Biology

Foundations Version by John Dutton
Campus International High School

Audiobook:

https://audiobook.teachduttonteach.com

Introduction

As an urban biology teacher with over ten years experience, I have found that my students have a wide range of reading abilities but are all still able to understand introductory biology. Since our textbook appeals to readers closer to the high school level, I wanted to make available a collection of readings that appeals to learners who may struggle with our textbook but want to be successful in biology and on the Ohio State Tests.

I have also included a link to an audio version of the readings for students who prefer to hear the text in order to increase comprehension. Please contact me with any questions, comments or concerns at john.dutton@campusinternationalschool.org .

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What is Science?

Science is a method of investigation, based on observation, testing hypotheses, measurement, experimentation, and creating theories. This leads to better explanations of the way the world works.

About Science

In science you ask a lot of questions, investigate the answers by doing tests (experiments) and report the results of those tests to other scientists. The most important part of asking questions is to have an idea of how things will turn out. This is called a **hypothesis**.

Think about it: Is it easier to get from home to a store you've never seen if someone just gives you a list of directions or if they simply tell you the location of the store? If you have the directions, then you have to think, "OK, I'm at the corner of Euclid and East 30th, and I'm supposed to turn right." If you have the location of the store, then you can figure it out as you go. Either way, you can get it wrong, but it's harder to figure out if you only have directions and you take a wrong turn!

When you make a hypothesis, you are essentially saying that you think you know where the store is, and the experiment will be to try and figure out how to get there. If you end up at the wrong store, it could be that your hypothesis was incorrect or that your experiment was done incorrectly. We all make wrong turns sometimes!

Thomas Alva **Edison**

The important part about science is that you realize that it is OK – in fact, it's *necessary* – to make mistakes. Thomas Edison tried over 700 times to invent the lightbulb, but failed each time. Only after those hundreds of experiments did he get it right. When Edison was asked how he felt about making so many mistakes, he said, "I have not failed 700 times. I have not failed once. I have succeeded in proving that those 700 ways will not work. When I have eliminated the ways that will not work, I will find the way that will work." This means that those 700 ways are actually useful knowledge: Understanding why something does not work the way you think it should will help you understand how it *actually* works!

Once you have completed the experiment, you need to tell other scientists your hypothesis, how it works (in our example, sharing the directions to get to the store), and the results (**data**) of your experiment. You can also form a **conclusion** based on the data. In our example, the conclusion might be: "You need to make two left turns and a right turn in order to get to the store." If the conclusion is something that is a completely new scientific idea, then other scientists need to test your experiment and get similar results. What this means is that they need to do your experiment exactly as you did it and see if they end up with the same data that you have.

If the experiment is repeated by enough different scientists, and they come up with the same results, then a **theory** is formed in order to explain what is happening. A theory is

different from a hypothesis because it has been tested over and over again, and scientists are pretty sure that it's true. A hypothesis that has not been tested can not be a theory; a hypothesis that *cannot* be tested is not scientific! For example, science cannot test to see if God exists, what you are thinking at this exact moment, or if unicorn eyeballs taste salty.

Questions

1. Complete: After a _____ has been well-tested and confirmed by other scientists, it can become a _____ .
2. Define data in your own words.
3. Name a famous theory about anything that you are familiar with.
4. Explain why it's not bad to make mistakes in science.
5. Compare and contrast a conclusion and a theory. You can use a Venn Diagram.
6. Imagine you were a great inventor like Thomas Edison. You have an interest in inventing things to make your life easier.
    a. What would you invent?
    b. How would you do it? Include at least four steps that are used in any scientific experiment!

How Do You Do Science?

By making observations about the world, experiments can be designed that test for a dependent variable, which depends on the independent variable (that the scientist controls).

About Doing Science

You are making **observations** about the world all of the time. You may notice that it's cold outside, that it's raining, that your friend has a pink shirt on, that a drink has spilled on the ground, or that someone has food caught in their teeth. Most of the time, these observations happen and they cause some sort of reaction: You put on a hoodie in order to warm up, grab an umbrella, compliment your friend, clean up the drink, or tell the person that they have food in their teeth.

The Black-Eyed Peas (the group, not the bean)

However, sometimes you observe something and then you wonder why it happened the way it did. This is the birth of science! Scientists are no different than anyone else – in fact, anyone can be a scientist. When you are doing science, you are asking questions and then going through a process to answer them. We've already seen some parts of the scientific method: Making hypotheses, collecting data and drawing conclusions are all part of the scientific process. But how do you go about actually answering the questions?

Typically, scientists do not work alone when answering scientific questions. There is way too much scientific knowledge for any one person to remember all of it. In fact, for any one branch of science (biology, physics, chemistry, geology, etc.), there are hundreds more branches, and finding an "expert" who knows all that there is to know for any one of those smaller branches is nearly impossible. For example, the bacterium E. coli is such a well-studied bacterium that thousands of scientists research and study it, write papers and books about it, and go to conferences to talk about it. Yet, no one person has all of the information about E. coli – these scientists still must work in groups in order to put all of the information together.

Black-eyed peas (the bean, not the group)

This works for your life, too: think about your favorite musician or group. Do you know everything there is to know about them? What if you got in a group of people who knew a lot about this musician or group? How many people do you think it would take to form a group who knew everything there was to know? And do you think it might be useful to include people who had a different favorite musician or group?

Many people think that the internet has the answers to all of the questions, but this is definitely not true. For example, if you tried typing, "Who is the best football player in the world?" into Google, you would not only get websites that talk about soccer, but you get over 33 million results! If you get a group of people together who have studied football for a long time, they would more accurately be able to come to a conclusion than the internet currently can.

So far, we've only talked about simple questions: the questions that books and the internet are very good at answering. Scientists are much more interested in open-ended questions. To answer these types of questions, scientists design experiments. Experiments are actually very basic, so let's take a simple one: does a plant need light in order to grow?

First of all, the question needs to be more specific. What kind of plant? What kind of light? What is meant by "grow"? So, let's use a black-eyed pea plant, a normal incandescent light bulb (like the kind you might use in your house), and let's say that "grow" means to make a leaf that's longer than one centimeter. Now, our question is: can a black-eyed pea plant grow at least a one-centimeter leaf with only incandescent light?

After we make our hypothesis (go ahead, make your own right now), then we can design our experiment. Clearly, we're going to need some black-eyed peas, some soil, some water, an incandescent light and a metric ruler. Those are our **materials**. Now, we need to identify the **independent** and **dependent variables**.

Black-eyed pea plant

Independent and dependent variables are related to one another. The independent part is what you, the experimenter, change in order to do your experiment. The dependent variable is what changes when the independent variable changes – the dependent variable depends on the outcome of the independent variable. What are you going to change in order to do this experiment? Think about it … it's the light!

So, the incandescent light is the independent variable, which means that we're going to need two plants: a plant that grows with the light bulb and a plant that grows without the light bulb. In fact, the experiment will go even better

if we use more than one plant, so let's try growing three plants with the light bulb and three plants without the light bulb. The plants in the light are called the **experimental group** and the plants without the light are called the **control group**.

Experimental Group	¼ cup water	8 hours incandescent light	75 F
Control Group	¼ cup water	8 hours sunlight	75 F

Black-eyed pea Experiment

The experimental group always contains what we are testing for, while the control group usually contains what we know normally works. So, in the control group, we'll give the black-eyed peas 50 mL of water every day and we'll let them sit in the sun for eight hours every day at 75°F (did you notice how the experiment got even *more* specific?). This means that in the experimental group, we also need to give them 50 mL of water every day and let them sit underneath the light bulb for exactly eight hours at 75°F. A good scientific experiment has *one and only one change* between the control group and the experimental group (or, in some cases, groups).

If we design our experiment in this way, we'll be able to say if eight hours underneath an incandescent light bulb works to grow leaves better or worse than eight hours in the sunlight, at 75°F. However, we cannot draw any conclusions past that: we can't say that it will work at 30°F, that it will work with any amount of light, or that you can use any amount of water. In other words, your conclusions need to be as specific as your experiment!

Questions

1. What is:
    a. An experimental group?
    b. A control group?
2. What do you need in order to have a good scientific question?
3. Summarize the experiment performed in the passage using the Describing Wheel (in the back of the book)
4. Why do scientists work in groups?
5. Describe the relationship between an independent and dependent variable.
6. Let's say that the experiment in the passage turned out to show that an incandescent light bulb actually made the plants grow leaves, but you noticed that those leaves were a lighter green color. How would you go about designing an experiment to test the effect of the type of light on the color of the leaf? Include:
    a. The independent variable
    b. The dependent variable
    c. The control group
    d. The methods (procedures or steps) to follow

What is Life?

Based on what happens inside of cells, the characteristics of life include: homeostasis, transfers of energy, transportation of molecules, disposal of wastes, creation of new molecules

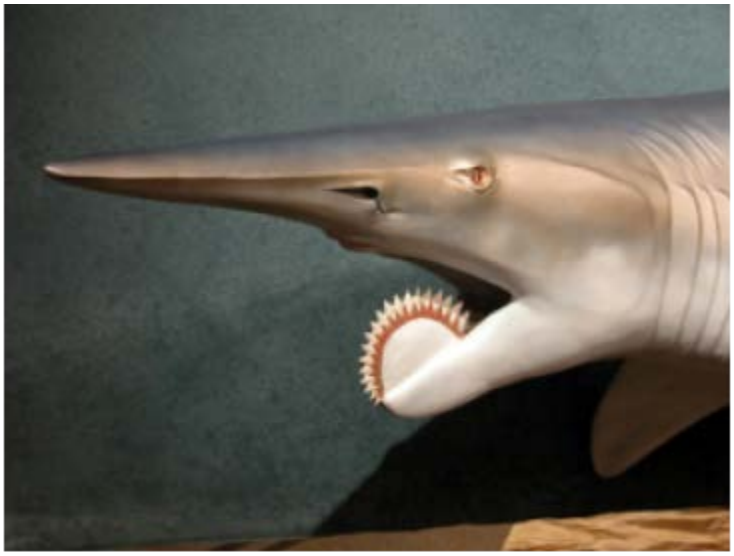
NASA realized too late that there was intelligent life on this newly discovered planet.

Characteristics of Life

One of the most popular questions that students have in biology class is, "Are there really aliens?" Although most scientists will say that no aliens have been discovered yet, this is actually a much more difficult question to answer than you might think. What really *is* an alien? A little green man with antennae? A slimy mass that inches around?

An alien is any form of life that does not come from Earth. Unfortunately, that doesn't make it much easier to be able to tell what an alien is. There are millions of undiscovered species of life here on Earth, and many of them look like they might come from other planets. In fact, scientists estimate that over 100 undiscovered species go extinct *every day* just in the world's rain forests!

Even as we're still just looking on Earth, how do we figure out what is alive and not alive? Is something alive because it moves? By that definition, air and water would be alive. The real answer is much more complicated, and not all scientists agree on what things are alive and which are not living.



Helicoprion, a fish genus that lived about 250 million years ago

The first way that we can tell something is alive is by whether it creates new **molecules**. Just as you are growing, making new blood, hair and skin all of the time, all living things make new molecules. Even single-celled organisms are renewing parts of their cell and growing so that they can reproduce. In fact, just think what would happen if organisms *didn't* make new molecules all of the time – how would

sperm and eggs ever form, how would one cell split into two cells, how would the organism ever grow? In other words, for an organism to use the food and water around it, it must somehow make new molecules.

When those new molecules aren't needed any more, all organisms must have some way of getting rid of wastes. Humans do this in many ways: we breathe out carbon dioxide through our mouths, we often sweat out urea (which is also in our urine) and we defecate solid matter that our bodies can't use. On a smaller level, however, each one of our cells is getting rid of wastes. When our cells let certain materials in, they also release other materials that aren't needed any more. Every cell produces its own waste, from the simplest bacteria to the strangest deep sea creature (like the "dumbo" octopus to the right). Again, imagine what would happen if our cells were able to make new molecules, but not get rid of wastes: We'd get full of carbon dioxide and explode very quickly!

The "Dumbo" octopus, which lives 1000 feet below the surface of the ocean

The "trash" that we make inside of our bodies has to be transported to places like the nose, bladder and anus. If it weren't for the transportation of materials, bad *and* good, we wouldn't be able to get oxygen and nutrients to all of our cells. This is another characteristic of all living things: the ability to move materials from one place to another. In humans and many other animals, we accomplish this by having blood that reaches every single cell in the body. In fact, our blood makes a full trip around our body about every 45 seconds. Single-celled organisms don't have to transport molecules very far, but they still move molecules around their cells so that nutrients can get to parts of their cell that can make use of these nutrients.

In addition to moving nutrients around, all living things have to move energy around. Our stomachs digest our food and move that food to the small intestine, where most of the nutrients are passed directly to the blood. There is a tremendous amount of energy inside of these nutrients that helps our muscles move, our nerves send signals and our organs to expand and contract. If it weren't for the fact that this energy could get to our muscles, we wouldn't be able to move at all! All organisms have this same problem: Food comes in one place, but must be used in another place.

A twig-like insect

The final characteristic of life is the most complicated: **Homeostasis**. Put simply, homeostasis is the ability of an organism to maintain a balance between what's going on outside and what's going on inside itself. As humans, we keep our bodies at a pretty constant 98.6°F (except when we're sick and trying to create an unfavorable environment for bacteria or viruses). We maintain 98.6°F by sweating off heat when it's hot outside of our bodies and by shivering and shaking to produce more heat when it's cold. A dog does not have the ability to sweat, so it releases heat by panting; a reptile can't produce its own heat, so reptiles need to sit in the sun or on warmed earth in order to digest their food. All organisms need to maintain a balance of more than just heat. Just think what would happen if you couldn't keep all of the water inside of your body from evaporating! What would happen to a tree that couldn't absorb water from its environment? All living things need to be in balance with their environment.

One of the smallest known snakes in the world

If we ever find an alien, there will certainly be a lot of questions to answer. For biologists, they will be quick to ask how it is that the alien accomplishes these five tasks that form the basis of all living things.

Questions

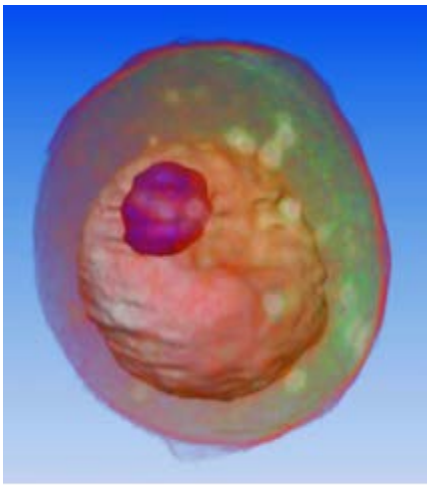
1. Identify the five characteristics of life and define each of them.
2. Describe homeostasis in your own words.
3. What are two substances that your body makes?
4. Choose any organism. Predict the effects of this organism not being able to get rid of wastes.
5. Name something that is involved in human homeostasis that is not mentioned in the passage.
6. Imagine that tomorrow, a new life form on a distant planet in the Milky Way is found.
    a. Name it.
    b. Describe it in one sentence.
    c. Draw a quick sketch of it.
    d. For each characteristic of life, how can the organism be considered alive?

What is a Cell?

Living cells: are made up of just a few important chemical elements (carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur); are the basic unit of structure and function of all living things; come from other cells after life began; and are different from viruses

Living Cells

Have you ever been asked to sweep or vacuum around your house? If not, have you ever noticed the dust that collects all around a room? Believe it or not, most of this dust comes from you and the other people you live with – as dead skin cells!

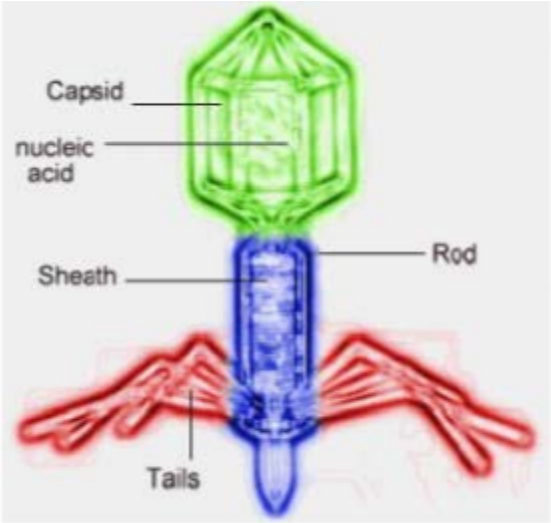


A cell

Your body is constantly producing more and more new cells while other cells die. In fact, our bodies are only made up of cells and some fluids that are trapped between them. This means that living cells make new cells – but really, what are they?

A cell is actually very complex. Some scientists spend their entire lives studying just one little part of how just one type of cell works. However, understanding what a cell is and what it does is actually quite simple. Each cell is basically a bag of water, DNA, protein and some things called **organelles**. The organelles inside of a cell are responsible for making energy, getting rid of waste and making proteins, among other things.

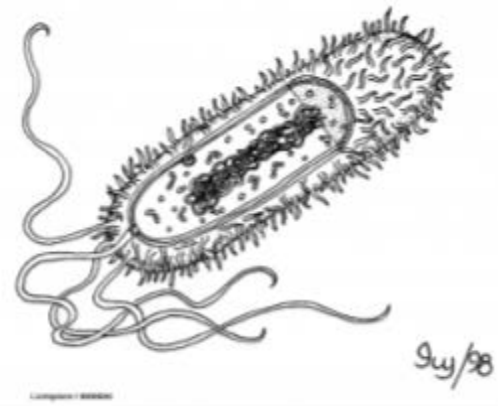
A living thing is made up of a collection of one or more cells. However, one lone cell cannot accomplish very much – take a swim, eat some lunch, find a mate – but a group of cells can get together and form a much more complicated organism. Sure, that group of cells can take swims, find mates and even eat dinner, but it can do more than one thing at one time. A plant, which is a group of cells, can capture the energy of the sun, pick up water with its roots, turn carbon dioxide into sugar and oxygen and open up its flowers all at the same time! And if you as a human are really talented, you can text message, listen to your teacher, and make googly eyes at your boy/girlfriend across the room *all at the same time*. Just think, if you were a single-celled amoeba, you wouldn't even have a pocket for your phone. How wonderful it is to have more than one cell!



A virus

We say that cells are the most basic unit of structure. This is true for all living things, whether or not they have bones. For example, a jellyfish has no bones, but cells make up their arms and body. Also, a jellyfish is is able to swim and sting their prey because they have special cells that perform certain functions. As humans, we have special cells that beat around 80 times every minute called heart (cardiac) cells. We also have cells that carry oxygen around our

bodies called red blood cells. Our bodies need to do thousands of things, or functions, every second. For these reasons, we say that cells are also the basic unit of function in all living things.



A bacterium

You know that if your teacher catches you texting on your phone, that you might get a call home to your grandmother, grandfather, mom or dad. Why are those people most closely related to you, anyway? Because your cells came from their cells! All living cells come from other living cells. A famous experiment was once done on rotting meat. At the time, people believed that flies came from rotting meat – not other flies. So a scientist took two containers of rotting meat; over the first container, he put a screen that prevented flies from landing on it. He left the second container uncovered. Sure enough, flies started to land on top of the second container, and before long, the rotting meat was covered with maggots (fly babies). However, the flies never got on the meat in the first container, no maggots appeared, and no flies appeared inside the container. Flies could only come from other flies!

Since then, scientists have discovered much about cells and also about things that are not considered living cells, such as **viruses**. Viruses, which lack a nucleus, can infect living cells by using the cell to make more viruses, but without a living cell, a virus cannot make more copies of itself. The virus never gets any bigger or smaller, and doesn't take any gases or other materials from its environment. Different viruses can survive in different environments, such as HIV which needs to be in body fluids like blood or semen, but no virus can make more copies of itself, by itself. This is why most scientists do not consider viruses to be alive, even though they have organic molecules like proteins.

At this point, you may be asking yourself, what are living cells actually made up of? Truthfully, you're probably *not* asking yourself this question, but it would be a good question to ask. All of those organelles in the cell (like the cell membrane, DNA, ribosomes, etc.) are made up of different combinations of just a few chemical elements. It's thought that these chemical elements were around when the Earth first cooled down 4 billion years ago: carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur. Believe it or not, almost your entire body is made up of combinations of these elements, elements that originally came from our sun!

Questions

1. State how new cells come about.
2. Identify the role of a cell to an organism.
3. In our cells, carbon, oxygen, nitrogen, phosphorus and sulfur are present. Where did those chemical elements originally come from?
4. Differentiate (tell the difference between) a cell and a virus in two ways.
5. Paraphrase (summarize briefly in your own words) the experiment done to prove that cells come from other living cells.
6. Argue for the case that a virus is actually a living thing.

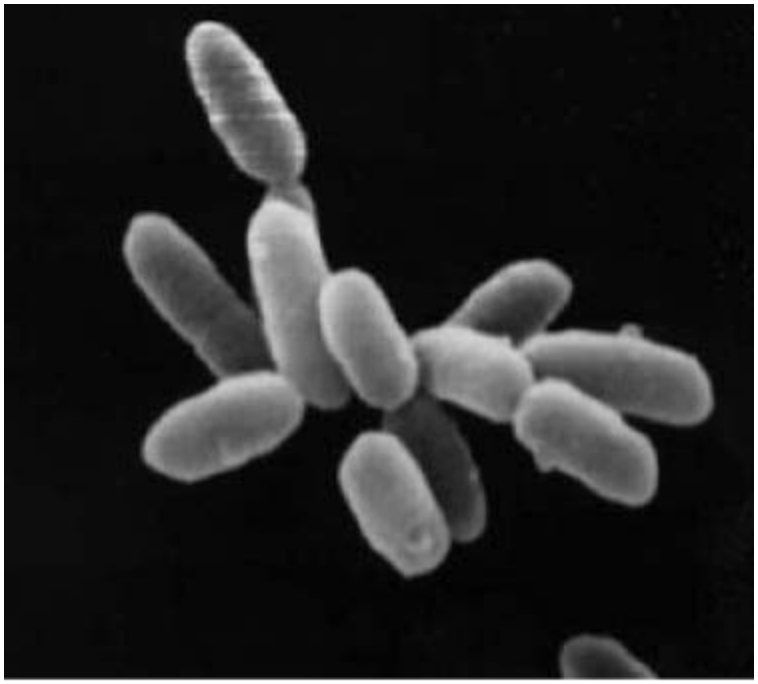
What Is Inside a Cell?

Compare the structure, function and the relationships of cell organelles in eukaryotic cells and prokaryotic cells. For example, nucleus, chromosome, mitochondria, cell membrane, cell wall, chloroplast, cilia, flagella.

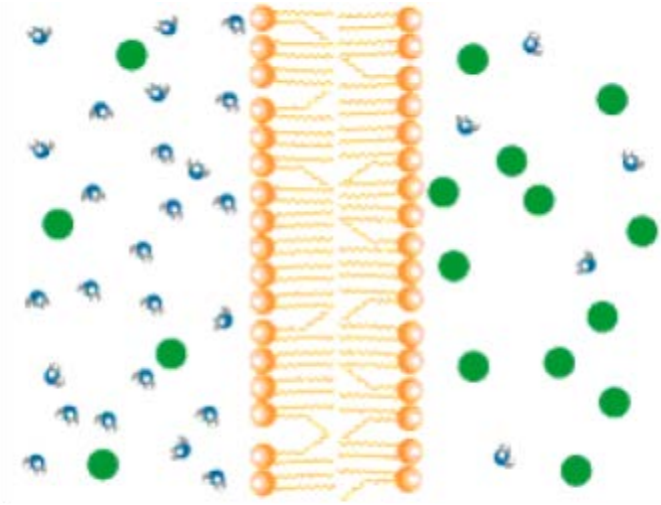
Organelles

Cell Type	Prokaryote	Eukaryote			
Kingdom	Monera (Bacteria)	Protist	Plant	Fungus	Animal
Nucleus?	No	Yes	Yes	Yes	Yes
Mitochondria?	No	Yes	Yes	Yes	Yes
Multicellular?	No	No	Mostly	Mostly	Mostly
Chloroplasts?	No	Sometimes	Yes	Sometimes	No
Cell Wall?	Yes	Yes	Yes	Yes	No

Get out your phone. No, not really. You'll probably get into trouble. But think about opening up your phone. It's made up of quite a few parts: computer chip, display, battery, camera, case, microphone, speaker and much more. If all of those parts don't work together, then the phone



Archaea, a type of prokaryote. To its friends, it likes to be called Bob.



Osmosis: The smaller molecule is water and the middle is a cell membrane

doesn't work. Well, living cells work the same way. Without all of the parts (organelles) of a cell working together, the cell itself won't work.

As we've seen before, there are two major types of cells, prokaryotes and eukaryotes. The main difference, remember, is that prokaryotes have no true **nucleus** while eukaryotes have a nucleus (and can be multicellular). Prokaryotes came *before*

eukaryotes, by about 3 billion years. While there are many theories as to how this happened, scientists are certain that the prokaryote is the older organism.

There are two domains of prokaryotes, bacteria and a type of organism called archaebacteria or "archaea". We will only be focused on bacteria, as they are more well-known (even though archaea can be found in every corner of the world, too). Bacteria, even though they are very simple, still have DNA organized into one or more **chromosomes**. Bacteria have ribosomes and are surrounded by both a cell (plasma) membrane and then a **cell wall.** The **cell membrane** decides which nutrients and other materials can come into and out of the cell. If the cell membrane doesn't let important nutrients in, the cell itself will die. At the same time, if the cell membrane doesn't let waste leave the cell, the cell will also die very quickly.

The cell membrane doesn't always have to use energy to let certain things go into and out of the cell. One of those things is water; water moves into and out of the cell because of **osmosis**. Osmosis is when water molecules move from a higher to a lower concentration. In the picture of osmosis, the smaller molecules are water, which pass from the left to the right-hand side until they are equal because they are in a lower concentration on the right-hand side. Osmosis is a type of **diffusion**. Diffusion is where molecules spread out until they are evenly distributed in a medium, such as the air.

The cell wall gives shape and structure to the cell. Inside all living cells, including bacteria, there are one or more chromosomes. These chromosomes contain all of the genetic information needed for the cell to stay alive and carry out all of the things that a cell does. Sometimes, cells like bacteria also have things called **cilia** or **flagella**. These are like tails for the cell and help it move around in liquids. Human sperm cells have flagella so that they can move toward the egg.

Since plants use the energy from the sun, they need to have specific organelles to capture that energy. The organelles that do this are called **chloroplasts**. The chloroplasts are green themselves because of chlorophyll, which captures sunlight. It is inside the chloroplasts that **photosynthesis** happens where carbon dioxide and water gets turned into sugar and oxygen.

As you can see in the chart at the beginning of this chapter, there are many differences between prokaryotes and eukaryotes. Eukaryotes have a nucleus which contains the DNA (that is made up of chromosomes). Also, they have **mitochondria** which are responsible for producing the energy that the cell needs. The nucleus, chloroplasts and mitochondria have membranes surrounding them (like the cell membrane) that decide which materials can enter and leave the organelle.

Going back to the comparison between cells and phones, we can see that there are a lot of similarities. The nucleus is like the computer chip: it contains the information necessary to keep the phone working and the chromosomes are like the instructions on the computer chip. The case of the phone acts like the cell wall; the microphone and speaker allow sound to enter and leave the phone just like the cell membrane in a cell. The battery, of course, is like the mitochondria. Phones don't have anything that's like chloroplasts, but wouldn't it be cool if they did? Think about it: a cell phone with a solar panel so that you could charge it by leaving it in the sun!

Questions

1. Which kingdom of living things does not have a cell wall?
2. How is DNA organized?
3. What is the role of chloroplasts?
4. Differentiate prokaryotes and eukaryotes in three ways (from this chapter).
5. Predict the consequences of eukaryotes not having a nucleus to hold their DNA.
6. Draw a sample plant cell.

How Do We Name Organisms?

Biological classification represents how organisms are related with species being the most specific part. Biologists arrange organisms into a hierarchy of groups and subgroups based on similarities and differences, which have to do with how closely related they are.

Classification

Classification is a way of organizing anything into categories so that we can figure out how those things are similar to and different from each other. Any group of living or nonliving things can be classified. For example, we can classify students according to many characteristics: their grade level, credits earned, whether they pick their nose, small school or age, among other things.

In the world outside of school, there are between 5 and 30 million different species of living things. Scientists have only named about 2 million of these species. Because we keep finding more species all of the time, we estimate that there must be many more species than already have been found! In fact, we can't even keep up with the number of species.

Because there are so many organisms in the world, it is very important to be able to figure out how all of them are related. In order to do this, we use **biological classification**. The different levels of biological classification are often accepted to be, in order:

An amoeba. Her name might be Bobbi.

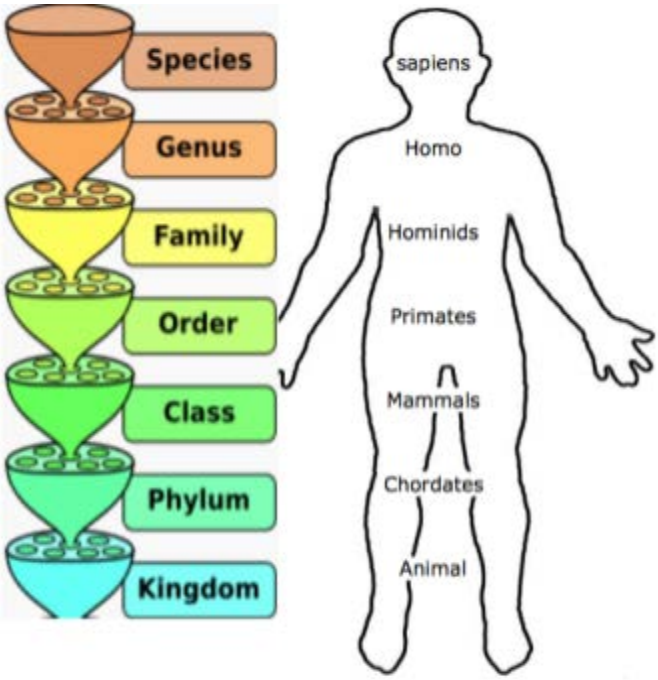
Domain
Kingdom
Phylum
Class
Order
Family
Genus
Species

According to many scientists, there are three **domains** (Archaea, Bacteria, Eukarya) and four major **kingdoms** in the Eukarya domain: Animals, Plants, Fungi, and Protists. This means that *all* organisms must fit into one of these domains or kingdoms. For example, we are in the Eukarya domain and Animal kingdom, trees and bushes are in the Plant kingdom, mushrooms and yeast are in the Fungi kingdom, amoebas are in the Protist kingdom, and bacteria are in the Archaea and Bacteria domains. Within each kingdom, there are *phyla* (the plural of phylum). For example, the Animal kingdom has over 9 major phyla, among them Chordates (like us), Arthropods (insects and spiders), Porifera (sponges) and Annelids (worms). Then, there are several classes in the Chordata phylum, like Birds, Mammals, Reptiles and Amphibians.

