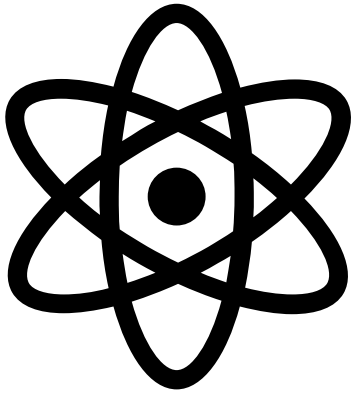
U.S. BIOLOGY TEACHING

Save Time, Engage Students, Love Teaching

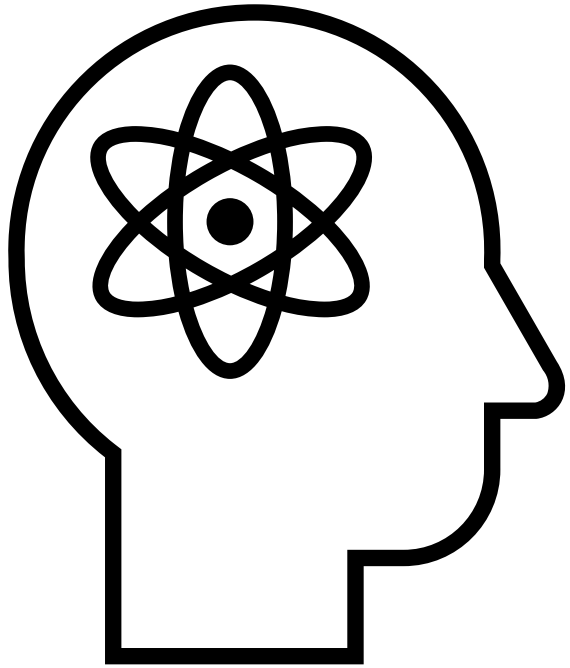


Lesson 2: Science, Matter, Energy and Systems

Environmental Science

The Nature of Science

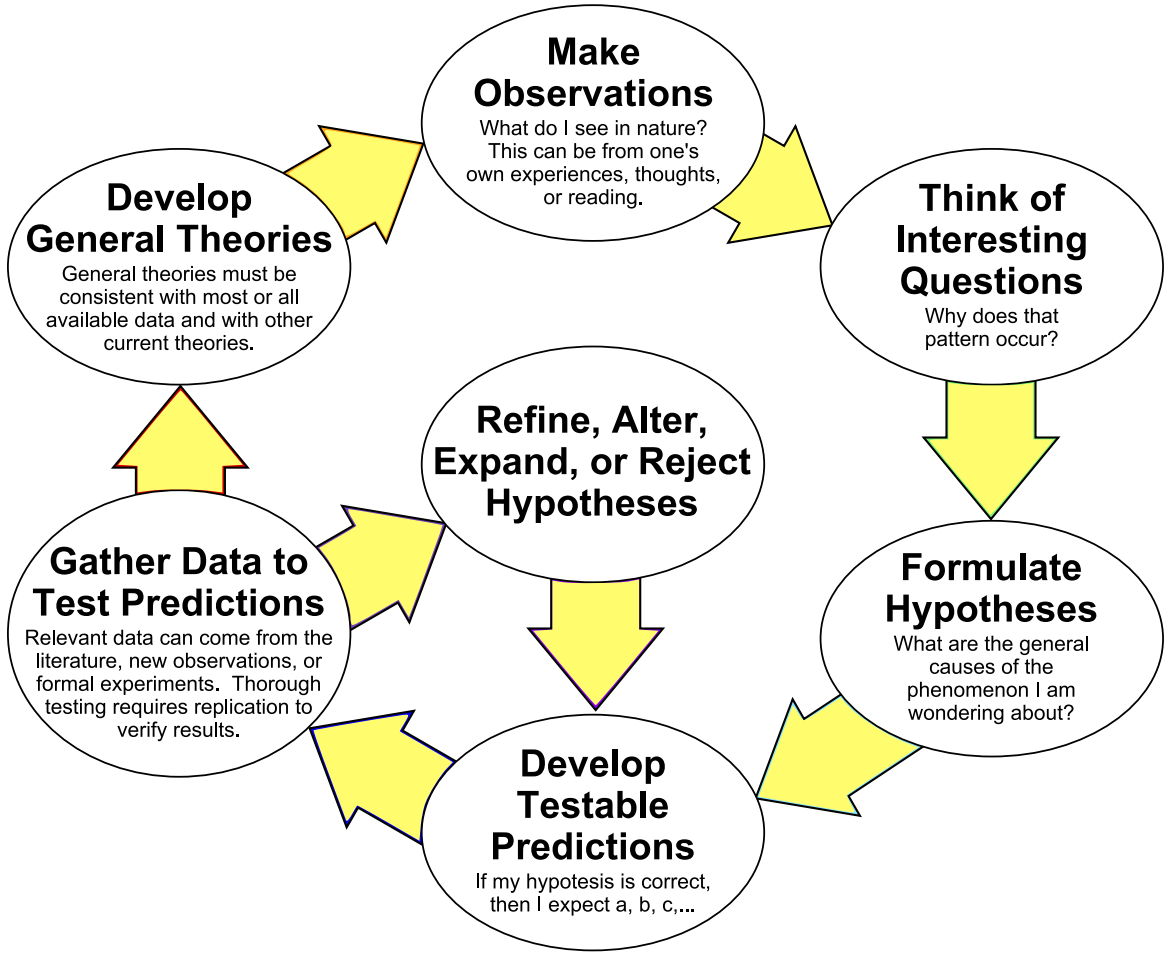
- **Science** is a broad field of study that is focused on discovering how nature works.
- By building knowledge of science we can better describe what is likely to happen in a specific situation as we learn more.
- Careful experimentation, **observation,** and measurements help us to develop an understanding of the natural world.



