Name: ____________________
Unit 1: Introduction to Living Environment
Science Skills, Tools and the Scientific Method

List words or thoughts that come to mind when you think about SCIENCE.

_________________  __________________

☆ Ok, well what is science really? From Latin 'scire', which means to know

☆ BIOLOGY = the study of life and living things

☆ ORGANISM = any living thing

☆ What is the goal of science? To understand more about the world around us

☆ Why study science? To become better global citizens

☆ Branches of Science

B _ _ _ _ _ _ _ _ C _ _ _ _ _ _ _ _ P _ _ _ _ _ _ _ _ E _ _ _ S _ _ _ _ _ _ _

☆ Careers in Biology/Chemistry/Physics/Earth Science:
  Medicine (nurse/doctor), research health/vaccines, forecast weather, work in a museum, design software, food science, sports therapy, etc.

☆ Skills that good scientists have...
  Curious- ask questions
  Problem solve- propose solutions
  Follow directions
  Collaborative
Practicing Lab Safety

Science is an active, hands-on class. We will be doing many activities that require the use of equipment and potentially hazardous chemicals.

Safety is the #1 priority in our classroom.

To ensure a safe learning environment, all students will practice classroom safety in science. Here are a few general guidelines to follow:

- Act responsibly at all times in the lab/classroom. Fooling around, jokes, and pranks are not appropriate.
- Follow all instructions, written and verbal, about the laboratory procedures given by your teacher.
- Perform only those activities that have been authorized by your teacher.
- Keep your table/lab bench and the area around it clean and neat.
- Wear safety goggles, gloves, or other protective items as needed and instructed by your teacher.
- Notify the teacher immediately of any emergency or potentially hazardous situation.
Tools and Techniques of Science

Compound Light Microscope

Uses 2 sets of lenses - **eyepiece (ocular)** and the **objective lenses** (usually 3 of them)

- **Scanning** = 4x
- **Low** power = 10x
- **High** power = 40x

*To calculate **TOTAL MAGNIFICATION** multiply…

<table>
<thead>
<tr>
<th>Type</th>
<th>Eyepiece</th>
<th>Objective</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanning</td>
<td>10x</td>
<td>4x</td>
<td>40x</td>
</tr>
<tr>
<td>Low Power</td>
<td>10x</td>
<td>10x</td>
<td>100x</td>
</tr>
<tr>
<td>High Power</td>
<td>10x</td>
<td>40x</td>
<td>400x</td>
</tr>
</tbody>
</table>
***To look at an object under the microscope…

- Always **start on SCANNING power** (4x) and use the **COARSE ADJUSTMENT** (large knob)

- Only use **FINE ADJUSTMENT** (small knob) under **high power**! If you use the coarse adjustment under high power you could break the lens

**ADJUST DIAPHRAGM** - regulates (controls) the **amount of light** coming through the stage (located **underneath the stage**)

**TO MAKE A WET MOUNT SLIDE:**
Place a drop of liquid on the slide
Bring coverslip in **at an angle** and then gently lower (this prevents air bubbles)

**Microscopic Measurement**
Unit to use when making measurements under the microscope = **micrometer** or micron
   
The symbol for the micrometer or micron is: **µm**

1 mm = 1000 µm

*When going from a larger unit to a smaller unit, move the decimal 3 spaces to the right! Use your **metric conversions**!!

Ex. 2.4 mm = 2400.0 µm or just 2400 µm
     0.6 mm = 600.0 µm or just 600 µm
     .09 mm = 90.0 µm or just 90 µm
*When going from a smaller unit to a larger unit, move the decimal 3 spaces to the left!

Ex. 2800 µm = 2.8 mm
630 µm = .63 mm
58 µm = 0.058 mm

**Metric Conversions:**

King Henry Died Unusually Drinking Chocolate Milk

<table>
<thead>
<tr>
<th>Metric Conversion</th>
<th>King</th>
<th>Henry</th>
<th>Died</th>
<th>Unusually</th>
<th>Drinking</th>
<th>Chocolate</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilo</td>
<td>10 x 10 x 10 x LARGER than a unit</td>
<td>10 x 10 x LARGER than a unit</td>
<td>10 x LARGER than a unit</td>
<td><em>Unit</em></td>
<td>10 x SMALLER than a unit</td>
<td>10 x 10 x SMALLER than a unit</td>
<td>10 x 10 x 10 x SMALLER than a unit</td>
</tr>
<tr>
<td>Hecto</td>
<td>1 hecto = 100 units</td>
<td>1 deca = 10 units</td>
<td>1 unit</td>
<td>Meter (length)</td>
<td>1 unit</td>
<td>Centi 1 unit</td>
<td>Milli 1 unit</td>
</tr>
<tr>
<td>Deca</td>
<td>1 deca = 10 units</td>
<td>1 unit</td>
<td>1 unit</td>
<td>Liter (liquid volume)</td>
<td>1 unit</td>
<td>10 deci = 1 unit</td>
<td>100 centi = 1 unit</td>
</tr>
<tr>
<td><em>Grammar</em></td>
<td>1</td>
<td>1</td>
<td><em>Unit</em></td>
<td><em>Unit</em></td>
<td>1</td>
<td>100 centi = 1 unit</td>
<td>1,000 milli = 1 unit</td>
</tr>
<tr>
<td>Kilometer</td>
<td>km = kilometer</td>
<td>hm = hectometer</td>
<td>dam = decameter</td>
<td>m = meter</td>
<td>cm = centimeter</td>
<td>mm = millimeter</td>
<td></td>
</tr>
<tr>
<td>Kiloliter</td>
<td>kl = kiloliter</td>
<td>hl = hectoliter</td>
<td>dal = decaliter</td>
<td>L = liter</td>
<td>mL = milliliter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kilogram</td>
<td>kg = kilogram</td>
<td>hg = hectogram</td>
<td>dag = decagram</td>
<td>g = gram</td>
<td>cg = centigram</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example: 5 kilo | 50 hecto | 500 deca | 5,000 units | 50,000 deci | 500,000 centi | 5,000,000 milli

**Divide** numbers by 10 if you are getting bigger (same as moving decimal point one space to the left)

**Multiply** numbers by 10 if you are getting smaller (same as moving decimal point one space to the right)

**Measuring the Field of View Under the Microscope:**

How do you find the length of a specimen under the microscope?

1. Find the **diameter** of the field of view (in micrometers or microns)
2. Estimate how many organisms will fit across the field of view
3. Divide the diameter by the # of organisms that could fit across
4. Your units should still be micrometers or microns
**STAINING** a microscope slide:

Why do it? Allows you to see cell parts much better
Ex. Iodine

How do you add a stain? Place a drop **NEXT** to the coverslip and then place a piece of paper towel on the opposite side. **Stain is then pulled under the coverslip.**

**DISSECTING MICROSCOPE**
2 eyepieces
3D images
allows you to view **OPAQUE** objects...(opaque = light can't pass through it)
can fit it with microdissection tools

Ex. To transplant a nucleus from one cell to another

**ELECTRON MICROSCOPE**
*the most powerful microscope
*provides the best resolution
*you can only look at dead stuff with this type of microscope
ULTRACENTRIFUGE
Spins very fast and separates things based on density Ex) Separating blood cells:

- *least dense at the top*
- *most dense at the bottom*

CHROMATOGRAPHY
Separates parts of a solution based on solubility

Here’s an example:
We can identify the different compounds found in plant pigments by using this method.
Making Observations and Inferences

**Observation** - recognizing and noting some **FACT** to gather information about the world around you.

You make observations using your **five senses**

Observations must be **specific** and **accurate**, not ambiguous, so that it means the same to everyone.

**NOTE:** Observations are statements of fact, as seen here

Example:
- Incorrect - the burning bag smelled *nasty*
- Correct - the burning bag smelled *similar to rotten eggs*

Observations can be **qualitative** or **quantitative**

**Qualitative observations** - factual descriptions that **do not use numbers**
Example: Mr. Jones has blue eyes

**Quantitative observations** - factual descriptions that **do use numbers**
Example: Mr. Jones has two eyes

**Inference** - a possible **explanation or guess** about an observation
Example: you leave the movie theater and see the ground is wet so you infer that it rained.
The Scientific Method

The scientific method is an organized, logical approach used to solve a problem or question. The scientific method is a list of steps, not set in stone necessarily, but rather used as a guide or framework for problem solving.

* How many steps does the scientific method (SM) have? 6

An easy way to remember all six steps 😊

<table>
<thead>
<tr>
<th>Pigs</th>
<th>Get</th>
<th>Hiccups</th>
<th>Eating</th>
<th>Rotten</th>
<th>Cheese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem</td>
<td>Gather</td>
<td>Hypothesis</td>
<td>Experiment</td>
<td>Record</td>
<td>Conclusion</td>
</tr>
</tbody>
</table>

😊 Step 1: Identify the **Problem:**
This is the **question** you have about what you are trying to figure out, or the **reason** that you are doing the experiment! Must be **measurable.**

😊 Step 2: Gather **Information:** Do some **background research**

😊 Step 3: Form a **Hypothesis:** What you **THINK** will happen...a hypothesis is an educated **guess.** *A hypothesis must start with the word “if” and continue with the word “then”*

* Example: If we do this, then that will happen...

😊 Step 4: Do the **Experiment:** Perform multiple trials for accuracy

😊 Step 5: Collect and record your **Results:** Use data tables or charts

😊 Step 6: Write your **Conclusion:** What is your overall outcome

* Look over your data and figure out a conclusion. Be sure to share your results to others too (**Communication** is important!)
Understanding Variables in an Experiment

In science, a **variable** is any item, factor, or condition that can be controlled or changed in an experiment. That change happens to the items you are experimenting on known as the **experimental group**. (Unlike the **control group** which is merely used for comparison)

**Recall:**

An experiment is used to determine a connection between different variables looking for a **cause and effect relationship**. A cause and effect relationship means that when you alter one or more variable(s), another variable responds to that change and can be measured.

Let’s take a look at the types of variables used in science...

**Independent variable** - This variable is the one that is **manipulated** or changed by the scientist. You pick something you want to test and that’s the only part of the experiment you change.

**Dependent variable** - The variable that is observed or measured in the experiment, and it is known also as the "responding" variable. The observation or measure of the dependent variable will **change** as the independent variable is altered.

**Controlled variable** - (also known as the **constant variable**) is the variable that the scientist wants to remain the same.

Check out an example
Graphs provide a **visual** way to display your results. Different types of graphs are appropriate for different experiments.

Three types of graphs commonly used in science are the **bar** graph, **line** graph, and **pie** graph.

**Line Graph vs. Bar Graph**

**Graphing Key Words:**

- **Data**: is the **information collected** from observations, sometimes displayed in a chart or table.

- **Bar graphs**: are used to **compare** information about similar things.

- **Line graphs**: are connected line segments that show **changes occurring over a period of time**.

- **Pie Chart**: •Circle that shows how parts relate to the whole. •Shows proportions

An **interval**, **increment**, or **scale** is the **increase** in size or number.

The **horizontal axis** is found on the **bottom** of the graph and is used to show the **manipulated** variable.

The **vertical axis** is found on the **side** of the graph and is used to show the **responding** variable.

When graphing all that you need to remember for the perfect graph is in the words “**DRY MIX**” and “**TAILS**”…

<table>
<thead>
<tr>
<th>D – DEPENDENT</th>
<th>M – MANIPULATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>R – RESPONDING</td>
<td>I - INDEPENDENT</td>
</tr>
<tr>
<td>Y - Y AXIS</td>
<td>X - X AXIS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T – TITLE</th>
<th>A – AXIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – INTERVAL</td>
<td>L – LABEL</td>
</tr>
<tr>
<td>S - SCALE</td>
<td></td>
</tr>
</tbody>
</table>
Unit 2: Organization of Life
Cells, Life Processes, and Classification

Do you remember how living things are organized?

Recall: A **CELL** is the basic unit of structure and function in a living thing.

CELLS that are organized together to perform the same function make up **TISSUES**. For example, blood tissue is made of red and white blood CELLS. *Other examples of tissue include: Muscle tissue, connective tissue, epithelial tissue.

Organs are made of TISSUES that act together. Examples of organs include: **Kidneys, heart, stomach**

Organs that function together make up **ORGAN SYSTEMS**.

Organ systems we will be studying...

1. **Skeletal** (bones)
2. Muscular (muscles)
3. Circulatory (heart & **vessels**)
4. **Respiratory** (nose, lungs)
5. Digestive (**stomach**, intestines)
6. **Excretory** (kidneys, bladder)
7. Nervous (brain, spinal cord)
8. Immune (**White blood cells**)

**Other important systems include integumentary (skin), endocrine (glands), and reproductive (male and female organs, which we will look at in more detail later)**

Levels of Organization in order are...