As you can see, every step you take on the classification list, the more specific it is. Once you get down to the species level (like *Homo sapiens*), there is only *one* type of organism. This organization of things

is called a **hierarchy** because it lists the category that has the most things first, and the category with the least things last.

Just as importantly, you can tell a lot about an organism based on where it's classified. Because we and dogs are both in the same class (Mammals), that means that we are more closely related to dogs than we are to spiders, as spiders are in a different phylum (Arachnids). If two organisms are in the same genus, that means that they are very highly related. If they are only in the same kingdom, then that means that they are not very highly related at all.



Another view of classification, with human classification on the right.

Questions

1. What are the three domains of life?
2. List four phyla of the animal kingdom.
3. About how many species of organisms *have not* been found?
4. How many types of organisms are referred to by the same species name?
5. Organisms A and B are in the same Order but not the same Family. Organisms A and C are in the same Class but not the same Order. Which two organisms are more highly related?
6. Create a fictional mammal that you would like to keep as a pet. Describe this mammal, then choose which order of mammals it should fit into: Artiodactyla (hoofed animals), Carnivores, Cetaceans (whales), Chiroptera (bats), Insectivores (eat insects), Marsupials (pouched), Monotremata (egg-laying), Proboscidea (elephants) or Rodents. Invent a Family, Genus and Species name for your mammal. List the entire classification of this mammal, from Domain to Species!

How Did Life Begin?

Life on Earth is thought to have started as simple, one celled organisms approximately 4 billion years ago. For about 3 billion years, only single celled microorganisms existed, but once cells with a true nucleus developed about a billion years ago, multicellular organisms evolved.

The Beginning of Life

There is nobody who knows exactly how the universe began, how the Earth came about, or how life on Earth started. In fact, it is likely that we will never know for sure. This is the important part about science: there are no definite answers to questions, but there are answers that are commonly accepted.

Artist's rendition of the Big Bang

If you drop a pen and it falls to the ground, a scientist would say that it fell due to the force of gravity. However, gravity is just one idea, an idea that happens to explain our experience of the universe around us very well. Consider this: Brandon and Jasmine, scientists from Cleveland, come around and discover evidence that there is a mysterious glue which holds everything in the universe together, and then they find that it is the glue which caused the pen to fall to the ground. Brandon and Jasmine could take this evidence, write up a lab report, send it to other scientists, and then see if other scientists can make the same thing happen. If enough other scientists agree, the theories and laws actually *change*! In other words, science is changing all of the time.

The Earth, from space

According to all of the evidence, scientists theorize that the following is true: the universe began 13.7 billion years ago, the Earth was formed about 4.6 billion years ago, life on Earth began about 4 billion years ago with unicellular organisms, and **multicellular organisms** evolved about 1 billion years ago. What does all of this really mean? And how do scientists "know" this?

First of all, it means that the universe has been around for a very, very, very, very, very, VERY long time. It started with something called the **Big Bang** when all of the matter in the universe exploded out of a single point at a speed that is unimaginable. Scientists came up with this number by measuring something called **cosmic background radiation** that was given off by the Big Bang. Cosmic background radiation is like an echo that is as old as the universe.

The Big Bang created galaxies of stars. From there, it took about 9 billion years just for our Earth to be separated from our star, the sun, and start to cool down enough so that a few million years later, life could develop. Nobody's exactly sure how life

began, but a few scientists have been able to create the building blocks of DNA and cells from the basic elements of a young Earth, light and heat. It is thought that with enough time (throw in a few million years), that a cell develops from this basic stew of ingredients.

Even though it only took about 500 million years for life to develop on Earth, it took a very long time for complex life, **eukaryotes** and then multicellular organisms, to evolve. Before eukaryotes, no cells had a nucleus. They were all **prokaryotes**. But it is thought that one cell swallowed another, and instead of killing the prokaryote, this cell started to put the prokaryote to work! The prokaryote became part of the new eukaryotic cell (such as things like **mitochondria**), and from there life began to get very complicated very quickly.

Within a few million years, protists, plants, fungi and animals all evolved and one billion years later, humans evolved from some unknown ancestor. To get from the Big Bang to the first human took such a long time that you can imagine the following scenario: you are driving from Los Angeles to New York, a distance of about 3000 miles. The Big Bang happens when you leave Los Angeles, the Earth is formed when you cross the Mississippi River, and eukaryotes evolve by the time you are just outside Philadelphia (about 1½ hours from New York). Humans? The first humans are seen in the last block (200 feet) before you cross into New York and your entire lifetime is less than the width of a hair on the ground on that block.

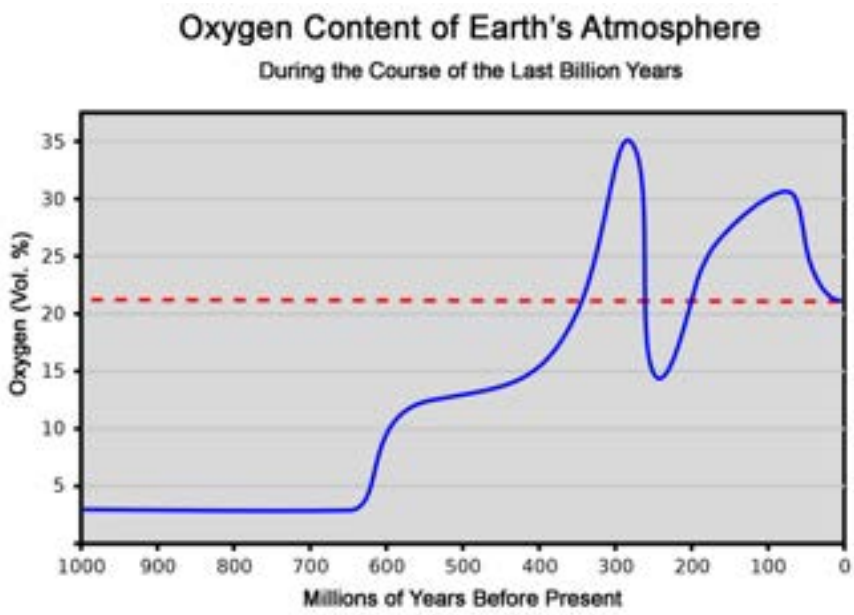
Questions

1. Describe the two types of cells.
2. Complete: The beginning of the universe, the _____ happened about _____ billion years ago and life on Earth began _____ billion years ago.
3. How was Earth formed?
4. Explain why science doesn't have firm answers to questions.
5. Create a map showing the “evolutionary trip” from Los Angeles to New York in the last paragraph of the reading.
6. Predict what kind of evidence might make scientists think that life on Earth was in fact much older than 4 billion years.

Was There Always Oxygen on Earth?

Describe how organisms on Earth contributed to the big change in how much oxygen there was in Earth's early atmosphere.

Oxygen on Earth



When the Earth was first formed, about 4.6 billion years ago, there was almost no oxygen in the atmosphere. Because the early Earth was very hot, there were a lot of volcanoes. Two of the things that come out of volcanoes are water (which formed the oceans) and carbon dioxide (CO_2). The first organisms that developed on Earth used that carbon dioxide and produced oxygen. Over the course of billions of years, enough oxygen was in the atmosphere to do two major things. The first was that the oxygen could be changed into ozone, in order to help protect the Earth from **ultraviolet rays** (UV). UV rays can kill cells, so it was very important that there was a layer of ozone before plants, animals and fungi (all multicellular organisms) could develop.

The second major consequence of oxygen in the atmosphere was that animals and some fungi could then use that oxygen to breathe. Even more importantly, those animals and fungi give off carbon dioxide so that the amount of oxygen and carbon dioxide stays about the same.

Right now, global warming is happening because there is too much carbon dioxide in the atmosphere. This is because we are burning things (and burning requires oxygen) that have carbon in them, like gasoline. Just like the volcanoes, carbon dioxide is given off into the atmosphere when you burn anything with carbon.

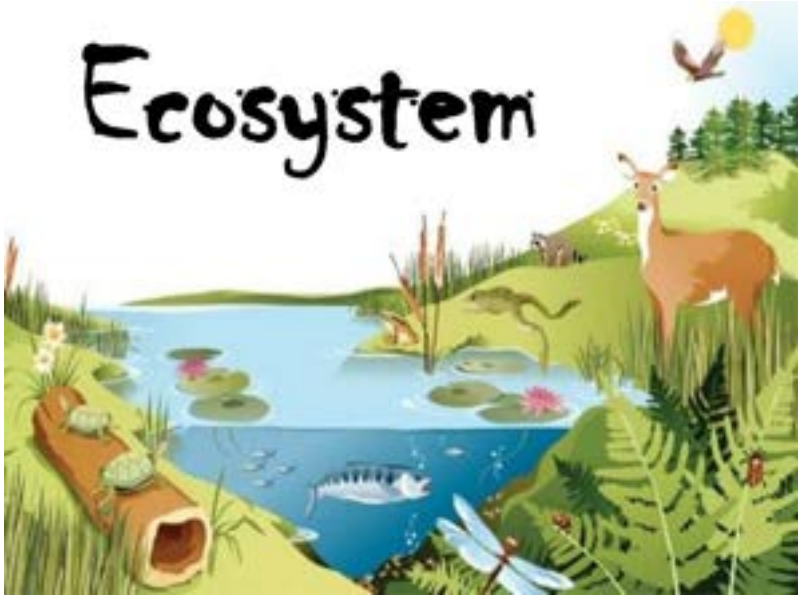
Questions

1. What protects the Earth from UV rays?
2. Name two chemicals that are released by volcanoes.
3. What do animals breathe in? What do animals breathe out?
4. Explain why the amount of oxygen in the atmosphere increased soon after the Earth was formed.
5. What did volcanoes do for the Earth's early atmosphere?
6. Create a cycle (you can use the graphical organizers to help you) showing what happens to oxygen and carbon dioxide on Earth. Include plants, animals, the ozone layer and the ocean in your cycle.

What Do Living Things Need to Survive?

How many organisms are in an ecosystem and where they are is limited by how well the ecosystem recycles materials and by how much food, water, space and shelter is available.

Basic Needs



What would happen if a polar bear ended up in the middle of the jungle? What about a palm tree in the middle of the arctic? Living things have to be in certain conditions of temperature and precipitation (rain) in order to survive. Those conditions can be the same in different parts of the world, like the Cleveland area has a similar climate to much of Japan. Since the conditions are similar, then these areas tend to have the same living things, too. Areas that have similar climates and living things are called **biomes**.

Inside of biomes, there can be trillions of living things. Those living things can be inside of completely different environments, even though the general climate is very similar. Think about the Cleveland area, for example. There are ponds, forests, cities, hills and even a lake! Areas within a biome like these can represent a different **ecosystem** because of the different materials available and the different living things that make up that particular area.

It's not easy to say that one ecosystem starts at one place and ends at another. It is true that ecosystems influence other ecosystems, and biomes influence other biomes. In fact, scientists even like to talk about the "butterfly effect": the way a butterfly flaps its wings here in North America could affect whether there's rain in China! Since the entire world is connected, the best place to start with ecosystems is what is necessary to have an ecosystem.

The carrying capacity is the maximum number of organisms that can survive in a place

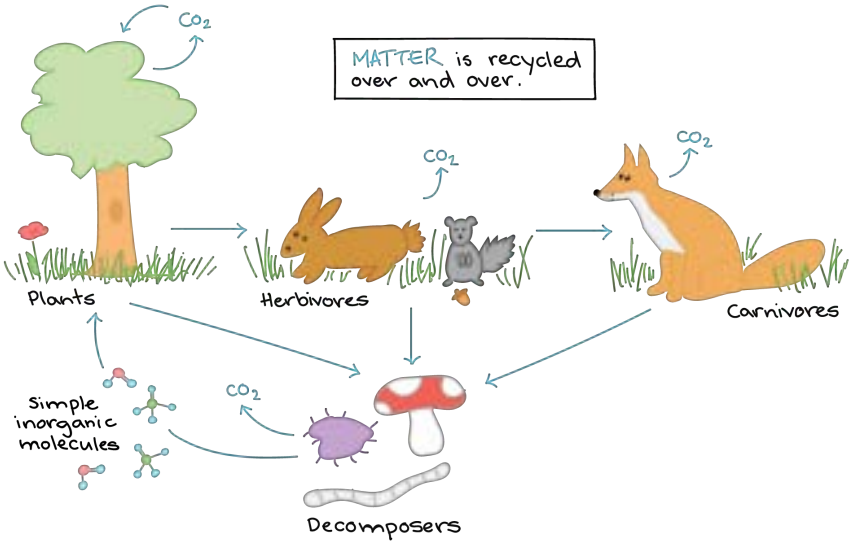
Think about what you need in order to survive. Doctors say that you can survive 4 to 6 weeks without food and at most 10 days without water. It's clear that all living things need food and water, in some form, even if food comes from the sun or water comes from the air. But what else do you really need?

Believe it or not, you need space. All living things require space, so that they can get their food and water, especially if they have to hunt down that food. The other surprising need of all living things

is shelter of some sort. Many living things are capable of making their own shelter (like a snail has a shell or a human builds homes), but all living things have fragile parts that need to be protected from the environment.

Depending on how much food, water, space and shelter is available in the ecosystem, a certain amount of organisms will be able to survive in the ecosystem. Think about it: if there are a lot of oak trees around to provide food for squirrels, and those squirrels have plenty of space (and shelter from the trees), but there is no river, stream or lake, then the population of squirrels will be low because they won't be able to get very much water. The maximum number of a particular organism that can survive is called the **carrying capacity** of the ecosystem for that organism; the maximum number of squirrels that can live in our oak tree forest would be the carrying capacity of that forest for squirrels.

More importantly, a healthy ecosystem also *recycles* materials. This means that after a deer eats the leaves off a tree, the deer poop can then be decomposed by bacteria and worms into the soil, where plants use it for nutrients to make new leaves. This also means that a river carries water from the top of a mountain, and that water collects in a lake. The water from that lake evaporates into the atmosphere, falling as rain onto the mountain, where rivers take it back down into the lake.



Questions

1. Draw a picture showing the four basic needs of living things.
2. Explain the "butterfly effect" in your own words.
3. What does it mean that an ecosystem recycles materials?
4. Pick two ecosystems (areas) from different biomes that you are familiar with and contrast them in three ways.
5. What would happen if organisms could not find shelter? What about space?
6. Imagine that you were given a farm the size of Campus International's parking lot. What animals do you think you could raise on this farm? What would the carrying capacity be for each one? For example, if I wanted to raise cows on the farm, I might say that the carrying capacity for cows is 4.

What Do We Need to Eat?

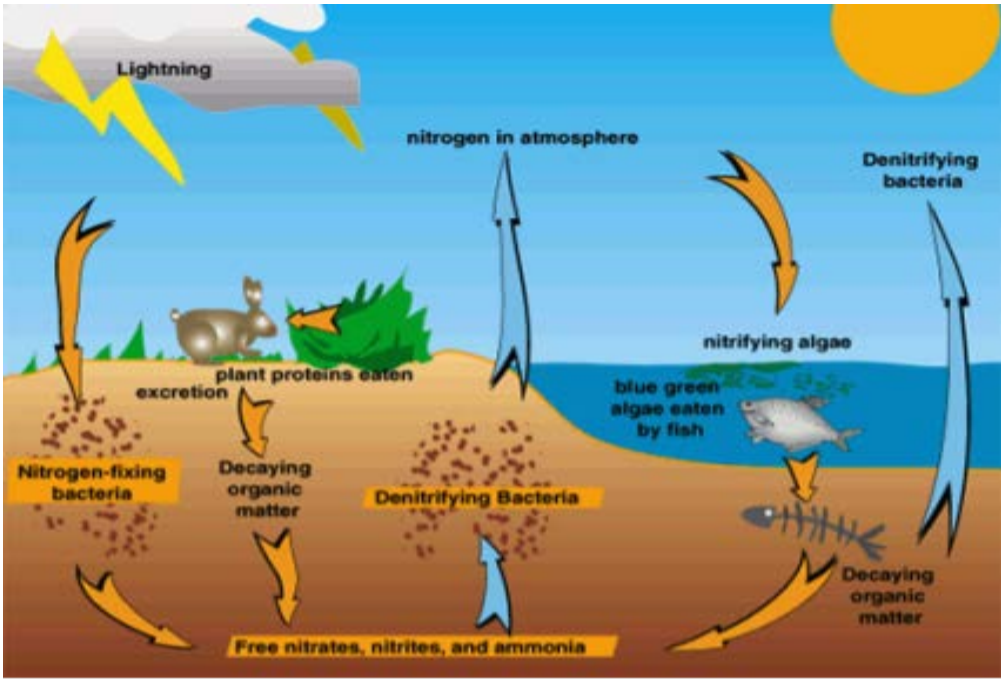
Living organisms use matter and energy to create a wide variety of organic molecules (e.g., proteins, carbohydrates, lipids and nucleic acids) and to allow life to happen in growth, reacting to the environment, reproduction and movement. Ecosystems also recycle many materials, such as water, carbon and nitrogen.

Organic Molecules

Think about your last meal. What did you eat? Chicken, beef, bacon, beans, fish, pork, tofu, eggs, or cheese? Then you had plenty of **protein**. Did you eat french fries, chips, corn, noodles, pancakes, bagels, or cereal? Then you probably got plenty of **carbohydrates**. Did you eat cookies, a snack food, donuts, potato chips, or anything that was greasy, oily, or cooked in butter? Then you probably got plenty of fat (**lipids**).

These three major nutrients are the most important **organic** molecules, meaning that they all come from living things! Of course, we use all three of these nutrients in order to live. Proteins are used to build muscle, help your immune system, help brain and nerve function, and assist in almost every biological function in your body! The body uses carbohydrates for the energy to do many things, build cell membranes and cell walls, and to store energy as fat. Aside from being stored energy, fats (lipids) are used by the body to make hormones. Lipids contain much more energy than carbohydrates, which are used immediately by your body. Since carbohydrates are broken down into sugars, this is why people sometimes feel a "sugar high" that ends very suddenly!

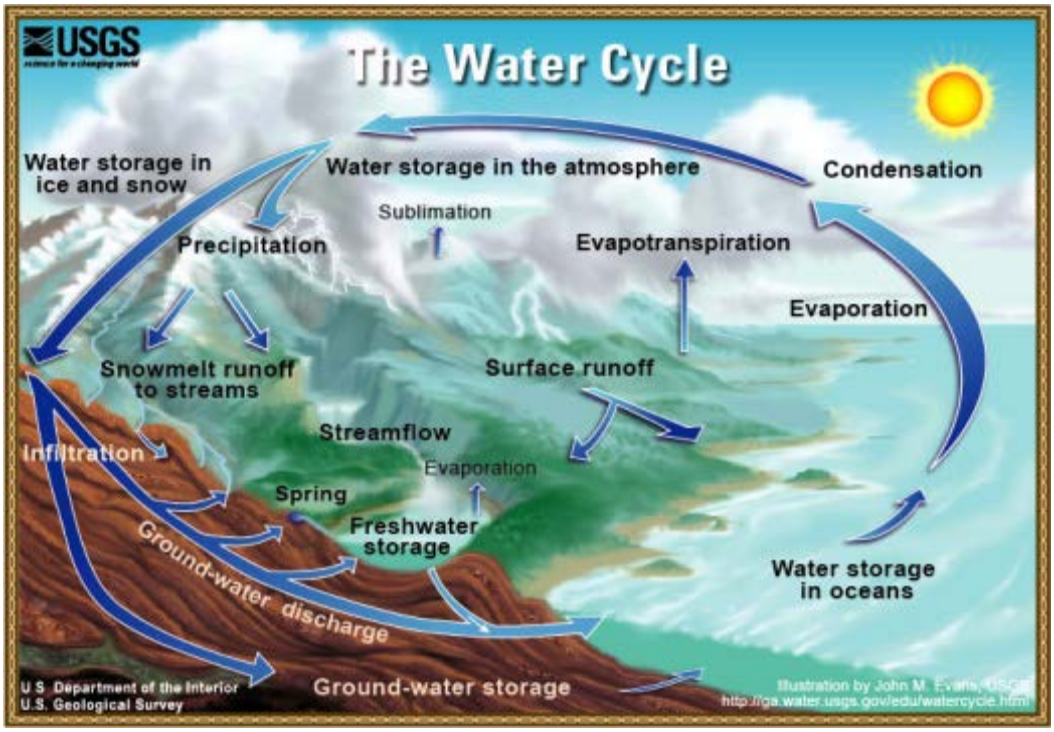
It's important to get a balance of all of these nutrients in your body because they are necessary for growth, homeostasis, reproduction and movement: all characteristics necessary for life. Since all living things use these nutrients, over and over again, how is it that we don't run out? Where does more protein come from? How do we get carbohydrates and lipids, anyway?



The Nitrogen cycle

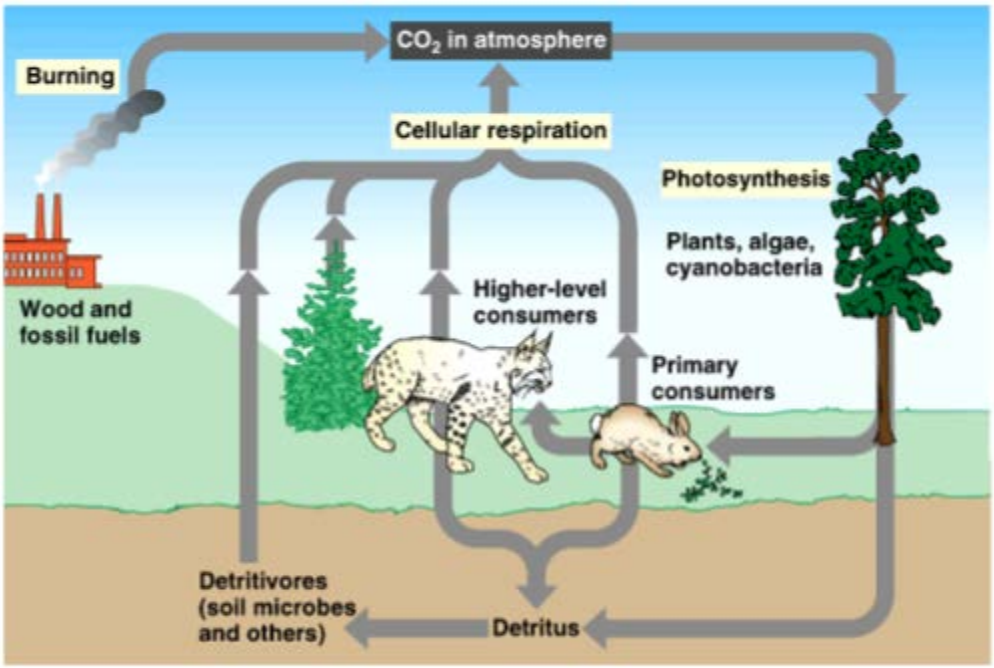
We get proteins from amino acids: Remember how the ribosomes put amino acids together to form proteins? Those amino acids, eventually, come from plants. Those plants make amino acids from molecules that have nitrogen, which they get from bacteria. And what about the bacteria? The bacteria get nitrogen from – the air! This is the **nitrogen cycle**.

The main ingredient in urine is urea, which has nitrogen in it. In other words, after we use the nitrogen, we pee it back out! That nitrogen is again used by bacteria and is often put back into the atmosphere. Other times, it is used again by plants, where we eat the nitrogen again and turn it into proteins.



Speaking of urine, it is important to understand how **water cycles** through the ecosystem. All of us drink water all of the time, but how is it that rivers and lakes continue to flow, even though we are using it? After we use the water, it gets filtered through the ground and returns to rivers, lakes and oceans. We can use the water from Lake Erie (that comes through our pipes), but sometimes that water evaporates – and then falls back down to the ground as **precipitation**. More importantly, salty water from the ocean evaporates and falls back down to the ground as fresh water that living things can use more easily.

The last major cycle is the **carbon cycle**. Carbon is the most important part of carbohydrates and lipids, which are critical to your survival. Carbon dioxide is taken up by plants to make stems, roots, fruit, seeds and leaves, which are then eaten by **consumers**. Consumers, using up those carbohydrates and lipids, give off carbon in the form of carbon dioxide. This cycle works just fine, as long as it's only between plants and consumers. Unfortunately, humans



The Carbon cycle

have started to burn all sorts of **fossil fuels** which contain fossilized carbon. Once that carbon dioxide is released into the atmosphere, it adds more carbon dioxide than can be taken up by plants! This is how **global warming** becomes such a big problem and why we need to stop burning so many fossil fuels.

Questions

1. For each of proteins, carbohydrates and lipids, list their functions in the human body.
2. Which cycle is most important for the health of the Earth? Why?
3. For each of proteins, carbohydrates and lipids, list what foods they can be found in.
4. Predict what would specifically happen first if you didn't get enough protein in your diet.
5. What effect would insufficient carbon dioxide in the atmosphere have on humans?
6. Combine the three major cycles (carbon, nitrogen, water) into one cycle. Include the ground, a plant, a consumer, a body of water, and the atmosphere. Draw and label arrows showing the path of carbon, nitrogen and water through these five biotic and abiotic factors.

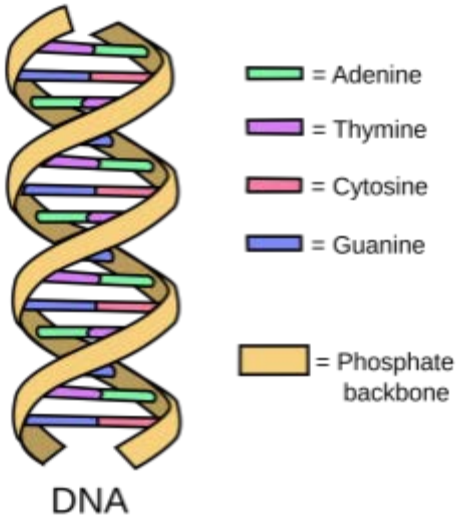
What is DNA?

Understand the relationship of the structure and function of DNA to protein synthesis and the characteristics of an organism.

DNA

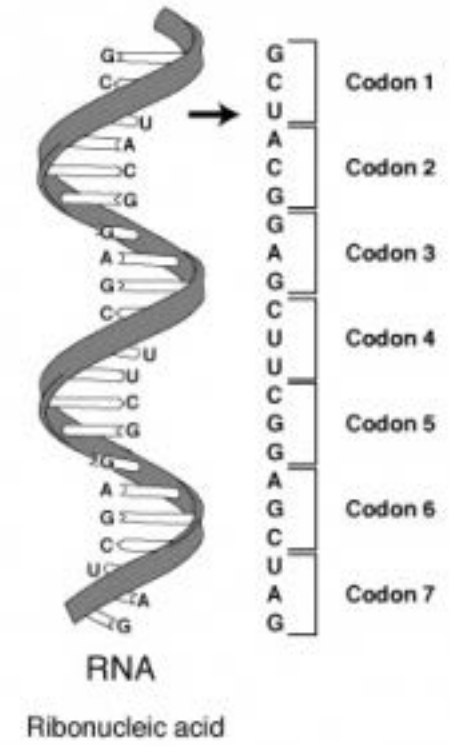
"It's in your genes!"

Have you ever been told that you look just like your mother, or that you act just like your brother or sister? You may not think it's true, but there's a good reason that people say that. It's because, in every cell in your body, you have (more or less) the same DNA. As you already know, you get one copy of your DNA from your mother and one from your father. Also, you know that the DNA is split up into strands called chromosomes, and that the ribosomes use the DNA in order to make proteins.



Structure of DNA

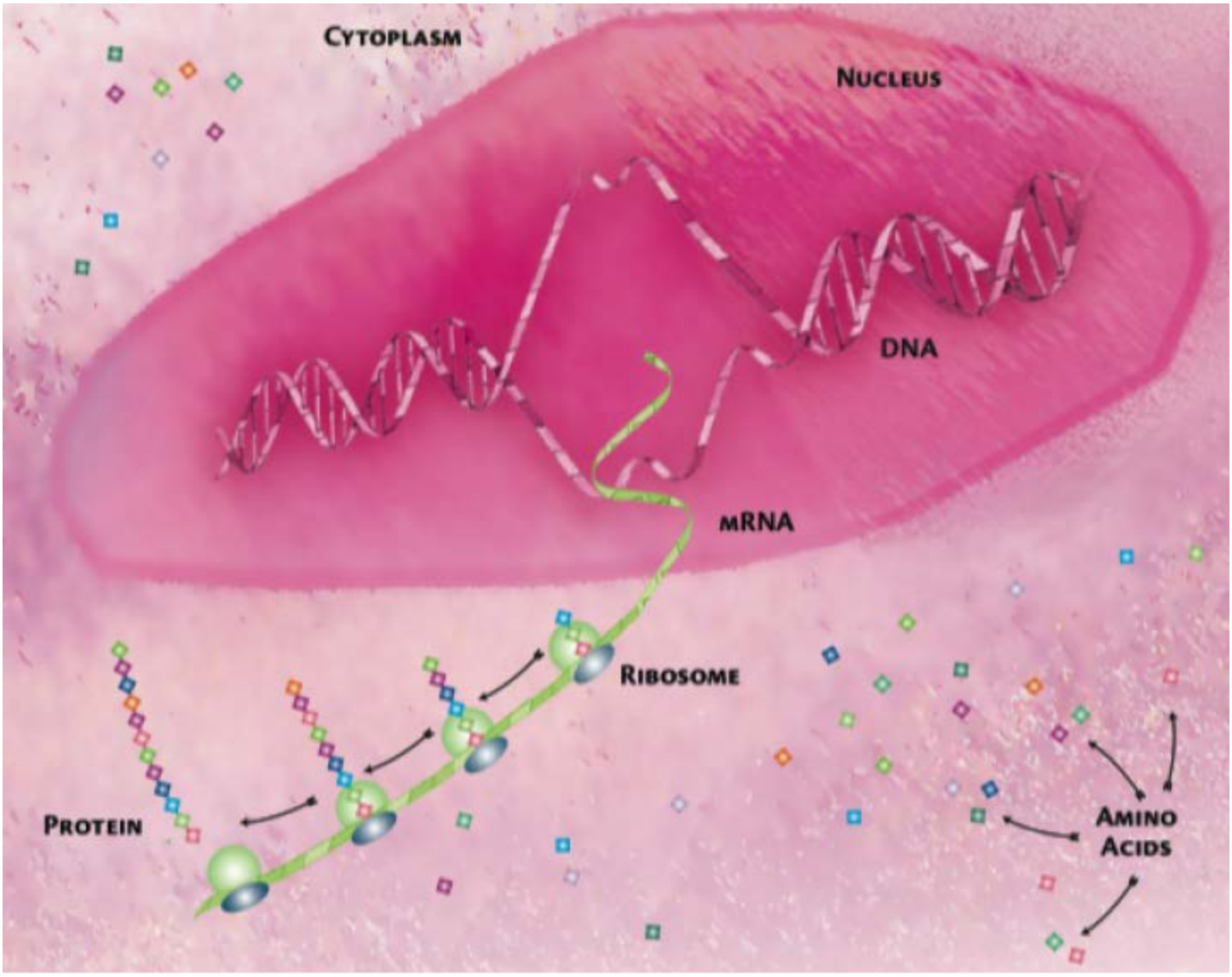
But what does it really mean that this DNA is in every single one of your cells? After considering this for a while, many people ask themselves things like, "Why do the cells in my heart need to have the same information as the cells in my stomach?" It's true that all of the 37 trillion cells in your body have all of the genetic information to be or do anything that your body does. It's also true that your DNA is 3 billion "letters" long; in other words each one of those 37 trillion cells contains 3 billion pieces of information!



