BIOGEOCHEMICAL CYCLES

QUICK REVIEW OF MATTER:

- Atoms are the basic building blocks of matter
- Atoms bond together to form chemical bonds (covalent and ionic)
- These chemical bonds are a way to store energy for living things

OBJECTIVES FOR THIS LECTURE

- By the end of this week's lecture, you should be able to:
  - Understand what makes a molecule "organic" and why organic compounds/molecules are important
  - Understand what "fixation" is and why it's important
  - Understand photosynthesis and why it's important
  - Understand cellular respiration
  - Understand and be able to describe the carbon cycle, nitrogen cycle, and phosphorous cycle

ORGANIC COMPOUNDS & FIXATION

ORGANIC COMPOUNDS

- All living things, or once living things, (organisms) are made up of *organic compounds*.
- Organic compounds are made up mainly of carbon bonded to hydrogen atoms, and there are bits of other things, but the key is the carbon and hydrogen.
- The carbon-hydrogen (C-H) bonds in organic compounds contain energy that living things use.

WHAT YOU NEED TO KNOW ABOUT ORGANIC COMPOUNDS

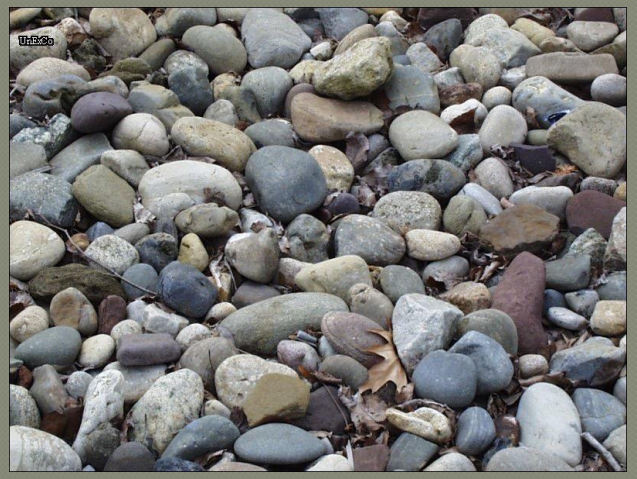
1. Organic molecules/compounds are needed by all living things and are contained in all living and once living things

2. A molecule or compound is organic if it contains C-H bonds

ORGANIC vs. INORGANIC

The key to something being organic is that it must contain C-H bonds. If it doesn't have C-H bonds, it's not organic!

C-H



C-H

BIOTIC vs. ABIOTIC

- Just because something is dead, does not mean that it is no longer organic.

- The organic molecules in that leaf still exist and still contain C-H bonds even though it is no longer alive.

- What type of adaptation?
- How did this adaptation come about?

ORGANISMS NEED ORGANIC COMPOUNDS

- A living being must take in organic compounds in order to obtain nutrition & energy for cellular processes.

- Side note: the term *organic* in this lecture does not mean the same thing as the organic you see in the grocery store.

NCHOPS – THE MAIN INGREDIENTS

- Living organisms nitrogen, carbon, hydrogen, oxygen, phosphorous, and sulfur or NCHOPS – these are the main "ingredients" for life




- Living organisms have different minor "ingredients" to make them unique, but still have all the main (NCHOPS) elements.

HOW DO WE GET ORGANIC COMPOUNDS?

The inorganic forms of these elements must undergo a process called “fixation”

FIXATION

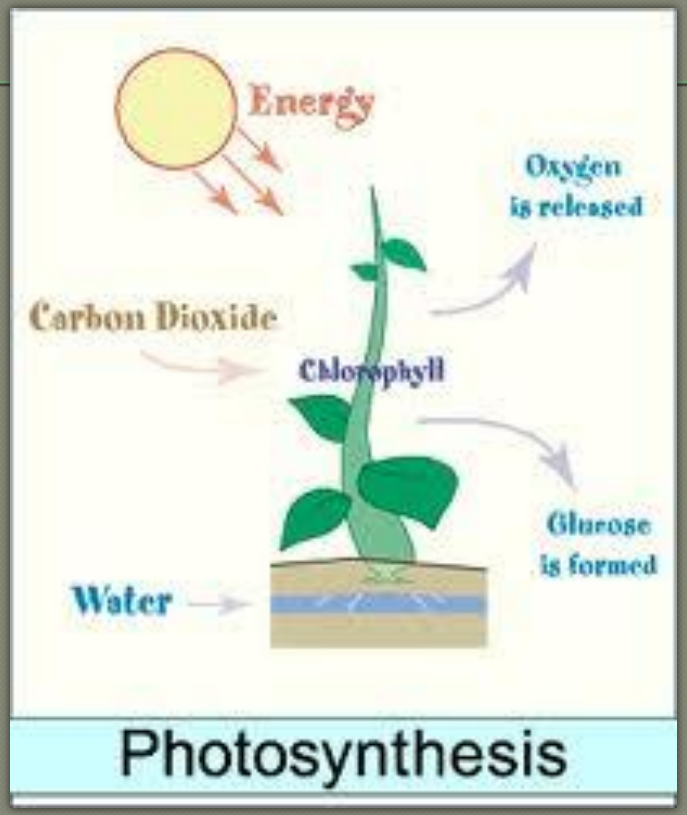
- Fixation is the process that changes or transitions the inorganic forms of nutrients/elements into organic forms of these nutrients

- Fixation takes the atoms and **fixes** them into a molecule that is now useful to organisms

PHOTOSYNTHESIS, CELLULAR RESPIRATION, AND THE CARBON CYCLE

PHOTOSYNTHESIS

- Photosynthesis is the process that green plants (those containing chlorophyll) undergo when they take CO_2 and water and use sunlight (for energy) to convert these to sugar and oxygen.



