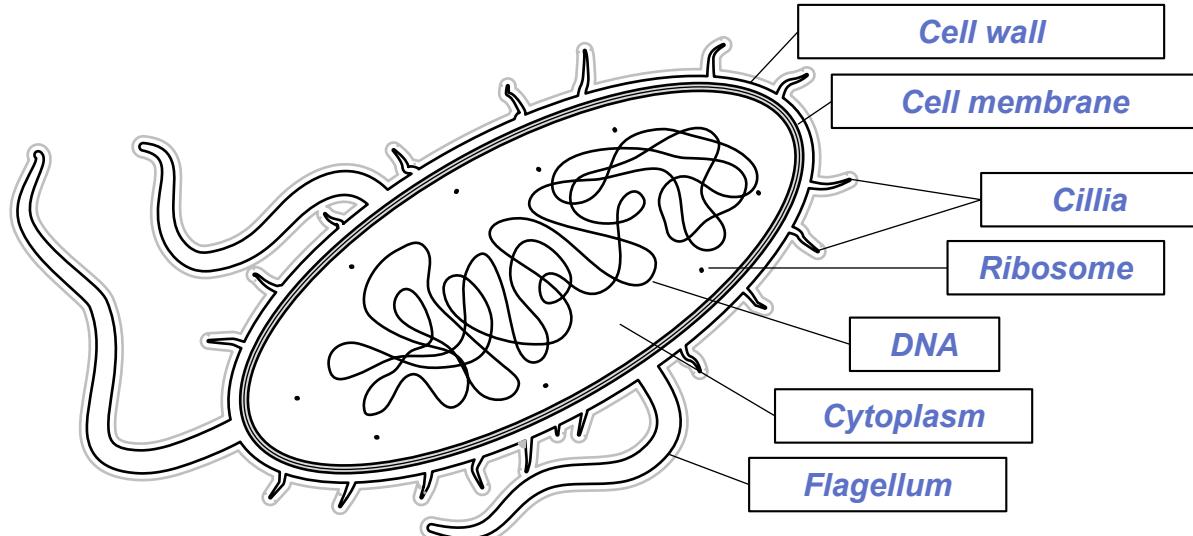
### Mitochondria

Uses oxygen and sugar to create energy for the cell.

Why yes,  
I am



# PROKARYOTIC CELLS



FILL IN THE LABELS ABOVE  
USING THESE WORDS:

CYTOPLASM	CELL WALL	PLASMA MEMBRANE	DNA	CILLA
			FLAGELLUM	RIBOSOME

Example: *Salmonella*  
Size: 2-5 Microns long

Your notes:

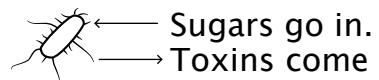
Most prokaryotic cells are 10 to 100 times smaller than eukaryotic cells.  
They have DNA but it isn't specially wrapped or packaged, it just floats inside the center of the cell. The word prokaryote comes from Greek words meaning "before" and "nut" or "kernel," in reference to the fact that these cells do not have a nucleus.

The prokaryotic cells that you hear about most often are bacteria. Some bacteria are beneficial to humans but others (like salmonella) cause disease.

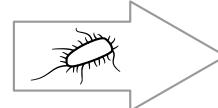
IS SOMETHING AS SMALL AS A SALMONELLA BACTERIUM REALLY ALIVE? LET'S CHECK:

Metabolism ✓

IT EATS FOOD AND PRODUCES WASTE.



Responds to Stimuli



Will move toward a wetter and better environment

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



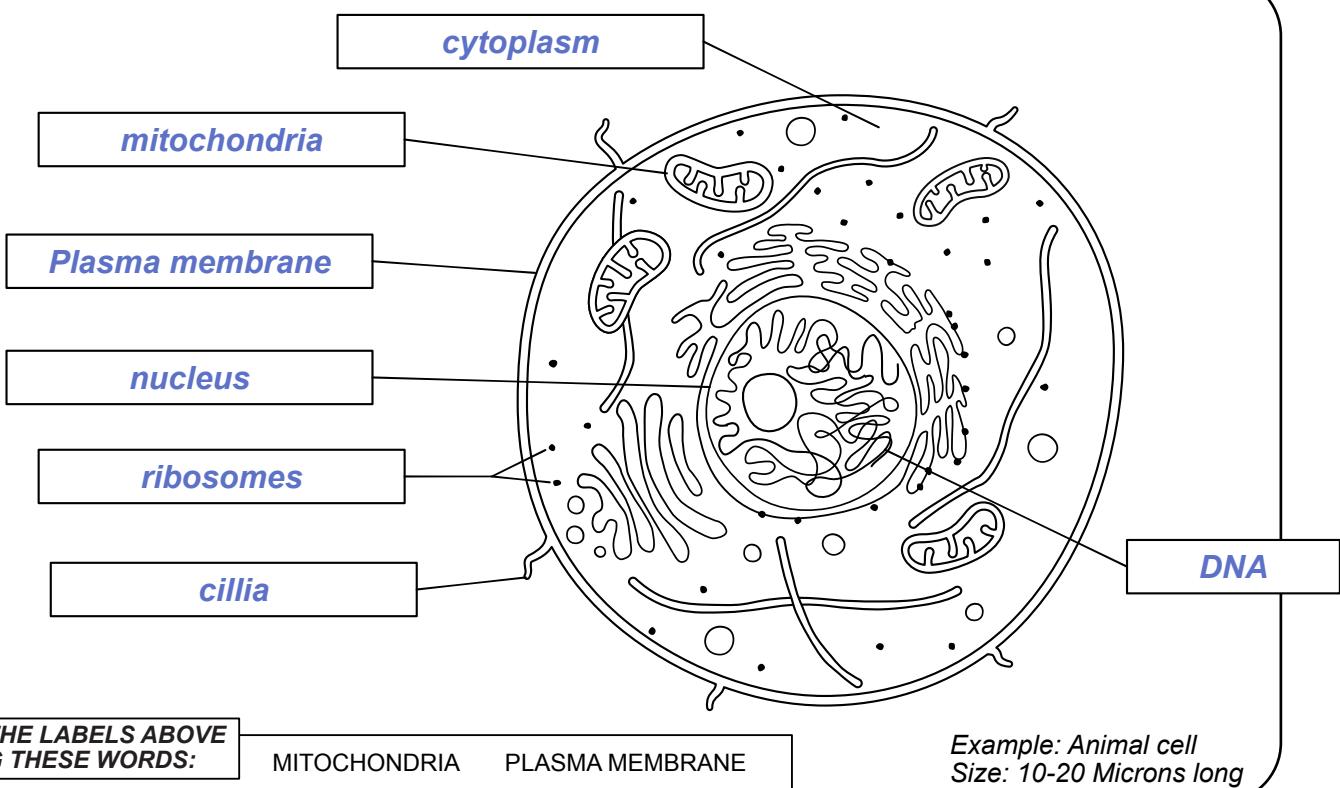
Ha ha! They'll never get rid of us now!  
Team work makes the dream work!

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:**

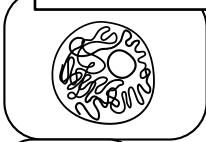
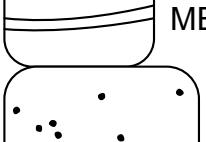
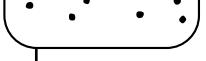
MITOCHONDRIA    PLASMA MEMBRANE  
RIBOSOMES    DNA    CILLIA    NUCLEUS    CYTOPLASM

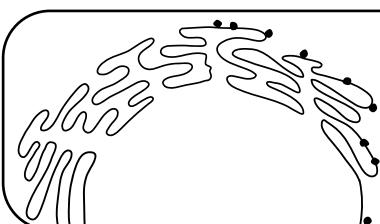
*Example: Animal cell  
Size: 10-20 Microns long*

Your notes:

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

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

-  A NUCLEUS which holds the DNA
-  MITOCHONDRIA which provide energy
-  MEMBRANE which surrounds the cell
-  RIBOSOMES which make proteins

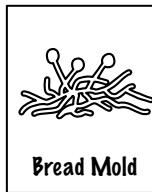
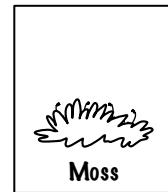
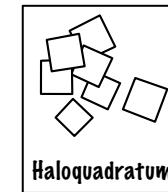
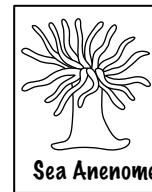
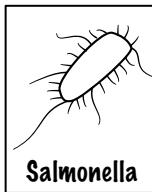
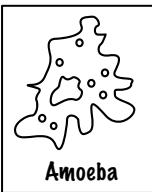


## BONUS ORGANELLE!

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

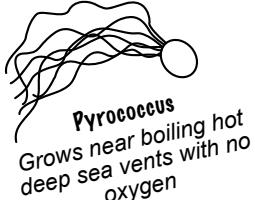
# Cellular Life

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

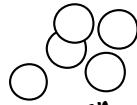


## Unicellular

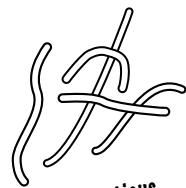
### ARCHAEA



*Pyrococcus*  
Grows near boiling hot deep sea vents with no oxygen



*Arman*  
Grows in extremely acidic mine drainage



*Thermus aquaticus*  
Heat-loving. Lives in hot springs.

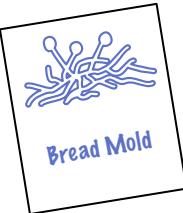


### FUNGI



*Bakers Yeast*

### FUNGI



Giant Puffball



Bracket Fungus



Button mushroom

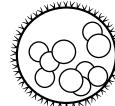
### PROTISTS



*Malaria*



*Paramecium*

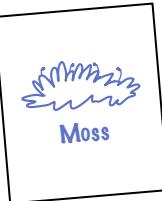


*Volvox*

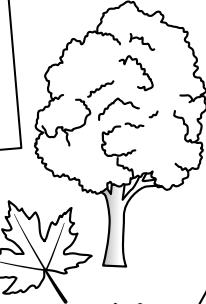


*Amoeba*

### PLANTS



*Moss*

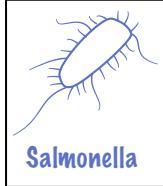


Maple Tree

### BACTERIA



*Borrelia Burgdorferi*  
(causes lyme disease)



*Salmonella*

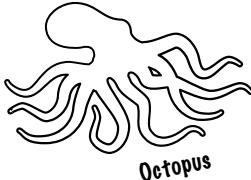


*Staphylococcus*

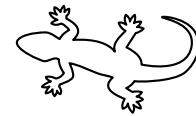


*Lactobacillus*

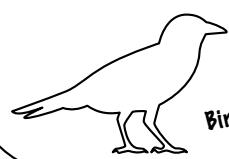
### ANIMALS



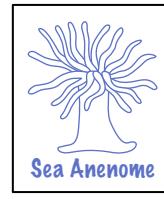
*Octopus*



Lizard



Bird



*Sea Anemone*

**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

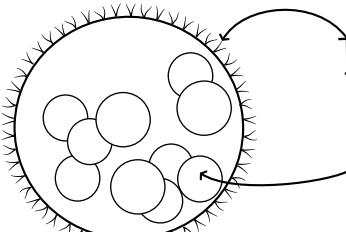
Scientists group things into categories to better understand them, but some organisms don't exactly fit! This page is dedicated to five organisms that people often mistake for something else. One is already filled out as an example. Choose 4 more from these lists to fill in the remaining blocks!

**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 barbieri*  
An algae colony made of thousands of cooperating cells!

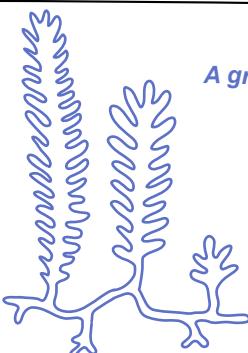


Thousands of cells arrange themselves so that they form a sphere with flagella facing out.

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!

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



A green seaweed

**Caulerpa taxifolia**

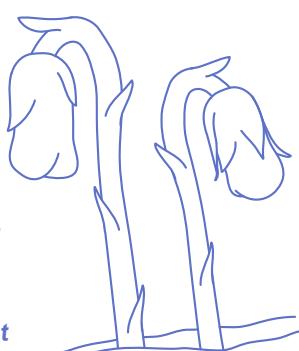
The LARGEST known single celled organism!

Is coenocytic (has many nuclei inside one cell)

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

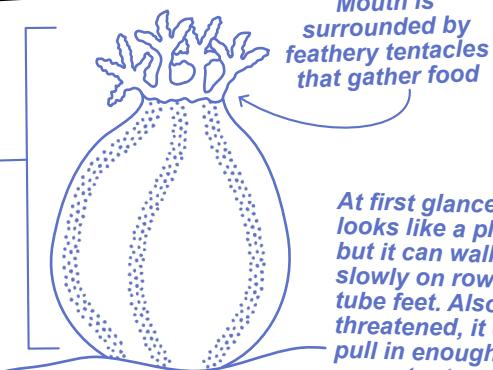
**Monotropa uniflora**  
Also called Ghost Pipe

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



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

About 20 cm (7 inches) tall.



Mouth is surrounded by feathery tentacles that gather food

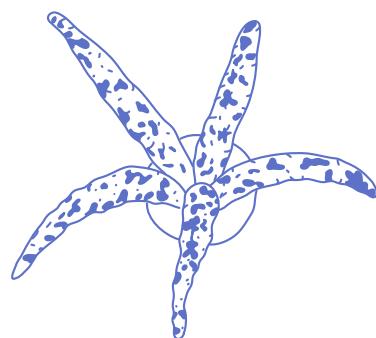
This animal is closely related to sea cucumbers. It can release a toxin (and its internal organs!) when stressed.

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

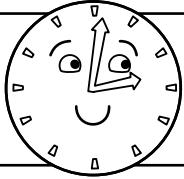
**Clathrus archeri**

Devil's Fingers or Octopus stinkhorn

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



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



# Quiz Time!

Answer the questions to see what you learned About cellular life!

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

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

- 2 What are two characteristics of living things?

*Growth, homeostasis, metabolism, made of cells, responds to stimuli, reproduction*

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

- A. 1665 *The invention of the ultramicroscope in 1903 allowed scientists to observe particles this small. Richard Zsigmondy, the inventor of the ultramicroscope, later won a Nobel Prize for his research in chemistry.*
- B. 1850 *particles this small. Richard Zsigmondy, the inventor of the ultramicroscope, later won a Nobel Prize for his research in chemistry.*
- C. 1903 *later won a Nobel Prize for his research in chemistry.*
- D. 1951 *later won a Nobel Prize for his research in chemistry.*

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

- A. True *While most are too small, many can be seen! (egg, certain amoebas and algae, Caulerpa taxifolia and acetabularia)*
- B. False *While most are too small, many can be seen! (egg, certain amoebas and algae, Caulerpa taxifolia and acetabularia)*

- 5 Which type of cell has a nucleus?

- A. Prokaryotic
- B. Eukaryotic

- 6 Fungi are plants, but plants are not fungi.

- A. True
- B. False

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

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

- 8 Which of the following are prokaryotic?

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

- 9 Protists are which type of cell?

- A. Prokaryotic
- B. Eukaryotic

- 10 A cell can only have one nucleus.

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

- 11 The average prokaryotic cell is \_\_\_\_\_ than the average eukaryotic cell.

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

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

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

- 13 Which of the following are made of cells?

- A. Wood *Plastic and polyester are polymer most often made from petroleum. Although petroleum and other fossil fuels originally came from living things, they have changed through intense pressure and long amounts of time and have no cellular structures remaining.*
- B. Plastic *Plastic and polyester are polymer most often made from petroleum. Although petroleum and other fossil fuels originally came from living things, they have changed through intense pressure and long amounts of time and have no cellular structures remaining.*
- C. Tomato *Plastic and polyester are polymer most often made from petroleum. Although petroleum and other fossil fuels originally came from living things, they have changed through intense pressure and long amounts of time and have no cellular structures remaining.*
- D. Polyester fabric *Plastic and polyester are polymer most often made from petroleum. Although petroleum and other fossil fuels originally came from living things, they have changed through intense pressure and long amounts of time and have no cellular structures remaining.*

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

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

- 15 Which of the following statements is true?

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

- 16 Which organelle is only found in plants or protists?

- A. Chloroplasts
- B. Mitochondria

- 17 Eukaryotic cells are bigger than prokaryotic cells.

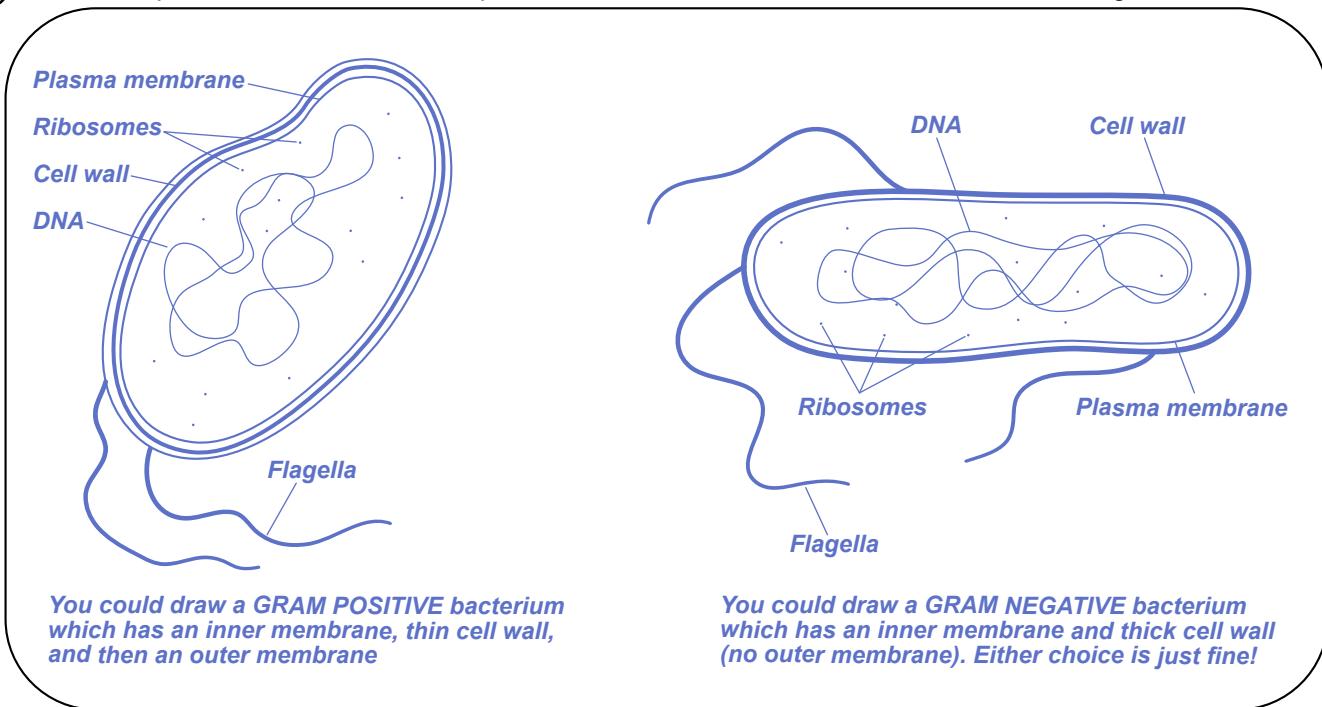
- A. True
- B. False

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

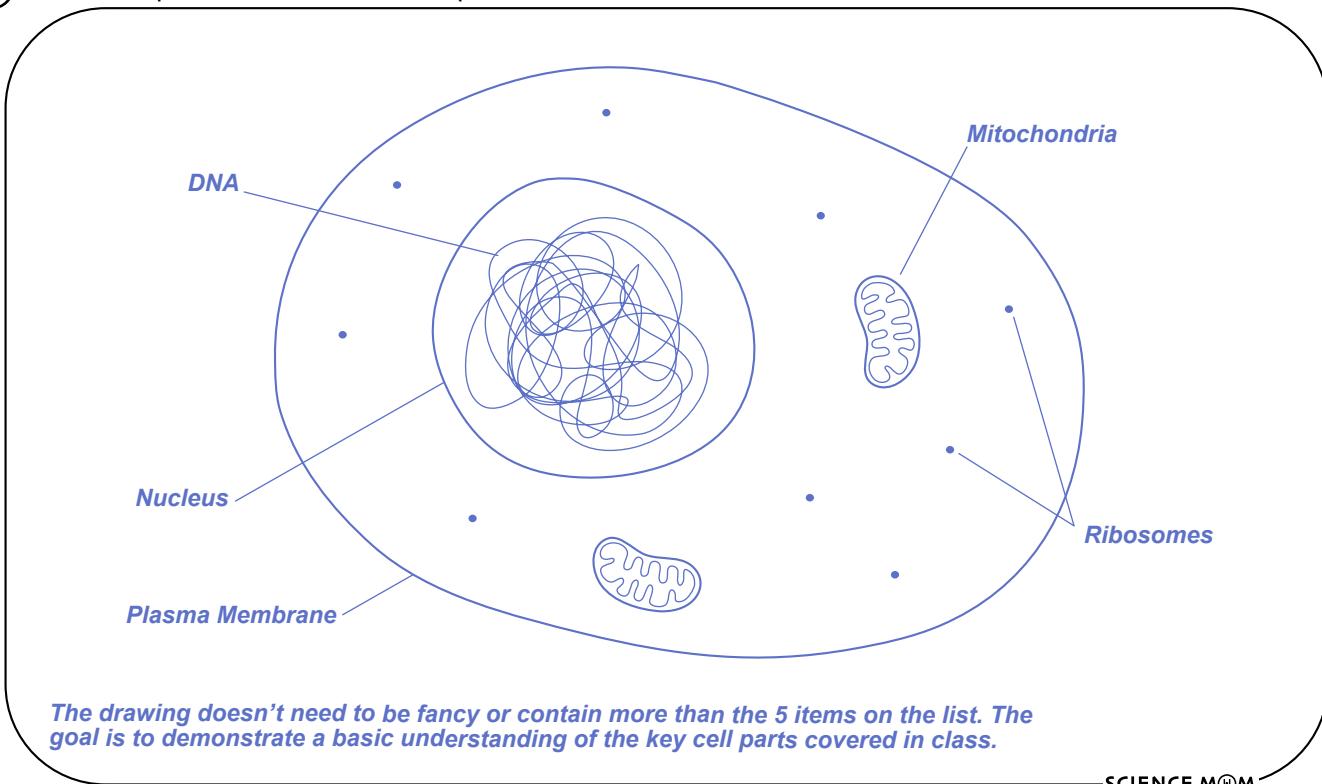
18) Which of these is the best simple definition for the word metabolism?

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

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



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

MEMBRANE

RIBOSOME

MITOCHONDRIA

DEOXYRIBONUCLEIC ACID

CYTOPLASM

NUCLEUS

CHLOROPLAST

FLAGELLA

ARCHAEA

PROKARYOTIC

UNICELLULAR

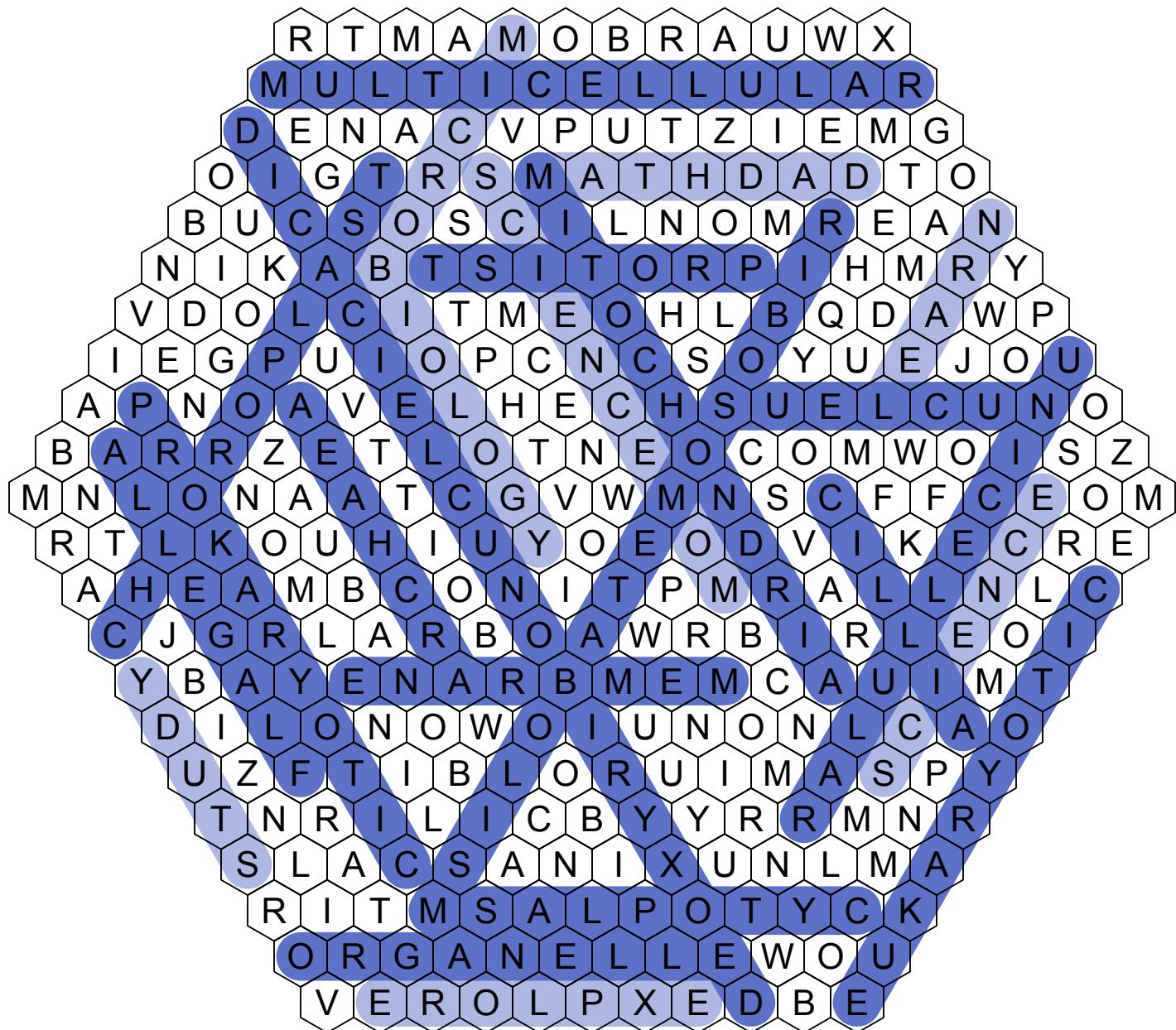
MULTICELLULAR

EUKARYOTIC

PROTIST

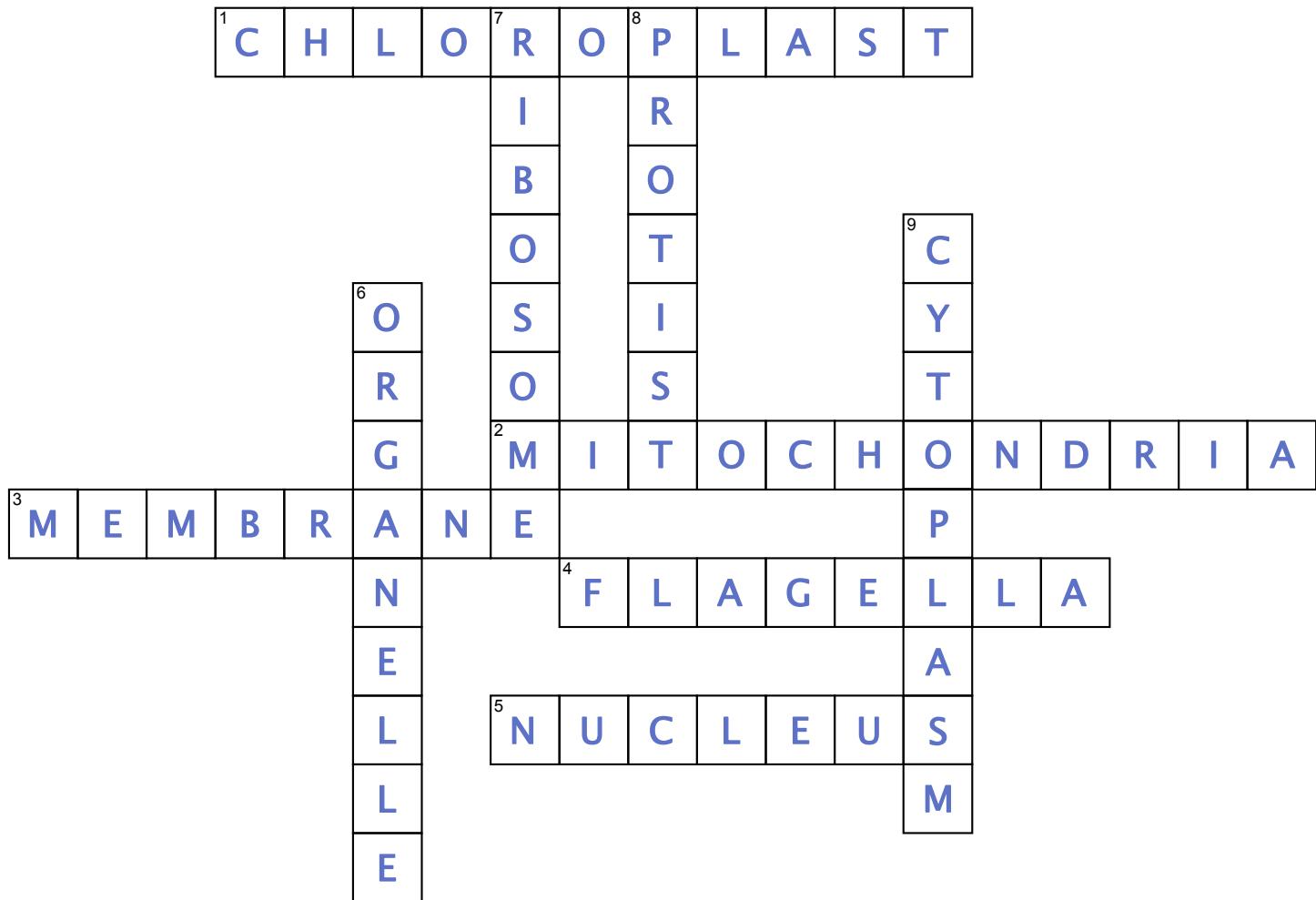
CILLIA

ORGANELLE



# Biology Crossword

Use the clues below to fill in the crossword puzzle.



## Horizontal Words

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

## Vertical Words

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

# BIOMOLECULES

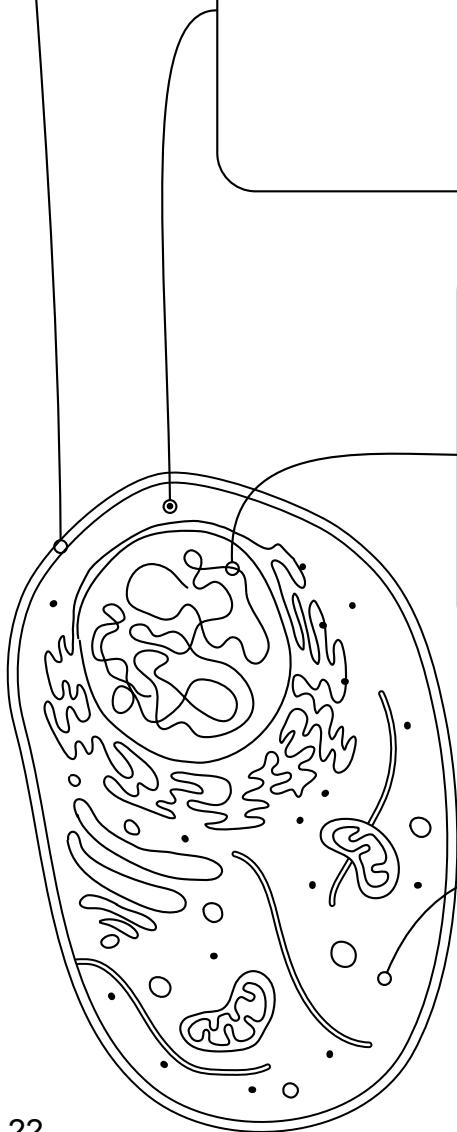
The molecules that make living things! After completing each topic, return to this page and draw or write a favorite fact you learned about each biomolecule.

LIPIDS

PROTEINS

DNA

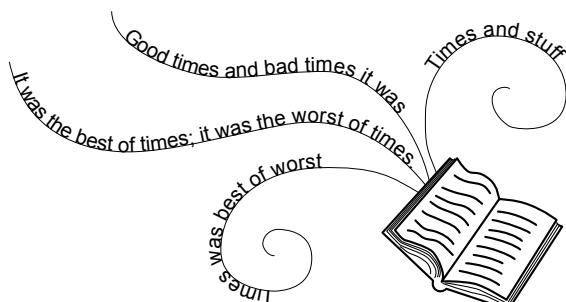
SUGARS



# POLYMERS AND MONOMERS

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

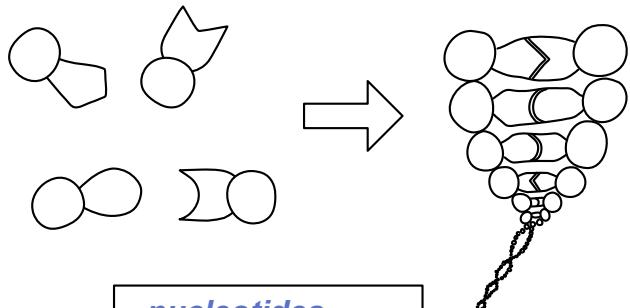
DNA	protein	beads	starch	words	amino acids
stories	HDPE	ethylene	nucleotides	glucose	necklace



Monomer: **words**

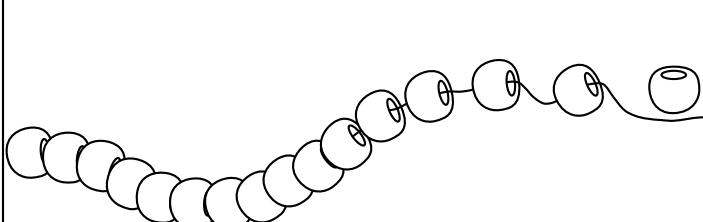
Polymer: **stories**

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



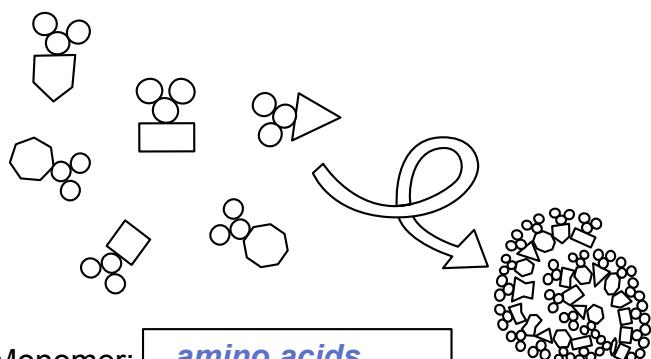
Monomer: **nucleotides**

Polymer: **DNA**



Monomer: **beads**

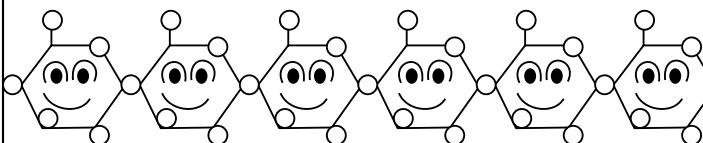
Polymer: **necklace**



Monomer: **amino acids**

Polymer: **proteins**

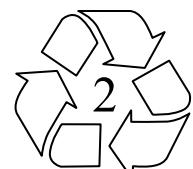
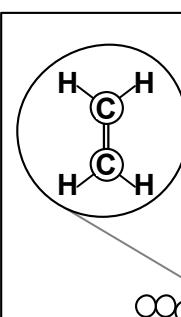
Clue: This polymer is used to store energy.