Each cell in your body only uses the information that it needs from the DNA; in other words, your heart cells only use the heart information, the stomach cells the stomach information. But the cells carry everything around in case they need to become something else, a power which scientists are just beginning to use themselves!

So, how does that DNA actually *do* anything? The trick is that DNA is turned into proteins, and it's the proteins that make a heart cell beat, a nerve cell send messages, and a lung cell take up air. You can think of the relationship between DNA and protein like this: The DNA is like a page of instructions to build a house and the proteins are the wood, steel, nails, screws and glass that actually make up the house. Clearly, to get from the instructions (DNA) to the building materials (proteins), something needs to put it all together – so in come the ribosomes to actually make the protein!

The instructions contained in DNA are made up of only four bases: the chemicals **adenine** (A), **thymine** (T), **cytosine** (C) and **guanine** (G). Each base (or "letter") has a pair: every A is paired with a T, every T with an A,

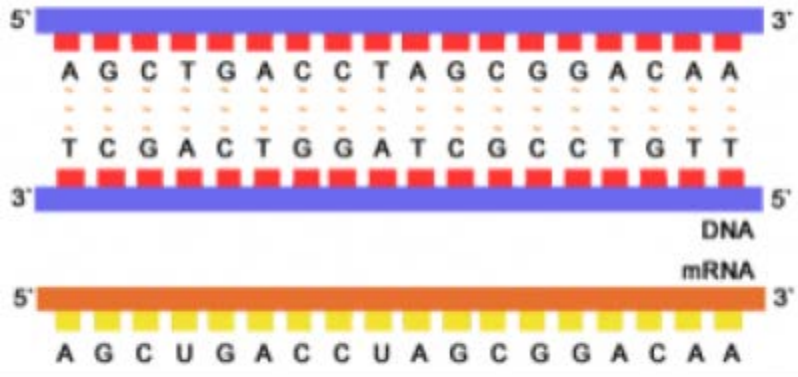


An overview of how the message from DNA becomes a protein

every C with a G, and every G with a C. Different combinations of these chemicals make "words", otherwise known as **codons**. Codons are made up of three letters in a row: ATG, GCC, ATC, etc. Ribosomes look at each codon and grab a different **amino acid**. The ribosomes keep adding amino acids until they get to the end of a **gene**. The string of amino acids that has been made is called a **protein**.

There is one step in the diagram which has not been mentioned yet. You may have already noticed that the DNA stays in the nucleus but the ribosomes stay outside the nucleus. So, how is it that the ribosomes make proteins from the DNA? There is a messenger that takes the instructions from the nucleus to the ribosomes: it's called **messenger RNA** (mRNA). As in our example from before, the instructions are contained in the DNA and the actual building materials are the proteins. Often, just like building a house, the instructions cannot be read by simply anyone. It's the job of the mRNA to put the bases into a language that the ribosomes can understand, which is called **transcription**.

RNA, as we saw with viruses, is very similar to DNA. There is one major difference: where DNA has thymine (T), RNA has uracil (U). This means that, if a DNA codon reads “ATA”, then the same codon in RNA will be “AUA”.



Transcription of DNA into mRNA

In summary, DNA contains the instructions in sets called genes. One gene is converted to mRNA, which goes outside the nucleus of the cell. Outside of the nucleus, the ribosomes read the mRNA, attaching one amino acid for every three base pairs (codon). This sequence of amino acids is a protein. For every gene of DNA, there is one and exactly one protein.

<u>Questions</u>

1. What are the four bases in DNA? What are they in RNA?
2. What takes the instructions in DNA from the nucleus to the ribosomes?
3. What is a gene?
4. CTACGCCATATTCGGCGATAC
    a. Convert the above DNA sequence into the opposite pair of each base.
    b. How many codons does it have?
5. CTACGCCATATTCGGCGATAC
    a. Convert the above DNA sequence into RNA.
6. Draw the following steps of how DNA becomes a protein in a Four Door foldable. The four doors should contain:
    i. A gene of DNA is transcribed into mRNA
    ii. mRNA leaves the nucleus
    iii. Ribosomes read the mRNA, adding amino acids
    iv. The amino acids form a protein

How Do We Pass On Our Genes?

Use the concepts of Mendelian and non-Mendelian genetics to explain inheritance. For example, incomplete dominance, independent assortment, sex-linked traits and linkage.

Inheritance

Mendel in his garden

Once upon a time there was a monk named Gregor Mendel. He was born in 1822 in (what is now) the Czech Republic, in Europe. He came from a farming family and was very interested in not only the family business, but also in beekeeping. When he joined a monastery in order to become a monk, he was sent to college to learn more science.

While he was at the University of Vienna, he was inspired to perform a few experiments on pea plants. He was particularly interested in how it was that some pea plants were different from one another.

Mendel had a lot of time on his hands – and peas. So he separated the pea plants that he had into several groups. Two of these groups were tall pea plants and short pea plants. The tall ones were actually taller than him, about 6 feet tall! The short ones were only about a foot tall, so it was easy to tell which was which. The interesting thing that he had noticed, though, was that there were no pea plants that were neither one nor six feet tall. This observation meant to Mendel that there had to be something else going on inside the pea plant.

Remember, in 1822, nobody knew anything about DNA, genes or **chromosomes**. So, Mendel took his two groups of pea plants, the tall plants and the short plants, and separated them completely. From his work in beekeeping, he knew that bees could carry the pollen from one plant to another, so he made sure there was no way the tall plants could share pollen with the short plants. After a few generations, there was nothing but tall plants in the one group and nothing but short plants in the second group. Mendel had successfully made two pure groups of pea plants.

After this, he started a third group. He brought together the tall plants and short plants in this third group, making sure that every new plant was a combination of a tall and a short plant. What surprised him was that *every single one* of the resulting pea plants was tall! What was going on here? Wouldn't you expect to see a mixture of tall and short pea plants, or plants that were medium-sized?

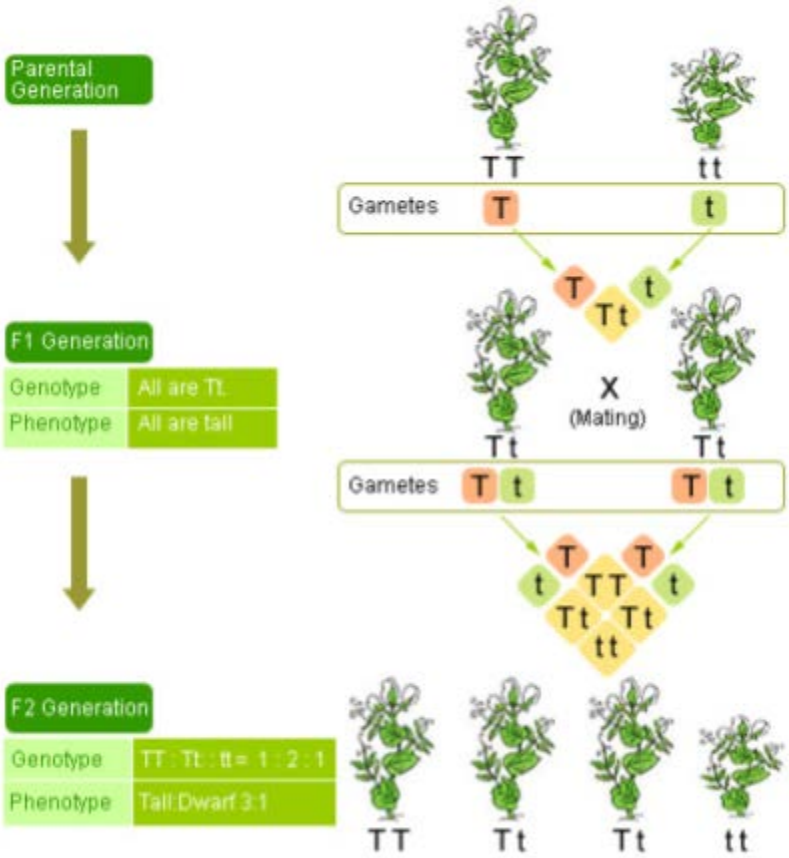
Mendel needed to know more. He called these new tall plants the *F1 generation* (after the Latin for the first children). He wanted more information: specifically, he wanted to know what would happen when these tall plants had offspring with each other. Would they have all tall offspring? Was the shortness of the one parent completely lost?

Mendel then combined the F1 generation (the tall plants) with each other. The results were incredible: 75% of the offspring were tall, and 25% of them were short! Somehow, these plants had "remembered" their short grandparents – but how? So Mendel made a hypothesis

that traits are carried from generation to generation in genes. Each individual has one copy from each of their parents, and the trait can either be **dominant** or **recessive**. In this case, he thought that the trait for being tall (for a pea plant) was the dominant trait and being short was recessive. But here's the tricky part of what he figured out.

Mendel figured that each plant in the F1 generation got one tall trait from one parent and one short trait from the other parent. Since the tall trait (or **allele**) was dominant, then it hid the recessive trait for being short. Even though he didn't use a Punnett square, he figured out that the cross between the two F1 plants went like this (T = tall, t = short) below to the right:

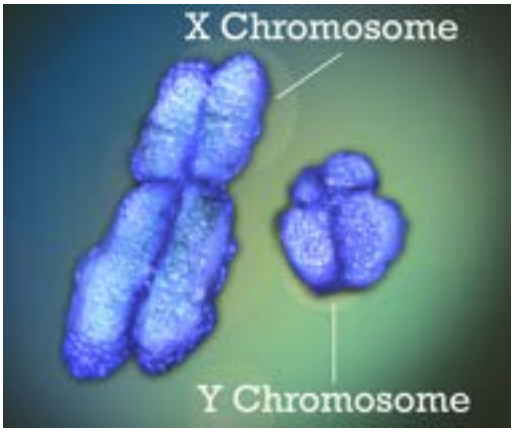
	T	t
T	TT	Tt
t	Tt	tt



Mendel's pea plant experiments

He repeated this experiment with many more traits and many more plants, coming up with roughly the same results each time.

Mendel looked at a total of seven traits of pea plants. One of the other traits was whether the seed of the pea was smooth or wrinkled. He observed that when he did the same experiment with this trait, the results were the same. So he decided to take the experiment one step further. He then combined the two traits: he took tall plants that made smooth seeds, tall plants that made wrinkled seeds, short plants that made smooth seeds, and short plants that made wrinkled seeds. He combined them in every way that he could think, but he found that no matter what he did, when he combined purely smooth seeds with purely wrinkled seeds, the offspring were all smooth. It didn't matter if they were tall or short at all. After trying this with several more traits, he found a pattern. One trait didn't affect any of the others. This came to be called the **Law of Independent Assortment**. All of the genes seemed to mix themselves up, and it didn't matter what the other traits were.

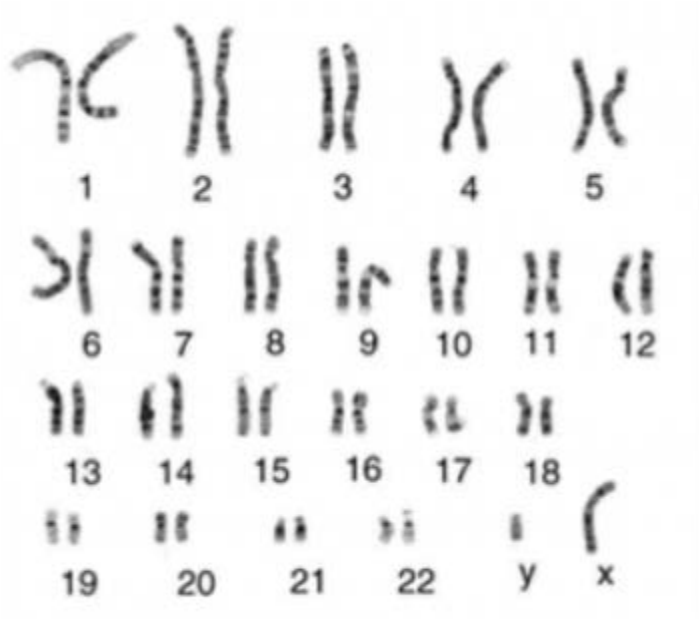


Later, scientists came to find that things weren't so simple. They actually saw that there were some traits that did depend on other traits. For instance, plants with yellow flowers were usually tall and plants with blue flowers were usually short. They explained this by saying that when genes are close together on a chromosome,

they can sometimes show **linkage**. This means that some genes are "linked" together and are not independent.

There's another type of linkage, called **sex-linked traits**, that Mendel did not describe. These traits are not necessarily traits that have anything to do with sex organs or sex cells. Traits that are sex-linked are on the sex chromosomes. It's important to understand that male humans and female humans have one major difference in their chromosomes: The 23rd and final pair of chromosomes is "XX" in females and "XY" in males. The "Y" in males is actually just a small chromosome (see picture) and contains much less information than the "X" chromosome. Because of this, there are alleles on the X chromosome that are not on the Y chromosome. For the alleles that are on the X chromosome but not the Y, they will always show up, dominant or recessive! Examples of sex-linked traits include hemophilia and color blindness. These traits, since they can be dominated in a female but not a male, often show up much more often in males than in females.

Well after Mendel passed, other scientists looked at his work and figured out that it fit in with their theories of inheritance. In fact, it wasn't until the 1930's that Mendel was recognized for his efforts and people began to accept that genes could be responsible for evolution! But Mendel's work still didn't explain quite a few things about genetics.



A karyotype of a male human showing all of the chromosomes

Questions

1. Why did the F2 generation of pea plants include short plants?
2. Define a sex-linked trait in your own words.
3. List all of the possible crosses among plants in the F2 generation.
4. Paraphrase the main experiment that Mendel performed in one paragraph.
5. Compare and contrast the Law of Independent Assortment and linkage in at least two ways.
6. Ask two thoughtful (not just factual) questions about Mendel's life to three other people. Record your results and underline your most difficult question.

What is on our Genes?

A gene is a piece of information passed from parents to offspring, and genes often are in different forms called alleles. For example, the gene for pea plant height has two alleles, tall and short.

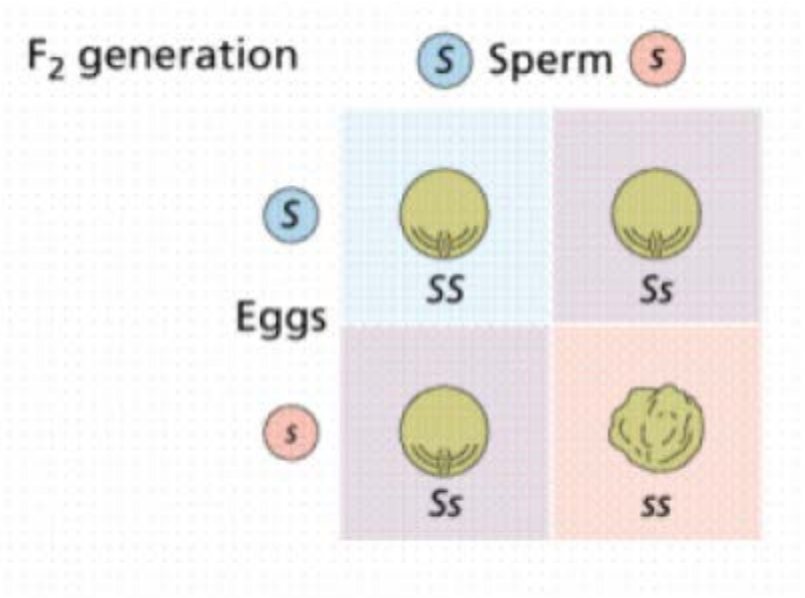
Genes

Every gene on a chromosome in our DNA makes a different protein. There are 20,500 of these genes in every human. Almost every single one of these genes are the same from person to person, which means that almost every one of these genes contain information for our lungs, heart, liver, kidneys, bones, brain and more. There are only a few genes that contain information for the color of our skin, hair, eyes, and the shapes of our faces, hands and feet.

Allele from mother	Allele from father	Gene that turns into a protein
Dominant	**Dominant**	**Dominant**
Dominant	Recessive	**Dominant**
Recessive	**Dominant**	**Dominant**
Recessive	Recessive	Recessive

Since we have two copies of (almost) every gene in our body, we call these copies **alleles**. We get one allele from our father and one from our mother. Since only one of those alleles can turn into a protein, it is the more **dominant** allele that gets turned into a protein by our cells. If both alleles are dominant, then it is clear that the dominant protein is made. If one allele is dominant, then the other trait (the **recessive** trait) is ignored and the dominant protein is made. Only when both alleles are recessive is the recessive protein made.

In order to try and figure out what the chances are of having a child with a dominant or recessive trait for a particular gene, something can be done called a **Punnett square**. A Punnett square is used to predict the probabilities and possibilities of traits in offspring. Along the top of the Punnett square, the alleles that could come from the father are listed, and the alleles from the mother are listed along the side. In the middle of the Punnett square, the possibilities for offspring are listed. Each square represents a 25% chance of getting that type of offspring. If an offspring has two of the same allele, it is called **homozygous**. If it has two different alleles, it is called **heterozygous**.



A Punnett square showing a cross between two pea plants

Questions

1. What does dominant mean? Recessive?
2. Define, in your own words:
    a. Homozygous:
    b. Heterozygous:
3. In terms of homozygous, heterozygous, dominant and recessive, label:
    a. HH –
    b. Mm –
    c. bb –
4. Give names and percentages for the following Punnett square:

	R	r
R	RR	Rr
r	Rr	rr

Genotype	Homozygous or heterozygous Dominant or recessive	%
	Homozygous Dominant	
Rr		
		25%

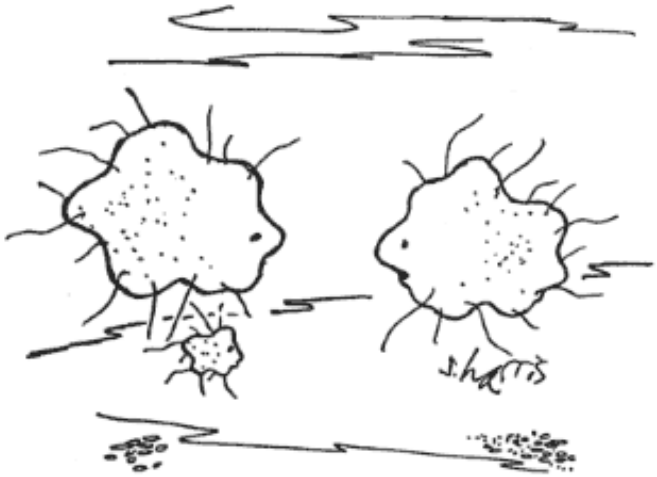
5. As you did above, complete the Punnett square and percentages for the following:
    a. Between homozygous dominant for round peas and heterozygous
    b. Between homozygous dominant for unattached earlobes and homozygous recessive for attached earlobes
    c. Between homozygous recessive for green eyes and heterozygous
6. With a partner, agree on a gene for making a Punnett square. Also, agree on the dominant and recessive alleles. Independently, come up with the genotype of both parents (one of you should be the mother, the other the father), then create a Punnett square for the combination of the two parents. If these two parents have six children, what would be the most likely numbers of dominant and recessive traits in the children?

How Do Cells Form New Cells?

The way that body cells divide and become organized groups of cells is called mitosis.

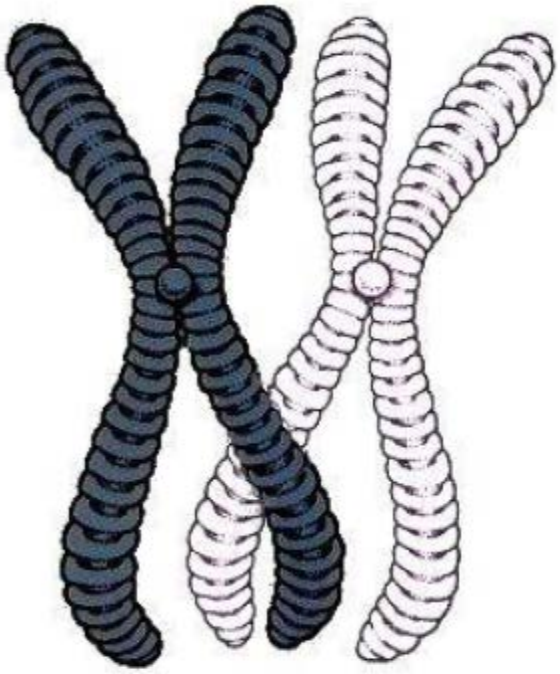
Mitosis

When a human sperm and an egg come together, they combine all of their genes to form the first **cell** of a new human being. This first cell then must become all of the cells that make up a human: nose, hair, skin, teeth, heart, bones, and everything else! **Mitosis** is the process where one body cell becomes two body cells. The two cells that result are called *daughter cells*. Even though the two daughter cells have exactly the same genetic information as the *mother cell*, they may be slightly different from each other.



"He looks just like you.
But he looks just like me, too."

Every cell in the human body has 46 chromosomes of DNA in the nucleus. Those 46 chromosomes are all paired up, so we often say that humans have 23 pairs of chromosomes. You get one set of chromosomes from your mother and one set from your father. In the diagram, we can say that the dark chromosome came from your father and the light chromosome from your mother. This is called a pair of **homologous chromosomes** because they contain similar genetic information. What's interesting is that every cell in your body (except one special place which we'll see in a minute) has the same exact chromosomes!



Two homologous chromosomes: together they have four chromatids

When we talk about mitosis, we're concerned with what the chromosomes do in each cell. The trick is that each of those 46 chromosomes needs to make a copy of itself so the two daughter cells can have the same chromosomes. The first thing that the cell needs to do is to grow in order to prepare for splitting into two cells. This first *phase* is called **interphase**, or the growth phase.

While the cell is growing, the chromosomes are not organized: they are like strands of spaghetti spread throughout the nucleus. During the next phase of mitosis, **prophase**, the chromosomes get organized and ready for mitosis. Then, all of the chromosomes line up in the middle of the cell in **metaphase**. In **anaphase**, the chromosomes split apart at the **centromere**, which is the button-like structure in the

middle, into their *sister chromatids*. Those sister chromatids go to opposite sides of the cell, and then the cell begins to split into two separate cells. This final phase is called **telophase** and results in two identical cells. During the next interphase, each sister chromatid now makes a copy of itself in order to be complete. After that, the whole process happens again!

Normally, mitosis stops in parts of the body where cells are crowded together. In fact, certain genes in your cells tell them when they should stop reproducing. Sometimes, these genes get damaged and the cells keep reproducing; often, these cells that are growing out of control form **cancers**. There are many causes of cancer, because there are many reasons that the genes can become damaged: age, viruses, tobacco smoke, diet and disorders that you inherit from your parents can all cause cancer.

Questions

1. In which cells does mitosis happen?
2. What are homologous chromosomes?
3. Identify one word for each phase of mitosis that will help you remember what happens in that phase.
4. Why should it be useful that most cells stop growing and reproducing at some point?
5. When would it be necessary for the two daughter cells to be different than the mother cell?
6. Design a small flip book of approximately 8 pages to demonstrate mitosis. Label all illustrations and include a small description of what is occurring on each page. Each part of the cell should be colored the same throughout the book.

How Come We Have Different Cells?

Certain cells become different types of cells (differentiation), and they all play a certain role that is useful to organisms.

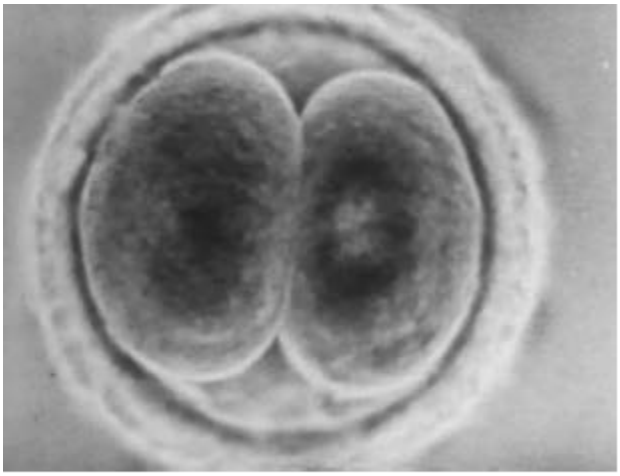
Cell Differentiation

After meiosis, you have either sperm cells or egg cells. Eventually, one of those sperm or egg cells may combine and form a **zygote**, or the beginning of a new life. As soon as the sperm donates DNA from the father to the the DNA of the mother (that's in the egg), the cell begins to divide. In other words, two haploid cells (n) combined to form one diploid cell (2n). Now, this zygote is undergoing mitosis.

Organs of the human body

Soon, this bag of cells will begin to *differentiate*, or become different types of cells. Different types of cells are called **tissues**, such as muscle tissue, cardiac tissue (that makes up your heart) and nervous tissue (making up nerves, brain and spinal cord). Tissues can be organized into **organs** (such as the heart, skin, brain and liver) and then organs can be grouped into **organ systems** (such as the nervous system).

If your body didn't start to produce different types of cells, then you would just be a 140-or-so-pound ball of living cells that couldn't really do much of anything. It would be just about as boring as it sounds. But because the purpose of life is to make more life, we need to have a reproductive system that is made up of the organs like ovaries and testicles. Also, we need to be able to eat so that we can get nutrients for our reproductive system; therefore, we need a digestive system that includes organs like the mouth, stomach and anus.



A dividing zygote

You can see that for every need, there is a system of organs that is responsible for taking care of that need. Since we have a skeletal system, we can walk around; our nervous system allows us to communicate among all the different parts of our body. What is most interesting, however, is the fact that all of these systems come from two simple cells that combine to form a zygote: a sperm and an egg. **Cell differentiation** means that all of these cells – heart, skin, bones, nerves, ovaries – essentially come from one zygote. This zygote has to divide enough times and make enough changes each time so that all of these different cells can be made. Even

though mitosis produces two cells that have the same DNA, these two cells may not look or act the same!

Students in a school can all be presented with the same lunch, not every student will do the same thing with the lunch. Some students will say, “Eww, this looks disgusting,” and choose to eat chips instead. Other students will say, “Well, I guess I could eat this,” and still others will say, “Wow, this looks great!” In other words, different people had different reactions to the same lunch. In the same way, the different cells that your body produces have different reactions to the same DNA. Over time, all of the different cells in your body will be produced. After a cell has been *differentiated*, it usually can’t turn into any other type of cell. For example, a nerve cell will always be a nerve cell; a heart cell will always be a heart cell.

Questions

1. What is cell differentiation?
2. What is the difference between a cell that is haploid and a cell that is diploid?
3. Identify five organ systems and the problems that they solve.
4. Make a diagram to show the relationship between cells, tissues, organs and organ systems.
5. Like the lunch story in the passage, what is another case where people have different reactions to the same thing? Explain!
6. Imagine that you could add a whole new function onto your body. What would it be? Design an organ system that has at least three organs. Give names to everything!

Who Came Up With Evolution?

Describe historical scientific developments that happened in evolutionary thought. For example, Lamarck and Darwin and Mendelian Genetics.

History of Evolution

Once scientists started noticing that the best organisms were surviving and the weak were dying, they called this **natural selection**. This part was clear to all scientists, as natural selection happened in all parts of their daily lives. What scientists did not agree upon, though, was how organisms got more advantageous characteristics, like long necks, specially adapted noses, or short beaks.

There is now a lot of evidence for the type of evolution that Darwin first proposed. It is not a fact that evolution happens this way, as the theory is always changing very slightly. Unlike natural selection, evolution is actually a fairly complicated theory that takes some time to truly understand. However, evolution takes into account all of the current evidence that scientists have brought to light.

Evolution basically means that groups of organisms change over time. These groups, or populations, get more and more advantageous characteristics for their environment over the course of many generations. Short-trunked elephants were not suddenly taken over by one mysterious long-trunked elephant. What most likely happened with elephants is that the elephants in each generation with the longest trunks were the ones to survive.

Evolution does not happen to individual organisms. Individual organisms can change, but unless that change gives them an advantage and they can pass it on to their offspring, it will not matter. If the male elephant with a longer trunk is unattractive and smelly, then it's possible he won't be able to find a lady elephant and will never pass on his longer trunk to any offspring. How sad!

Evolution is not just a series of accidents. Unless a change has some advantage, the organism will not survive as well and die. It is also not a series of events to get to some end animal. Evolution didn't happen to elephants because elephants were destined to have long trunks.

Evolution happens for a reason: The changes in the population help the organisms survive better. Since there can be millions of different possible changes, there is no "correct" change that has to happen. Nobody can predict how evolution will change bacteria, elephants or even humans over the next million years.

Evolution is not just a theory about humans, it's about all living things. Evolution is also not a system of beliefs! Evolution just happens to be the best explanation for what scientists

can observe about the world. Therefore, evolution says nothing about the presence or absence of God, or about what you should or should not believe.

There are many misconceptions about evolution. Scientists do not think that humans evolved from monkeys; rather, humans and monkeys are thought to have a common ancestor some many millions of years ago. This ancestor was not necessarily like today's monkeys and also not exactly like a human. But because evolution means that organisms are constantly improving themselves over time, this ancestor of ours does not exist any more because some of their offspring evolved into monkeys and some into humans.