**CELLS → TISSUES → ORGANS → ORGAN SYSTEMS → ORGANISMS**

**Homeostasis** is the goal! All of your **body systems** work together to maintain **equilibrium** and keep the body in **balance**.
Cell Parts Review

ANIMAL CELL

- lysosome
- Golgi vesicles
- rough ER (endoplasmic reticulum)
- smooth ER (no ribosomes)
- cell (plasma) membrane
- mitochondrion
- Golgi apparatus
- nucleolus
- nucleus
- centrioles
- microtubules
- cytoplasm
- ribosome

PLANT CELL

- Golgi vesicles
- ribosome
- smooth ER (no ribosomes)
- nucleolus
- nucleus
- rough ER (endoplasmic reticulum)
- large central vacuole
- amyloplast (starch grain)
- mitochondrion
- cytoplasm
- cell wall
- cell membrane
- Golgi apparatus
- chloroplast
## Review of Cell Structures

<table>
<thead>
<tr>
<th>Cell Part</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleus</td>
<td>Control center of the cell, contains DNA needed to make new cells</td>
</tr>
<tr>
<td>Cell membrane</td>
<td>Thin outer covering of a cell controlling what goes in and what comes out, selectively permeable</td>
</tr>
<tr>
<td>Cytoplasm</td>
<td>Fluid inside the cell holding organelles in place</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>Helps cell convert food into energy, site of respiration</td>
</tr>
<tr>
<td>Vacuole</td>
<td>A sac-like organelle that stores food, water, and other materials</td>
</tr>
<tr>
<td>Chromosomes</td>
<td>Threadlike structure in the nucleus that contains DNA</td>
</tr>
<tr>
<td>Ribosomes</td>
<td>Small organelle that produces protein</td>
</tr>
<tr>
<td>Endoplasmic Reticulum</td>
<td>An organelle that provides passageways for proteins and other materials to move around the cell</td>
</tr>
<tr>
<td>Cell Wall</td>
<td>Thick outer covering of a plant cell providing structure and support</td>
</tr>
<tr>
<td>Chloroplast</td>
<td>Site of photosynthesis in plants, traps light energy to make food</td>
</tr>
<tr>
<td>Golgi Body</td>
<td>Packaging center</td>
</tr>
</tbody>
</table>
Life Functions

What are the characteristics of life? Living things perform all of these life functions:

1) **Respiration** = the release of energy
   (Recall: oxygen + glucose → Carbon Dioxide + water + energy)

2) **Regulation** = controls and coordinates body functions to maintain **HOMEOSTASIS** (Ex. Maintain body temperature)

   *HOMEOSTASIS = maintaining a stable internal environment despite external conditions

3) **Reproduction** = making new organisms (offspring)

   *not every individual has to do this...but it is necessary for the survival of a species

4) **Growth** = increasing in size and/or number of cells

5) **Excretion** = getting rid of cellular metabolic wastes

   *METABOLISM = all of the chemical reactions (life activities) your body does to survive

6) **Nutrition** = obtaining and processing food

   **AUTOTROPHIC** NUTRITION = organism uses light energy to make its own food (photosynthesis)

   **HETEROTROPHIC** NUTRITION = organism must obtain food from the environment

7) **Transport** = absorbing and circulating (distributing) materials

8) **Synthesis** = “to make”; going from simple to complex

   **How do I remember all these?** 3RGENTS or RRRGENTS
Classification of Living Things

**Classification**—grouping of different types of organisms based upon similarities in **structure** and **evolutionary relationships**.

**Why Classify?**
We can study the unity and diversity of living organisms in an **organized manner**, and group organisms based on their **common characteristics**.

**How do we classify living things?**
Very broad (**general**) categories to very **specific**

<table>
<thead>
<tr>
<th>King</th>
<th>Kingdom (Brodest category)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phillip</td>
<td>Phylum</td>
</tr>
<tr>
<td>Came</td>
<td>Class</td>
</tr>
<tr>
<td>Over</td>
<td>Order</td>
</tr>
<tr>
<td>From</td>
<td>Family</td>
</tr>
<tr>
<td>Germany</td>
<td>Genus</td>
</tr>
<tr>
<td>Saturday</td>
<td>Species (<strong>most specific</strong>)</td>
</tr>
</tbody>
</table>

**Naming Living Organisms**

The branch of biology that groups and names organisms based on their **characteristics** is called **taxonomy**.

In the early 1700s, **Carolus Linnaeus** developed a system of classifying organisms that is still used today.

Linnaeus developed a two-word naming system called **binomial Nomenclature**, which is a scientific name to identify a specific individual organism.
SCIENTIFIC NAMES = **GENUS** + **SPECIES** name

Genus + species

Capital letter + lower case letter

EXAMPLE: **Homo sapien** *(scientific name for a human)*

Living organisms are divided by groups called **taxa** which go from very **broad** characteristics → **specific** characteristics.

**Species** = organisms look alike and are able to breed with one another.

Take a look at this example →

The raccoon and guinea pig are both animals *(Animalia)*, with backbones *(chordata)* that are mammals *(mammalia)*. They start to branch off based on their characteristics and habits which makes them different species.

But, how can we figure out the name of something we are not familiar with? If only there was a tool to use...

**Dichotomous Keys**

**Dichotomous** keys (also known as **taxonomic** keys) are used to identify objects or organisms. In its name, *di-* means “two” so a dichotomous key is made up of **paired** statements. Using a series of statements, you can narrow down an organism to determine its name by identifying its unique characteristics.
Let's try one:

Can you identify this creature using the dichotomous key provided? Give it a try.

Answer: __________________

Let's Take a Closer Look at Kingdoms...

*FYI- though we are not going into detail, technically there is a broader classification category known as **DOMAIN**, which includes **bacteria** (prokaryotic organisms), **archaea** (meaning ancient in Greek), and **eukarya** (all living things with eukaryotic cells).*
<table>
<thead>
<tr>
<th>Kingdom</th>
<th>Main Characteristics</th>
<th>Examples</th>
</tr>
</thead>
</table>
| Eubacteria       | • “true bacteria”, prokaryotic  
• have strong cell walls  
• some are autotrophs, some are heterotrophs | Bacteria such as streptococcus, E.coli       |
| Archaebacteria   | • make their own energy  
• no nucleus (prokaryotes)  
• have cell wall  
• survive in extreme environments | Heat-tolerant bacteria such as thermoplasma |
| Protists         | • eukaryotic  
• most are unicellular (not all)  
• typically live in moist surroundings  
• classified as either plant-like, animal-like, or fungus-like protists | Algae – plant like (chlorophyll)  
Protozoa –animal like (move)  
Slime mold- fungus like (release spores) |
| Fungi            | • eukaryotes  
• have cell walls  
• absorb food using hyphae from living or dead organisms (heterotrophs)  
• many reproduce by releasing spores | budding yeast (unicellular)  
mushrooms  
athletes foot ringworm |
| Plantae          | • multicellular  
• make their own food by photosynthesis (autotrophs)  
• cannot move  
• have cell walls | tree moss  
tulip  
cactus |
| Animalia         | • multicellular eukaryotes  
• motile (can move)  
• cannot make their own food (heterotrophs)  
• either vertebrates/invertebrates | insects  
reptiles  
humans |
What is cell theory?
The cell theory. It is one of the fundamental ideas of the science of biology. The three main parts of the cell theory are summarized below:

1. All living things are made of one or more cells.
2. Cells are the basic units of structure and function in living things.
3. All cells come from other cells.

Cells also must perform basic functions, as described below:

Cell Transport
How do materials get into, and out of the cell?

The cell membrane is considered selectively permeable, because some things are allowed to pass through while others are not.

Substances will either get through the cell membrane without the help of any energy, or they will require energy to be able to push through. Movement through the cell without energy is known as passive transport, and movement of materials with the help of energy is known as active transport.
### Types of Passive Transport (NO ENERGY NEEDED)

**: Diffusion** - Molecules (such as gases) move across the cell membrane from areas of **high** concentration to **low** concentration. Molecules move to reach **equilibrium**, and do so without any help.

**: Osmosis** - Movement of **WATER** from an area of high concentration to low concentration. Same as diffusion but **specific** to water molecules only.

**: Facilitated Diffusion** - Larger molecules like **glucose** can’t fit through the cell membrane so they have helpers to guide them through called **carrier proteins**.

### Types of Active Transport (ENERGY NEEDED)

**: Active transport** - Requires energy because materials are moving from areas of **low concentration** to areas of **high concentration**. They need a little extra “push” to go through. Certain **ions** will bond to ATP to get through the membrane.

Other forms include:

**Exocytosis** = materials in cell “exit” by being wrapped in a **vesicle** and sent out.

**Endocytosis** = materials “taken in” by being wrapped in a pocket formed by the membrane.
The goal of transport is to maintain **homeostasis** (the regulation of the cell’s internal environment).

How does osmosis affect cells? Creates different types of solutions such as...

In an **isotonic solution**, dissolved substances inside and outside of the cell have the **same concentration**.

In a **hypotonic solution**, the concentration of dissolved substances is **lower outside of the cell than inside**. The cell swells because of the extra water that enters.

When a cell is in a **hypertonic solution**, the concentration of dissolved substances **outside of the cell is higher than inside** of the cell. As water leaves the cell, the cell shrinks,
All organisms require energy to do work. Plants get energy from the sun to make their food. Energy must be in a form that can be used by cells. That form is ATP. Organisms that can make their own food are known as PRODUCERS (aka – AUTOTROPHS), and do this through Photosynthesis (photo = light; synthesis = to make).

How does photosynthesis happen?

**The formula is...**

\[ \text{CO}_2 + \text{H}_2\text{O} + \text{energy} \rightarrow \text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6 \]

which translates to:

Carbon Dioxide + Water + Energy (from sun) = Oxygen + Glucose (sugar)

This whole process takes place in the chloroplast. Chloroplast contains CHLOROPHYLL which is a green pigment molecule that absorbs light. red and blue wavelengths are absorbed the best, green and yellow are the worst - they are reflected!!!

**If you reverse this equation then you have the equation for respiration!**

Chloroplast

Grana/Granum: Green, contain chlorophyll, light reactions happen here

Stroma (like the cytoplasm of the cell): clear, dark reactions occur here
How do plants get materials for Photosynthesis?

Stomata

- *Stomata* (sing. *stoma*) = pores in a leaf, mostly on the undersurface
- Each pore is surrounded by a pair of guard cells
- Guard cells can change shape to open or close the stoma

Epidermis contains a waxy outer covering to prevent water loss
How do animal cells get their energy?

**Cellular respiration** - process which cells get energy from glucose in food.

*ENERGY is in the form of **ATP**!

*ATP = Adenosine triphosphate

Here is the formula:

\[
\text{Oxygen} + \text{Glucose} \rightarrow \text{Carbon Dioxide} + \text{Water} + \text{ENERGY}
\]

\[
O_2 + C_6H_{12}O_6 \rightarrow CO_2 + H_2O + \text{ATP}
\]

Respiration occurs in **ALL CELLS, ALL THE TIME!** The rate will change, depending on activity level, but there is still some!

**DURING WORK:**

\[
\text{ATP} \rightarrow \text{ADP} + \text{Energy (used to do stuff!)}
\]

Ex. White blood cell will use this energy to change its membrane to engulf bacteria!
There are TWO types of respiration:

1. **AEROBIC Respiration** - needs **OXYGEN**!

   Oxygen + Glucose \[\rightarrow\] Carbon Dioxide + Water + ENERGY
   \[O_2 + C_6H_{12}O_6 \rightarrow CO_2 + H_2O + \text{ATP}\]

   *Aerobic respiration is **VERY EFFICIENT**, uses oxygen, happens in the **MITOCHONDRIA** (except first stage of glycolysis which happens in the cytoplasm).

   How do organisms generate energy when oxygen is not available?

2. **ANAEROBIC RESPIRATION** (also known as **FERMENTATION**)

   * less efficient, NO oxygen needed, happens in the **cytoplasm**

   Glucose + 2 ATP \[\rightarrow\] pyruvic acid + 4 ATP

   TOTAL NET GAIN of 2 ATP

   During fermentation, some organisms produce the by-product **ethyl alcohol** (**yeast**), whereas **humans** produce **lactic acid**. Lactic acid build-up is often the cause of muscle cramps.

In Summary:

During Aerobic Respiration, **36 ATP are created** (**34 from cellular respiration and 2 from glycolysis**).

During Anaerobic Respiration, **4 ATP are created** (**2 from fermentation and 2 from glycolysis**).
Unit 4: Biochemistry

The study of chemistry begins with the basic unit of matter, the *atom*. Atoms are made of...**protons, neutrons, and electrons**!

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTON</td>
<td>+</td>
</tr>
<tr>
<td>NEUTRON</td>
<td>0</td>
</tr>
<tr>
<td>ELECTRON</td>
<td>-</td>
</tr>
</tbody>
</table>

A chemical **element** is a pure substance consisting of one type of atom.

There are over 100 elements known, but only a few are commonly found in living organisms. Examples include:

In smaller amounts:

- C = **Carbon**
- H = **Hydrogen**
- O = **Oxygen**
- N = **Nitrogen**
- P = Phosphorous
- S = Sulfur
- Ca = Calcium
- Fe = Iron
- Na = Sodium
- Cl = Chlorine
- I = Iodine
- K = Potassium
- Mg = Magnesium

Elements combined in certain ratios give us **compounds**.

**Types of Compounds:**

- **Organic** – **Carbon** compound usually with H, and O in some ratio (referred to as chemicals of life)
  - ex. Carbohydrates, Proteins, Lipids, Nucleic Acids

- **Inorganic** – usually "support" life - no specific ratio of C, H, and O

How are atoms held together?

**Chemical Bonds!**

The main types of chemical bonds are **ionic** bonds and **covalent** bonds.
Ionic bonds - one or more electrons are transferred from one atom to another (forms a charged atom called an ion)
- ions are attracted to each other
- medium strength bond…it is what holds salt together

Covalent bonds - share electrons
- forms molecules
- bonds are shown as lines between the elements

Hydrogen Bonds - very weak bonds

The way atoms are bonded together can affect their properties. Water is an example of a unique substance that demonstrates polarity.

A molecule in which the charges are unevenly distributed is said to be “polar.”

With 8 protons, water's oxygen nucleus attracts electrons more strongly than the single protons of water’s two hydrogen nuclei.
As a result, water’s shared electrons are more likely to be found near the oxygen nucleus.

Because water is a polar molecule, it is able to form multiple hydrogen bonds, which account for many of water's special properties.

Weird Properties of Water (H₂O)

1. Ice is less dense than liquid water = ice floats!
2. Water changes temperature very slowly
3. Universal solvent (dissolves lots of stuff!)
4. Clings to itself and to other stuff (adhesion and cohesion)
Mixtures and Solutions

Water is often found as part of a **mixture**.

**RECALL:** A **mixture** is two or more elements or compounds that are **physically mixed together but not chemically combined**.

Ex.) Salt water- a **solution** (substances are evenly distributed throughout) of water and NaCl, where they are mixed but not chemically combined.

In a saltwater solution, table salt is the **solute**—the substance that is dissolved. Water is the **solvent**—the substance in which the solute dissolves.

Water is also found commonly in a **suspension**. Particles in a suspension are not chemically combined or dissolved, nor do they settle out.

Biological fluids like blood are both **solutions** and **suspensions**. Blood is mostly water, which contains many dissolved compounds. Blood also contains cells and other **undissolved particles** that remain in suspension.