-**PHOTO** means light, UV light.

- SYNTHESIS means combining components to make new components.

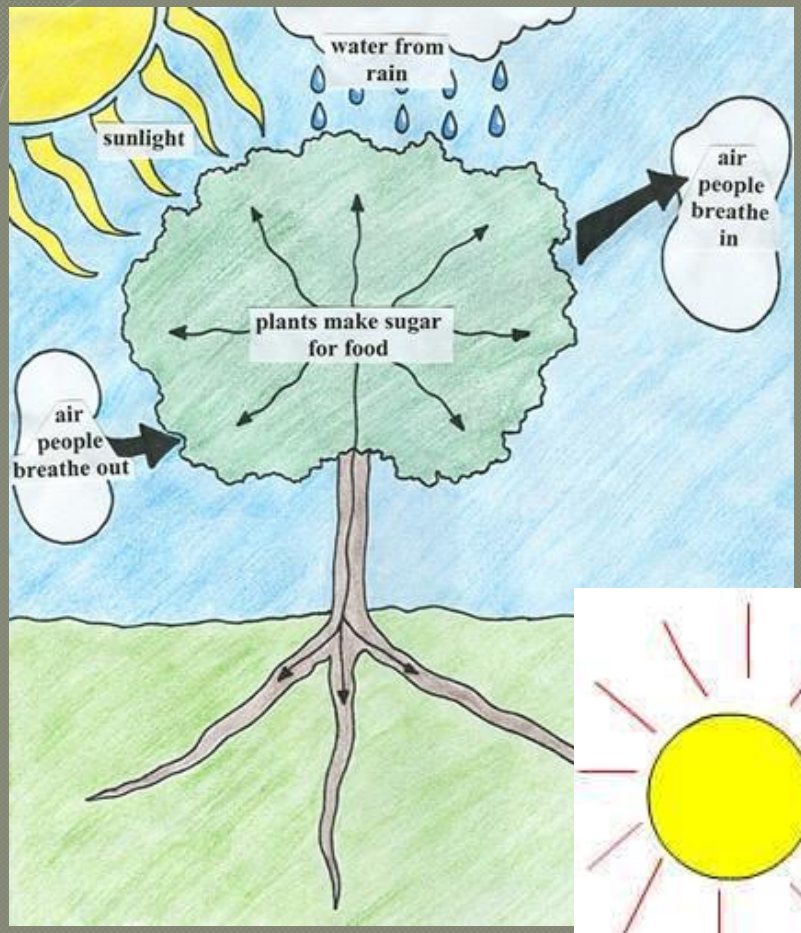
THE BASE OF ALL LIFE

- Almost all organisms on earth depend on the process of photosynthesis.
- The type of sugar that is produced in photosynthesis is glucose.
- Glucose is an energy-rich sugar that is the primary fuel for cells – it is used to make other organic compounds.
- We also get atmospheric oxygen from the process of photosynthesis.