The Scientific Method

The Scientific Method as an Ongoing Process

- Scientists use the **scientific method** to advance knowledge and understanding of how the natural world works.
  - The key takeaway is that it is a logical **process** to solving a problem or answer a question.



One Approach to the Scientific Method

Steps of the Scientific Method

1. Make an **observation**
2. Pose a question
3. Form a **hypothesis**
4. Make a **prediction**
5. Design an **experiment**
6. Collect Data
7. Analyze Data
8. Draw a conclusion
9. Communicate Results

Hypothesis

- A **<u>scientific hypothesis</u>** is a possible, testable answer to a scientific question or explanation of what scientists observe in nature.

- Example Hypothesis: Grass growth is limited by the amount of available water.

The thought process that may have occurred prior to this hypothesis:

- **<u>Observation</u>**- Hmmm…I have only had to cut the grass once in ten days.
- **Question**- Why is my grass not growing as fast?
- Hypothesis (see above example)-Notice the hypothesis is a testable explanation or answer to the question.

After the hypothesis

Using the same scenario as the previous slide…

- **Prediction-** If the grass is given more water then it will grow faster.

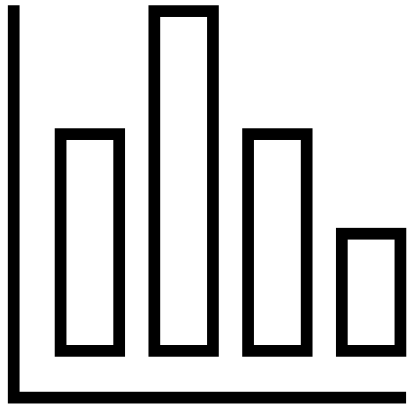
- **Experiment-** The scientist will set up a controlled experiment testing only ONE variable everything else must be kept constant (same)

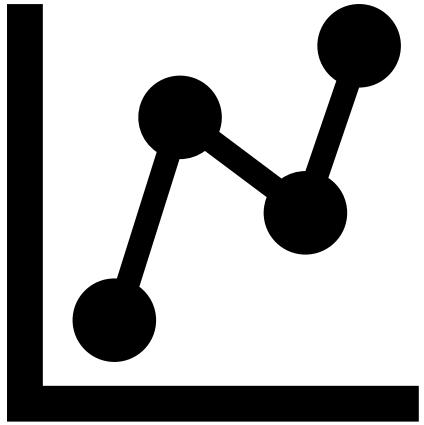
Experimental Design Key Terms

- **Independent variable-** the variable that is being manipulated by the experimenter. It is the one thing that is changed in an experiment.
- **Depended Variable-** the variable that is being measured to determine the effect of the independent variable.
- **Control (group)-** the standard for comparison or normal.
- **Constant**- factors that are kept the same between the control group and experimental group.
- **Experimental Group-** The group that is receiving the independent variable.

Other Scientific Terms to Know

- **Data** is information that is collected to test the hypothesis.
  - **Quantitative data-** A quantity or number that can be measured directly with a tool. (example-the number of centimeters the grass grew)
  - **Qualitative data-** data describes qualities or characteristics.
- A **model** is a physical or mathematical representation of a structure or system.
  - Models are often necessary to display data in a way that is easier to interpret.





Scientific Theory

The term "**theory**" is often used in everyday life to as a synonym for a hunch or a prediction but in science, it is much different.

- In science the term theory is **a well-tested** and widely accepted hypothesis (explanation) or group of hypotheses.
  - It is based on a large body of evidence often from multiple disciplines.
  - Examples: Cell theory, plate tectonics theory, and climate change theory

Advances in Human Knowledge

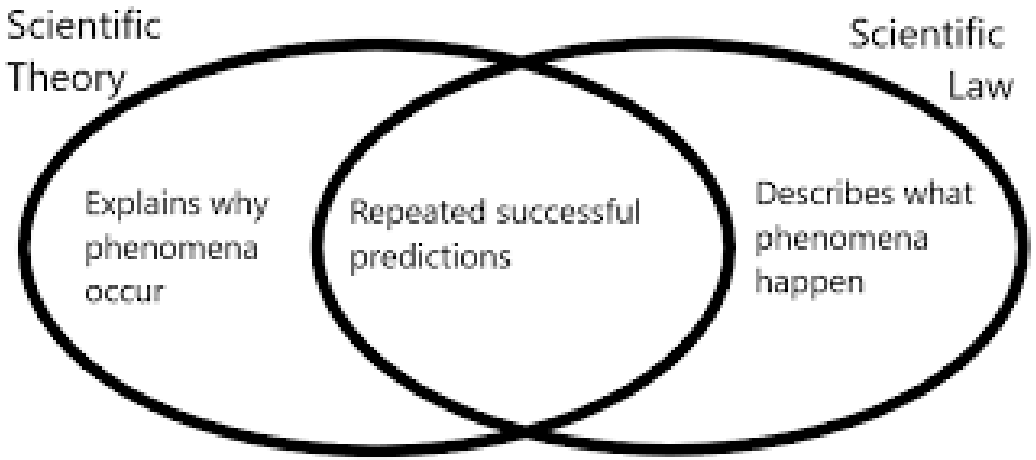
- It is important to understand that theories, though well supported can change over time as technology develops and better explanations are discovered.

Part of the scientific process is peer reviewing.

- A **peer review** involves scientists publishing the details of the methods they used, the results of the experiment, and their reasoning for their interpretations.

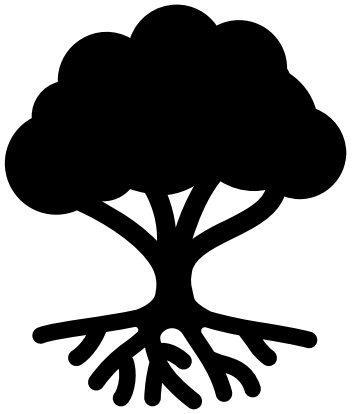
Scientific Law

- **A scientific law** is a well-tested and widely accepted description of observations that have been repeated many times in a variety of conditions.
  - Example- Newton's Law of Universal Gravitation or Mendel's Law of Independent Assortment
- **Scientific laws** describe observations but **not how or why** they occur, that is what theories are for.