**Acids, Bases, and pH**

Water molecules sometimes split apart to form **ions**. Particles such as H⁺ and OH⁻ in solution can change the **pH**. We use a **pH scale** to indicate the concentration of H⁺ **ions** in solution.
Organic Chemistry

*To be organic…**MUST HAVE C (carbon) & H (hydrogen)**

Why?

Carbon **can bond with many elements**, including hydrogen, oxygen, phosphorus, sulfur, and nitrogen to form the molecules of life.

*examples: **CARBOHYDRATES** *(sugars)*, **PROTEINS** *(amino acids)*, **LIPIDS** *(fatty acids + glycerol)*, **NUCLEIC ACIDS**

Organic compounds in living cells are so large that they are known as **macromolecules**.

Formed by the process of **polymerization**, which joins together single units *(monomers)* to make larger compounds called **polymers**.

Let’s start with the most common macromolecule…

**Carbohydrates**

**Carbohydrates** are compounds made up of **carbon**, **hydrogen**, and **oxygen** atoms, usually in a ratio of **1 : 2 : 1**.

Used as the main source of **energy** for living things.

Names of sugars end in **-ose**    EXAMPLES: glucose, sucrose, lactose

Have a ring structure:

**Monosaccharide** = simple sugar (mono = 1; saccharide = sugar)  
Ex. **GLUCOSE** *(C₆H₁₂O₆)*

**Disaccharide** = 2 simple sugars stuck together by **DEHYDRATION SYNTHESIS***

Ex. **SUCROSE** *(C₁₂H₂₂O₁₁)*
*Dehydration Synthesis* = join together small molecules by removing water (H from one and OH from another)

Molecules can be broken down (digested into glucose by *HYDROLYSIS* (adding water to break it apart)

**Polysaccharide** = many simple sugars stuck together
Ex. Starch, Glycogen

**Lipids**
Lipids are biological molecules that are generally not soluble in water (FATS, OILS, and WAXES)

Lipids make up membranes, store energy, provide insulation and make up steroids.

The elements found in lipids are: C H O but, there is NOT a 2:1 H to O ratio (ex. C_{48}H_{73}O_{6})

The building blocks of lipids are: **FATTY ACIDS** & **GLYCEROL**

If carbon has *single bonds* in the fatty acid chain, the lipid is said to be **saturated**.

If there is at least one carbon-carbon *double bond* in a fatty acid, the fatty acid is said to be **unsaturated**.
Proteins

Proteins are macromolecules that contain nitrogen as well as carbon, hydrogen, and oxygen. Proteins are polymers of molecules called amino acids. (Remember: amino acids are the building blocks of all proteins!)

Proteins work to:
- Control rates of reactions
- Regulate cell processes
- Form cellular structures
- Transport materials into and out of cells

Important!! The elements found in proteins are: CHON (*If you see an N in a molecule you must think protein!)

*N-C bond is called a PEPTIDE bond (a covalent bond that forms between amino groups and carboxyl groups)

*C double bonded to an O and an OH is called the CARBOXYL GROUP (this is what makes it an acid!)

*N bonded to the H's is called an AMINO GROUP

Dipeptide = 2 amino acids stuck together by dehydration synthesis

Polypeptide = PROTEIN...many amino acids put together by dehydration synthesis (poly=many)
*these have a very specific shape

DEHYDRATION SYNTHESIS of a PROTEIN:

\[
\text{Reactants: Amino acid + Amino acid} \rightarrow \text{Dipeptide} + \text{H}_2\text{O}
\]
Nucleic Acids

Nucleic acids are macromolecules containing hydrogen, oxygen, nitrogen, carbon, and phosphorus \( \text{C H O N P} \).

Nucleic acids store and transmit hereditary, or genetic, information (DNA and RNA).

Nucleic acids are polymers assembled from individual monomers known as nucleotides.

Rules for Identifying Structures:

1. **Look for "N" (nitrogen)**
   - If it has **one** N then it is an AMINO ACID
   - If it has **two** N's then it is a DIPEPTIDE
   - If it has **3+** N's then it is a POLYPEPTIDE or PROTEIN!

2. If there are no "N's", **Look for a ring shape**
   - If there is **one** ring then it is GLUCOSE (aka simple sugar or monosaccharide)
   - If there are **two** rings then it is a DISACCHARIDE (ex. Maltose)
   - If there are **3+** rings then it is a POLYSACCHARIDE or STARCH (Carbohydrate)

3. If there is no "N" and no ring shape, **Look for a double-bonded oxygen!**
   - If there is one double bonded oxygen then it is a FATTY ACID
   - If there are 3 double bonded oxygen then it is a LIPID (fat)

4. If there is no "N", no ring shape, no double-bonded oxygen then it is GLYCEROL
Chemical Reactions and Enzymes

A chemical reaction is a process that changes, or transforms, one set of chemicals into another.

Chemical reactions change bonds joining atoms together.

Reactants = substances that start a chemical reaction
Products = ending substances of a chemical reaction

Energy is released or absorbed whenever chemical bonds are formed or broken.

ENZYMES

- Made of protein
- Are CATALYSTS...a catalyst speeds up chemical reactions and can be used over and over again
- Lower activation energy
- Exhibit SPECIFICITY...enzymes have a very specific shape and only work on specific molecules
- Enzyme names end in -"ase"

Ex. LIPASE for LIPIDS
MALTASE for MALTOSE
PROTEASE for PROTEIN

* Often written on the ARROW in chemical reactions
Ex. Glucose + Glucose \rightarrow Maltose + water
(reactants/substrates) enzyme (products)
How do enzymes do their jobs?

Reactants must collide with enough energy so existing bonds will be broken and new bonds formed.

Enzymes provide a site where reactants can be brought together to react.

**What is the LOCK AND KEY MODEL of enzyme action?**

Enzymes are specific based on shape...just like a key is specific to a lock, based on its shape!

The steps of an enzyme working on two smaller substrates to build a larger product...

What effects the RATE (speed) OF ENZYME ACTION?

1. **Temperature**
   
   Increasing temperature will increase enzyme action UP UNTIL A CERTAIN POINT...then, the enzyme will become DENATURED (destroys the shape of the enzyme) and it will stop working 😞

2. **Concentration of Substrate (or enzyme)**
   
   If we increase the substrate concentration then the reaction rate will increase

3. **Coenzymes** - non-protein piece of an enzyme that is needed for the enzyme to work
   
   Ex. VITAMINS

4. **pH** - measures how acidic or basic things are
Unit 5: Human Body Systems

Skeletal System

The skeletal system is the bony framework inside the body that provides the foundation for all other body systems.

The skeletal system functions to provide:
1. **Shape**
2. Support
3. Ability to **move**
4. **Protection** of organs
5. Production of **red blood cells**
6. Storage of minerals

There are **206** bones in the human body (more for babies, over **300**, when they are born because the bones haven’t fused together yet)

Structure of a bone:

- **Periosteum**: Connective tissue covering the bone
- **Red Marrow**: Makes red blood cells
- **Yellow Marrow**: Stores fatty tissue
- **Compact Bone**: Contains hard outer covering
- **Small spaces in the bone that make it lightweight but still strong**
How is the skeleton held together?

LIGAMENTS!! (Ligaments are bundles of connective tissue that connect one bone to another bone)

What is a joint?

A joint is a place **where two bones come together**. Joints allow bones to move in certain ways. See examples below of types of joints.

These examples are **movable joints**. Several places in our body, including the skull and pelvic bone, are **fixed** or non-movable joints.

Malfunctions of the skeletal system:

- **Arthritis** - inflammatory disease affecting **joints** and surrounding tissues
- **Osteoporosis** - bone loses **calcium**, becomes thinner, can easily break
- **Scoliosis** - s-shaped curve of the **spine**
What does the muscular system do?

- Skeletal Movement
- Movement of materials throughout your body (blood, food, etc.)
- Works to help maintain body temperature (shivering if a person is cold = muscle contractions)

Types of Muscle Tissue in the Body

**Voluntary Muscle:**
Muscles that you can control as you use them.

**Example:** You decide to raise your hand in class or not which uses muscles that you consciously control

**Involuntary Muscle:**
Muscles that function whether you want them to or not.

**Example:** Food will be digested or your heart will beat regardless of whether or not you try to control it

**Skeletal Muscle:**
AKA Striated are muscles that are attached to your bones (by tendons) and allow you to make deliberate movements.

Skeletal muscle is called striated because of its banded appearance

**Smooth Muscle:**
Found in places such as the digestive system, these muscles work to move materials throughout your body

**Cardiac Muscle:**
Your HEART! Cardiac muscle is only found in the heart, and your heartbeat is something you have no control over 💔
Three types of Muscle:

Cardiac muscle cell

Skeletal muscle cell

Smooth muscle cell

Major Muscles to Know:
What is the Function of Skin?

Skin helps our bodies to:

- Regulate body **temperature**
- Eliminate **waste**
- Be **protected** from the environment
- Produce **vitamin D**
- Gather **information** from the world around us

What Makes up Skin?
What is the nervous system?

The nervous system receives **messages** about the body’s internal and external environments and responds to this information.

What makes up the nervous system?

Brain, Spinal Cord, and Nerves

Makes up **CENTRAL** nervous system  Makes up **PERIPHERAL** nervous system

**Central Nervous System:** Made up of brain and spinal cord. These parts do the “thinking” in order to interpret messages that come in.

**Parts of the Brain:**

1. **Cerebrum:** Controls movement, interprets sensory information, and controls complex thinking such as remembering and learning
2. **Cerebellum:** Coordinates muscles and maintains balance
3. **Medulla** (brain stem): Controls involuntary processes such as breathing and heartbeat

**Peripheral Nervous System:**

Nerves that branch out from the central nervous system and **transfer information** to the body as either voluntary or involuntary responses. Nerve cells that carry information throughout the body are called **neurons.**

There are three types of neurons (nerve cells):

<table>
<thead>
<tr>
<th><strong>Sensory neurons</strong></th>
<th>Picks up stimulus and converts it into a nerve impulse</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inter</strong> neurons</td>
<td>Carries a nerve impulse to another neuron</td>
</tr>
<tr>
<td><strong>Motor</strong> neurons</td>
<td>Sends an impulse to a muscle or gland to help it respond</td>
</tr>
</tbody>
</table>
Parts of a nerve cell:

- **Cell body**- Contains the nucleus and other organelles of the cell. Performs same **metabolic activities** as ordinary cell.
- **Dendrite**- Receives **messages** from other cells or environment and transmits them to the cell body.
- **Axon**- conducts messages **away** from the cell body towards the terminal branch (synapse).
- **Myelin Sheath**- An **insulating membrane** that surrounds and protects an axon.

What is a nerve impulse?

An **electrical signal** carried by a neuron. A nerve impulse is similar to the flow of electrical current through a metal wire. Check it out:

When a neuron is resting (not transmitting an impulse), the outside of the cell has a net positive charge, and the inside of the cell has a net negative charge. The nerve cell membrane pumps Na\(^+\) ions out of the cell and K\(^+\) ions into the cell by means of **active transport**. The active transport mechanism that performs this pumping action is called the sodium-potassium pump. The impulse causes a movement of ions across the cell membrane.

Take Note:

What role does the nervous system play in maintaining homeostasis?

- Detects changes in the internal and external environment
- Issues commands to respond to those changes.
- If the body can't respond, malfunctions can occur, such as multiple sclerosis
How are messages carried across the synapse? **Neurotransmitters** (chemical messengers) are released and cross the synaptic gap to reach special proteins called **receptors** that transmit that signal along the next neuron. Nerve signals travel from dendrite to axon.

What role does the nervous system play in maintaining **homeostasis**? (Recall: Homeostasis is a state of **dynamic equilibrium**)

- Detects changes in the **internal** and **external** environment
- Issues commands to **respond** to those changes.

What if the nervous system cannot maintain homeostasis?

**Disease** and/or **death** can occur when the body cannot maintain homeostasis. Some examples of malfunctions related to the nervous system include:

**Drug Addiction**

Drugs affect the **synapses** and how substances like **neurotransmitters** are released.

**Parkinson's Disease**

Happens as the result of the loss of **dopamine**-producing brain cells. Causes tremors and loss of coordination.

**Alzheimer's Disease**

A degenerative disorder that attacks the brain's **nerve** cells, or neurons, resulting in loss of memory, thinking and language skills.
The respiratory system is the system of the body that takes in oxygen that the body needs and removes the carbon dioxide that it doesn’t. Our bodies do this through *breathing*. All aerobic organisms need to obtain oxygen and remove carbon dioxide to perform *cellular respiration.* (can you recall the formula?)

Single celled organism can readily exchange these gases through their **cell membrane**. (see amoeba →)

Larger multicellular organisms use specialized structures to transfer oxygen and carbon dioxide (see human ↓).

**NOTE**: Breathing is NOT the same as respiration. Remember, respiration is a **chemical reaction** that takes place in our cells where we take in food and oxygen to release carbon dioxide and make energy.

What are the parts of the respiratory system?
Pathway of Oxygen:

1. Body breathes in the air which is pulled through the nose or mouth and down through the **trachea**. Contraction of **diaphragm** pulls lungs open to allow air to move in.

2. The trachea is a pipe shaped by rings of **cartilage**.

3. It divides into two tubes called **bronchi**.

4. Bronchi carry air into each lung.

5. Inside the lung, the tubes divide into **smaller and smaller tubes** called **bronchioles**.

6. At the end of each of these tubes are small **air sacs** called **alveoli**.

7. **Capillaries**, which are small blood vessels with thin walls, are wrapped around these alveoli to deliver blood back and forth to the lungs.

The capillaries which surround the alveoli are involved in gas exchange between the blood and the alveoli.

Oxygen, which is loosely bound to the **hemoglobin** (biochemical compound that combines with oxygen) **diffuses** into the cells where it is used during aerobic cellular respiration.
How is breathing controlled by the nervous system?

The **medulla** controls breathing by detecting the levels of carbon dioxide in the blood.

Malfunctions/diseases of the respiratory system:

**Pneumonia**: alveoli fill with fluids and mucus resulting in coughing and breathing difficulties

**Asthma**: allergic reaction in which bronchiole contractions create breathing difficulties

**Emphysema**: air sacs lose their elasticity and breakdown resulting in a loss of respiratory surface in the lungs
Also known as the “cardiovascular” system, this system is made up of

- **Heart**
- **Vessels**
- **Blood**

All work to transport oxygen, nutrients, hormones, and cellular waste products throughout the body.