Monomer: **glucose**

Polymer: **starch**

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



Monomer: **ethylene**

Polymer: **HDPE**

FILL IN THE BLANKS USING THESE WORDS:

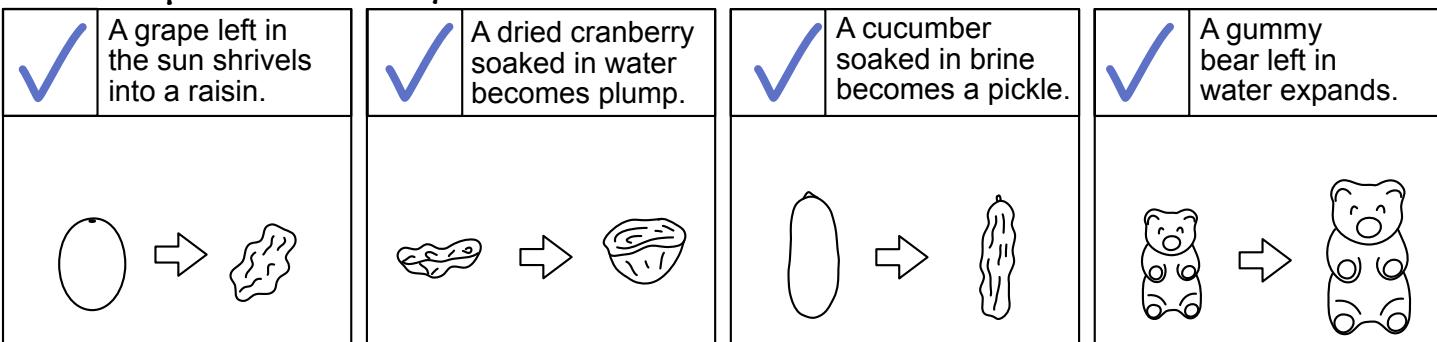
osmosis      impermeable      semipermeable

# Osmosis

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

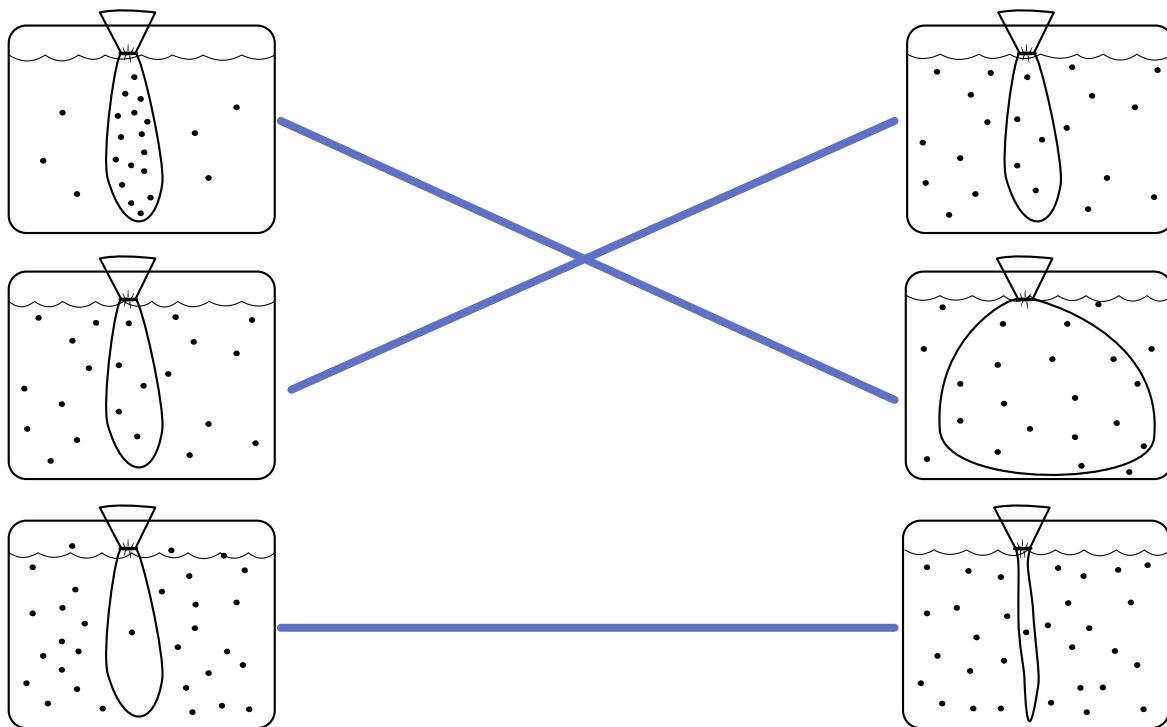
Grape skins, gummy candy, and cell membranes are all semipermeable. They allow water and other small molecules to pass through them. This movement of water or other molecules through a semipermeable membrane is called osmosis.

## Which examples of osmosis have you seen?



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.

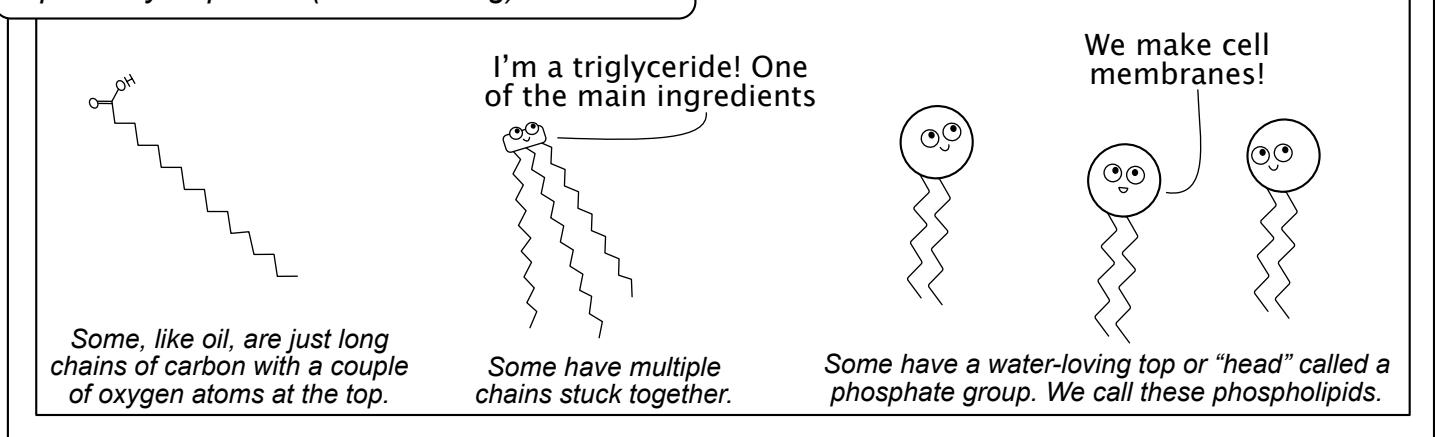


# Lipids Make Membranes

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.

Sugar	Protein Powder	DNA	oil
<b>Mix completely</b>	<b>Mix completely</b>	<b>Mix completely</b>	<b>Does not mix</b>

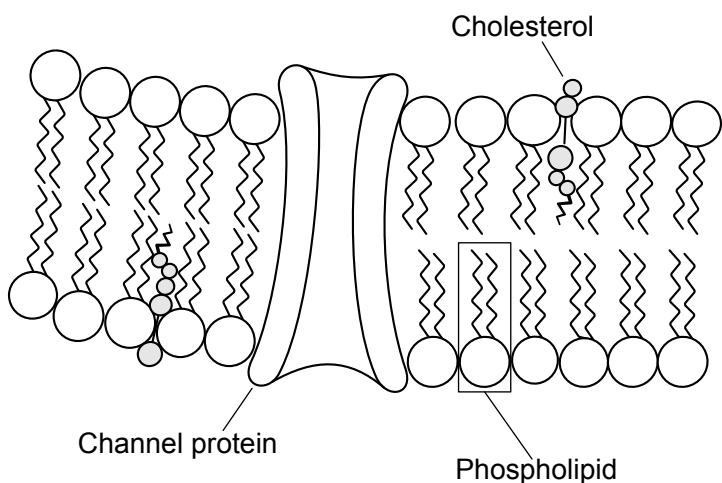
*Lipid: a hydrophobic (water fearing) molecule.*



FILL IN THE BLANKS USING THESE WORDS:

phospholipids	channel
cholesterol	hydrophobic

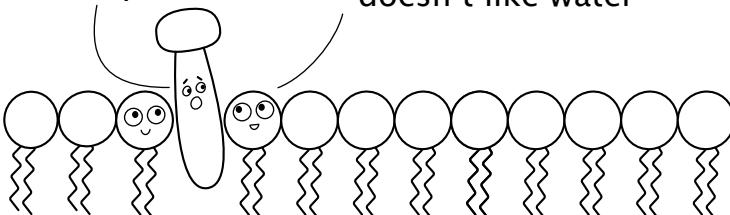
The membranes of animal cells are made of phospholipids. These molecules have a "head" that is hydrophilic (attracted to water) and a "tail" that is hydrophobic (repelled by water). Cholesterol molecules stabilize the membrane and channel proteins can open to allow molecules to pass through and enter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



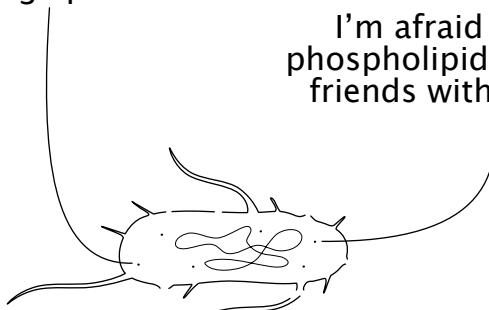
### A note about soap

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

Let me in! There's water everywhere.

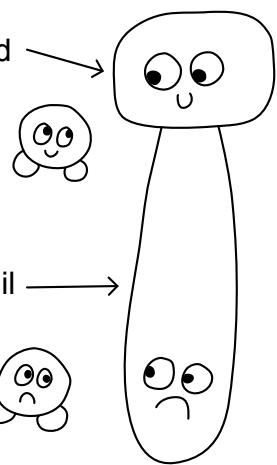


Hang on, why is the membrane falling apart!?

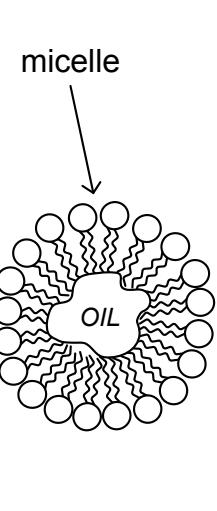


### SOAP

Hydrophilic head



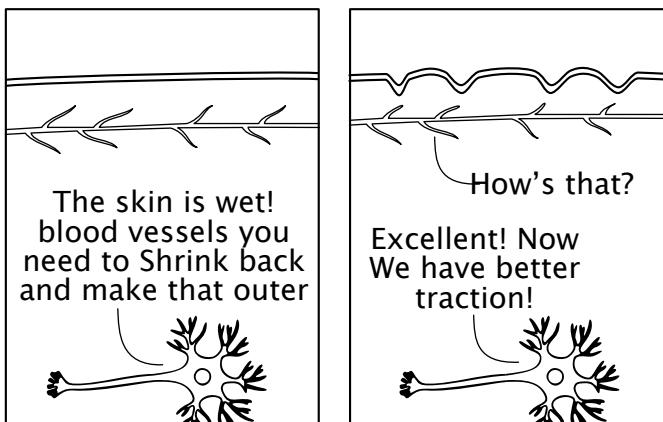
Hydrophobic tail



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

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

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



**FACT**

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



**FICTION**

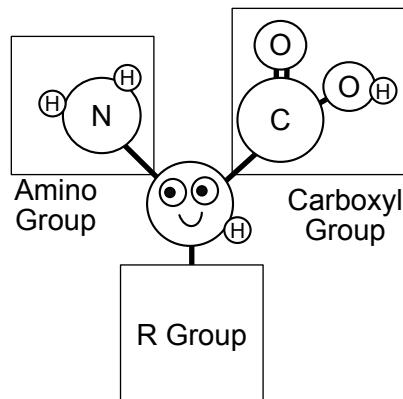
# Amino Acids Make Proteins

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.

An Amino Acid



## Match each description with a picture

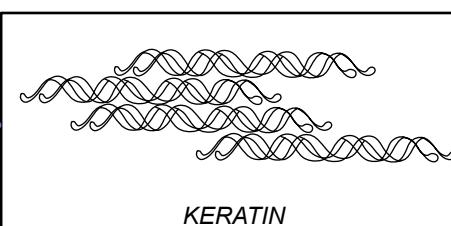
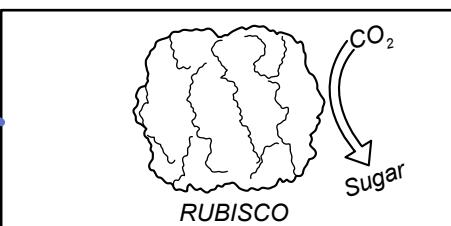
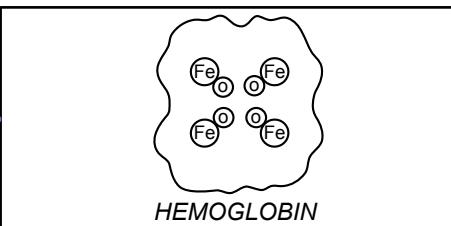
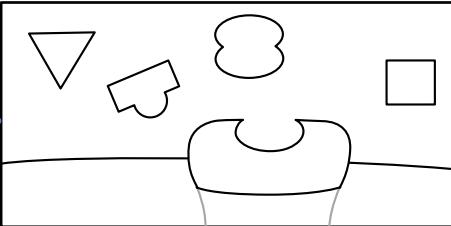
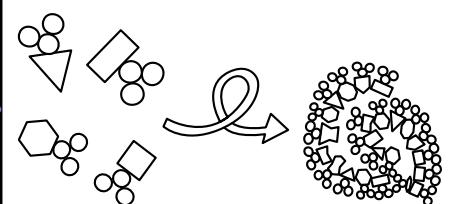
A **receptor** is a protein on the surface of a cell that binds to something specific.

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

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

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

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



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

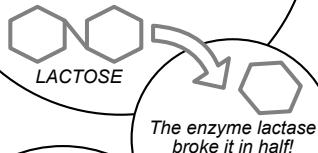
# Enzymes are amazing catalysts!

FILL IN THE BLANKS USING THESE WORDS:

sugar lactose substrate catalysts specific protein controlled

## Did you know?

Lactose is the most common sugar in milk. Every mammal is born with the enzyme *lactase* so they can digest milk.



Now the body can digest the smaller sugars.

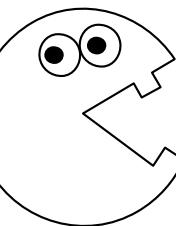
Most adults in the world (about 70%) are lactose intolerant because their body stops making the enzyme *lactase*.

If human cells don't make lactase and break it apart in the small intestines, then bacteria in the large intestines digest it and produce way too much gas, causing bloating and diarrhea.

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

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

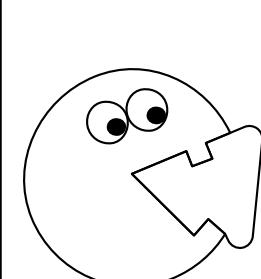
Lactose-intolerance can be solved by avoiding lactose sugar, but breathing oxygen also uses enzymes and it's something we can't live without! Almost everything that happens in the cell is **controlled** by or influenced by enzymes. They're the most important proteins around.



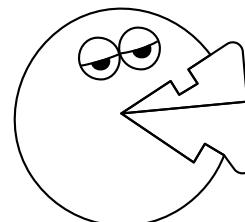
Enzyme



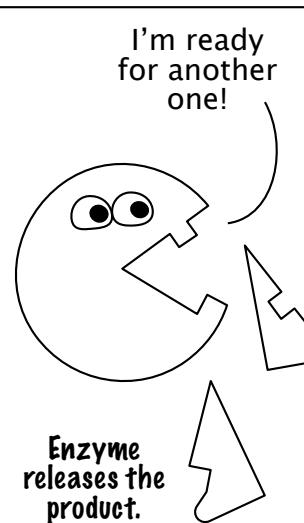
Substrate



Enzyme binds the substrate.



Substrate is changed by the enzyme. It has become something new! Now we call it the product.



Enzyme releases the product.

# Sugars Store Energy

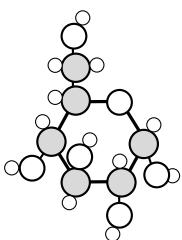
FILL IN THE BLANKS USING THESE WORDS:

molecules starch energy essential glucose

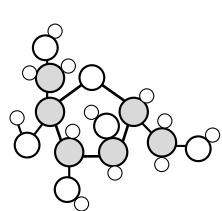
Sugars are molecules made of carbon, oxygen, and hydrogen. The simplest sugars (monomers) have a ring shape and are sometimes drawn as hexagons or pentagons. When simple sugars are linked together to form polymers, they make starch. Sugars can be broken apart by the cell to produce energy. They are an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

WRITE DOWN A FACT ABOUT EACH MOLECULE:

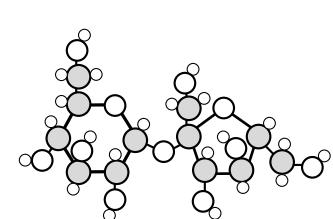
CARBON  
OXYGEN  
HYDROGEN



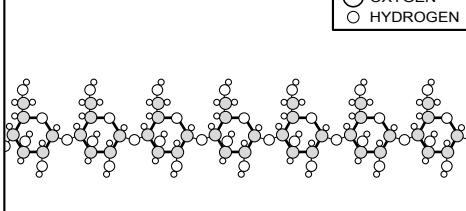
GLUCOSE



FRUCTOSE



SUCROSE



STARCH

Most popular  
energy source!

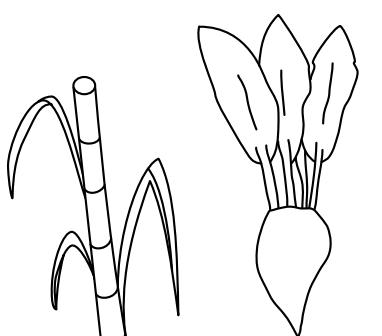
Tastes sweeter  
than glucose.

Also known as table,  
granulated, or white  
sugar.

Found in potatoes, rice,  
wheat, pasta, and bread etc.

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

White sugar comes from sugar cane, while brown sugar comes from sugar beets.



**FICTION**

Corn has higher sugar content than strawberries

Hah! Take that, Fruit!



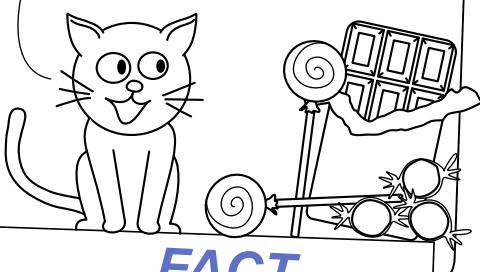
29 grams per cup

7 grams per cup

**FACT**

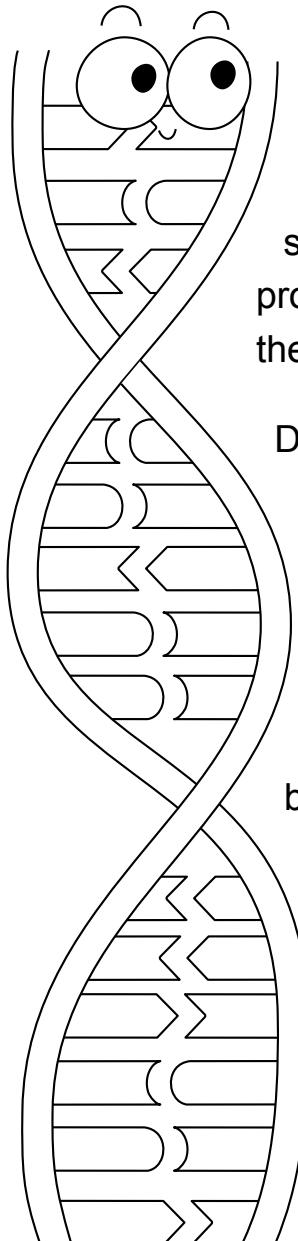
Cats can't taste sweetness.

Why would you eat that? It doesn't have any flavor at all.



**FACT**

# DNA stands for Deoxyribonucleic Acid



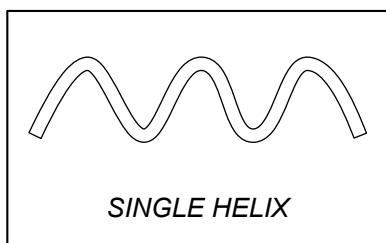
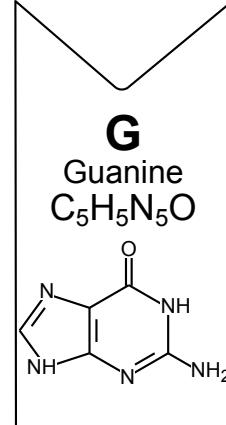
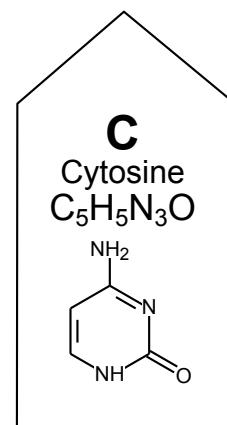
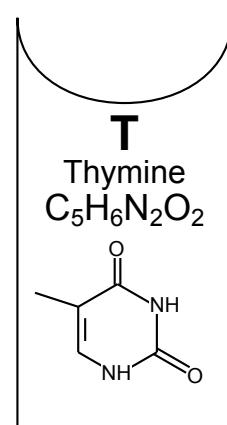
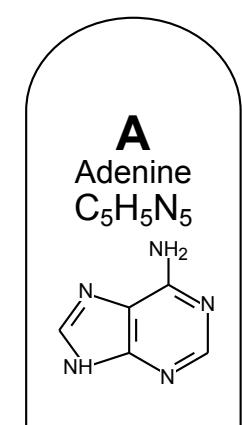
FILL IN THE BLANKS USING THESE WORDS:

nucleotides    cell    polymer    instructions    molecules    four

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

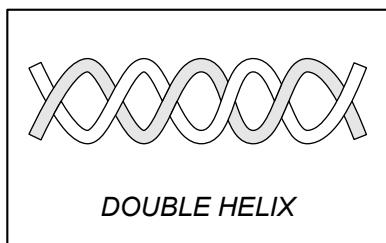
DNA is like a set of instructions for everything that happens in the cell. It is an incredibly long molecule with millions of nucleotides repeating in long sequences. But there are only four types of nucleotides in DNA: adenine, thymine, cytosine, and guanine.

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



SINGLE HELIX

CAN YOU FIGURE OUT WHICH BASES PAIR TOGETHER?



DOUBLE HELIX

Adenine pairs with Thymine.

Cytosine pairs with Guanine.

# THE BLUEPRINT FOR LIFE

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

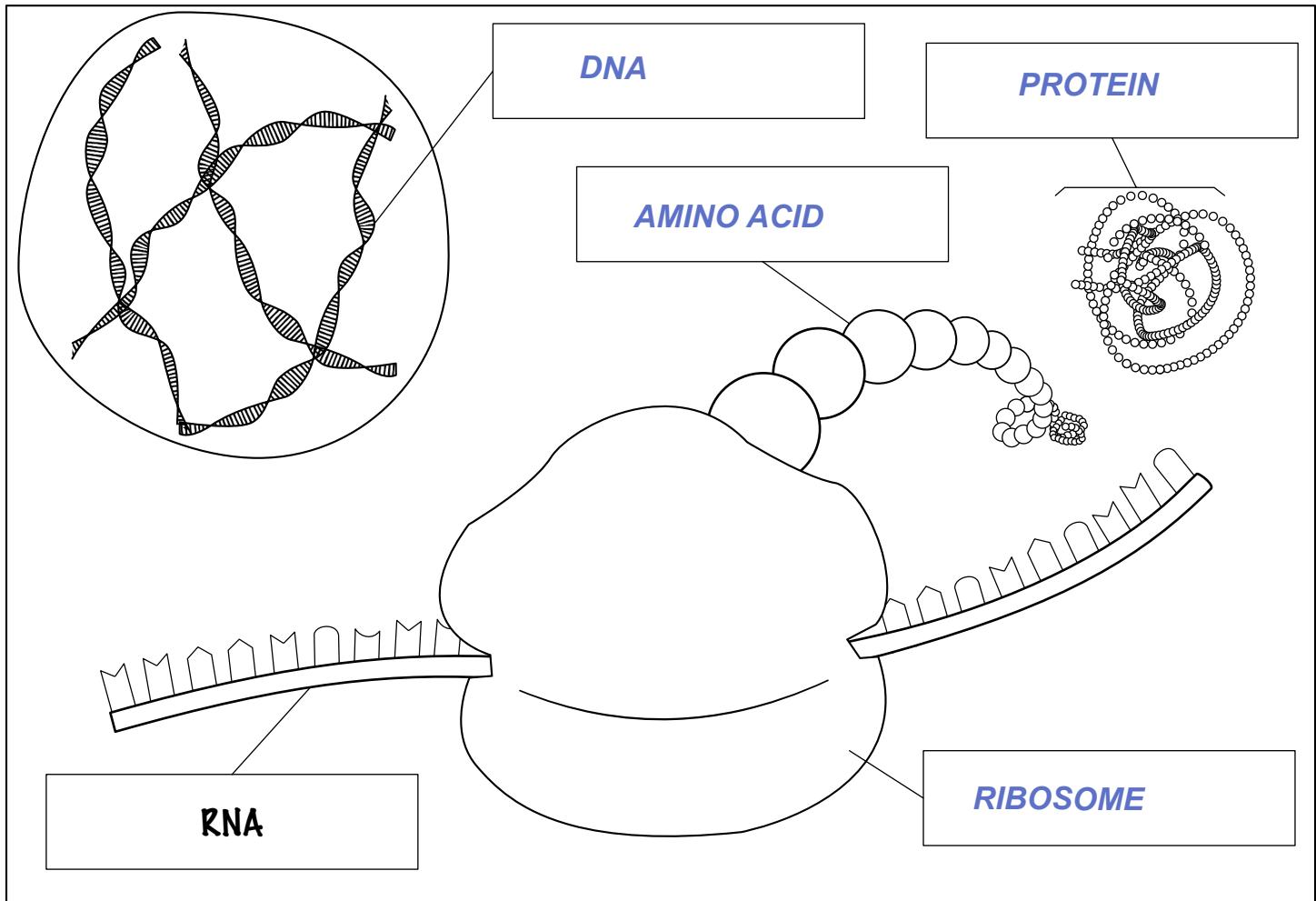
Use the following words to label each box in the drawing below:

RIBOSOME

DNA

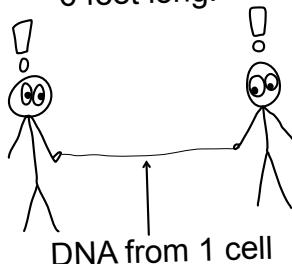
AMINO ACID

PROTEIN



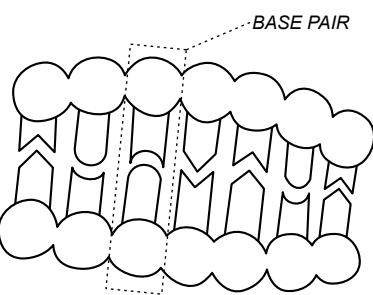
## ARE THESE FACT OR FICTION? Write your verdict below each statement:

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



FACT

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



FACT

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

Hey! How come you got to keep your nucleus?



I don't know.

FACT

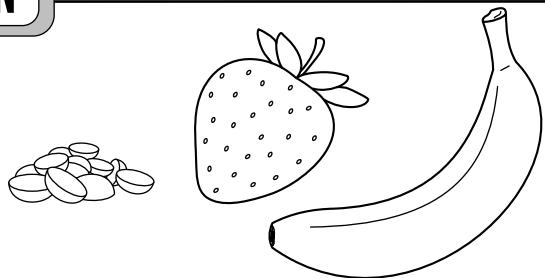
# Hands-on Science Project

## DNA EXTRACTION



### Take Note!

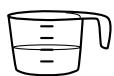
This activity can be done with split peas, bananas, OR strawberries. You can choose whichever version is most convenient or try them all and compare them!



### OPTION ONE: STRAWBERRY



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



½ cup warm water  
(4 ounces)



1 tsp salt  
(6 grams)



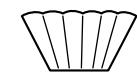
Plastic bag OR a bowl and fork for squishing the strawberry to a pulp.



2 tsp concentrated dish soap  
(10 ml)



Rubbing alcohol  
(91 percent)



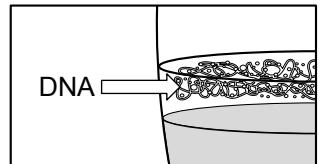
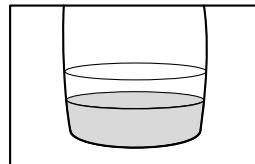
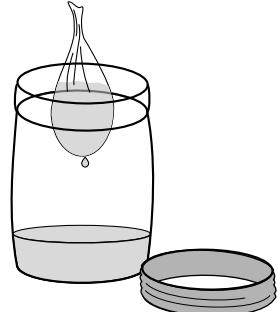
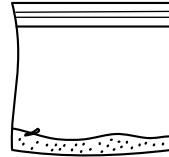
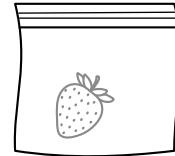
Coffee filter



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

### Instructions

1. Place your rubbing alcohol in the fridge.
2. Thoroughly squish the strawberries. There should be no chunks or large pieces when you are done.
3. Make your extraction solution by mixing together the water, salt, and dish soap. Then add 2 to 3 teaspoons of extraction solution to your squished strawberry and stir gently for one minute.
4. Pour the strawberry mixture into a coffee filter and let sit for 5 minutes. VERY GENTLY close the tops of the coffee filter and press to extract more liquid. Be careful not to press too hard. If the coffee filter breaks you will need to strain the liquid again.
5. Take the rubbing alcohol out from the fridge and carefully pour a layer on top of the fruit liquid. The goal is for the amount of rubbing alcohol to be roughly equal in height to the layer of fruit liquid.
6. Observe and watch for a white foamy substance to form in the rubbing alcohol. This is your DNA! If desired, you can use a toothpick or fork to lift it out.



## OPTION TWO: BANANA



$\frac{1}{2}$  ripe banana, completely frozen and then thawed.



$\frac{1}{2}$  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)



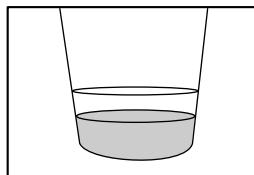
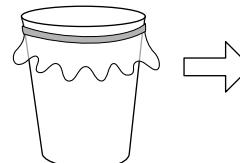
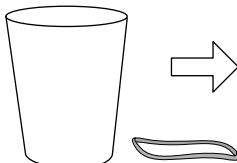
Coffee filter



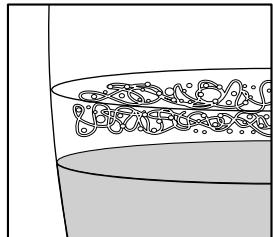
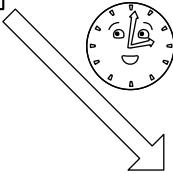
Cup or glass jar and a  
rubber band or ring for  
securing the coffee filter

### Instructions

1. Place your rubbing alcohol in the fridge.
2. Add  $\frac{1}{2}$  cup warm water and  $\frac{1}{2}$  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.



Be patient!



## 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)

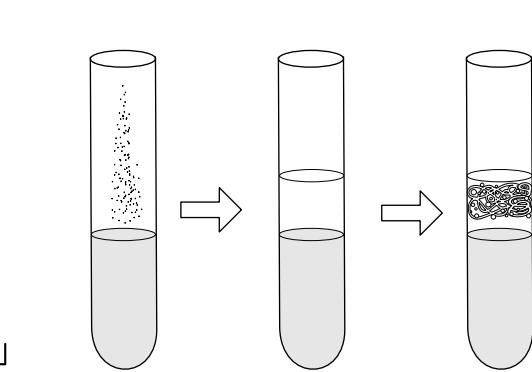
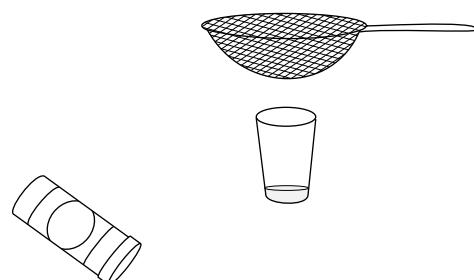
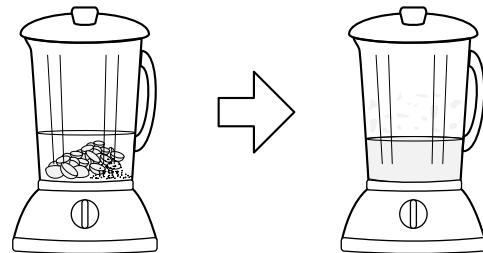
Mesh strainer

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?

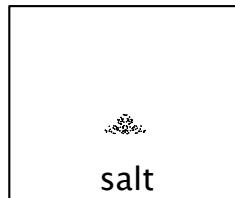
Draw lines to match each ingredient or step with what it's doing:



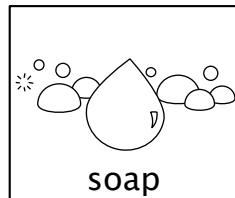
Rubbing



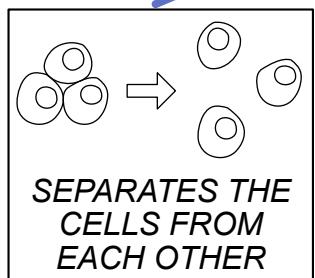
Mashing or  
blending the



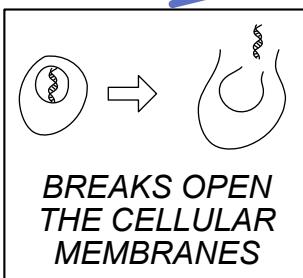
salt



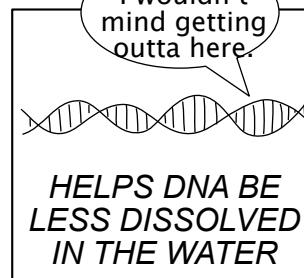
soap



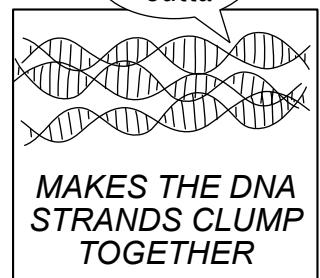
SEPARATES THE CELLS FROM EACH OTHER



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?

Hopefully it did!

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

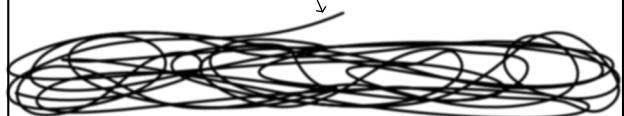
Don't give up if it doesn't work the first time!

Be patient and wait a few more minutes if you

don't see DNA. Sometimes it takes a little while to precipitate.

### DNA UNDER A LIGHT MICROSCOPE

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\*

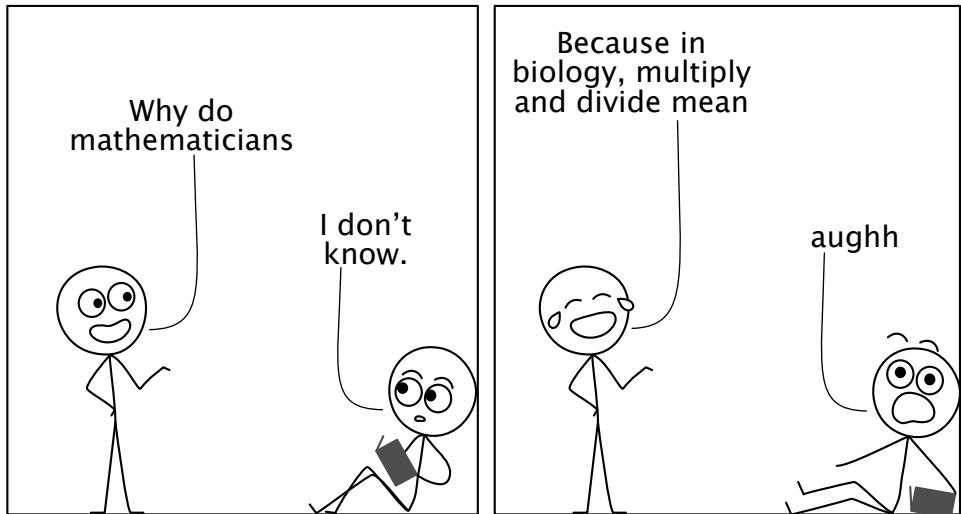
STILL DIFFICULT TO SEE. WE KNOW DNA HAS A DOUBLE HELIX STRUCTURE BECAUSE OF HOW XRAYS DIFFRACT OR BOUNCE OFF THE MOLECULE.