Limitations of Science

- Scientific research does not aim to “prove” anything absolutely.
  - For example, we cannot prove or accurately measure how many tons of topsoil are eroded away each year. However, we can use tools, gather data, and apply statistics to get a logical estimate.
- **Scientists** are humans. Humans are not free of bias about their own results and hypotheses though good scientists recognize their biases and try to avoid them.
- Our data is only as good as the **tools** we use to measure.



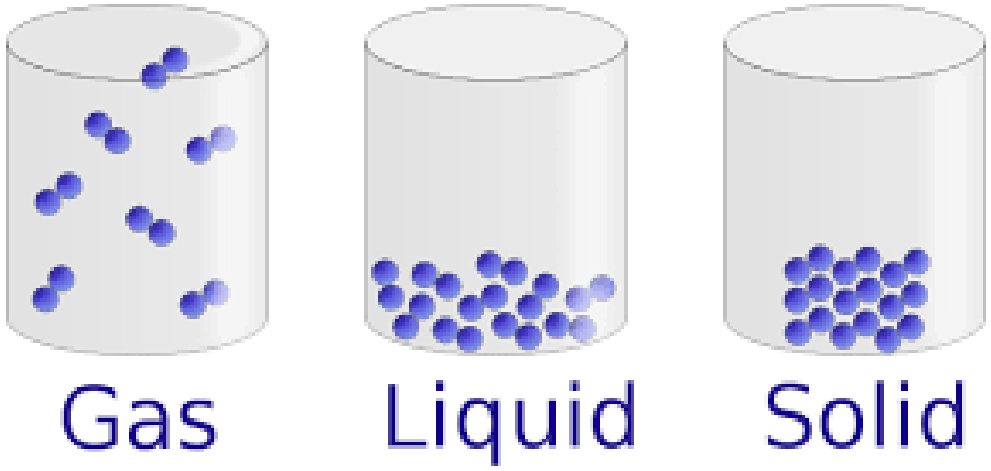
Bell Ringer: Where does a tree get its mass from?

What is matter?

- In order to understand many aspects of environmental science we must understand the basics of chemistry and energy.

- **Matter** is anything that has mass and takes up space. It can be in three common states –solid, liquid, or gas.

- Matter can be an **element**, or it can be a **compound**.

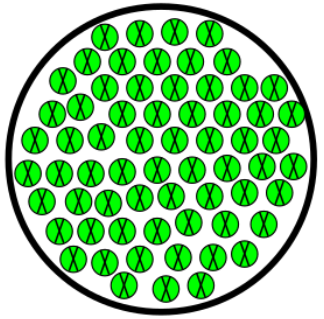


Element vs Compound

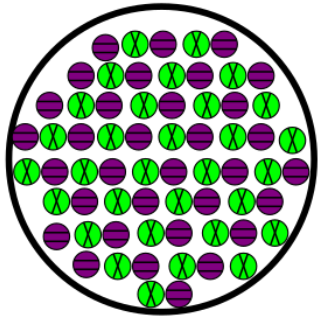
- An **element** is a type of matter with a unique set of properties that cannot be broken down into simpler substances by chemical means.
  - Example- C (Carbon), Ca (calcium), O (oxygen)

- **Compound**- A compound is two or more different elements held together in fixed proportions.
  - Example: Water (H_20), Glucose ($C_6H_{12}O_6$)

Pure Substances

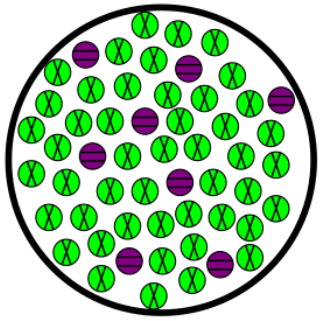


Element

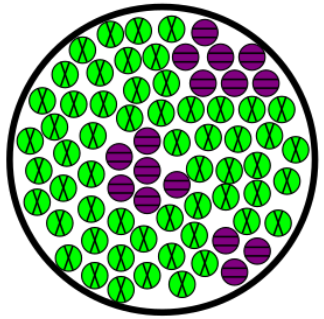


Compound

Mixtures



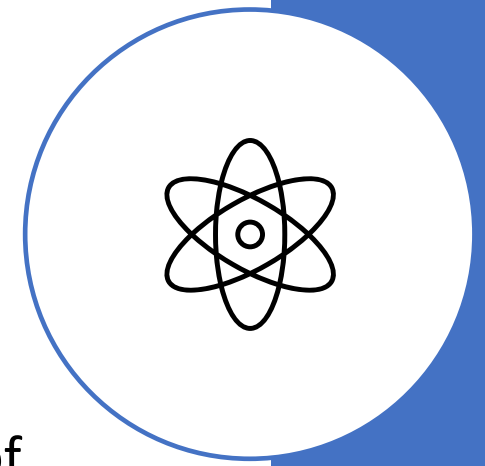
Homogeneous



Heterogeneous

Atoms

An **atom** is the basic building block of matter.



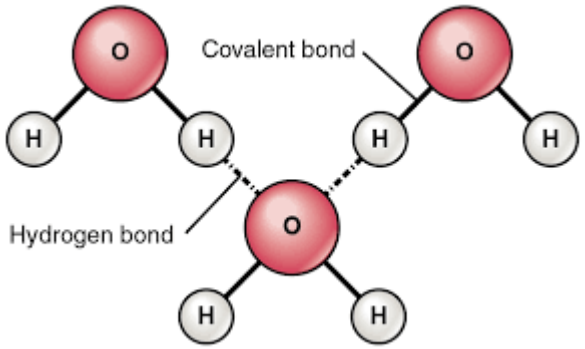
Atoms are composed of 3 subatomic particles:

- **Neutrons**-particles with no charge that are located at the center (nucleus) of the atom
- **Protons**-particles with a positive (+) charge located in the nucleus of the atom.
- **Electrons**-smaller particles with a negative (-) charge in rapid motion outside the nucleus.