Structure of the HEART ♥

1. **Septum**: muscular wall dividing the mammalian heart into two halves
2. **Atria**: thin walled upper heart chambers which receive blood pump blood to the ventricles
3. **Ventricles**: muscular thick walled chambers which pump blood from the heart -- the lower chambers
4. **Valves** - prevent the backward flow of blood in the heart

Let’s take a look at how the heart

<table>
<thead>
<tr>
<th>Pathway of blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inferior &amp; superior vena cava (blood from body, needs oxygen)</td>
</tr>
<tr>
<td>2. Right atrium</td>
</tr>
<tr>
<td>3. valve</td>
</tr>
<tr>
<td>4. Right ventricle</td>
</tr>
<tr>
<td>5. valve</td>
</tr>
<tr>
<td>6. Pulmonary arteries (blood to the lungs to pick up oxygen)</td>
</tr>
<tr>
<td>7. Pulmonary veins</td>
</tr>
<tr>
<td>8. Left Atrium</td>
</tr>
<tr>
<td>9. valve</td>
</tr>
<tr>
<td>10. Left ventricle</td>
</tr>
<tr>
<td>11. valve</td>
</tr>
<tr>
<td>12. Aorta (delivered to body)</td>
</tr>
</tbody>
</table>

*Important Note: **Arteries** always carry blood away from heart, veins always back to heart.*
Look at the heart attached to vessels. The **right** side carries **deoxygenated** blood, while the left side carries oxygenated blood.

Special cells called “**pacemaker** cells” cause electrical impulses that make the heart pump blood.

**Types of Vessels:**

**Artery**
- Carry blood **away** from heart.
- **Thick**-walled, muscular, blood vessels.
- Very elastic.
- Expansion and contraction of wall (pulse) aid in flow of blood.

**Vein**
- Brings blood **back to the heart**. Thin walled, slightly elastic, blood vessels. Contains **Valves** (which prevent the backflow of blood).

**Capillaries**
- Readily exchange nutrients, wastes, oxygen, and other substances between the blood and the intercellular fluid. **Tiny** blood vessel only one cell thick.

Among the blood capillaries throughout your body is another network of tiny, thin-walled vessels called lymphatic capillaries. **Lymphatic capillaries** are designed to pick up the fluid that leaks into your tissues from your bloodstream and return it to your circulatory system. Lymph circulates throughout the body’s lymphatic system carrying **white blood cells**, **metabolic waste**, fat cells, **proteins** and dead cell particles away from the in the body to be excreted.
What is blood and what does it do?

- **Transport** - nutrients and oxygen are delivered, waste and carbon dioxide are removed.
- **Regulation** - absorbs and releases heat, releases chemical messengers that regulate body *(hormones, enzymes)*
- **Protection** - carries specialized cells that defend body against diseases. Also has ability to clot to reduce blood loss

Blood is made of:

* **Plasma** 55% (liquid part of the blood)

<table>
<thead>
<tr>
<th>Blood Cells</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Blood Cells</td>
<td>45%</td>
</tr>
<tr>
<td>White Blood Cells</td>
<td>45%</td>
</tr>
<tr>
<td>Platelets</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Plasma**
Contains dissolved substances *(nutrients, proteins, enzymes, antibodies etc.)* for transport.
Maintains body temperature and proper pH.

**Red Blood Cells**
- Most numerous
- **Disc** Shaped
- Smaller than white blood cells, larger than platelets
- **No nucleus** when mature
- Produced in the **red marrow** of long bones
- Contain the iron protein compound **HEMOGLOBIN** whose chief function is to combine with oxygen and carry it to the cells

**White Blood Cells**
- **Largest** blood cells
- Formed in the **bone marrow** or in the lymph tissue
- Protect the body against diseases by forming **antibodies** or engulfing bacteria
- Phagocytes-- engulf **bacteria** and **viruses** by phagocytosis
- **Platelets** --smallest blood cells (fragments), needed for clotting
Malfunctions and Disorders of the Circulatory System

**Hypertension** (High Blood Pressure)
Caused by a narrowing of the arteries resulting in an increased resistance to the flow of blood--increases strain on the heart.

**Angina pectoris**
Caused by a reduction of blood supply due to partial blockage(s) of coronary arteries. Causes pain in the chest which radiates into the left shoulder and arm. Can lead to heart attack.

**Coronary thrombosis - heart attack**
Caused by a blood clot in a coronary artery that stops circulation to part of the heart muscle. Attack is fatal if too much heart muscle is involved.

**Sickle Cell Anemia**
People that have two recessive traits for this genetic disorder suffer from the disease. Shape of red blood cells changes which can lead to pain, damage to organs/muscles, or clots.
What is the digestive system?

Organ system that converts food into **simpler molecules** that can be absorbed and used by the cells of the body to perform **life functions**

There are two types of digestion:

**Mechanical**

Large pieces of food are cut and crushed into smaller ones. Your mouth, esophagus and stomach are organs of mechanical digestion. Works to **increase surface area**.

**Chemical**

Large food molecules are broken into smaller food molecules through **chemical reactions**. Digestive juices, such as hydrochloric acid in your stomach, and bile from the liver aid in chemical digestion.

**BIOCHEM THROWBACK!!!**

**Chemical digestion is HYDROLYSIS.** Remember...The splitting of large, insoluble molecules into small, soluble molecules with the addition of water.

Let’s recall some examples:

1. **Polysaccharide** + water $\rightarrow$ simple sugars (glucose)
2. Proteins + water $\rightarrow$ **amino acids**
3. **Lipids** + water $\rightarrow$ 3 fatty acids + glycerol

System lingo to know:

**Ingestion**- process of **taking food into the digestive system** so that it may be hydrolized or digested.

**Digestion**- the **breakdown** of food (either chemically or mechanically) in order to utilize nutrients
Food moves through the digestive tract through an **IN Voluntary** muscular action called **peristalsis**.

Now let’s talk nutrition...
**Nutrition**

Process by which organisms obtain and utilize their food

Two Parts:
1. **Ingestion** - process of taking food into the digestive system so that it may be hydrolized or digested.

2. **Digestion** - the breakdown of food (either chemically or mechanically) in order to utilize nutrients

We already know that…

* **Autotrophs** - Make their own food through photosynthesis

* **Heterotrophs** - Cannot create their own food

**Nutrients:**
There are 6 nutrients that the body uses for growth, repair and maintenance:

- **Micro**nutrients (include vitamins, minerals, & water)
- **MACRO**nutrients (include proteins, lipids, carbohydrates)

**Note:** Food energy is measured in Calories

All chemical reactions in an organism, including utilizing nutrients, are known as metabolism

**Healthy Eating:** Watch portions
Eat a variety of fruits and vegetables
Stay physically active
Limit bad fats, sugars, and processed Food
Digestive Homeostasis Disorders and Malfunctions

**Ulcers** - Stomach ulcers are painful sores that can be found in the stomach lining or small intestine. They occur when the thick layer of mucus that protects your stomach from digestive juices is reduced, causing the digestive acids to eat away at the lining of the stomach tissues.

**Constipation** – a condition in which the large intestine is emptied with difficulty.
* **Too much water** is reabsorbed and the solid waste hardens

**Diarrhea** – a gastrointestinal disturbance characterized by decreased water absorption and increased peristaltic activity of the large intestine.
* This results in watery stool which can lead to severe dehydration, especially in infants

**Appendicitis** – an inflammation of the appendix due to infection
* Common treatment is removal of the appendix

**Gallstones** – an accumulation of hardened cholesterol and/or calcium deposits in the gallbladder. Can either be “passed” (OUCH!!) or surgically removed

**Heart Burn** – AKA Acid Reflux; Acid from the stomach backs up into the esophagus.
How Does the Body Get Rid of Waste?

The removal of cellular waste products from an organism is called **excretion** and is accomplished by the **excretory** system.

What waste products does the body need to remove?

* **Carbon Dioxide** – as a result of cellular respiration
* **Water** – Product of **Dehydration Synthesis**, and cellular respiration
* **Nitrogenous waste** – resulting from **protein metabolism**, ammonia, urea, uric acid made from the breakdown of amino acids.
* **Mineral salts** – byproducts of certain **metabolic processes**, salts used in various activities of the body. ex. Bile salts, Sodium-potassium pump.

The excretory system includes:

- **Kidneys**
- **Ureters**
- **Urinary bladder**
- **Urethra**
- **Lungs**
- **Skin**
- **Liver** (secondary organ of excretion)

*Note*: Large intestine is sometimes included in the excretory system, but is mostly considered an organ of elimination

How is excretion related to **homeostasis**?

Excretory organs **remove waste products** that build up from normal **cellular activities**, failure to remove them would cause waste products to build up to **toxic** levels leading to disease.
Let’s focus on the urinary system briefly…

The urinary system (still part of the excretory system) works to remove urine and includes the kidneys, ureters, bladder, and urethra. Kidneys act as filters and include millions of tiny tubes called nephrons that remove waste from blood.

The nephron includes a filter, called the glomerulus, and a tubule. The nephrons work through a two-step process. The glomerulus lets fluid and waste products pass through it; however, it prevents blood cells and large molecules, mostly proteins, from passing. The filtered fluid then passes through the tubule, which sends needed minerals back to the bloodstream and removes wastes. The final product becomes urine.

Other excretory organs:

**Skin → Perspiration**
gets rid of excess water, salts, and some urea.

**Lungs →** Get rid of carbon dioxide and some excess water as we exhale

**Liver →** While not a primary organ of excretion, the liver produces urea and helps break down certain wastes
Excretory System Disorders:

* Kidney Disease – malfunctioning of the kidney or the nephron of the kidney. Kidney Failure is VERY serious because without filtration toxic metabolic wastes build up in the body cells. Poor diet, high blood pressure, salt & chemical imbalance, and severe physical stress can bring about kidney failure.

If kidneys can no longer cleanse the blood and maintain homeostasis, a person is said to be in kidney failure.

* Gout – disease caused by inflammation in the joints associated with uric acid production and its deposition resulting in arthritic-like, painful attacks

High blood pressure and diabetes cause most cases of kidney damage in the United States. The presence of protein or glucose in urine can be indicators of diseases such as dangerous high blood pressure or diabetes.

* Kidney Stones - Substances such as calcium, magnesium, or uric acid salts in the urine can crystallize and form kidney stones. When kidney stones block a ureter, they cause pain.
The endocrine system is made up of glands that produce and secrete chemical substances called hormones which regulate the activity of cells or organs. Short-term and long-term activities are regulated by sending chemicals throughout the body that are important for growth, metabolism and development.

How do hormones find the target cells?

Hormones bind to specific receptors on target cells.

Just like the Lock and Key model we studied in biochem!
<table>
<thead>
<tr>
<th>Organ/Gland</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pituitary Gland</td>
<td>Controls other glands, and regulates processes such as growth, blood pressure and water balance</td>
</tr>
<tr>
<td>Hypothalamus</td>
<td>Controls physiologic functions such as temperature regulation, thirst, hunger, sleep, mood, and the release of other hormones within the body.</td>
</tr>
<tr>
<td>Thyroid Gland</td>
<td>Produces hormones involved in energy related reactions in cells</td>
</tr>
<tr>
<td>Parathyroid</td>
<td>Control the body’s calcium levels</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Produces hormones insulin and glucagon to control blood sugar levels</td>
</tr>
<tr>
<td>Adrenal Gland</td>
<td>Release adrenaline which helps prepare our bodies for emergency situations</td>
</tr>
<tr>
<td>Ovaries (female)</td>
<td>Produce female reproductive hormones that aid in growth and egg development</td>
</tr>
<tr>
<td>Testes (male)</td>
<td>Produces the hormone testosterone which controls a male’s growth and regulates sperm production</td>
</tr>
</tbody>
</table>

To make sure the conditions in your body are just right, the endocrine system uses feedback mechanisms, which are responses that trigger other activities or processes.

The diagram shown is an example of negative feedback. Negative feedback mechanisms attempt to maintain a target level in the body.
The **immune system**, which is made up of special cells, proteins, tissues, and organs, defends people against germs and microorganisms every day.

**Diseases** cause disruptions in homeostasis, and a response from the immune system will follow to help restore balance.

**What is a disease?**

Disease is an **abnormal condition** affecting the functions of an organism.

Diseases are caused by **bacteria, viruses, fungi**, or other microscopic organisms such as **parasites**.

<table>
<thead>
<tr>
<th>Type of pathogen</th>
<th>Description</th>
<th>Human diseases caused by pathogens of that type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>Single-celled organisms without a nucleus</td>
<td>Strep throat, staph infections, tuberculosis, food poisoning, tetanus, pneumonia, syphilis</td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Herpes simplex</em></td>
<td>Thread-like particles that reproduce by taking over living cells</td>
<td>Common cold, flu, genital herpes, cold sores, measles, AIDS, genital warts, chiken pox, small pox</td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Death cap mushroom</em></td>
<td>Simple organisms, including mushrooms and yeasts, that grow as single cells or thread like filaments</td>
<td>Ringworm, athlete's foot, tinea, candidiasis, histoplasmosis, mushroom poisoning</td>
</tr>
<tr>
<td><strong>Parasites</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tapeworm</em></td>
<td>an organism that lives in or on another organism (its host) and benefits by deriving nutrients at the host's expense</td>
<td>Pinworm, blood flukes, tapeworm</td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Giardia lamblia</em></td>
<td>Single-celled organism with a nucleus</td>
<td>Malaria, “traveler's diarrhea” giardiasis, trypanosomiasis (“sleeping sickness”)</td>
</tr>
</tbody>
</table>
How are diseases spread?

1) **Infectious disease:**
   - From person to person through coughing, sneezing, or other physical contact
   - Contaminated food and water
   - Infected animals or other organisms

2) **Non-Infectious disease:**
   - Cannot be passed from person to person - not contagious
   - Develop as a result of genetics, or other environmental factors

**Pathogens** - Viruses, bacteria and other microorganisms that cause disease

**Antibiotics** are compounds that kill bacteria without harming the cells of humans or animals.

How does our body defend against disease?