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

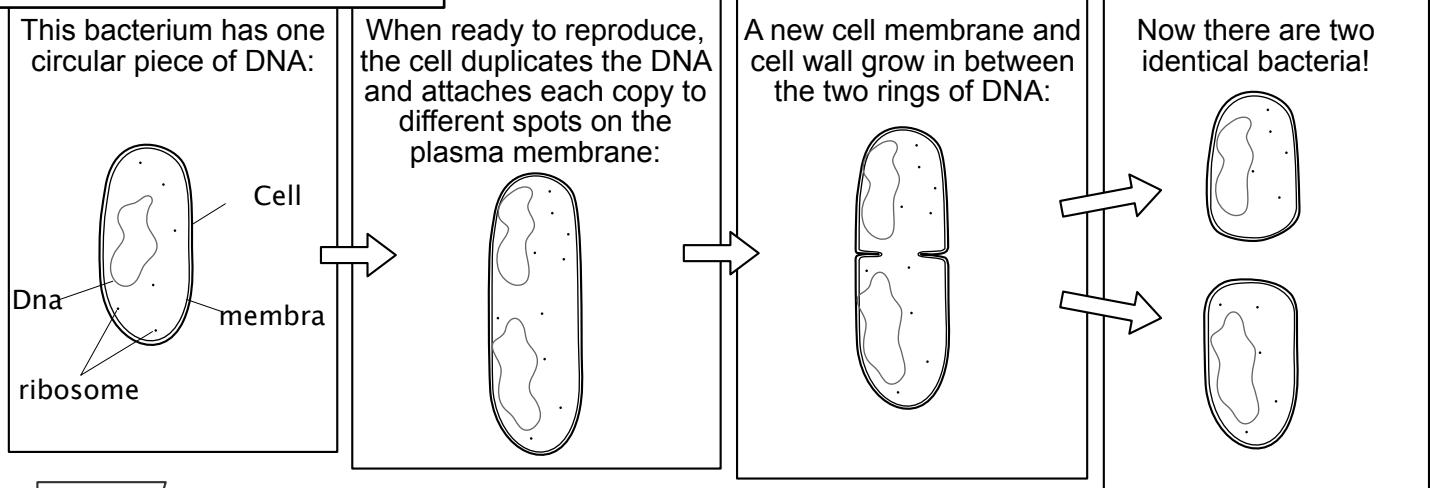
# Cell Division

**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 produces cells that are identical.	A normal human cell will only divide about 20 times.	Out of control cell division causes cancer.
<b>FACT</b>	<b>FICTION</b>	<b>FACT*</b>

**Left Column (FACT):** Two cartoon cells are shown. One says 'We're twins!' and the other says 'We're twins!'. Below them is a box labeled 'FACT'.

**Middle Column (FICTION):** A cartoon cell is shown next to a 20th birthday cake. A blue box contains the text: 'A normal human cell will only replicate 40-60 times. This is known as the Hayflick Limit.' Below them is a box labeled 'FICTION'.

**Right Column (FACT\*):** A large, irregularly shaped cartoon cell is shown. It has multiple nuclei and a chaotic internal structure. A smaller cell next to it says 'Stop! You're going to ruin'. Below them is a box labeled 'FACT\*'. The asterisk indicates a note: '\*A cascade of mutations need to occur in the same cell for it to become cancerous. But once it is cancerous it will grow and replicate at an abnormally rapid rate.'

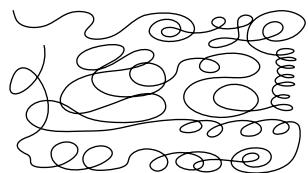
FILL IN THE BLANKS USING THESE WORDS:

replicate DNA proteins membrane mitosis

# Mitosis

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

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



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

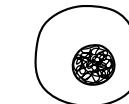
Same strand as above! Now it's just packed



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

### Prophase

The cell prepares to divide by condensing the DNA.



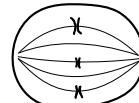
### Interphase

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



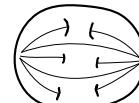
### Metaphase

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



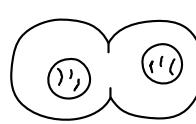
### Telophase and Cytokinesis

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



### Anaphase

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





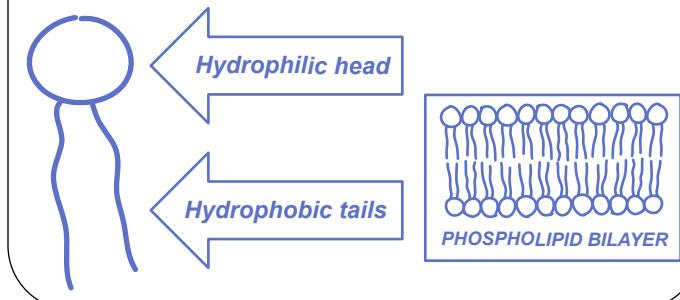
# Quiz Time!

Answer the questions to see what you learned about biomolecules!

- 1 DNA is a polymer made of which monomer?  
A. Amino acids  
**B. Nucleotides**  
C. Sugars  
D. Phospholipids
- 2 A substance that will allow some molecules to pass but not others is best described as:  
A. Impermeable  
**B. Semipermeable**
- 3 During osmosis, water will flow from an area with a \_\_\_\_\_ concentration of solute to an area with a \_\_\_\_\_ concentration of solute.  
A. Higher, lower  
**B. Lower, higher**
- 4 A raisin placed in warm water will:  
A. Shrink  
**B. Swell**  
C. Stay the same size
- 5 Membranes of animal cells are made of:  
A. Protein  
B. DNA  
**C. Phospholipids**  
D. Amino Acids
- 6 Something that mixes well with water is described as being \_\_\_\_\_.  
A. Hydrophobic  
**B. Hydrophilic**
- 7 Lipids are classified as being \_\_\_\_\_.  
**A. Hydrophobic**  
B. Hydrophilic
- 8 What is cholesterol's role in a cell membrane?  
**A. It stabilizes the membrane and keeps it from falling apart.**  
B. It allows molecules to pass from one side of the membrane to the other.  
C. Most of the membrane is made of cholesterol.
- 9 Just like a phospholipid, soap has a \_\_\_\_\_ head and a \_\_\_\_\_ tail.  
A. Hydrophobic, hydrophilic  
**B. Hydrophilic, hydrophobic**
- 10 True or False: Soap molecules will naturally form tiny spheres when they are mixed with water.  
**A. True** *They are called micelles*  
B. False
- 11 Proteins are polymers made of which monomer?  
**A. Amino acids**  
B. Nucleotides  
C. Sugars  
D. Phospholipids
- 12 The most abundant enzyme on the planet is:  
A. Hemoglobin  
**B. Rubisco**  
C. Keratin  
D. Receptor proteins
- 13 Something that helps a chemical reaction happen more quickly is called a *Enzyme or Catalyst*  
*Both are correct.*
- 14 An enzyme binds to a \_\_\_\_\_.  
A. Catalyst  
**B. Substrate**  
C. Sugar  
D. Phospholipid
- 15 True or False: All enzymes are catalysts but not all catalysts are enzymes.  
**A. True** *There are many elements and compounds that can catalyze a reaction without being changed by the reaction.*  
B. False
- 16 Starch is a polymer made of which monomer?  
A. Amino acids  
B. Nucleotides  
**C. Sugars**  
D. Phospholipids
- 17 How many different types of nucleotides are used to make DNA?  
**A. 4**  
B. 5  
C. 21  
D. More than a million
- 18 True or False: Guanine pairs with cytosine.  
**A. True**  
B. False

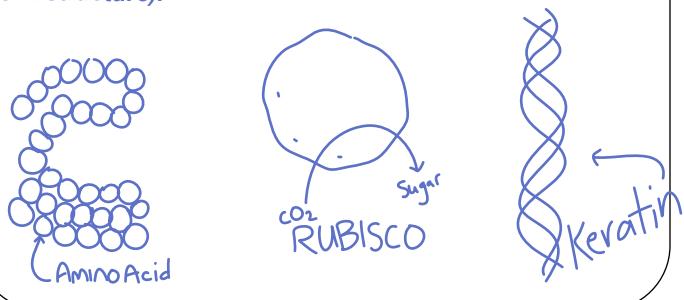
**19** Draw a picture of a phospholipid:

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



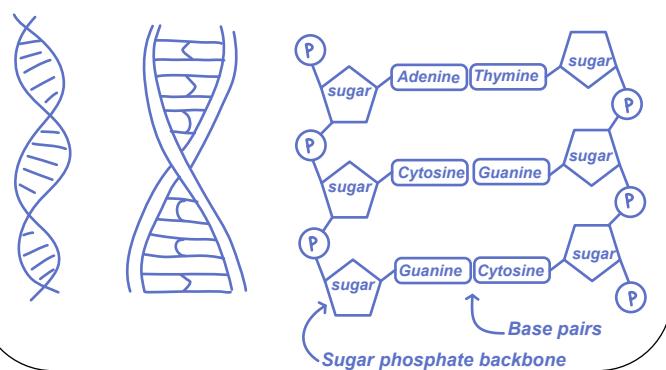
**20** Draw a picture of a protein molecule:

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



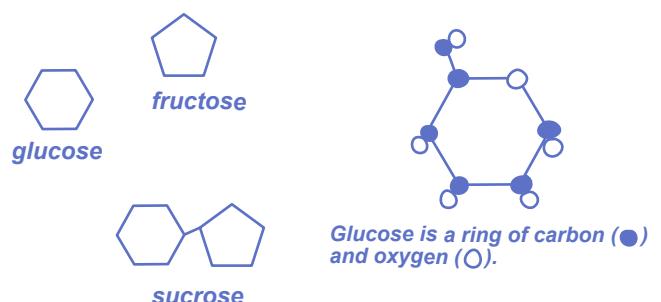
**21** Draw a picture of a DNA molecule:

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



**22** Draw a picture of a sugar molecule:

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

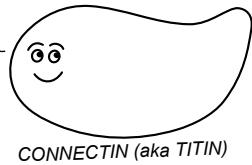


## ARE THESE FACT OR FICTION? Write your verdict below each statement:

The biggest protein in the human body is made of more than 34,000 amino acids.

They call me

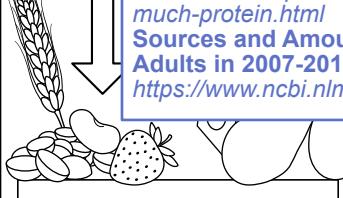
Wow! I only have



**FACT**

Protein is only found in animal products.

No protein



When it comes to protein, how much is too much? March 30, 2020, Harvard Medical School <https://www.health.harvard.edu/nutrition/when-it-comes-to-protein-how-much-is-too-much>

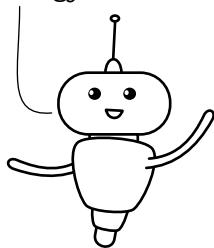
Can You Get Too Much Protein? By Roni Caryn Rabin, Dec 6, 2016 New York Times <https://www.nytimes.com/2016/12/06/well/eat/can-you-get-too-much-protein.html>

Sources and Amounts of Animal, Dairy, and Plant Protein Intake of US Adults in 2007-2010, by Pasiakos et al, Nutrients. 2015 Aug. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4555161/>

**FACT**

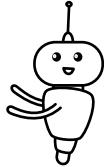
# WHERE DOES THE ENERGY COME FROM?

All living things use energy!



Some get energy from eating food.

Others make their own food (and then eat it).

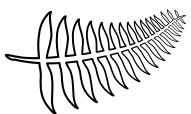


One of the most important questions to ask about a living thing organism is **where** and **how** it gets its energy. The graphic on page 16 divides life into single-celled and multi-celled categories. Another way to divide living things is to look at whether they **can** make their own food (**autotroph**) 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

### PLANTS



Fern

A plant that doesn't have flowers



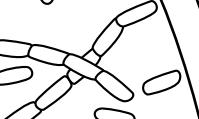
Tulip

A flowering plant



Brown Algae

Also called kelp



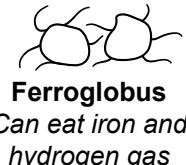
Cyanobacteria

Photosynthetic



Halobacterium

Photosynthetic salt-loving archaea



Sulfolobus

Can do both using sulfur!

## HETEROTROPH

How come none of us get to go above that

There's a reason they call us the consumers.

### ANIMALS



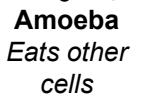
### FUNGI



### PROTISTS



Dodder  
a parasitic plant!



Amoeba

Eats other cells



Acidophilus

Used to make yogurt

### BACTERIA

### STREPTOCOCCUS

Can cause pneumonia

### Thermus aquaticus

Grows in hot springs

### ARCHAEA

# Amazing Animals

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



worm



ladybug



snail



sponge



cow



blue whale



koala



giraffe



raccoon



tiger



spider



bear



shark



axolotl



tadpole



frog

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

## DETRITIVORE - eat decaying things

worms  
Snails and slugs  
Sea sponge

## HERBIVORES - eat plants or algae

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

## CARNIVORES - eats other animals

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

## OMNIVORES - eat plants and animal matter

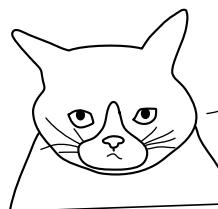
Worms Raccoon Bear Sea sponge  
Most ladybug adults are omnivores  
Snails and slugs Tadpole Frog  
Axolotl (larva eat algae, adults eat invertebrates)

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

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

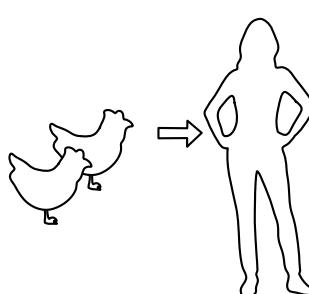
All animals are multicellular consumers made of eukaryotic cells.  
*This is the definition of an animal.*

No one can know what I'm



FACT

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



FICTION

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

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

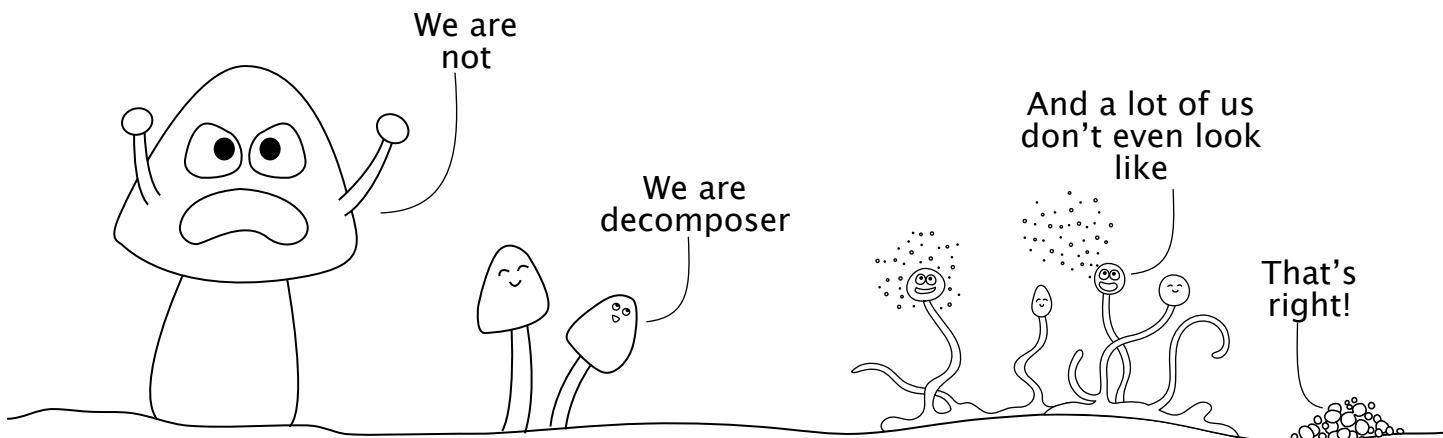
FACT

# Fabulous Fungi

FILL IN THE BLANKS USING THESE WORDS:

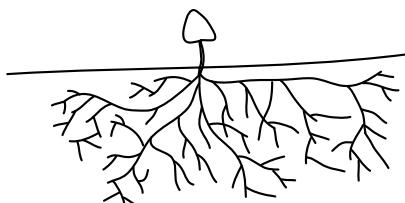
agrees      yeast      trees      organic      infecting  
energy      digest      plants      specialize      consumers

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



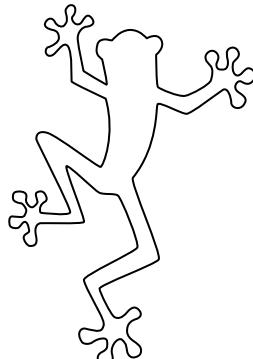
## ARE THESE FACT OR FICTION? Write your verdict below each statement:

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



**FACT**

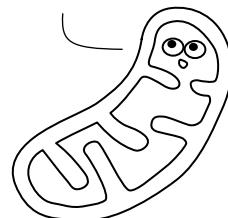
The chytrid fungus has caused the extinction of several species of frogs.



**FACT**

Fungi cells don't contain mitochondria.  
*Mitochondria are found in all animal, plant, and fungi cells.*

That's me!  
I'm an



**FICTION**

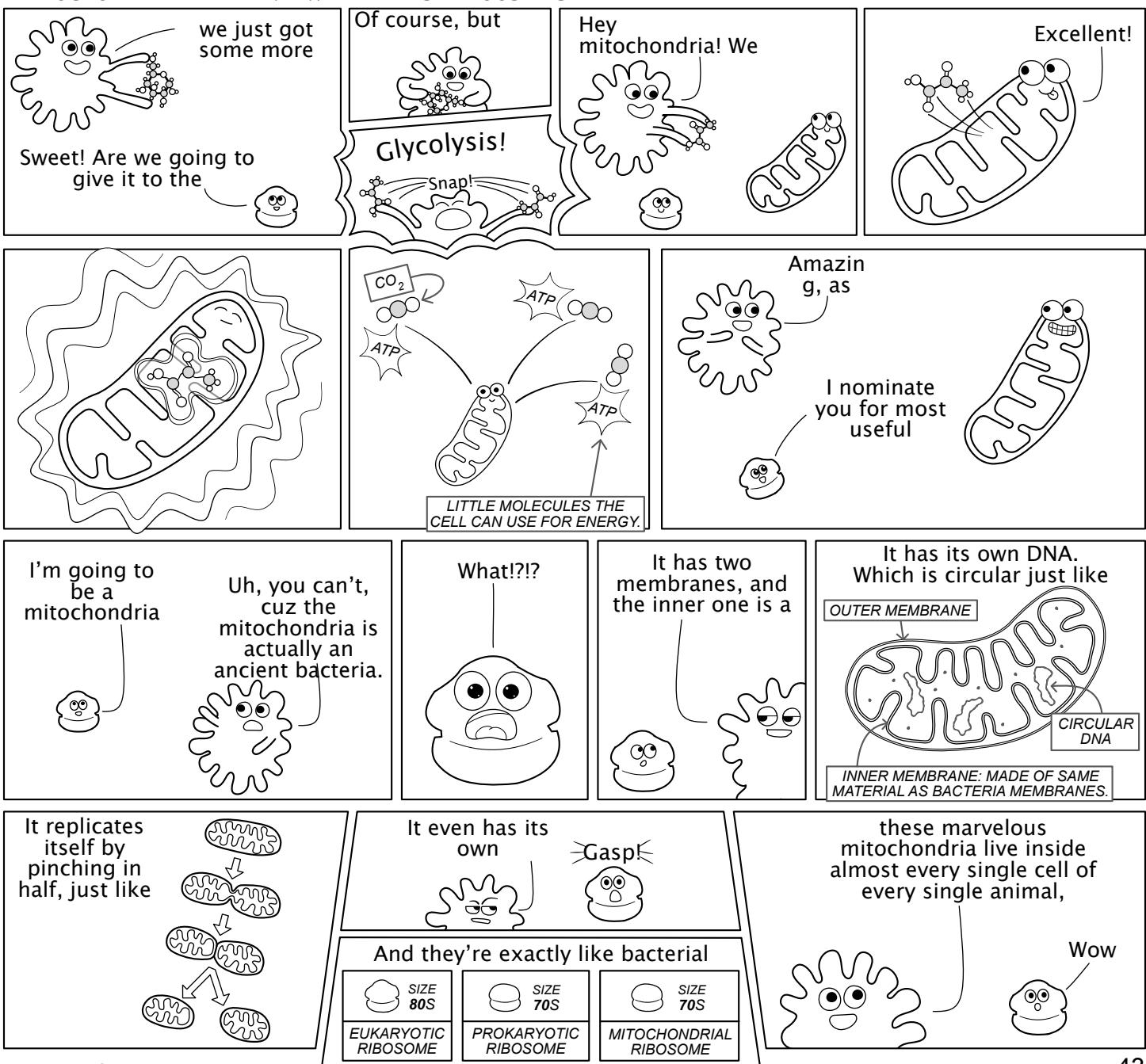
# CELLULAR RESPIRATION

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

FILL IN THE BLANKS USING THESE WORDS:

energy	glucose	glycolysis
carbon	respiration	mitochondria

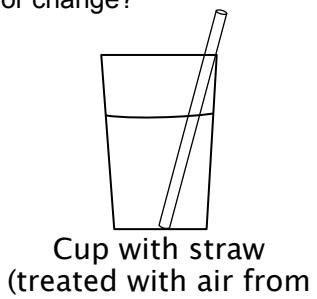
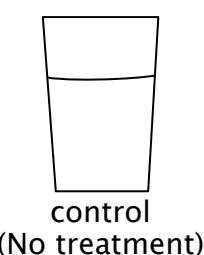
## MITOCHONDRIA - THE MVP WITH A MYSTERIOUS PAST



Try these activities to learn more about cellular respiration!

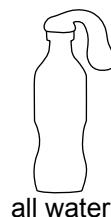
## Carbon

Each time you exhale, you breath out carbon dioxide, or CO<sub>2</sub>. 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?

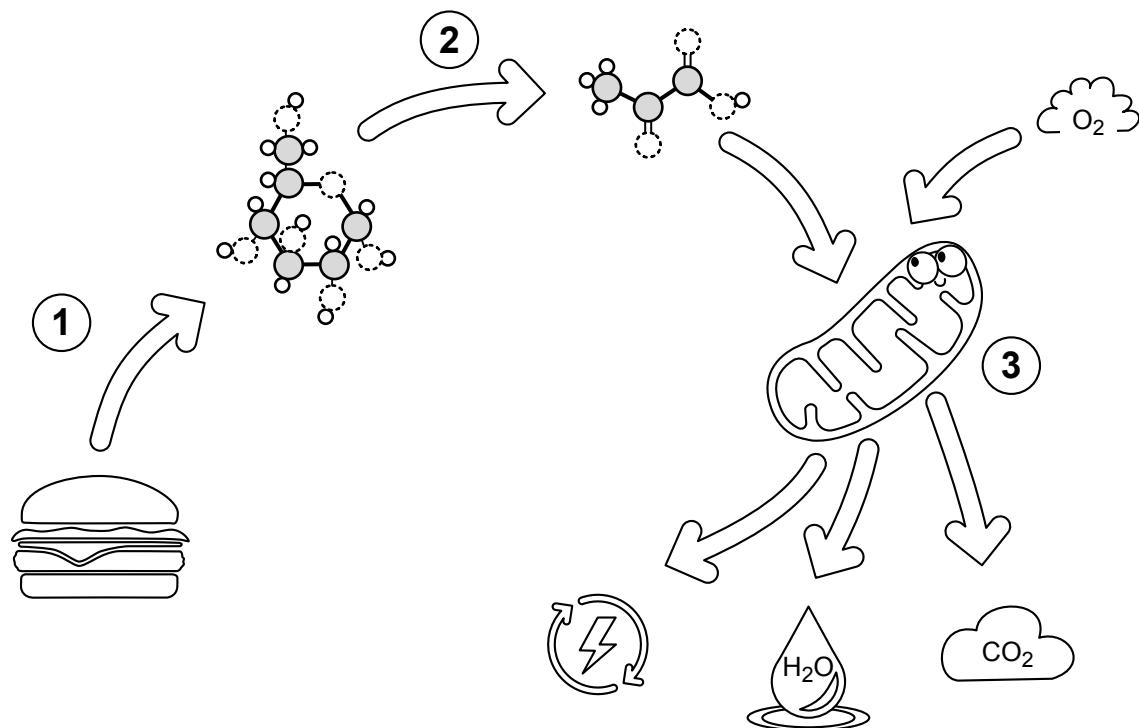


## With or without

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?



## THE EQUATION



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

3

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

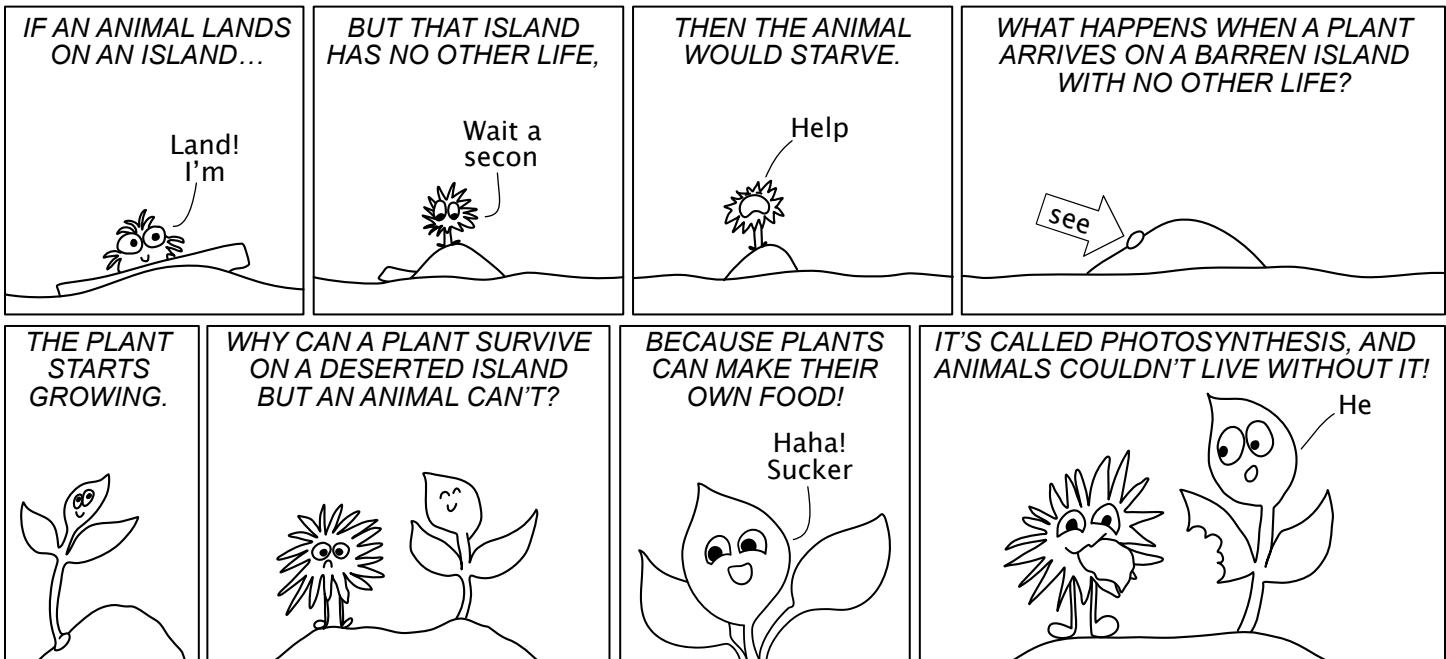
2

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

1

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

# Phenomenal Plants



**What plants are you using?**

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

**Example:** A wooden Desk made from Particleboard comes from poplar trees and  
*There are many possible answers for this activity. If someone doesn't know where to look, you could suggest they open their fridge or start reading ingredient labels on household products.*

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

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

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

Where do trees come from?  
Mostly air.

**FACT**

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

wheat      corn      rice

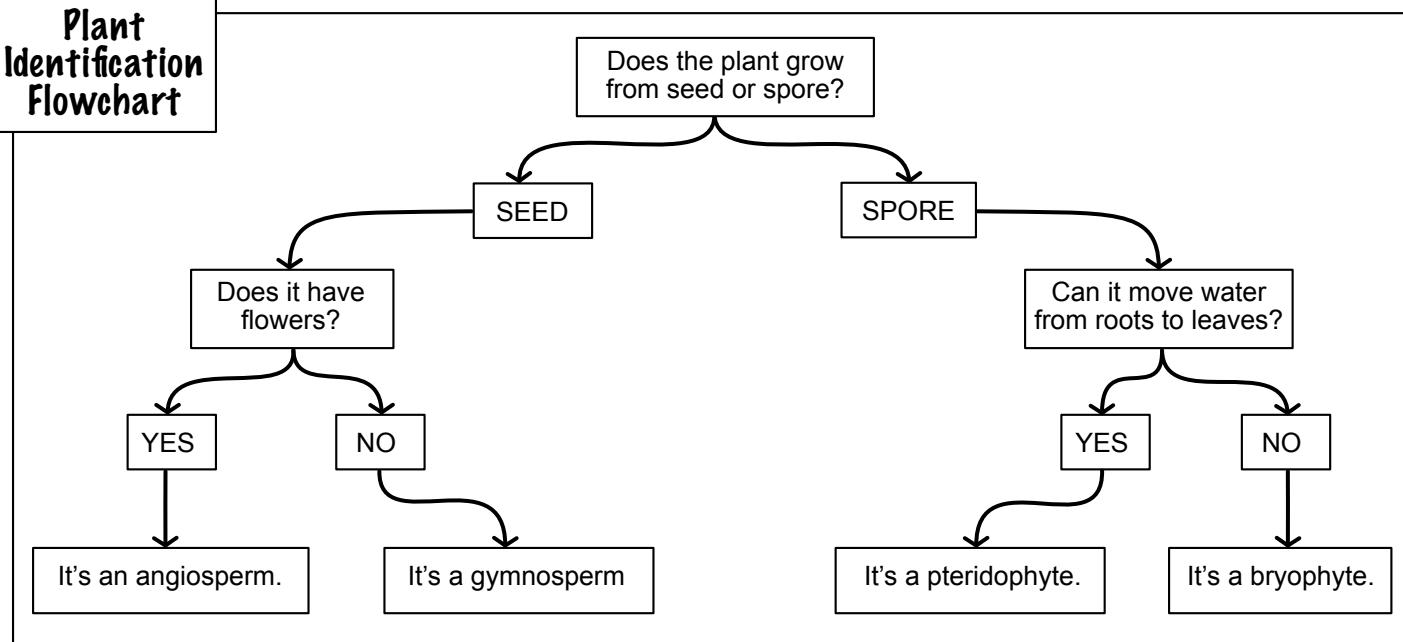
**FACT\***

Carnivorous plants don't perform photosynthesis.

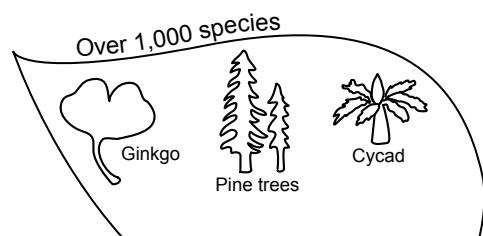
**FICTION**

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

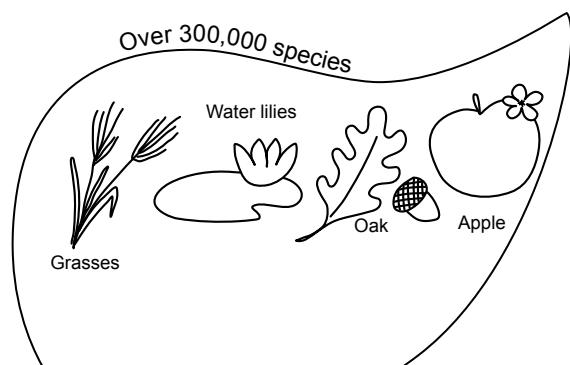
## Plant Identification Flowchart



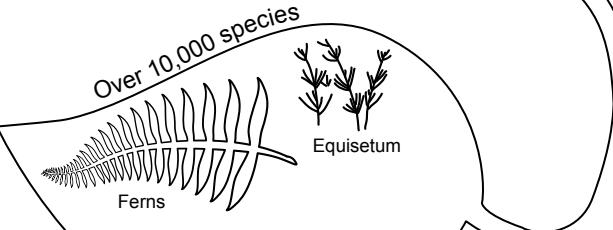
Use the clues below to label each leaf with the name of that group of plants!



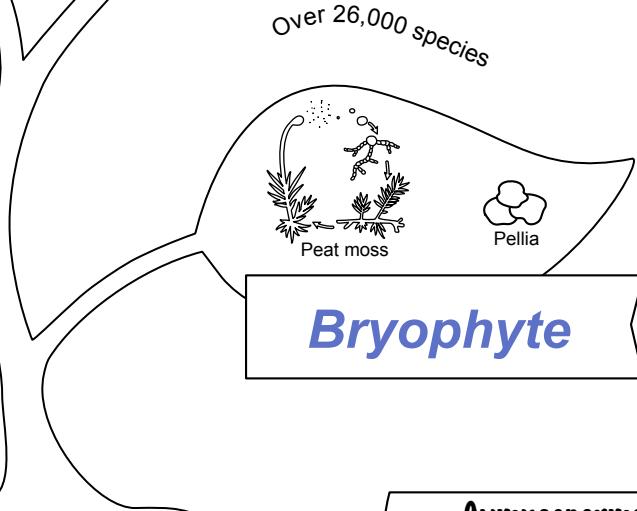
**Gymnosperm**



**Angiosperm**



**Pteridophyte**



**Bryophyte**

**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

Plants, algae, and cyanobacteria are all able to make their own food by capturing carbon dioxide in the atmosphere

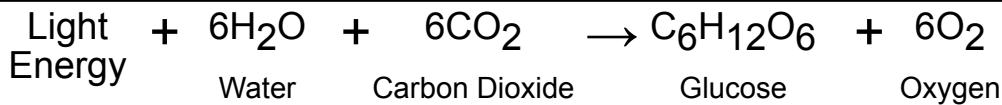
FILL IN THE BLANKS USING THESE WORDS:

carbon	sugar	light	energy
food	chloroplast	dioxide	

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

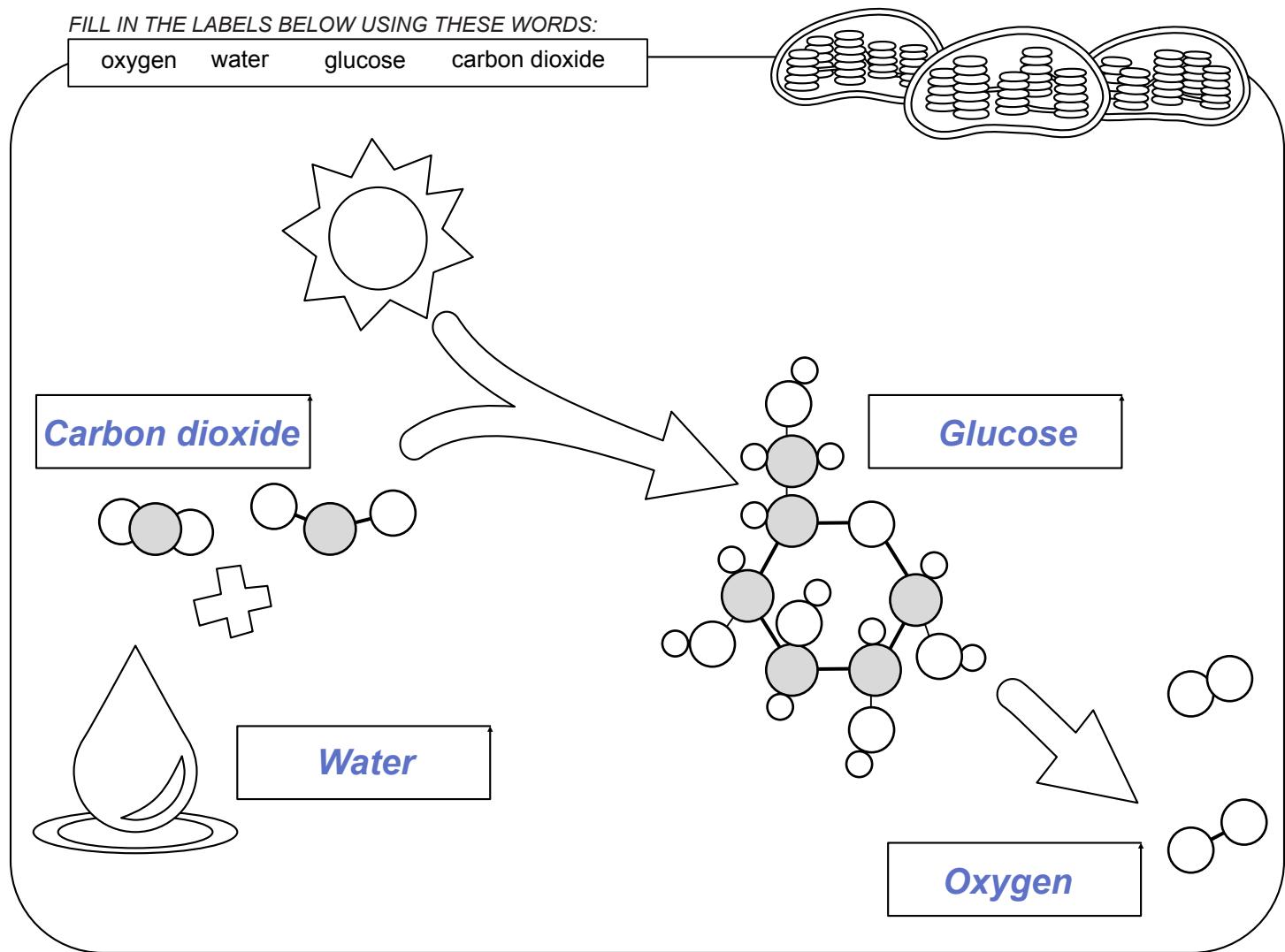
In plants and many algae, photosynthesis takes place in an organelle called the chloroplast.