Another misconception about evolution is that humans and dinosaurs lived at the same time. Well, it is true that ancient ancestors of humans, about the size and shape of a large mouse, lived at the same time as dinosaurs. However, it took millions of years after dinosaurs went extinct for most of the mammals that are around today to evolve, including humans!

Questions

1. Complete this phrase in your own words: Evolution means that …
2. Did humans evolve from monkeys? Explain!
3. Is evolution happening right now?
4. Is there such a thing as scientific fact? Why or why not?
5. Infer what would have happened if the common ancestor between monkeys and humans had never been able to reach the ground from the trees it lived in. Come up with at least two points to support your hypothesis.
6. Think about the small mammal that was described at the end of the reading. After the dinosaurs went extinct, how do you think this population of mouse-like mammals started to evolve? Come up with three different populations of organisms that you feel must have evolved from this one mouse-like population. Describe each one in one paragraph that explains why they evolved the way that they did and make a quick sketch of each one.

How Can You Tell Evolution Is Happening?

Recognize that a change in gene frequency (the number of organisms that have a gene) in a population over the course of years is an important aspect of biological evolution.

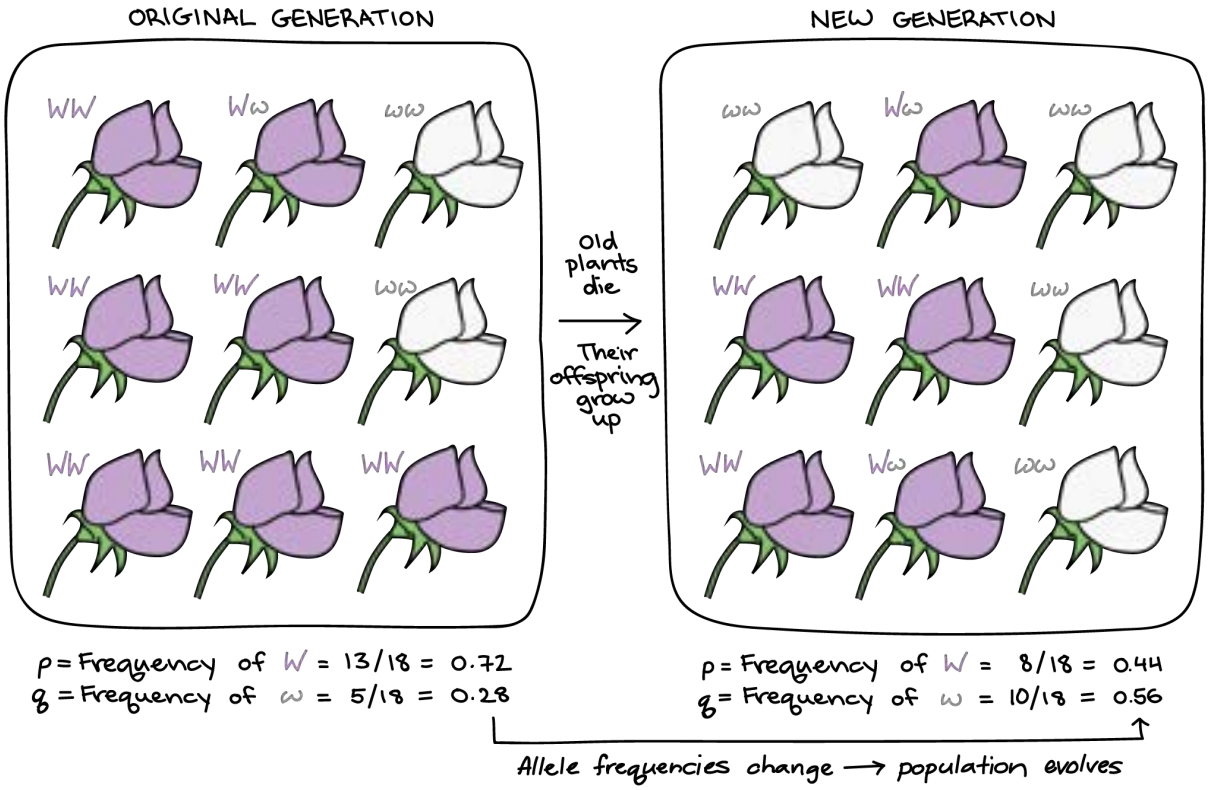
Gene Frequency

A gene, or a characteristic that is part of your DNA, determines your traits. Genes have all of the information that makes you who you are, including hair color, skin color, eye color, height, and which hand you use to write. Since some characteristics are advantageous in certain environments, what color and texture your hair is, the color of your skin and more all depend on the environment where your ancestors were.

Two very happy people. With different skin tones.

For example, people who come from southern Africa typically have darker skin and darker hair than Europeans or northern Africans. There is a good reason for this. When sunlight hits human skin, our bodies use that energy to make vitamin D. Vitamin D is necessary for us to have strong muscles and fight disease, but we can also get too much vitamin D. An excess of vitamin D can cause your kidneys to fail and eventually result in death where there is a lot of sunlight! So, in areas where there is not a lot of sunlight, it pays to have light skin and absorb more sunlight and therefore make more vitamin D. In areas with a lot of sunlight, it pays off to have dark skin in order to not absorb as much sunlight and avoid an excess of vitamin D. Of course, there are many other reasons that we have a certain skin tone. More importantly, our skin tone is not just controlled by several different genes, it's also affected by our environment!

Gene frequency refers to the amount of times in a population that a certain gene happens. From our example above, we would expect that the genes which cause a darker skin tone in humans have a higher frequency in Africa than in Europe. It is much easier to talk about evolution when you can talk about the differences in gene frequencies between different populations. When talking about human populations, the differences between an African and a European are actually very small – even though they are very noticeable! If you choose two random Americans that have similar skin color, facial features, height and weight they will still have many genetic differences. In fact, they will have as many genetic differences as between a light-skinned European and a dark-skinned African! As humans, we are all very complex and have millions of small differences, some more noticeable than others.



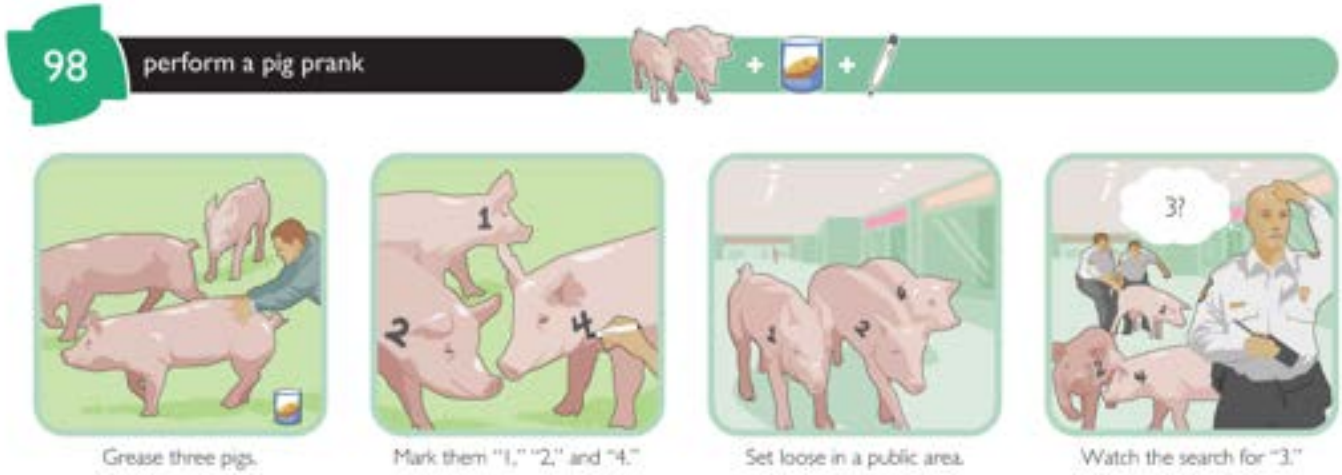
Questions

1. What is a gene?
2. Define gene frequency.
3. List at least four genetic characteristics.
4. Explain why there is a difference in skin tone between Europeans and Africans.
5. Give an example of a gene that has different frequencies in different populations (meaning, a trait that looks different).
6. Skin tone is one of many human characteristics. Choose a different human characteristic. Create a timeline with at least five events as to what will happen to this characteristic in American people over the next 500 years. Then, write three sentences:
    a. What is your prediction of what will happen with this characteristic over the next 500 years?
    b. Why do you think that this will happen?
    c. Give a summary of your timeline.

Why Do Animals Survive or Die?

Natural selection means that there are random differences in characteristics that organisms inherit from their parents. These characteristics may give individuals an advantage or disadvantage compared to others in surviving and reproducing. The advantaged offspring are more likely to survive and reproduce. In this way, there will be more of the organisms with advantageous characteristics. When an environment changes, characteristics that give an organism an advantage may change.

Natural Selection



Grease three pigs. Mark them "1," "2," and "4." Set loose in a public area. Watch the search for "3."

Natural selection exists everywhere. If you are into sports, then you already know that you have to be a good team to win the Super Bowl, NBA Finals, or the NCAA Championship. From your everyday experiences, you know that the stores in Cleveland will only survive if they do good business. The stores that have prices that are too high, things to buy that are of low quality, or are not well maintained will fail.

Sports teams and stores on the street are both excellent examples of natural selection, even though it may not seem like it at first! You may think that some scientist came up with some very complicated and hard to understand theory, but natural selection is actually the simplest explanation of what has been going on for billions of years. If you do well, you survive – if you don't, then you die.

Natural selection in football

Going back to sports, if the Cleveland Browns (magically) won the Super Bowl this year, that would mean that they were a good team. It doesn't matter what you *think*, but because they out-competed all of the other teams, that means that they played the game better than those teams. It's important to realize that natural selection isn't about what scientists think *should* happen, it's about noticing what *does* happen. So, if the Browns win the championship, they are a good team. Furthermore, if they win, then companies will want to give them money so that the company can be associated with a "winner." With this money, the

Browns can improve their training, their stadium, or go out and get better players. This means that because they won, they will be better prepared for the future.

Natural selection says that the best organisms will survive *and* reproduce more individuals like themselves. The weakest individuals die and do not get to reproduce. In a population of wild cats, the cats that are able to hunt the most birds survive and produce kittens; the cats that are unable to hunt birds die.

Going back to the stores, if Bob's Discount Gas offers gas for $3.00 a gallon, even though it costs them $3.50 a gallon, then they will eventually go out of business. This means that the other gas stations will benefit and get more money that people aren't spending at Bob's. The weakest die off, leaving the strongest with the rewards.

When scientists are talking about living things and natural selection, there are a few key terms that are used in order to make things easier. The individuals that have characteristics which make them stronger than the others are the **advantaged offspring** (in the example, this would be the Browns). The characteristics that make them stronger are called **advantageous characteristics**. Again, it doesn't matter what you think is a better characteristic – it all depends on what ends up helping an organism survive and reproduce!

Even more importantly, what happens when the environment changes? In other words, what happens if the NFL decides to make the field 20 yards longer, the NBA decides to move the 3-point line to half-court, or the NCAA decides that the shot clock should be 24 seconds instead of 35 seconds? You can imagine that different teams would do better under these circumstances. The same thing would happen to Bob's Discount Gas if all of the other gas stations went out of business; all of a sudden, they would be doing very well because they could set whatever price for gas that they wanted! If the environment changes, then some characteristics that did not help the organism before may now be advantageous. If suddenly there are no birds for our wild cats to hunt, then the cats that are better mouse hunters will survive better and reproduce more good mouse-hunters.

Questions

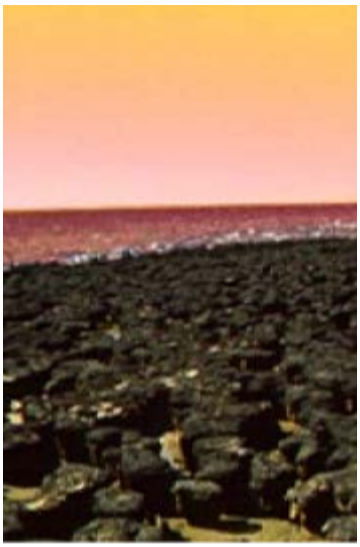
1. Define natural selection in your own words.
2. Which are the advantaged offspring out of any population of offspring?
3. Why doesn't it matter what scientists think about natural selection?
4. Describe an advantageous characteristic using an example of your own.
5. Select one sports team that you think will win this year. Explain why!
6. Create a change in the environment of Cleveland. Predict at least three stores that will survive and three stores that will go out of business because of this environmental change. Explain why they would survive or go out of business.

How Do We Know So Much About Life?

Geologic time can be estimated in many ways. For example, rock sequences, matching up fossils and radiometric dating.

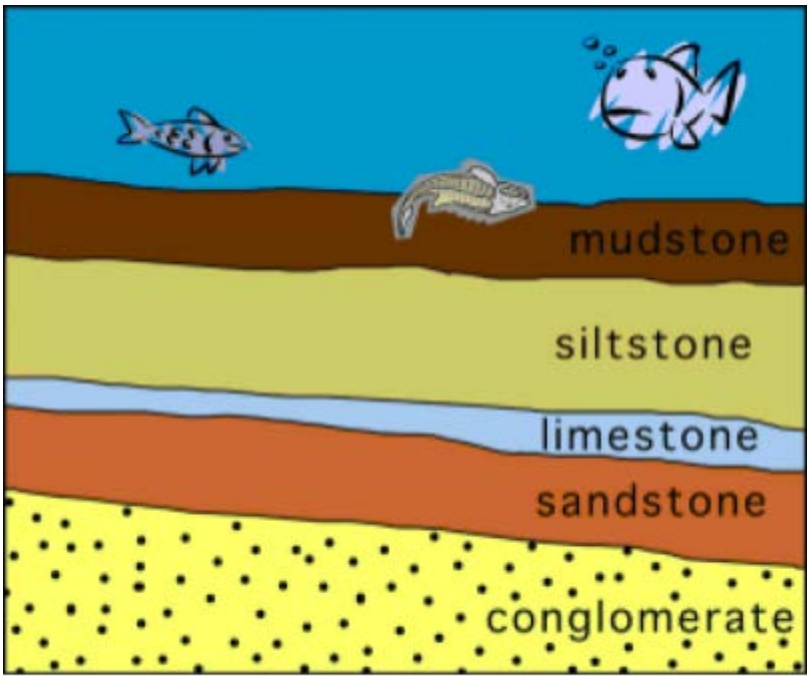
Geologic Time

The Earth is really old. Really, really, really old. We've already seen that scientists estimate it's about 4.6 billion years old. That's much older than you can think back. But what's even more interesting is the fact that it was so hot that there wasn't even any solid rock for about 500 million years. This means that Earth was a ball of boiling hot liquid with no land to speak of. After a few million years, the outer layer of the Earth cooled down enough to be solid (like the crust of a pizza) but the inner part of the Earth was still hot liquid magma. Of course, that magma wanted to get out of the middle of the Earth. So, the magma bubbled up through the crust (these are volcanoes), and so gases and water vapor ended up coming out of the hot Earth and landing in the atmosphere. That water vapor cooled down enough to become the ocean, which is where it's believed life began.



An artist's idea of what the early Earth looked like

So there were these tiny, microscopic living things in the ocean. Amazingly, some of them actually turned into **fossils** so that scientists know that at least 3.5 billion years ago, these small organisms existed! Furthermore, scientists find these organisms inside of certain types of rocks that only existed during a certain time period. By doing all sorts of chemical testing, scientists can estimate how old a particular type of rock is, and once they know that, they know how old the fossils are inside of that rock. The guides which help scientists all over the world figure out how old rocks are are called a rock sequence.



A sample rock sequence

One of the tests that scientists can do to figure out the age of rock is called **radiometric dating**. Radiometric dating uses processes that happen naturally to be able to tell how old certain things are. For example, you have a squirrel and an apple tree. Well, this squirrel happens to like eating apples, but will only eat *one* per day and leaves behind the core of the apple. One day, you happen to go past your apple tree and notice that there are 90 apples still on the tree and 10

apple cores on the ground. Assuming that nothing else happened with the apples or the cores, you know that the squirrel has been eating apples for 10 days. If you went by the tree seven days later, you would expect to see 17 apple cores instead of 10.

Radiometric dating is very much like this. There are certain chemicals, like uranium, which are **radioactive** and break down over time. They actually form other chemical elements, as uranium will form lead, just like the squirrel in our example turned the apple into a core. Scientists know how long it takes for uranium to break down into lead, so if they find some uranium and lead together, they can figure out how long that uranium has been around, and therefore how old the rock is. For example, if 90% of the rock is uranium, then it's older than rock that's 95% uranium.

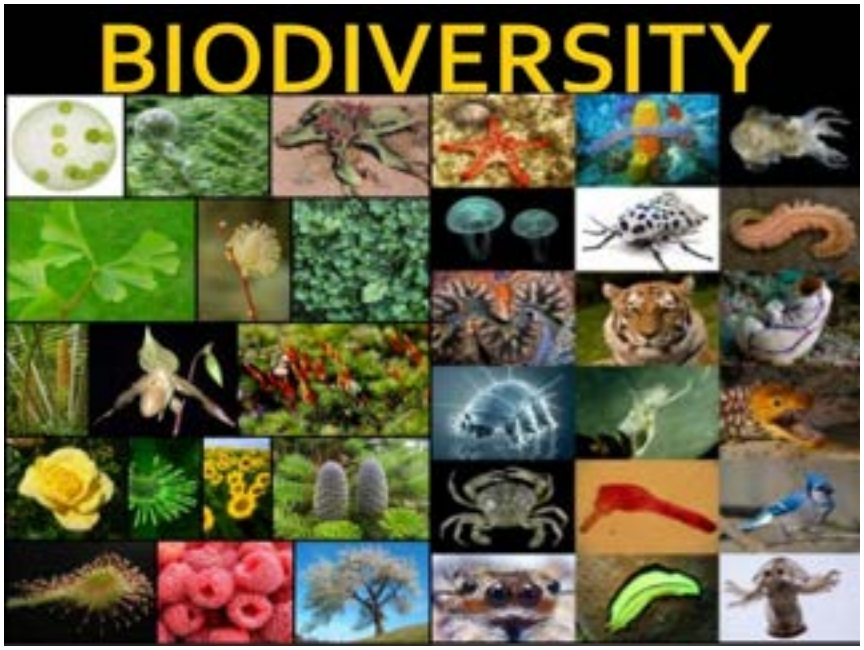
Questions

1. What is a fossil?
2. What can radiometric dating tell scientists?
3. Is there just one rock sequence? Why or why not?
4. If you compare the rock at the bottom of a rock sequence with the rock on top, what do you know about how old the rock at the bottom is?
5. Carbon-14, which is an unstable chemical, breaks down to form carbon-12. If sample A has a higher percentage of carbon-14 than sample B, then what do you know about the age of sample A?
6. Create a rock sequence (like the sample from the reading) from the following information:
    a. Scientists found four layers of a rock sequence in Cairo, Egypt
    b. A fish fossil, Andrea, was found in a layer of conglomerate
    c. The layer of granite was the oldest rock found in Cairo
    d. A dinosaur fossil, Beth, was found in a layer of limestone
    e. A layer of shale was found in between the conglomerate and limestone
    f. Beth was found to have a lower percentage of carbon-14 than Andrea

Why Are There So Many Butterflies?

Understand how the diversity in an ecosystem and the adaptation of organisms to an ecosystem relates to structures and their functions in living organisms. Natural selection helps explain the diversity of life.

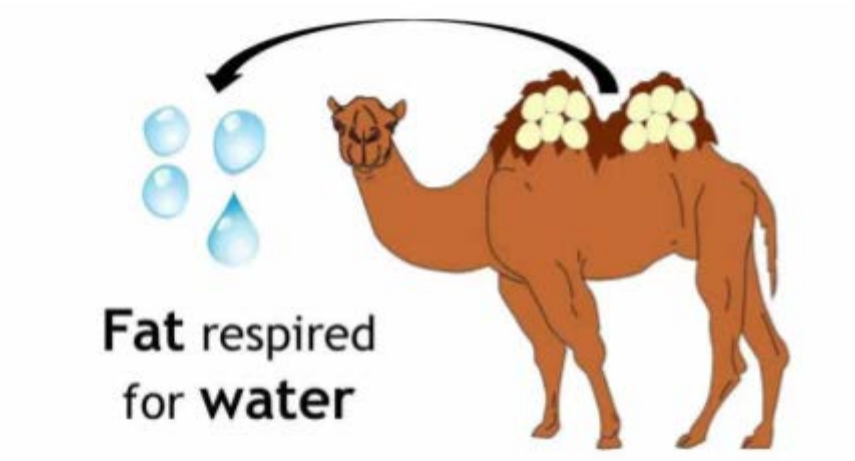
Diversity and Adaptation



We hear a lot about **diversity** in our society. We understand diversity in humans to mean how we speak different languages, eat different foods, have different value systems or how we look different. Many types of scientists study diversity, like anthropologists who study social relationships, linguists who study languages, and dieticians who study nutrition. Biologists are mostly concerned with the genetic diversity between populations. When we consider biomes, now we're concerned with the **biodiversity** among populations in an ecosystem.

What does this all mean? Well, different populations make different **adaptations** to their environment. If we're studying the tundra, all living things need to deal with the cold. A polar bear will gain more fat in order to keep its heat inside; an arctic fox will keep warm blood from reaching its feet so that it doesn't lose heat to the ground; shrubs will grow a protective coating around their stems to protect them from low temperatures and high winds. All of these adaptations allow these living things to live in the tundra.

You can see how diversity and adaptations are linked together: organisms find diverse ways to adapt to their environments. We can even introduce another concept that we've learned, natural selection! The organisms that are able to adapt better to their environment survive better, which means that they are more likely to reproduce.



An adaptation that camels have is that they can use the fat that they store in their humps to get water!

If we go back to the example of the butterflies and birds, it's completely possible that there were *no* blue and black butterflies a few weeks before we visited the field. It's very likely that among the thousands of butterflies, some mutations will happen: one of

them happened to change the color of the butterfly from yellow to blue. This caused the butterfly population to have higher diversity. When birds started to hunt the yellow and black butterflies, the population adapted to the change in the environment by favoring the blue and black butterflies. Natural selection happened when those blue and black butterflies reproduced, eventually making more that had the same coloring!

Questions

1. How are diversity and adaptation related?
2. Explain natural selection using terms from this chapter.
3. Define biological diversity in your own words.
4. Choose an animal that you are familiar with. Explain how different populations of this animal are diverse, in three ways.
5. Select a biome and a living thing. What sorts of adaptations has this living thing made in order to survive in this biome?
6. Design a T-shirt to represent the term “biodiversity.”

Do All of Our Cells Divide the Same Way?

The way that gametes are formed is called meiosis.

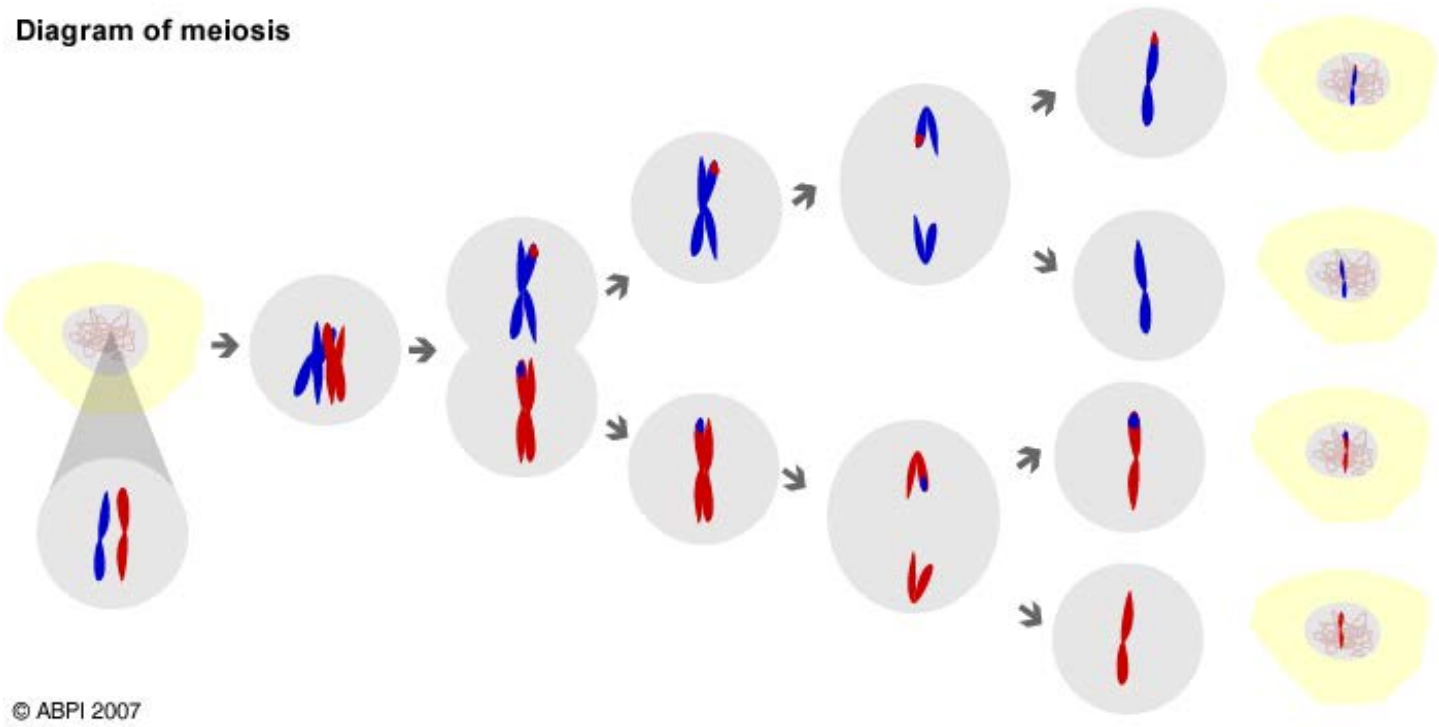
Meiosis

Think about this: Every sexual organism gets half of its DNA from its mother and half from its father. How does that happen? If every parent gave its offspring *all* of its DNA, then the offspring would have double what it needs. That's why there's meiosis.

Meiosis is just like mitosis except for a couple of important things. Mitosis happens in all of the cells *except* for the sex cells. In humans, these are the sperm and egg cells; these cells divide by the process of **meiosis**. In a human being, meiosis begins with one cell and ends with four. Each cell starts with 46 chromosomes and ends with 23 chromosomes!

Just like mitosis, there are five phases, but the important difference is that those five phases happen *twice*. The first time they happen, they are called **prophase I**, **metaphase I**, **anaphase I**, and **telophase I**.Interphase of meiosis actually doubles the number of chromosomes before meiosis starts, so prophase I happens with two copies of each chromosome, for a total of 92 chromosomes (in a human). At the end of telophase I, each cell has 46 chromosomes.

In the second half of meiosis, the phases are called **prophase II**, **metaphase II**, **anaphase II**, and **telophase II**. This time, each cell begins with 46 chromosomes in prophase II, and like mitosis, ends with 23 chromosomes. Unlike mitosis, however, the chromosomes do not make copies of themselves. The reason that this is important is because these 23 chromosomes will combine with 23 from another cell. If this is a sperm cell, it will combine with an egg to form 46 total chromosomes.



We call the cell that is normally found in the body of a human a **diploid** cell because it has *two* copies of each homologous chromosome. We can also represent this by saying that it

is “2n”. A **haploid** cell has only one copy of each homologous chromosome, represented with “n”. Body cells are diploid, but sperm and egg cells are haploid.

Questions

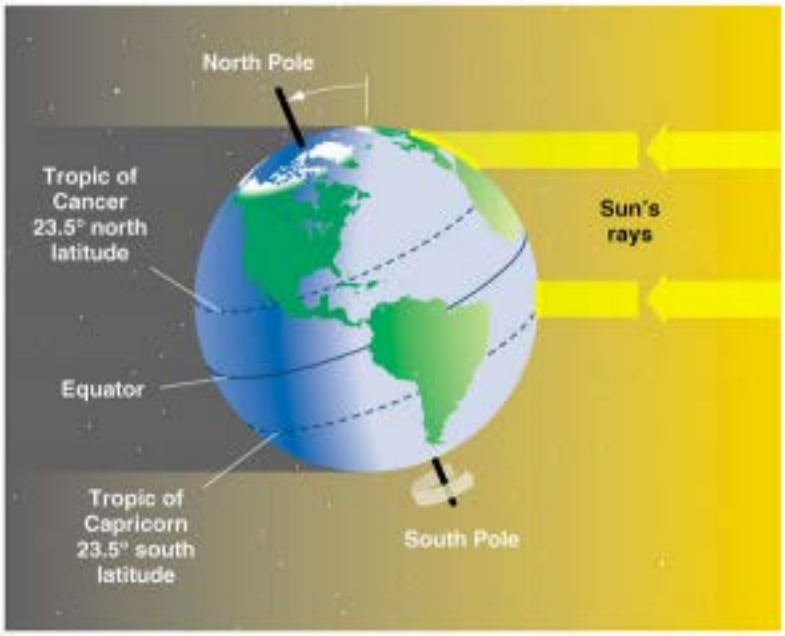
1. In which cells does meiosis happen?
2. What is the difference between diploid and haploid?
3. What human cells are haploid?
4. Complete a compare/contrast chart comparing meiosis to mitosis.
5. Complete a cycle chart for meiosis. Include both the name of the phase and a summary of what happens in that phase.
6. Draw a cell going through meiosis. Assume that the cell normally has 6 chromosomes, so that it will have twelve in Prophase I and three chromosomes by the end of Telophase II.

Why Are There Different Environments?