1st line of defense - physical and chemical **barriers** of the body such as skin, mucus, and stomach acid that prevent pathogens from getting in

2nd line of defense - **inflammatory response**: This causes swelling, redness, warmth and pain in the area of infection.
   Chemicals are released, causing an increase in blood flow. This attracts white blood cells.

3rd line of defense - the **immune response**, which is a specific response to an intruder that has been identified and will be attacked and destroyed.

Did you know? Fevers can be helpful!

Elevated **temperature** slows down or stops the growth of some pathogens.
Speeds up **white blood cell** delivery
Any substance that produces an immune response is called an **Antigen**

**Antibodies** are proteins that help destroy pathogens.

How do they help white blood cells?

Antibodies recognize **specific** antigens and clump them together so they can be **destroyed**.

How do killer T cells destroy pathogens?

They transfer **proteins** with the membrane of the cell they are attacking and cause it to **rupture**.

**Active immunity** gives a person permanent immunity to the disease. Person made **antibodies** and B and T cells will remember antigen and be ready for it.

**Passive** immunity is borrowed immunity. It is only temporary. Antibodies were borrowed not produced.

How does a vaccination give a person active immunity?

A person is exposed to an **inactive** or **weakened** version of a virus. This allows the body to produce antibodies and **memory** white blood cells without actually getting the illness.

**Immune System Disorders**

The immune system can **overreact**, causing allergies or autoimmune diseases. Also, a **suppressed, absent, or destroyed** immune system can result in acute illness or disease as well.
Let’s take a look at some common pathogens that can disrupt immune function:

**Bacteria**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Effect on Body</th>
<th>Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyme disease</td>
<td>&quot;Bull’s-eye&quot; rash at site of tick bite, fever, fatigue, headache</td>
<td>Ticks transmit the bacterium</td>
</tr>
<tr>
<td>Tetanus</td>
<td>Lockjaw, stiffness in neck and abdomen, difficulty swallowing, fever, elevated blood pressure, severe muscle spasms</td>
<td>Bacteria enter the body through a break in the skin.</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>Fatigue, weight loss, fever, night sweats, chills, appetite loss, bloody sputum from lungs</td>
<td>Bacteria particles are inhaled.</td>
</tr>
<tr>
<td>Bacterial meningitis</td>
<td>High fever, headache, stiff neck, nausea, fatigue</td>
<td>Bacteria are spread in respiratory droplets caused by coughing and sneezing; close or prolonged contact with someone infected with meningitis</td>
</tr>
<tr>
<td>Strep throat</td>
<td>Fever, sore throat, headache, fatigue, nausea</td>
<td>Direct contact with mucus from an infected person or direct contact with infected wounds or breaks in the skin</td>
</tr>
</tbody>
</table>

**Viruses**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Effect on Body</th>
<th>Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common cold</td>
<td>Sneezing, sore throat, fever, headache, muscle aches</td>
<td>Contact with contaminated objects; droplet inhalation</td>
</tr>
<tr>
<td>Influenza</td>
<td>Body aches, fever, sore throat, headache, dry cough, fatigue, nasol congestion</td>
<td>Flu viruses spread in respiratory droplets caused by coughing and sneezing.</td>
</tr>
<tr>
<td>AIDS</td>
<td>Helper T cells, which are needed for normal immune-system function, are destroyed.</td>
<td>Contact with contaminated blood or bodily fluids; mothers can pass it to babies during delivery or during breastfeeding.</td>
</tr>
<tr>
<td>Chicken pox</td>
<td>Skin rash of blisterlike lesions</td>
<td>Virus particles are spread in respiratory droplets caused by coughing and sneezing; highly contagious</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>Jaundice, fatigue, abdominal pain, nausea, vomiting, joint pain</td>
<td>Contact with contaminated blood or bodily fluids</td>
</tr>
<tr>
<td>West Nile</td>
<td>Fever, headache, body aches</td>
<td>Bite from an infected mosquito</td>
</tr>
<tr>
<td>Human papillomavirus (HPV)</td>
<td>Genital or anal warts, also cancer of the cervix, penis, and anus</td>
<td>Sexual contact</td>
</tr>
</tbody>
</table>

**Protists**

**Malaria**

Life threatening condition caused by parasite carried by the female **mosquito**. Malaria organisms enter liver and infect RBC, causing them to burst.

**African Sleeping Sickness**

Spread by **fly bite**, damaging blood cells and nervous system.

**Giardia**

Found in various water sources, causing severe diarrhea and digestive system problems.
What happens when the immune system overreacts or attacks itself?

**Allergies**

Allergies result from immune system *hypersensitivity* to weak antigens that do not cause an immune response in most people. In an allergic response, antigens attach to mast cells which release chemicals known as **histamines**. This can cause sneezing, runny eyes and nose, and other irritation. Histamines work to **increase the flow of blood and fluid** to surrounding tissues.

**Autoimmune Disease**

The immune system attacks and destroys cells and tissues *of its own*. Your immune system, which defends your body against disease, decides your **healthy cells are foreign**. As a result, your immune system attacks healthy cells.

**Cancer**

Cancer is a disease where the cells of the body **grow out of control**. Normally this happens from time to time but our immune system responds and destroys these cells. Cancer develops when our immune system is **unable to respond** appropriately.
What is Cell Division?

Cells **divide** (copy themselves and split apart) to make more cells needed for **growth** of an organism, **repair**, or **reproduction**. Cells divide rather than grow larger for 2 reasons:

1. The genetic information in the nucleus (DNA) would not be able to get instructions out efficiently enough if the cell was too large.

2. It would be difficult to exchange materials into and out of the cell with a large amount of cytoplasm to move through.

**Mitosis**

Mitosis is a form of cell division. Many organisms, including **unicellular** ones (such as amoeba), reproduce by means of mitosis. More complex organisms, such as humans, originate from a single fertilized egg, then **specialize** and change to fulfil their various roles.

* All replicated cells (aka- daughter cells) contain the **same** genetic information from the original parent cell from which it was copied.

This all happens during the **CELL CYCLE**

The **cell cycle** is the series of events that cells go through as they grow and divide. During the cell cycle, a cell **grows**, prepares for **division**, and divides to form two **daughter** cells, each of which then begins the cycle again.
Let's take a closer look at the cell cycle:

When a cell divides, it only does so for a short amount of time. During most of the life of the cell, it is getting bigger, copying its DNA, and getting ready to divide.

How does the cell divide?

**Mitosis (cell division)** is a complex process requiring the cell to go through several stages before the new cells are produced.

Here is a simplified breakdown →

We are going to look at each step in more detail below:

1. **Interphase**: Technically not part of the division process, **interphase** is the “in-between” stage where the cell is preparing to divide. **DNA is copied**.

2. **Prophase**: DNA begins to uncoil in the nucleus, and **condenses to form pairs** of chromosomes. **Nuclear membrane** breaks down to let DNA out, and **centrioles** start to move toward opposite ends. Spindle fibers are forming.

3. **Metaphase**: “Meta” means middle. Chromatid pairs are aligned along the **center** of the spindle (the EQUATOR).

4. **Anaphase**: Ana = Away. Chromatids are moving away toward **opposite poles**.

5. **Telophase**: Chromosomes have separated and are now at either end of
each cell, and a **new nuclear membrane** is beginning to form around them. Spindles have almost disappeared and the cell is beginning to **pinch** off into two new cells.

6. **Cytokinesis:** Not actually part of the division process, but rather the stage where we have the “final product.” The cells are completely replicated and divided and we now have two identical **“daughter cells.”**

To help you remember the steps in order:

Interphase
Prophase
Metaphase
Anaphase
Telophase
Cytokinesis

**IPMATIC**

I Pray More At The Church

Did you know?

**Cytokinesis is different in plant and animal cells. Check it out:**

![Cytokinesis in Animal and Plant Cells](image)

Note: Organs which need to produce new cells continuously have the highest turnover, thus the most frequent rate of mitosis.

69
For example:

* **Bone marrow** - producing replacement blood cells
* **The testes** - producing sperm/semen

What happens when cell growth is not controlled or there are mistakes that happen during division?

**Cancer** = uncontrolled cell growth

What are some factors that can contribute to uncontrolled cell growth?

- **Smoking**
- **Exposure to radiation**
- **Genetics**
- **Contact with carcinogenic substances**
- **Viral infections**

Since cancer cells do not respond to the signals that regulate the growth of most cells, uncontrolled cell growth can lead to **tumors**.
Mitosis and Asexual Reproduction

Asexual reproduction occurs by the process of mitosis. Single celled organisms reproduce asexually, whereas more complex organisms such as humans, reproduce sexually.

There are several ways in which asexual reproduction can be done and although each method may be slightly different they all share one thing in common, all the offspring are genetically identical to the parent.

1. **Binary Fission** - asexual reproduction where one parent splits into two identical offspring

2. **Budding** - a small bud grows off of the parent and becomes an offspring

3. **Sporulation** - microscopic spores are created by the parent, when conditions are good these spore grow into the new organism.

4. **Regeneration** - when a piece of the parent is removed and grows into a new organism

5. **Vegetative propagation** - Asexual reproduction in plants which can happen through cutting, runners, tubers, or grafting.
**Meiosis** is a type of cell division that reduces the number of chromosomes in the parent cell by half and produces four gamete (sex) cells. This process is required to produce egg and sperm cells for sexual reproduction.

Meiosis takes a cell with two copies of every chromosome (diploid) and makes cells with a single copy of every chromosome (haploid).

Why do we need cells with half the DNA? Sexually reproducing organisms require 2 parents, so each must contribute half of their genetic information to the offspring.

Meiosis mixes the specific forms of each gene that each sex cell (egg or sperm) receives. This makes for a lot of genetic diversity. This trick is accomplished through independent assortment and crossing-over.

Here’s the super simple explanation:

Let’s break it down…

- **Original cell (parent cell) showing one chromosome pair**
- **Chromosomes are copied**
- **1st Division - Pairs split**
- **2nd Division - produces 4 gamete cells with ½ the original no. of chromosomes**
Interphase

Each of the chromosomes **replicate**

The result is two genetically identical sister chromatids which remain attached at their centromeres

Metaphase 1

The chromosomes **line up at the equator** attached by their centromeres to spindle fibers from centrioles. Still in homologous pairs

Anaphase 1

The spindle guides the movement of the chromosomes toward the poles

Sister chromatids remain attached

Move as a unit toward the same pole

Telophase 1

This is the end of the first meiotic cell division. The cytoplasm divides, forming **two new daughter cells**. Each of the newly formed cells has the same number of the parent cell’s chromosomes, and each chromosome is already replicated ready for the second meiotic cell division

**Cytokinesis**

Occurs simultaneously with telophase I

Forms 2 daughter cells

Plant cells – **cell plate**

Animal cells – **cleavage furrows**

**NO FURTHER REPlication OF GENETIC MATERIAL PRIOR TO THE SECOND DIVISION OF MEIOSIS**
Unlike mitosis, we don’t stop there…

**Prophase 2**
Each of the daughter cells forms a spindle, and the **double stranded chromosomes move toward the equator**

**Metaphase 2**
The chromosomes are positioned on the **metaphase plate** in a mitosis-like fashion

**Anaphase 2**
The centromeres of sister chromatids finally separate. The sister chromatids of each pair move toward opposite poles. **Now individual chromosomes**

**Telophase 2 and Cytokinesis**
Nuclei form at opposite poles of the cell and cytokinesis occurs. After completion of cytokinesis there are four daughter cells. All are haploid (n)

Check it out in real cells
## SUMMARY

<table>
<thead>
<tr>
<th>Event</th>
<th>Mitosis</th>
<th>Meiosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA replication</td>
<td>Occurs during interphase before nuclear division begins</td>
<td>Occurs once, during the interphase before meiosis I begins</td>
</tr>
<tr>
<td>Number of divisions</td>
<td>One, including prophase, metaphase, anaphase, and telophase</td>
<td>Two, each including prophase, metaphase, anaphase, and telophase</td>
</tr>
<tr>
<td>Synapsis of homologous chromosomes</td>
<td>Does not occur</td>
<td>Synapsis is unique to meiosis: During prophase I, the homologous chromosomes join along their length, forming tetrads (groups of four chromatids); synapsis is associated with crossing over between nonsister chromatids</td>
</tr>
<tr>
<td>Number of daughter cells and genetic composition</td>
<td>Two, each diploid (2n) and genetically identical to the parent cell</td>
<td>Four, each haploid (n), containing half as many chromosomes as the parent cell; genetically nonidentical to the parent cell and to each other</td>
</tr>
<tr>
<td>Role in the animal body</td>
<td>Enables multicellular adult to arise from zygote; produces cells for growth and tissue repair</td>
<td>Produces gametes; reduces chromosome number by half and introduces genetic variability among the gametes</td>
</tr>
</tbody>
</table>

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**Boy or Girl? The Y Chromosome “Decides”**

![Diagram showing the process of meiosis and fertilization, leading to a male and female offspring.](image)
What is reproduction?

Reproduction is the formation of **new individuals**. This organ system is unique because unlike other body systems which work to carry out life processes, a living thing can be healthy and maintain homeostasis **without** ever reproducing.

The goal of the reproductive system is to **produce**, **store**, and **release** specialized sex cells known as **gametes**.

Sexual reproduction is the production of offspring from **two parents**, which results in greater variation than asexual reproduction.

**RECALL:** The cells of the offspring have two sets of chromosomes (one from each parent), so they are **diploid**.

Sexual reproduction involves two stages:

- **Meiosis** - the special cell division that makes **haploid gametes**
- **Fertilization** - the fusion of two gametes to form a diploid **zygote** (fertilized egg)

**Human Life Cycle**

All body cells (AKA **somatic** cells), which include any cell but sperm or ovum cells, have **46 chromosomes**.

**Homologous** chromosomes (homologues) – chromosomes from **each parent** that make up a pair having the same length, centromere position, and location of genes.
EXCEPTION: **SEX CHROMOSOMES**

X and Y – only a small part are homologous

Y is much shorter than the X

X has few Y counterparts, Y is lacking many X genes

Remember - **XX** (female) **XY** (male)

A **karyotype** is an organized profile of a person's chromosomes. We can see the 22 pairs of **autosomal** chromosomes (chromosomes that are not sex chromosomes) and one pair of sex chromosomes (X and Y).