Molecules

- **<u>Molecules</u>** are combinations of two or more atoms of the same or different elements.
  - Example: Water (H_20), Glucose ($C_6H_{12}O_6$) ← you may have noticed these are also examples of compounds
  - Example: Oxygen (O_2) ← Oxygen is a molecule but not a compound.

- **<u>Ions</u>** are atoms or groups of atoms with a charge (+ or-)
  - Example- Na^+, Cl^-



The extra H+ combines with water to create Hydronium H_3O+

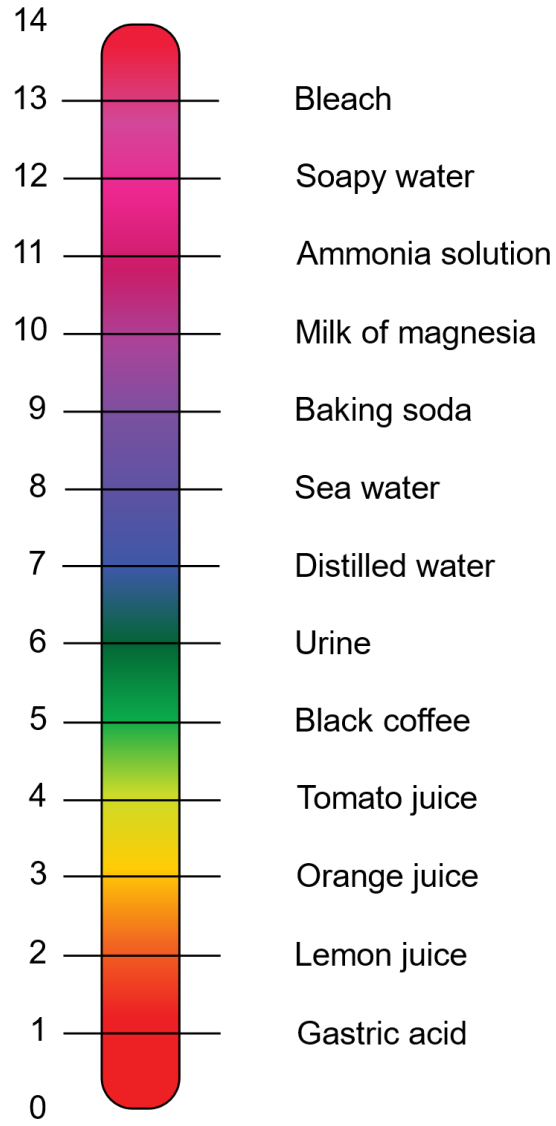
pH

pH is how acidic or basic something is based on how many ions of hydrogen (H^+) or **hydroxide** (OH^-) are present.

If a solution has more hydroxide ions (OH^-) it is a basic or alkaline solution. (pH greater than 7)

If a solution has more hydrogen ions (H^+) it is an acidic solution. (pH less than 7)

If the concentration of the (H^+) and (OH^-) are equal then the solution is neutral (pH 7)



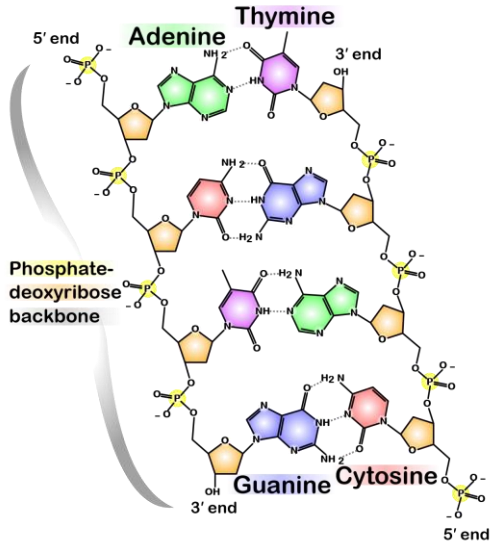
Molecules of Life

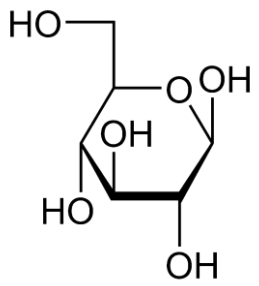
- **Organic Compounds** are compounds that contain at least two carbon atoms and one or more other elements. Most chemicals in your body are organic
  - Example- Glucose ($C_6H_{12}O_6$)
  - Exception- CH_4

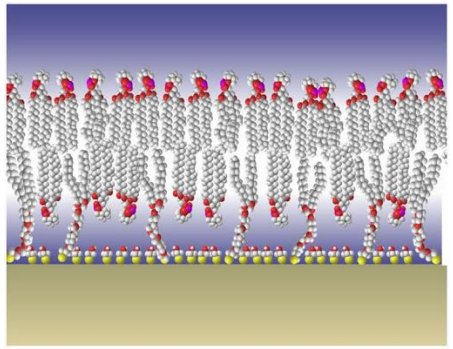
The 4 Organic Molecules (Macromolecules)

- **Proteins**-made of amino acids (Enzymes, muscles)
- **Lipids**-made of fatty acids. Consists of fats, waxes and oils.
- **Carbohydrates-** made of monosaccharides (single sugars)
- **Nucleic Acids-** made of nucleotides (DNA, RNA)

You will learn or did learn about these more in Biology.







Matter Can Change

- **Matter** can undergo either chemical or physical changes.