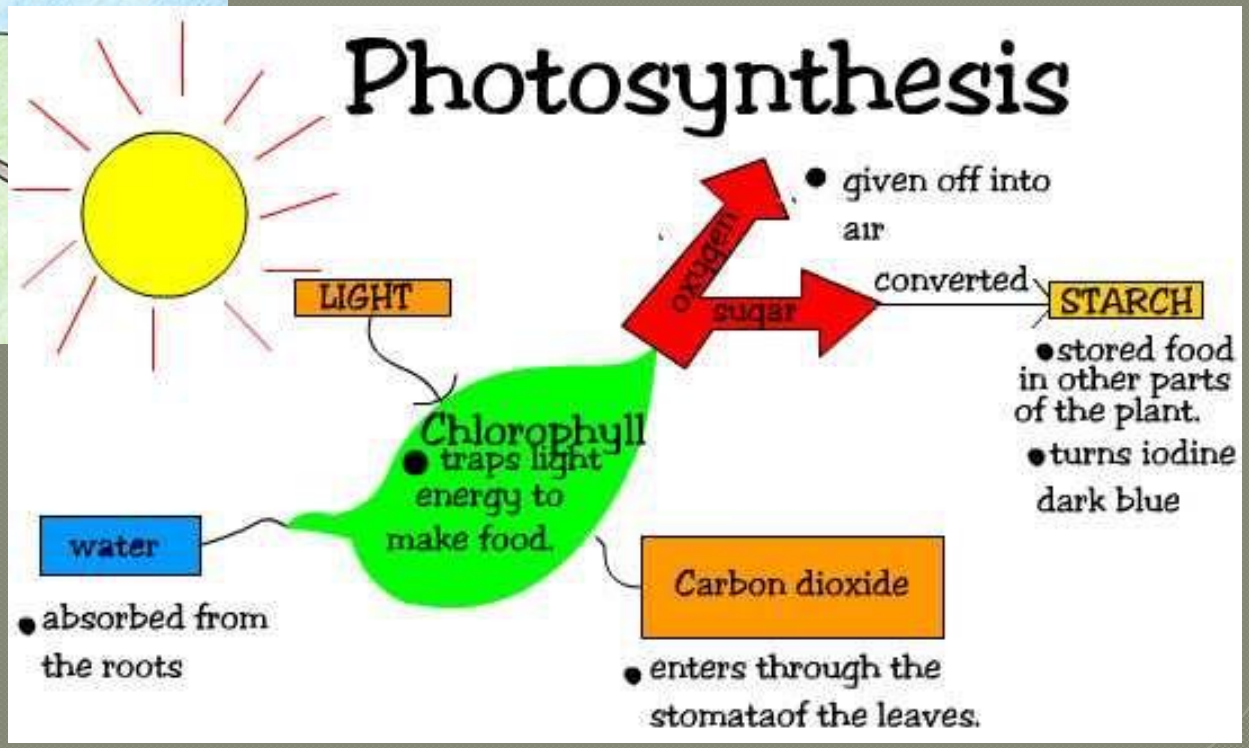
CHEMICAL EQUATION FOR PHOTOSYNTHESIS

- The arrow represents chlorophyll. Chlorophyll is a molecule that green plants have which allows them to use energy from the sun to power the reaction.

- Exactly the same number of atoms of each element must be on both sides of the equation. Remember, matter cannot be destroyed. It can only be transformed, recycled, and converted into different forms



2 ways of looking at photosynthesis



AUTOTROPHS

- Green plants use photosynthesis to fix, or store, the sun's energy into glucose so that energy can be used by the plant to grow and reproduce

- Green plants can make their own food - this is called an autotroph (self-feeder)

CELLULAR RESPIRATION

- Cellular respiration is the opposite of photosynthesis.
- Organisms take in food (glucose) and oxygen and through the process of respiration, break up the C-H bonds in the glucose to obtain energy
- The by-products of respiration are water and CO_2 (which is what is exhaled)

CHEMICAL EQUATION FOR CELLULAR RESPIRATION

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

- The chemical equation for cellular respiration is the opposite of the photosynthesis equation
- The difference between the two is that in photosynthesis, energy is captured - in cellular respiration, energy is released
- So together, the two processes form a balanced cycle/system

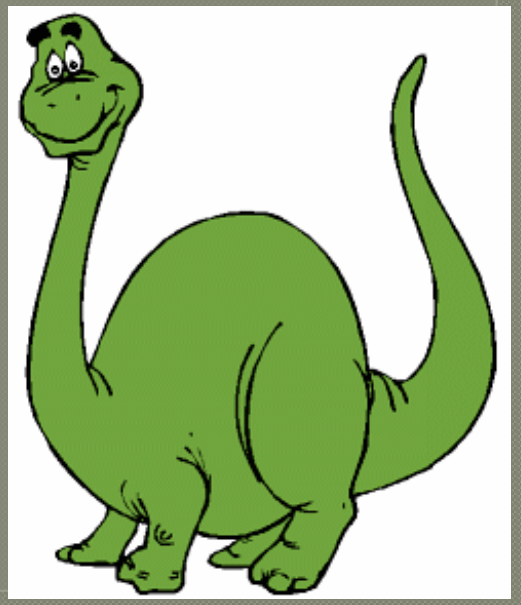
THE LAW OF CONSERVATION OF MATTER & BIOGEOCHEMICAL CYCLES

LAW OF CONSERVATION OF MATTER

- Matter cannot be created or destroyed, it can only be transformed.

- This means we can't just make more carbon atoms because we need them, or nitrogen atoms, etc. Thus, these atoms must be pulled from already existing sources of carbon, nitrogen, etc.

- This means that every carbon atom, nitrogen atom, etc. that makes you up has always been here on earth and has been part of other things previously – like dinosaurs! Part of you could have been part of a dinosaur



WHAT DOES IT MEAN?

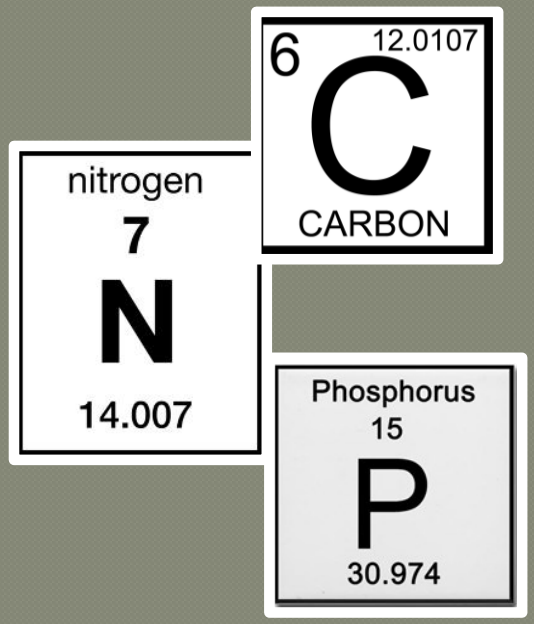
For essential elements – NCHOPS – there is a cycle constantly taking place.

