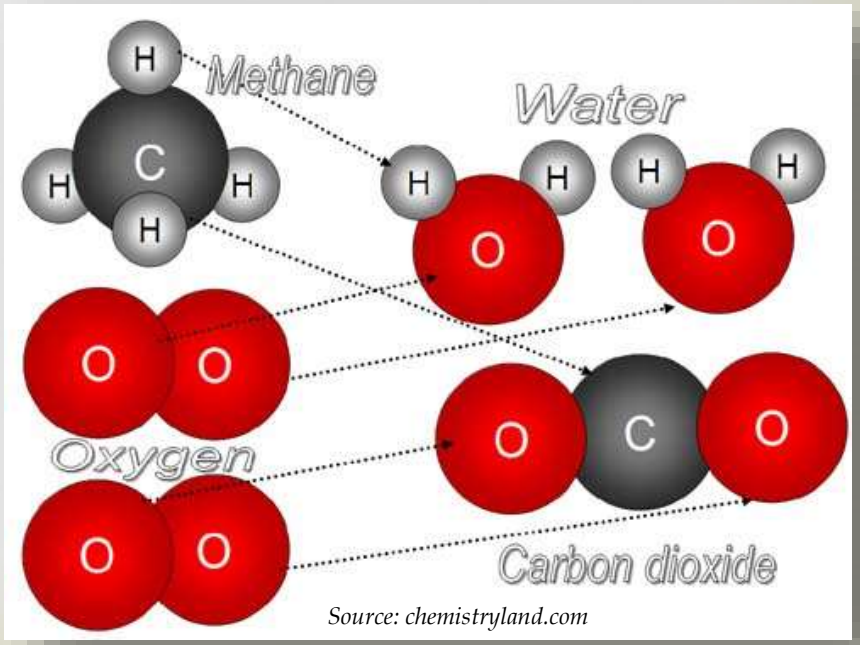
The Carbon Cycle

By C. Kohn
Agricultural Sciences
Waterford, WI

Carbon, an Element

- **Carbon is an element, or a specific kind of atom.**
  - Atoms are the smallest indivisible unit of matter.
  - If you were cut a piece of paper smaller and smaller and smaller, an atom is the smallest you can get under normal circumstances.
    - *Although you could never down to the level of an atom with just a scissors.*

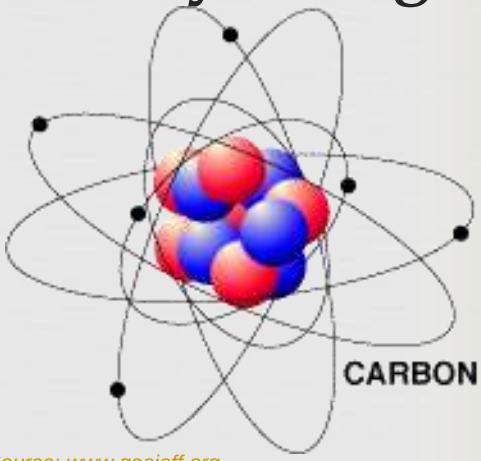
- **Groups of atoms bond together form molecules.**
  - For example, water is a molecule because it is made of one oxygen atom bonded to two hydrogen atoms.



Source: chemistryland.com

Living things are carbon-based

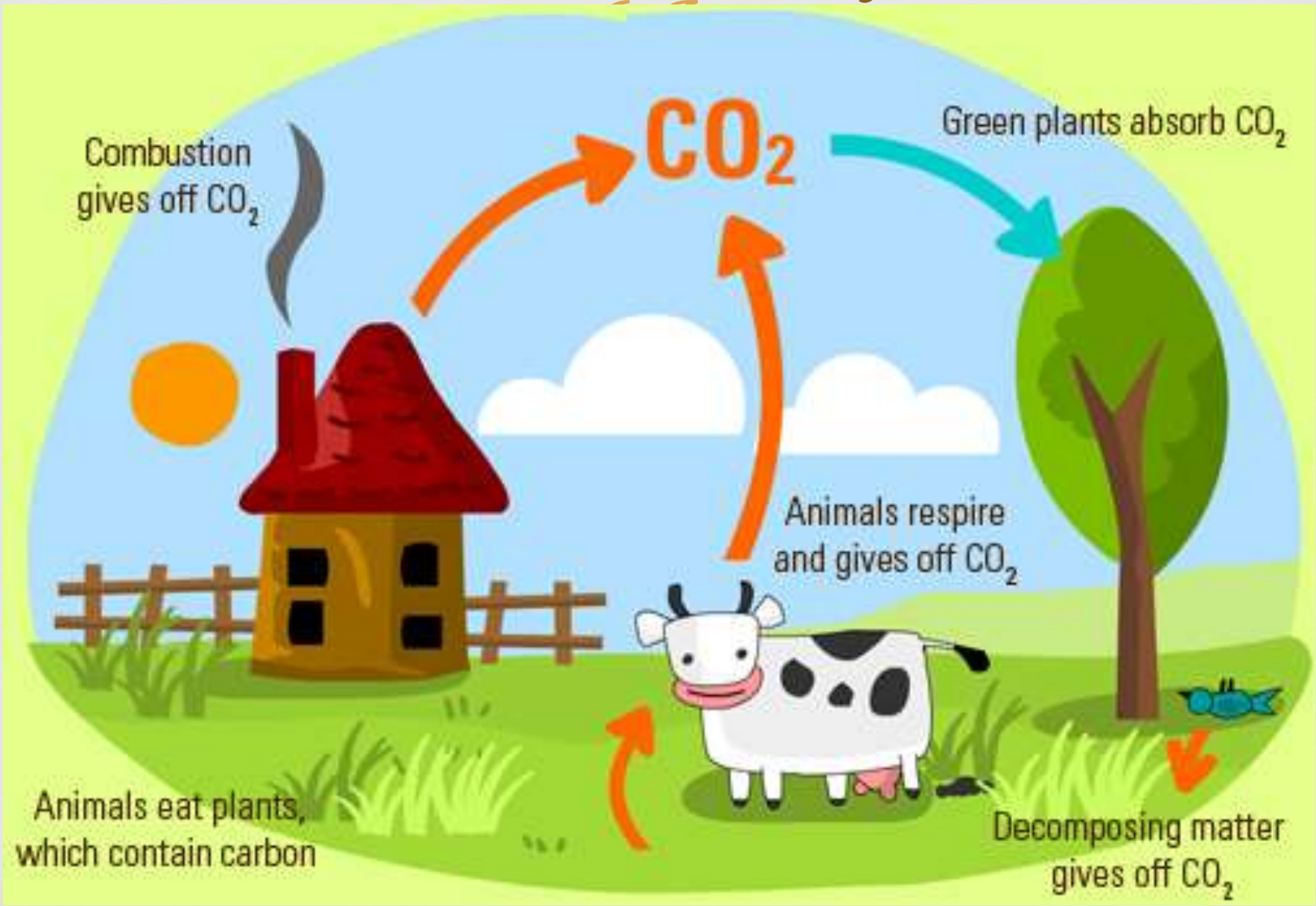
- **All living organisms are carbon-based, meaning that carbon is the most widely utilized element by living organisms.**
  - Carbon can form four bonds with other atoms, which is the most an atom can usually form.
  - Because carbon is a small atom, its bonds are stronger than other larger atoms.