![Karyotype](image)

Sperm, Egg, Fertilization, and Chromosomes

Both sperm and **ova** (egg) have a chromosome count of **23**

- 22 autosomes – in a single set
- Plus a single set of **sex** chromosomes (X or Y)
- HAPLOID (n)

A haploid sperm reaches and fuses with a haploid ovum during **sexual** intercourse

- Results in a fertilized egg or **zygote**
- The zygote contains the two haploid sets of chromosomes bearing genes representing the **maternal** and **paternal** family lines
- Diploid (2n) = 46

Fertilization

- **Sperm** and **egg** fuse to form a zygote.
- Start of development
- Restores the **diploid** number of chromosomes
Male Gametes

* Sperm cells are the male gametes, very large numbers

* The combination of sperm and seminal fluid is known as **semen**.

* Between 50 million and 130 million sperm are present in 1 milliliter of semen—about **2.5 million sperm per drop**!

* **Motile** - they can propel themselves, using the whip-like tail structure called the **flagellum**.

Sperm Development

Sperm cells are produced in the **seminiferous tubules** within the testes, and then are moved into the **epididymis**, in which they mature and are stored.

From the epididymis, some sperm are moved into a tube called the **vas deferens**.
The vas deferens extends upward from the **scrotum** into the abdominal cavity and eventually merges with the **urethra**, the tube that leads to the outside of the body through the **penis**.

The scrotum is a pouch of skin containing the **testes** outside the body, which is helpful in maintaining a **lower temperature** for proper **sperm** production.

Glands lining the reproductive tract—including the seminal vesicles, the **prostate**, and the bulbourethral glands—produce a nutrient-rich fluid called **seminal fluid**.

The seminal fluid nourishes the sperm and **protects** them from the **acidity** of the female reproductive tract.

When the male is sexually aroused, the **autonomic** nervous system prepares the male organs to **deliver** sperm. Sperm are ejected from the penis by the **contractions** of smooth muscles in the reproductive tract. This process is called **ejaculation**.

**Secondary Male Characteristics**

The release of FSH (follicle stimulating hormone) and LH (luteinizing hormone) stimulates cells in the testes to produce testosterone. **Testosterone**, produced in the testes, contributes to a number of secondary sexual characteristics in males including:

- Development of a beard, body **hair**
- **Muscular** growth
- Deepening of the **voice**
- More **angular** features
- Less **fatty** tissue
- Stimulates the **production** of sperm

“Except for his testosterone level being out of whack, Frankie is a normal 7-year-old.”
Female Reproductive System

Front View

![Female Reproductive System Front View](image)

Side View

![Female Reproductive System Side View](image)

External Anatomy

![External Anatomy](image)

Female Reproductive Structures

**Ovaries** - Each ovary contains about 400,000 primary **follicles**, which are **clusters of cells** surrounding a single **egg**. Follicles help an egg mature for release into the reproductive tract, where it can be **fertilized**. Eggs, or ova, develop within their follicles. When a follicle has completely matured, its egg is released in a process called **ovulation**.

The main function of the female reproductive system is to produce **ova**. In addition, the female reproductive system prepares the female's body to nourish a developing **embryo**.
Fallopian Tubes (oviduct) - Tube (Fallopian) that transports egg to the uterus with the help of cilia. Egg is usually fertilized in the oviduct and then moves to the uterus for implantation.

RECALL: The female gamete is the ova or egg in animals (sometimes also called an oocyte), and ovule in plants.

Did you know? Human females release about 1000 ova in a reproductive lifetime.

Female gametes contain food reserves (lipids, proteins, carbohydrates) to nourish the embryo after fertilization.

Uterus: Thick walled muscular organ where fertilized egg implants and develops. During ovulation, uterine wall becomes filled with blood to support a fertilized egg. The uterus is also known as the womb. The outer end of the uterus is called the cervix. Beyond the cervix is a canal, sometimes referred to as the “birth canal”— the vagina—that leads to the outside of the body.

Secondary Female Characteristics

Secondary female sex characteristics appear during puberty. They are caused by hormones such as estrogen, released at the time of puberty. This is usually around two years earlier in girls than in boys, and includes:

- Development of the uterus
- Menstrual cycle
- Broadening of the pelvis
- Development of breasts
- Presence of body hair
- Distribution of body fat
What is the Menstrual Cycle?

The menstrual cycle is a series of steps over a 15-30 day period in which the uterus prepares for the implantation of an embryo. The uterine wall builds up for implantation of egg. If no fertilization occurs, the wall breaks down and passes out of body. This is controlled by the action of hormones.

**Follicular Phase**
On day 1 of a menstrual cycle, blood estrogen levels are low. The hypothalamus secretes a releasing hormone that stimulates the pituitary gland to secrete FSH and LH. These two hormones travel to the ovaries, where they cause a follicle to mature.

**Ovulation**
The sudden increase in these hormones causes the follicle to rupture, resulting in ovulation and the release of an egg from the ovary into one of the Fallopian tubes.

**Luteal Phase**
As the egg moves through the Fallopian tube the ruptured follicle turns yellow, and if no fertilization occurs, it will become inactive. If the egg is fertilized, the corpus luteum enlarges to provide more hormones for development.

**Menstruation**
At the start of the new follicular phase, low estrogen levels cause the lining of the uterus to detach from the uterine wall. This tissue, along with blood and the unfertilized egg, are discharged through the vagina during menstruation.
Pregnancy

The menstrual cycle ceases if a woman becomes pregnant. During the first two days of the luteal phase, immediately following ovulation, the chances that an egg will be fertilized are the greatest. This is usually from 10 to 14 days after the completion of the last menstrual cycle.

Fertilization

Sperm swim actively through the uterus into the Fallopian tubes. If an egg is present in one of the Fallopian tubes, its chances of being fertilized are good.

Implantation

As the embryo grows, a cavity forms in the center, until the embryo becomes a hollow ball of cells known as a blastocyst. About six or seven days after fertilization, the blastocyst attaches to the wall of the uterus and begins to grow into the tissues of the mother. This process is known as implantation.

Gastrulation

The result of gastrulation is the formation of three cell layers called the ectoderm, mesoderm, and endoderm.

- The ectoderm will develop into the skin and the nervous system.
- Mesoderm cells differentiate and form many of the body’s internal structures, including bones, muscle, blood cells, and gonads.
Endoderm forms the linings of organs in the digestive system, such as the stomach and intestines, as well as in the respiratory and the excretory systems.

The Placenta
The developing embryo is surrounded by the amnion, a sac filled with amniotic fluid that cushions and protects the developing embryo.

What is the function of the placenta?
- The placenta allows the exchange of nutrients and wastes between the embryo and the mother.
- Secreteres hormones that stop certain functions of the menstrual cycle.
- Supports development in the uterus

The Placenta and the Umbilical Cord
0-3 months
By the end of three months, most of the major organs and tissues are fully formed. The muscular system is well developed. The fetus may begin to move and show signs of reflexes. The fetus is about 8 centimeters long and has a mass of about 30 grams (about the mass of a small lime).

Months 4–6
The fetal heart becomes large enough so that it can be heard with a stethoscope. Bone continues to replace the cartilage that forms the early skeleton. A layer of soft hair grows over the skin of the fetus. Mass is around 200 grams, and the fetus is about the size of a banana.

Months 7–9
The fetus doubles in mass, and the lungs and other organs undergo a series of changes that prepare them for life outside the uterus. The fetus is now able to regulate its body temperature. The central nervous system and lungs complete their development.

Childbirth
A complex set of factors triggers the birth process; one of these factors is the release of the hormone oxytocin from the mother’s posterior pituitary gland.

Oxytocin affects a group of large involuntary muscles in the uterine wall. As these muscles are stimulated, they begin a series of rhythmic contractions known as labor.
As labor progresses, the contractions become more **frequent** and more **powerful**.

Within a few hours after birth, the pituitary hormone **prolactin** stimulates the production of milk in the mother’s breasts.

The nutrients present in breast milk contain everything the baby needs for **growth and development** during the first few months of life.

---

**Internal vs. External Fertilization and Development**

**Internal** fertilization and development

- Most terrestrial (land) **vertebrate** animals fertilize their eggs in the **reproductive tract** of the female.
- Protection from the outside environment **increases** chances of fertilization
- Fertilization can only take place at **certain times**
- Development of an embryo occurs **within the body** of the parent.
• Provides better **protection** while offspring are developing
• **Fewer** eggs are produced.
• Requires more care by the mother during **development**

**External fertilization and development**

• Most aquatic animals (*Fish and Amphibians*)
• Sperm and the egg are **released closely together** in the water to potentially join
• Very **little care** needed
• Eggs are **unprotected** so to ensure survival **many eggs** are released.

External development on **land** - underdeveloped embryo completes development after fertilization **outside the parent**

• Food source is **yolk** stored in egg.
• **Shell** provides protection and membranes help to provide a favorable environment.
• Some care maybe required
• **Birds, many reptiles, and a few mammals** carry out external development

**Sexually Transmitted Diseases**

• Sexually transmitted diseases that are spread by **sexual contact** are known as sexually transmitted diseases (STDs).
• More than **half of all people** will have an STD/STI at some point in their lifetime
• A 2008 study by the Centers for Disease Control and Prevention showed that one in four females aged 14 to 19 were infected with an STD. **Chlamydia** is the most common bacterial STD and can damage the reproductive tract and can lead to **infertility**.

**Viral STDs** include hepatitis B, genital herpes, genital warts, and AIDS. Unlike the bacterial STDs, viral infections cannot be treated with antibiotics. Some viral STDs, such as AIDS, can be fatal.

Several strains of the virus that causes genital warts—human papillomavirus (**HPV**)—are a major cause of **cervical cancer** in women.
Mendelian Genetics

Modern genetics had its beginnings in an abbey garden, where a monk named Gregor Mendel documented the mechanisms of inheritance by breeding garden peas.

What is Genetics?

Genetics is the study of heredity.

Heredity – the passing of traits (physical characteristics) from parent to offspring. These traits are controlled by genes.

The genes and environment influences the kind of person you are.

Genes are the part of the DNA molecule containing the genetic code.

An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one cell.

Gregor Mendel – A European monk who first detailed the scientific study of how traits pass from generation to generation.

While tending his garden, he wondered why different pea plants had different traits. He decided to set up some experiments to find out how pea plants passed certain characteristics to their offspring.

Mendel’s Experiments

He used pea plants (easy to breed through cross-pollination)

Crossed purebreds (2 same genes) with plants of contrasting traits

Studied 7 different traits in peas as shown

Plants all had different alleles from each parent

Alleles are different forms of a gene associated with a particular characteristic (ex. Height: tall/short)
First, he crossed tall and short plants... Guess what plants came about???
They were all **TALL**!!
- the tall height appeared to be dominant

**Dominant**: trait that always shows in the physical **appearance** of the organism, overpowering other traits

We always use a **Capital** letter to express the dominant trait (and usually the first letter of the trait Ex. T for tall)

**Recessive**: trait that is present in the genes, but **hidden** in appearance

We always use a **lowercase** letter Ex. t

Second, he allowed the new plants to cross-pollinate. Now, guess what type of plants came about?? ?? **Tall and Short** plants!!

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>are the version of the alleles passed on. They identify the <strong>genetic makeup</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phenotypes</strong></td>
<td>The <strong>physical</strong> appearance of the organism. The characteristic that is actually shown.</td>
</tr>
</tbody>
</table>

Look at the plant circled: the **Genotype** is Tt, the phenotype is **Tall**.
What is Probability?

Probability is the **likelihood** that a particular event will occur. It is expressed mathematically as a number in the form of a **fraction** or **percent**. The probability that something will take place is how **likely** it is to happen **not** necessarily that it **will** happen.

…and how exactly is this related to genetics?

The chance of **inheriting** certain characteristics or **traits** is based on **probability**. Gregor Mendel was one of the first in the field of genetics to apply probability to predict the results of **genetic crosses**.

We can predict probability using Punnett Squares!!

**Punnett Square**: a **chart** that shows all the possible combinations of traits that can result from a certain **cross**. Check it out!

Ex. **R** – (dominant allele) for round face
REMEmBER: ALWAYS USE THE **SAME** LETTER FOR BOTH ALLELES
**r** – (recessive allele) square face

Recall: the letters represent the **GENOTYPE** of the organism

* Every cell in your body has **two alleles** for every trait

**New Vocab Alert:**
**Homozygous** (AKA **PURE**): having TWO **identical** genes for a trait (Ex.TT or tt)
**Heterozygous** (AKA **HYBRID**): having TWO **different** genes for a trait (Ex. Tt)
You try: A pea plant that is homozygous for yellow seeds (YY) is crossed with a pea plant that is heterozygous for yellow seeds (Yy). What might the offspring look like?

Accessing prior knowledge:

**Determining Gender:**

Sex Chromosomes: A set of genes that determine whether offspring is male or female

- Females: Have two x chromosomes
- Males: Have both an x and a y chromosome

Note: Gender is determined by the male since the male can pass on EITHER an X or Y chromosome, and females ONLY carry X chromosomes.

** An egg (X) fertilized by a sperm with an X chromosome will produce a female (XX).

** An egg (X) fertilized by a sperm with an Y chromosome will produce a male (XY).

** Some traits are considered “sex-linked” since they are found on the X chromosome. Sex linked traits tend to show up more in males since they only have one X chromosome, and if the trait is passed down it will be shown.**
Other Patterns of Inheritance

**Incomplete Dominance**
Not all genes are completely dominant or completely recessive. A case of contrasting alleles in which one allele is only partially dominant over the other is referred to as incomplete dominance, or blending. In this case genes combine and a mixture of both traits show up. --the dominant allele is only partially expressed when the recessive allele is present. Sometimes it is also called blending inheritance.

**Example:** Four o’ clock flowers are usually red or white. Red and white are equally strong traits in this species. Neither color is dominant. When a pure red (RR) crosses with a pure white (WW), the colors blend and the offspring have pink flowers (RW).