These cycles are called biogeochemical cycles

BIOGEOCHEMICAL CYCLES

- The 4 main cycles we will be looking at are:

1. Carbon Cycle
2. Nitrogen Cycle
3. Phosphorus Cycle



4. Water Cycle (we will look at this one later)

THE CARBON CYCLE

CARBON CYCLE PARTS

- The carbon cycle is made up of two basic things:

1. Photosynthesis – when inorganic carbon is taken up by plants and fixed into organic carbon and

2. Cellular respiration – when organic carbon is used by living organisms and inorganic carbon in the form of CO2 is given off into the atmosphere

THE CARBON CYCLE IN DEPTH

1. It begins when the inorganic carbon atoms in atmospheric CO_2 are taken up by green plants and **FIXED** via photosynthesis into glucose

2. The glucose molecule in the plant contains organic carbon atoms (usable to organisms)

3. The organic carbon then enters the food web, when an organism, such as a caterpillar, comes along and eats the plant/glucose/organic carbon

CARBON CYCLE continued

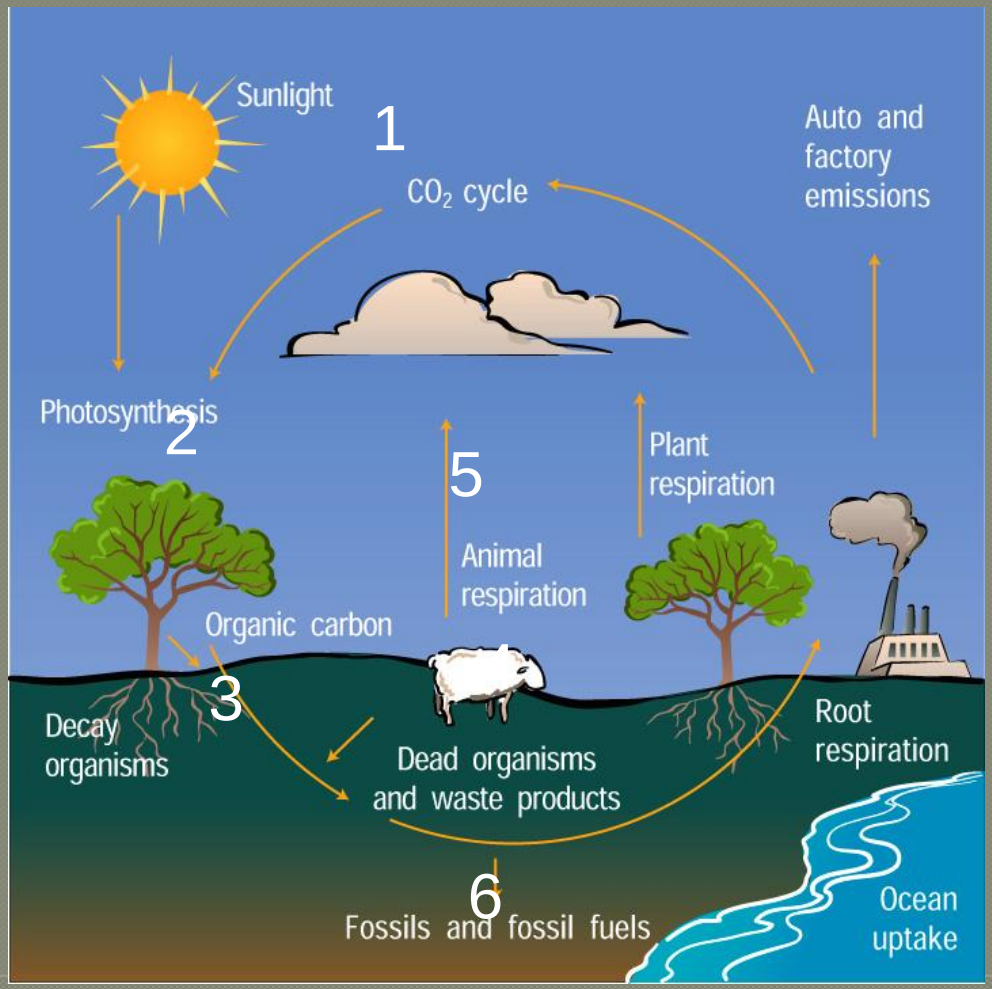
4. The organic carbon is used by the caterpillar in one of two ways

    1. Some of the carbon is used for cellular respiration and exhaled back into the atmosphere in the form of CO_2 (inorganic carbon)
    2. And some of the carbon stays in the caterpillar and is either passed into the environment as waste or when the caterpillar dies
        - This organic carbon (dead organisms and waste matter) decomposes and is eventually turned into fossil fuel, or is taken back up by plants

5. And the cycle is complete

CARBON CYCLE DIAGRAM

- Photosynthesis and Respiration are complimentary processes that primarily comprise the carbon cycle.



1. CO2 in the atmosphere
2. Carbon fixed by plants via photosynthesis
3. Carbon then used by plants or used by animals that eat plants
4. Carbon passed from one animal to the next in a food chain (or food web)
5. Carbon released by animals as inorganic CO2 via cellular respiration to begin cycle again
6. Or, carbon released into soil thru decomposition as organic carbon to be used by plants again.

HUMAN ACTIVITIES ALTER THE CARBON CYCLE

- Fossil fuels release more CO_2 than can be naturally absorbed and processed by plants.
- Cutting trees reduces the natural cycle's ability to absorb CO_2.
- Cutting trees also reduces nature's ability to produce O_2. This impacts our air supply.
- Carbon dioxide is a greenhouse gas (a gas that traps heat in the atmosphere). Additional amounts that we emit trap more heat and make the atmosphere warmer.

THE NITROGEN CYCLE

THE NITROGEN CYCLE

- Nitrogen comprises 78% of our atmosphere and is contained in proteins, DNA, and RNA.

- **Nitrogen Fixation**: The nitrogen atoms in our atmosphere occur as a gas (N_2). This is an inorganic form of nitrogen (unusable to organisms) and it must be converted to an organic state so organisms can use it. In other words, atmospheric nitrogen must be fixed.

- The N_2 molecule is a very stable molecule and must first be broken apart so that the nitrogen atoms can undergo fixation and the rest of the nitrogen cycle.