Source: www.geojeff.org

- **Carbon atoms are constantly moved onto different molecules as different organisms acquire the carbon they need to build the molecules necessary for cells to exist and function.**
  - The movement of carbon atoms between different kinds of molecules is called the carbon cycle.

The Carbon Cycle

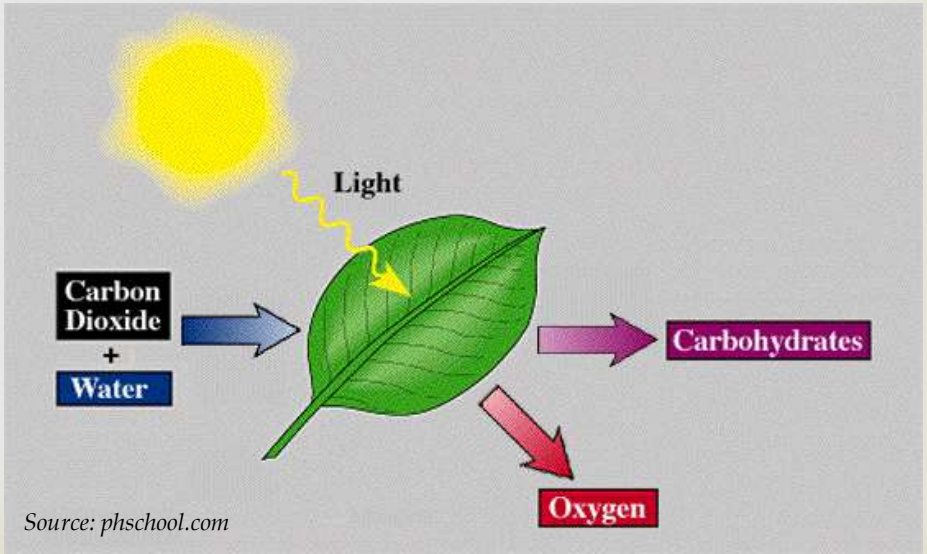


Source: eschooltoday.com

The Carbon Cycle

- **The carbon cycle begins with carbon dioxide in the air.**
  - Carbon dioxide is a molecule that is made of a carbon atom bonded to two oxygen atoms.
    - *The oxygen atoms are double-bonded to the carbon atom, resulting in an extra-strong bond.*

- **Plants absorb carbon dioxide from the air in order to make glucose, the simplest sugar molecule.**
  - Plants rearrange carbon dioxide molecules (CO_2) from the air and water (H_2O) molecules from the soil to make glucose ($C_6H_{12}O_6$) and oxygen (O_2).

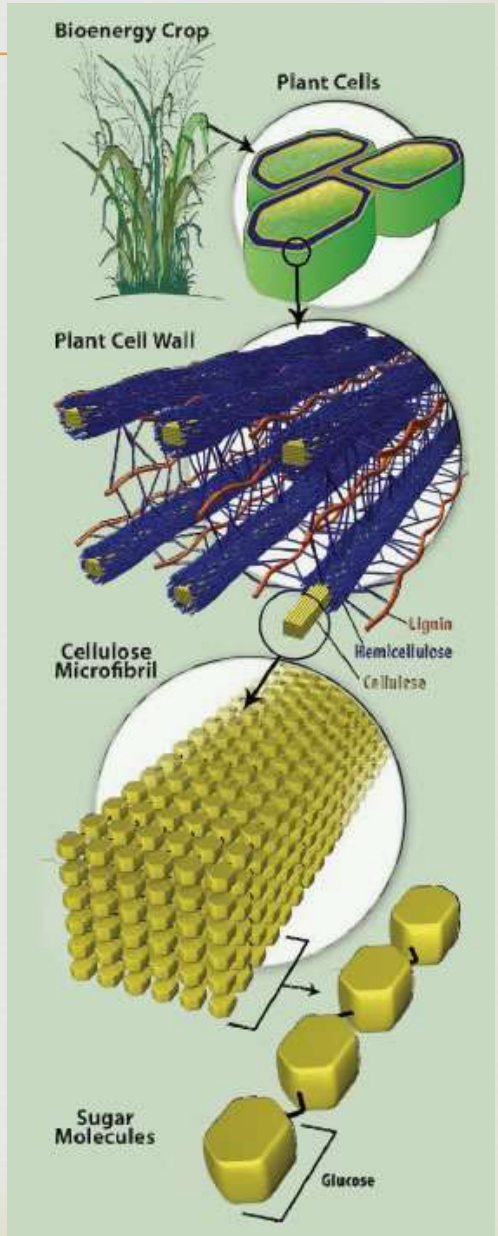


Source: phschool.com

Photosynthesis

- **The process in which glucose is produced by a plant is called photosynthesis.**
  - In photosynthesis, water (H_2O) and carbon dioxide (CO_2) are absorbed and glucose ($C_6H_{12}O_6$) and oxygen (O_2) are produced.
  - Plants can use glucose as a building block to make more complex molecules such as starch (like in corn or rice) or fiber (such as cellulose, the tough molecule that is found throughout the plant and gives it its structure and rigidity).