In a **physical change** there is no change in the composition of the substance.

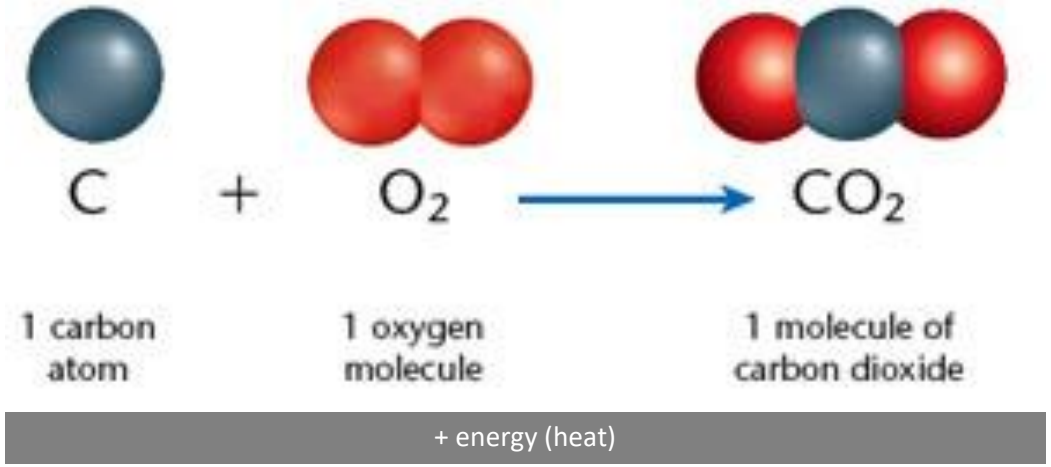
- For example- Ice melting and becoming water, cutting a piece of metal in half.

Chemical Change

In a **chemical change,** there is a change in the composition of the substance.

Chemists use chemical equations to represent these changes.

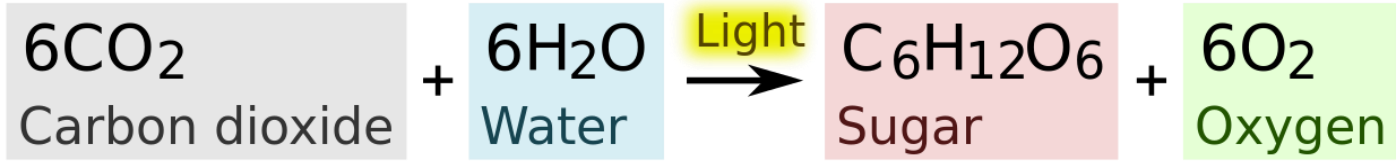
For example, the burning of coal which is mostly carbon (C) is combined with O_2 from the atmosphere to produce carbon dioxide (CO_2).



Law of Conservation of Matter

- **<u>The Law of Conservation of Matter</u>** states that whenever matter undergoes a physical or chemical change, no atoms are created or destroyed.

- Looking at a balanced chemical equation you can keep track of the changes and even the atoms.



Ball Observations

- How high does the basketball bounce?
- How high does the tennis ball bounce?