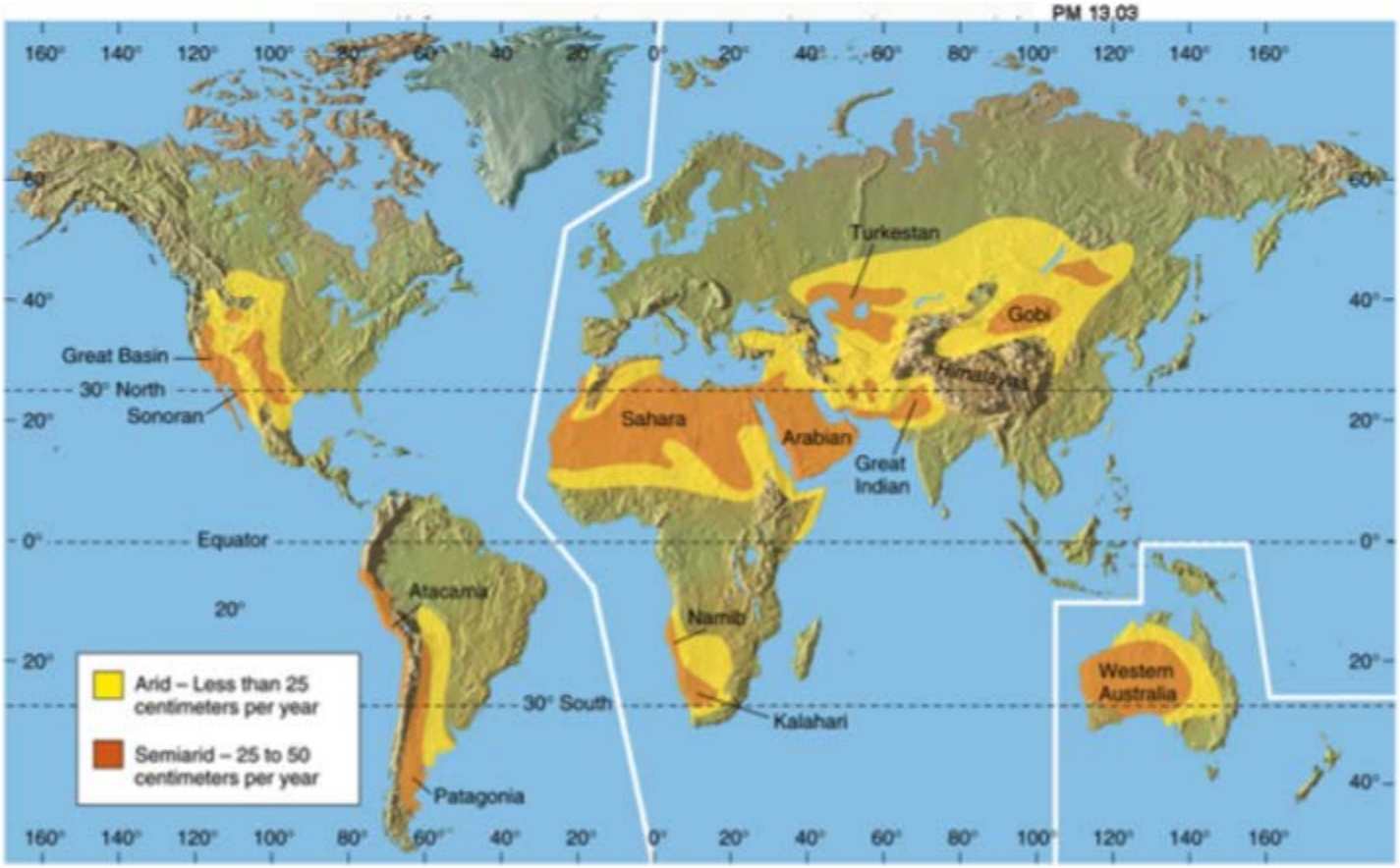
Understand the relationship between the climate of an area and the biome that it is in. Also, understand why rain falls in certain places and what that has to do with temperature.

Biomes

Here in Northeastern Ohio, we have four seasons: summer in June, July and August, winter in January, February and March. But this isn't the case all over the world. Some places in the world have a very long winter and a short summer, like in northern Canada. Other places have a very long summer and a short winter, as in Sub-Saharan Africa. Obviously, Canada feels a lot different than Africa. We can see that temperature has a big effect on **climate**.



Take another scenario: even though the temperatures and locations are very similar, Miami and Los Angeles are very different. Miami gets almost 5 feet of rain every year, while Los Angeles only receives

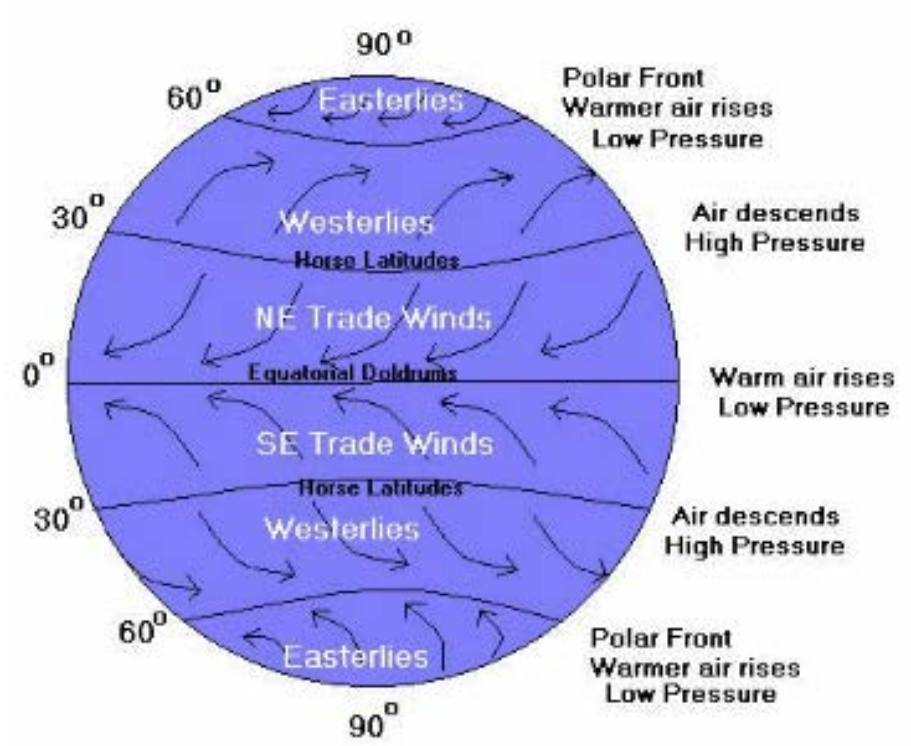


Deserts throughout the world

slightly more than a foot of rain annually. Cleveland, by comparison, is in between Los Angeles and Miami at about 3 feet of **precipitation** per year. Los Angeles is in a climate that can be considered a desert but Miami is not. Precipitation (rain, snow, sleet, hail, etc.) also has a big effect on climate.

So what is climate? Climate is the group of conditions of the atmosphere near the earth's surface at a certain place on Earth. We can say that the climate of Cleveland is that we have warm, humid summers and cold, snowy winters. Of course, there is a lot more that we could say about the climate of Cleveland, but that's enough to start talking about **biomes**.

A biome is the combination of a particular climate and the living things on Earth that live in that climate. An easy way to describe a biome is to say what the temperatures, precipitation, plants and animals are in that particular biome. In our biome (temperate deciduous forest), we have a lot of deciduous trees, which are the ones that lose their leaves in fall. We also have plenty of grasses, small mammals, insects and a high population of humans.



A biome depends greatly on climate. Certain animals and plants cannot survive in certain climates: just like there can't be evergreen trees in the desert, palm trees don't survive well in Antarctica! Likewise, certain animals are adapted to certain biomes, but not other ones. It's hard to imagine an elephant in a snowy field or a polar bear on a tropical island. Of course, if global warming continues, this type of situation may happen.

Speaking of global warming, it's important to understand how certain parts of the world get more heat than others. The sun remains about the same distance away from the Earth all year, every year. What causes the change in seasons is the amount of *direct* sun that a certain area gets. Because the Earth is slightly tilted on its axis, the sunlight that we get in the summer is much more direct than the sunlight that we get in the winter. Summer is like shining a flashlight directly into someone's eyes, and winter is like shining the flashlight from underneath your chin as if you were telling a scary ghost story. From the diagram, you can see that indirect sunlight gets spread out over the surface of Earth more than direct sunlight.

Precipitation, or when water falls from the atmosphere in any form, is caused by a combination of factors. The sunlight that hits the Earth and the rotation of the Earth both play a role in the winds that control Earth's climate zones. From the diagram, you can see that winds take moisture away from certain parts of Earth and deliver precipitation to other parts.

Depending on the temperature of that air, the precipitation will be rain, snow, or something in between. And if global warming causes the temperature of the oceans to continue to rise, then more and more water will evaporate, causing more and more precipitation!

Questions

1. What is climate, in your own words?
2. State the relationship between climate and biomes.
3. List at least five different types of precipitation (you need to come up with one of them on your own).
4. Support the following statement with two pieces of evidence (including pictures) from this chapter: "The equator is the hottest place on Earth." One of your pieces of evidence must have to do with winds.
5. Why are most of the world's deserts around 30°N or 30°S latitude? Use the diagrams and pictures in this chapter to help illustrate your answer, including "How Sunlight Hits Earth" and "Winds on Earth".
6. Draw a diagram showing the Earth's axis and the United States during the four seasons in the northern hemisphere. Include the sun in the middle and show how direct the sunlight is in each season.

Why is Balance Important?

Ecosystems tend to have cycles that change around a state of equilibrium that can change when climate changes, when one or more new species appear as a result of immigration or when one or more species disappear.

Equilibrium

Every living thing needs to be in balance with its environment. In northeastern Ohio, there are tens of thousands of deer. In some places the deer population has gotten too big, meaning that it's out of balance. When there are too many deer, then they start eating peoples' bushes, shrubs and grass. This results in unhealthy deer and unhappy people! In other words, the deer are out of balance with their environment; there isn't enough food to support them all.

Equilibrium is about balance

Equilibrium is when there is a balance between two or more things. In biology, when we talk about equilibrium, we're talking about living things being spread out so that they can get their four basic needs met: food, water, shelter and space. If they are unable to get any of these basic needs met, then they are out of equilibrium with the environment. Even more importantly, if *other* organisms are unable to get any of their basic needs met because of the deer, then the deer are out of equilibrium with their environment. If you take too much or get too little from your environment, then you're not in balance with your surroundings!

The example between the deer and peoples' trees, shrubs and grass is a little silly: the deer don't prevent us from getting our basic needs met. But there are areas of Ohio where deer are responsible for the destruction of **crops** (plants farmed for food) which does threaten that most basic of our needs, food.

Rabbits in Australia

The reason that there are so many deer in the first place is actually our society's fault. Wolves and cougars hunt deer, but we hunted so many wolves and cougars that by 1900 the only ones around had fled north to Canada. Over the last hundred or so years, deer have been able to survive and reproduce because they have no natural predators (other than us). When species become

extinct or if they **emigrate** (leave a particular area), it often leaves a gap in the food web. Other species can benefit, while others can be harmed in this change in equilibrium.

A mongoose eating a snake

The opposite change can be just as destructive: when a new species is introduced, it can often be disastrous. Take, for example, rabbits in Australia. Rabbits were never **native** to Australia; they were introduced by the British who brought rabbits there in 1788. They were kept in cages until 1859, when just 24 rabbits were released into the wild. Because there were no natural predators in Australia, and the climate was perfect for rabbit reproduction, they reproduced so rapidly that they spread throughout the entire country. Within 10 years, hunters were able to kill 2 million rabbits in the wild, and it had no noticeable effect on the rabbit population!

The rabbits in Australia is an example of an **invasive species** (or **non-native species**). When invasive species enter a particular area, they usually change the equilibrium in their favor by pushing out one or more native species. When humans use invasive species to solve problems, it can often cause even bigger problems.

Rats, not native to Hawaii, were accidentally introduced when they hitched a ride on boats headed to the islands. Since rats eat crops, some farmers had the idea to introduce an animal that could eat the rats: the mongoose. Well, mongooses do eat rats, but they also eat almost anything else; what's more, the mongoose sleeps at night and rats sleep during the day. The mongooses didn't end up hunting the rats, so the rat problem was not solved; it only created a new mongoose problem! Most of the Hawaiian native species (plant and animal) are now considered endangered species due to the destructiveness of the mongoose.

Species **immigrate** (move into a certain place) and emigrate quite often, but as we've learned, there are more than biotic factors in an ecosystem. Since the abiotic factors can often influence living things, climate changes often cause shifts in equilibrium. For the hundreds of millions of rabbits in Australia, it would be disastrous if the average temperature dropped significantly; suddenly, the rabbits would not be able to survive in such a cold climate, and Australia's rabbit problem would disappear. However, Australia would end up with a lot of other problems!

<u>Questions</u>

1. Describe equilibrium in your own words.
2. Name three crops that you eat in some form.
3. What happens when non-native species are introduced into particular ecosystems?

4. Choose an animal that doesn't live in Cleveland. What do you think would happen if several of these animals were introduced to Cleveland?
5. Give examples of both a biotic and an abiotic factor affecting the equilibrium of an ecosystem. Describe how changing the factor would affect the equilibrium.
6. In Rockefeller Park, there are snakes and rabbits (among other animals). For each snake to survive a year, they need to eat 10 rabbits. However, since rabbits reproduce quickly, each rabbit produces three new rabbits every year. Snakes don't reproduce as quickly, each one only producing one new snake per year. You are going to find out what happens to the rabbit and snake populations of Rockefeller Park over the course of 10 years, starting in 2019. To start off your populations, take the number of the month that you were born (January = 1, February = 2, March = 3, etc.) and multiply it by 5. Add to that number the day of the month that you were born. This number is the number of snakes in 2019. Enter it into the table below for Column A in 2019. Then multiply the number of snakes by 12 to get the number of rabbits in 2020. Enter it into the table below for Column B in 2020. Due to the size of Rockefeller Park, if the number of snakes goes above 100, then there is not enough space in the ecosystem for the snakes. They die off in huge numbers, and there will only be 10 surviving snakes. If the number of rabbits goes over 10,000, then there is not enough food or space for the rabbits. They die off in huge numbers, so there will only be 100 surviving rabbits.

	(A) # of Snakes	**(B)** # of Rabbits	**(C)** Surviving Snakes	**(D)** Rabbits killed	**(E)** Surviving Rabbits	**(F)** New Rabbits
Year	*Column C (from previous year) X 2*	*Column E + Column F (both from previous year)*	*Equal to Column A unless A is over 100; then this is 10*	*Column C X 10*	*Column B - Column D; If it's over 10,000, this drops to 100*	*Column E X 10*
2019						
2020						
2021						
2022						
2023						
2024						
2025						
2026						
2027						
2028						

Now create a graph for Columns A and E. Use one color for Column A, and another for Column E.

What is an Environment?

Explain how living things interact with biotic and abiotic parts of the environment (for example: predation, competition, natural disasters and weather).

Biotic and Abiotic

Mutualism between clownfish and sea anemone

Look around at the ecosystem around you. Right now, it probably includes humans, bacteria, maybe some small animals (some you can't see), and maybe even some plants. But what you might not consider is that the non-living things also affect you, like the amount of humidity, the amount of heat, the chair you are sitting in, and the desk where you are sitting.

When we talk about biomes, climates and ecosystems, we're talking about different ways to describe the living and nonliving things around us. Climate determines the type of biome, which in turn determines the ecosystems that can exist. Inside any ecosystem, we can divide everything into two large groups: **abiotic** and **biotic**.

The biotic part of the environment is easy to understand: since "bio" means "alive", you know that these must be the living things in the environment. All animals, plants, bacteria, fungi and protists are part of the biotic part of the environment. We also know that these living things interact with each other. Plants are often known as **producers**, because they take energy from the sun and turn it into usable energy for animals. Animals are often divided into **primary consumers** and **secondary consumers**. The primary consumers eat the producers, and the secondary consumers eat the primary consumers. Some animals can act as primary *and* secondary consumers, like humans (we can eat plants and animals). Some animals, bacteria and fungi act as **decomposers**, breaking down dead organic matter so that the producers can reuse it.

So, what is meant by the abiotic part of the ecosystem? It's the opposite of the biotic, which means that it's all the nonliving parts of the environment. Abiotic includes sunlight, amount of water, amount of shade and the rockiness of the land. But we can take this one step further: the biotic can affect the abiotic and the abiotic can affect the biotic. Animals can drink and use up water; too much sun can kill plants.

There are thousands of ways that the different parts of an ecosystem interact that are all equally important. For example, if the sun kills all the plants that the animals eat, then the animals will die and will not use up the water. There are a lot of different interactions that happen between abiotic and biotic parts of the environment, but there are also several important interactions that happen among the biotic parts of the environment:

Type of relationship	Description of relationship	First organism in relationship	Second organism in relationship
Parasitism	When one organism benefits from and harms another organism while it's still alive	Parasite benefits	Host harmed
Predation	When one organism feeds off another organism by killing it	Predator benefits	Prey killed
Commensalism	When one organism benefits from another organism without harming it or helping it	Commensal benefits	Host unaffected
Mutualism	When two organisms help each other	Benefits	Benefits
Competition	When two organisms try to get the same resources and end up harming each other	Harmed	Harmed

Questions

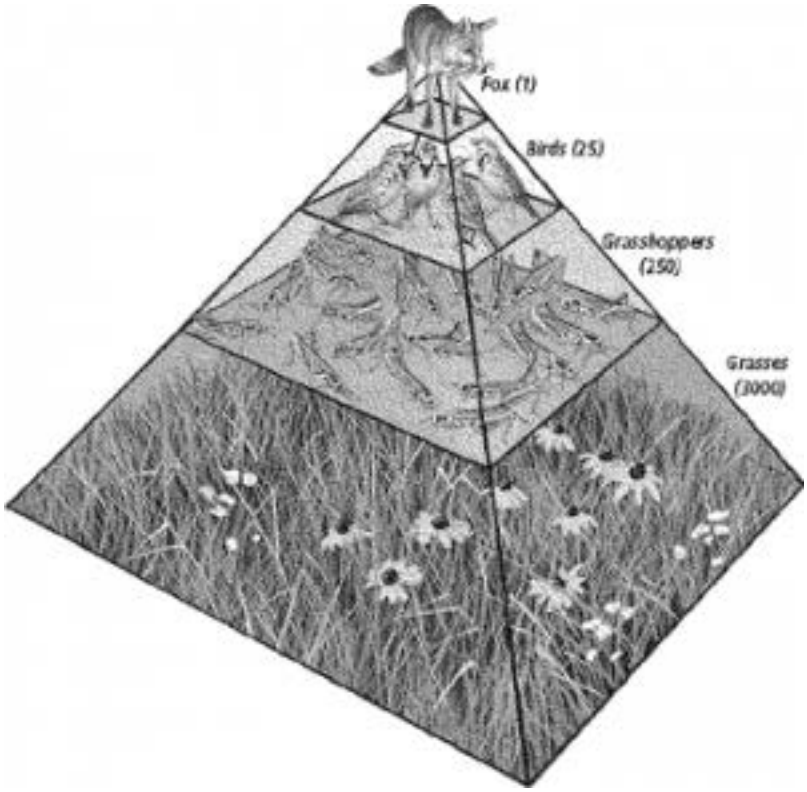
1. Define the four major roles of the biotic part of the ecosystem in your own words.
2. Differentiate biotic from abiotic.
3. Classify each of the following interactions according to the role that they play:
    a. Ex: Hail injures cattle, **answer: abiotic affects biotic**
    b. A hurricane drives buffalo from their watering hole
    c. A snowstorm creates an avalanche that destroys a forest
    d. Ice on the north pole reflects sunlight away from Earth
    e. A giraffe eats a leaf on a tree
    f. Humans drill through rock to find precious metals
4. Come up with an example for three of the five interactions in the table.
5. List three biotic and three abiotic factors for a biome of your choice.
6. Make a three-way Venn diagram for three of the types of interactions from the chart. For example, you can compare mutualism, parasitism and commensalism: you would need to know how they are all unique, what they all have in common and how each pair (mutualism & parasitism, mutualism & commensalism, parasitism & commensalism) has something in common.

How Do Living Things Get Energy?

Energy flows through all living things and the environment. Some energy is stored and much is lost into the environment as heat. Food webs, food chains and energy pyramids are used to represent energy flow.

Flow of Energy

Imagine you're driving down the road in a car. As you look out the window you notice a stretch of land with plants as far as the eye can see. Grass, flowers, trees, and other plants are visible in every direction. You probably wouldn't be too shocked or surprised to see this image. But imagine, instead, looking out the window and only seeing animals as far as the eye can see. Snakes, hawks, rabbits, and other animals so thickly packed together that you would have to step over them to take a walk; what would that sound like and smell like?



There's no place in the world where we can see animals packed together like this. So then, why does our world have so many more plants than animals? One explanation for this that scientists have developed is called the **Pyramid of Energy**. You know that all living things need energy, from the smallest bacteria to the largest plants or mammals. You may also know that people use **food chains** and **food webs** to show how this energy is passed from the sun to producers(plants) and then to consumers (animals, fungi, bacteria, etc.). What you may not know is that every time energy is passed from one living thing to the next, only a small portion of the energy makes it to that next living thing. Only the tiniest amount of the sun's energy reaches us here on Earth, only a small amount is used by an apple tree, and then we only get a very small amount of energy from the apple. By the time you get to the end of any food chain, most of the energy that was available at the beginning is no longer available. Scientists came up with the Pyramid of Energy to explain how this works.

The Pyramid of Energy is a model that uses a pyramid shape to show that the energy that consumers (like animals) can use decreases as it travels through organisms. Producers are at the bottom of the pyramid because they are able to transform the sun's energy into a large amount of plant energy through the process of photosynthesis. Producers are the base of energy for most food chains and food webs, like the basement is for a house.

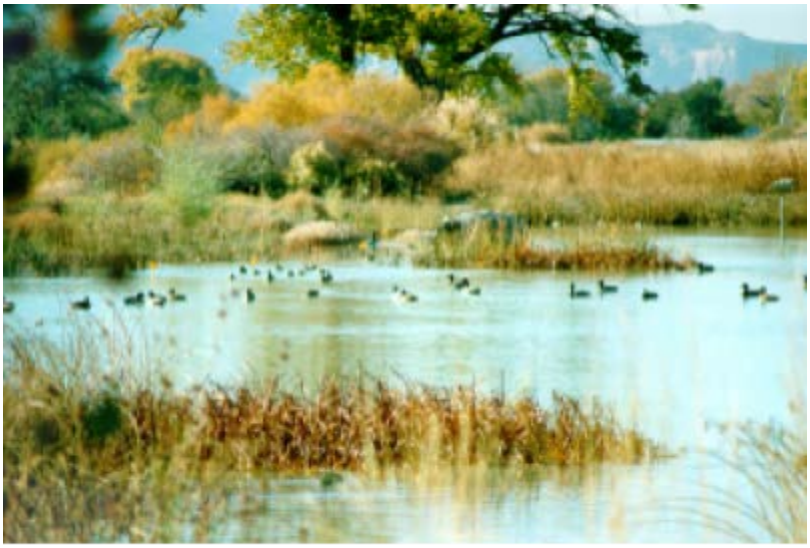
Primary consumers make up the next level because they rely on plants for their energy. This level of the pyramid is smaller than the producer level because most of the energy used at

the producer level is used by producers for their life processes (respiration, photosynthesis, reproduction, etc.) and transformed to heat before they are eaten.

Secondary consumers make up the next level because they rely on primary consumers for most of their energy. This level of the pyramid is smaller than the primary consumer level because most of the energy used at the primary consumer level is used for their life processes (respiration, digestion, reproduction, etc.) and transformed to heat before these animals are eaten.

The highest level can be either **tertiary consumers** or decomposers. They rely on secondary consumers for most of their energy. This level of the pyramid is smaller than the secondary consumer level because most of the energy used at the secondary consumer level is used for their life processes and transformed to heat before these animals are consumed. It's possible to have additional levels of consumers, but in most food chains energy runs out by the second or third level.

How much energy is lost from one level to the next? Scientists say that on average 90% of the available energy is used for life processes such as respiration, photosynthesis, and reproduction and transformed to heat energy before an organism is consumed. A molecule called **ATP** is used to store this energy, and when the energy is taken from ATP, some of the energy is lost as heat. This means only about 10% of the original energy is left to feed the next level. This 10% is stored in the tissues (leaves, stem, muscles, organs, fat, etc.) of the organism.



Wetlands

Let's take an example, using the wetlands. The wetlands is a biome found in very moist areas, usually on the banks of rivers, oceans or lakes. Here producers such as phytoplankton (types of plants) are producing 500,000 calories of energy from sunlight each day. If you gathered all of this **phytoplankton** into one spot, they might fill a space the size of a room. Since only about 10% of this energy reaches the zooplankton (types of animals), this leaves about 50,000 calories of energy to support the **zooplankton** each day. If you gathered all of these zooplankton into one spot, they might fill a space the size of a school dumpster. Since only about 10% of this energy reaches the sunfish, this leaves about 5,000 calories of energy to support the sunfish each day. If you gathered all of these sunfish into one spot, they might fill a space the size of a trash can. Since only about 10% of this energy reaches the great blue herons (a type of bird), this leaves about 500 calories of energy to support herons each day. If you gathered all of the herons into one spot, you would have only one! Fortunately, animals don't just depend on one type of consumer to meet their energy needs. But in essence it takes the energy of a room full of phytoplankton just to support one great blue heron.

This is why we have so much plant life at the bottom of each food chain yet so few consumers at the top of each food chain. So the next time you take a car ride, you'll know why there's so many green plants and so few animals. It's all about energy!

Questions

1. What are the four major biotic roles in an energy pyramid?
2. If you ate herons in this ecosystem, how many calories would you get per day? Would a human be able to survive (we need about 2000 calories per day)?
3. Why are there so many producers at the bottom of the food chain?
4. Why does energy get lost between each level of the energy pyramid?
5. Suppose that you eat one cheeseburger. Where do each of the parts of the cheeseburger come from? And where do each of these parts get energy from?
6. Cut out the 3-D Energy Pyramid that's in the appendix of this book. Starting with the left side, you will use a colored pencil to color in a representative area of that section. Start by dividing the bottom section into ten equal parts, then coloring in the entire bottom section. Next, you will color in an area equal to just one of those ten parts in the middle section. Divide the colored part of the middle section into ten equal parts. Finally, color in an area equal to one of those ten parts in the top section. On one of the other sides, label the bottom section, "Producers", the middle section, "Primary Consumers", and the top section, "Secondary Consumers". On the remaining side, make a sketch to represent each of these trophic levels.

Where Does Energy Go?

Cells and organisms get and give off energy in a variety of ways: photosynthesis, chemosynthesis, cellular respiration and fermentation.

Cycles of Energy

Energy is needed for all living things to survive. We need energy to get nutrients, move nutrients around our bodies, get rid of wastes, and maintain a balance between our bodies and the environment. But where does all of that energy come from?

Ultimately, we all "eat the sun." If you are a plant, you use the sun directly. If you are a primary consumer, then you use the energy that the plants get from the sun. If you eat a primary consumer, then you are still eating energy that's essentially coming from the sun! Without **photosynthesis**, there would be very little usable energy on Earth. So, here's what happens in the chloroplasts of plants:

Photosynthesis happens in the chloroplasts of plants

Photosynthesis: $6CO_2 + 6H_2O + \text{sunlight} \rightarrow 6O_2 + C_6H_{12}O_6$

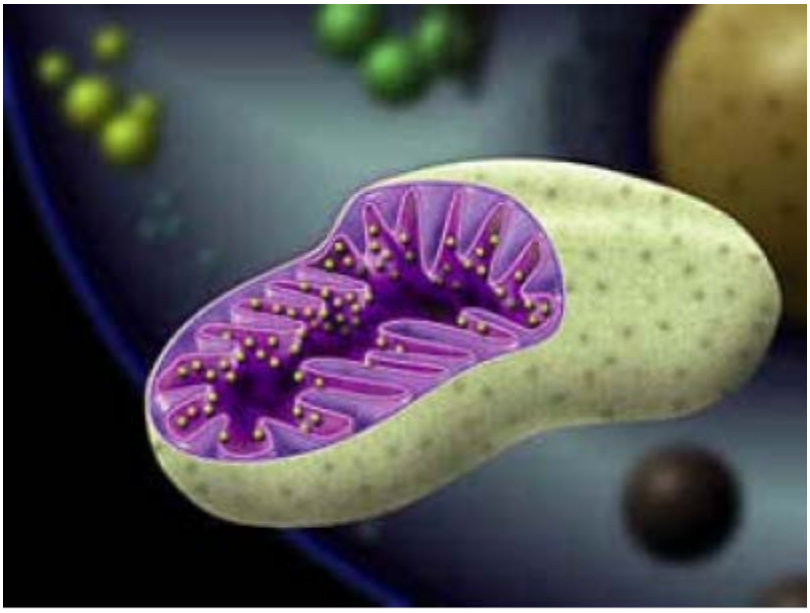
Tubeworms that perform chemosynthesis

This means that carbon dioxide, water and sunlight are all combined to make oxygen and glucose (a type of sugar). The energy from the sun is stored in the chemical bonds of glucose, which can then be used by the plant or by anything else that eats it.

There are some producers that cannot get sunlight because they are deep in the ocean, where the sun does not reach. However, like many forms of life, they have found a way to survive. These organisms gather around vents in the sea floor that spit out hydrogen sulfide. They then combine the hydrogen sulfide with carbon dioxide and oxygen to make formaldehyde, sulfur and water:

Chemosynthesis: $CO_2 + O_2 + 4H_2S \rightarrow CH_2O + 4S + 3H_2O$

The hydrogen sulfide that comes from the vents in the sea floor contains energy; this energy comes directly from inside the Earth. Since the Earth came from the sun, this energy, too, is ultimately from the sun! In the case of **chemosynthesis**, it gets stored as formaldehyde, which humans use to preserve dead organisms.



A mitochondrion, where respiration happens in eukaryotes

Once either photosynthesis or chemosynthesis has trapped energy from the sun, the sugar (or formaldehyde) that gets produced can then be moved around. Just like we have power plants to produce electricity and electrical lines to move that electricity around, producers use sugars to move energy around. All living things then need to free up that energy and use it, to do things like move around, eat, drink, and reproduce. If there's oxygen available, then a living thing will do **respiration**:

Respiration: $6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O$ + energy

Some products of fermentation

In respiration, oxygen is combined with glucose to make carbon dioxide, water and energy. Inside of us, our cells are constantly doing respiration, which is why we need to breathe in oxygen and we then give off carbon dioxide. This is what happens most of the time in organisms' mitochondria.

Some of the time, however, when oxygen is unavailable, **fermentation** happens. Most famously, this happens in yeast, bacteria and in our muscle cells. When our muscle cells cannot get oxygen because we are working very hard, then they do fermentation instead. In our muscles, this produces lactic acid which causes a burning sensation: if you "feel the burn", then your muscles are not getting enough oxygen:

Fermentation: $C_6H_{12}O_6 \rightarrow C_2H_5OH + CO_2$ + energy

In yeast and some bacteria, fermentation takes glucose and produces ethanol (a type of alcohol), carbon dioxide and energy. Different types of fermentation produce bread, beer, cheese, yogurt, sour cream, and wine!