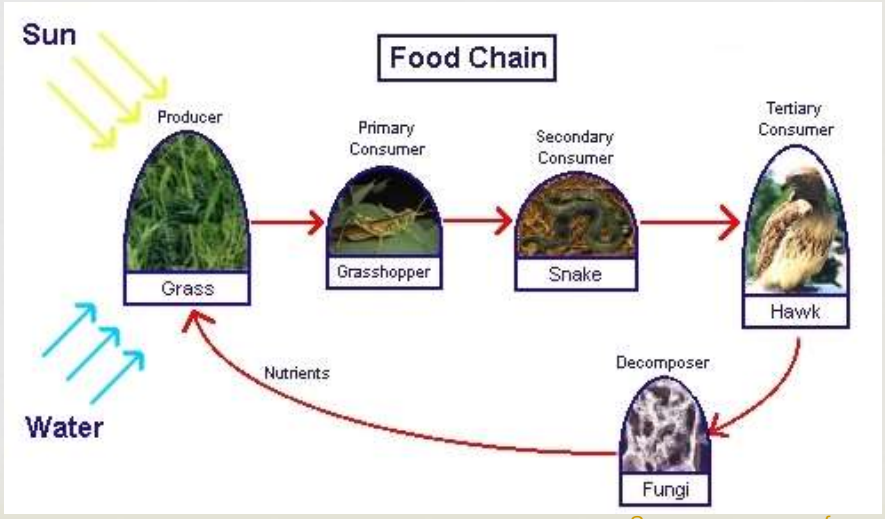
- **Sugars, starches, and fiber are all called carbohydrates.**
  - A carbohydrate is a molecule made of carbon, oxygen, and hydrogen and is used by plants, animals, and other living organisms as a source of chemical energy.



Carbohydrates

- **Neither plants nor animals can get the energy they need directly from the sun.**
  - Plants must convert the light energy of the sun into chemical energy (such as sugar) in order to provide its cells with a source of usable energy.
  - Plants produce glucose ($C_6H_{12}O_6$) so that it can be used by the plant for its own energy needs.

- **Animals and other <u>consumers</u> must consume carbohydrates because they cannot produce their own source of cellular energy.**
  - All carbohydrates consumed by animals are broken down into glucose.
  - The cells of animals use this glucose to create the energy they need to power cellular activity.

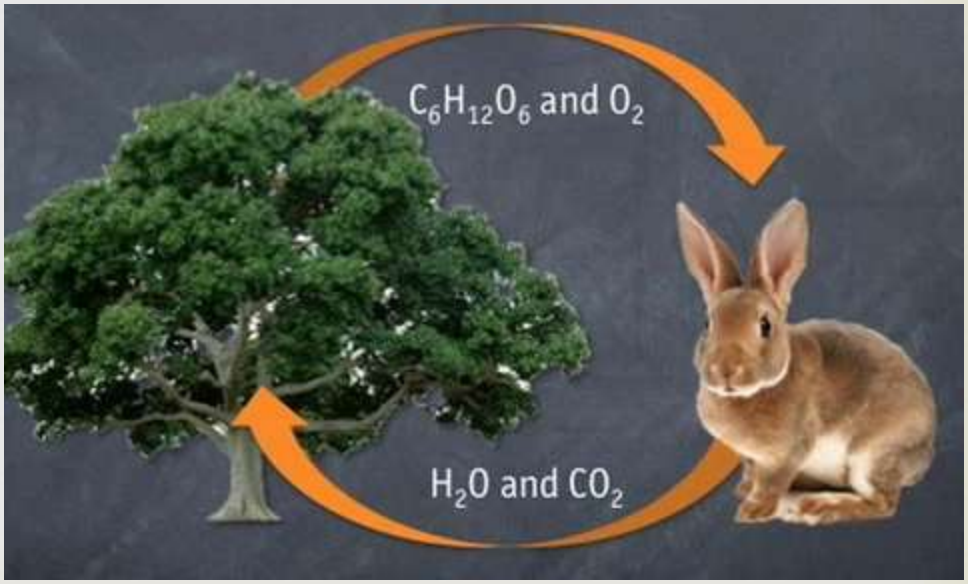


Source: www.proprofs.com

Respiration

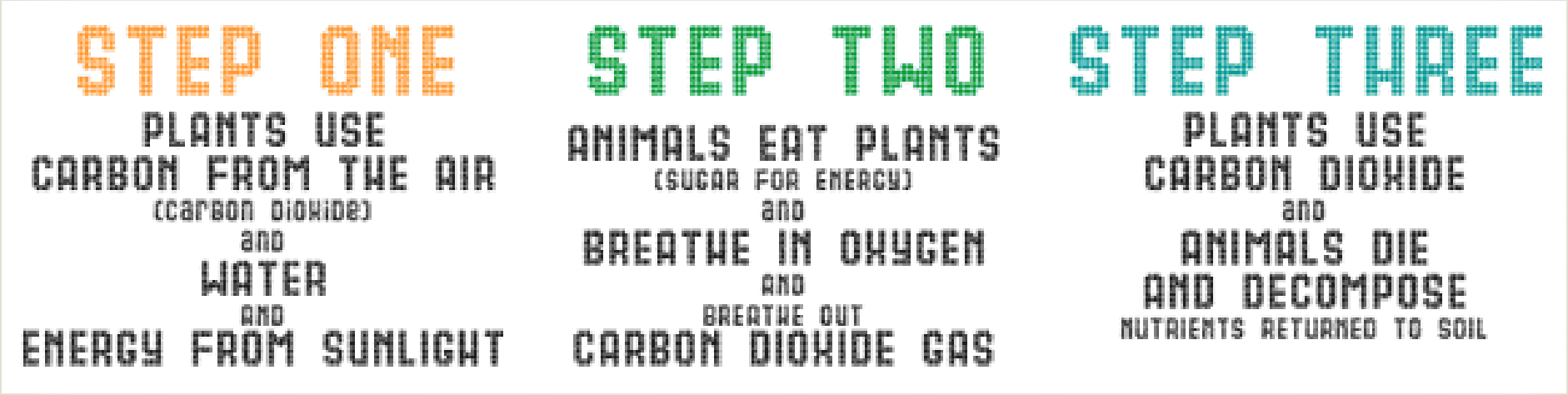
- **The process in which plant and animal cells use glucose and oxygen is called <u>respiration</u>.**
  - In respiration, glucose and oxygen are absorbed by an organism and carbon dioxide and water are released.