- There are 3 ways to fix Nitrogen:
  - Lightning, Legumes and the Haber Process

NITROGEN FIXATION VIA LIGHTNING

- When lightning strikes, it comes into contact with N_2 gas and breaks the N_2 bond.
  - Lightning fixes 750,000 tons of nitrogen per day.
- Then the single nitrogen atoms drift down and fall into the soil where they can enter nitrification (the next step in the nitrogen cycle)

NITROGEN FIXATION VIA LEGUMES:

- There are N-fixing bacteria that live in nodules on the roots of legumes (plants with seeds in pods - acacia, mesquite, peas, beans, lentils)

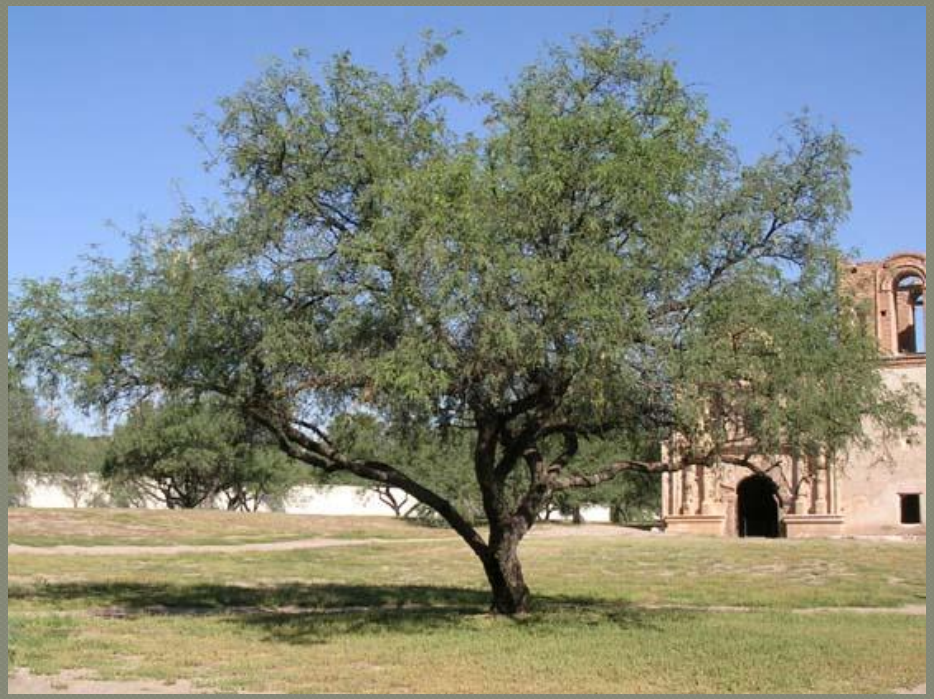
- These bacteria are able to break apart the very stable N_2 bond and the single nitrogen atoms can then enter into nitrification (the next step in the nitrogen cycle)

Nodules of N-fixing bacteria

LEGUMES IN THE COACHELLA VALLEY

Leguminous plants native to the Coachella Valley fix N_2 and help put needed nitrogen into the desert soil.

Palo Verde tree in bloom. Has green bark and tiny leaves.



Mesquite trees

STEPS OF THE NITROGEN CYCLE

1. **Break Apart N_2:** The first step is breaking apart atmospheric nitrogen (N_2) by either by lightning or by N-fixing bacteria on the roots of legumes.

2. **Nitrification:** In the soil, the individual nitrogen atoms undergo a complex series of chemical changes where they become parts of different molecules. This process is called nitrification. Many different bacteria in the soil are responsible for these chemical reactions. Nitrogen atoms are converted into ammonium ions (NH_4), then they are converted into nitrite ions (NO_2-), and then into nitrate ions (NO_3-).'

3. **Assimilation:** Now nitrogen is ready to be taken up by plants. Plants absorb the nitrate ions and convert the nitrogen to organic nitrogen by attaching carbon atoms to it. The nitrogen is now fixed and is useful to organisms.

STEPS OF THE NITROGEN CYCLE (continued)

4. **Food Chain/Web**: Organic nitrogen is used by plants, and also passed from plants to consumers through the food chain. Nitrogen is also deposited back into the soil by waste matter and dead organisms and then reused by plants.

5. **Denitrification**: Another type of special bacteria that lives freely in the soil is called, denitrifying bacteria. These bacteria convert unused/excess nitrates in soil back to gaseous nitrogen (N_2) and release it back into the atmosphere.