THE EQUATION



FILL IN THE LABELS BELOW USING THESE WORDS:

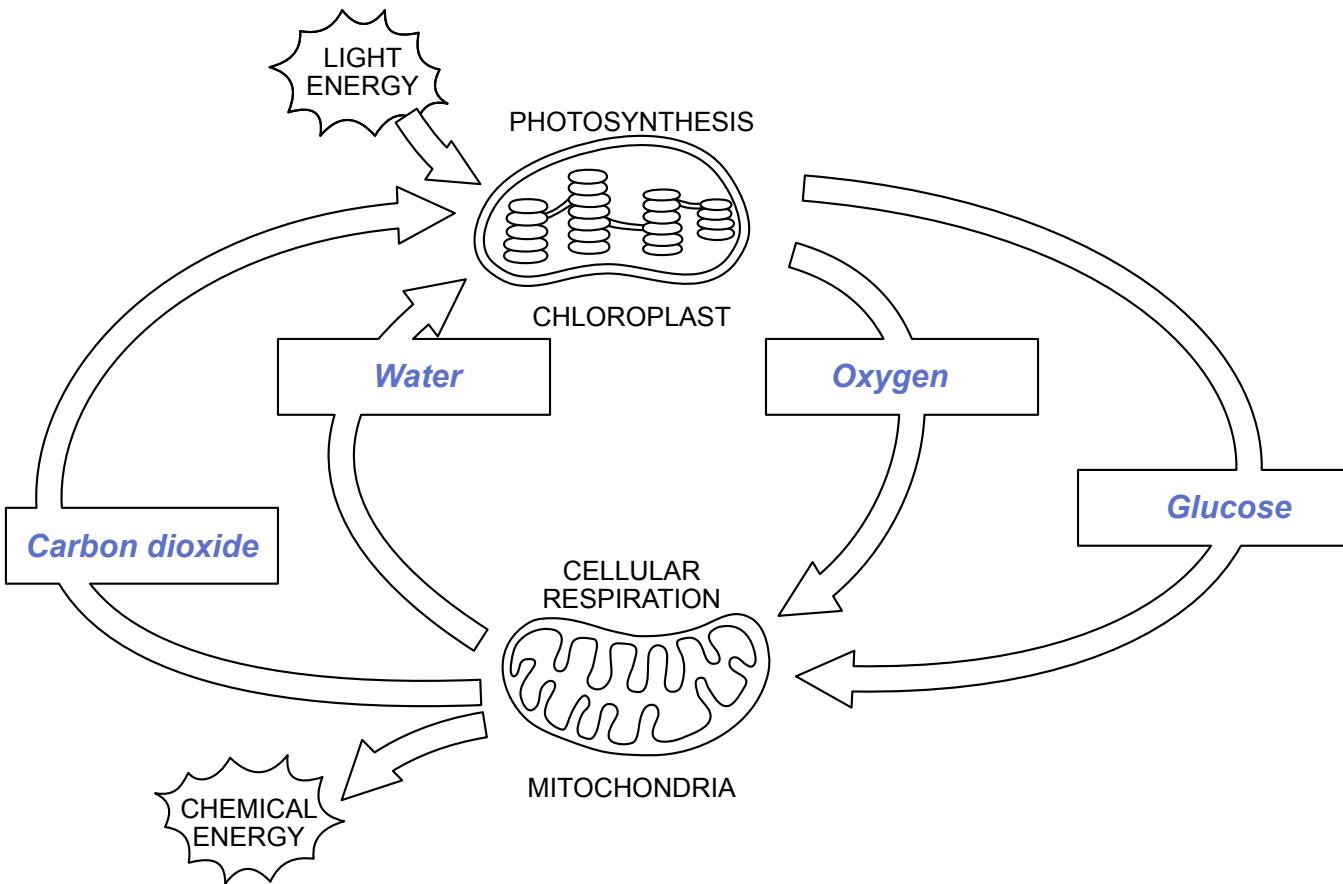
oxygen	water	glucose	carbon dioxide
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# THE CYCLE OF PHOTOSYNTHESIS AND RESPIRATION

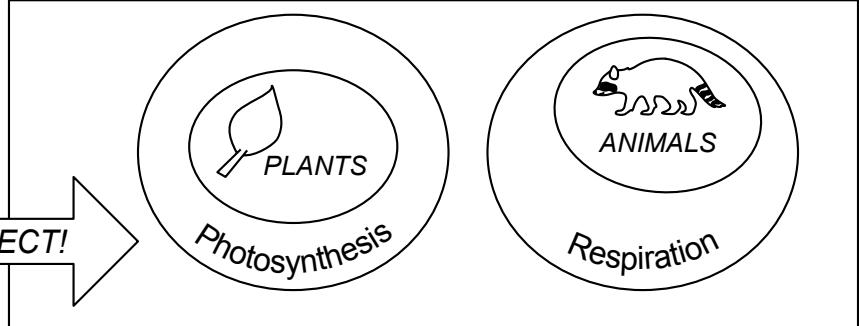
FILL IN THE LABELS BELOW USING THESE WORDS:

oxygen water glucose carbon dioxide



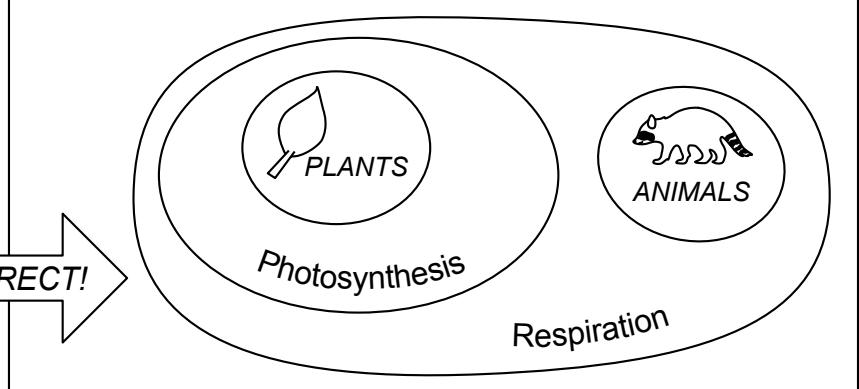
Some people think that plants only do photosynthesis and that animals only do respiration. If this were true, a Venn diagram of these organisms and their energy pathways would look like this:

INCORRECT!



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

CORRECT!



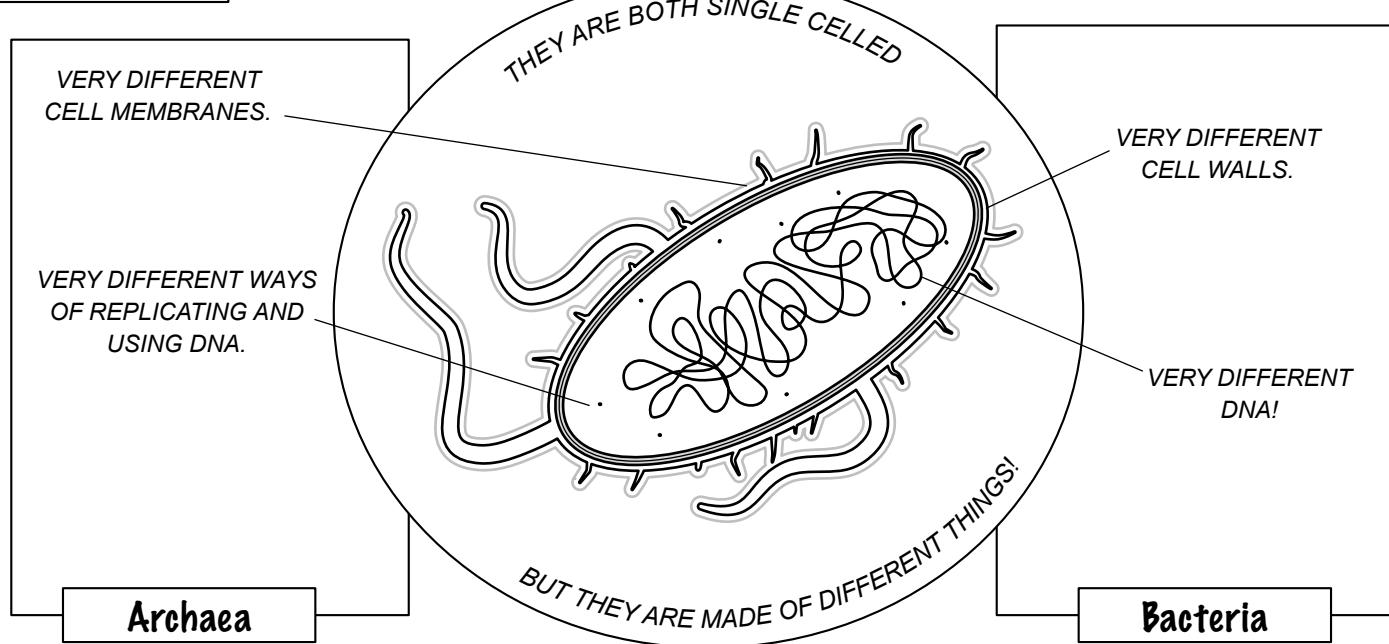
# Prolific Prokaryotes

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

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

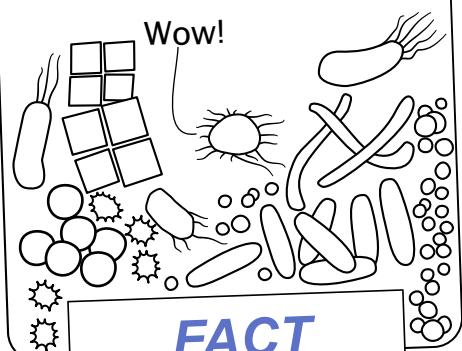
## Why two domains?

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



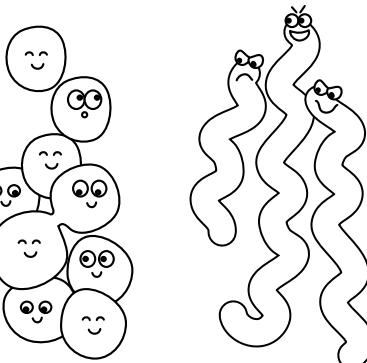
## ARE THESE FACT OR FICTION? Write your verdict below each statement:

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



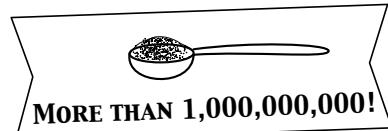
**FACT**

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



**FICTION!**

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



**FACT**

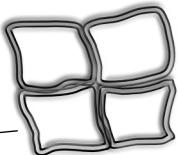
The vast majority of bacteria are neutral or beneficial to human health. Of the estimated one trillion microbial species on Earth, only 1,400 cause diseases in humans. That's less than one in a billion. Further reading: Balloux, F., van Dorp, L. Q&A: What are pathogens, and what have they done to and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

# Mixed up Microbes

Draw lines to match each microbe with the correct habitat?

## *Haloquadratum walsbyi*

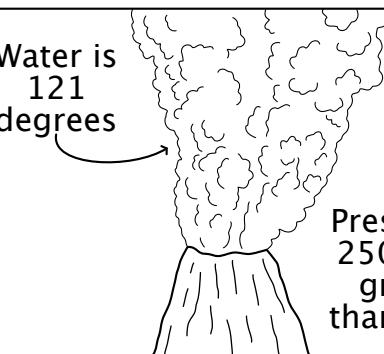
My name means The



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.

## DEEP SEA VENT

Water is 121 degrees



Pressure is 250 times greater than at sea

## *Methanobrevibacter smithii*

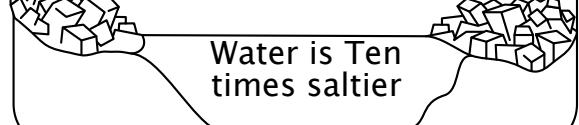
My friends



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

## SALTY BRINE POOL

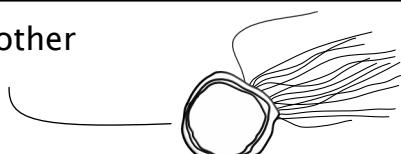
Salt crystals grow at edges of pool.



Water is Ten times saltier

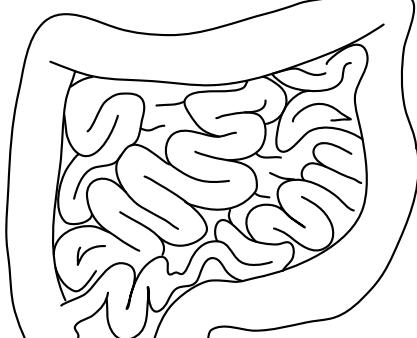
## *Geogemma barossii*

My other



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

## AN ANIMAL'S INTESTINES



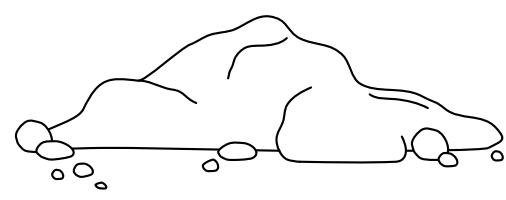
## *Deinococcus radii*

I survived 3



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."

## 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

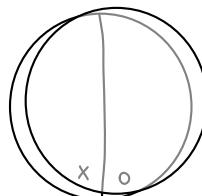
### 1. Prepare the Petri Dishes

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.

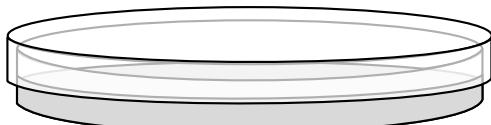


#### For BEST results

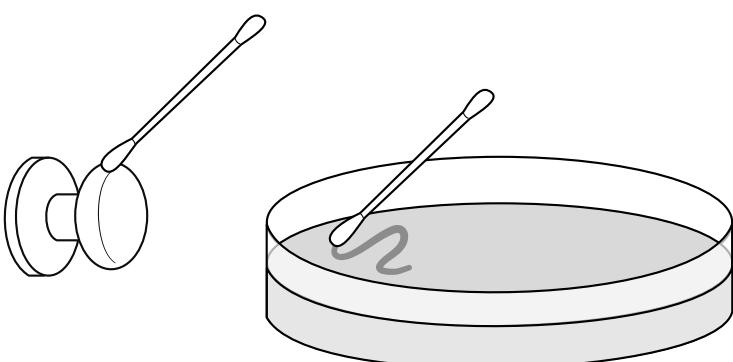
Watch the instructional video before you collect samples. Then decide what you want to investigate! Include a **control** as part of your experiment.



2. Use a permanent marker to draw a 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.



### 2. Collect samples and swab the plates!

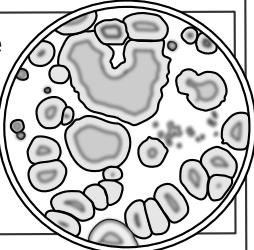


1. To collect a sample, take a cotton swab and rub it on the surface you are sampling. For best results, twirl the swab to get contact with the entire swab. It can also help to get the swab slightly damp with clean water before collecting your sample.

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

## SAFETY WARNING

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



## SUBSTITUTIONS

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

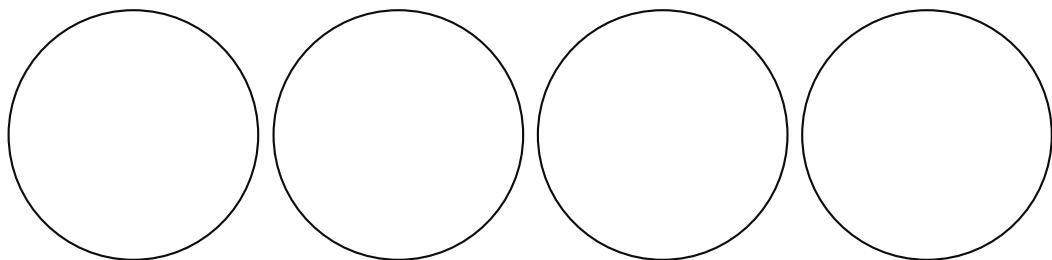
If you do not have **agar**, you can substitute a similar amount of unflavored gelatin. Some bacteria can cause the gelatin to dissolve and it can melt if it is stored above 95° F. But in general, it works as well as agar.

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

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

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

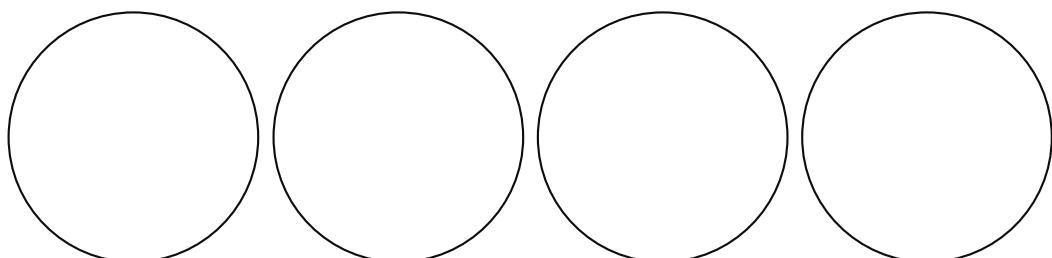
Observations:



DATE:

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

Observations:



DATE:

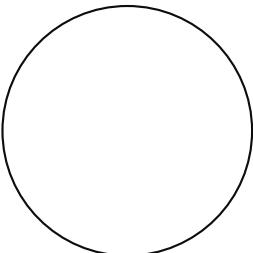
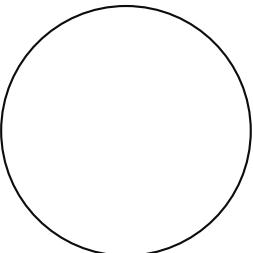
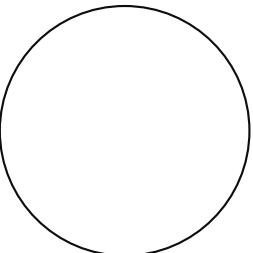
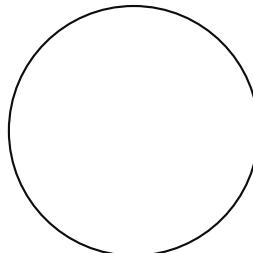
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**When to record data?** How fast your colonies grow depends very strongly on the temperature. The warmer it is, the faster they will grow.\* You should record what the plates look like immediately after gathering samples and then check them twice 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:

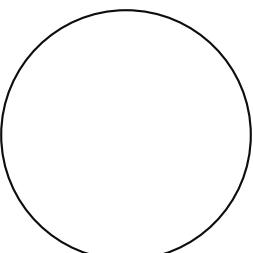
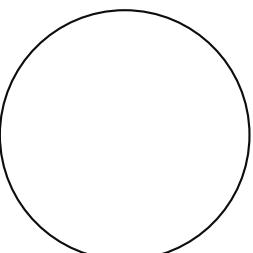
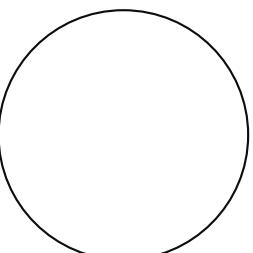
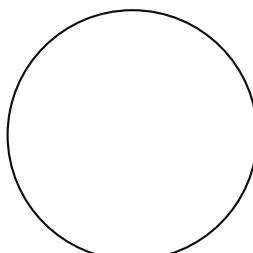


DATE:

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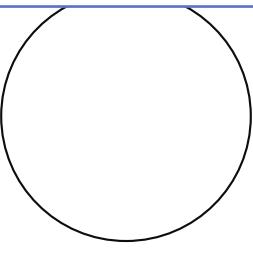
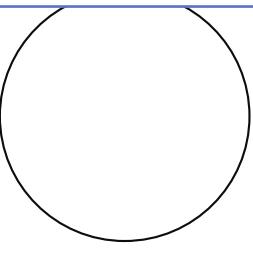
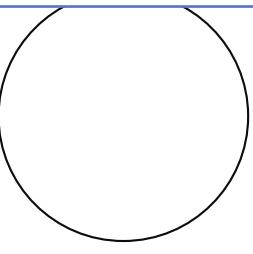
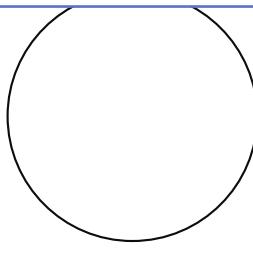
Observations:



DATE:

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

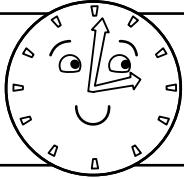
Observations:



DATE:

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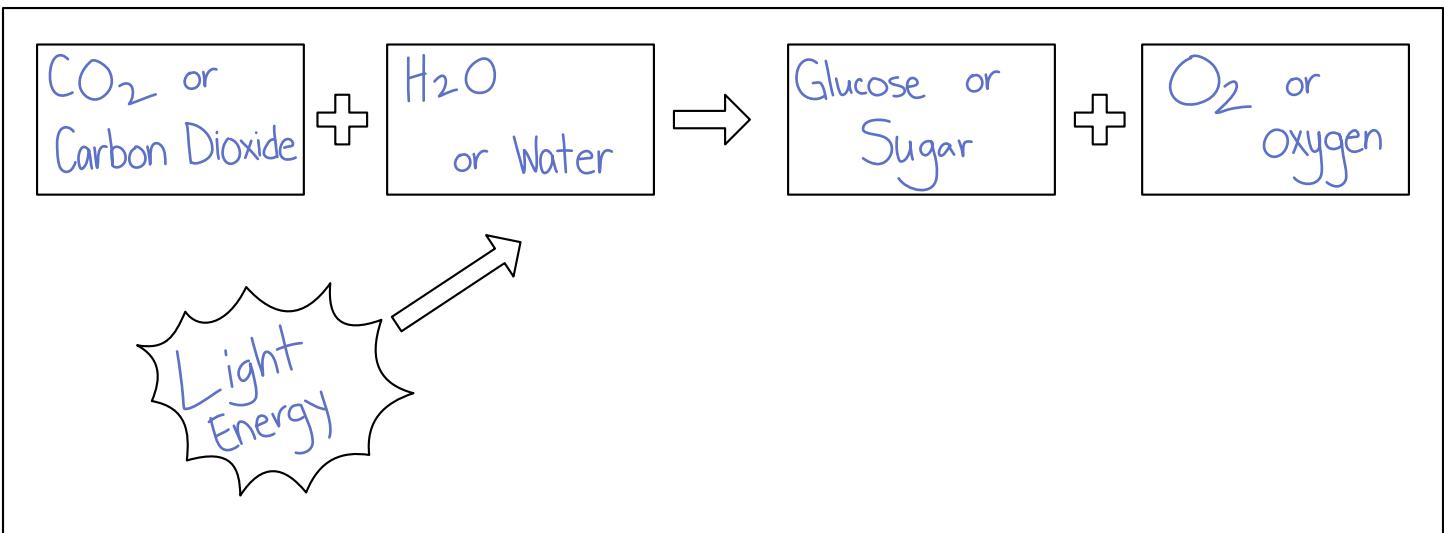


# Quiz Time!

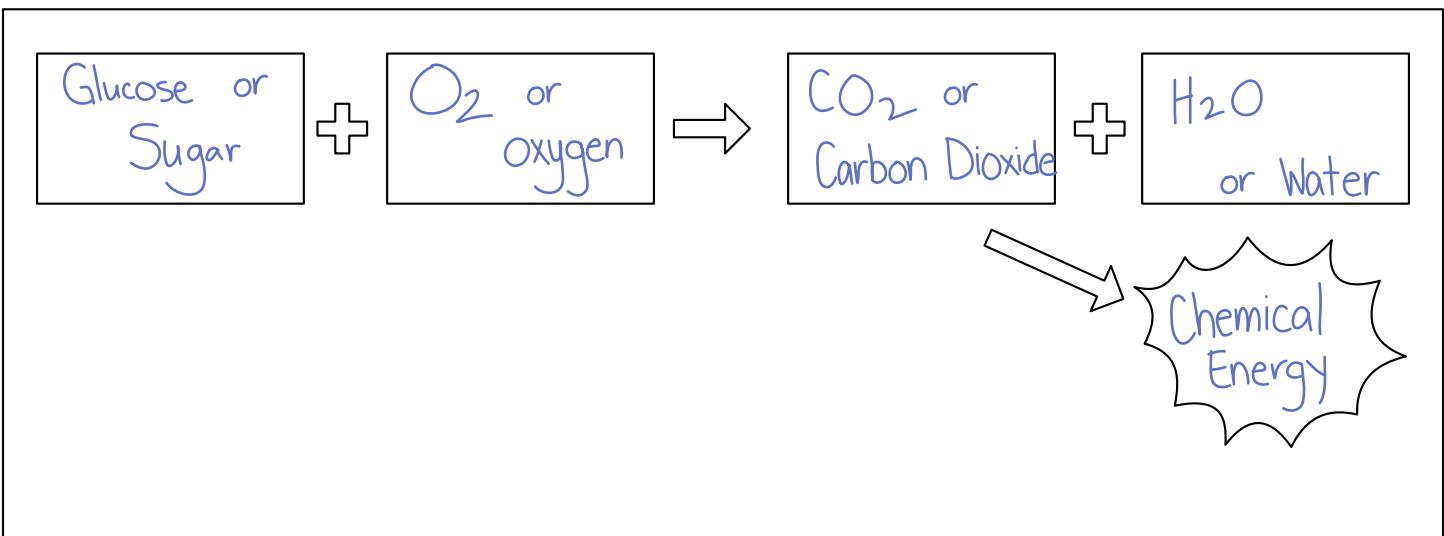
Answer the questions to see what you learned about the diversity of life!

- 1) Omnivores are heterotrophs.  
A. True **So are carnivores and herbivores.**  
B. False
- 2) The chloroplasts in fungi cells are white instead of green.  
A. True  
B. False **Fungi do not have chloroplasts! They are not plants.**
- 3) Most plant species fall into which of the following groups?  
A. Angiosperms  
B. Ferns  
C. Mosses  
D. Gymnosperms
- 4) What part of the cell contains the DNA?  
A. Ribosome  
B. Nucleus  
C. Plasma membrane  
D. Cytoplasm
- 5) Which organelle(s) came about when a cell incorporated a bacteria?  
A. Nucleus **For more on endosymbiosis check out <https://askabiologist.asu.edu/explore/cells-living-in-cells>**  
B. Chloroplast  
C. Ribosome and  
D. Mitochondria **<https://www.molbiolcell.org/doi/full/10.1091/mcb.e16-07-0509>**
- 6) What products are created by cellular respiration?  
A. Oxygen  
B. Carbon Dioxide  
C. Water  
D. Glucose
- 7) Which groups of living things contain both autotrophs and heterotrophs?  
A. Plants **Note that although there are no known photosynthetic archaea, there are**  
B. Animals **archaea that use light as an energy source. There are also archaea that can**  
C. Fungi **capture CO<sub>2</sub> and create sugars from non-organic carbon, but they do this with a different chemical process (one that does not produce oxygen).**  
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.



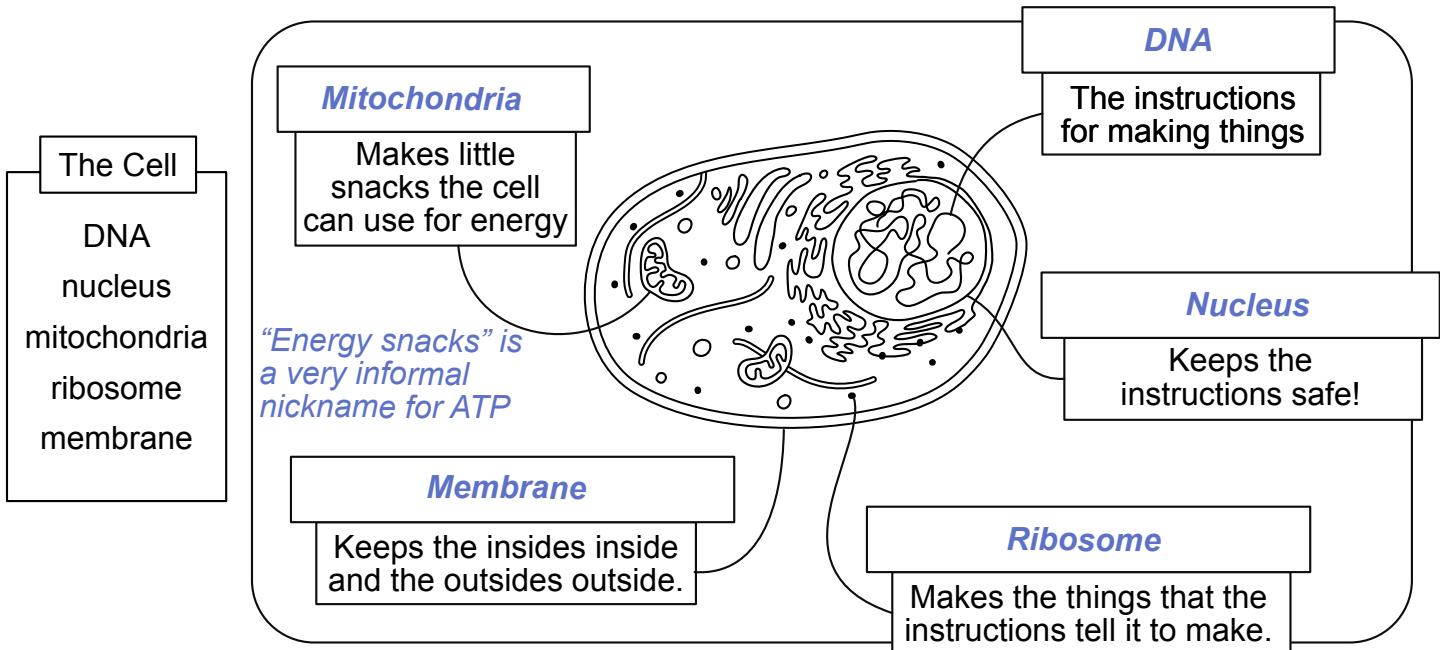
- 20) Write the name of each organism or group of organisms in the correct box according to whether it performs photosynthesis, respiration, or both processes:

PINE TREE, MUSHROOM, BACTERIA, GRASS, MOLD, FERN, MAMMOT,

ONLY PHOTOSYNTHESIS	PHOTOSYNTHESIS AND CELLULAR RESPIRATION	ONLY CELLULAR RESPIRATION
<b>Some species of archaea</b>  <b>Some species of bacteria</b>	<b>Pine tree</b> <b>Bacteria (Green and purple non-sulphur bacteria)</b> <b>Archaea (<i>halobacterium salinarum</i>)</b> <b>Grass</b> <b>Fern</b> <b>Moss</b>	<b>Mushroom</b> <b>Various species of bacteria</b> <b>Mold</b> <b>Mammot</b> <b>Various species of archaea</b> <b>Animal</b>

# 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?



Inside an animal CELL there will be

**RIBOSOMES** to help make **PROTEINS**

Can you rearrange the letters to reveal the part of the cell?

**DNA** located inside the **NUCLEUS**

AND **USCLUNE**

**MITOCHONDRIA** that generate chemical **ENERGY**

All of it is surrounded by the **PLASMA MEMBRANE**

SCIENCE MAM

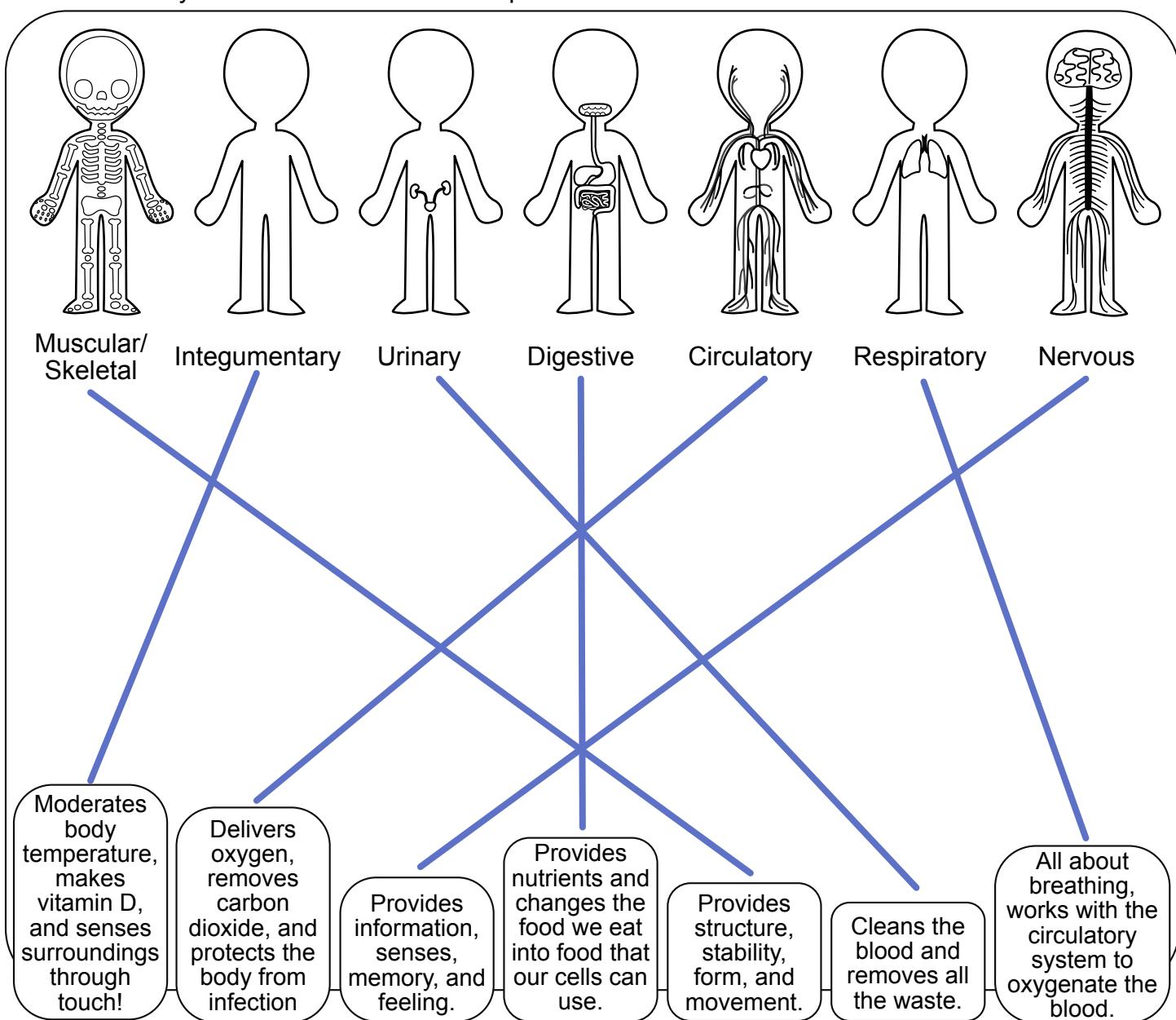
# BODY SYSTEMS

FILL IN THE  
BLANKS USING  
THESE WORDS:

systems  
cells  
organs  
perform  
body

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

Match the system with the correct description.