- **Both plants and animals will release carbon dioxide and water as their cells utilize glucose.**
  - This is why it is called the carbon *cycle* – plants will use carbon dioxide (CO_2) and water (H_2O) to make glucose ($C_6H_{12}O_6$) and oxygen (O_2).
  - Glucose and oxygen are rearranged into carbon dioxide and water by the cell during respiration.



Organic vs. Inorganic

- **Carbon is cycled between organic molecules such as carbohydrates and inorganic molecules such as carbon dioxide.**
  - Organic molecules are molecules that are or were a part of something that is alive.
    - *This can include carbohydrates, the molecules in the cells of animals, and even feces and dead leaves.*
  - Inorganic molecules are molecules that are not a part of something that is alive.
    - *Carbon dioxide is not a part of a living organism.*
  - NOTE: the term "organic" in food is a different concept from organic and inorganic carbon molecules.

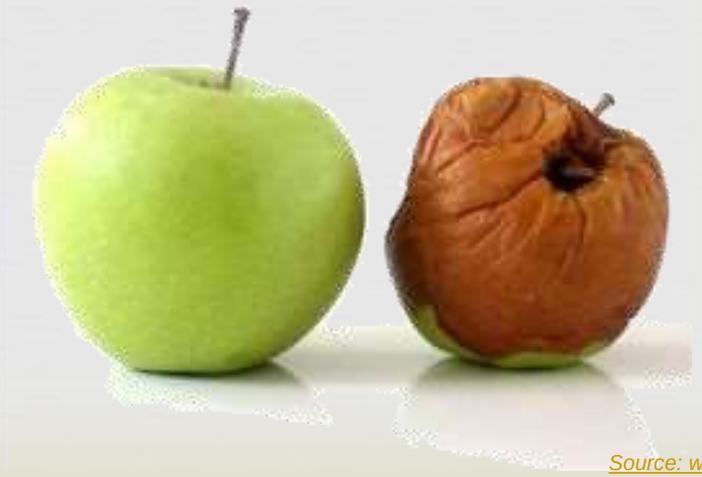


Source: www.geography4kids.com

Decomposition

- **When a plant or animal dies, the organic carbon molecules that made up these organisms are broken down by organisms called <u>decomposers</u>.**
  - Decomposers include fungi (such as mushrooms), bacteria, and some animals such as earthworms.

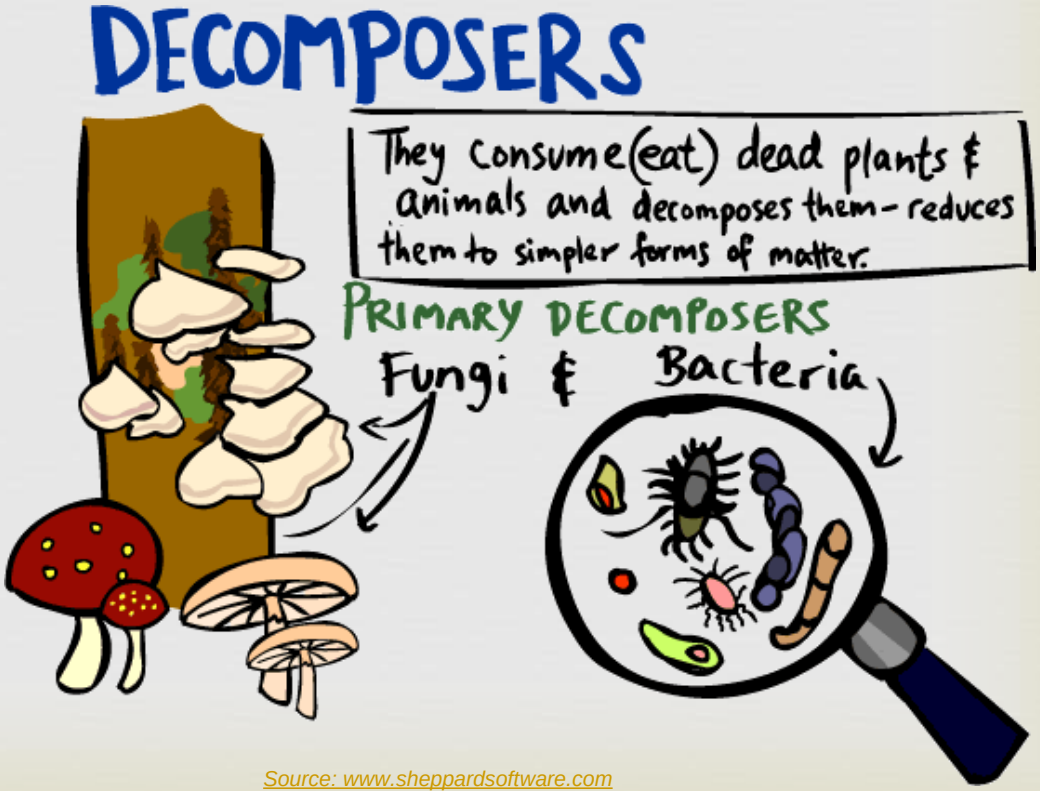
- **<u>Decomposition</u> is the process in which organic carbon molecules within dead organisms are converted into inorganic carbon molecules.**
  - In decomposition, organic carbon molecules and oxygen are converted into inorganic carbon molecules (such as carbon dioxide and methane) and water.