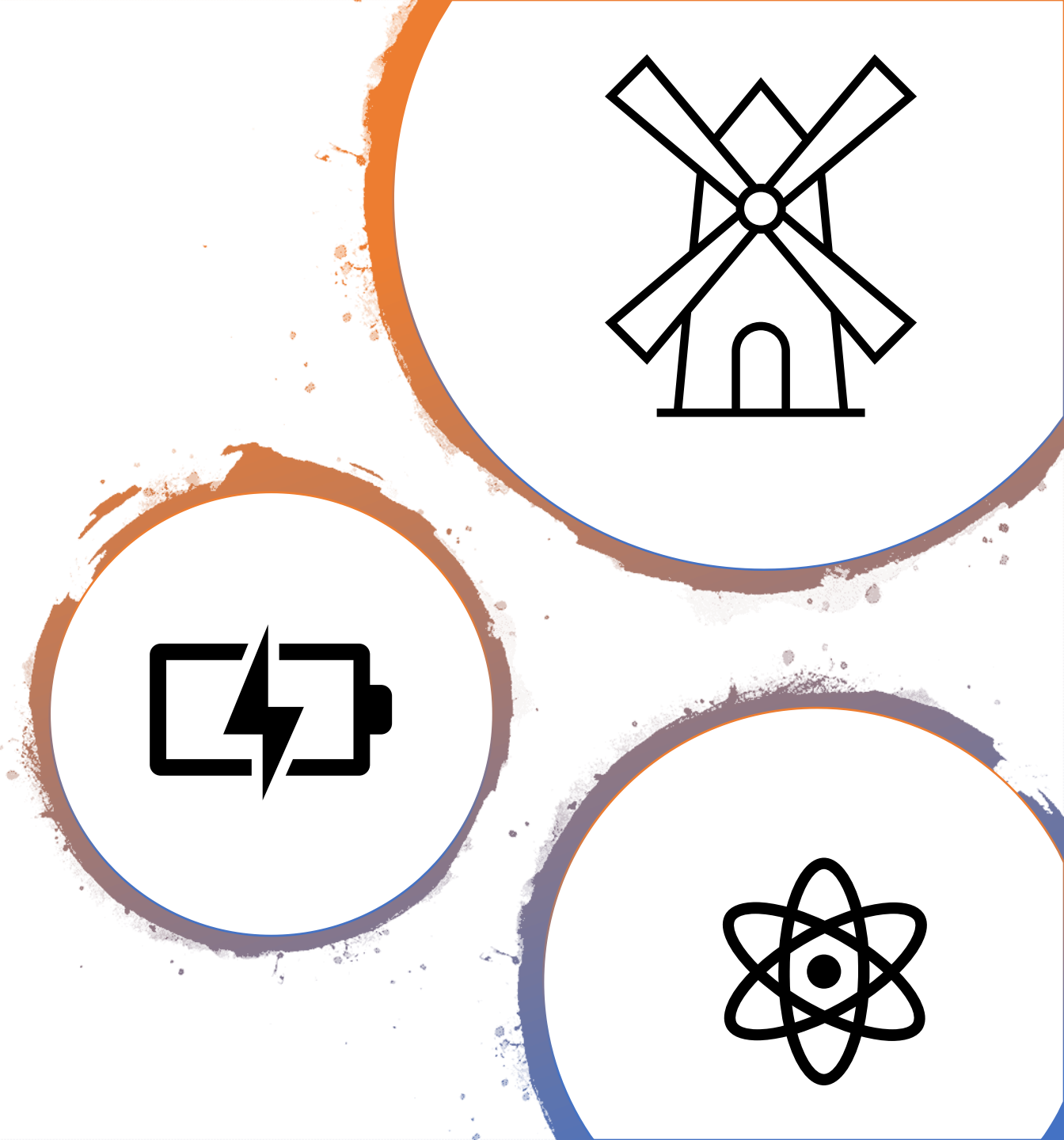
Prediction

- What do you think will happen when they are dropped together (tennis ball on top of the basketball)? Will the distance each ball bounces be the same? Why? Why not?

Energy

Energy comes in many forms. **Energy** is the capacity to do work.

As you may recall, understanding how to secure a source(s) of renewable energy is critical to allowing us to become a **sustainable planet**.



Types of Energy

Kinetic Energy is the energy associated with motion.

- Examples- a moving car, flowing electrons (electricity), and wind.

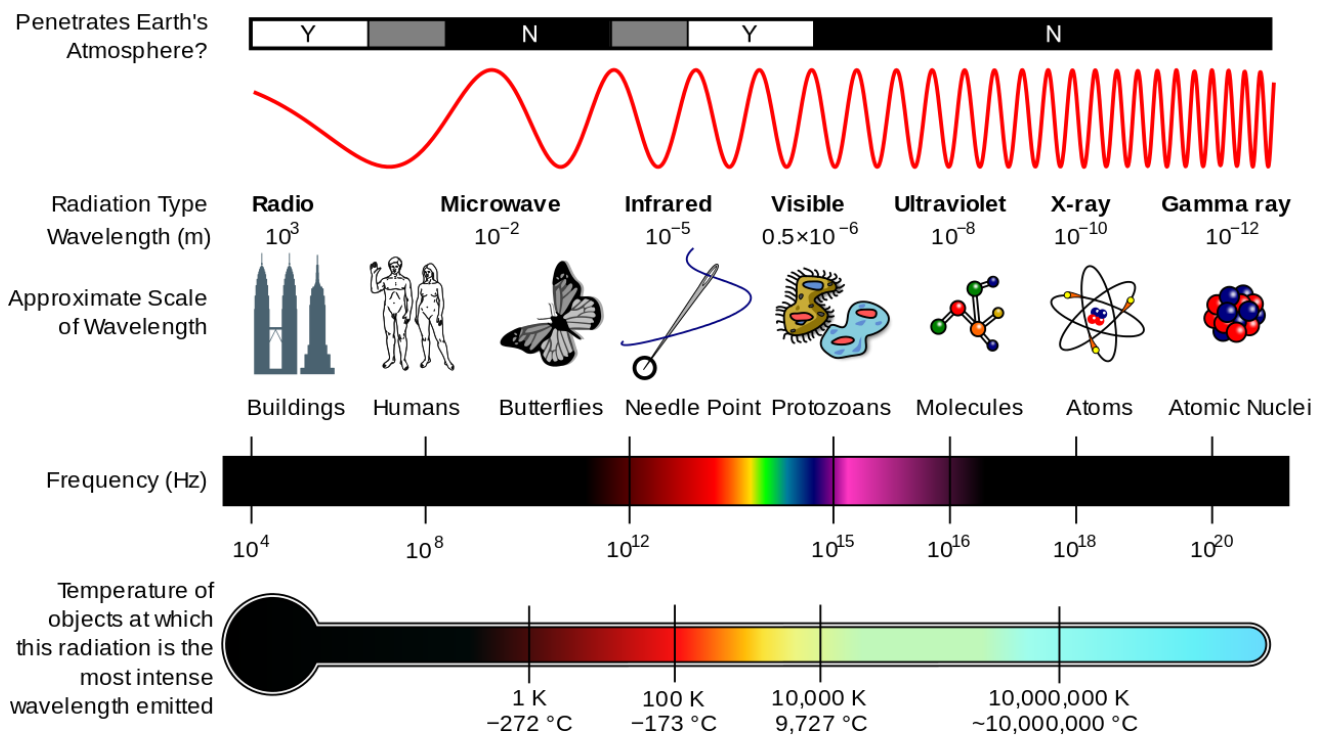
Thermal Energy is also a type of kinetic energy. The hotter an object is the faster the molecules, atoms or ions are moving

Temperature is the measure of the average heat or thermal energy of a sample of matter.

Electromagnetic Radiation is another form of kinetic energy where the energy travels as a wave.

Ocean thermal energy plant

Kinetic Energy Continued



<u>Electromagnetic Radiation</u> is another form of kinetic energy where the energy travels as a wave. Different wavelengths have different amounts of energy.

The Sun emits electromagnetic radiation. This is the energy that fuels many of the processes on Earth.