**Codominance:** With codominance, a cross between organisms with two different phenotypes produces offspring with a third phenotype in which both of the parental traits appear together. They are not necessarily “blended” as in incomplete dominance, but rather they appear in equal amounts in their original form.

**Example:** Speckled chickens have an equal representation of black feathers and white feathers.

* NOTE: Oftentimes when writing letters to represent traits for incomplete dominance genotypes are capital letters, whereas codominance shows genotypes as capital letters with superscripts.
Multiple Alleles: Many genes have **more than two alleles** and are therefore said to have **multiple alleles**. This does not mean that an individual can have more than two alleles. It only means that **more than two possible alleles exist** in a population.

**Example:** A rabbit’s coat color is determined by a single gene that has at least four **different alleles**. The four known alleles display a pattern of simple dominance that can produce four possible coat colors.

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Allele</th>
<th>Possible Genotypes</th>
<th>Order of Dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full color</td>
<td>C</td>
<td>CC, Cc,Cc, Cc</td>
<td>Dominant over all others</td>
</tr>
<tr>
<td>Chinchilla</td>
<td>c^h</td>
<td>c^h,c^h,c^h,c</td>
<td>Dominant over Himalayan and albino</td>
</tr>
<tr>
<td>Himalayan</td>
<td>c</td>
<td>c,c,c</td>
<td>Dominant over albino</td>
</tr>
<tr>
<td>Albino</td>
<td>c</td>
<td>c,c,c,c</td>
<td>Recessive to all others</td>
</tr>
</tbody>
</table>

Polygenic Traits: Many traits are produced by the interaction of several genes. Traits controlled by **two or more genes** are said to be **polygenic** traits, which means “having many genes.” Polygenic traits often show a wide range of **phenotypes**.

**Example:** The wide range of skin color in humans comes about partly because more than four different genes probably control this trait.

Skin color is a **polygenic trait**

- Skin color is controlled by at least 6 genes
- Each gene product is **additive** to the others
- The hallmark of a polygenic trait’s phenotype expression is:
  - A bell curve distribution
  - A continuous distribution
Environmental Effects on Genes

While our genes code for the production of proteins, sometimes our environment may turn genes on or off. Height and Intelligence are two good examples. While we may have genes that code for a certain height or level of intelligence, it is our environment that influences how closely we reach that potential.

Factors that influence gene expression include:

- **Temperature**
- Light
- Nutrition
- Gender (sex-linked traits)
- Exposure to chemicals/drugs

Notice the effect of temperature on the Himalayan rabbit as the gene for black fur is active only at very low temperatures.

Another example: Identical twins raised in different environments may be vastly different in intelligence or even height.
What is a Pedigree Chart?

- A pedigree chart is a **visual representation** of an individual’s family history through **several** generations.
- It is used to study the **transmission** of a hereditary condition.
- Can show the **presence or absence** of a particular trait in each member of each generation.

Let’s look at the parts of a pedigree chart below:

I. Roman numerals are used to represent each generation. A circle represents a female. A square represents a male. A horizontal line connecting a male and female represents a marriage.

II. A half-shaded circle or square indicates that a person is a carrier of the trait. A completely shaded circle or square indicates that a person expresses the trait. A vertical line and a bracket connect the parents to their children.

III. A circle or square that is not shaded indicates that a person neither expresses the trait nor is a carrier of the trait.

**TRY IT!!**

**Fur Color in Mice**

1. How many generations are shown? ______________
2. Which trait is dominant? ______________________
3. How many mice have white fur? _________________
4. How many mice have black fur? _________________
5. How many mice are heterozygous? ____________
Modern Genetics
Mendelian genetics and modern genetics are really the same thing. Gregor Mendel formed the basis of modern genetics. Later scientists built on his ideas and laws. The big difference between the modern science of genetics and Mendel's basic laws is that modern scientists have a much clearer understanding of the mechanisms behind the patterns Mendel observed.

DNA Basics:

**Chromosomes** found in the nucleus of our cells carry the hereditary material – **DNA**

DNA- **Genetic** material that carries information about an organism and is passed from **parent to offspring**.

DNA (which stands for deoxyribonucleic acid) - Controls cellular activity by influencing the production of **proteins**.

Basically, DNA tells your body how to function

The Genetic Code:
1. Supplies **instructions** for cell processes
2. Has the ability to **copy** itself, so each cell has an **identical** set of genes.
3. DNA is a very long chain of repeating units called **nucleotides**.
4. Nucleotide unit is composed of a **phosphate** group, **sugar**, and a nitrogenous **base**.
5. The Nitrogenous Bases are; **adenine** (A) **thymine** (T) **guanine** (G) **cytosine** (C)
   *They pair in a particular way where adenine and thymine go together, and guanine and cytosine pair together*

**Quick Tip:** Remember **AT Gates-Chili**
DNA Structure:

The sides of the ladder are made up of alternating deoxyribose sugar and phosphate group units.

The rungs of the ladder are made of 2 nitrogenous bases per rung linked together by a weak hydrogen bond.

Only 2 combinations of base pairs can form the rungs of the DNA molecule.  
**Adenine - Thymine** (A-T)  
AND  
**Guanine – Cytosine** (G-C)

This specific matching up of the nitrogenous bases is called **complementary base** pairing.
DNA Replication

How do cells make new cells?

To ensure that each new daughter cell has the exact same instructions as the original, DNA must replicate, or make an exact copy of itself.

Here's how it works:

1. The two sides of the DNA **unwind** and begin to **separate** (like a zipper), between the bases as an enzyme breaks apart weak hydrogen bonds.

2. **DNA polymerase** enzyme attaches to single strands adding free nucleotides to each existing base to create new double strands that are exactly the same.

3. The new DNA strands will twist up to form two new DNA **double helixes**.

   1. A representative portion of DNA, which is about to undergo replication.
   2. The two strands of the DNA separate. The hydrogen bonds between the bases break.
   3. Free nucleotides are attracted to their complementary bases.
   4. Once the new nucleotides have lined up, they are joined together by the enzyme DNA polymerase.
   5. Finally, all the nucleotides are joined to form a complete polynucleotide chain using DNA polymerase. In this way, two identical strands of DNA are formed. As each strand retains half of the original DNA material, this method of replication is called the semi-conservative method.
Protein Synthesis

How do cells make proteins?

Recall: Proteins are made of amino acids, and even though there are only 20 different amino acids, they can combine in such a way that thousands of different proteins are possible.

Protein synthesis takes place outside the nucleus in the cytoplasm. Chromosomes are found inside the nucleus so a messenger needs to bring the message to make the protein from inside the nucleus to the cytoplasm. This genetic messenger is called RNA (ribonucleic acid).

RNA is slightly different than DNA. First, it only has one strand and second, it contains a different sugar than DNA. The last, most important difference is that there is one base that is not the same. RNA has uracil instead of guanine.

Types of RNA involved in protein making:

1. **Messenger RNA** (mRNA)- made in nucleus to carry the message from the chromosomes within the nucleus to the cytoplasm.

2. **Transfer RNA** (tRNA)- molecules that transport amino acids from the cytoplasm of a cell to a ribosome.

3. **Ribosomal RNA** (rRNA)- helps translate the information in messenger RNA (mRNA) into protein.
Translation involves “decoding” a messenger RNA (mRNA) and using its information to build amino acids.

Translation involves “decoding” a messenger RNA (mRNA) and using its information to build amino acids.

Here’s how it works:

During protein synthesis, the cell uses information from a gene on a chromosome to produce a specific protein. Proteins help determine the size, shape, and color of other traits of an organism by triggering cellular processes.

mRNA is made during the first step of protein synthesis, which is called transcription.

The instructions for building a polypeptide come in groups of three nucleotides called codons.

**mRNA Enters the Cytoplasm**

DNA unzips between its base pairs. Then one of the strands of DNA directs the production of a strand of mRNA. To form the RNA strand, RNA bases pair up with the DNA bases. The process is similar to DNA replication. Cytosine always pairs with guanine. However, uracil, not thymine, pairs with adenine. The mRNA leaves the nucleus and enters the cytoplasm.

**Ribosomes Attach to mRNA**

A ribosome attaches to mRNA in the cytoplasm. On the ribosome, the mRNA provides the code for the protein that will be made. In the cytoplasm, specific amino acids are attached to specific molecules of tRNA.

**tRNA Attaches to mRNA**

Molecules of tRNA and their amino acids attach to the mRNA. The bases on tRNA “read” the message and pair with bases on mRNA.
How to read a **codon chart** to determine **amino acids**:

You can use a square chart following the order shown below:

<table>
<thead>
<tr>
<th>1st base in codon</th>
<th>U</th>
<th>C</th>
<th>A</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>Phe</td>
<td>Ser</td>
<td>Tyr</td>
<td>Cys</td>
</tr>
<tr>
<td></td>
<td>Phe</td>
<td>Ser</td>
<td>Tyr</td>
<td>STOP</td>
</tr>
<tr>
<td></td>
<td>Leu</td>
<td>Ser</td>
<td>Trp</td>
<td>STOP</td>
</tr>
<tr>
<td></td>
<td>Leu</td>
<td>Ser</td>
<td>Cys</td>
<td></td>
</tr>
</tbody>
</table>

Use the circular chart below starting in the center and working out:

[Protein Chain Forms]

As the ribosome continues to move along the mRNA adding amino acids, the protein grows. Once an amino acid is added, the tRNA is released and picks up another amino acid of the same kind. The protein continues to grow until the ribosome reaches a three-base code that signals it to stop. The protein is then released.
Mutations

Some traits are not inherited from a parent organism. Some traits are a result of changes in DNA. A mutation is any change in the DNA of a gene or chromosome. Changes in nucleotide sequence that occur in the DNA changes the codes to build proteins. An incorrect protein made during protein synthesis may result in a beneficial or a harmful mutation.

Types of mutations

Point Mutations

Point mutations occur when a single base is changed in the sequence. Here are some examples:

**Substitution:** a mutation that exchanges one base for another. Causes a change in a single codon and may code for a different amino acid.

**Insertion:** Insertions are mutations in which extra base pairs are inserted into a new place in the DNA.

**Deletion:** Deletions are mutations in which a base or section of DNA is lost, or deleted.

Frameshift Mutations

Protein-coding DNA is divided into codons three bases long, insertions and deletions can alter a gene so that its message is no longer correct because the bases have shifted position.

For example, consider the sentence, "The fat cat sat." Each word represents a codon. If we delete the first letter and reconstruct the sentence in the same way, it no longer makes sense.

These types of mutations, as well as others, can happen on a chromosomal level as well…
Chromosomal Mutations
A mutation involving a **long segment** of DNA. These mutations can involve deletions, insertions, or inversions of sections of DNA. In some cases, deleted sections may attach to other chromosomes, **disrupting both the chromosomes** that loses the DNA and the one that gains it.

The causes of mutations

1. **DNA fails to copy accurately**- When a cell divides, it makes a copy of its DNA — and sometimes the copy is **not quite perfect**. That small difference from the original DNA sequence is a mutation.

2. **External influences can create mutations**- Mutations can also be caused by exposure to specific **chemicals** or **radiation**. When the cell repairs the DNA, it might not do a perfect job of the repair. So, the cell would end up with DNA slightly different than the original DNA and hence, a mutation.

The effects of mutations

1. **No change occurs in phenotype**- Some mutations don't have any noticeable effect on the phenotype of an organism.

2. **Small change occurs in phenotype**- A single mutation caused this cat’s ears to curl backwards slightly.

3. **Large change occurs in phenotype**- Some mutations can cause the **death** of an organism, such as Huntington’s disease.
Advances in Genetic Technology

Due to advances in genetics, DNA evidence can reveal a great deal of information such as family relationships and heritage, probability of inheriting certain traits, and new ways to manipulate DNA. Additionally, through the use of modern technology organisms can be developed that exhibit desired traits. Some methods for producing organisms in a way that manipulates their DNA include:

- Selective Breeding
- Cloning
- Genetic Engineering

Selective Breeding

The process of selecting organisms with desired traits to be the parents of the next generation is called selective breeding. This process could take many generations for characteristics to show up with consistency.

For example, many of the fruits and vegetables we consume have been selectively bred to be larger, sweeter, hardier, and even juicier. Corn has been selectively bred by farmers for generations whereby only the healthiest, best seeds were planted each spring weeding out undesirable characteristics.

There are two common methods of selective breeding—hybridization and inbreeding.

The technique of inbreeding involves crossing two individuals with similar desirable characteristics. Example - Breeding two golden retrievers with similar color and disposition.

In hybridization, breeders cross two genetically different individuals in an effort to get the best traits from both organisms. Example – Farmer crosses one type of corn that produces a lot of kernels with another type that resists disease.

*Inbreeding does increase the chance of inheriting recessive genetic disorders*
Cloning
Creating an organism, asexually, that has the same genes as the organism from which it was produced. Example – Dolly the sheep. Clones can happen naturally—identical twins are just one of many examples. Or they can be made in the lab as shown below:

Genetic Engineering
Another technique for producing organisms with desired traits is genetic engineering, which involves transferring genes from one organism into the DNA of another.

This may mean changing one base pair (A-T or C-G), deleting a whole region of DNA, or introducing an additional copy of a gene.

Genetic engineering has helped develop medicine as well as many crops and genetically modified foods we eat.

Example - Normally insulin is produced in the pancreas, but in people with type 1 diabetes there is a problem with insulin production. Genetic engineering has been used to produce a type of insulin, very similar to our own, from yeast and bacteria.
What is Evolution?

**Evolution**—a process of change over a period of time

Evolution includes the change in characteristics of populations throughout generations. Existing life forms have evolved from earlier life forms.

**Evolutionary theory** is a unifying principle that explains the differences in structure, function, and behavior among life forms.

The Fossil Record

Fossils have been found that indicate organisms existed well over 3 billion years ago. Fossils consist of direct or indirect remains of organisms preserved in media such as sedimentary rock, amber, ice, or tar.

Why is it that the fossil record is incomplete?

Fossils are rare and need the right environmental condition to be made.

Law of **Superposition**

Fossils in the upper strata of rock layers are newer (younger) than those in the lower layers.