Source: www.ehow.com

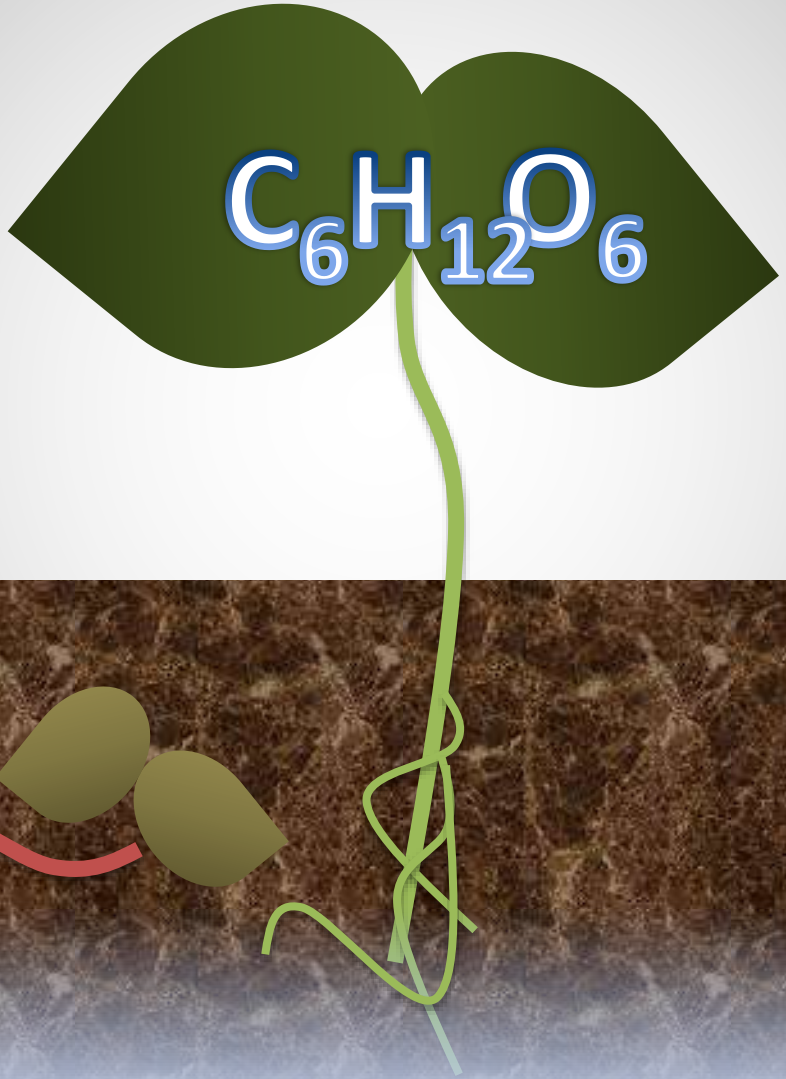
Decomposers

- **Decomposers convert organic carbon molecules into inorganic molecules.**
  - In the same way that both plants and animals convert carbohydrates into carbon dioxide and water, decomposers will convert the carbon molecules in dead organisms into carbon dioxide and water.
  - This enables the carbon cycle to continue even if the organism is no longer alive to break down carbohydrates.



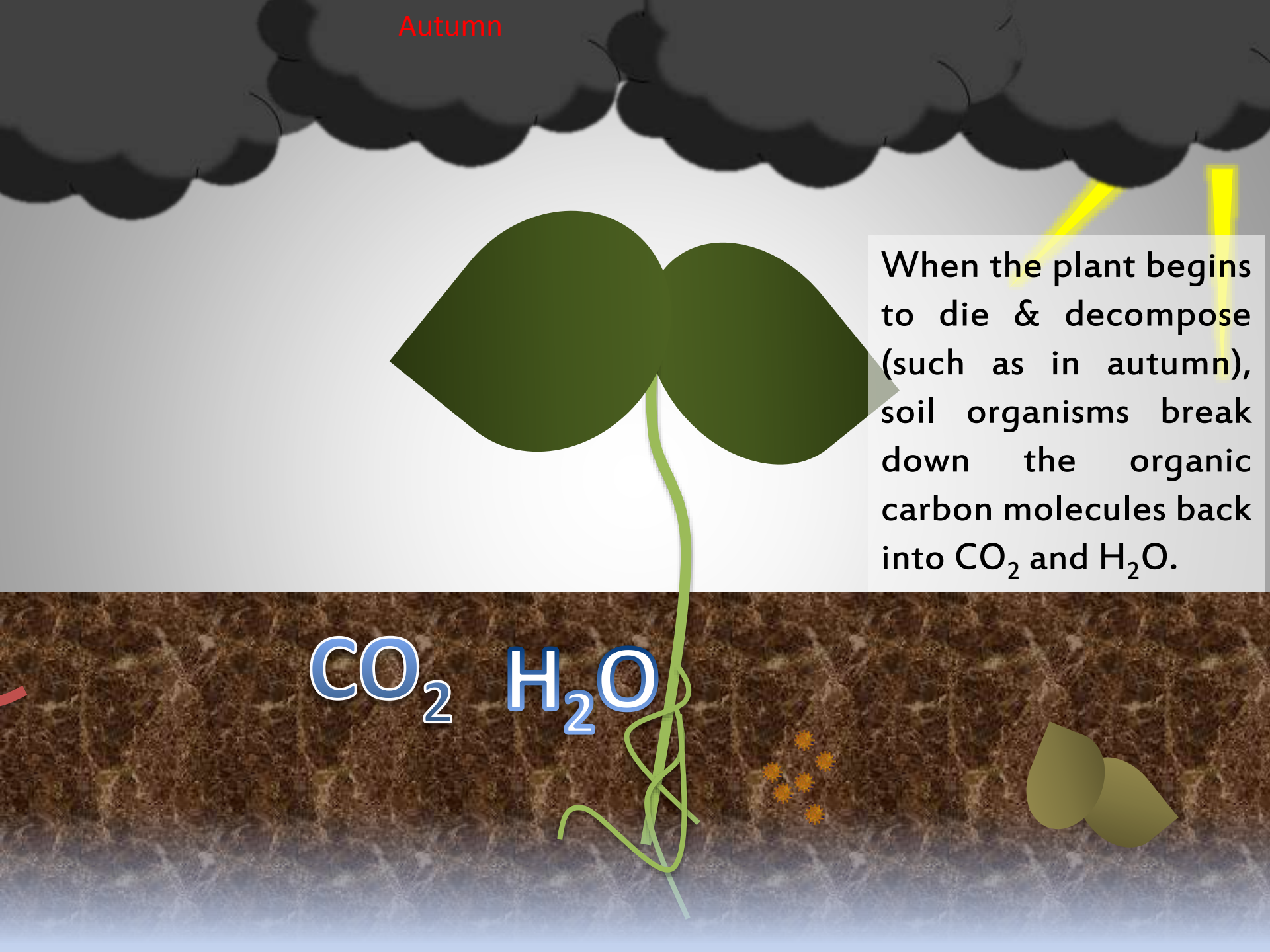
Source: www.sheppardsoftware.com

During photosynthesis, plants assemble organic versions of carbon molecules (including simple sugars, starch, and cellulose) using carbon dioxide (CO_2) and water (H_2O).