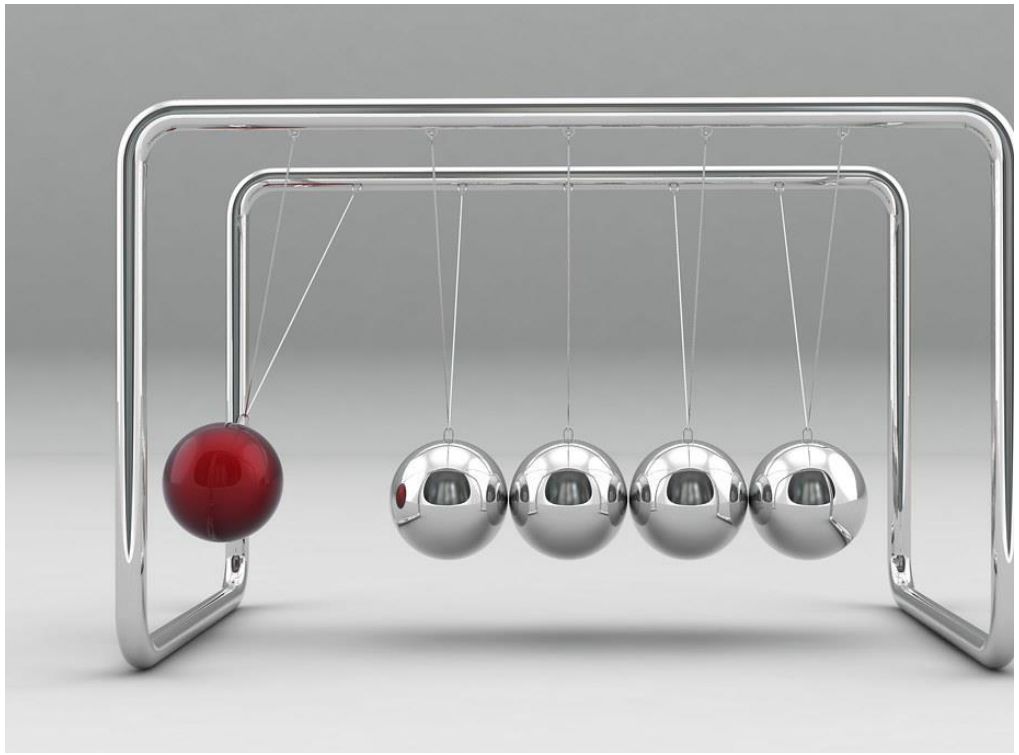
Solar energy is a key factor in achieving sustainability.

Potential Energy

- **Potential Energy** is energy that is stored and potentially available for use.
- Examples: A cell phone sitting on a desk. Energy is stored in the molecules of food and is released during digestion.
- Potential energy can be **converted** to kinetic energy. For example, water behind a dam can be used to power a turbine and convert the potential energy into kinetic energy.

Energy Laws

- **First Law of Thermodynamics** (Law of Conservation of Energy)- When energy is converted from one form to another in a physical or chemical change no energy is created or destroyed. The total amount of energy does not change.



Second Law of Thermodynamics

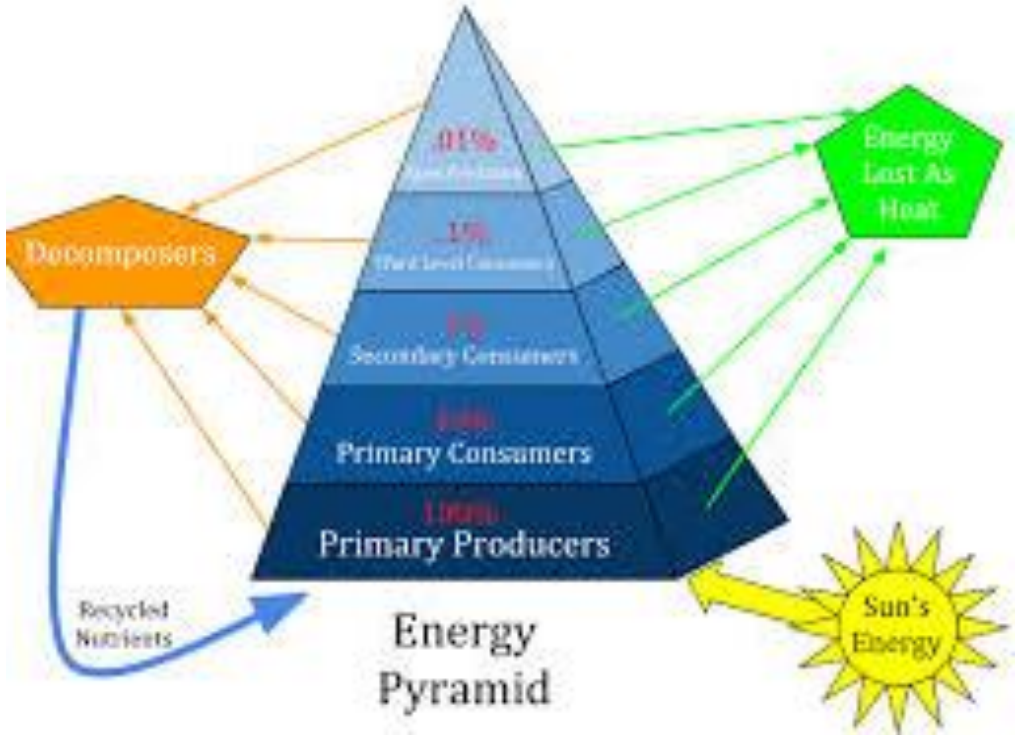
- **<u>Second Law of Thermodynamics-</u>** Whenever energy is converted from one type of energy to another type of energy in a physical or chemical change the resulting energy is lower-quality energy or less usable energy than before. This occurs because some energy is lost as heat.

- This means that we cannot recycle high-quality energy.

Systems

A **system** is a set of components that function and interact in some regular way.

- Example- The human body, a forest, an ecosystem and Earth.