Questions

1. In your own words, define photosynthesis, chemosynthesis, respiration and fermentation.
2. List at least three organisms that do not perform photosynthesis.
3. You have already learned that oxygen was not available on the early Earth. Given that information and the information from this chapter, which of these four energy cycles do you think came before the other ones? Which one was next? Which one was last? Give a reason you came up with this order!
4. In a Venn diagram, compare/contrast grid, or paragraph, differentiate photosynthesis and chemosynthesis in two ways.
5. In a Venn diagram, compare/contrast grid, or paragraph, differentiate respiration and fermentation in two ways.
6. Use the Four Door for the four energy cycles mentioned in this chapter. For each one, write the formula inside with an explanation of the reactants and products. Also, write one interesting fact inside each door.

How Do We Affect Equilibrium?

Describe ways that human activities can change the equilibrium in ecosystems. Explain how changes in technology can cause significant changes, either positive or negative, in environmental quality and carrying capacity. Describe ways that human activity can alter geological and chemical cycles as well as food webs and energy pyramids.

Human Activities and Equilibrium

Humans are the only species on Earth that uses both living and nonliving things to take care of most of our everyday functions. There are other species that use tools; primates use sticks to dig ants out of their holes; blue jays can use leaves to dig food out of places that are hard for them to reach. However, no other species uses technology like we do, which means that we affect the Earth in ways that other species do not.

Among other things, humans use land for farming, **mining** and **timber** (trees). Since we have chosen a few crops to farm over other crops, we have changed the equilibrium of the ecosystems around us. Corn is a good example of a crop that we use all of the time. Of course, we get corn on the cob, popcorn, cornmeal, grits and corn syrup. But did you know that we also use corn to get oil, ethanol, building materials, paint, various food ingredients, shoe polish, cosmetics and even toothpaste? Can you imagine what our society would be like without any one of these products? There is so much corn grown on Earth that other species have adapted to feed off of corn and other crops that we farm.

Strip mining

The first farmers on Earth had small farms, and changed where they farmed every season. Now, we have farms where the same crop is grown every year, in the same place. This has a negative impact on the soil because minerals are removed from the soil and there is not enough time for decomposers to get those minerals back into the soil. This means that farmers have to use chemical fertilizers to replace the minerals, which causes excess **nitrogen runoff**. The high levels of nitrogen disrupts the nitrogen cycle and interrupts plant and animal growth elsewhere.

One way that farmers can make sure that the soil is healthy is **crop rotation**. When a farmer rotates crops, the farmer does not plant the same crop every year, and they

also don't plant crops in every plot every single year. By letting natural decomposers add minerals back into the soil, it reduces the amount of minerals that need to be artificially added in by the use of fertilizers.

When we mine resources from the Earth, we take them away from the Earth and then use them in products. Those resources don't get returned to where they are; the land does not get end up the way we found it. We are changing equilibrium in two major ways when we mine: certain resources are unable to be used by plants and organisms are driven off of the land they previously used. Furthermore, when we mine resources like coal, we then burn that coal. The coal is gone, and we have put carbon dioxide and other gases into the atmosphere. This means that more plants need to do more work in order to keep the amount of carbon dioxide in equilibrium.

Timber is often taken from forests that can't grow trees as fast as they are cut down. This is known as an **unsustainable behavior**, which is behavior that cannot continue because it is destructive. In order to make sure that forests aren't completely destroyed, there are several ways to get timber but not destroy an entire forest. However, current human society uses wood for construction, paper products, fuel, tools and even packaging. Even though we do plenty of **recycling** of wood materials, new wood needs to be obtained from the environment.

Questions

1. Name one unsustainable behavior for each of farming, mining and timber.
2. Find the nutrition labels for at least two foods or beverages. What are at least three corn products that you've used or eaten? In what form was each one in?
3. What is the effect of one of the mentioned unsustainable behaviors on the energy pyramid?
4. What are at least two things that you think our government can do to support farmers who help ecosystems by practicing sustainable behavior?
5. Think of two ways that timber can be obtained without destroying forests.
6. Write a letter to a farming, mining or timber company asking them to practice sustainable behavior. The letter must be two paragraphs of at least five sentences each and must include: reasons why their behavior is unsustainable, reasons why you are concerned, what effect their behavior has on food webs and energy pyramids, and what they can do to improve their techniques. You cannot tell them to stop completely!

How Does the Planet Work Together?

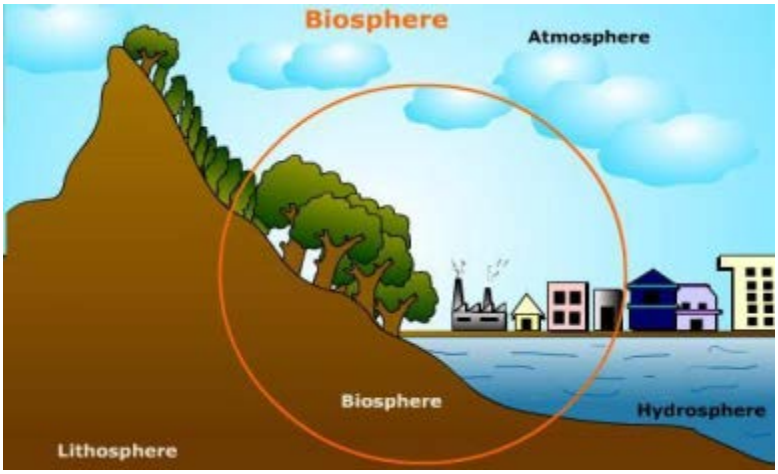
Explain how Earth has a hydrosphere, lithosphere and atmosphere and that they all interact with each other. The carbon cycle drives several relationships and is the main factor behind climate change.

Equilibrium of Earth

There's a popular hypothesis that Earth acts as if it were a living thing. This doesn't mean that some scientists think that there's a giant mouth somewhere next to a pair of gigantic eyeballs that are staring at you. No, that would be weird. The thinking that Earth is a living thing is called the "Gaia Hypothesis," and isn't so strange once you actually get to thinking about it.

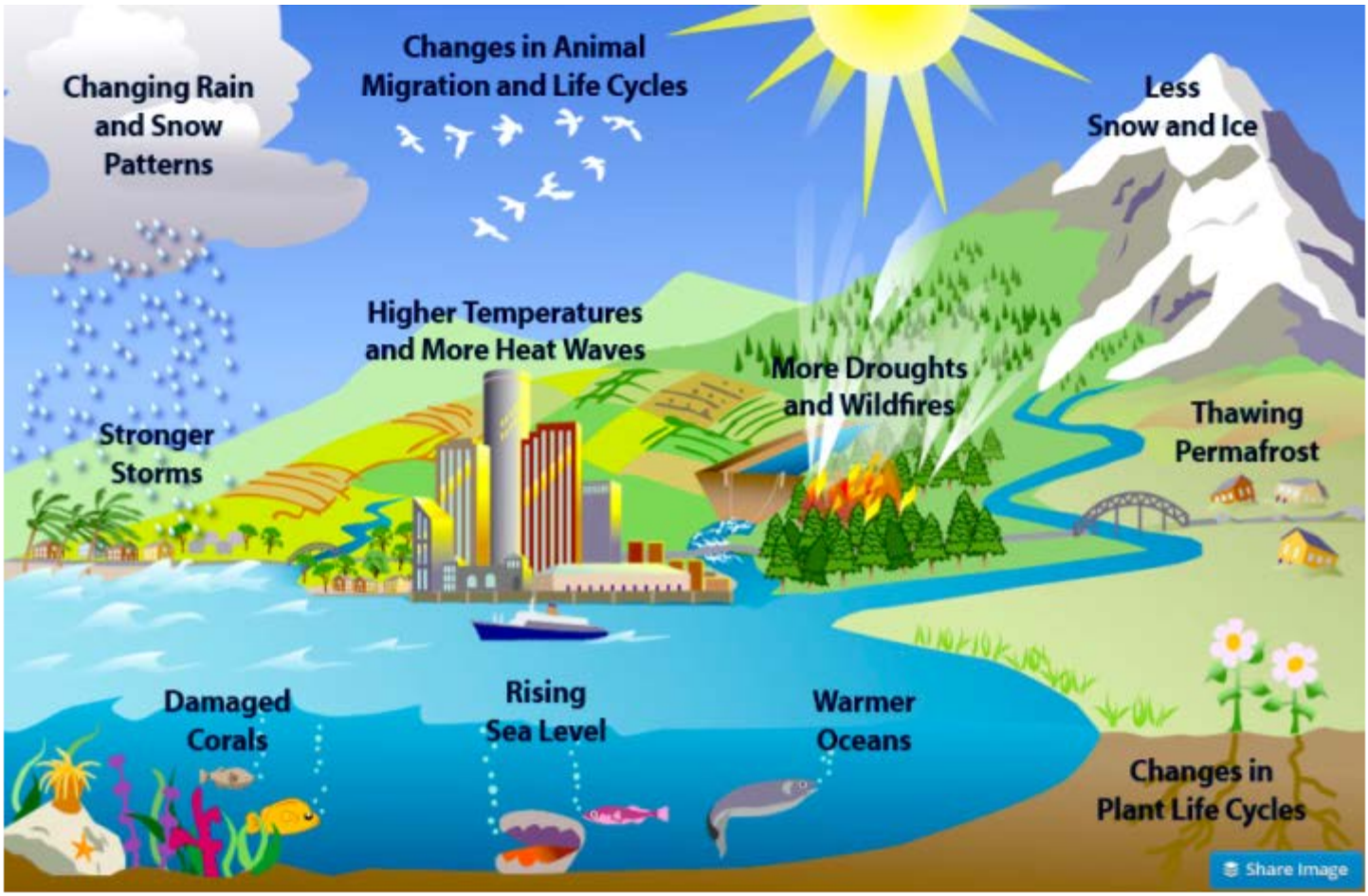
Gaia, "Mother Earth"

Earth is made up of several different big spheres, or units, that work together. The biosphere contains all living things, the hydrosphere has all of the water, the lithosphere is made up of rock, and atmosphere contains all of the gases. These aren't separate things in separate places. Consider your body: you are made up of living cells (biosphere) that contain water (hydrosphere) and minerals (lithosphere) which are used to convert oxygen to carbon dioxide (atmosphere). You have a miniature Earth in your body! Creepy!



All of these different spheres depend on each other in order to maintain the equilibrium of Earth. The oceans absorb carbon dioxide and heat from the atmosphere, helping to make sure that the atmosphere has the right balance of gases for living things to survive. Rocks on Earth break and form things like valleys, which often fill with water to catch rainfall from the atmosphere. Some organisms help to break larger rocks up to form soil so that plants can grow and convert carbon dioxide to oxygen. In fact, it took billions of years just for Earth to get to the point where there is a balance, and now due to many destructive activities, we humans are throwing off that equilibrium.

Just like a living thing, Earth transports nutrients, gets rid of wastes, moves energy around and maintains homeostasis. But it's this last part that we are in danger of messing up: the homeostasis of Earth. Do you remember that homeostasis is the balance between the inside and outside of an organism? Right now, Earth has dangerously high levels of carbon dioxide in its atmosphere, and much of that carbon dioxide is coming from burned fossil fuels that were mined from deep inside the Earth. This is causing temperatures on the surface of Earth (and the oceans) to rise very quickly. Guess what? That's *not* homeostasis!



Global warming changes

Global warming is the name for this increase in carbon dioxide, methane and other gases that cause Earth's temperature to rise. 97.5% of climate scientists agree that global warming is happening because of what we are doing: driving, flying, raising cattle and pigs for meat, and destroying forests. Some scientists disagree, stating that Earth always has warmed up and then cooled down in a cycle, and that humans have little to nothing to do with current global warming. What do you think?

Questions

1. What are the four major spheres of the Earth? Name what each one contains.
2. What is the Gaia Hypothesis?
3. In what ways is Earth like a living thing?
4. Consider the fossil fuels that are extracted from Earth:

    a. Where did those fossil fuels originally come from?
    b. How long did it take for the fossil fuels to get there?
5. What do *you* think about global warming? Explain your opinion with at least two reasons.
6. Make a diagram or drawing demonstrating how Earth's equilibrium is maintained. Include at least four different ways that equilibrium is maintained and clearly label each one.

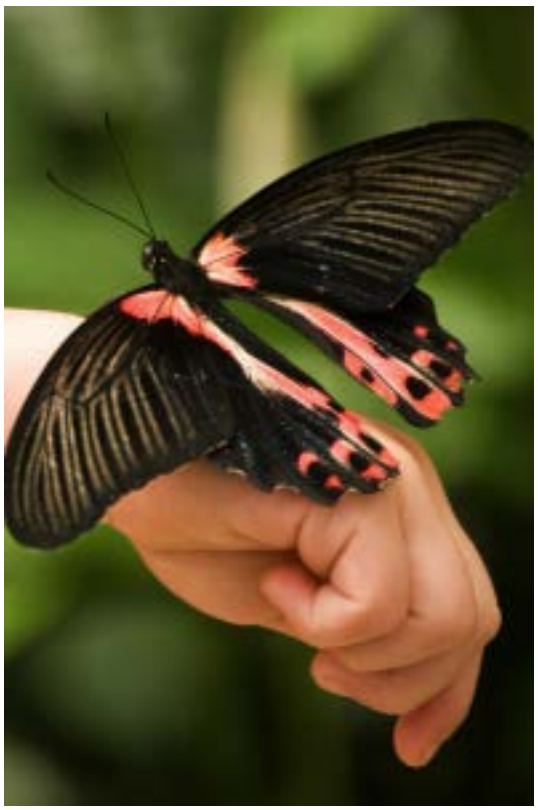
How Do Ecosystems Change Over Time?

Remember that a change in gene frequency in a population over the course of years is evolution. Explain that the g

enetic differences of organisms within a species increases the chances that at least some members of a species will survive under changing environmental conditions.

Ecosystems and Evolution

In biology, we talk about organisms alone and in groups. So far, we've been concerned mainly with individual organisms, which together form populations. Those populations of organisms combine with other populations in order to form communities, and those communities come together with abiotic factors to form entire ecosystems. As we've already seen, those ecosystems can be grouped together as a biome when they exhibit similar climates. So, when we study ecosystems and evolution, we are concerned with how the populations in those communities change.



When you look at a population of humans, there are always certain similarities and differences that you notice. For instance, skin color, hair type and color, eye color, average height are all genetic characteristics that are the easiest to notice about people. Biologists don't just study humans; we study all sorts of living things.

Imagine that you were looking in a field of butterflies: you see thousands that have yellow and black coloring and also a few dozen that have blue and black coloring. You also notice that there are hundreds of birds hunting the butterflies. Before we look at the behavior of the birds, we can make a conclusion about the **gene frequency** of the yellow color among the butterflies. Specifically, we can say that the gene frequency of yellow is around 99%, because 99% of the butterflies have yellow instead of blue. Similarly, we can say that the gene frequency of blue is about 1% for this population of butterflies.

Gene frequency, or the percentage of individuals in a population that have a certain characteristic, is a way to measure evolution. Going back to the butterflies and the birds, you notice that the birds are only hunting the yellow and black butterflies. For some reason, they are leaving the blue and black butterflies alone. You leave and come back a week later to the same field to find that there are only a few hundred butterflies; what's more, half of them are now blue and black butterflies!

This is an example of evolution – in this case, the population of butterflies has changed. The gene frequency of yellow coloring has decreased to about 50% because of changing environmental conditions. What were the "changing environmental conditions"? The birds that were hunting the butterflies made the change in the butterfly population. Even though the

total number of butterflies has decreased, the blue and black butterflies are surviving better because of the hunting patterns of the birds.

We have seen that there are many factors that go into making a biome: temperature, precipitation, animals, plants, mountains, rivers, oceans, etc. All of these factors affect the evolution of the living things within the biome.

Questions

1. What is the biotic relationship between the yellow and black butterflies and the blue and black butterflies that feed on the same plants? Explain.
2. What is the biotic relationship between the butterflies and the birds? Explain.
3. Calculate the gene frequencies if there were 150 yellow and black butterflies and 100 blue and black butterflies in the field.
4. List at least two reasons that the birds could be only eating the yellow and black butterflies.
5. Predict what would happen if the climate became mostly cloudy, changing the birds' vision so that both types of butterflies appear to be the same. What type of interaction is this, in terms of biotic and abiotic factors?
6. Consider the Rockefeller Park ecosystem. Inside the ecosystem, among other things, are bushes, trees, and rabbits.
    a. Come up with any genetic characteristic for the rabbits that has two forms (in the butterfly example, this was the yellow and blue colors). This can be something like the color of fur, type of nose, length of ears, etc.
    b. Come up with genetic frequencies for these two forms, as percentages. Keep in mind that all percentages need to add up to 100%.
    c. What do you think will happen to these gene frequencies if snakes are introduced to Rockefeller Park? Assume that evolution will happen, and list the gene frequencies after the snakes are introduced.

How Are We Using Natural Resources?

Explain how getting and using resources, urban growth and waste disposal can increase natural change and impact the quality of life. The use of resources at local, state, regional, national, and global levels have affected the quality of life in terms of energy production, global warming, depletion of resources and exponential population growth.

Resource Use

Natural resources must be used for many reasons. When you wake up in the morning, you benefit from natural resources that power the alarm clock, lights, refrigerator and water heater. Getting to school, you use natural resources in the fuel used for the train, bus, car, or if you walk, the manufacturing of your shoes! Natural resources were used to make the streets, buildings, stop lights, telephone poles and sewer systems. More resources are used within the school to keep the heat on (or the air conditioner) and to provide students with pens, pencils and paper.

The most important natural resources are the ones that give us usable energy. At every step along the way of anything we do, energy is used. Even if it's energy that we provide, we still need food in order to provide that energy; food needs to be grown, transported and prepared, which all requires energy. Energy is produced at **power plants** that can use a variety of fuels: diesel, wood, natural gas, oil, coal, **nuclear** fuel, the sun (**solar**), naturally running water (**hydroelectric**), wind, or even heated water from inside the Earth. That energy is transformed into electricity, which is then often transformed into other forms of energy. Sometimes, the energy is used directly, such as on cars and buses; the engine of a car is actually a small power plant!

Nuclear power plant

All natural energy resources can be grouped as either **renewable** or **nonrenewable**. Renewable resources are resources like solar power, hydroelectric power or wind power, because they are constantly being produced. These resources only run out when the sun runs out of fuel – not for another few billion years. Non-renewable resources take longer to make more of than they take to use: for example, it takes just minutes to use up a gallon of gasoline, but it takes the Earth millions of years to turn fossils into oil which is transformed into gasoline. The most famous of the nonrenewable resources are **fossil fuels**, such as coal, oil and natural gas.

Wind turbine at the Science Center

Once we use up fossil fuels, nuclear fuels and other forms of energy, we have to do something with the waste that is left behind. There are more natural resources than the ones that produce energy; the water that we and other organisms drink, the land that all living things live in and on, and the air that we all breathe are considered **natural resources** (or **natural capital**). When we use anything up, there is always waste involved. Sometimes that waste is heat, sometimes it's carbon dioxide, but more often than not, it's simply known as "trash." It's very convenient to think that when you are done drinking a soda pop, you can just throw the bottle away and it's gone. The truth is very different. If you recycle the empty bottle, it gets trucked to a recycling center where it gets chopped up into very small pieces that are used to make new plastic items.

On the other hand, if you just throw it into the trash, then it usually gets trucked to a **landfill**. A landfill is a big, plastic-lined hole in the ground where trash is stored. When it gets full, a plastic cover is placed on the top, and the garbage is sealed up. Soil is usually placed on top of that landfill in order to hide the trash, but it's still there. Sometimes, the plastic doesn't even make it into the landfill, and instead gets carried out to a river, lake or stream. Eventually, all water leads to an ocean, so the plastic bottle could end up in the ocean, where it gets broken down into small pieces. Fish and other animals (like birds) eat the small pieces of plastic (that are often too small to see).

Coal power plant near Cleveland

As our population grows, more and more trash is being thrown away, polluting our water, air and land. But pollution isn't the only problem: when there are more people, then more resources are needed. More people need more land, more energy and more clean water. **Urban growth** refers to patterns that cities follow when they get bigger. Cities interrupt ecosystems because they are bright, noisy and big. Even an average-sized city like Cleveland is visible at night for dozens of miles around because of **light pollution**. Streetlights, highways, and tall buildings all contribute to a glow that changes the

behavior of birds, insects and even some mammals.

Urban centers (cities) are the center of our highest growing populations of humans. In fact, human population is growing so quickly, it is considered to be at an **exponential growth rate**. This means that human population isn't just growing; this means that every year, the *population grows faster*. There are about 6 billion people on Earth, and if current growth rates continue, we will have 9 billion people on Earth by 2050, or by the time that you are in your 50's! Imagine if all of our problems, including global warming, were multiplied by one and a half times. There is already evidence that the average temperature of Earth is increasing due to an increase in carbon dioxide and other gases that we put into the atmosphere. What would happen if that not only kept happening, but happened at a much faster rate?

Power Plants in Cleveland Area

Name of plant	City	Capacity (MW)	Type
Bowling Green Solar Facility	Bowling Green	20	Solar
Painesville Plant	Painesville	54	Coal
Lake Road Generating Station	Cleveland	160	Coal
West Lorain Plant	Lorain	545	Natural Gas
Wyandot Solar Facility	Upper Sandusky	12	Solar

Questions

1. What is a landfill?
2. What is the difference between renewable and nonrenewable resources?
3. How is the sun involved in all renewable resources?
4. Using a chart, about when did human population start to have an exponential growth rate?
5. Why do you think the human population stayed at about the same level for 11,000 years?
6. Using the chart that shows power plants in the Cleveland area, answer the following:
    a. Does Cleveland use renewable energy sources?
    b. What is the total energy production in the Cleveland area?
    c. Suggest a solution to Cleveland's energy production problems by choosing three power plants to replace with new, alternative energies and explain your decision. Use the following information to help you choose which power plants can replace the ones that you want to get rid of:

Unit Type	Capacity (MW)

Wind Turbine - Can operate day and night - Little environmental disturbance - Takes up little space	2
Solar Panels - Can only operate during day - Dependent on good weather - Takes up a lot of space	14
Hydroelectric Dam (for Cuyahoga River) - Can operate day and night - Disturbs fish breeding - Takes up moderate amount of space	1

Why Do We Look Different?

Changes in DNA are mutations which create variation between different organisms. When mutations happen in sex cells (sperm and eggs), they may be passed on to future generations and influence natural selection; mutations that occur in body cells may affect the cell or the entire organism.

Mutations

Deletion

DNA doesn't always stay the same. Often, there are changes that happen to the DNA inside of a cell because of asbestos, cigarette smoking, ultraviolet radiation, or just random chance. These changes to DNA are called mutations. Some mutations in DNA are harmless and cause no problems for the organism or its offspring. Many mutations are harmful and can cause cancers in the organism or birth defects in offspring. Even other mutations cause the death of the cell because it can't survive any more.

There are three main types of mutations: substitutions, insertions and deletions.**Substitutions** are mutations where one base is substituted for another, such as G for A. These can often be harmless because the protein that the gene ends up producing can be exactly the same.

Substitution

If a gene suffers from an **insertion** mutation, then the entire gene can be affected or even destroyed. An insertion is when one or more bases are inserted into the gene and it shifts all of the codons down by one or more bases.

Lastly, a **deletion** mutation is when one or more bases are removed from the gene. This again can destroy the entire gene because it can shift all of the codons up by one or more bases.

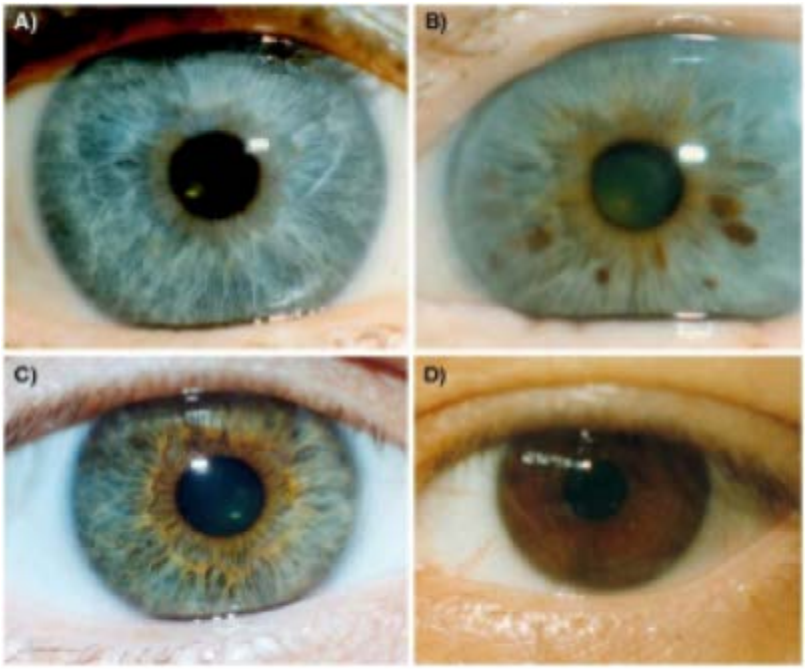
Insertion

When any of these mutations happen in a body cell, they only affect the organism itself. However, when these mutations happen in a sex cell, they can affect the offspring. This is one of the key concepts behind natural selection – yes, back to evolution! See, if it weren't for mutations, there would be no new genes, and all life would look just like the first, simple one-celled bacteria.

Mutations are the source of new genes: it's thought that all humans started off having brown eyes. A mutation in the gene for eye color caused some humans to have blue eyes. In the bright sun of Africa, it made no sense to have blue eyes, which are more sensitive to light. But when humans immigrated into Europe, which receives less direct sunlight, individuals with blue eyes were more fit and survived to reproduce more than the brown-eyed individuals. In fact, the emigration from Africa would have been impossible without mutations to the genes for skin color, hair type, digestion of different foods, and more!

However, the only way that these mutations were passed on from generation to generation is that the initial mutation happened in either a sperm or egg cell. If the gene for eye color had changed in a body cell, that only would have affected the individual – *not its offspring*!

Even though most mutations result in offspring that don't survive to reproduce, the "good" mutations more than make up for the "bad" ones. These mutations that take hold in a population cause the genes of the population to change. To continue our example, when Africans first immigrated to Europe, almost nobody had blue eyes, and these individuals were limited to the southernmost areas of the continent. However, as time went on and the mutation for blue eyes spread through the population, the percentage went up; in some areas in northern Europe, 100% of the population had blue eyes. This change over time in the percentage of a particular gene in a population is called **genetic drift**. As you can see, peoples' genes "drifted" from brown to blue eyes over time.



Different eye colors

Questions

1. How can you avoid mutations that can cause cancer?
2. Describe genetic drift in your own words.
3. Differentiate a substitution, insertion and deletion.
4. Summarize the relationship between mutations and natural selection.
5. Why is it that mutations in body cells do not affect offspring?
6. Predict a mutation in humans that will spread through the population over the next fifty years. What is the mutation? Where did it start? How is it advantageous?

Can We Change Our Genes?

Analyze and investigate emerging scientific issues. For example, genetically modified food, stem cell research, genetic research and cloning.

Genetic Issues

What if you could grow yourself a new arm? What if you knew exactly what disease you might get in 40 years? What if you had a clone 15 years younger than you who you could teach to do things differently than you did?

Dolly, the sheep, and her clone

Genetics is a relatively new field of scientific study, only having been around for about the last 60 years. With new technology, scientists are able to do more and more to help improve our lives, but they are often controversial. **Cloning** can result in new organs, **stem cells** can be used to do research on many diseases, the DNA of our food can be changed so that it grows better, and **genetic research** can tell us what diseases we or our offspring might develop.

It is important to stay informed of these issues because they will form many of the political and ethical issues of the future, if not the present! Many people take a side on these issues based on fear and misinformation; if you understand what these issues are actually about, you can make more informed decisions that could ultimately lead to a better life for you and your children.

Cloning is not all about making copies of oneself. Scary movies and sci-fi television series would have us believe that scientists would like to make armies of super-intelligent humans that could dominate the entire world. However, that's completely untrue! Cloning is mainly the use of DNA to make organs that can be used to treat diseases and to replace organs that have failed. If someone has a heart attack and needs a new heart, their own DNA could be used to create that new organ!

As we have previously seen, a zygote starts dividing and the cells differentiate. This power to divide into any other cell of the body is used by scientists in **stem cell research**. Stem cells can be taken from aborted embryos, but can also be taken from adult cells through often complicated and painful procedures through the bone marrow. Stem cells can be used to

create organs, like cloning, that can replace failed or diseased organs in a patient. Stem cells can also be used to research human diseases, as they do not harm living humans, instead of performing those experiments on mice.

Genetically modified food (GM) is food that has been genetically changed so that it will be resistant to pests, will grow bigger, taller or otherwise be more healthy and more valuable when it is sold. In a way, GM has been happening for thousands of years, as farmers choose the most healthy crops to plant for the next year. GM food is a more technical, and less understood, way of making changes to crops so that farmers can get the most out of their land.

Scientists have raised concerns over GM food; the mouse on the right was fed GM food

In general, genetic research that is done on humans allows us to see inside ourselves and truly figure out who and what we are. Many people argue that this information can be misused; for example, an insurance company may deny health insurance to someone who has a certain genetic disease that they will only suffer from in 20 years. On the other hand, if we know what diseases we may get, we can start treatment for those diseases before it even becomes an issue.

Questions

1. What is genetic research?
2. Are stem cells differentiated? How do you know?
3. Why could GM food be bad for you?
4. Choose one of the issues and make a one paragraph argument in support of it.
5. Choose one of the issues and make a one paragraph argument against it.
6. Food companies want to patent foods that they breed so that they can make money off of selling the seeds. Take the viewpoint of a company that wants to patent a new tomato that doesn't ever go rotten. Write a two paragraph persuasive argument to the Supreme Court of the United States arguing the point.

How Does Energy Affect the Inside of the Earth?