Early ideas about evolution

Though Charles Darwin’s work is most well-known, he was not the first scientist to ponder how things changed over time. Early scientists in the 1700-1800’s such as Jean-Baptiste Lamarck proposed that changes in the environment caused an organism’s behavior to change, leading to greater use or disuse of a structure or organ. Ex.) **Giraffe neck**
Charles Darwin

Charles Darwin was a British naturalist who studied his surroundings, and came up with questions about the diversity of different species. A species is a group of organisms that are similar and able to mate with each other.

Darwin looked at many different species in the Galapagos Islands near the coast of South America. What he noticed was that similar species were found on the various islands and the mainland, but depending on where they lived, they had some differences. This caused him to wonder if species changed over time. He noticed this particularly with a group of birds now known as “Darwin’s Finches.”

Darwin speculated that at some point, before they were all different, all of the finches must have had to compete for food. So they adapted to their environment and those most able to survive lived on to reproduce.

An adaptation is a feature that allows an organism to better survive in its environment. Adaptations can lead to genetic change in a population over time.

Darwin used his observations and thoughts on adaptation to formulate his theory of natural selection. Natural selection is a mechanism by which individuals that have inherited beneficial adaptations produce more offspring on average than do other individuals.

In nature, characteristics are selected only if they give advantages to individuals in the environment, thus those individuals will be more successful in reproducing.
Natural Selection

Darwin noticed a lot of variation in domesticated plants and animals. Through selection of certain traits, breeders could produce a great amount of diversity. He used these concepts of selective breeding to shape his ideas on natural selection.

There are four main principles to the theory of natural selection: variation, overproduction, adaptation, and descent with modification.

1. **Variation** - differences among individuals result from differences in the genetic material of the organisms, whether inherited from a parent or resulting from a genetic mutation.

2. **Overproduction** - Having many offspring raises the chance that some will survive, but also results in competition between offspring for resources.

3. **Adaptation** - Sometimes a certain variation allows an individual to survive better than other individuals it competes against in its environment.

4. **Descent with modification** - natural selection will result in species with adaptations that are well suited for survival and reproduction in an environment. More individuals will have the trait in every following generation.
Evidence That Points to Evolution

Darwin found evidence from a wide range of sources to support his argument for evolution, most notably the following:

<table>
<thead>
<tr>
<th>Fossils</th>
<th>Embryonic Similarities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fossil records</strong> provide information related to how organisms have changed in their <strong>body structures</strong> over time. We can use the fossil record to compare to more modern species and draw conclusions as to how or why they changed over time.</td>
<td>Scientists can infer based on the early stages of <strong>development</strong> that some species may have a common <strong>ancestor</strong>. Similar features of <strong>embryos</strong> in very different organisms suggest this relationship.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anatomy</th>
<th>Biochemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similar <strong>body structures</strong> in different species that have been <strong>inherited</strong> from a common ancestor are known as homologous structures.</td>
<td>Scientists compared the sequences of <strong>DNA</strong> and found that the more <strong>closely</strong> related a species was to another the more closely their DNA sequences matched up.</td>
</tr>
</tbody>
</table>

**Vestigial structures** are relatively **useless** body parts that once served a purpose, but changes in our environment cause them to **no longer serve a particular function**.
Examining Rate of Change and Evolutionary Trees

**Geographic Isolation**

New species can form if a group of individuals remains *isolated* from the rest of its species long enough to evolve *different traits*, which could prevent reproducing with the rest of the species.

**Example: Kaibab and Abert’s Squirrels**

The populations of Kaibab and Abert’s squirrels are separated by the **Grand Canyon**. They are the *same species* but have *different characteristics*. Over time they could become so different due to adaptations that they *can no longer mate* with one another.

Patterns of Rate of Evolution

Scientists have described two patterns of evolution, based on how *quickly* or *slowly* change happens.

1. **Gradualism** - *small* changes over *long* periods of time

   ![Gradual evolution of modern horse](image)
2. **Punctuated equilibrium** - Species evolve during periods of rapid change, then remain stable for a time.

Notice the comparison between the gradual change model and the rapid change model. →

**Phylogenetic Trees**

Also known as **evolutionary trees/diagrams**, these diagrams show the evolutionary interrelations of a group of organisms derived from a **common ancestor**. The ancestor is in the tree “**trunk**”; organisms that have arisen from it are placed at the ends of tree “branches.” The **distance of one group from the other groups indicates the degree of relationship**; i.e., closely related groups are located on branches close to one another.

**How to read a phylogenetic tree:**

- The tips of the branches represent the **species** (taxa) that scientists compare.
- Branches meet at points called **nodes** that represent the **common ancestor** of the two taxa.
- Scientists call groups that branch out from the same common ancestor **sister groups**.
- An ancestor plus all its descendants form a **clade**.
- Scientists call groups that branch from the tree's base and are separate from the other groups **outgroups**.
Ecology - the study of the **interactions of living things** with each other and their physical environment.

How are things organized? **Ecologists** study nature on different levels from a local to a global scale. Take a look 🦿

- **Organism** - an **individual** living thing, such as an alligator.
- **Population** - a group of the **same species** that lives in one area, such as all the alligators that live in a swamp.
- **Community** - a group of **different species** that live together in one area, such as groups of alligators, turtles, birds, fish, and plants that live together in the Florida Everglades.
- **Ecosystem** - ecosystem includes all of the **organisms** as well as the climate, soil, water, rocks, and other **nonliving (abiotic)** things in a given area.
- **Biome** - a collection of **different ecosystems that share similar climate conditions**, and are characterized by the plant communities that thrive there.
- **Biosphere** - the part of the earth's crust, waters, and atmosphere that supports **life**.

**Biotic vs. Abiotic**

All the **living things** that directly or indirectly affect the environment

The **non-living factors** that effect a population, which can become **limiting factors** that determine types of organisms that can live in that area.
Carrying Capacity

The **maximum number of organisms** the resources of an area can support.

The carrying capacity of the environment is **limited** by the available abiotic and biotic **resources**.

**Biodiversity** - the assortment, or **variety, of living things in an ecosystem**. An area with a high level of biodiversity, such as a rain forest, has a large assortment of different species living near one another.

Increased **biodiversity** = increased **stability** of an ecosystem

Energy in Ecosystems

All organisms must have a **source of energy** in order to survive. However, not all organisms obtain their energy by eating other organisms.

**Producers** are organisms that get their energy from nonliving resources, meaning they **make their own food**. Producers are also called **autotrophs**.

**Consumers** are organisms that get their energy by **eating other living or once-living resources**, such as plants and animals. Consumers are also **heterotrophs**.

Consumers can be **herbivores** (plants only), **carnivores** (meat only), or **omnivores** (plants and meat).

** Decomposers** - break down organic matter into simpler compounds. Fungi, for example, are decomposers. Decomposers are **important to the stability of an ecosystem** because they return vital nutrients back into the environment.
Food Chains and Food Webs

The simplest way to look at energy flow in an ecosystem is through a food chain. A food chain is a sequence that links species by their feeding relationships. For example, in the food chain shown, grasshoppers feed on grass.

Trophic levels (AKA energy pyramids) Trophic levels are the levels of nourishment in a food chain. For example, the producer–herbivore–carnivore chain has three trophic levels. Carnivores are at the highest trophic level. Herbivores are at the second trophic level. Producers are at the first, or bottom, trophic level. Energy flows up the food chain from the lowest trophic level to the highest.

Check out the marine trophic energy pyramid shown ↑ Generally, only about 10 percent of the energy at one level is available to the next level. Why?? It is used for metabolic processes or given off to the environment as heat.
Food Webs

A food web is a model that shows the complex network of feeding relationships and the flow of energy within and sometimes beyond an ecosystem. The stability of any food web depends on the presence of producers, as they form the base of the food web. An organism may have multiple feeding relationships within a food web (generalists).

Symbiotic Relationships

**Symbiosis**: living together with another organism in close association

**Mutualism**: both organisms benefit. Both organisms use each other for a variety of reasons, which could include getting nutrients or protection. Ex) The oxpecker is a bird that lives on a rhino or a zebra. The oxpecker eats parasites off the larger animal, providing food for the bird and fewer parasites for the larger animal. The oxpecker will also make a shrill noise when there is danger.

**Parasitism**: the parasite benefits at the expense of the host. Ex) Fleas or ticks that live on dogs and cats are parasites. They are living off of the blood of the host animal.

**Commensalism** is a type of relationship where one of the organisms benefits greatly from the symbiosis. The other is not helped but is not harmed. Ex) Barnacles are a crustacean that attach to whales. Barnacles cannot move on their own, so they use the whale to move around and find food.
Cycling of Matter

In addition to organism interaction with one another and the environment, matter cycles in and out of an ecosystem as well.

Matter changes form, but it does not disappear. It can be used over and over again in a continuous cycle.

The water cycle is a common example:
the water cycle, is the circular pathway of water on Earth from the atmosphere, to the surface, below ground, and back

includes processes such as:
- runoff
- evaporation
- condensation
- transpiration
- precipitation

Elements essential for life also cycle through ecosystems, such as oxygen, carbon, phosphorus, and nitrogen. All of these elements cycle through ecosystems, just as water does.

The diagram shown of the oxygen cycle, illustrates how oxygen flows into the atmosphere as a byproduct of photosynthesis. Organisms take in this oxygen and release it as carbon dioxide through respiration.

The Carbon Cycle
Carbon is the building block of life. It is an essential component of carbohydrates, proteins, fats, and all the other organic molecules. Carbon continually flows from the environment to living organisms and back again in the carbon cycle.
Carbon exists in the abiotic world in several forms:
- Carbon dioxide (CO2) gas in the atmosphere
- Bicarbonate (HCO3\(^{-}\)) dissolved in water or found in rocks (limestone)
- Fossil fuels
- Dead organic matter in the soil

The Nitrogen Cycle
About 78 percent of Earth’s atmosphere is made of nitrogen gas. Most organisms can use nitrogen only in the form of ions such as ammonium (NH4\(^{+}\)) or nitrate (NO3\(^{-}\)).

Certain types of bacteria convert gaseous nitrogen into ammonia (NH3) through a process called nitrogen fixation. Nitrates released by soil bacteria are taken up by plants, which convert them into organic compounds such as amino acids and proteins.

The Phosphorus Cycle
Unlike the other cycles, the phosphorus cycle does not include an atmospheric portion. Instead, most of the cycle takes place at and below ground level. Phosphorus moves from producers to consumers through the food web. Phosphorus is a limiting factor for the growth of plants.
Interactions in an Ecosystem

What is the difference between a habitat and a niche?

A **habitat** can be described as **all of the biotic and abiotic factors** in the area where an organism lives. Ex) Lion in the African Savannah has a habitat that consists of all the living things, grasses, water, air, etc.

Each species interacts with its environment in a different way. Within an ecosystem, each species has an **ecological niche** or role. An ecological niche is composed of all of the physical, chemical, and biological factors that a species needs to survive, stay healthy, and reproduce.

You can think of a **habitat as where a species lives** and a **niche as how it lives** within its habitat.

Many species can **share similar habitats** and they may use some of the same resources. Notice in the example, bees and butterflies use the same flowers but have a different niche.

If they **occupied the same niche**, they would be in **competition for resources**.

Another way species interact with one another is through **predation**. Predation is the process by which one organism **captures and feeds upon another organism**.

An organism’s role in the environment is just one of many factors that can impact overall **population density**. Population density is a measurement of the number of individuals living in a defined space.

We use this formula to calculate →

\[
\frac{\text{# of individuals}}{\text{area (units^2)}} = \text{population density}
\]
Factors affecting population growth:

Changes in a population’s size are determined by immigration, births, emigration, and deaths.

**Immigration** is the movement of individuals into a population from another population.

**Births** increase the number of individuals in a population.

**Emigration** is the movement of individuals out of a population and into another population.

The size of a population decreases when individuals **die**.

Population growth is a function of the environment. **The rate of growth for a population is directly determined by the amount of resources available.**

The environment determines how many individuals of the species can be supported based on natural cycles and species diversity. An environment, therefore, has a carrying capacity for each species living in it. The **carrying capacity of an environment is the maximum number of individuals of a particular species that the environment can normally and consistently support.**

The factor that has the greatest effect in keeping down the size of a population is called the **limiting factor.** Examples of limiting factors include:

- **Competition**
- **Predation**
- **Disease**
- **Resource Availability**
Ecological Sucession

If an ecosystem experiences a catastrophe and begins to regrow, the space re-forms itself through a process known as succession. **Succession** is the sequence of biotic changes that regenerate a damaged community or create a new community.

**Primary** succession establishes an ecosystem in an area that was previously uninhabited.

The first organisms that live in an uninhabited area are called **pioneer species**.

Here’s how it works:
1. Glacier retreats exposing rock
2. Lichen/moss spores blown in by the wind
3. Over time seeds are blown into the area, small flowers & shrubs grow
4. Soil grows thicker, small trees begin to take root
5. Larger trees take root

**Disturbances** such as a fire or hurricane, halts the progress of succession or destroys an established community. **Secondary** succession, is the reestablishment of a damaged ecosystem.
Human Impact

Population Growth- Human population continues to grow which exerts pressure on Earth’s natural resources. Use of non-renewable resources (coal, gas, etc.) can lead to depletion and greater pollution.

Pollution is any undesirable factor that is added to the air, water, or soil.

Examples of Types of Pollution

<table>
<thead>
<tr>
<th>Smog</th>
<th>Acid Rain</th>
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</thead>
<tbody>
<tr>
<td>Air pollution caused by the interaction of sunlight with pollutants produced by fossil fuel emissions</td>
<td>Precipitation produced when pollutants in the water cycle cause rain pH to drop below normal levels</td>
</tr>
</tbody>
</table>

Air pollution is changing Earth’s biosphere. Scientists have found that changes in Earth’s temperature correspond with fluctuations in global carbon dioxide levels.

This causes what is known as the “Greenhouse Effect.” Water vapor, carbon dioxide, and methane are gases that absorb radiant energy and contribute to global warming.

Preserving biodiversity is important to the future of the biosphere. A decrease in an ecosystem’s biodiversity will have a ripple effect through the entire ecosystem. Medical and technological advancements come from nature.