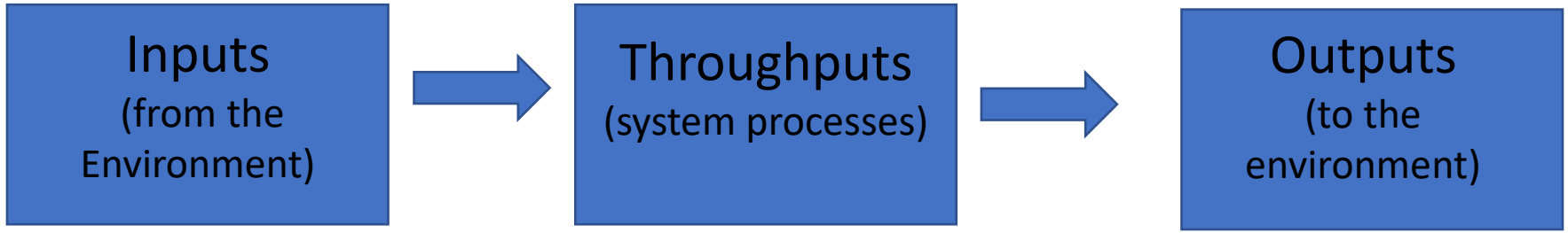


Systems Continued

Systems have a few key components; **inputs**, **throughputs,** and **outputs**.

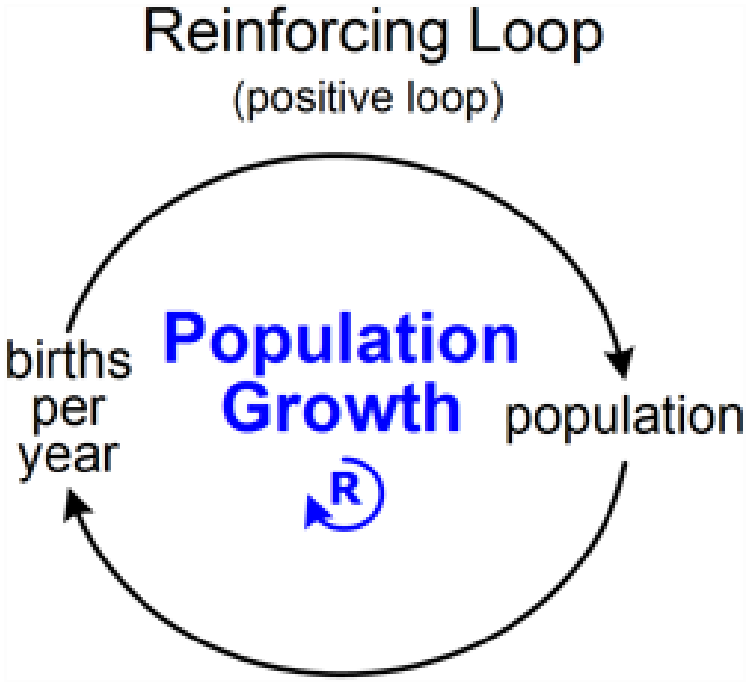
For a system to be sustainable the throughputs must be able to handle the inputs and the environment must be able to absorb the outputs.

Do you think our system is sustainable? What are some examples of each component?



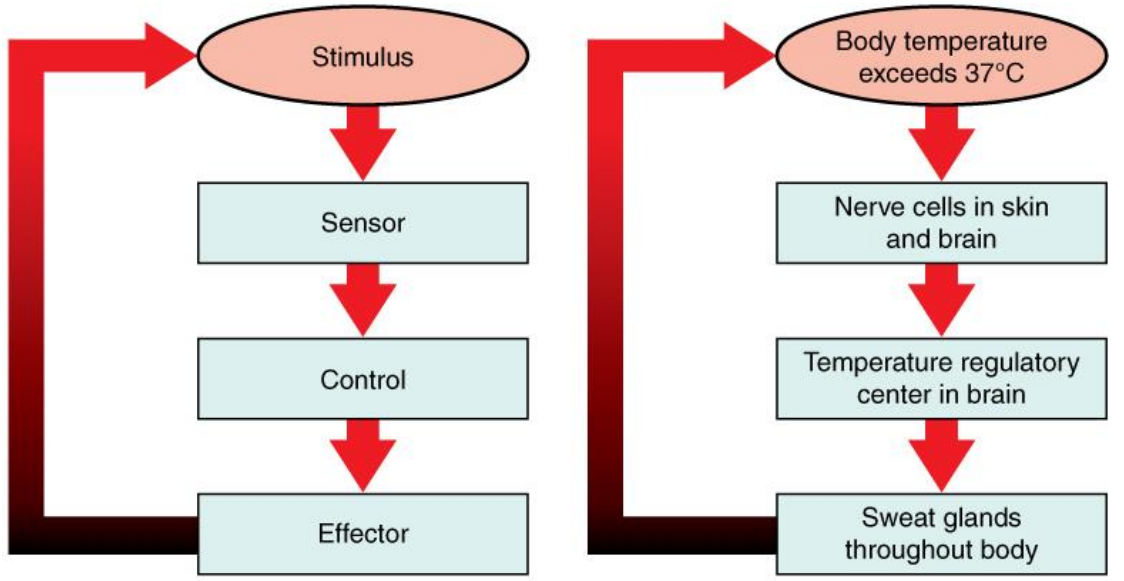
Feedback Loops

- A **feedback loop** occurs when an output of matter, energy, or information is fed back into the systems as an input and it can lead to changes in the system.
- **Positive Feedback Loop-** Causes the systems to change in the same direction.
  - Example- As vegetation in an ecosystem is lost more nutrients are washed away and as a result more vegetation is lost and even more nutrients are lost.
  - When an ecosystem becomes locked into a feedback loop it can reach an **ecological tipping point** where the ecosystem can experience a collapse.



Negative Feedback Loop

- A **<u>negative feedback loop-</u>** causes the system to change in the opposite direction from which it is moving.
- An example of a negative feedback loop is a thermostat in your home. When it gets too cold the heat turns on until it warms up again and then it stops. If it gets too hot the A/C will turn on until it is back to the set temperature.



(a) Negative feedback loop

(b) Body temperature regulation