This process of assembling organic molecules of carbon is powered by the sun.

Autumn



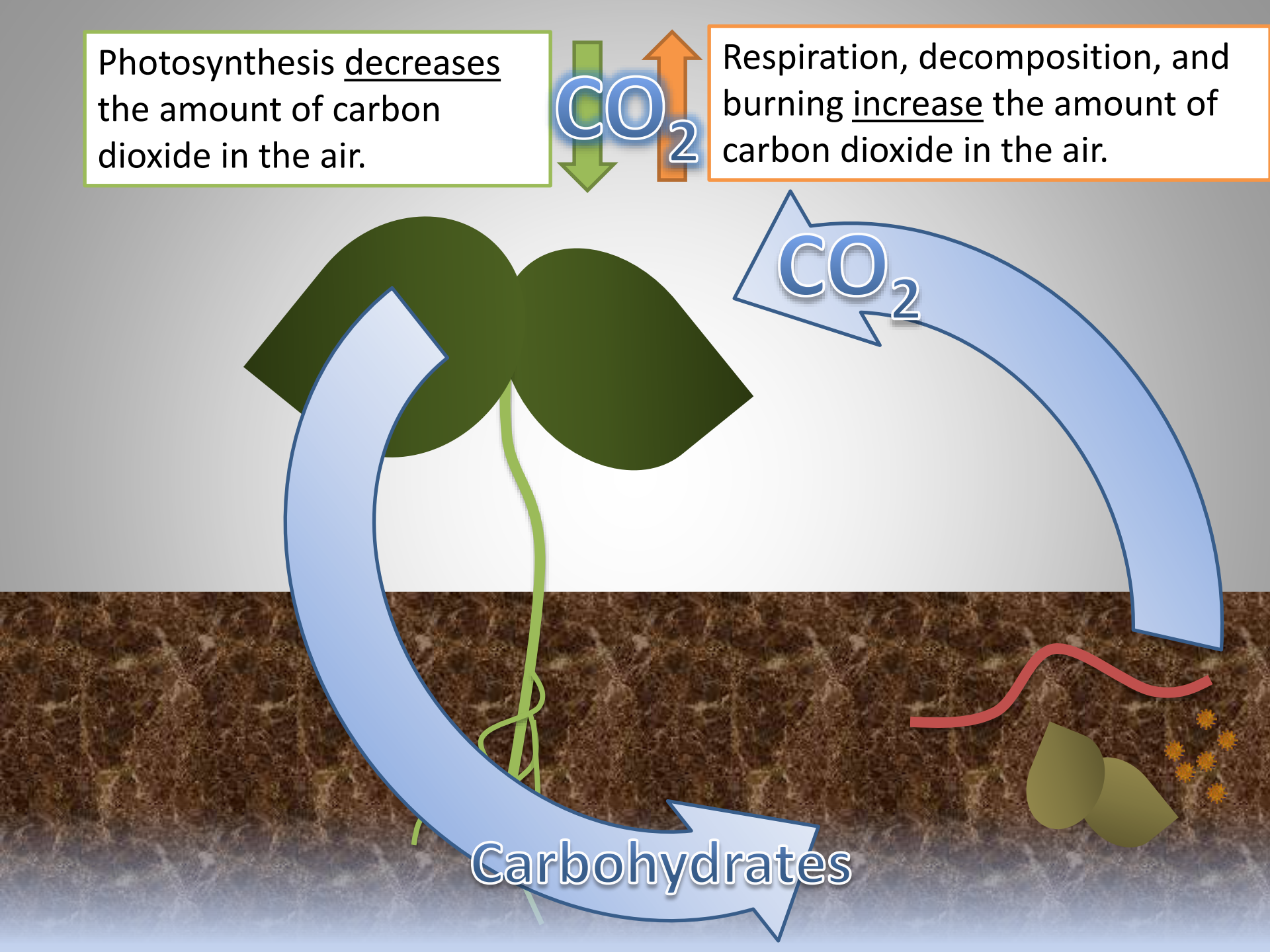
When the plant begins to die & decompose (such as in autumn), soil organisms break down the organic carbon molecules back into CO_2 and H_2O.

CO_2 H_2O

Carbon Cycle Balance

- **In order to function properly, the carbon cycle must be balanced.**
  - We cannot change the amount of carbon atoms that exist; we can only change the amount of the kinds of molecules in which carbon atoms are found.

- **For example, we can change the amount of carbon dioxide in the air by increasing or decreasing the amount of respiration and decomposition that occurs.**
  - However, we cannot change the amount of carbon atoms.
  - For living organisms to function properly, the amount of carbon dioxide released into the atmosphere by plants, animals, and decomposers should roughly equal the amount of carbon dioxide absorbed by plants.


Photosynthesis decreases the amount of carbon dioxide in the air.
CO_2
Respiration, decomposition, and burning increase the amount of carbon dioxide in the air.
CO_2
Carbohydrates