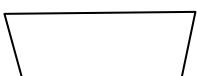
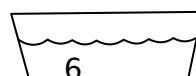
# The circulatory system

Try these activities to learn more about your circulatory system!

## Race the

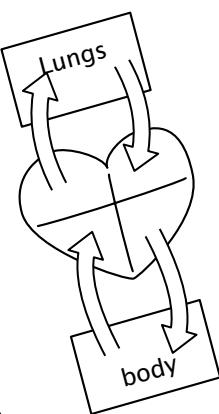
The average adult heart pumps about 6 liters of blood each minute when at rest. How much water can you move in a minute? Fill up a container and give it a try!

1/3 measuring



## Make a Model

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



## On the Clock

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

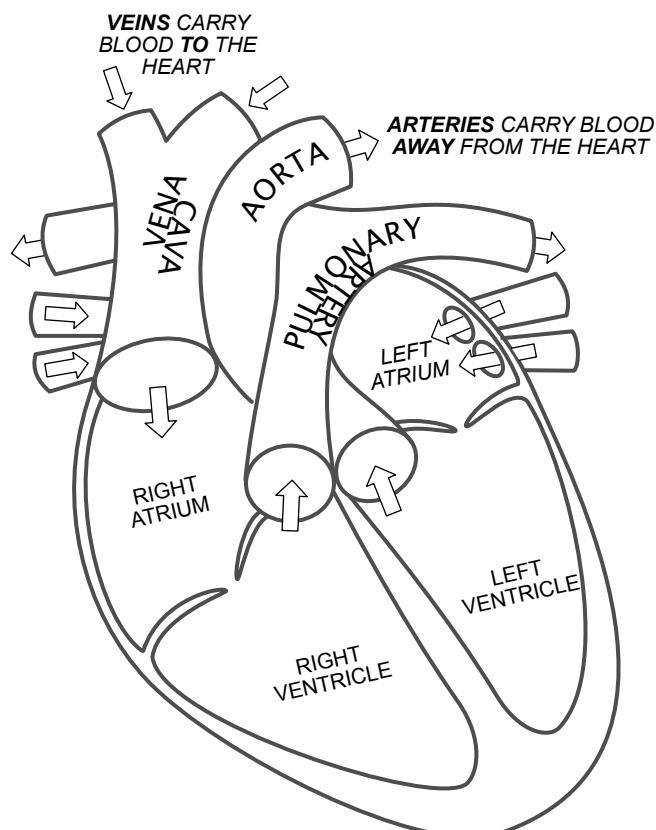
Then do 30 jumping jacks or some other type of exercise and count your pulse again. How did it change?

Pulse at rest:

Pulse after exercise:

75

160



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

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

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

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

## Find your pulse

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

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

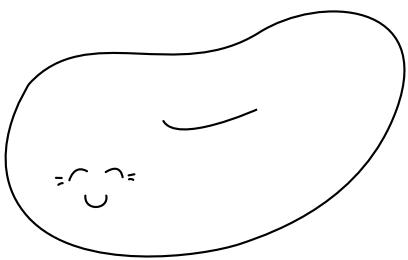
Some of these are easier to find than others! It's perfectly fine if you aren't able to feel all of them.

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

# WHAT IS BLOOD MADE OF?

## Red Blood Cell

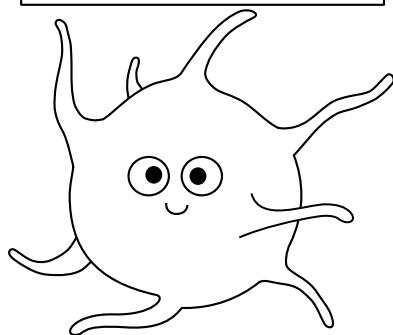
Also known as: Erythrocyte



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

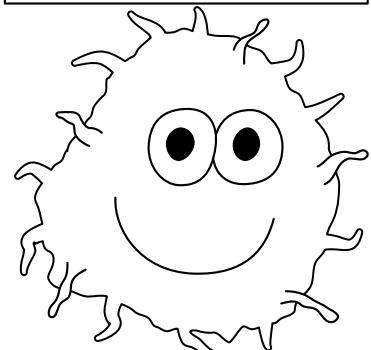
Also known as: Thrombocyte



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

## White Blood Cell

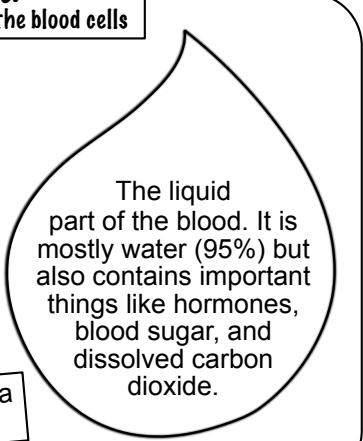
Also known as: Leukocyte



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



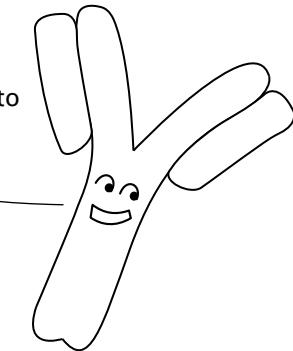
Cool fact: blood plasma isn't red. It's yellow!

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

## Antibodies

Small proteins

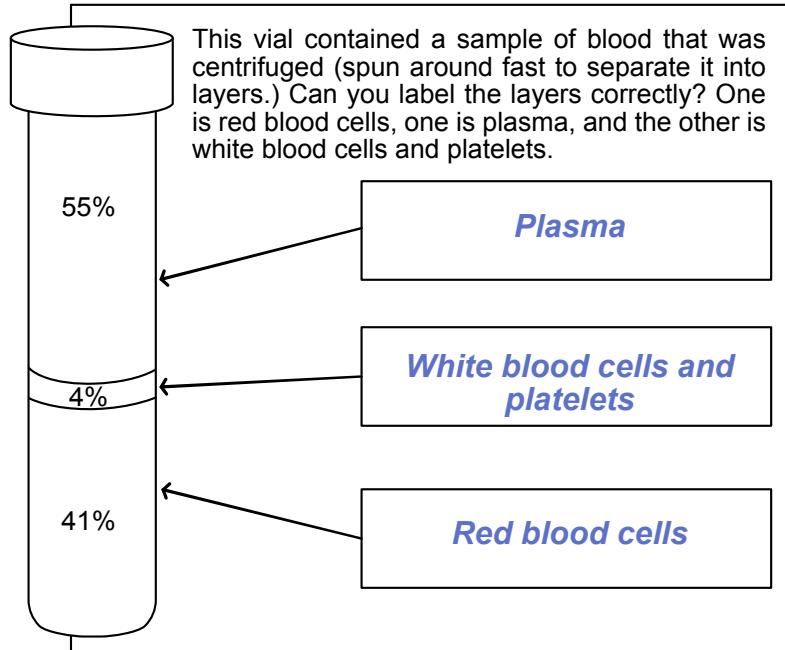
We tell the white blood cells where to



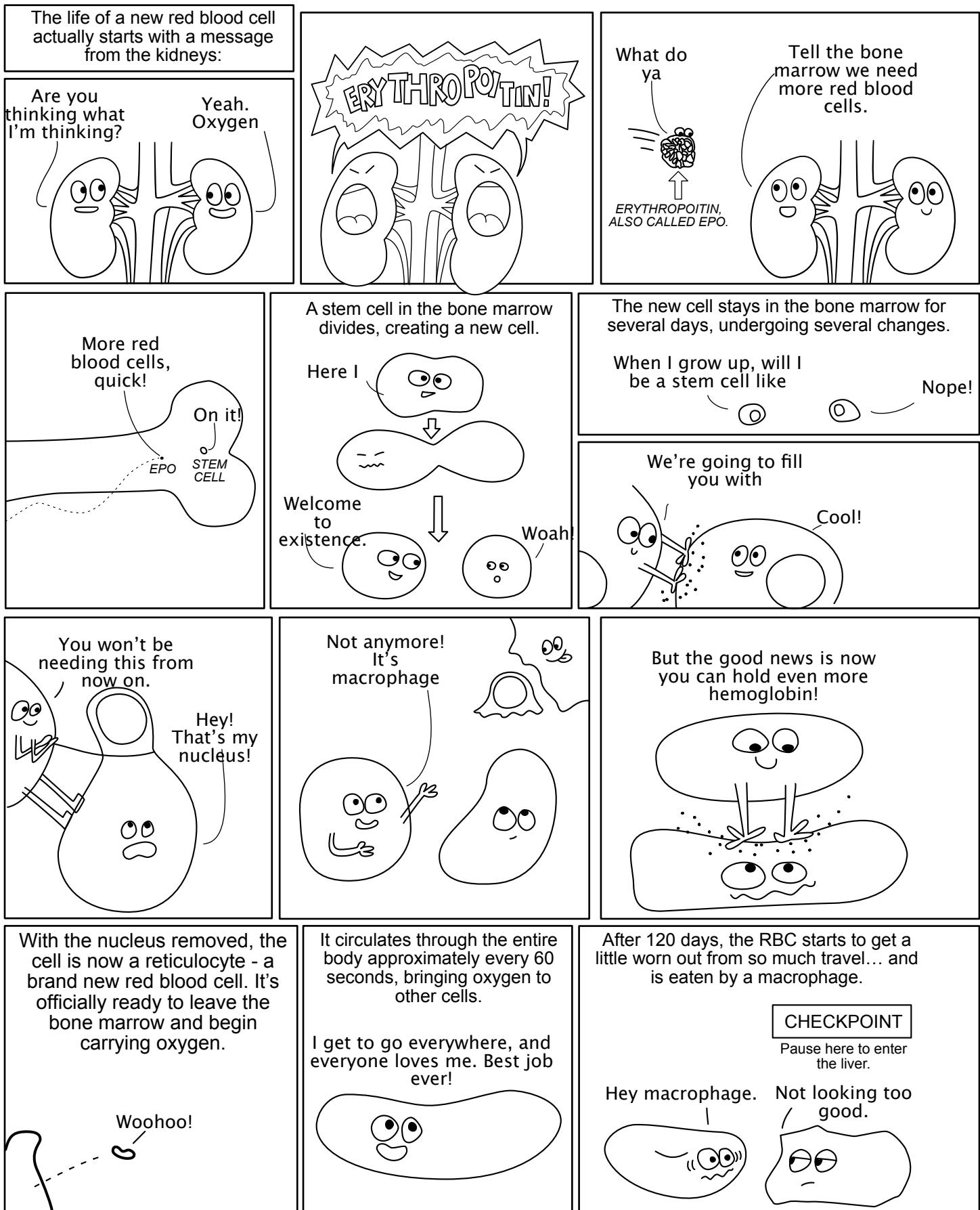
Your notes:

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

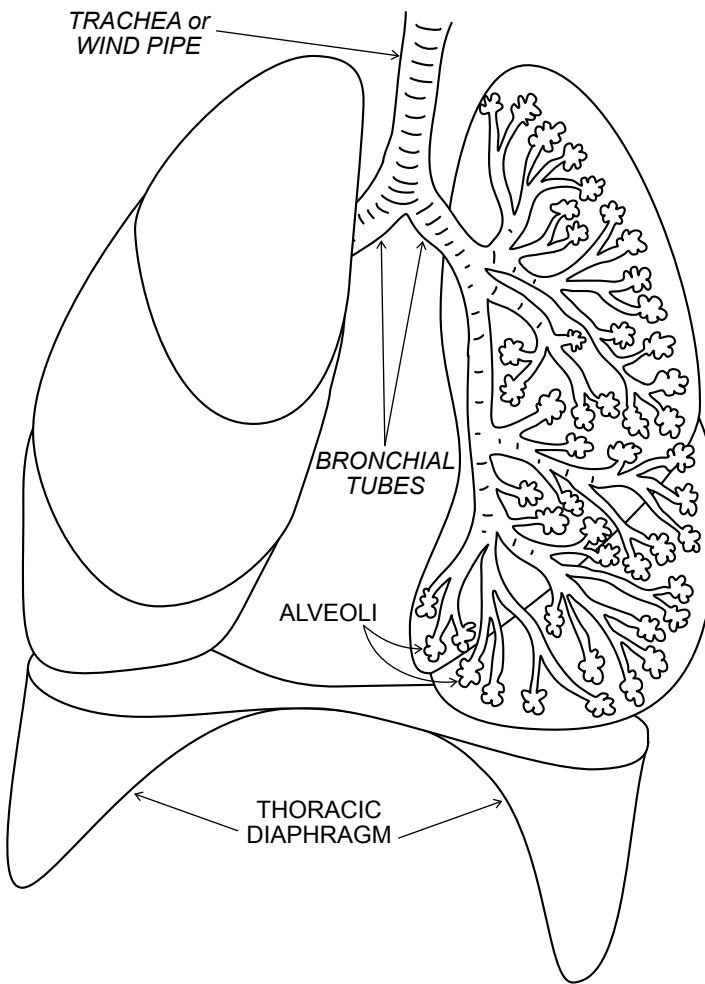
This vial contained a sample of blood that was centrifuged (spun around fast to separate it into layers.) Can you label the layers correctly? One is red blood cells, one is plasma, and the other is white blood cells and platelets.



# THE LIFE OF A RED BLOOD CELL



# The Respiratory System



## Just a hiccup?

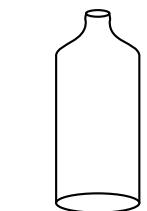
Hiccups are caused by the muscle that separates the lungs and heart from the abdomen: the thoracic diaphragm. When the diaphragm spasms it causes air to suddenly rush past the vocal chords and into the lungs. This is what produces the hiccup sound. Hiccups can be caused by many different things and severe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

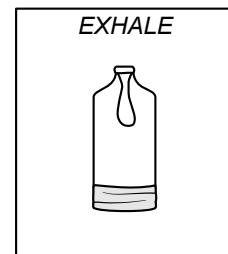
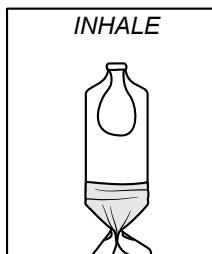
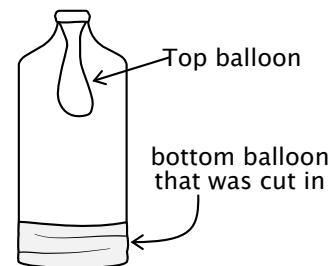


2 BALLOONS



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.



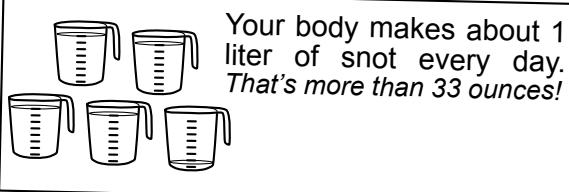
FILL IN THE BLANKS USING THESE WORDS:

carbon dioxide	lungs	gills
gases	oxygen	alveoli

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

## Did you know?

The cells on the inside of your lungs are coated in mucus! 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 mucus is either swallowed (sent into the acidic stomach) or it comes out your nose!



Your notes:

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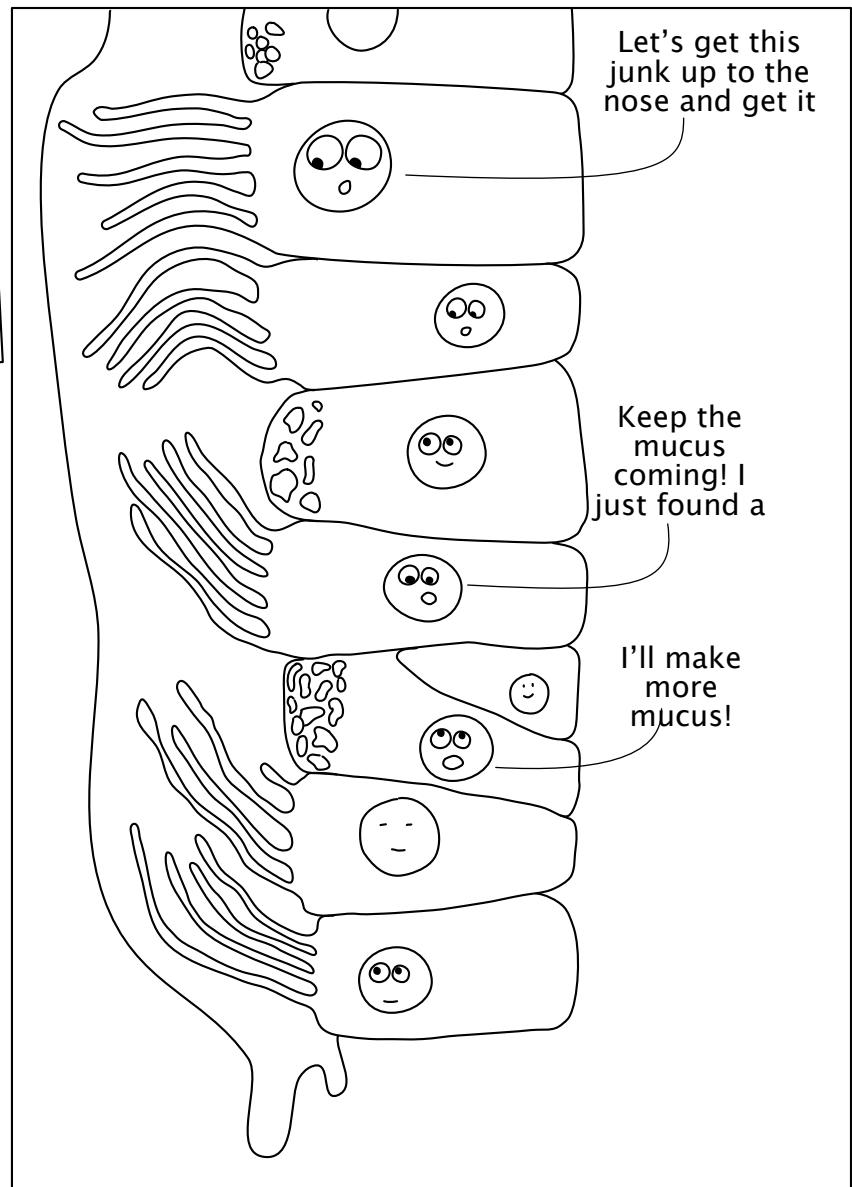
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## ARE THESE FACT OR FICTION? Write your verdict below each statement:

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

I can breathe more

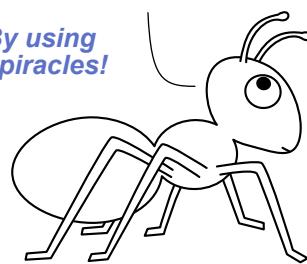
Says who?

**FICTION**

Insects have no lungs.

Then how do we

By using spiracles!

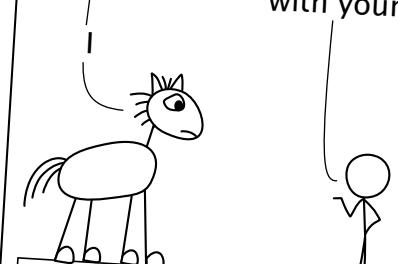


**FACT**

Horses can only breathe through their noses.

I hab a tewible cold and a stuffy

Just breathe with your

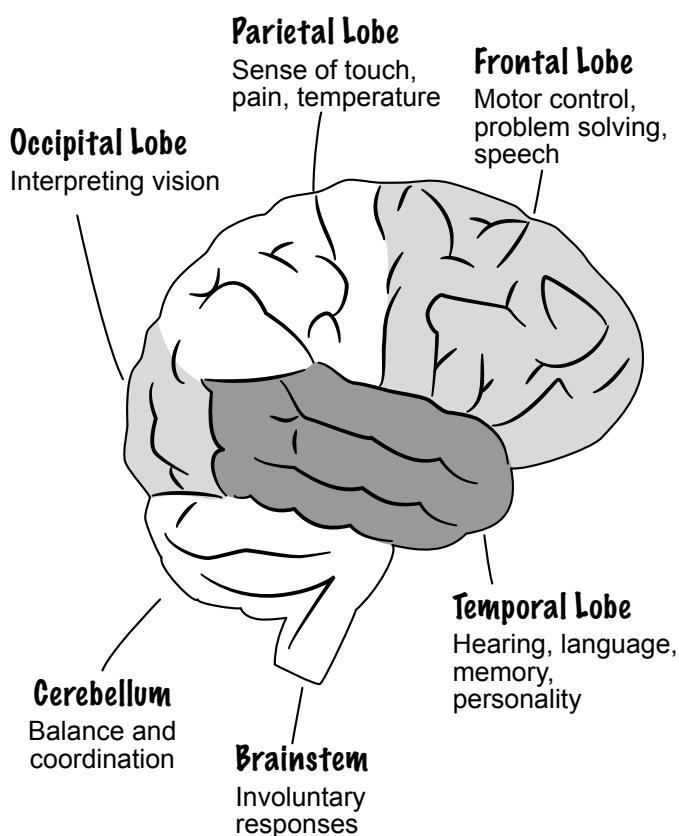


**FACT**

# The Nervous System

FILL IN THE BLANKS USING THESE WORDS:

spinal cord	involuntary	neurons
store	peripheral	sense



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

Try this activity to learn more about your nervous system!

## Time your



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

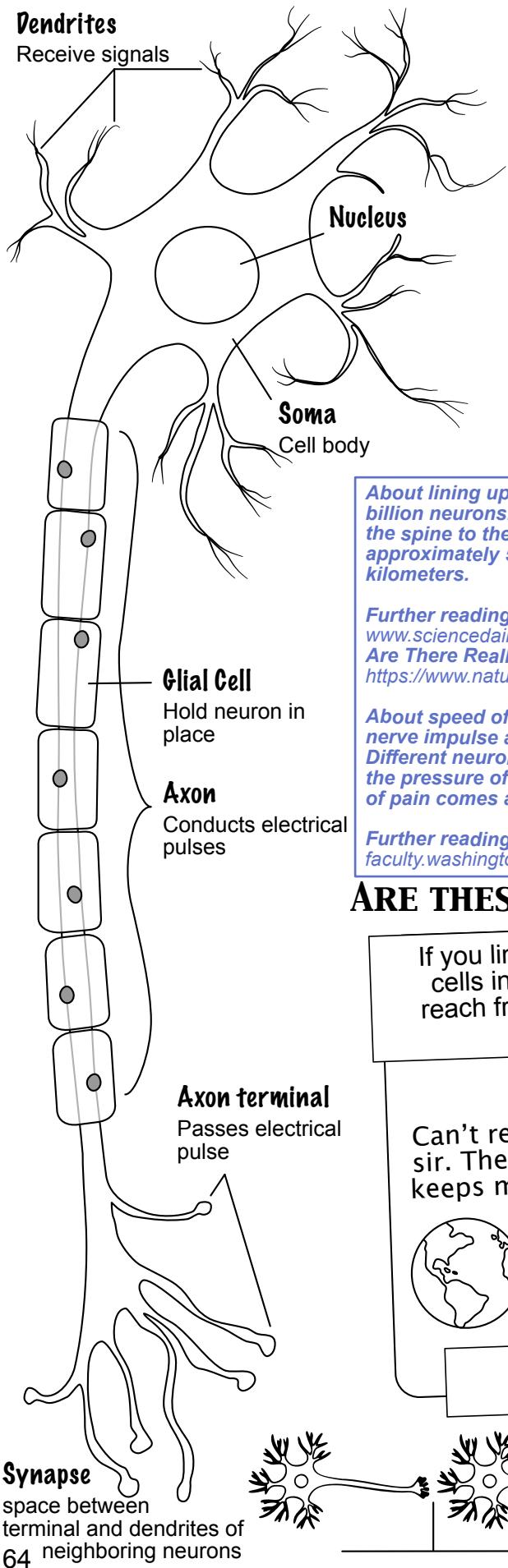
Try the experiment 10 times and then average your results:

### Reaction

Your average took for you to react. Your nervous system sends a signal to your brain, which decides what movement to make and your brain sending the MOVEMENT signal to the muscles in your hand.

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

YES	NO
-----	----



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

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

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

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

*Further reading: Navigation System of Brain Cells Decoded, 2017. <https://www.sciencedaily.com/releases/2017/10/171025105041.htm>*

*Are There Really as Many Neurons in the Human Brain as Stars in the Milky Way? [https://www.nature.com/scitable/blog/brain-metrics/are\\_there\\_really\\_as\\_many/](https://www.nature.com/scitable/blog/brain-metrics/are_there_really_as_many/)*

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

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

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

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

Can't reach it, sir. The target keeps moving.

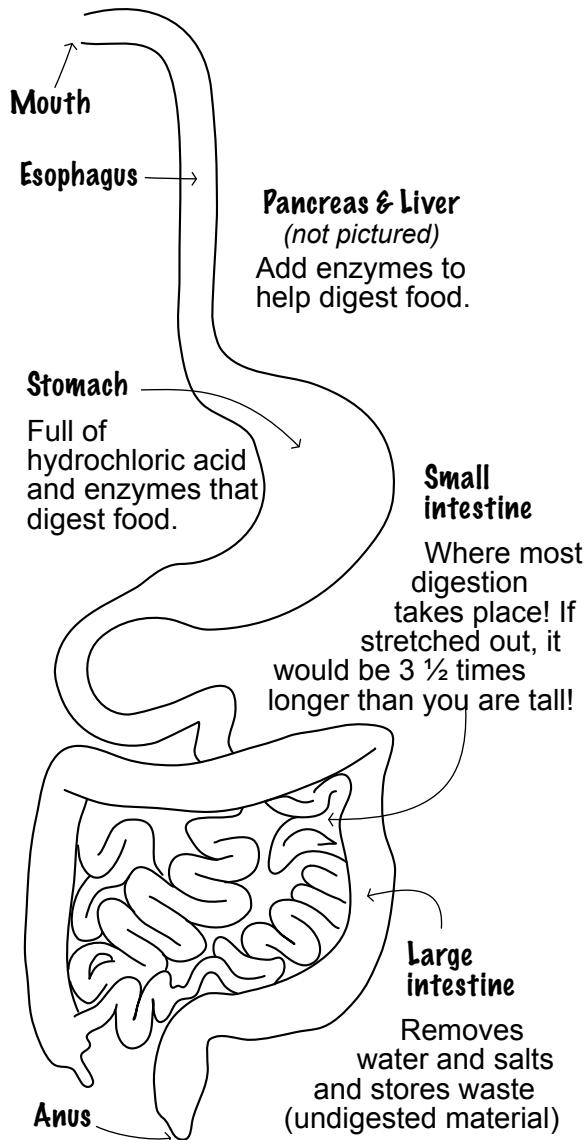
Nerve impulses can travel more than 100 m/s (223 mi/h).

Yahoo!!

**FACT**

**FACT**

# The Digestive System



FILL IN THE BLANKS USING THESE WORDS:

nutrients	protect	signal	repair
lining	bacteria	tract	hormones

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

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

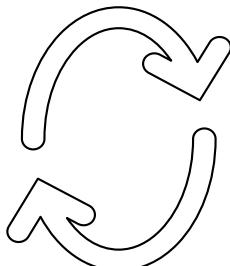
A platypus doesn't have a stomach.

So hungry!

**FACT**

Echidnas and many fish don't have stomachs either.

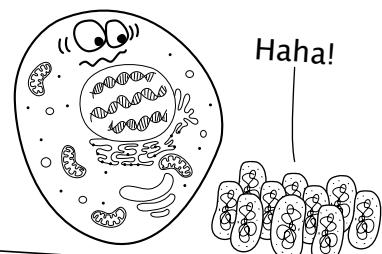
You can't swallow food while hanging upside down because gravity is required for swallowing.



**FICTION**

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

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

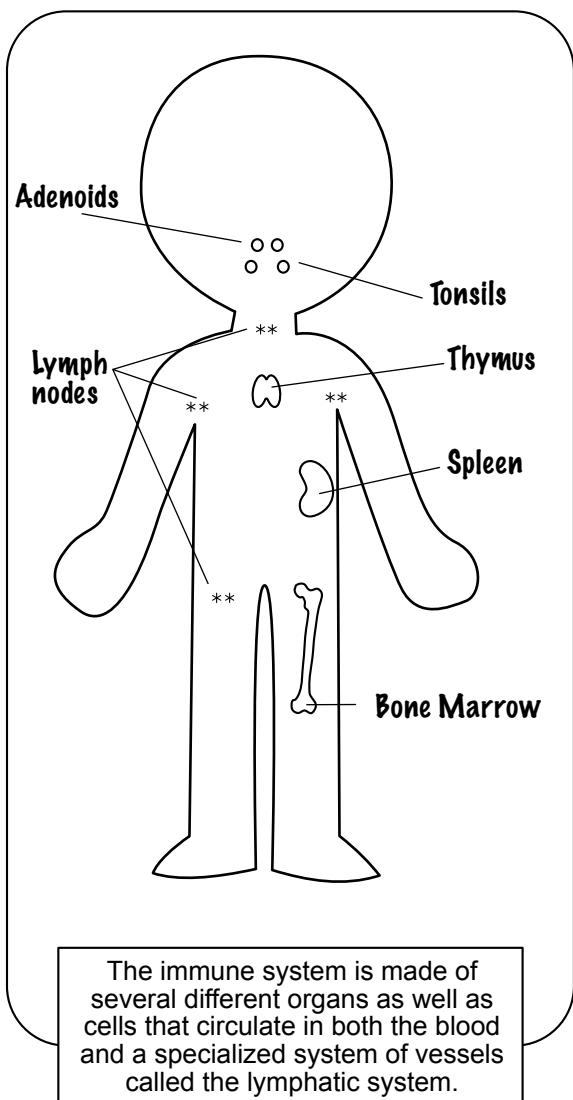


**FACT**

# The Immune System

FILL IN THE BLANKS USING THESE WORDS:

pathogens	infection	immune response
primary	secondary	memory



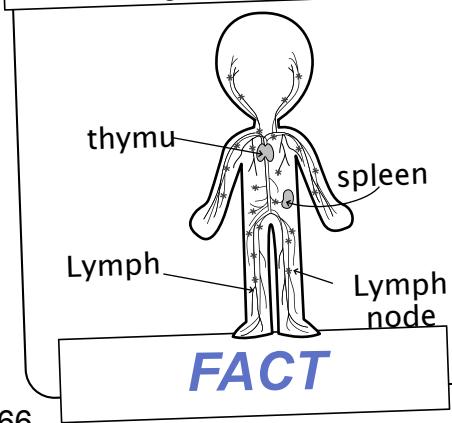
The immune system protects the body from outside invaders like bacteria, viruses, fungi, and toxins. Microorganisms that can make us sick are called pathogens (or germs). When pathogens invade and multiply, we call this an infection.

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

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

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

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



You can never catch the same cold twice.

A fever helps your body fight an infection.

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

Also, the strength of your immune system can be weakened by illness or stress. If you are immunocompromised, a pathogen you previously had could still make you sick.

**FICTION\***

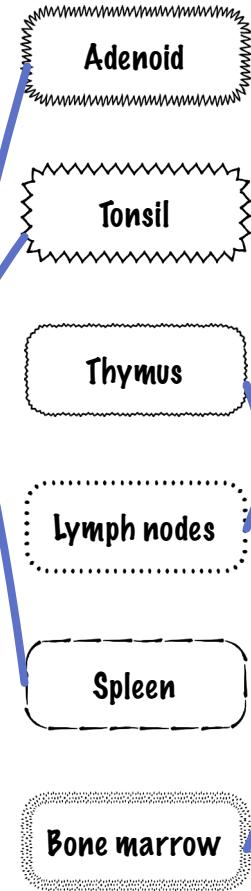
**FACT**

## 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.



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:

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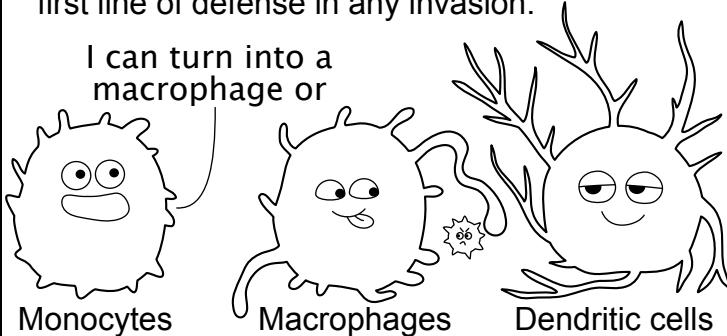
# THE WHITE BLOOD CELLS

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.

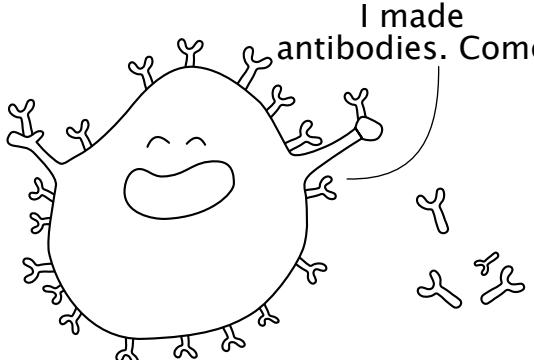
I can turn into a macrophage or



## B lymphocytes or B cells

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

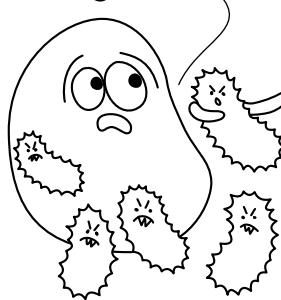
I made antibodies. Come



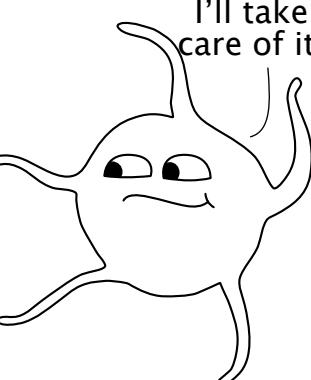
## T lymphocytes or T cells

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

Help!  
Pathogens are



I'll take  
care of it.



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

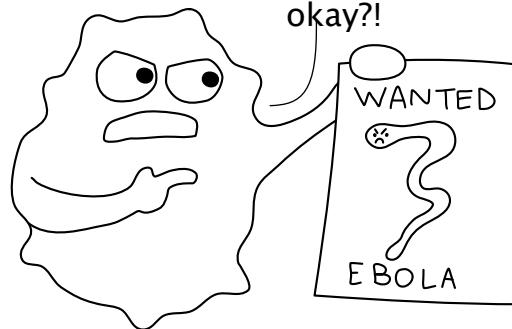
We will only survive if we assemble the team! B cells and other T cells, report for duty at once!



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

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

Don't forget  
this one,  
okay?!