SUMMARY OF NITROGEN CYCLE

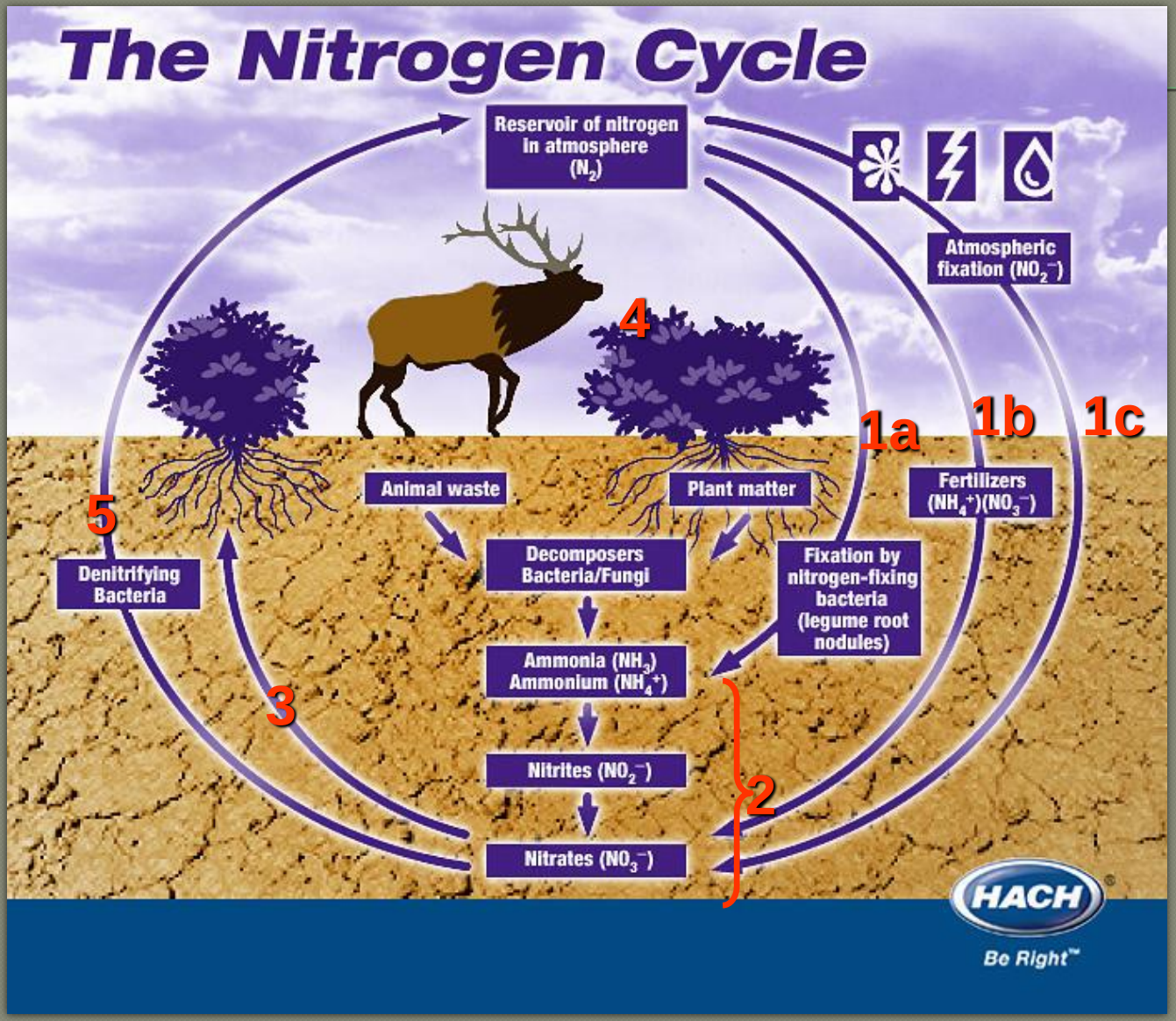
- The process can be summarized as follows:

1. Break apart N_2: by lightning and by N-fixing bacteria on legume roots.
2. Nitrification: nitrogen undergoes a series of changes in the soil facilitated by bacteria.
   - NOTE - you do not need memorize the exact ion steps. <u>You only need to understand that Nitrification includes a series of molecular changes.</u>
3. Assimilation: nitrate ions are taken up by plants and fixed as organic nitrogen.
4. Food Chain: organic nitrogen is passed through organism and deposited back into the soil.
5. Denitrification: excess nitrate molecules in the soil are taken apart by bacteria. N_2 molecules are put together and sent back to the atmosphere.

DIAGRAM OF THE NITROGEN CYCLE

- You will find a detailed diagram of the nitrogen cycle in your text book on p. 41 (5th ed.) or p. 40 (4th ed.).
- Please review this diagram and be sure you understand it. Again, don't worry about the petagram measurements.
- The next slide shows a more simplified version of the nitrogen cycle