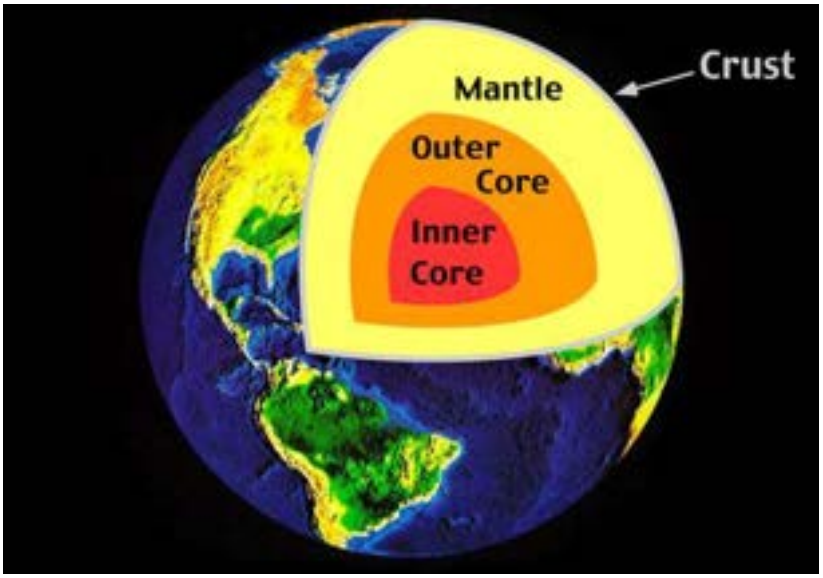
Explain how conduction, convection and radiation influence the movement of different layers of the Earth, resulting in volcanoes, earthquakes, mountain building, and other results of plate tectonics.

Inside the Earth

Have you ever eaten a jawbreaker? As you eat it, different colors and layers appear until you get to the white center that the jawbreaker company didn't bother to color. Maybe they figure that, by the time you get to the middle, you don't care about the colors any more. Anyway, it's easy to see the different layers in a jawbreaker, but it's not as easy to see them in Earth.

That's because the Earth is big. Real big. If you tried to dig a hole through the center of the Earth to the other side, it would be a 8,000 mile long hole. Think about it: if you tried to drive that distance at 80 miles per hour, without stopping, it would still take you over four days. Along the way, you'd get a little chilly, then extremely hot, then boiled and crushed. And that's just the first day!

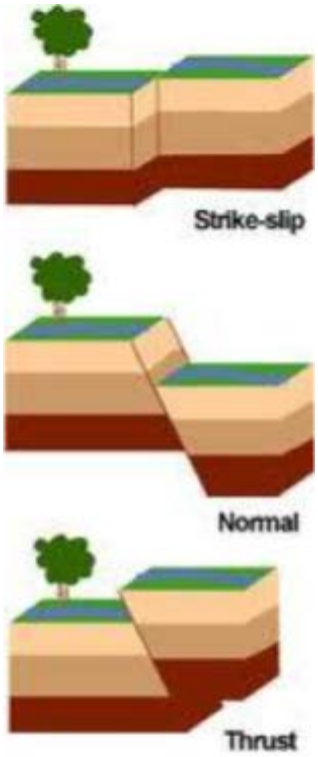
The Earth is made up of four major layers: the **crust**, the **mantle**, the **outer core** and the **inner core**. The crust averages about 25 miles in thickness, or about 20 minutes of your 80 mph journey to the center of the Earth. Not long at all. But the crust is the furthest down that humans have ever been in the Earth, and it's where everything else is: water, land, plants, animals, our stuff, etc. In other words, we know a tremendous amount about the crust but not nearly as much about the other layers.



That's too bad, because the other layers are pretty interesting, too. The mantle is about 1800 miles thick (almost as long as the Mississippi River) and makes up most of the mass of the Earth. But it's hot. The mantle is 1000F near the core and 4000F near the crust, so watch out! Despite the fact that it's that hot, it's mostly made up of solid rocks, not liquids. Those solid rocks move around quite a bit, the warmer materials moving toward the crust and the cooler materials moving towards the core. This is called a

convection current, just like the hot air in your house moves towards the attic and the cool air moves towards the basement.

Convection currents work because the outer core is *super* hot. We're talking about 6000F. In fact, it's so hot that almost any rock found in the outer core is completely melted. Because the outer core touches the mantle, it uses **conduction** (heat transfer by contact) to heat up that cool, 1000F rock, and sends it rising up to the top of the mantle. This keeps the mantle in motion and makes the **tectonic plates** riding on top of the mantle move. The bad news? We live on those plates, and so do the oceans. The good news? They only move at about an inch a year, or the same rate as your fingernails.



Types of earthquakes

OK, so really there's actually some more bad news. Because the mantle can't just stay where it is, tectonic plates end up crashing into each other, causing **earthquakes**, **volcanoes** and **mountain building**. Earthquakes happen when plates crash into each other (normal or thrust) or when they slide past each other (strike-slip). Volcanoes happen when the mantle finds an opening in the crust and pushes its way through, sending hot magma through the crust as lava. And mountain building happens when plates push together, but they're so evenly matched that the only place to go for the plates is up, resulting in nice, pretty mountains. In fact, the pointier and taller the mountain, the younger it is: the Rockies in the west are much younger than the Appalachians in the east of the U.S.

Finally, you may be wondering how all of this heat came about in the first place – how is it that the core and mantle are so hot? Well, remember that the Earth bubbled off the sun, so some of that same heat still remains deep inside the Earth. The inner core is thought to be as warm as the surface of the sun, and is made up of solid metals (mostly nickel and iron). It's part of the reason that, even when it's cold outside, it's still a lot warmer than it is in space. It's about -450F in space, so a 15F night doesn't seem so cold anymore, does it? Moreover, there's something else going on that keeps things warm on the surface of Earth. It's called **radiation**. During the day, electromagnetic radiation, otherwise known as light, strikes the surface of the Earth, warming it up. At night, some of that heat is released into the atmosphere. Cloudy days tend to lead to cooler nights due to this phenomenon!

Questions

1. Name the four layers of the Earth and describe briefly what is inside each one.
2. What makes the tectonic plates move?
3. What would you tell someone who asked you, "Is it true that you can travel to the center of the Earth?" Explain!
4. Make a three-way Venn diagram to show the similarities and differences between conduction, convection, and radiation.

5. Geothermal energy is a type of energy that uses the heat inside the Earth to heat up water for use inside peoples' homes. Using the information in this chapter, do you think this type of energy you is a good idea? Why or why not?
6. Los Angeles, in California, is on a different tectonic plate than Seattle, in Washington. Los Angeles is currently 1500 km from Seattle, and its tectonic plate is moving north at a rate of 1 cm per year. How long will it take for Los Angeles and Seattle to be neighbors? Should people in Los Angeles be concerned about this? Sketch out what California might look like in 1 million years.

Glossary

10% Rule: Rule that states that 10% of the energy in a trophic (feeding) level gets passed to the next level
Abiotic: The nonliving parts of the environment
Abiotic Factor: A non-living part of the ecosystem
Absorb: Take up or take in; The sponge absorbs water well
Abundance: More than enough; a lot
Acid: A chemical that reacts easily with other substances and turns litmus paper red; less than 7 on the pH scale
Active Transport: Way that some particles cross the cell membrane if they are polar or are too big
Adaptation: A feature of an organism that helps it meet a particular need in its natural habitat
Adaptive radiation: The development of many different forms from a single group of organisms as they adapt to different environments
Advantaged offspring: Offspring that have characteristics which help them survive better than others
Advantageous characteristics: Characteristics that help an organism survive better than others
Aerobic: Happens in the presence of oxygen
Agar: Substance used for growing bacteria or fungi
Agriculture: Using land to get food or to feed animals for human consumption (livestock)
Allele: One of the forms of a gene that is found in pairs on a chromosome; Some alleles are dominant over others
Amino Acid: A molecule that joins with other amino acids to form proteins
Anaerobic: Happens in the absence of oxygen
Analogous structures: Parts of two species that serve the same purpose but have different bone (or non-bone) structures
Analysis: Using the results of an experiment to come to some conclusions about the experiment
Analyze: Think about the different parts of a problem or situation to figure out how it is related to the whole.
Anaphase: Phase of cell division where the chromosomes separate to either side of the cell
Anion: An ion that has a negative charge
Antibacterial: Anything that kills bacteria
Aquaporin: Molecule in the cell membrane that allows water to pass through
Archaebacteria: Oldest kingdom of bacteria
Artery: Blood vessel that carries blood away from the heart
Arthropods: Phylum of animals that includes insects and spiders
Asexual Reproduction: Reproduction that happens without sex; one organism creates one or more organisms
Assembly Line: Process used to put products together where every worker has one job that they perform repeatedly
Atmosphere: The air surrounding a planet
Atom: The smallest unit of a substance that has all of the properties of that substance
ATP: Molecule in the cell that transports and contains energy
Autosomal Chromosomes: In humans, the 22 pairs of chromosomes that are not the sex chromosomes
Autotroph: Living thing that produces its own food
Bacteria: The kingdom of life which has no cell membrane or nucleus and is always unicellular
Base: A chemical that reacts easily with other substances and turns litmus paper blue; greater than 7 on the pH scale
Basic needs: The set of resources that are needed by all living things, water, space and shelter
Behavioral Isolation: Type of evolution where populations separate due to behavioral differences
Best Practice: A commonly agreed way to perform a certain procedure or experiment
Bias: An influence in an unfair way; You are biasing my choice by telling me yours
Biodiversity: Measurement of how many different species are in an ecosystem
Biogeochemical cycle: A way that a chemical element or molecule moves through both the biotic ("bio-") and abiotic ("geo-") parts of an ecosystem
Biogeochemical Cycles: Ways that nutrients cycle themselves through the environment, like carbon, water, nitrogen and phosphorous
Biological classification: Organization of how living things are related to each other
Biology: The study of living things
Biomagnification: What happens when toxic molecules increase in concentration as they move up a food chain or food web
Biome: A region of the world that has a particular climate and unique plants and animals that live there
Biomedical engineering: Designing and redesigning devices for medicine and other biological applications
Biosphere: The part of Earth defined as all living material
Biotechnology: The study of the use of small organisms to help industrial processes
Biotic: Anything that is alive
Biotic Factor: A living part of the ecosystem
Body cell: All of the cells in an organism not involved in reproduction
Bottleneck Effect: Type of evolution that happens when only a few individuals in a population survive some major event like a natural disaster
Brachiopods: Classification of living things that includes clams and oysters

Buffer: An area that serves as a natural boundary so that two populations don't interact; also a compound or mixture that keeps pH neutral
Calorie: Measure of energy
Camouflage: Way that living things have of blending in with the environment and hiding from predators
Cancer: Disease where cells grow in an uncontrolled way
Carbohydrate: An essential chemical in all cells that is broken down to form sugars; glucose, lactose, galactose
Carbon cycle: The flow of carbon dioxide and oxygen throughout the Earth
Carbon Dioxide: Molecule made up of one carbon and two oxygens
Carrying capacity: The most amount of a particular organism that can be supported by an ecosystem
Catalyze: To help to bring about
Cell: The basic structural and functional unit of all organisms
Cell differentiation: A process where cells change to perform different roles
Cell division: A process where one cell becomes more than one cell
Cell membrane: Surrounds the cell and keeps it together; also decides what material enters and leaves
Cell organelle: Parts of the cell that perform specific functions
Cell Theory: Theory that states that all living cells come from previously living cells
Cell wall: The stiff outer layer of a cell that protects the cell and gives it shape
Cellular respiration: The process where organisms get energy from organic molecules
Centromere: Part of the chromosome that connects the sister chromatids
Characteristic: A distinguishing quality of something; generosity is one of his best characteristics
Charles Darwin: Darwin introduced the idea of survival of the fittest which means that the organisms with the most advantageous characteristics survive to reproduce and others die
Chemical: Material produced by or used in a reaction involving changes in atoms or molecules
Chemical formula: The sequence of atoms that describes a certain molecule
Chemosynthesis: The creation of carbohydrate from carbon dioxide and water that only happens in certain bacteria and fungi
Chloroplast: Organelle in plants and some other organisms which is responsible for photosynthesis
Chromatid: One half of a chromosome
Chromosome: A thread-like strand of DNA or RNA in the cell
Cilia: A hair-like organelle on the outside of a cell used in movement
Cladogram: Way of representing evolutionary relationships with a diagram that shows how populations have branched off over time
Classification: Organization of anything (living or non-living) into categories according to their characteristics
Climate: The weather in some location over a long period of time
Climate Change: Phenomenon where climate is altered by natural and man-made causes
Cloning: The creation of genetically identical copies of some organism
Co-dominance: Two alleles for a characteristic that are equally dominant to each other and produce a characteristic that is not like either of them
Codon: A group of three bases of mRNA
Commensalism: A relationship between two organisms where one benefits and the other is unaffected
Common Ancestor: The most recent living thing that two species can claim as an ancestor (and usually extinct)
Communication: The successful transmission of information through a common system of symbols, behavior, speech, writing and/or signals
Community: The collection of all organisms that live together on an area of land
Comparative Anatomy: Method of showing evolutionary relationships by showing the similarities and differences among the parts of the organisms
Compare: Look for characteristics that resemble each other. Emphasize similarities and differences.
Competition: When more that one organism is trying to obtain the same resources
Computer engineering: Designing and redesigning software for computers
Conceive: To have the idea for something
Conclusion: An explanation of the results of an experiment
Condensation: When a substance changes state from a gas to a liquid
Coniferous Forest: One of Earth's biomes that has trees which do not lose their leaves, dry climate
Consensus: General agreement among a group of people
Conserve: To keep the same through a physical or chemical reaction; energy is conserved in this process
Constant: Does not change
Constraint: A limit to the design process. Constraints may be such things as appearance, space, materials, or human capabilities
Consumer: Living thing that eats other living things
Context: The set of facts that surround a situation or event
Continental Drift: The theory that states the continents are constantly in motion
Contrast: Stress the differences between things.
Control: What is kept the same in an experiment
Control Group: A group in an experiment that receives the normal condition (or lack) of the independent variable

Controversy: An issue that has two or more supported viewpoints and is generally not agreed upon by everyone
Convection: The process where heat causes fluids (gas or liquid) to rise and bring heat up
Convergent Evolution: Type of evolution that happens when unrelated organisms evolve similar functions
Covalent Bond: A type of chemical bond where electrons are shared between the atoms
Criticism: Pointing out flaws or errors in an experiment
Criticize: Express how you feel about how truthful the information is. Provide evidence and ask questions of the author!
Crop: A plant that is grown for food
Crop Rotation: Method of farming where the same crop is not planted in the same place two years in a row; often
Crossing Over: Part of meiosis where genetic information passes between homologous chromosomes
Crust: The outermost layer of Earth
Cyclic fluctuation: A process that involves change
Darwin: Charles Darwin
Data: The results or information that you get from doing a scientific experiment
Deciduous forest: A biome where the trees lose their leaves every year
Decomposer: A type of living thing that survives by consuming dead organic matter
Deduction: A way of making scientific discoveries where general ideas are tested very specifically
Define: Give concise and clear meaning to what you are asked to define.
Deletion: The removal of a DNA base that results in a genetic mutation
Density: The mass of a substance per unit volume
Density Dependent Factor: Something that affects a population, but affects it more based on how tightly packed the population is
Density Independent Factor: Something that affects a population, and affects it no more or less based on how tightly packed the population is
Dependent Variable: In an experiment
Describe: Recount or relate in sequence.
Design: All engineers participate in a design process where they plan out how their project is going to proceed
Design brief: A written plan that identifies a problem to be solved and its constraints. The design brief is used to encourage consideration of all aspects of a problem before attempting a solution
Design process: A systematic problem-solving strategy used to develop many possible solutions to solve a problem or satisfy human needs and/or wants and to narrow down the possible solutions to one final choice
Diagram: Provide a drawing
Dichotomous Key: A model of a classification that shows each characteristic as a series of yes/no (or this/that) decisions
Differentiate: Point out the details that allow the reader to tell two or more things apart.
Differentiated cells: Cells that have developed differently to have different functions
Differentiation: Process where cells grow and become different than their mother cell
Diffusion: Where molecules spread out until they are evenly distributed in a medium
Dihybrid Cross: A genetic mating between two organisms that are both heterozygous for two different characteristics
Dilemma: A philosophical or ethical problem
Diploid: Cell that contains two copies of each chromosome
Directional Selection: Natural selection moves characteristics in a particular direction
Discuss: Examine
Disruptive Selection: Type of natural selection that happens when the average trait is selected against and the organisms that survive are the extremes
Dissolve: To cause to go into a solution
Distribution: The amount of scattering over a certain area
Divergent Evolution: Type of evolution that happens when related organisms evolve different functions for the same structures
Diversity: The distribution and abundance of different plant and animal communities and species within a given area
DNA: Abbreviation for deoxyribonucleic acid
DNA Polymerase: Molecule that is responsible for putting DNA back together after it is split into parts
Domain: The most general classification group; often referred to as Archaea, Eukarya
Dominant: A genetic characteristic that is always expressed by the organism
Double Helix: Structure of DNA that is composed of two twisting strands, much like two spiral staircases
Ecological Niche: Role in an ecosystem that an organism occupies
Ecological Remediation: Bringing an ecosystem back to a usable state, but not its original state
Ecological Restoration: Bringing an ecosystem back to its original state
Ecosystem: An ecosystem is an area consisting of all plants
Electromagnetic spectrum: The range of all possible electromagnetic radiation
Electron: A negatively charged particle outside the nucleus of an atom
Element: A substance composed of atoms with the identical atomic number; organized in the periodic table
Embryology: The study of how organisms develop; the more closely related two organisms are
Emigration: The act of leaving one place for another

Endocytosis: Process by which cells absorb large particles by surrounding the particles with the cell membrane and pinching it off
Endoplasmic reticulum: Organelle that produces proteins and fats
Endosymbiosis: Theory that states that mitochondria and chloroplasts were once living bacteria that got absorbed by cells
Endothermic: A chemical reaction that absorbs heat energy
Energy: The property of something's ability to do work
Energy pyramid: A diagram showing that as you go up the pyramid
Energy transfer: Energy can be transferred from one place to another, energy is always lost
Engineer: Career field that involves designing things that other people use
Environment: The complex of physical, and biotic factors (e.g. climate soil living things) that act upon an organism or an ecological community and ultimately determine their forms and survival
Environmental Law: A body of laws that determines what can and cannot be done to the environment (e.g.
Enzyme: Molecule that helps a chemical reaction occur
Epistasis: Phenomenon in genetics where proteins on DNA control which genes get expressed by the organism
Equilibrium: A system is at equilibrium when no change is occurring
Ethics: A system of principles that talks about good conduct
Eubacteria: A kingdom of bacteria
Eukarya: The domain that contains all of the eukaryotes (nucleus-containing cells)
Eukaryote: A type of organism that has a true nucleus in its cell(s)
Evaluate: Consider the problem
Evaporation: A change in state from liquid to gas
Evolution: The events involved in the development over long periods of time of organisms
Evolutionary relationship: How closely related two organisms are in terms of evolution
Exert: To make a great effort
Exocytosis: When cells push out proteins and other particles
Exothermic: A chemical reaction that gives off heat energy
Experimental Group: A group in an experiment that receives the independent variable
Explain: Make a clear and simple argument for the materials that you are presenting. Give reasons why someone might think differently.
Exponential Growth Rate: Growth of a population that doesn't grow by the same number of individuals every year; every year it grows by an increasing number of people
Extinction: No longer in existence
Eyewash: A safety feature of a classroom which allows people to safely wash their eyes of any chemicals or objects
F1 Generation: The first generation of children from the P Generation
Facilitated Diffusion: When particles cross a membrane with help (from energy, usually)
Family: The classification group above genus
Fermentation: The process of energy production that happens in many organisms and does not require oxygen
Fertilizer: Chemicals used to add primarily nitrogen
Fission: The splitting of an atomic nucleus that releases energy. Also
Fitness: Ability to survive; well-adapted to the environment
Flagella: An organelle of some prokaryotes that allows for movement and resembles a tail
Fluid: Anything that flows; both gases and liquids are considered fluids
Folate: Nutrient that is required in the diet
Food Chain: A representation of an ecosystem that shows just the path of energy with one producer
Food web: A diagram that shows the relationships between different organisms in an ecosystem
Force: Something that produces a change in an object
Formulate: Express a thought or idea based on the review of information
Fossil: The remains (or an impression) of a plant or animal that existed in a past geological age and that has been removed from the soil
Fossil fuel: An energy source (fuel) made from ancient plant or animal remains (fossils)
Fossil record: A piece of evidence for evolution that shows the development of organisms over time across the entire world
Fossils: Any part of an organism or impression that is left behind
Founder Effect: Way that evolution happens when a few organisms in a population start a population in a new environment
Fuel: A source of energy
Full Disclosure: Concept in experiments where people are told afterwards the experiment that they just participated in
Function: What something is used for
Fungi: The kingdom of living things that are eukaryotic and make their own energy; mushrooms, molds
Gametes: The cells that are responsible for sexual reproduction; sperm
Gene: The basic unit of heredity
Gene: A section of DNA that codes for a protein
Gene Amplification: Way of doing genetic manipulation that increases the production of a particular gene

Gene frequency: The amount of times a particular gene is found in a population
Gene Linkage: When certain genes are passed to offspring along with certain other genes due to crossing over
Gene Pool: Term that refers to the collection of genes of a particular population
Gene Therapy: Way of helping humans by changing their genes to cure diseases
Genetic Base: One of A, T, C and G (and U in RNA) that make up DNA
Genetic Carrier: An organism that is heterozygous for a particular trait (meaning it has a dominant and recessive trait)
Genetic composition: The collection of all of the genes of a particular organism
Genetic Diversity: The amount of differences in characteristics within a population
Genetic drift: The frequency of a particular gene in a population changes in a certain direction
Genetic Equilibrium: When the genes in a population are in balance with each other; dominant and recessive traits are not changing relative to each other
Genetic Fitness: A description of how well an organism's genes help it survive in its particular environment
Genetic research: Research that investigates what information is in organisms' DNA
Genetic Transcription: The process of turning DNA into mRNA
Genetic Translation: The process of turning mRNA into tRNA and amino acids
Genetic variation: Changes between organisms that is based on their DNA
Genetically modified food: Food that has been changed so that its DNA benefits humans
Genetically Modified Organism: Organism, like a food crop, that has had its genes manipulated so that it can grow bigger, faster or more resistant to pests
Genotype: The letters that represent the two alleles that make up a gene
Genus: A classification of living things that is more specific than the species
Geographic Isolation: Type of evolution that happens when a geographic feature separates a population (like a mountain)
Geographic separation: Way that natural selection works when a physical barrier separates species for so long that they no longer can reproduce with each other
Geologic time scale: A chart that shows the eras and periods of major events on Earth
Geology: The study of the Earth
Germ: A small organism that causes disease
Germ theory: The theory that says that diseases come from small organisms (germs)
Global warming: The idea that Earth's temperature is rising and causing mainly negative effects
Goggles: A safety device used whenever the eyes could be injured by a chemical or physical experiment
Golgi apparatus: Organelle that packages proteins and fats so that they can leave the cell
Grams: Measure of mass
Grassland: One of Earth's biomes that has small plants (mostly grasses)
Gravity: The theory that all objects are drawn to each other depending on their distance from each other and their masses
Greenhouse Effect: A greenhouse traps solar energy as heat; the Earth radiates heat back into the atmosphere which is trapped by carbon dioxide and other greenhouse gases
Greenhouse gas: Any gas that causes heat to stay inside the atmosphere
Gregor Mendel: See “Mendel”
Growth: The increase of size of an individual; can also be the presence of something
Habitat: The environment that a species depends upon for its survival
Haploid: Cell that contains one copy of each chromosome
Hereditary: Something that is given by parents to offspring
Heredity: Study of how genetic characteristics are inherited from one generation to the next
Heterotroph: Living thing that needs to consume other organisms for food
Heterozygous: Meaning different; in genetics, Dd, Ff
Hierarchy: A sequence of groupings of things in a system; businesses have hierarchies which start with the president of the company
History of life on Earth: Knowledge on which to base an idea or belief
Homeostasis: Maintenance of a constant internal environment in an organism.
Hominids: Any of a variety of species of primates that were (or are) human-like, chimpanzees, humans and apes
Homo erectus: Ancestor of humans that was the first to walk upright
Homo habilis: Ancestor of humans that was the first to use tools
Homo sapiens: Modern humans; means "wise man"
Homologous chromosomes: Pair of chromosomes that contain similar genetic information
Homologous Pair: Two chromosomes that contain similar genetic information, where one chromosome is inherited from the mother and the other from the father
Homologous structures: Parts of two species that have the same bone (or non-bone) structure but play different roles for the organisms
Homozygous: Meaning same; in genetics, dd, FF
Humerus: Bone in the upper arm
Hybrid: A combination of two different things; in genetics

Hybrid Vigor: Description of the advantages organisms have when they are the product of a dominant and recessive individual mating
Hydroelectric Energy: Energy that comes from damming rivers - the energy is taken by the use of turbines that spin and make electricity
Hydrosphere: The part of Earth defined as all of the water
Hypothesis: An educated guess that is used for experiments; a hypothesis must be tested in order to figure out whether it is true or false
Illustrate: Give examples
Immigration: The movement of an organism into an area
Immunity: Ability to completely fight off disease
Inadvertently: Unintentionally; usually because something was not taken into account
Incomplete Dominance: Genetic relationship where two alleles share dominance and blend in the offspring (red and white flowers making pink flowers)
Independent assortment: Refers to the genetic concept that genes separate independently of each other during meiosis
Independent Variable: In an experiment
Indestructible: Cannot be destroyed
Index Fossils: Fossils that are used as representatives for geologic eras so that scientists can determine how old other fossils are
Indivisible: Cannot be divided
Infer: Extend information beyond what is directly stated.
Inference: A conclusion based upon facts
Informed consent: When performing an experiment involving people, but only when they know what will be done
Inheritance: Attributes that are received by offspring (children) from their parents
Inherited: To receive from ancestors by genetic transmission
Inherited characteristics: Attributes that are received by offspring (children) from their parents
Innovation: A change in a particular technology that improves it
Inoculate: Placement of something that will grow or reproduce
Inorganic: Comes from non-living things
Inquiry: The process where information is received by asking questions
Insertion: When a genetic base is put in between other bases of DNA
Interphase: Phase of cell division where cells grow
Interpret: Give the meaning of something by paraphrasing or explanation
Interrelatedness: Describes how genetically related two species of organisms are
Interspecies Competition: Competition that happens between different species for some resource
Intraspecific competition: When two organisms of the same species compete for the same resource
Invasive: Species that lives in an area that it is not originally from and kicks out native species
Invertebrate: Type of living thing that does not have a backbone
Investigation: The work of inquiring into something thoroughly and according to specific steps
Ionic Bond: A type of bond where ions are formed; electrons are not shared between the atoms as they are lost from one atom and attracted to the other
Jean-Baptiste Lamarck: See "Lamarck"
Jumping gene: A piece of DNA that can become a part of the chromosome at many different sites along the chromosome
Justify: State why you think something is the way that it is. Give supporting evidence.
Kingdom: A general classification of living things often placed under Domains; often Protista, Fungi, Plant and Animal.
Lamarck: Referring to the scientist who proposed the idea that evolution happens by the inheritance of acquired characteristics; Lamarck thought that giraffes' necks got longer because they grew during the lifetime of the parents and the parents passed long necks on to their offspring
Landfill: A place where trash is buried in the ground and covered over with soil and eventually a plastic shell
Laser: Type of light that is high-energy and is focused; used for many different applications
Law: A scientific law describes (usually in numbers) how nature always works
Law of Superposition: In geology, this describes how older rocks are found beneath younger rocks
Leukemia: Cancer of the blood or bone marrow
Lichen: A combination of a fungus and an algae that help each other
Life cycle: The series of stages in form and functional activity through which an organism passes between origin and expiration
Life process: Something that occurs in an organism that is necessary to keep it alive
Light Pollution: Type of pollution that involves extra light in the atmosphere, that ends up distracting birds and other organisms that are used to nighttime being dark
Linear Growth: A type of population growth where organisms increase at a constant rate
Lipid: Refers to a group of fats that cannot be dissolved in water
Living system: A group of organisms and their environment
Locus: Specific place on the chromosome

Logic: Reasoned and reasonable judgment; "it made a certain kind of logic"
Logistic Growth: Type of population growth that initially looks like exponential growth, then levels off at the carrying capacity
Lysosome: Organelle that digests food and waste in the cell
Malaria: A disease spread by mosquitoes which kills about 1.2 million people every year
Material Safety Data Sheet: A piece of safety equipment that comes with all ordered chemicals and states the properties of the chemical and safe handling procedures
Medium: The surrounding environment
Meiosis: The process of cell division which produces four sex cells (gametes) from one cell
Melanin: Pigment that causes skin, hair or eyes to be darker or redder
Mendel: Gregor Mendel
Messenger RNA: Molecule that brings a gene from the DNA to the ribosomes
Metamorphosis: A marked and more or less abrupt developmental change in the form or structure of an animal (e.g.
Metaphase: Phase of cell division where the chromosomes line up in the middle of the cell
Methane: A gas that is often burned and is one of the greenhouse gases
Microorganism: A small organism that is only visible underneath a microscope
Microscope: Instrument used to observe things that are smaller than can be seen with the naked eye
Miller-Urey Experiment: Experiment that showed that living molecules could spontaneously come about from the contents of the early Earth
Misconception: An idea that someone thinks they know
Mitochondria: An organelle in all eukaryotic cells which is responsible for energy production
Mitosis: The process of cell division which produces two body cells from one cell
Molecular Biology: Study of how molecules in cells make living things work
Mollusks: Type of living thing that includes clams, octopuses, and snails
Monera: Kingdom of life made up of bacteria (prokaryotes)
Morphology: Way of describing living things by talking about the way that they are shaped and the parts that they have
mRNA: Messenger RNA
Multicellular: Made up of more than one cell
Multicellular Organisms: Organisms that are made up of more than one cell
Multiple Alleles: When more than two alleles control the expression of a gene
Mutation: A change in the DNA of an organism; substitution, insertion, deletion
Mutualism: A symbiotic relationship where both organisms benefit
Native: Species that is well-established in a particular ecosystem and shows a balance between itself
Natural Radioactivity: Elements that give off energy into the environment
Natural Resource: Something that is useful that comes from the Earth
Natural Selection: The process in which some organisms live and reproduce and others die before reproducing
Niche: Role that an organism occupies in an ecosystem
Nitrogen Cycle: A description of the fact that nitrogen gets used and given off by a variety of organisms; without all of the organisms
Nitrogen runoff: Water containing too much nitrogen due to animal waste or too much fertilizer being used
Non-renewable: A resource that is used faster than it is produced
Nucleic acid: In the nucleus of a cell
Nucleolus: Part of the nucleus that creates ribosomes
Nucleotides: These are found on a strand of DNA or RNA as a sequence of bases
Nucleus: The part of a cell that contains the DNA
Nutrient: Any molecule that is needed for an organism to survive
Objective: Based upon fact
Observation: Noticing or paying attention
Offspring: Children
Order: Classification of living things between Class and Family
Organ: Group of tissues that perform a certain function
Organ system: Group of organs that together perform a common function
Organelle: Part of a cell that performs a function for the cell
Organic: Comes from living things
Organic molecule: A molecule that contains carbon atoms bonded together
Organism: A living thing that can live and reproduce independently
Osmosis: When water molecules move from a higher to a lower concentration
Oxygen: One of the chemical elements on the periodic table that is used by all living things
Ozone: A form of oxygen that protects living things from ultraviolet rays
P Generation: The parent generation
Parasitism: A relationship in which one organism lives in or on another organism and benefits from that relationship while the host organism is harmed by it
Passive Transport: Way that molecules move across a cell membrane without any energy

Patent: The rights that are given to inventors for their invention
Patient zero: The first person to have an infectious disease
Pedigree: A diagram that shows inheritance of a particular characteristic within a family
Peer review: A method of selecting essays to be published where a group of peers review and make comments about the submitted essays
Periodic table: An arrangement of chemical elements based on their atomic numbers and similarity of properties
pH scale: Measures the strength of acids and bases; an acid has a number below 7
Phenomenon: A fact
Phenotype: The physical expression (what can be seen) of a genetic characteristic; brown eyes
Phosphorous: One of the chemical elements on the periodic table that is used by all plants and animals
Photosynthesis: The process that happens in plants and some other organisms which takes the sun's energy and turns it into usable energy; $6CO_2 + 6H_2O + Light = C_6H_{12}O_6$ (glucose) + $6O_2$
Phylogeny: Study of the relationships between organisms
Phylum: Classification of living things just under Kingdom
Physical science: Any of the sciences chemistry astronomy and geology that discusses the nature and properties of energy and nonliving matter
Pioneer: In biology
Plasma: Watery component of blood
Plasmids: A circular piece of DNA
Plate tectonics: The theory that the earth's surface is divided into a few large
Pleiotropy: What happens when one gene affects how other genes behave in an organism
Polygenic Traits: Genetic traits that result from the combination of more than one gene, like eye color and height
Population: The number of organisms in an area that all belong to the same species
Population Growth Rate: How fast or slow a population grows
Precipitation: Any form of water that falls from the atmosphere; rain, sleet, hail
Predation: When one animal hunts and feeds on another animal
Predator: An animal that hunts and feeds on prey
Predict: Use what is already known to make a statement about what will happen in the future.
Primary Consumer: An organism that eats producers
Problem: A statement of the unresolved issue facing the scientist
Procedures: The methods to perform an experiment
Producer: Living thing that makes its own energy from the sun
Products: In a chemical reaction
Prokaryote: A type of living thing that is single-celled and has no true nucleus
Propagate: To transmit or to continue a process
Property: A characteristic or trait of an object
Prophase: Phase of cell division where chromosomes organize themselves
Proportional: A good size compared to something else
Protein: A sequence of amino acids
Protein synthesis: The creation of proteins in the cell from DNA
Protist: Kingdom of life made up of single-celled eukaryotes
Proton: A positively-charged particle in the nucleus of an atom
Prototype: A conceptual model of a technology that works
Protozoans: Single celled animals that are very simple
Pulse: Pattern that the heartbeat makes in all of the blood vessels
Purebred: For every genetic characteristic
Pyramid of Energy: See "Energy Pyramid"
Qualitative observation: Observation made using words and descriptions
Quantitative observation: Observation made using numerical data
Radiation: Energy that is transmitted in the form of rays or waves or particles; when talking about heat
Radioactive: Chemical that breaks down over time
Radiometric dating: Determining the age of a rock or fossil based on the amount of one isotope compared with another isotope; for example
Radius: The bone in the lower arm that is on the thumb side
Random: A lack of order and predictability
Raw Material: A material that has not been processed and can be used to make something else
Reactants: In a chemical reaction
Reaction: When one or more substances are changed into other substances
Recessive: A genetic characteristic that is only expressed by the organism if there is no dominant characteristic present
Recombination: Concept that means that offspring get different genetic characteristics than either of their parents
Recycle: To break down a material so that it can be reused instead of throwing it away
Regeneration: The process that creates something over again
Relate: Show the connection between two or more things. Point out how one causes or is like the other.