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

Your notes:

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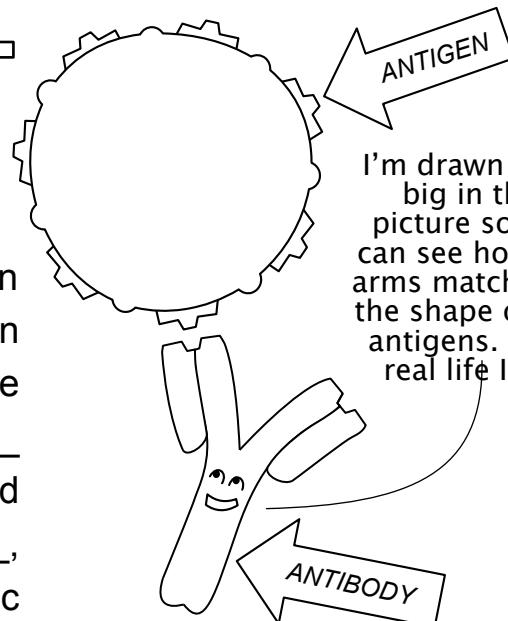
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# Antibodies & Antigens

FILL IN THE BLANKS USING THESE WORDS:

bind	pathogens	specific
inactivate	antibodies	antigens

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

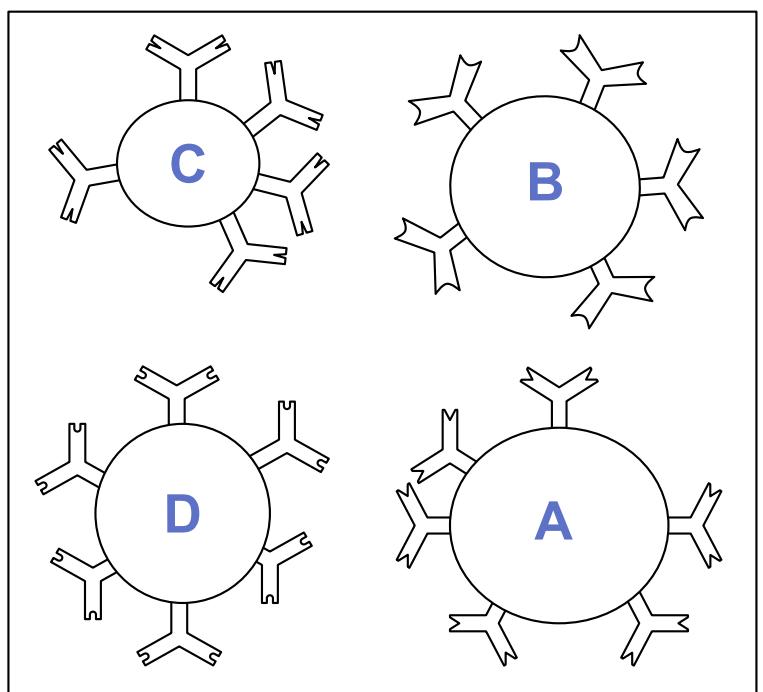
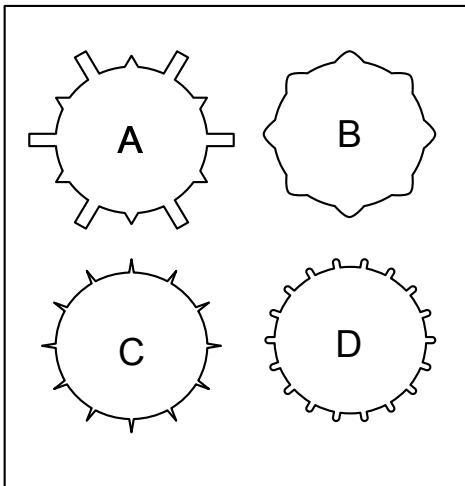


## SIZE COMPARISON

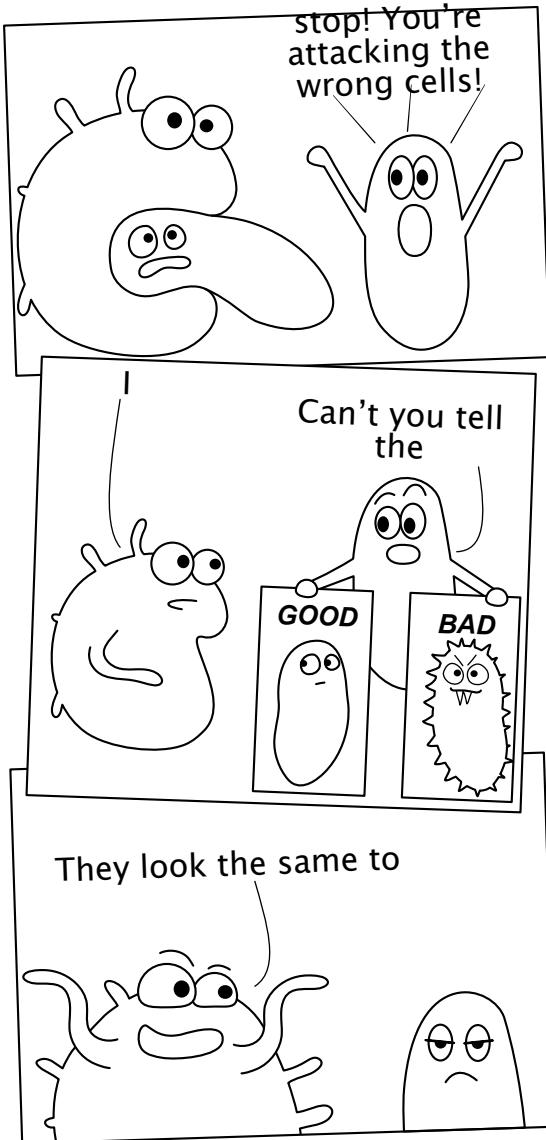
THE AVERAGE ANTIBODY IS ABOUT 10 NANOMETERS IN LENGTH.

THE AVERAGE ANIMAL CELL IS ABOUT 20 MICROMETERS IN DIAMETER. (THAT'S 20,000 NANOMETERS!)

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



# Autoimmune & Allergies



FILL IN THE BLANKS USING THESE WORDS:

nerve	autoimmune	allergies
connective	pancreas	allergen

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

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

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

It is possible to have an allergy to water.

Hookworm parasites can cure most allergies.

A tick bite can make you allergic to meat.

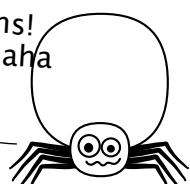
\**Aquagenic urticaria is an extremely rare condition where exposure of the skin to water of any temperature will cause a rash. A person with this condition is not allergic to water in the traditional sense of the word because they can still drink water with no ill effects. It is not clear if the rash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

**FACT\***

**FICTION\*\***

**FACT**

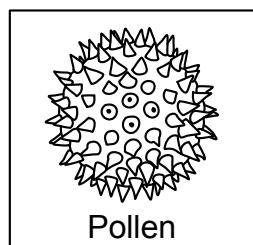
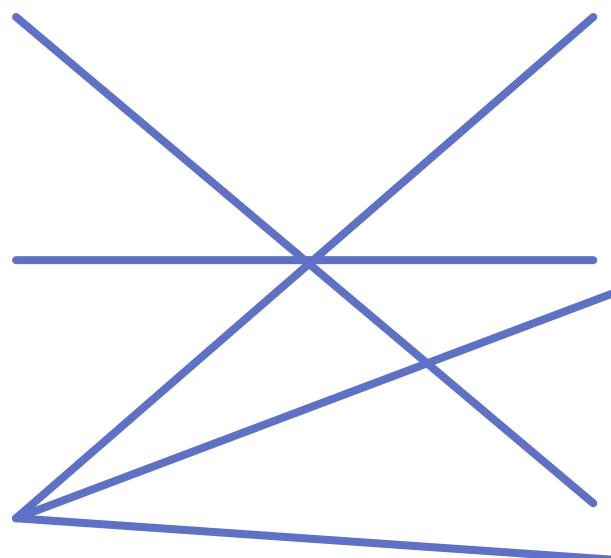
Soon, you'll all be vegetarians!  
Buwhahahaha!



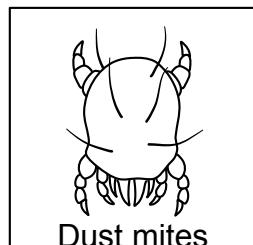
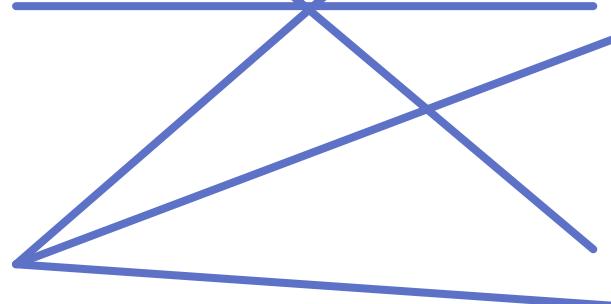
*It's called alpha-gal syndrome.*

## 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

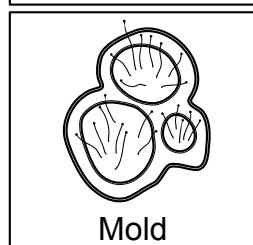


These animals eat flakes of human skin, mold, and cotton fibers. Proteins from their shells and feces are common allergens.

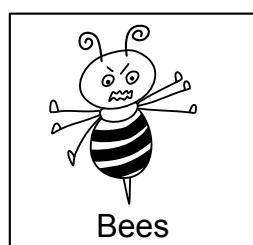


Hay fever, with symptoms of a runny nose, swollen eyes, and sneezing, is often caused by exposure to these things.

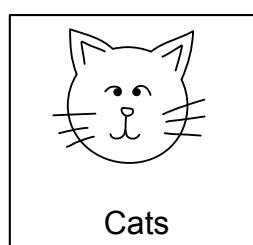
*Hay fever is commonly caused by pollen, but it can also be caused by dust mites or mold.*



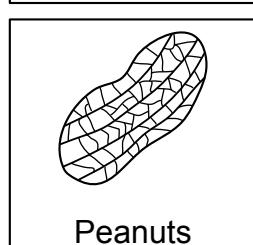
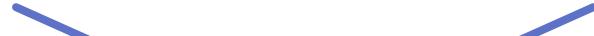
Approximately 5% of the population has a severe allergy to the venom of this animal.



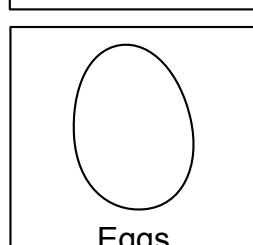
This is one of the most common food allergies and can be very severe.



Allergies to this animal are not caused by hair! They are caused by proteins in the saliva and skin.



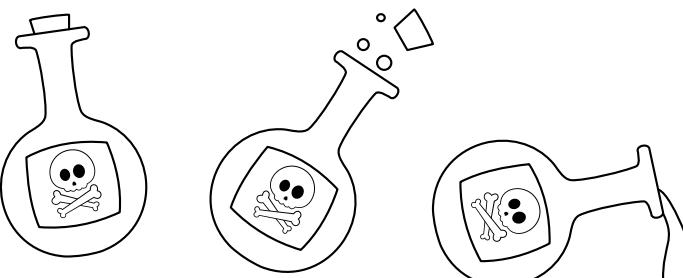
If you have an allergy to this food you also need to be careful about eating mayonnaise, marshmallows, and some types of pasta.



# Why are Poisonous Things Poisonous?

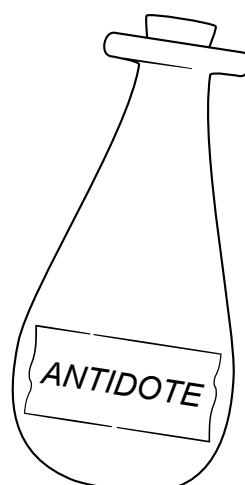
*Because they cause something to go wrong with the cell!*

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!



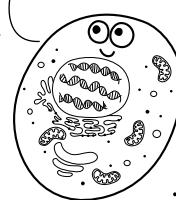
An **antidote** is a chemical that can stop the damage caused by a poison. Some poisons have antidotes and others do not.

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.

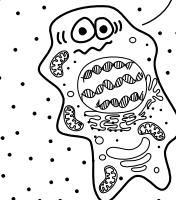


**WAY TOO MUCH OF SOMETHING UPSETS THE OSMOTIC BALANCE.**

This amount of

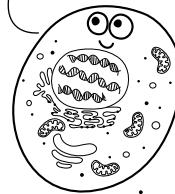


Too much salt!

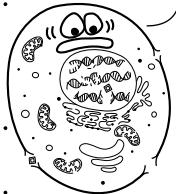


**SOMETHING EXTREMELY REACTIVE DAMAGES KEY PARTS OF THE CELL.**

Normally, my dna and membrane



But they're ruined by



STRONG ACID

Your notes:

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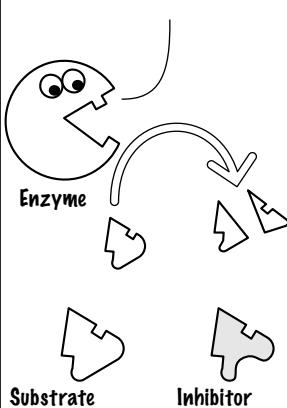
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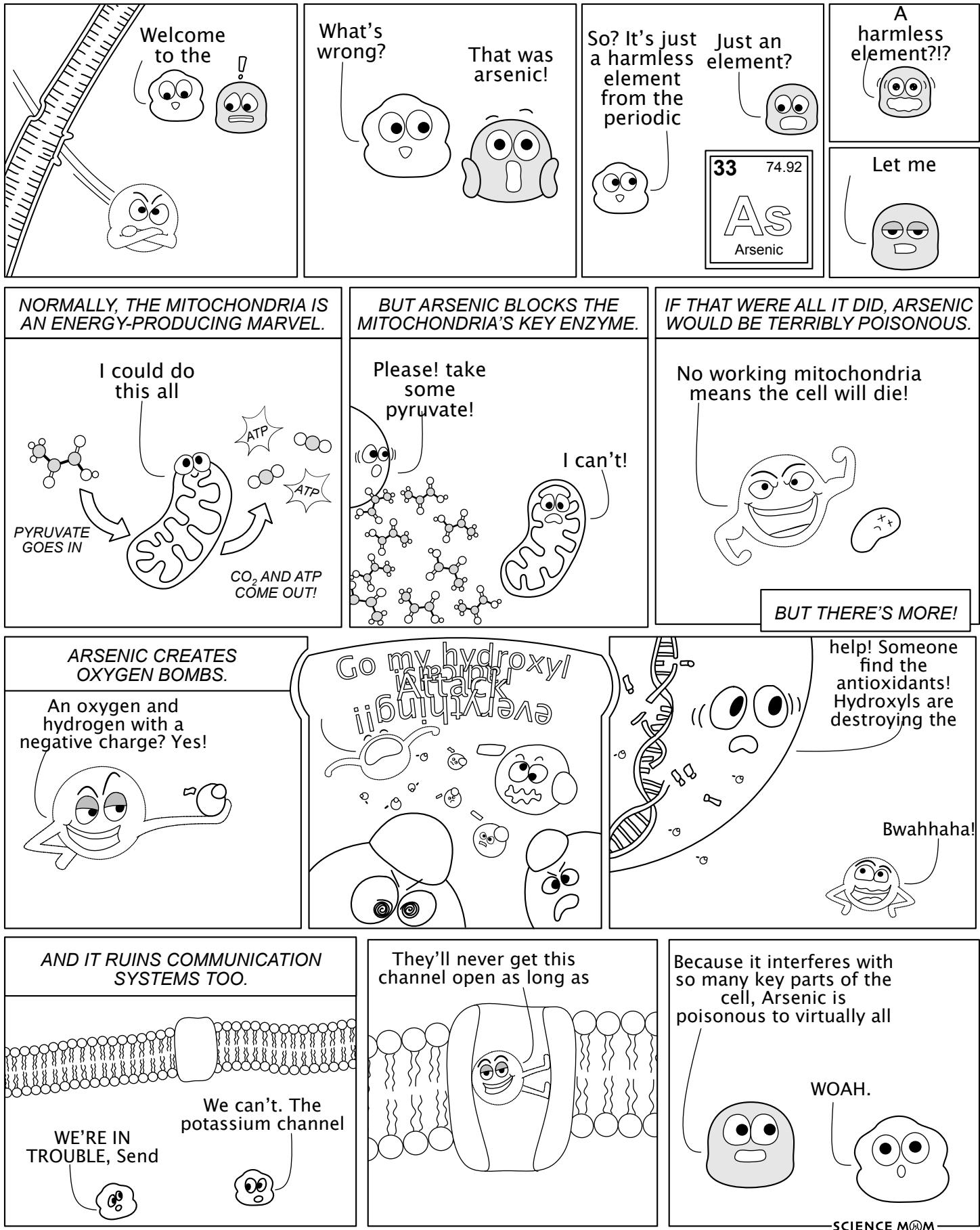
**ENZYME INHIBITORS PREVENT THE ENZYMES FROM DOING THEIR JOB.**



Come on,  
just  
break it

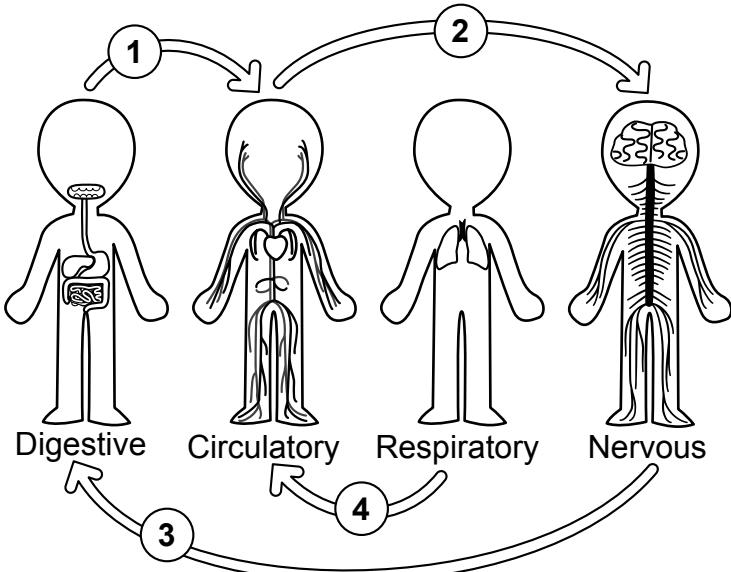
I can't!  
I'm  
stuck!

# AWFUL ARSENIC – A POISONOUS ELEMENT



## Interdependent Systems

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



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

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

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

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

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

### Which system was poisoned?

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

#### BOTULINUM TOXIN

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).

Nervous system

#### FOXGLOVE

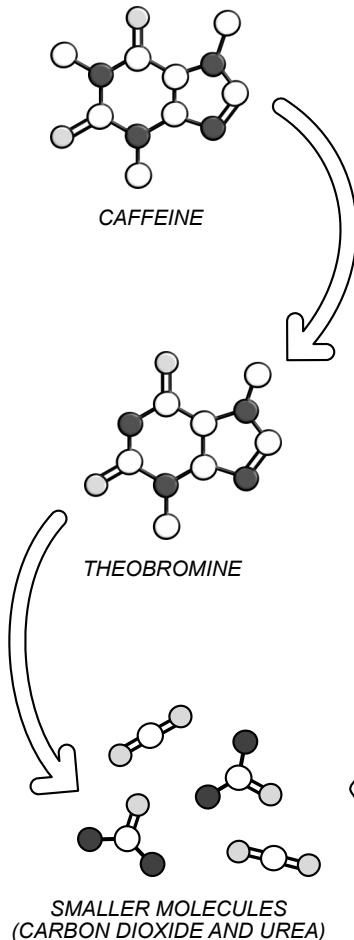
This plant contains cardiac glycosides, compounds that disable sodium-potassium ion pumps on cell membranes. They especially impact heart cells but also impact the nervous and gastrointestinal systems, causing, nausea, vomiting, and diarrhea.

Circulatory system  
And Nervous system

#### HEMOTOXINS FROM A RATTLESNAKE

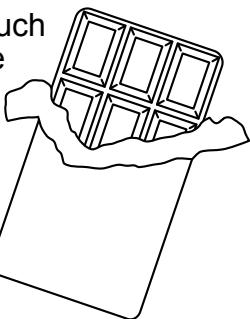
Rattlesnake venom contains an enzyme that destroys a protein in red blood cells, causing them to break open. This results in bruising and internal bleeding. The venom also has other compounds that prevent clotting and reduce platelets.

Circulatory system



## WHY NO CHOCOLATE FOR DOGS?

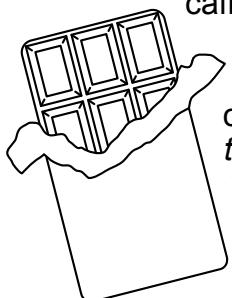
Caffeine and theobromine are found in many foods such as chocolate. They block certain **receptors** in the nervous system, producing a stimulating effect that makes people feel more alert and awake.



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

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

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



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

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

Your notes:

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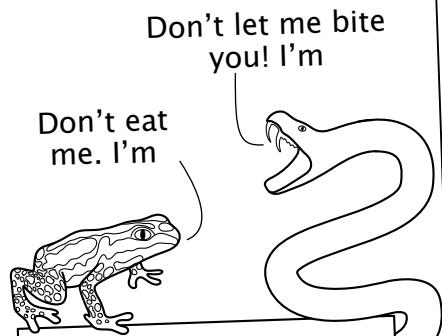
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## ARE THESE FACT OR FICTION? Write your verdict below each statement:

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



**FACT**

Platypuses are the only venomous mammals.



**FICTION\***

Kingsnakes are immune to viper venom because they eat rattlesnakes.



**FICTION**

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

# Physiology ART PROJECT

## MATERIALS:



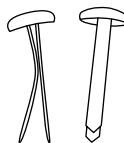
Several pieces of waxed paper, parchment paper, or tracing paper



Pencil

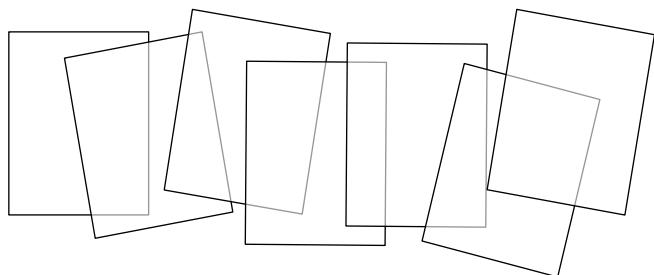


Markers

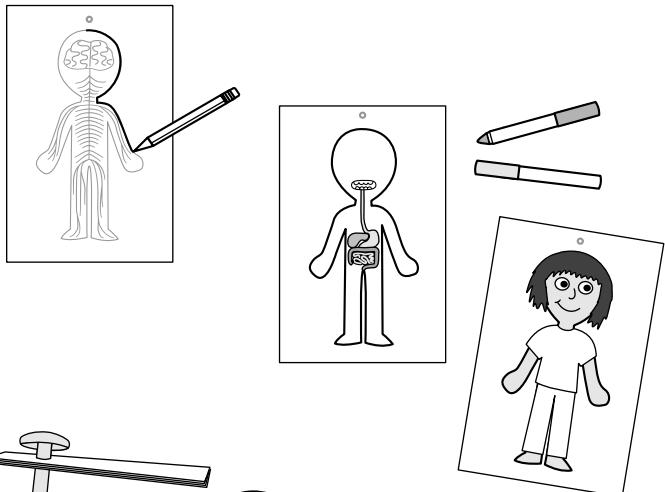


Paper Fastener  
(also called brads)

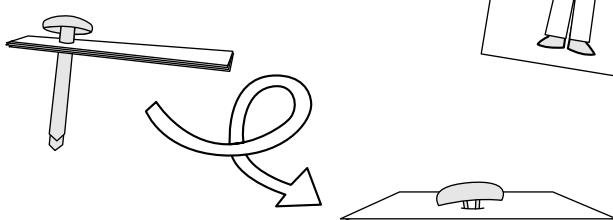
1. Cut seven pieces of transparent paper to be approximately the same size as a regular piece of paper.



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



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

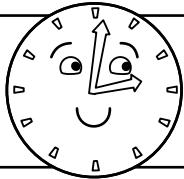


4. Stack the seven pieces of waxed paper together so that the dots above the outlines are all aligned. Carefully puncture the dots and fit the paper fastener through the hole, opening the wings so that the pieces are fixed together.



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

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



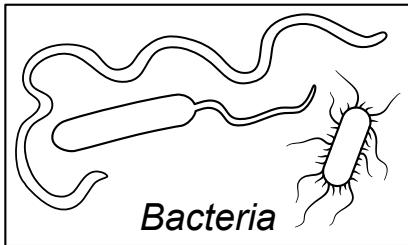
# Quiz Time!

Answer the questions to see what you learned About physiology!

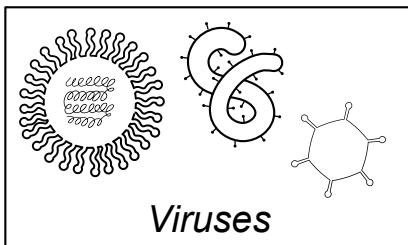
- 1 Which body system is responsible for cleaning the blood and removing waste?
- A. Integumentary system
  - B.** Urinary system
  - C. Nervous system
  - D. Digestive system
- 2 The flow of blood between the heart and the lungs is called:
- A. Limbic circulation
  - B.** Pulmonary circulation
  - C. Systemic circulation
  - D. Aortic circulation
- 3 The most numerous type of cell of the body is a
- A.** Red blood cell
  - B. White blood cell
  - C. Bone marrow cell
  - D. Skin cell
- 4 Where is the Carotid artery located?
- A. Behind the knee
  - B. The belly button
  - C.** The neck
  - D. The wrist
- 5 \_\_\_\_\_ are the component of blood that prevents bleeding.
- A. Plasma
  - B. Red blood cells
  - C. White blood cells
  - D.** Platelets
- 6 How long does a typical red blood cell circulate?
- A. 7 days
  - B. 36 days
  - C.** 120 days
  - D. 365 days
- 7 Where does most our digestion take place?
- A. Stomach
  - B.** Small intestine
  - C. Large intestine
  - D. Liver
  - E. Pancreas
- 8 The center of the nervous system is in the:
- A.** Brain
  - B. Spine
  - C. Heart
- 9 Which system of the body is the liver in?
- A. Circulatory system
  - B. Respiratory system
  - C.** Digestive system
  - D. Urinary system
- 10 Select all of the functions below that are carried out by the integumentary system of the body.
- A.** Sensing via touch
  - B. Cleaning the blood
  - C. Storing memories
  - D.** Providing protection
  - E. Breaking down nutrients
- 11 The ribcage is part of which system of the body?
- A. Respiratory system
  - B. Digestive system
  - C.** Skeletal system
  - D. Nervous system
- 12 What connects muscle to bone?
- A. Ligaments
  - B. Cartilage
  - C.** Tendons
- 13 The largest organ of the body is the:
- A.** Skin
  - B. Heart
  - C. Brain
  - D. Pancreas
- 14 Approximately how many times does a person breath each day?
- A. 230
  - B. 2,300
  - C.** 23,000
  - D. 230,000
- 15 The smallest type of blood vessels are called:
- A. Arteries
  - B. Veins
  - C.** Capillaries

# Pathogen: A microorganism that can cause disease

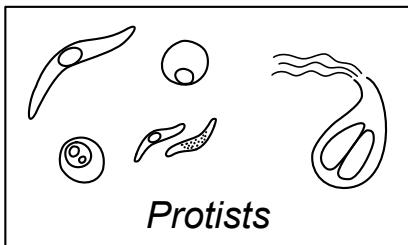
Match each family of pathogens with their description:



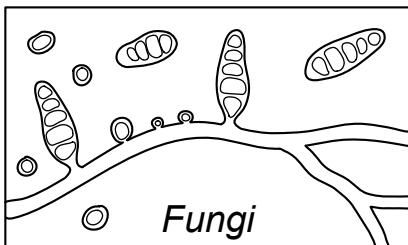
The genetic information of this pathogen is covered with a structure known as a capsule or envelope. It has no ribosomes or true cellular structure and cannot reproduce on its own.



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



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

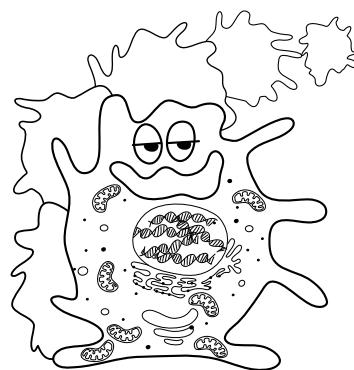


These pathogens can be difficult to treat because their cells are eukaryotic. The most deadly pathogen in this family is spread by mosquitos.

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

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

## What about diseases that are NOT caused by pathogens?

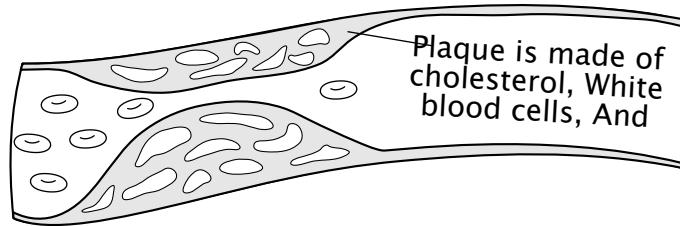


**Cancer** is caused by uncontrolled cell growth. When the body's own cells mutate and become malignant, they invade and grow in tissues where they shouldn't, causing pain and death. Some types of cancer are strongly genetic, others can be caused by things that damage DNA, such as radiation. But others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

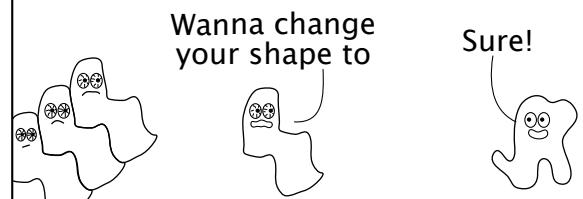


**Genetic Diseases** like sickle cell anemia or hemophilia are caused by pieces of DNA that cause a problem with an important protein. There are no pathogens involved in most genetic diseases. We'll learn more about them in Biology 2.

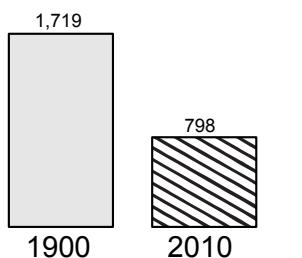
**Heart Disease** is the leading cause of death in developed countries. It is caused by a buildup of plaque in the arteries that stops the flow of blood through the heart. Diet, exercise, and genetics all play a role in heart disease, but infections do as well. Scientists are researching how certain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



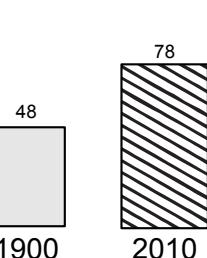
**Prion Diseases** like mad cow disease are caused by proteins that are folded differently. Their amino acid sequence is identical to the normal proteins found in the brain and nerves. But somehow, these infectious proteins cause the normal proteins to change shape and then cluster together, destroying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



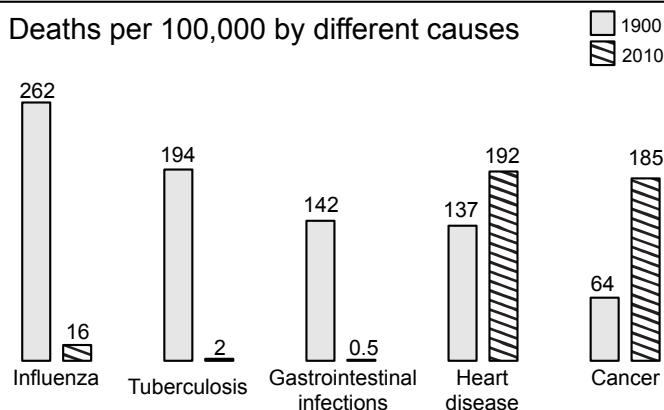
Total Deaths per 100,000 in the United States



Average Life Expectancy



Deaths per 100,000 by different causes



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

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

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

# Most Wanted Microbe

# ART PROJECT

## MATERIALS:



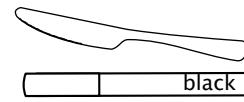
Several copies of the most wanted microbe templates (located in the appendix)



Pencil



Markers, colored pencils, crayons, or paint.



Knife and ink for weathering the edges (optional)

1. (Optional) Weather the paper to make it look old by scraping a knife along the edges and then wiping them with a piece of tissue wet with ink.
2. Select four microbes to study for the creation of your most wanted microbe posters. You can select them from the suggested microbes list in the appendix, or find your own. Make sure you have at least 1 virus and at least 1 bacteria.
3. Find photos of the microbe and make notes of key features. Record the official name of the organism as well as names for the disease the microbe causes. Make notes on a piece of scratch paper or computer as you do research, and then fill out the poster.
4. Draw a "wanted portrait" for your microbe. It can be realistic or cartooned, but whichever approach you choose, be sure to highlight key features of the microorganism.
5. Share your artwork with a friend and tell them something you learned!



Note how both the realistic and cartoon versions of smallpox have oval-shaped viruses with relatively smooth surfaces and dumbbell-shaped viral cores.

## What's in a name?

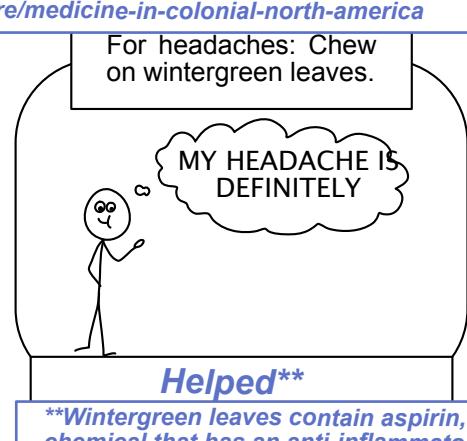
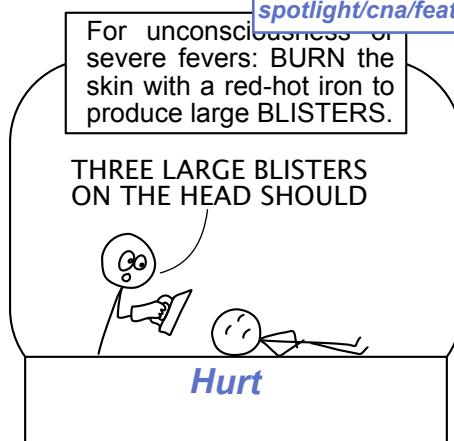
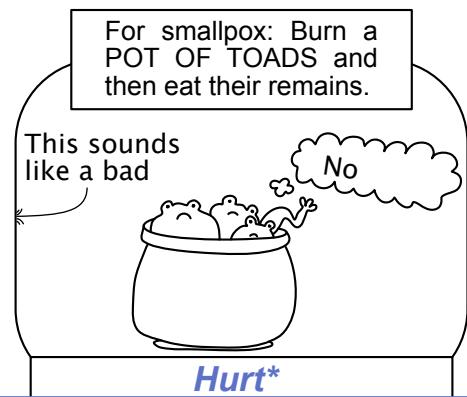
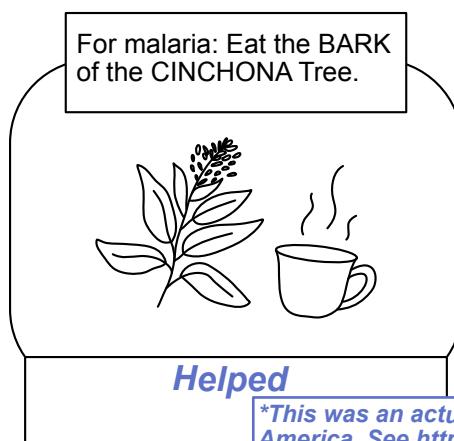
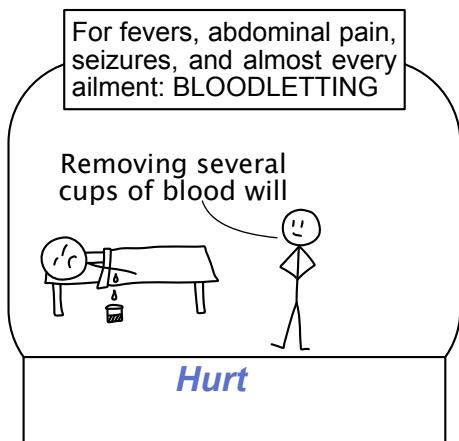
The name of the microorganism is often different than the name of the disease it causes. For example, **chicken pox** is caused by the **varicella-zoster virus** (VZV) which has an official name of "Human alphaherpesvirus 3."