DIAGRAM OF THE NITROGEN CYCLE



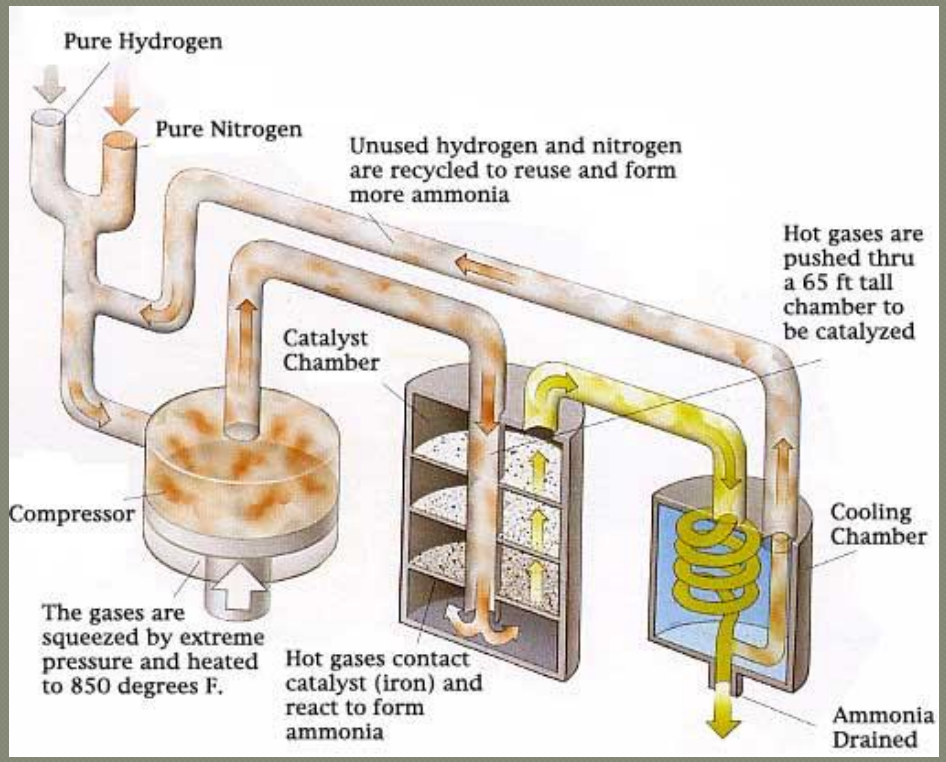
5 Steps

1. Break apart N_2
   a. legumes
   b. lightning
   c. Haber Process
2. Nitrification
3. Assimilation
4. Food Chain
5. Denitrification

THE HABER PROCESS

An industrial process called the Haber Process is used to make fertilizer. This process also breaks apart the N2 molecule.

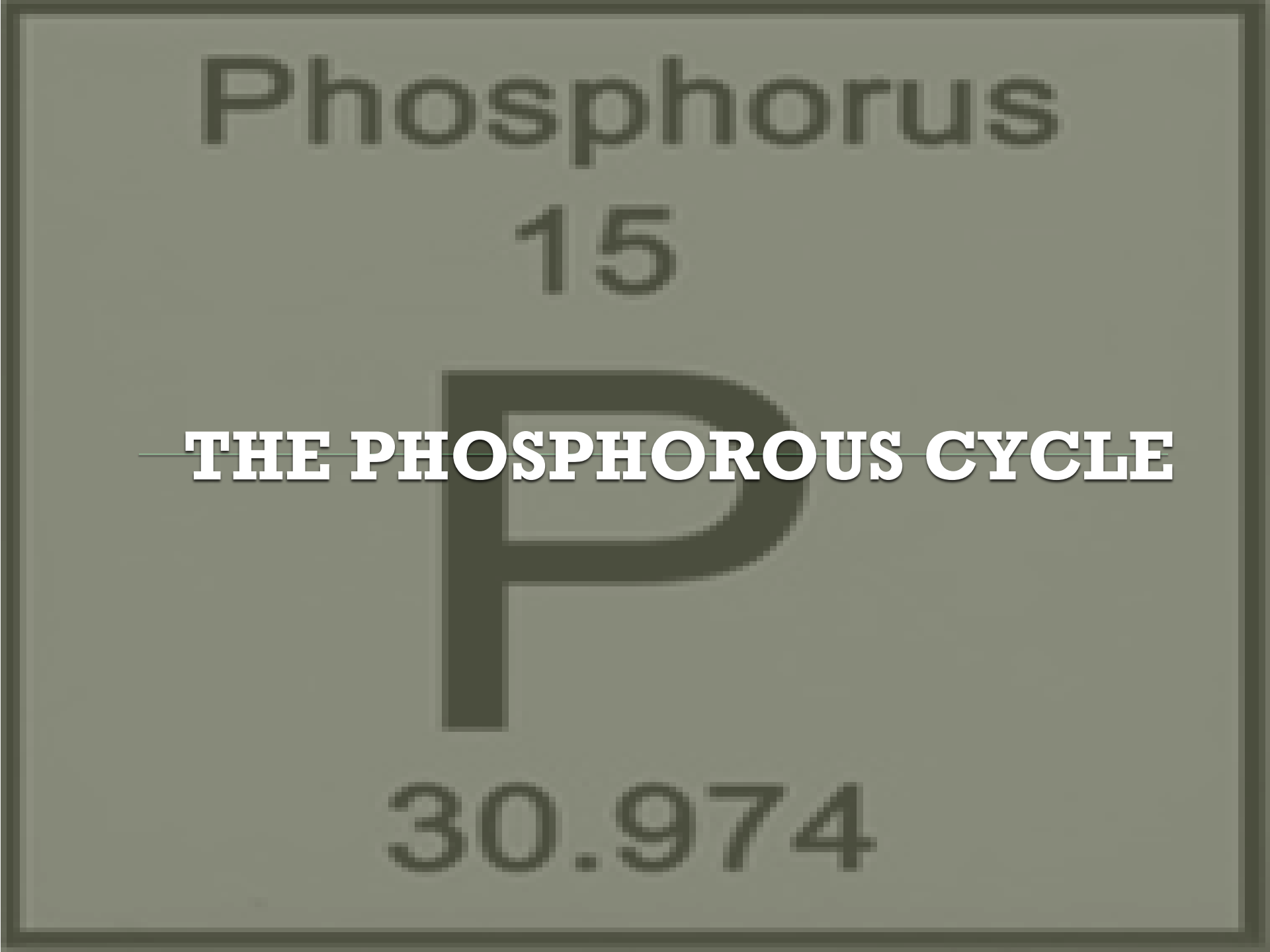
$$N_2 + 3H_2 \longrightarrow 2NH_3$$



HUMAN ACTIVITY AFFECTS THE NITROGEN CYCLE

Nitrogen emissions:

- Burning of fossil fuels leads to nitric acid in the atmosphere which can result in acid rain.
- Burning of fossil fuels leads to increased nitrous oxide, a greenhouse gas.
- Burning of fossil fuels leads to high amounts of other nitrogen oxides which can act like fertilizer and promote the growth of non-native plants which in turn choke out native plants.
- Use of synthetic fertilizers leads to excess algae and plant growth in waterways, which chokes out other organisms.