Relative Dating: Figuring out how old fossils or rock are by comparing their age with other fossils or rock
Renewable: A type of resource that is produced faster than it is consumed
Reproduce: To create more of
Reproduction: The process of creating offspring
Reproductive Isolation: Type of evolution that happens when organisms within a population stop reproducing with each other
Research: Discovering information that other scientists have already published
Resistance: (Biology) Ability to fight off some amount of disease
Resource: A supply of something that can be used when needed
Restriction Enzymes: A molecule that is used to cut DNA into pieces in order to do analysis on that DNA
Ribosome: Organelle that reads the mRNA to produce proteins
Rough Endoplasmic Reticulum: Type of endoplasmic reticulum that is responsible for helping protein synthesis; ribosomes are present on rough ER
Saturated: Completely full; for a solution
Scientific Method: A set of steps that describes how scientific investigations are performed
Secondary Consumer: An organism that eats primary consumers
Segregation: In genetics
Selectively Permeable: The cell membrane is considered to be this because it allows certain molecules in and out and not others
Sequence: An arrangement in which things follow a pattern; in genetics in order
Sex cell: A type of cell which is involved in reproduction; sperm
Sex Chromosomes: The 23rd pair of chromosomes that determines the gender of the human; the X and Y chromosomes
Sex-linked trait: A genetic characteristic that is present only on the X (or in some cases
Sexual reproduction: The combination of two individuals (genetically) to form one or more new organisms
Sexual Selection: Type of natural selection that happens based on sexual fitness, or how attractive to mates the organism is
Sickle Cell Anemia: Genetic disease where red blood cells are "sickled
Skepticism: Requiring sufficient evidence before believing ideas that others propose
Sketch: A rough drawing that represents the main features of an object or scene that is often made as a preliminary study
Smooth Endoplasmic Reticulum: Type of endoplasmic reticulum that is not responsible for helping protein synthesis and ribosomes are not present on it
Solar Energy: Energy harnessed from the sun's electromagnetic radiation
Somatic cells: The type of cells that form the body of an organism and are not involved in sexual reproduction
Speciation: The creation of new species through evolution
Species: A very specific classification of organisms; all members of a species can mate together
Stabilizing Selection: Type of natural selection that happens when the extreme characteristics evolve out of the population and the average characteristics increase
State: Fully and clearly describe the main points in specific terms. Don't include details or examples.
Stem cell: A type of cell that can turn into any other type of cell
Stimulus: Anything that affects an organism
Strata: Layers of rock
Subjective: Based upon opinion
Substance: A type of matter that has the same properties; water, carbon dioxide, diamond
Substitution: The replacement of one thing for another; in genetics, this refers to a mutation where one base of DNA changes to another
Sulfur: A chemical element that is a part of fossil fuels and can contribute to acid rain
Summarize: Give a brief description of the main ideas.
Supply: In economics
Support: Show evidence to back a conclusion or argument. In biology
Survival of the Fittest: Theory in biology where the organisms that are best suited for their environment survive to reproduce
Survive: In biology
Sustainability: Meaning any process that can continue without outside intervention
Sustainable agriculture: Agriculture that is done so the land is used well and can continue on forever
Symbiosis: A relationship between two or more organisms
Synthesis: The combination of two or more things or concepts
Synthetic material: Material that is not found in nature (e.g. concrete, plastics)
System: A group of interacting or interdependent elements or parts that function together as a whole to accomplish a goal
Taxonomy: Way of classifying living things into classifications like domain, kingdom, phylum, genus and species
Technology: The application of science to solve a particular problem
Technology education: The study of technology

Tectonic Plate: One of the many divisions of Earth's crust that move around and collide
Telophase: Phase of cell division where cell splits into two new cells
Temperature: The measurement of the average thermal energy of a system
Temporal Isolation: Type of evolution that happens when members of a population breed at different times, resulting in new species
Tertiary Consumer: Member of an ecosystem that eats secondary consumers
Tetrad: Two pairs of homologous chromosomes
Texture: The nature of the surface of an object but excluding temperature. Textures include rough smooth feathery sharp greasy metallic and silky
Theory: A well proven explanation of some part of the natural world
Thermal energy: Heat
Timber: Process of cutting down trees
Tissue: Group of cells that perform a similar function
Trace: Describe a path or sequence of events.
Transcription: See "Genetic Transcription"
Transfer RNA: Molecule in the cell that brings amino acids to the ribosomes during translation
Transgenic Organism: Type of living thing that contains genes from other organisms
Translation: See "Genetic Translation"
Trial: A run of an experiment
Trophic Level: Feeding level, like plants are producers, rabbits are primary consumers and snakes are secondary consumers
Tundra: One of Earth's biomes that has small plants (if any) and very cold temperatures; known as the cold desert
Ulna: The bone in the forearm that is on the pinky side
Ultraviolet: A form of electromagnetic radiation that has more energy than visible light; most ultraviolet light is usually blocked in our atmosphere by ozone
Undirected variation: Changes in a population that seem random but can result in mutations that benefit the organism
Unicellular: Made up of one cell
Unity: Property of something in that it is complete
Unsustainable behavior: A process that cannot be continued because it needs constant outside intervention
Urban growth: The distance that a city (an urban center) is expanding
Vacuole: Organelle that stores nutrients in the cell
Variable: What is changed in an experiment
Variation: Something that has changed; in biology
Vertebrate: Organism that has a backbone and bones
Vesicle: A covering that surrounds a nutrient or other molecule in the cell
Virus: A small particle that contains DNA or RNA and is able to reproduce only inside of a living cell
Vitamin D: Nutrient that humans get when exposed to sunlight
Waste Disposal: How waste is gotten rid of
Water cycle: Description of how water moves through oceans, streams, living things and the atmosphere in various ways
Weather: The current state of the atmosphere in terms of temperature, clouds and precipitation
Weather pattern: Weather that happens over and over again over a certain period of time
X-rays: A form of electromagnetic radiation that has low energy and is used in medical equipment
Zone of inhibition: The area around a substance where living things do not grow
Zygote: Combination of a sperm and egg cell

Appendix

MYP Key Concepts

Change is a conversion, transformation, or movement from one form, state or value to another. Inquiry into the concept of change involves understanding and evaluating causes, processes and consequences.

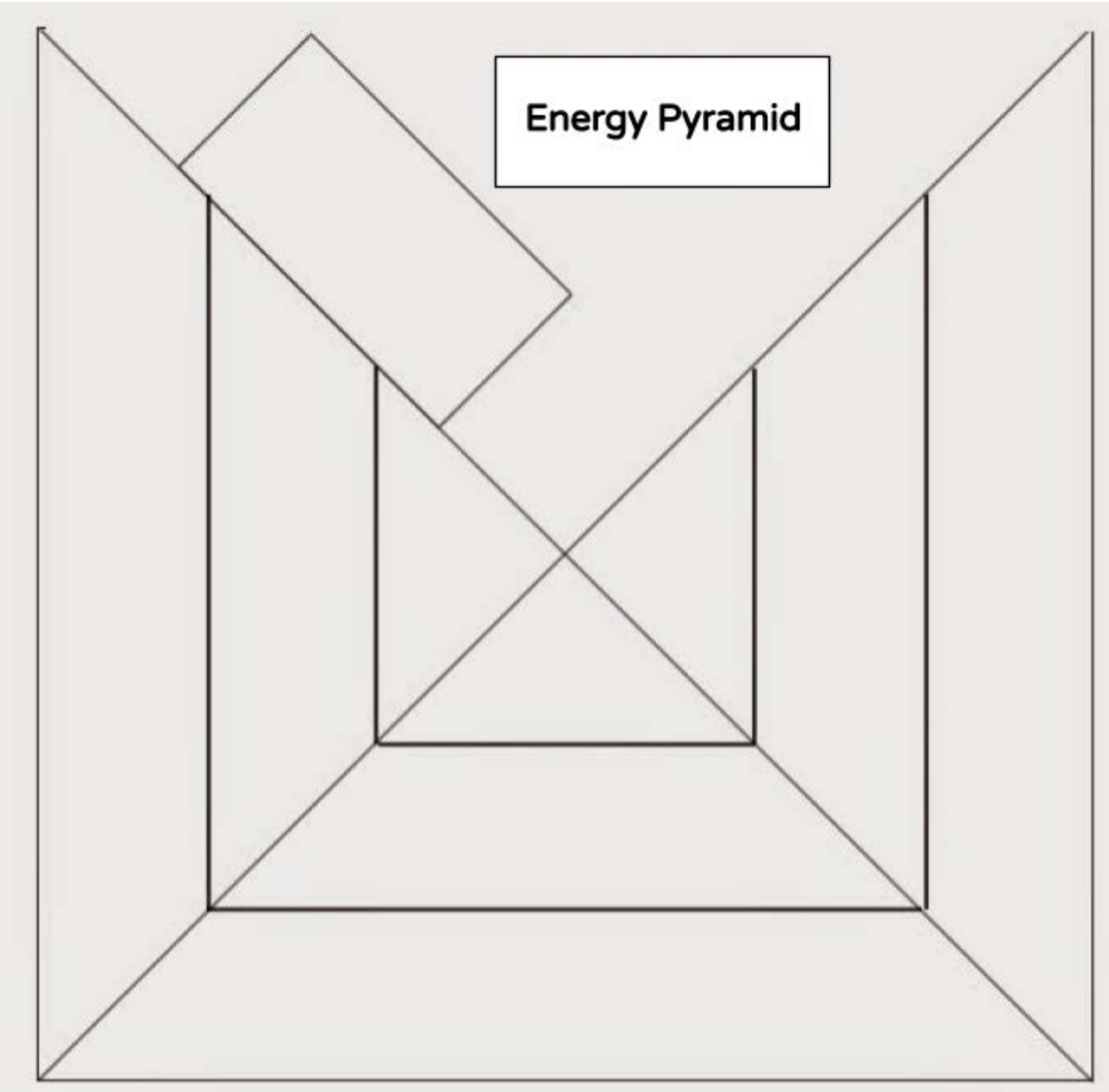
Relationships are the connections and associations between properties, objects, people and ideas-including the human community's connections with the world in which we live. Any change in relationship brings consequences-some of which may occur on a small scale, while others may be far reaching, affecting large networks and systems like human societies and the planetary ecosystem.

Systems are sets of interacting or interdependent components. Systems provide structure and order in human, natural and built environments. Systems can be static or dynamic, simple or complex.

MYP Related Concepts for Biology

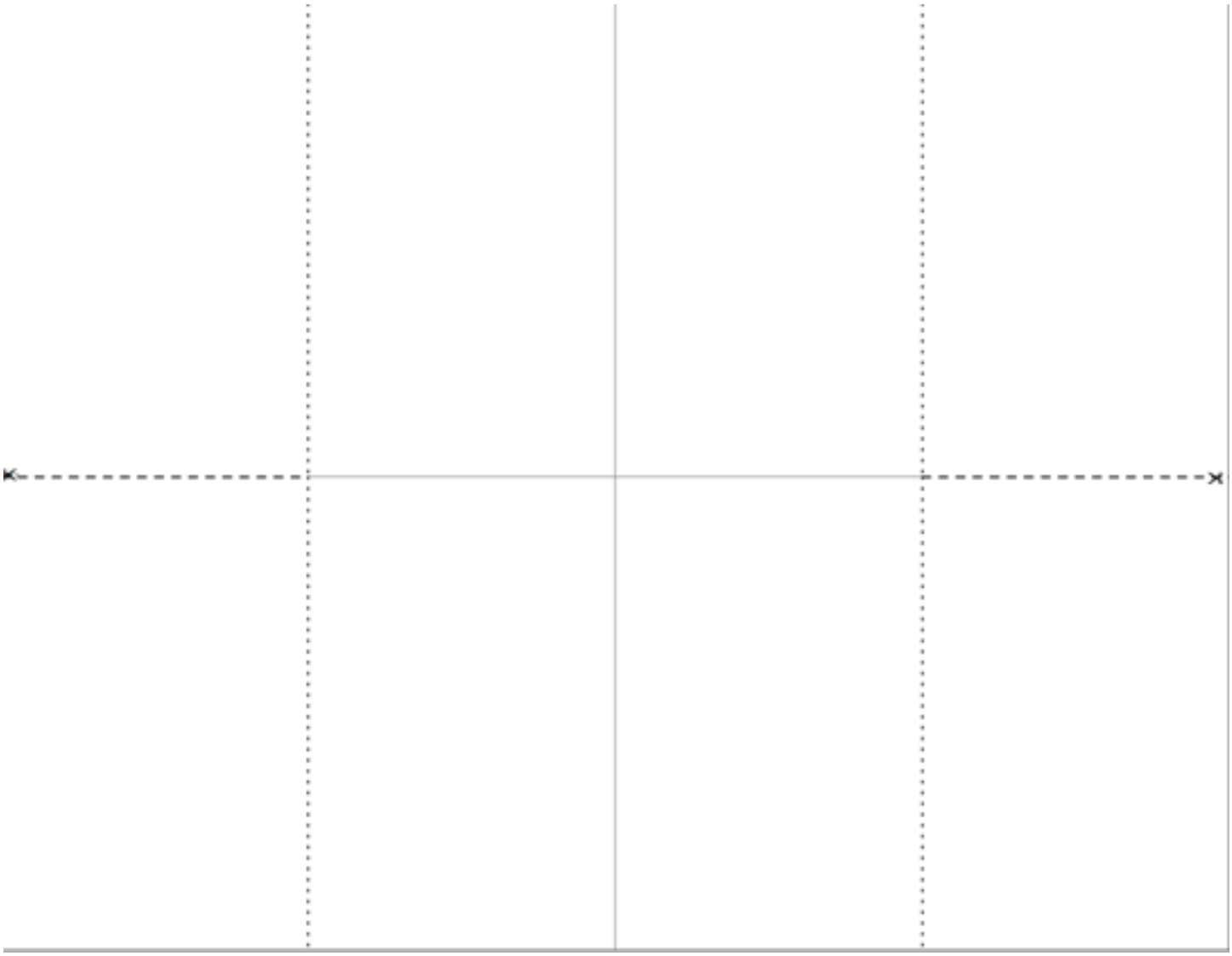
Balance	Ecosystems and humans have to be in *balance*
Consequences	Human impacts on the environment have *consequences* on ecosystems
Energy	All living things use *energy* in their cells in order to live
Environment	The *environment* is the place where all living things get their resources
Evidence	*Evidence* is necessary to draw an accurate conclusion
Form	All living things have different *forms* that determines what they can do
Function	The parts of cells and organisms all have certain *functions*, or what they do
Interaction	Members of ecosystems have many *interactions* with each other
Models	Instead of doing experiments directly on humans, we use *models* instead
Movement	Animals tend to show some sort of *movement*
Patterns	Genes get inherited from parents in predictable *patterns*
Transformation	DNA undergoes a *transformation* to RNA and then proteins

Energy Pyramid

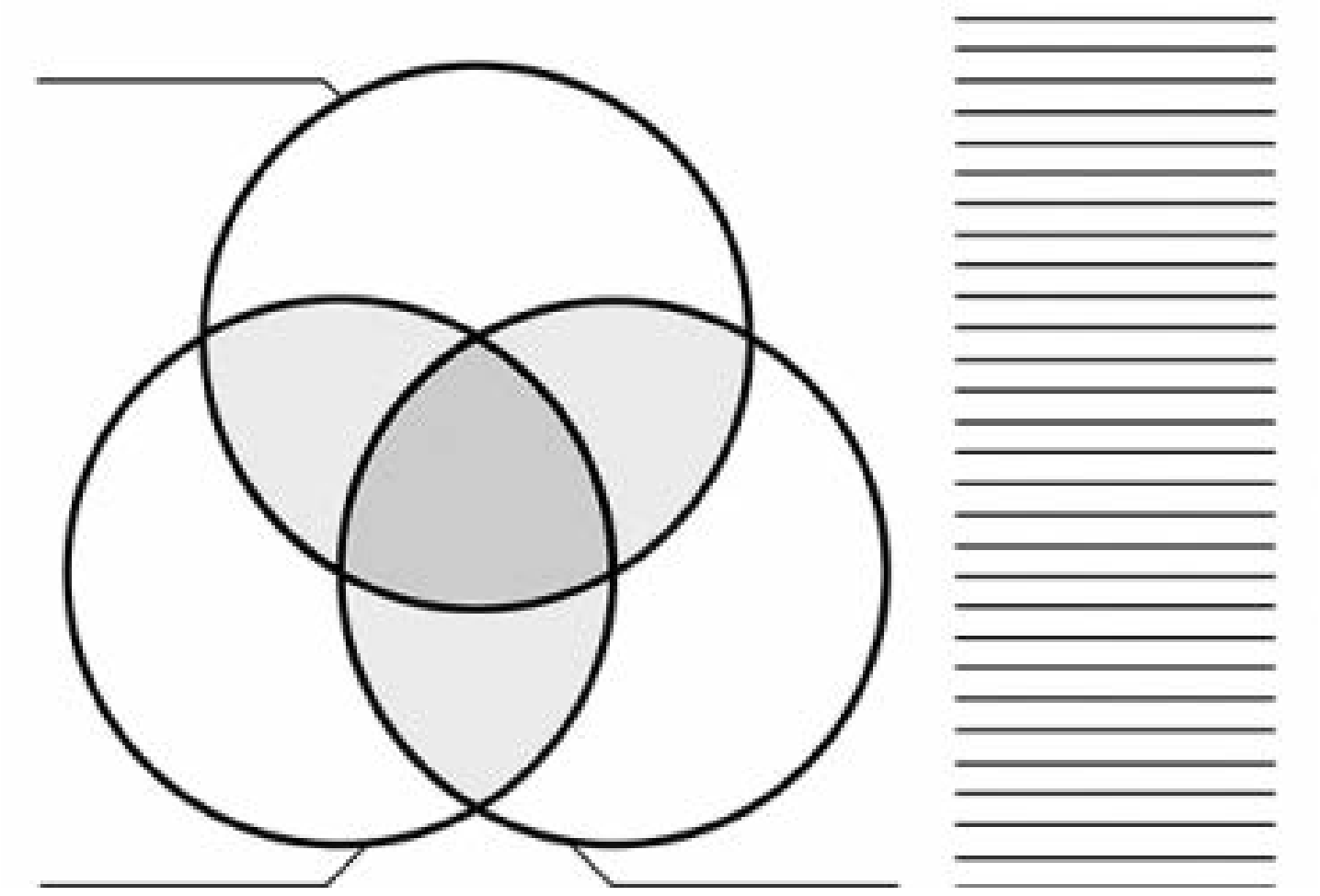


Four Door Foldable:

- Cut along dashed lines
- Fold along dotted lines

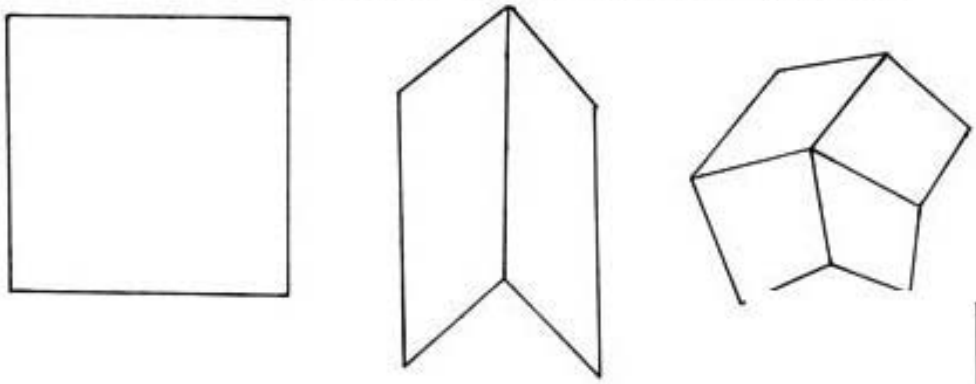


Three Way Venn Diagram

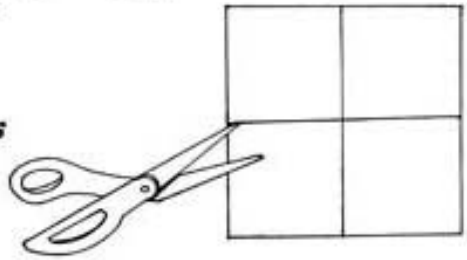


Life Cycle Flip Book

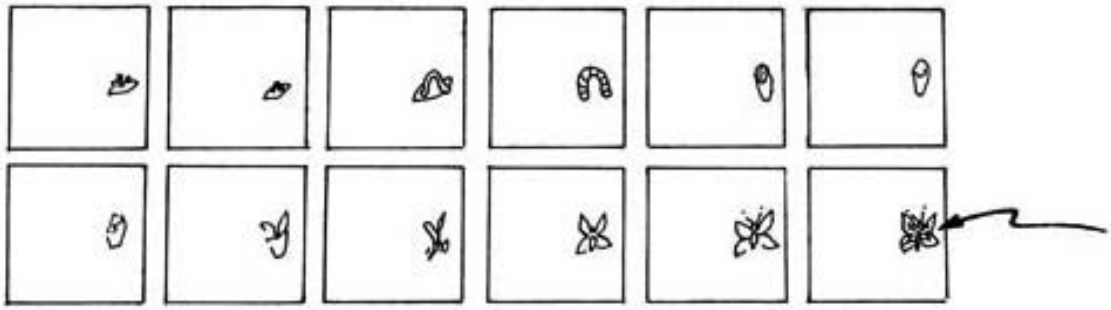
Making a Life Cycle Flip Book



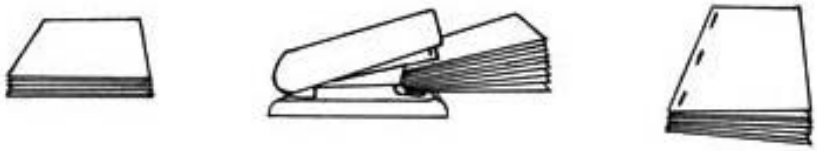
Fold 3 sheets of construction paper into four squares each and cut up.



Glue each of the 12 stages of the life cycle you have colored and cut out — on the right side of the the squares.



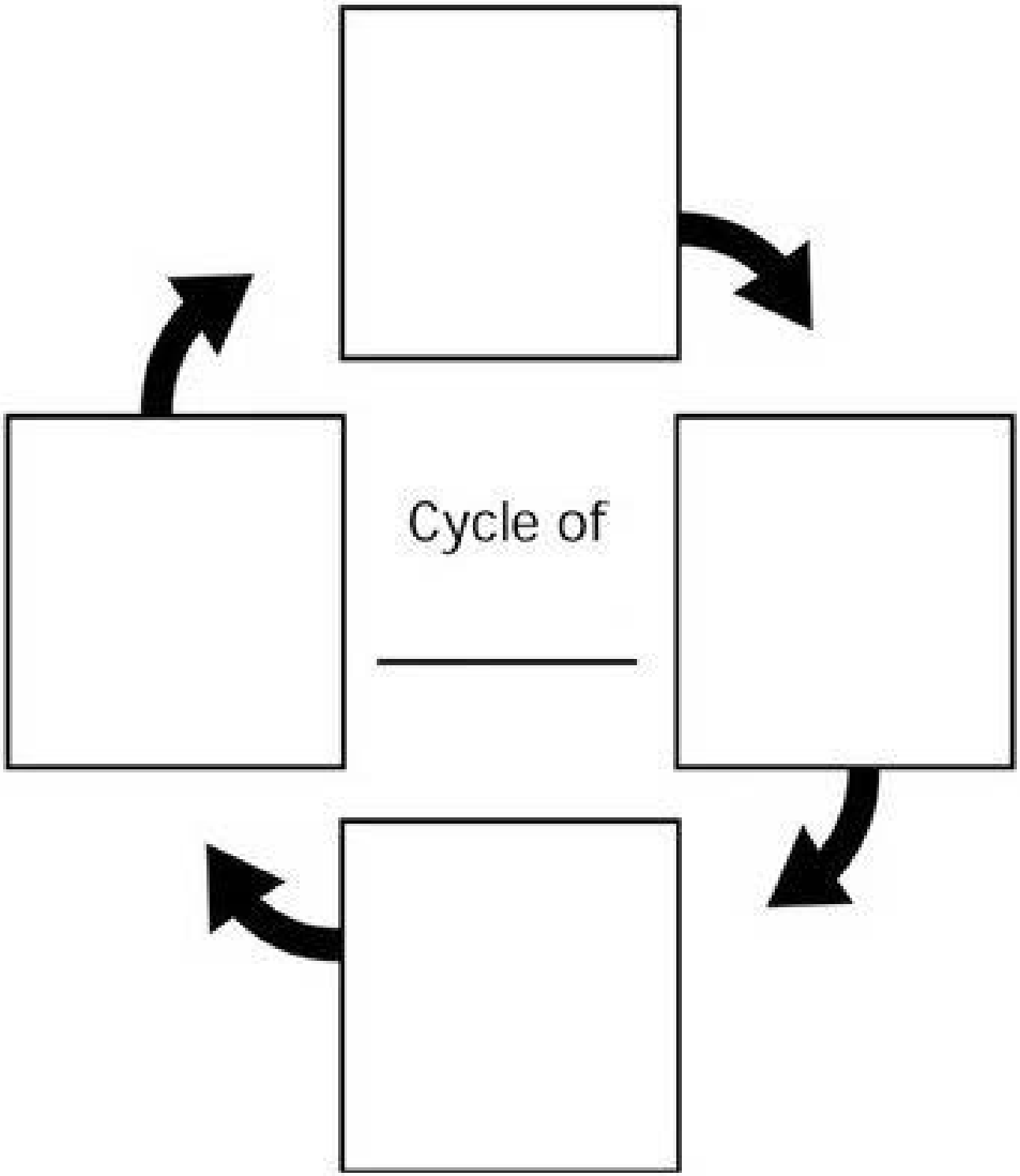
Put them together in order and staple them together on the left side.



Squeeze your book into a C-shape with your left hand so that the edges of all the pages show, then flip through the pages with your right hand and watch your creature grown and develop.

 www.exploringnature.org

Cycle Graphic Organizer



Describing Wheel