CO2 is Active

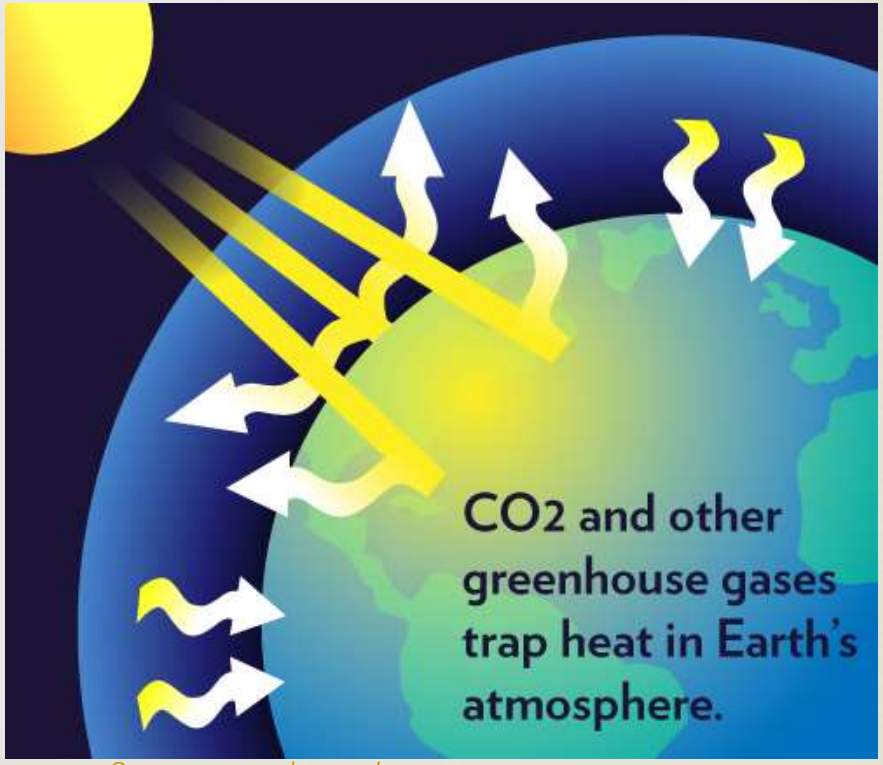
- **Carbon dioxide is a chemically- and biologically-active molecule.**
  - If you change the amount of carbon dioxide, you will also have an impact on the kinds of reactions that involve carbon dioxide.
  - If too much carbon dioxide was absorbed by plants, there would not be enough carbon dioxide to enable plants to produce glucose and other carbohydrates.
  - If too much carbon dioxide is released into the atmosphere by plants, animals, and decomposers, then the chemistry of the atmosphere begins to change.

Source: www.icr.org

Double-bond Energy

- **Carbon dioxide has double bonds that can hold lots of energy.**
  - For this reason, carbon dioxide has an 'insulating' effect on the atmosphere.
  - The more carbon dioxide in the atmosphere, the more energy that the atmosphere can hold.
  - This means that air with more carbon dioxide will cool off less quickly than air with less carbon dioxide.

- **Carbon dioxide is sort of like a blanket.**
  - Just like a blanket slows the loss of heat from your body (keeping you warmer on a cool day), carbon dioxide slows the loss of heat from the surface of the earth into space.



Source: www.wunderground.com

When it rains, it pours.

- **Because air with more carbon dioxide can hold more energy, this also means that the air can hold onto more moisture for longer periods of time.**
  - The increased ability of the atmosphere to hold onto moisture means that weather patterns will change as the amount of carbon dioxide changes.
  - An atmosphere with more carbon dioxide results in less days in which it rains (because the atmosphere has more energy to hold onto that moisture).
  - An atmosphere with more carbon dioxide also means that when it does rain, the risk of flooding is greater because the atmosphere can hold greater amounts of moisture.
  - Increasing the amount of carbon dioxide in the air means that it rains less often but when it does rain, it pours.

Ag & Carbon Cycles

- **Agriculture is dependent on a regulated carbon cycle.**
  - The production of food is really about maximizing the efficiency of the carbon cycle's ability to convert carbon dioxide into usable forms of carbohydrates.
  - Human beings depend on the carbon cycle for both the source of carbon-based molecules necessary for life as well as for the carbohydrates that provide the source of chemical energy.
  - Like all animals, human beings both depend on plants to convert the light energy of the sun into the chemical energy all living things need to survive, and to convert the unusable carbon dioxide in the air into the usable organic carbon molecules in our food.

Ag – Max Carbon Cycling

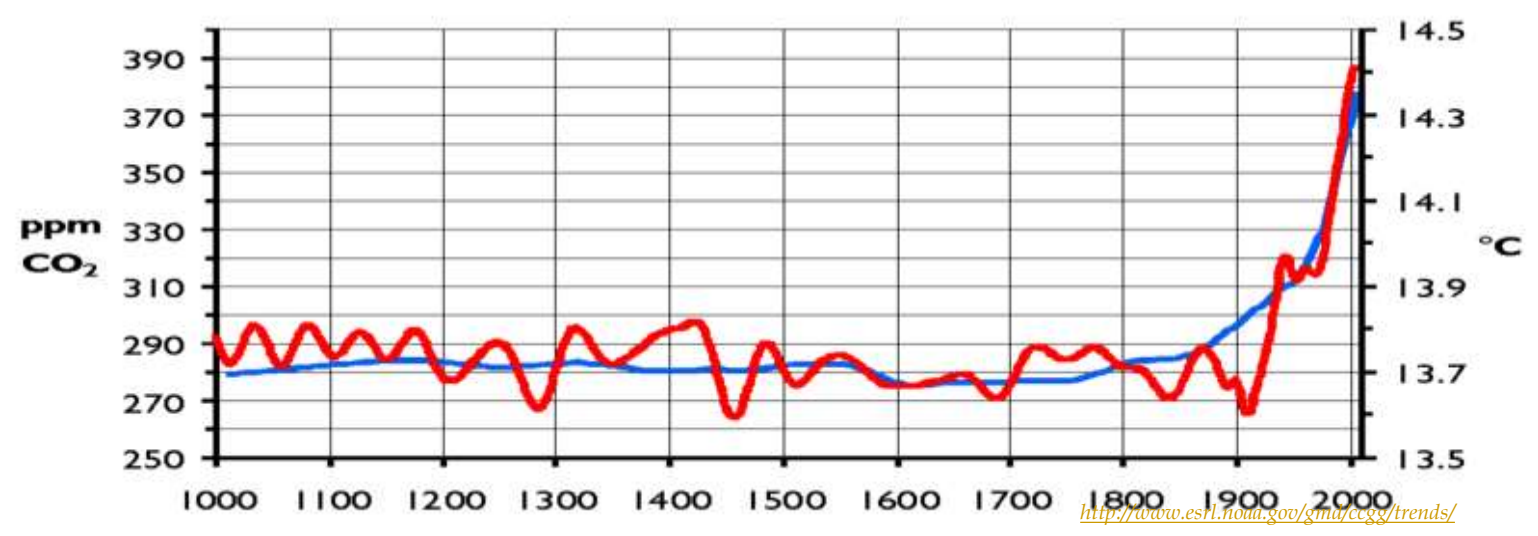
- **Agriculturalists use genetics to maximize the ability of domesticated plants to provide a concentrated source of carbohydrates.**
  - Agriculturalists plant the crops that they do because these species have been changed through generations of breeding to make carbohydrates that humans can use more effectively than other species of plants.
- **For example, wild strawberries have more leaves and stems and less berries.**
  - Domesticated strawberries have much larger berries, providing more of the digestible carbohydrates and less of the carbohydrates we cannot eat.