THE PHOSPHOROUS CYCLE

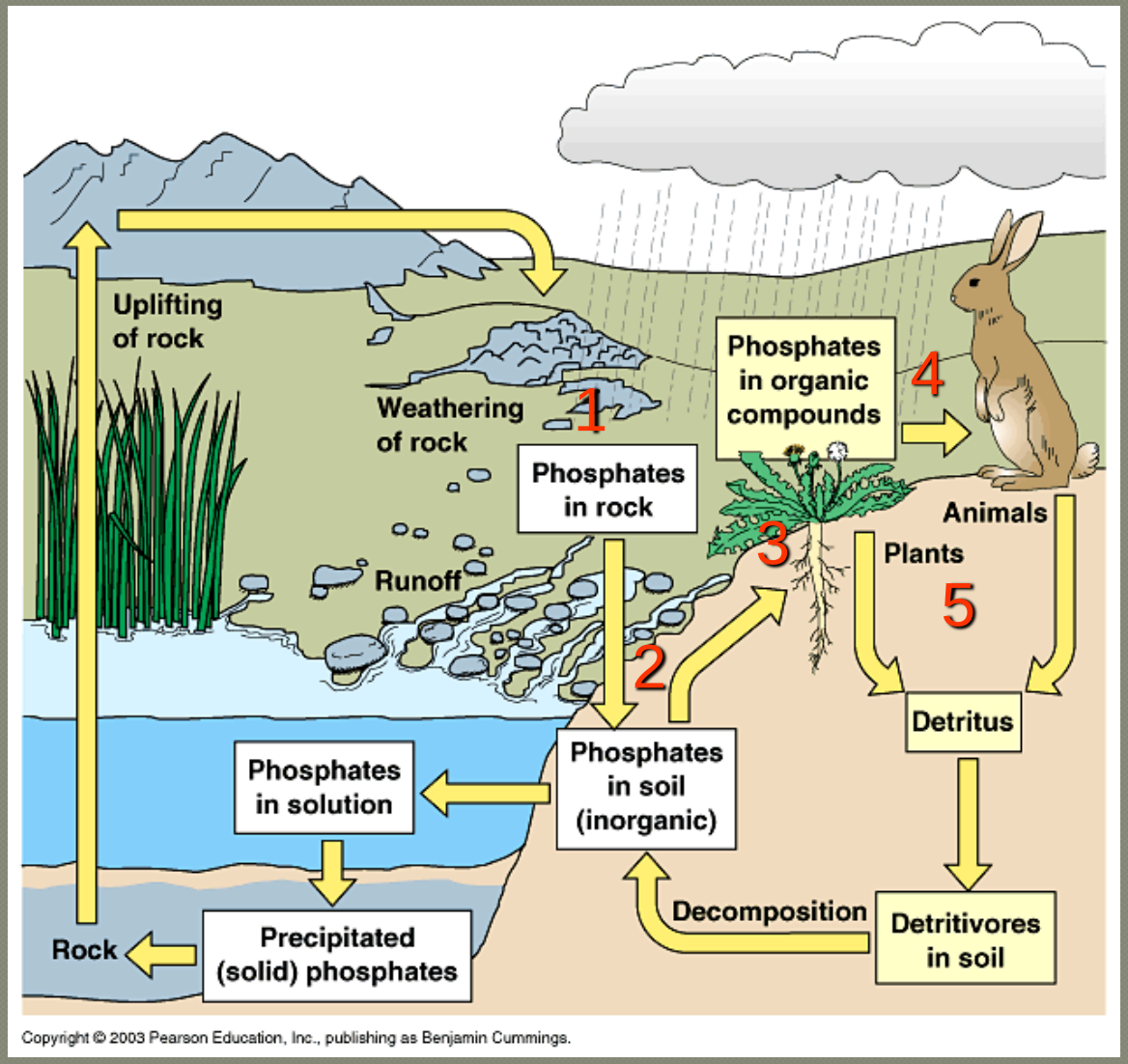
FIXING PHOSPHOROUS

- Phosphorus is a key component of cell membranes, DNA, RNA, and other biochemical compounds.
- So, how do we fix phosphorous so organisms can use it?
- Once again it's plants to the rescue. Green plants fix phosphorous.

THE PHOSPHOROUS CYCLE

1. Phosphorous leaches from the rocks and dissolves in water to form PO_4^{-3}, which goes into the soil and is taken up by plants
2. The plants convert PO_4^{-3} into an organic molecule which can now enter the food web and be used by plants and animals!
3. Organisms eat plants to get phosphorous, and their waste and remains return the phosphorous back to the soil to be recycled once again.
4. And the cycle is complete – this one is easy.

PHOSPHORUS CYCLE DIAGRAM



1. Phosphorus (P) leached from rocks by erosion.
2. P carried by water downhill and absorbed into soil.
3. Plants take in P and convert them to organic forms.
4. P used by plants and animals throughout the food web.
5. P returned to soil by animal waste and decomposition.

HUMAN ACTIVITY AFFECTS PHOSPHOROUS CYCLE

- Use of phosphates in detergents and synthetic fertilizers results in eutrophication, an unnatural growth of algae and plants in water systems.
- The rapid growth blocks out sunlight and chokes other organisms in the water. This is what happens out at the Salton Sea when we have fish kills.
- You can help decrease amount of phosphates entering waterways by buying detergents without phosphates.

The Salton Sea