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

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

# Medicine in the 1700s

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



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

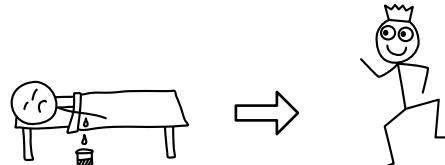
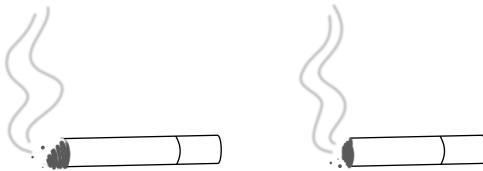
\*\*Wintergreen leaves contain aspirin, a chemical that has an anti-inflammatory and pain-reducing effects.

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

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

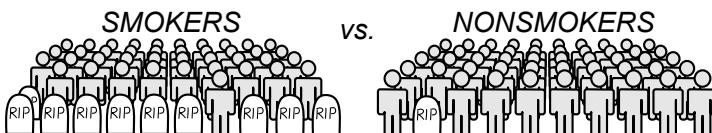
# Anecdote vs. Research

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



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

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



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

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

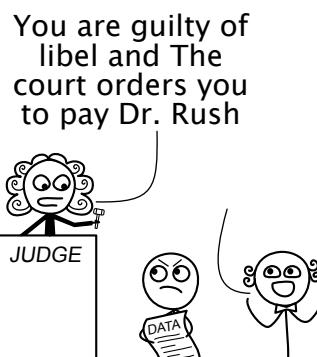
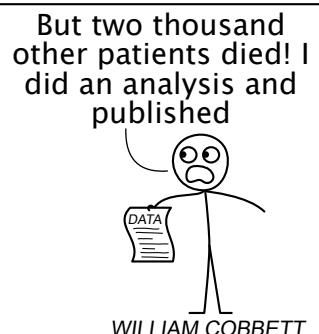
Your Thoughts: I would trust the study because there are more people involved and greater evidence about the effects.

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

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

Why didn't Benjamin Rush or the judge and jury in the trial recognize that bloodletting was causing 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

We lost three soldiers in battle, but nine hundred died from

I hear that's normal for a sea voyage.



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

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

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

## 16<sup>th</sup> & 17<sup>th</sup> 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

Scurvy is owing to a total lack of fresh vegetable food and greens.

The disease comes from acute depression and homesickness.

Scurvy is the result of too much exercise.

Scurvy is the result of too little exercise.

Breathing too much sea air will bring scurvy.

Scurvy comes from eating too

Anywhere with filth and poor morals, scurvy will follow.

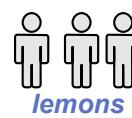
The illness results from excessively cold and damp weather.

## Cures for Scurvy:

Seawater      Vitriol  
Vinegar      Lemons

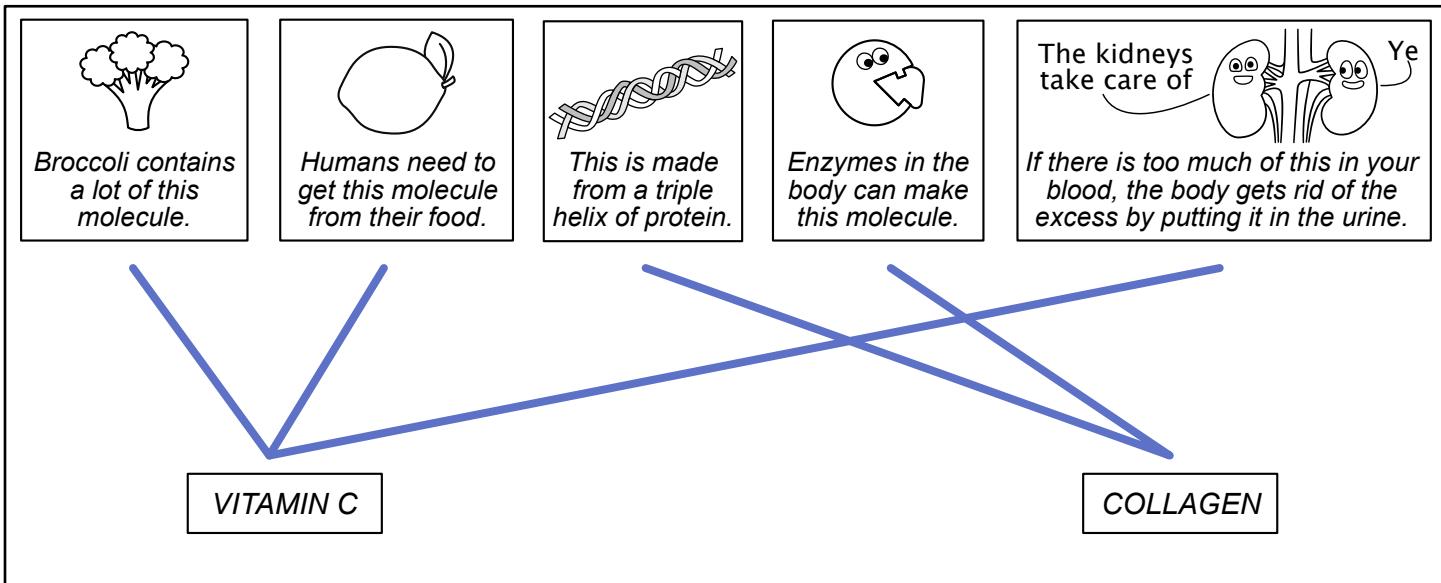
In the 16<sup>th</sup> and 17<sup>th</sup> centuries, shipowners and governments expected half of their sailors to die from scurvy on any long voyage. The disease was incredibly painful, common, and problematic. People generally agreed that it had *something* to do with diet, but there was no agreement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

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

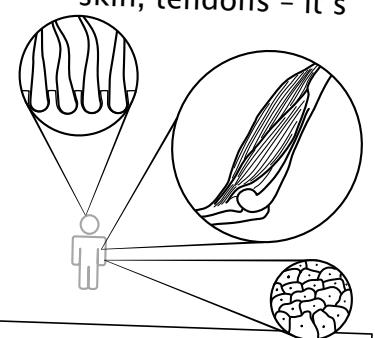


This example doesn't include a control group (people on regular sailor diet). But there should definitely be bonus points for including a control group in the experimental design!

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



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

Dogs and cats don't need vitamin C in their diet.	Bell Peppers have more vitamin C than oranges.	Collagen is the most abundant protein in the human body.
 We can make our own vitamin	 If I sell my bell pepper juice for \$10 per cup, I'll be rich, rich, rich!	 It's in bones, muscles, skin, tendons – it's
<b>FACT</b>	<b>FACT</b>	<b>FACT</b>

FILL IN THE BLANKS USING THESE WORDS:

cabbage trial lemons clinical scurvy oranges

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

# THE SCIENTIFIC METHOD IN MEDICINE

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

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

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

CONTROL GROUP

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

RANDOMIZED

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

PLACEBO

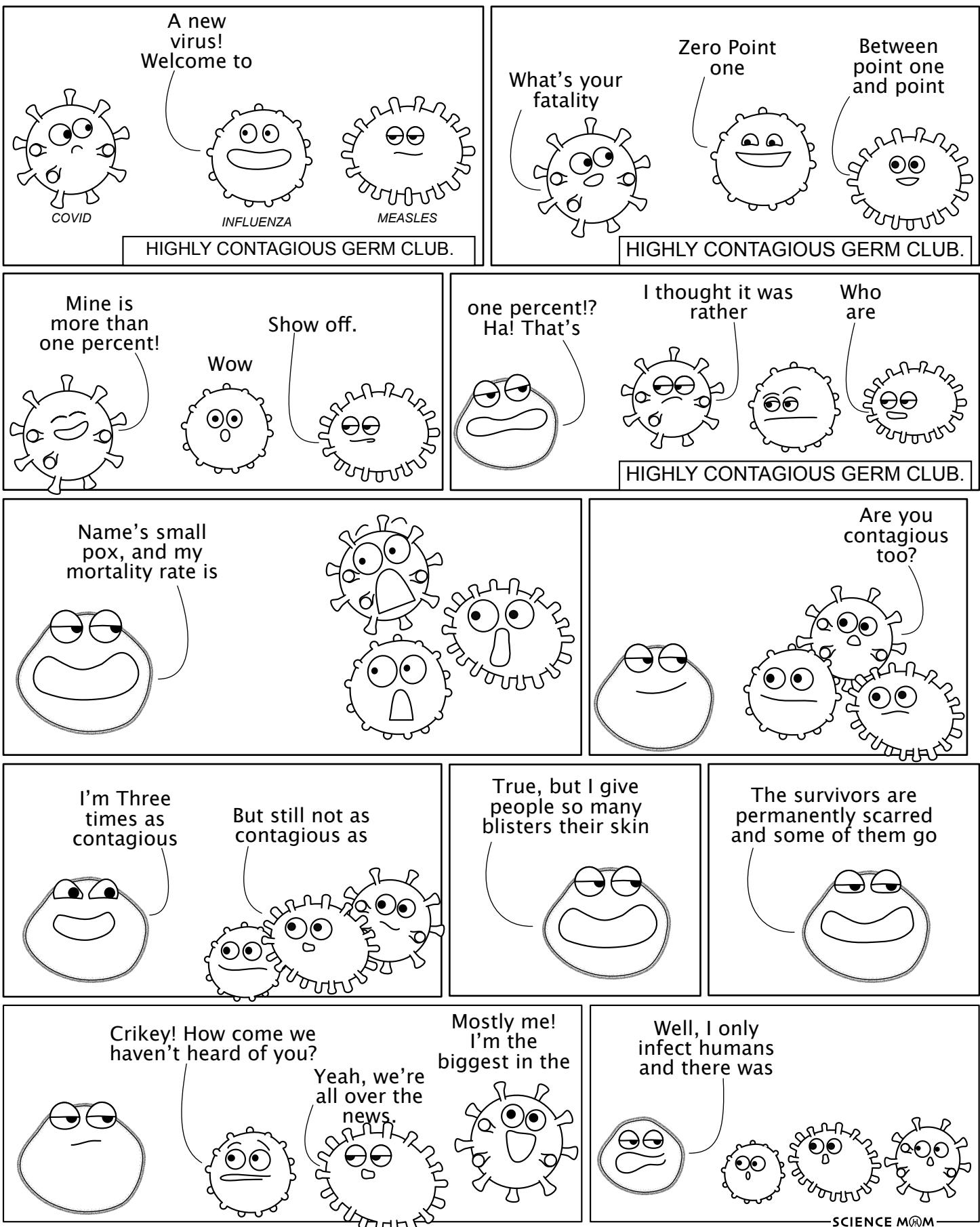
*Usually, any treatment is better than no treatment because it influences a person's attitude and expectations, which then have a measurable effect on health. If a treatment doesn't outperform a placebo, then you can conclude it is not very effective.*

DOUBLE BLIND

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

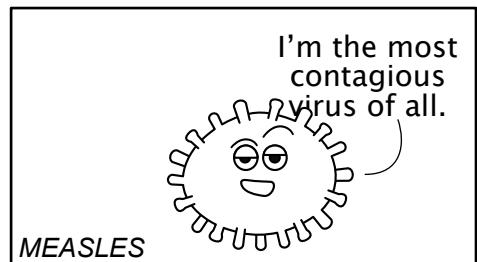
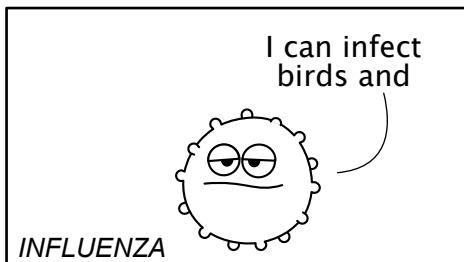
*The highest possible standard of medical testing is a randomized, placebo controlled, double-blind clinical trial.*

# SMALL POX & THE GERM CLUB



# The Pox: A Fearsome Disease

WRITE DOWN THE MAIN CHARACTERISTICS OF EACH DISEASE:



HOW IT SPREADS: \_\_\_\_\_

**Airborne or scab contact**

$R_0$ :\* **5-7**

MORTALITY: **30%**

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

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

HOW IT SPREADS: \_\_\_\_\_

**Airborne**

$R_0$ : **1-2**

MORTALITY: **0.01%**

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

HOW IT SPREADS: \_\_\_\_\_

**Airborne, touching surface**

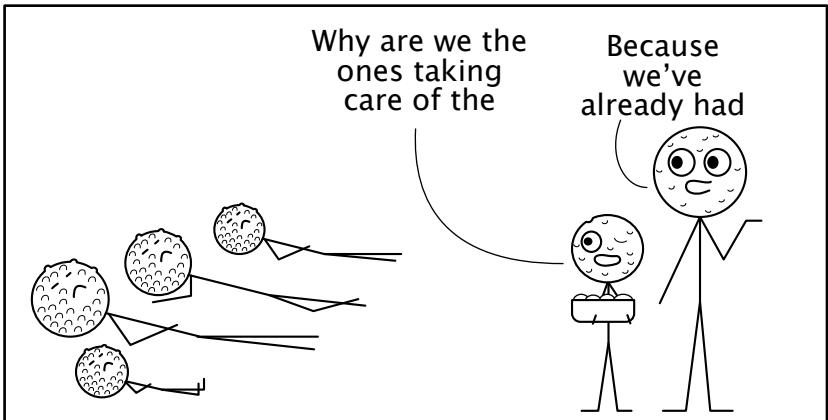
$R_0$ : **12-18**

MORTALITY: **0.012%**

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

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

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



**CHINA**

Ok, do I eat

Ready for your inoculation? I have Three old smallpox

No! I'm going to put them in a silver pipe and blow them

**INDIA**

First, a small scratch on your arm. Then I rub the powder of dry smallpox scabs into the

**SCOTLAND**

take smallpox pus and then dry it over peat smoke and mix it with camphor and bury it in the ground for 7 years! Then, with a homemade knife place a small

**VARIATIONS IN VARIOLATION** The approach varied from country to country, b

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

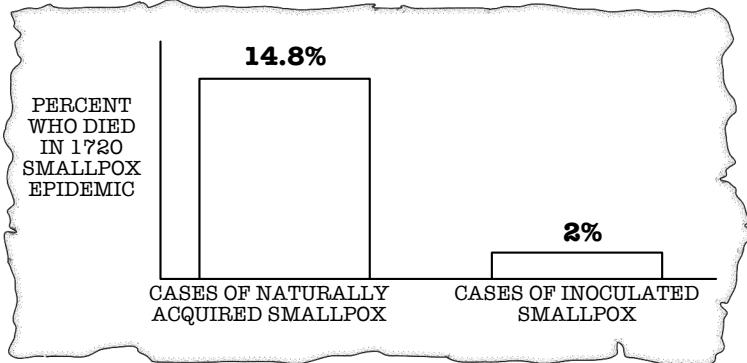
For further reading on different variolation techniques, see THE ORIGINS OF INOCULATION by Arthur Boylston, published in the Journal of the Royal Society of Medicine. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3407399/> e prevented a more serious illness. These

# The 1721 Outbreak

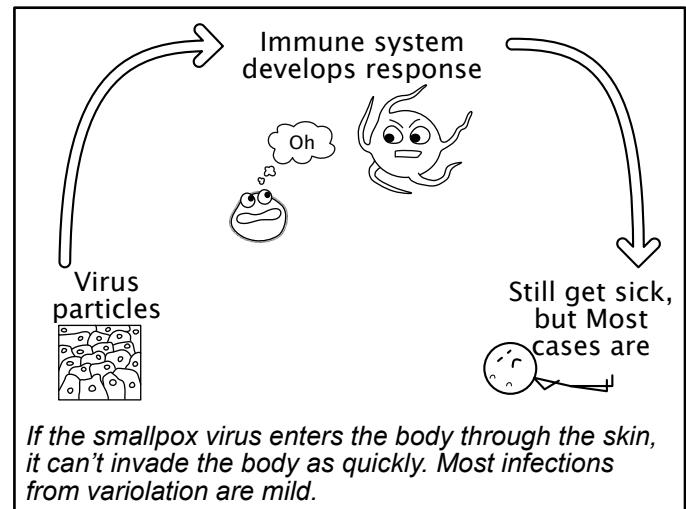
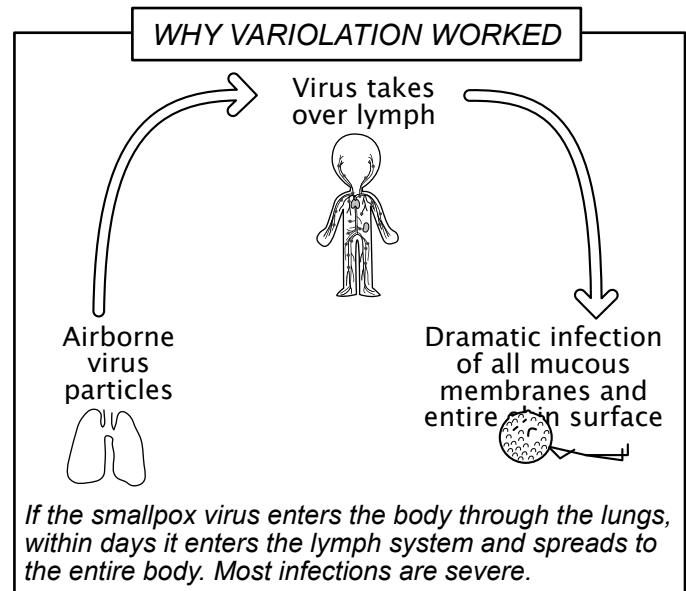
In the summer of 1721, a ship arrived at Boston with a sailor who had symptoms of smallpox. Despite the best efforts to quarantine, the disease began to spread. There had been a previous smallpox epidemic in 1703, but everyone under the age of 18 hadn't been around in 1703. They lacked immunity. A doctor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

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

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



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



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

The word "vaccine" comes from the Latin word for cow.

**FACT**

After exposure to smallpox, there is no known treatment.

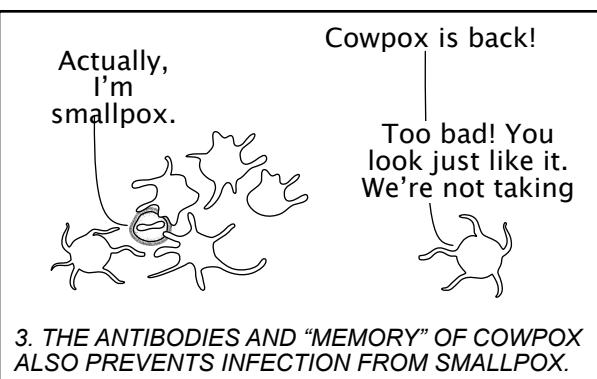
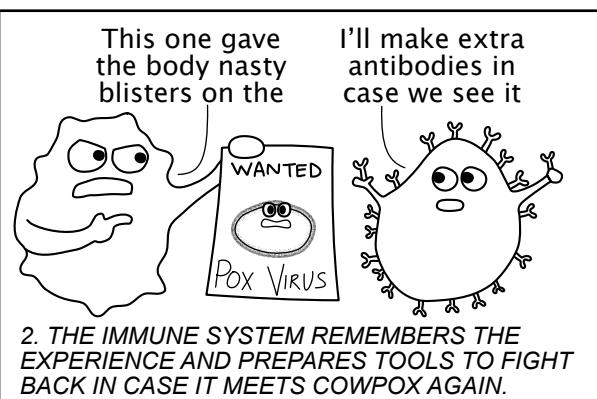
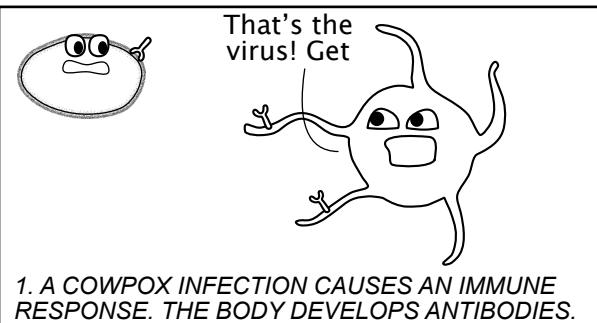
**FICTION\***

Six vials of smallpox virus were discovered in an FDA storage room in 2014.

**FACT**

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

# A pox on the pox



Your notes: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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 cowpox and inoculated a young boy with cowpox. Over the next few years he exposed the boy to smallpox multiple times. The boy never got sick.

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

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

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

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

**91% of the population of the United States**

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

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

**20% of the population of China**

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

I most often infect rodents, but just about any mammal



COWPOX VIRUS

I mostly infect rodents and



MONKEYPOX VIRUS

I was originally called a cowpox virus but then people realized my death rate was lower than the rest of my family members and



VACCINIA VIRUS

I'm the deadliest and the pickiest. I only infect

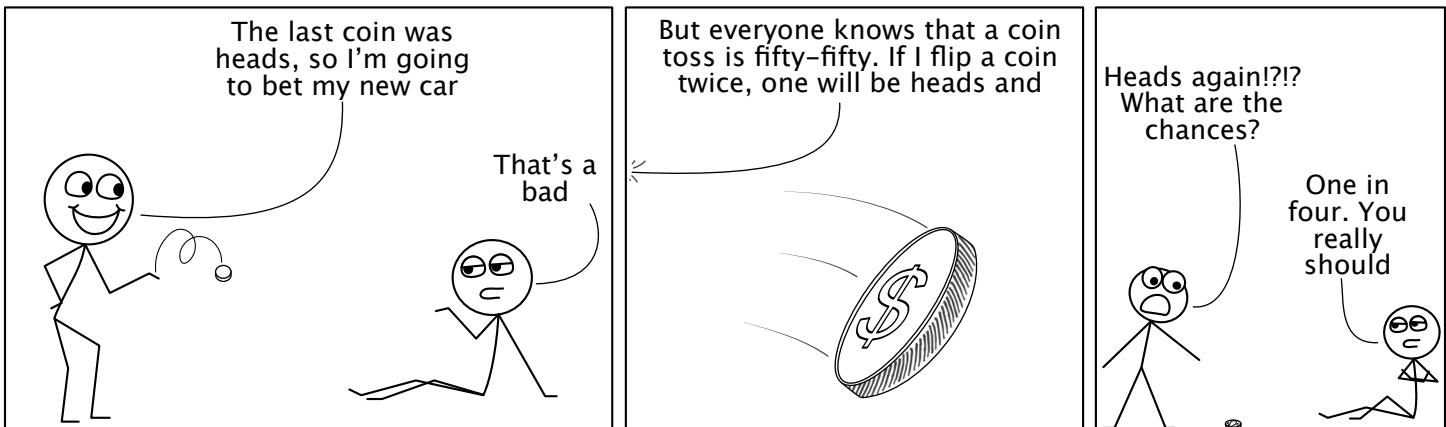


SIMPLPOX VIRUS

# 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.

# 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

**Smallpox outbreak**

If you rolled the following numbers:

7	3	6	9	8	9	4	12	10	6

Then the outcome for group 1 would be:

m	b		s		s	b		

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:

2	Mild sympto	2	Allergic Reaction	2	Mild sympto	2	died	2	Mild sympto
---	-------------	---	-------------------	---	-------------	---	------	---	-------------

# Smallpox Scenarios

Roll a pair of dice ten times for each group to show probable outcomes for each scenario.

Did you see more or less variation between the groups than you expected?

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

1	Smallpox outbreak		
	Smallpox caused by variola major had a mortality rate between 20–60%, but was as high		
# rolled:			
2,12	Healthy. Not exposed during outbreak	Group 1	Group 2
3,4,11	Survived but now blind	<b>2 dead, 2 blind, 1 severely scarred, 4 moderately scarred, and 1 healthy.</b>	<b>5 dead, 2 blind, 1 severely scarred, 1 moderately scarred, and 1 healthy.</b>
6,8,10	Died		
5,7	Survived with moderate scarring		
9	Survived with severe scarring		
Smallpox total for 40 people: 14 dead, 8 blind, 6 severely scarred, 10 moderately scarred, and 2 healthy.			

2	Cowpox inoculation		
	Although this was much safer, some ridiculed the idea and said people would turn into cows if they exposed		
# rolled:			
Roll 9, then roll a 10	Died	Group 1	Group 2
Even number	Mild symptoms of cowpox, now immune from smallpox	<b>0 dead, 3 moderate symptoms, 7 with mild symptoms</b>	<b>0 dead, 5 moderate symptoms, 5 with mild symptoms</b>
Odd number	Moderate to severely sick with cowpox but recovered, now immune from smallpox		
Cowpox inoculation total for 40 people: 0 dead, 16 with moderate symptoms and 24 with mild symptoms.			

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		
# rolled:			
Four 2s in a row	Died	Group 1	Group 2
Two 2s in a row	Allergic reaction or other adverse reaction	<b>0 dead, 5 moderate symptoms, 5 with mild symptoms</b>	<b>0 dead, 8 moderate symptoms, 2 with mild symptoms</b>
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		
Vaccinia inoculation total: 0 dead, 20 moderate symptoms, 24 mild.			

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

# The Problem of Polio

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

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



## Polio Outbreak

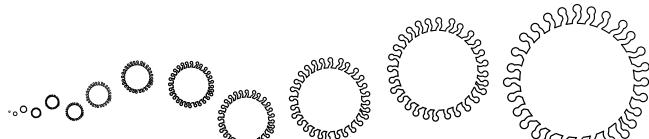
**95-99%** of infected people have **NO symptoms**. They feel completely healthy and do not know that they are spreading the virus to other people.

**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

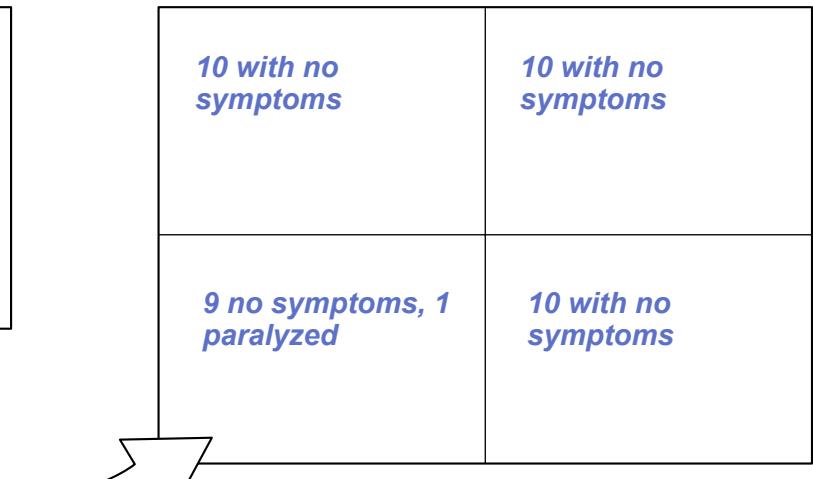


Less than 1 percent is a small number, but polio is highly contagious. Infected individuals who have symptoms will actively spread the virus for 7-10 days *before they have symptoms* and then for up to 6 weeks afterward.

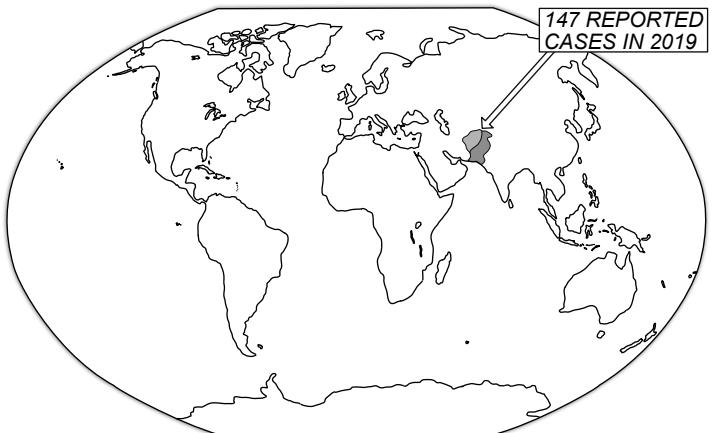
A disease as contagious as polio can easily infect the majority of a population. On average, 1 out of every 200 people exposed to polio will have permanent paralysis (usually in the legs, but sometimes in most of the body) and roughly 1 in 2,000 will die. Using those probabilities, answer question one:

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

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



*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.*

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

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

# Elementary Epidemiology

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

**R<sub>0</sub>**

## Basic Reproduction Number

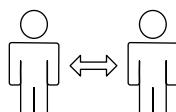
EXPECTED NUMBER OF PEOPLE A DISEASE WILL INFECT		
Measles		12 - 18
Rubella		6-7
Polio		5-7
Smallpox		5-7
Mumps		4-7
SARS		4-7
1918 Influenza		2-3
COVID-19		2 - 2.5
Ebola		1.5 - 2.4
MERS		0.3 - 0.8

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.

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

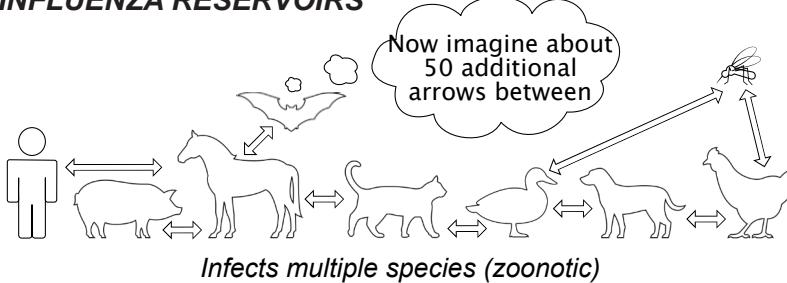
## Natural Reservoir or Disease Reservoir

### MEASLES RESERVOIR



Only infects humans

### INFLUENZA RESERVOIRS



A reservoir is the specific place where a pathogen naturally lives and reproduces. Some diseases have multiple species of animals that serve as hosts or reservoirs. Other pathogens, like cholera and giardia, can be free-living in water sources like rivers.

In general, pathogens with multiple reservoirs are more difficult to control or eradicate.

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

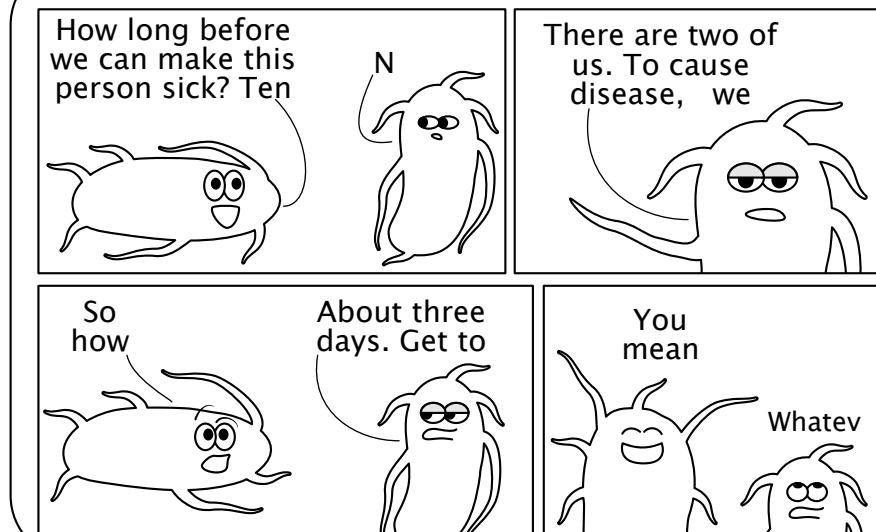
The disease of measles is more than twice as contagious as polio.

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

WHY ARE DISEASES WITH MORE RESERVOIRS HARDER TO CONTAIN?

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

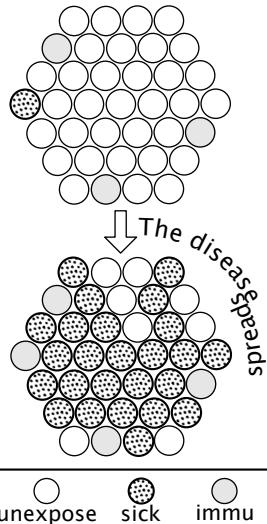
## Incubation Period



The incubation period is the amount of time between exposure and the first symptoms of illness. Some bacteria that cause food poisoning have an incubation period of just a few hours. The rabies virus has a long incubation period that can be between 2 to 12 months!

Most viruses have incubation periods between 2 to 14 days. The amount of pathogen (or viral load) in the initial

### A POPULATION WITHOUT HERD IMMUNITY

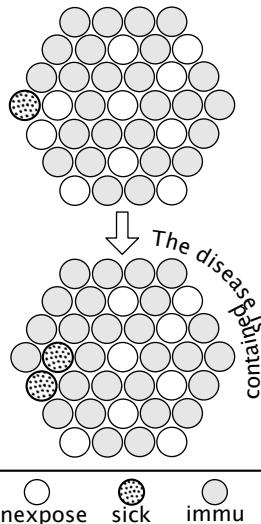


### Herd Immunity

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,

### A POPULATION WITH HERD IMMUNITY



## 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.

Higher risk of getting

Higher risk of persistent infections, during which time the pathogens can spread

Higher risk of serious complications

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

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

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

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

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

*Country A will have few to no smallpox outbreaks for several years after every person is exposed.*

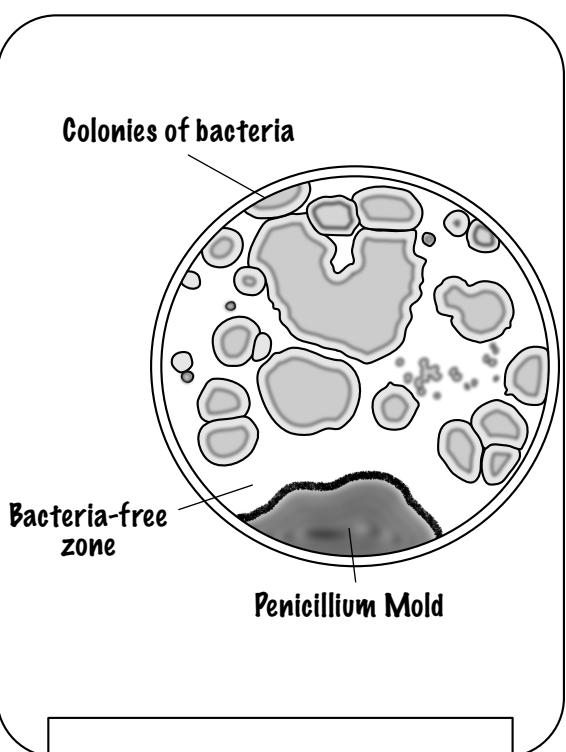
*But soon someone who was born after the “apocalypse” will pull an old blanket out of a chest or clean out a closet where dirty bedding had been stored. These chance encounters with the virus (which can last for decades outside of a host) will cause outbreaks where smallpox infects most people young enough to have been born without immunity. Without any effort at variolation or vaccination, smallpox will regularly kill between 20 to 80% of each rising generation. Outbreaks will become a regular part of life as each new generation pays the price to obtain herd immunity.*

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

# The Discovery of Penicillin

FILL IN THE BLANKS USING THESE WORDS:

secret ing      mold      penicillin  
mechanism      treatment      petri



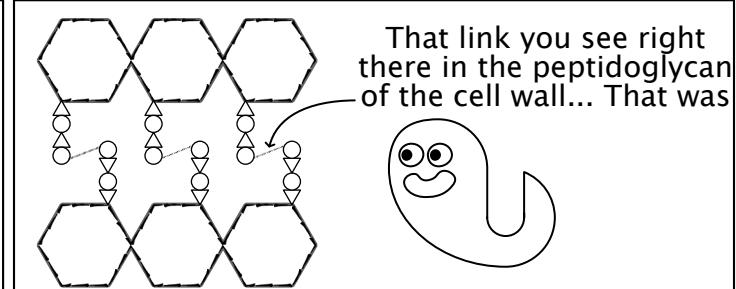
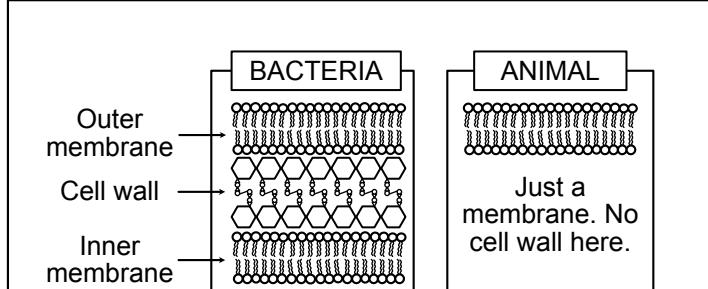
Drawing of petri dish with penicillin mold growing and ring of bacteria-free space around it.