Ag depends on predictions.

- **Humans can either consume carbohydrates from crops directly (such as when we have corn or potatoes), or we can feed these domesticated plants to domesticated animals.**
  - Regardless of if a farmer grows crops or animals, without the carbon cycle there is no way agriculturalists could produce food.
- **Agriculturalists depend on predictable weather patterns created by a balanced carbon cycle.**
  - For example, most people know that spring has more frequent rain than summer.
- **If the spring is too dry, the seeds planted by farmers will not be able to germinate and grow into mature plants.**
  - If the summer is too dry, the crops will not reach maturity or may even wilt and die.
- **If the spring is too wet, farmers won't be able to plant their crops or those crops might rot in the soil if they are planted.**
  - If a summer is too wet, the crops will likely not have the conditions they need to mature or may even die from flooded soil.

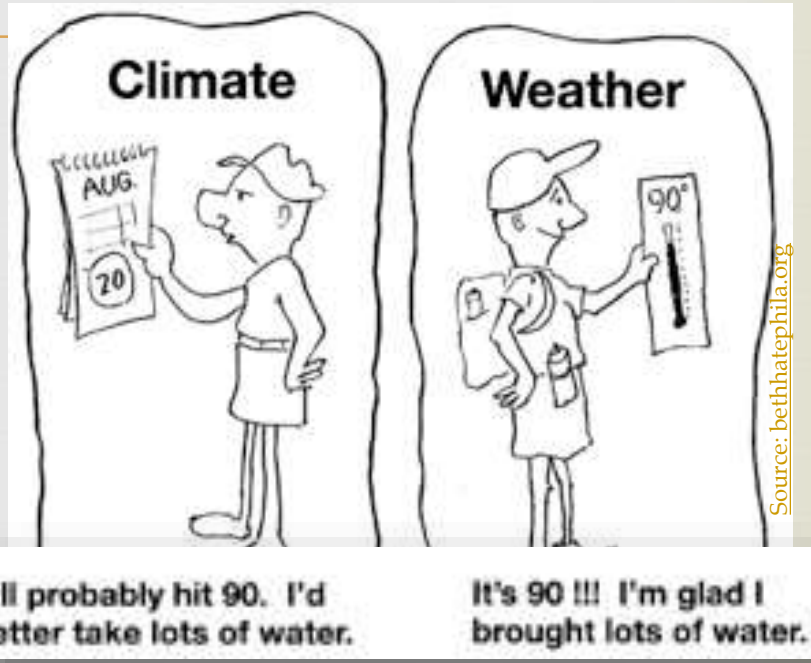
Carbon cycle imbalance.

- **Currently the carbon cycle is not balanced – more carbon dioxide is released than is absorbed.**
  - The amount of carbon dioxide released because of respiration, decomposition, and burning is greater than the carbon dioxide absorbed through photosynthesis.
  - Because of this imbalance, the amount of carbon dioxide in the atmosphere increases continuously.
  - For the first time in modern history, the amount of atmospheric carbon dioxide has exceeded 400 ppm (parts per million).



A changing climate.

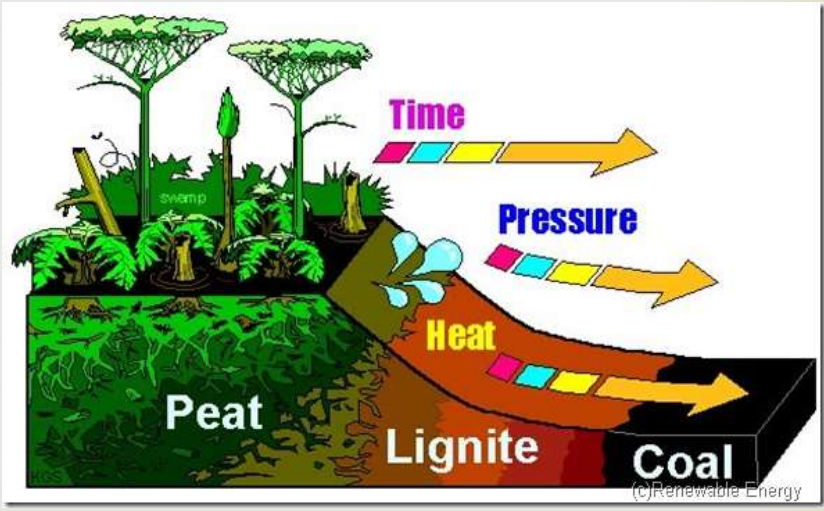
- **Because of the excess of carbon dioxide in the atmosphere, the once-predictable climate of the earth is beginning to change.**
  - Climate refers to long-term weather patterns.
  - While weather changes from day to day, climate normally changes over the course of tens of thousands of years.



- **The climate today has measurable changes occurring over the course of decades.**
  - This is hundreds of times faster than the normal rate of change.
  - Because geological and biological data show that this fast of a rate of change has not occurred at any other point in tens of millions of years, climate scientists are nearly unanimously-certain that these changes are because of human activity.

Fossil Fuels

- **Most evidence suggests that the extra carbon dioxide in the atmosphere is due to the use of fossil fuels.**
  - Fossil fuels, such as oil and coal, were formed millions of years ago.
  - Instead of decomposing, some organisms were quickly buried and oxygen was unavailable for decomposers to break down their bodies.
  - Heat and pressure 'squeezed out' everything except for carbon and hydrogen atoms from their bodies, which created the fossil fuels we have today.



Source: solarpowerwindenergy.org

An uncertain future.

- **Burning fossil fuels quickly releases large amounts of carbon dioxide into the air.**
  - Like respiration and decomposition, burning a fossil fuel causes the release of water and carbon dioxide.
  - Unlike respiration and decomposition (where plants can absorb the same amount of carbon dioxide that was released), the burning of fossil fuels creates an excess amount of carbon dioxide in the atmosphere.

- **Changes to the climate will make agriculture much more difficult.**
  - Agriculturalists depend on predictable seasons with predictable temperatures and precipitation.
  - Because scientists predict a greater frequency in droughts and flooding (as well as extreme temperatures), many are concerned about the ability of agriculturalists to produce food at the same rate that they are today.