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

## ATTACK THE CELL WALL - HOW PENICILLIN WORKS

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

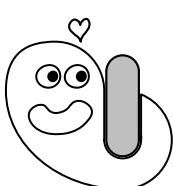
One of the most important steps in making the cell wall is done by an enzyme called transpeptidase.



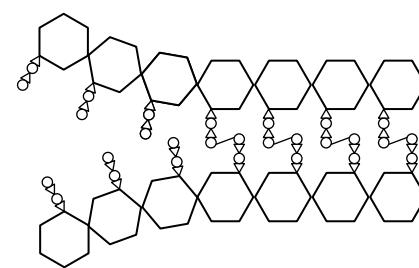
Penicillin is a small molecule that blocks the enzyme transpeptidase.

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

The cell dies.



Ah penicillin. I won't be building any walls while



The infection is finally gone. Hurray!



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 histolytica**  
A eukaryotic cell that has no cell wall.



**Aloe Vera**  
A plant with cell walls made of cellulose.



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

Penicillin damages the cell and/or stops the infection.

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

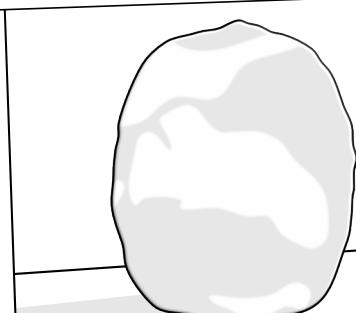
\*An important disclaimer that in real life, medicine and treatments can be quite complex. This exercise is not intended to prescribe or recommend treatment. See a doctor if you are sick.

What happens to your microbiome when you take an antibiotic?

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

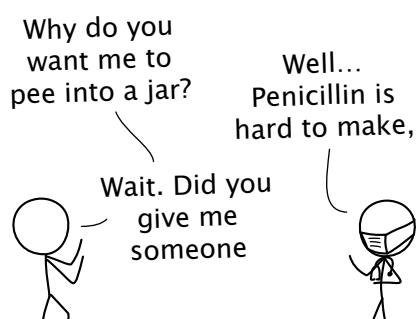
## ARE THESE FACT OR FICTION? Write your verdict below each statement:

The best strain of penicillin came from a moldy cantaloupe.



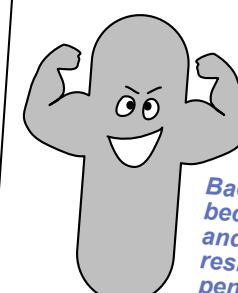
**FACT**

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



**FACT\***

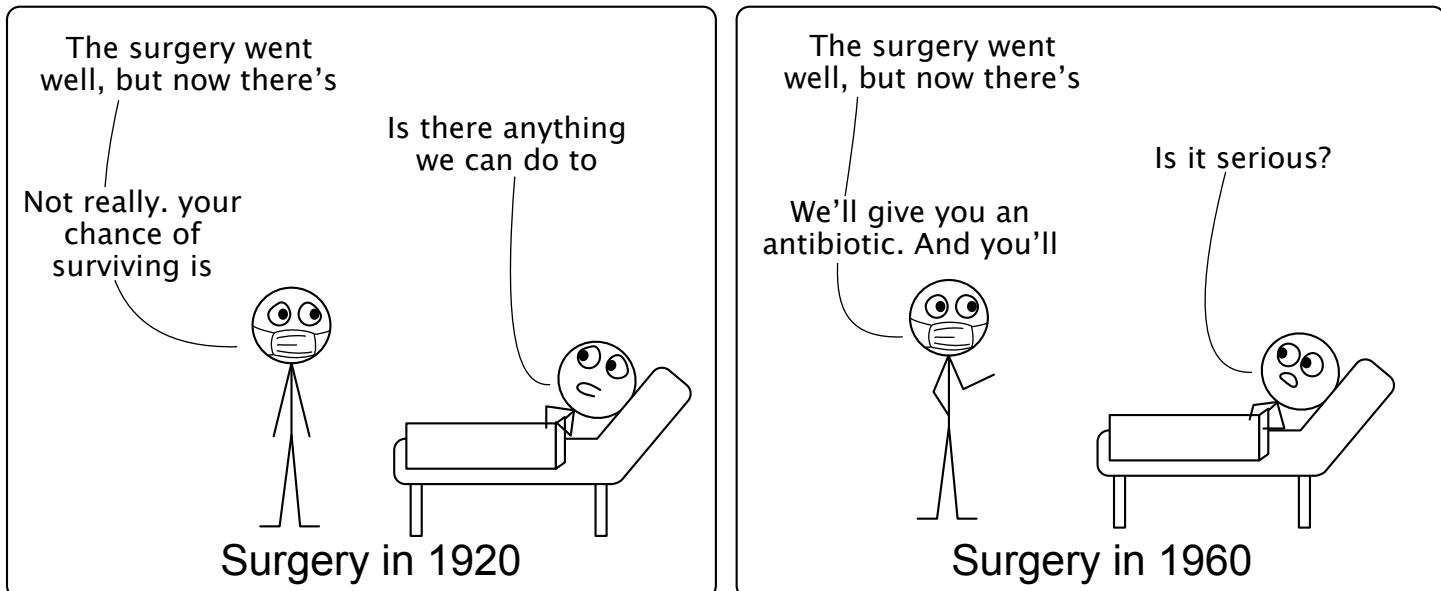
Penicillin is becoming even more effective against bacteria over time.



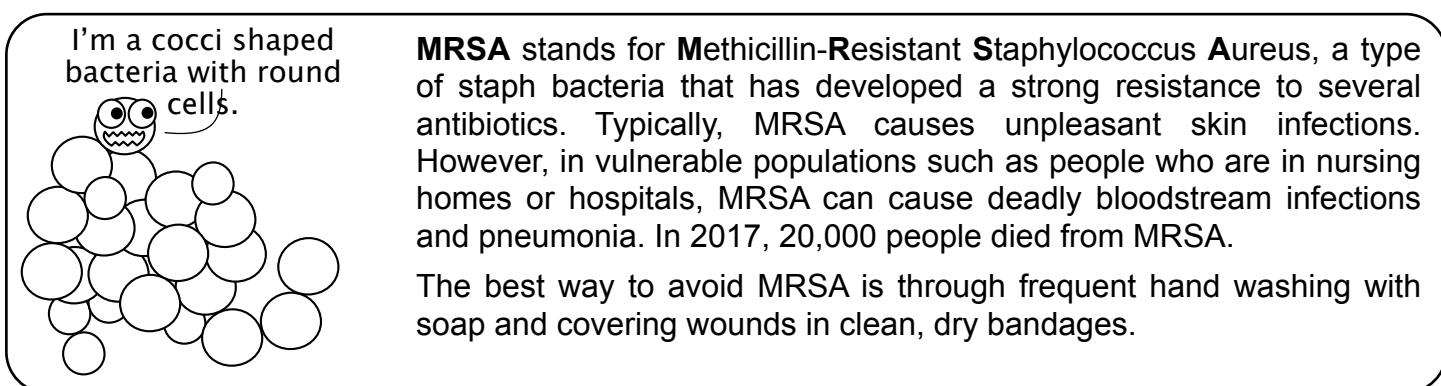
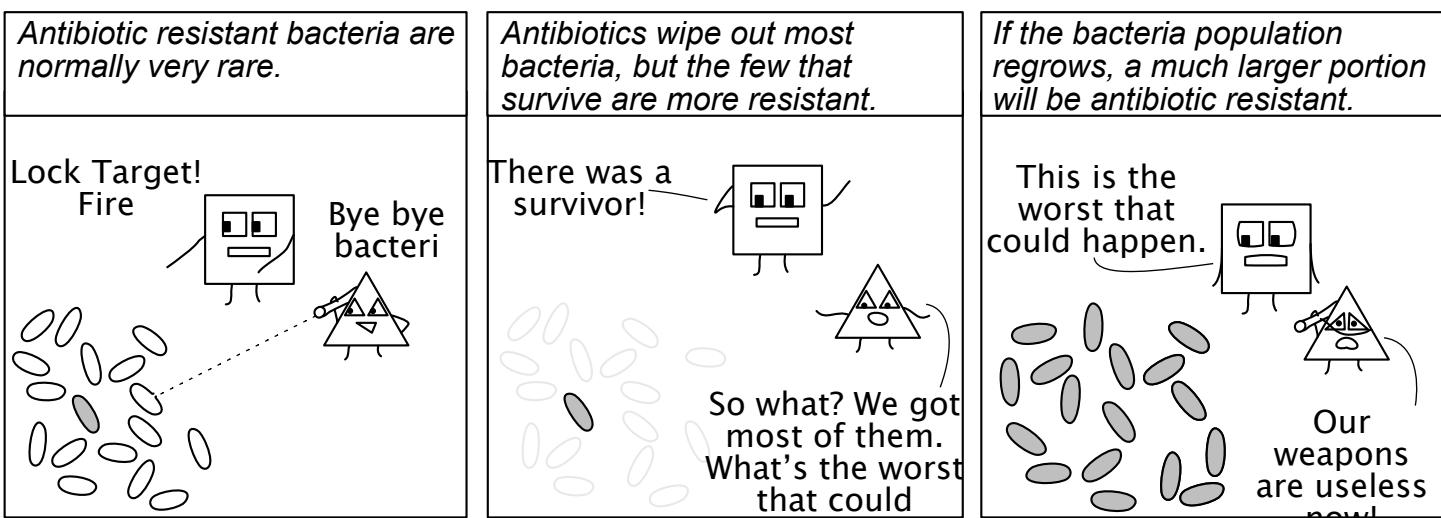
Bacteria are becoming more and more resistant to penicillin.

**FICTION**

## 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 - a dangerous superbug

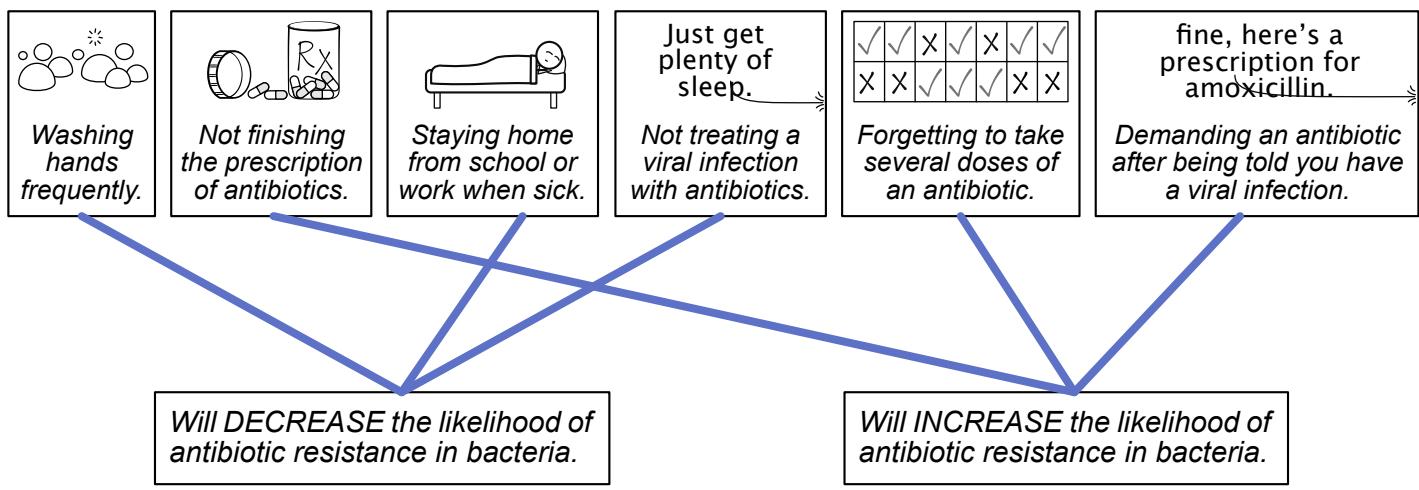
Staphylococcus (staph) is a common bacteria present on many healthy people. MRSA is a strain of staph that has developed a number of methods for resisting antibiotics like penicillin and methicillin. These bacteria secrete an enzyme that inactivates the antibiotic. They also have different proteins in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

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 antibacterial agents before our current antibiotics are no longer effective. But how do bacteria develop resistance to antibiotics? They evolve, which is something we'll learn more about in our next biology class.

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

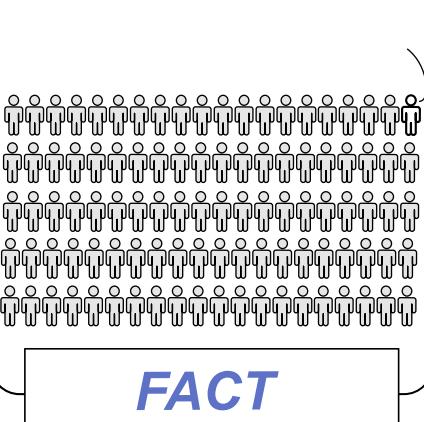


## ARE THESE FACT OR FICTION? Write your verdict below each statement:

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

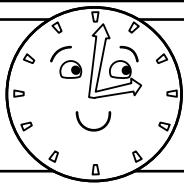


About 1% of the population has been colonized with MRSA bacteria but doesn't know it.



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

- p 101 - suggested microbe list for the most wanted microbe poster*
- p 102 - most wanted microbe templates*
- p 103 - body system templates*

# 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:

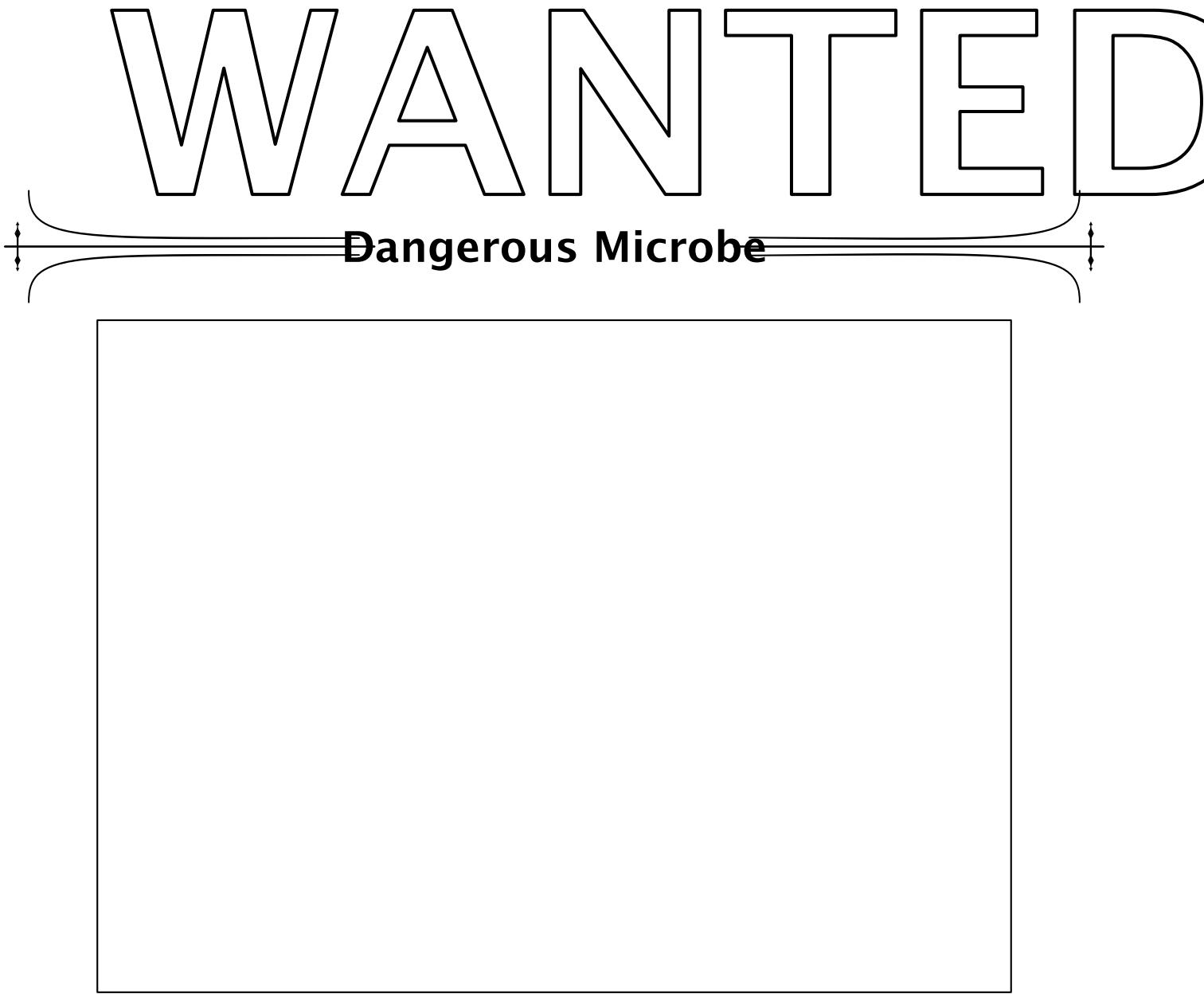
	ILLNESS:
Various species of Group A Streptococcus	Necrotizing fasciitis (flesh eating disease)
Corynebacterium diphtheriae	Diphtheria
Mycobacterium tuberculosis	Tuberculosis
Clostridium botulinum	Botulism
Bordetella pertussis	Whooping Cough or Pertussis
Borrelia burgdorferi	Lyme Disease
Salmonella bongori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



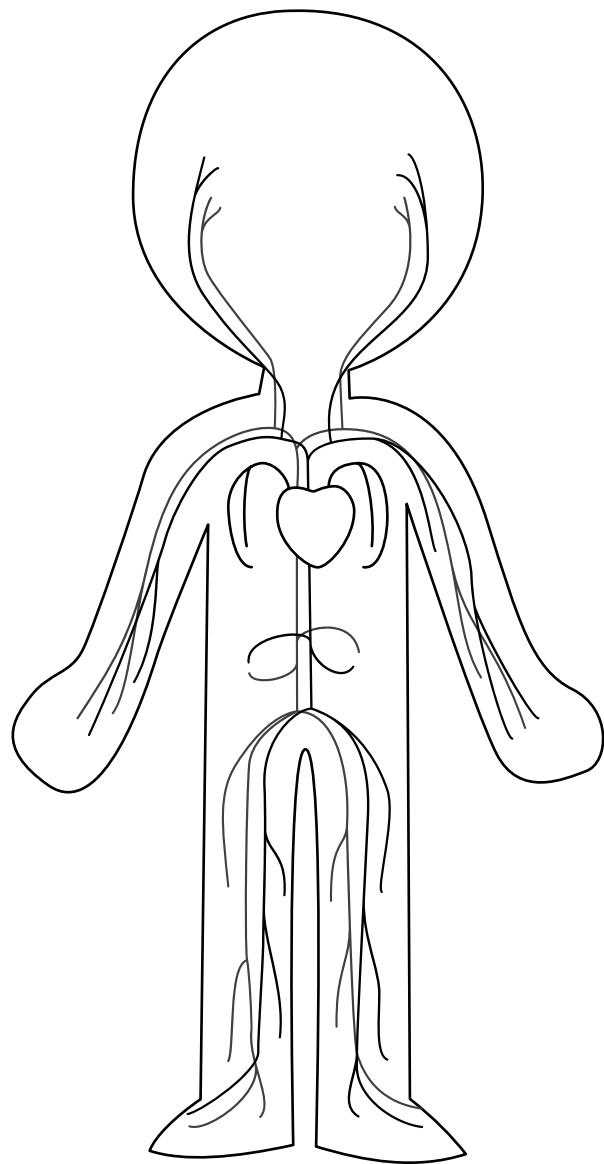
Microbe name: \_\_\_\_\_

Disease name: \_\_\_\_\_

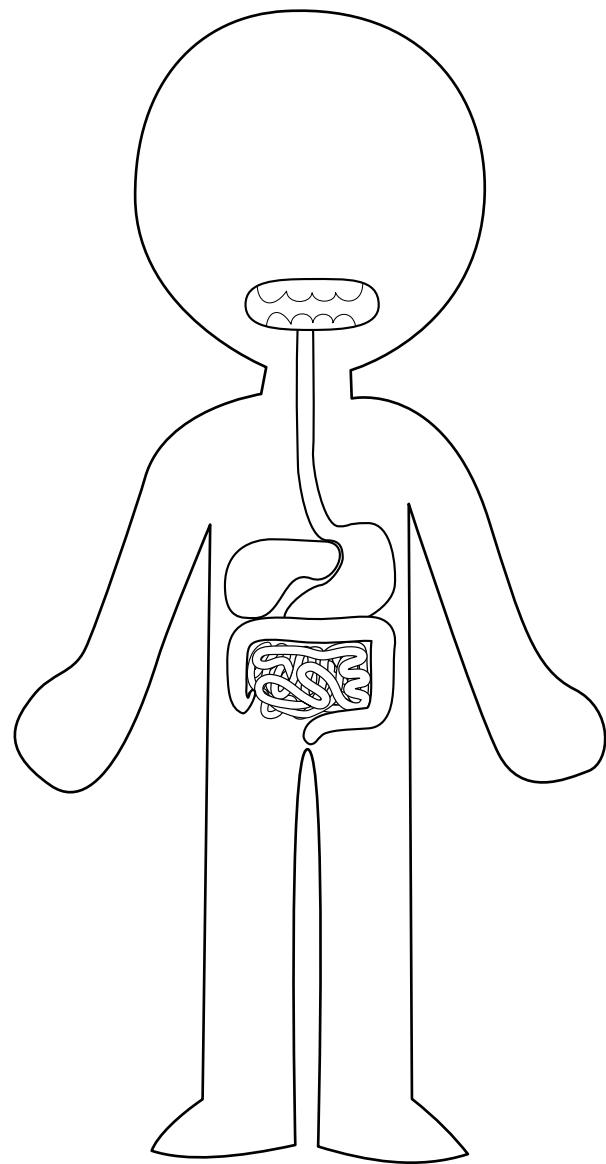
Description: \_\_\_\_\_  
\_\_\_\_\_

Symptoms of infection: \_\_\_\_\_  
\_\_\_\_\_

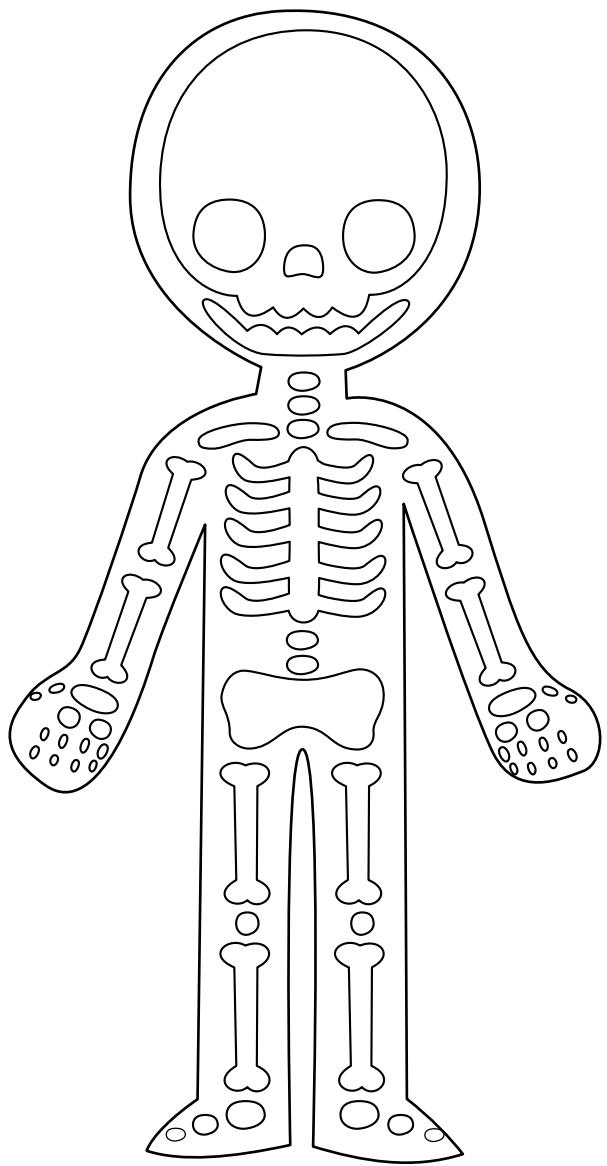
Likely locations: \_\_\_\_\_  
\_\_\_\_\_



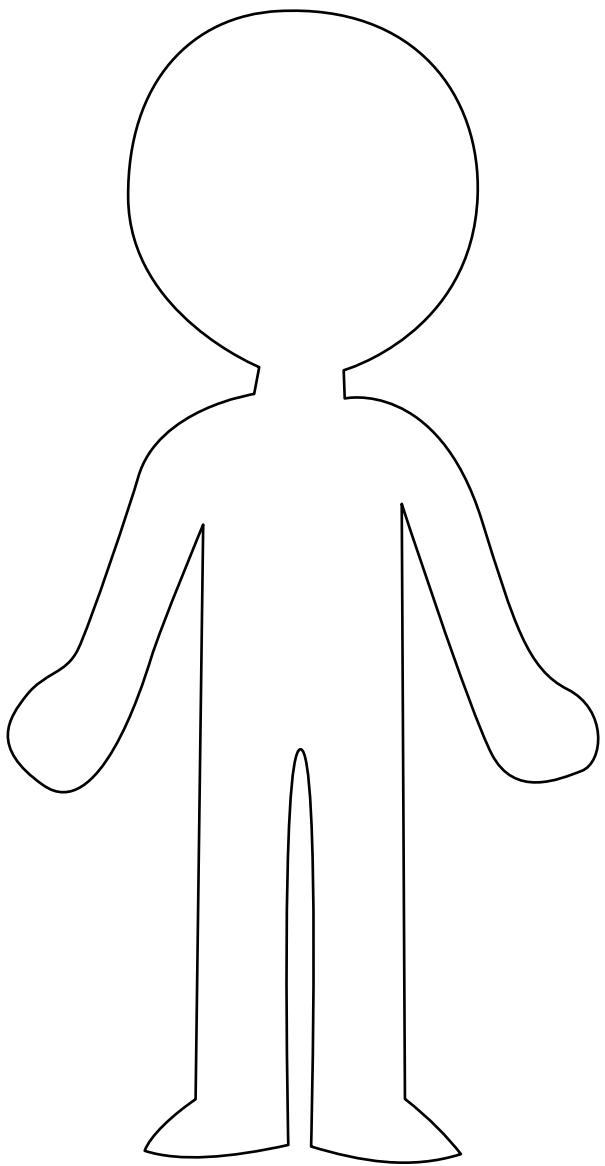
Circulatory



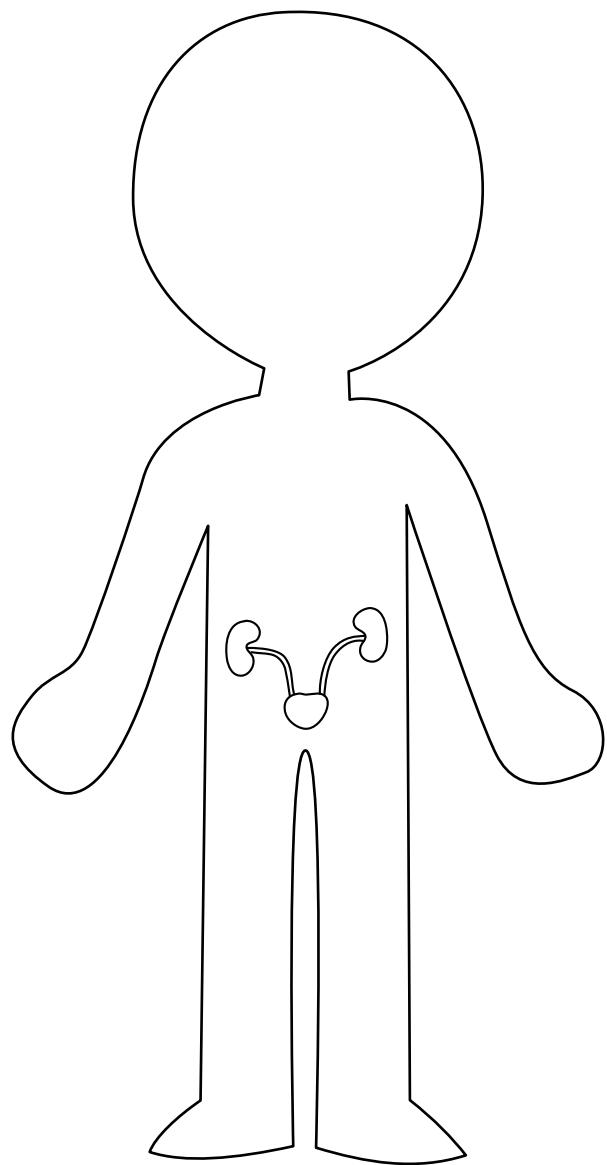
Digestive



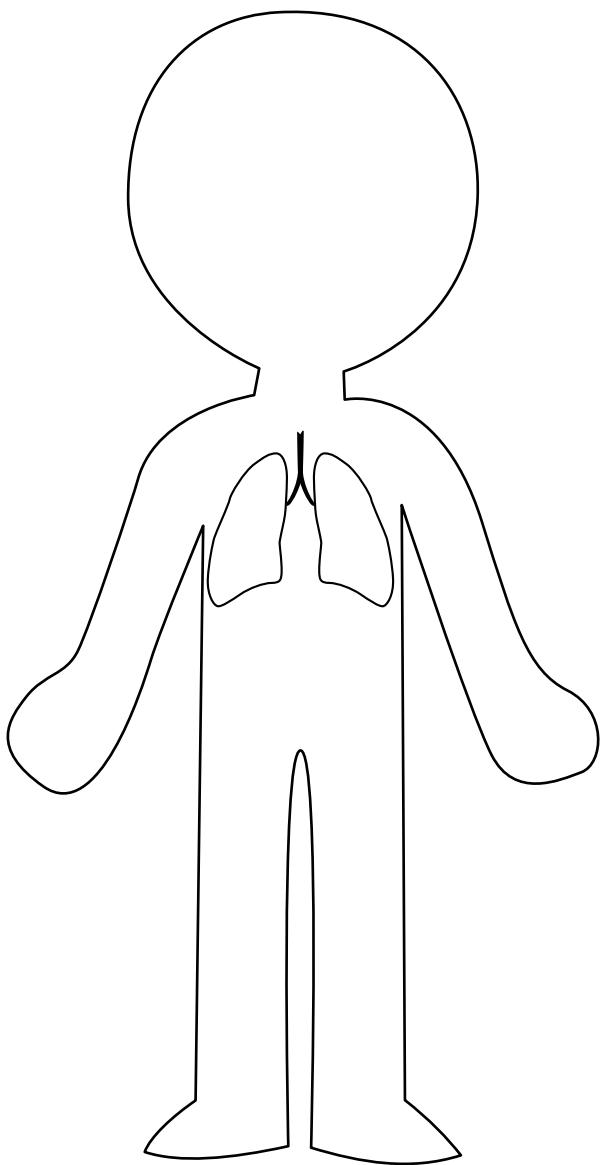
Muscular/  
Skeletal



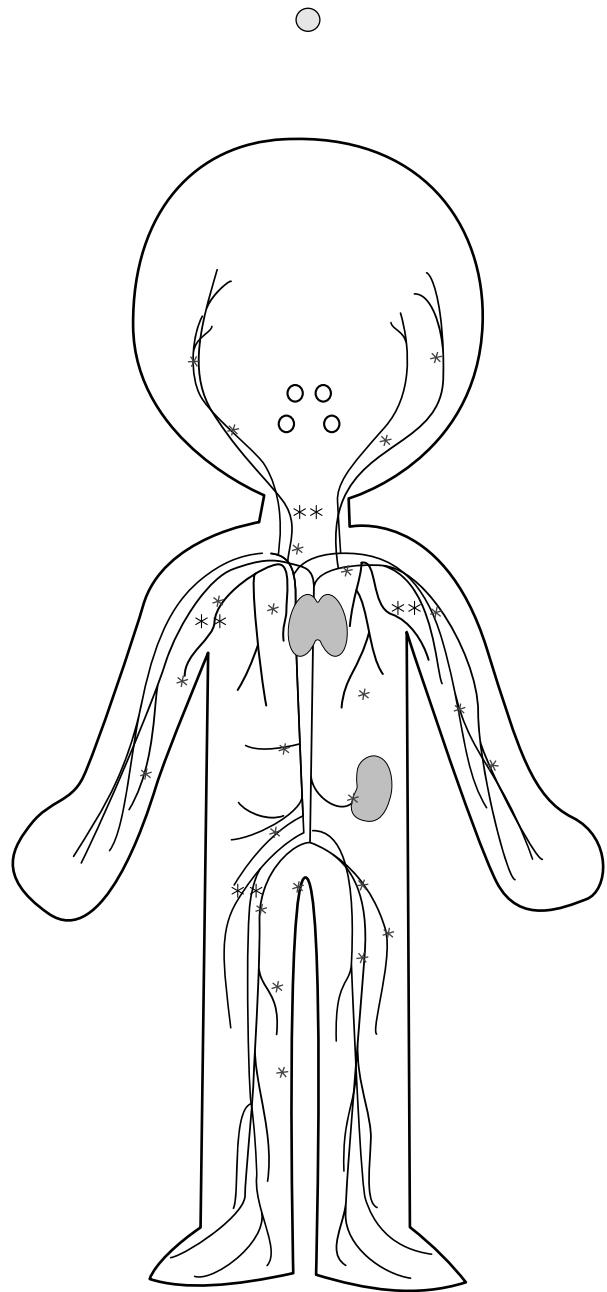
Integumentary



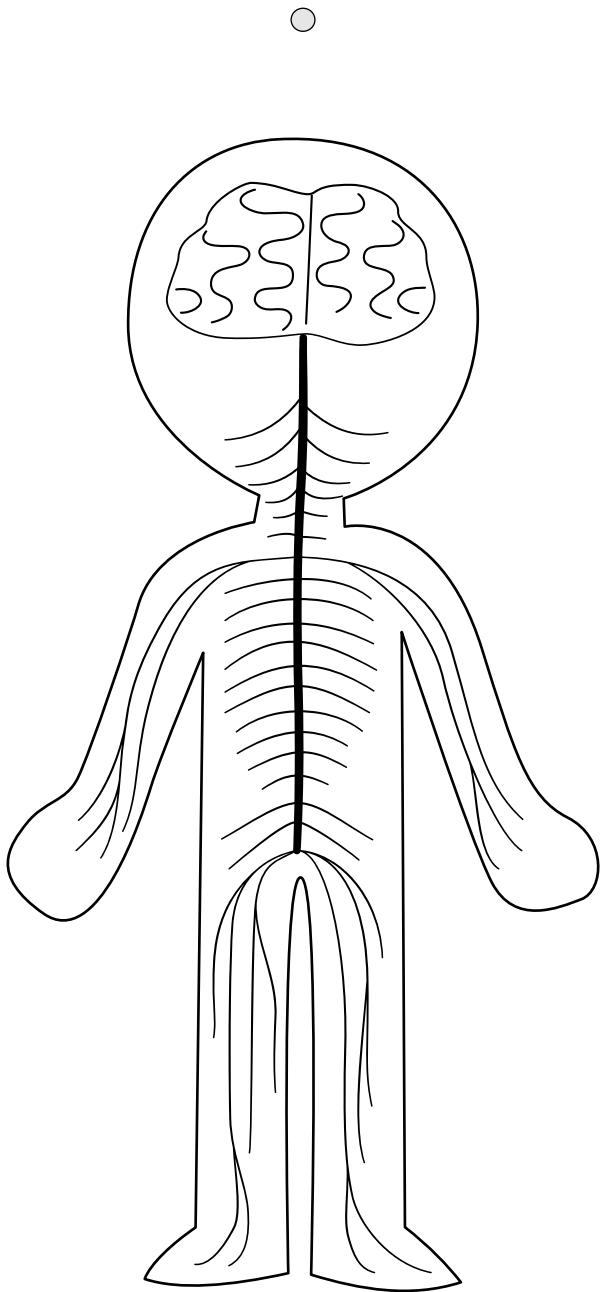
Urinary



Respiratory



**Immune**



**Nervous**