BIOGEOCHEMICAL and NATURAL CYCLES –

WHAT COMES AROUND, GOES AROUND

By Scientist Cindy of
www.scientistcindy.com

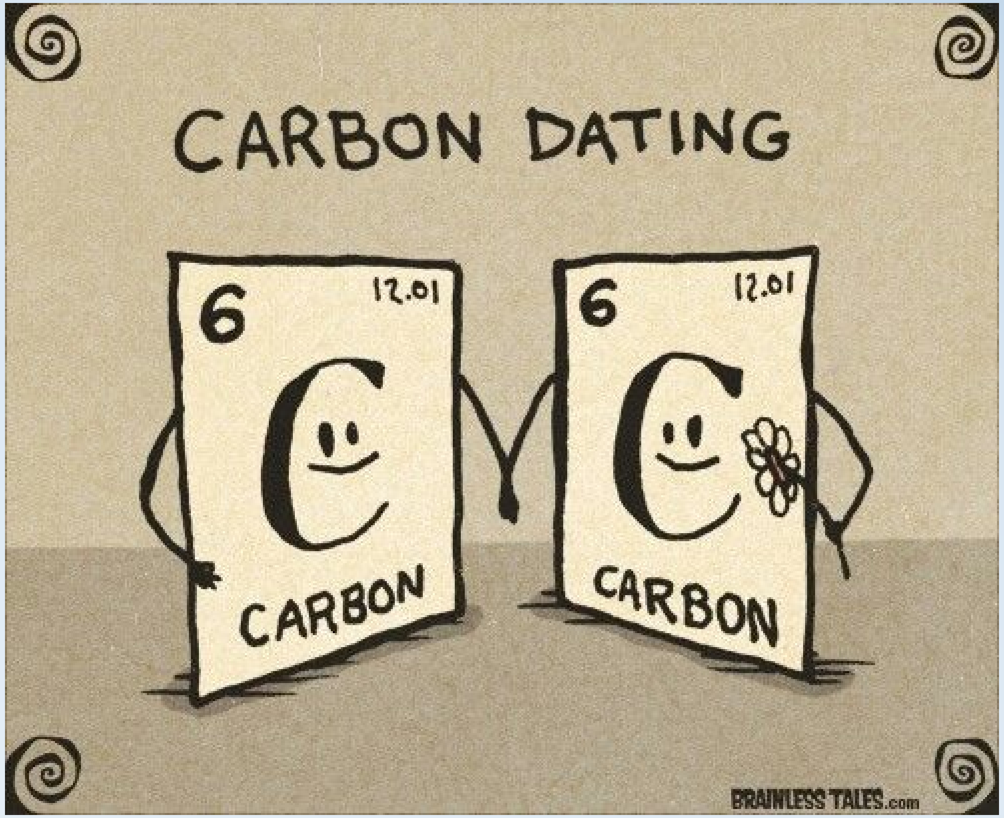
https://smartermoms.wordpress.com/2014/11/20/full-circle-moments/

What is the world is BIOGEOCHEMICAL RECYCLING?

- This simply means - The Cycling of Materials within Ecosystems

YOU SHOULD BE ABLE TO..

- Describe the main steps in each of these biogeochemical cycles:
  - **Carbon cycle**
  - Nitrogen cycle
  - Phosphorus cycle
  - Sulfur cycle
  - Hydrologic cycle (WATER CYCLE)



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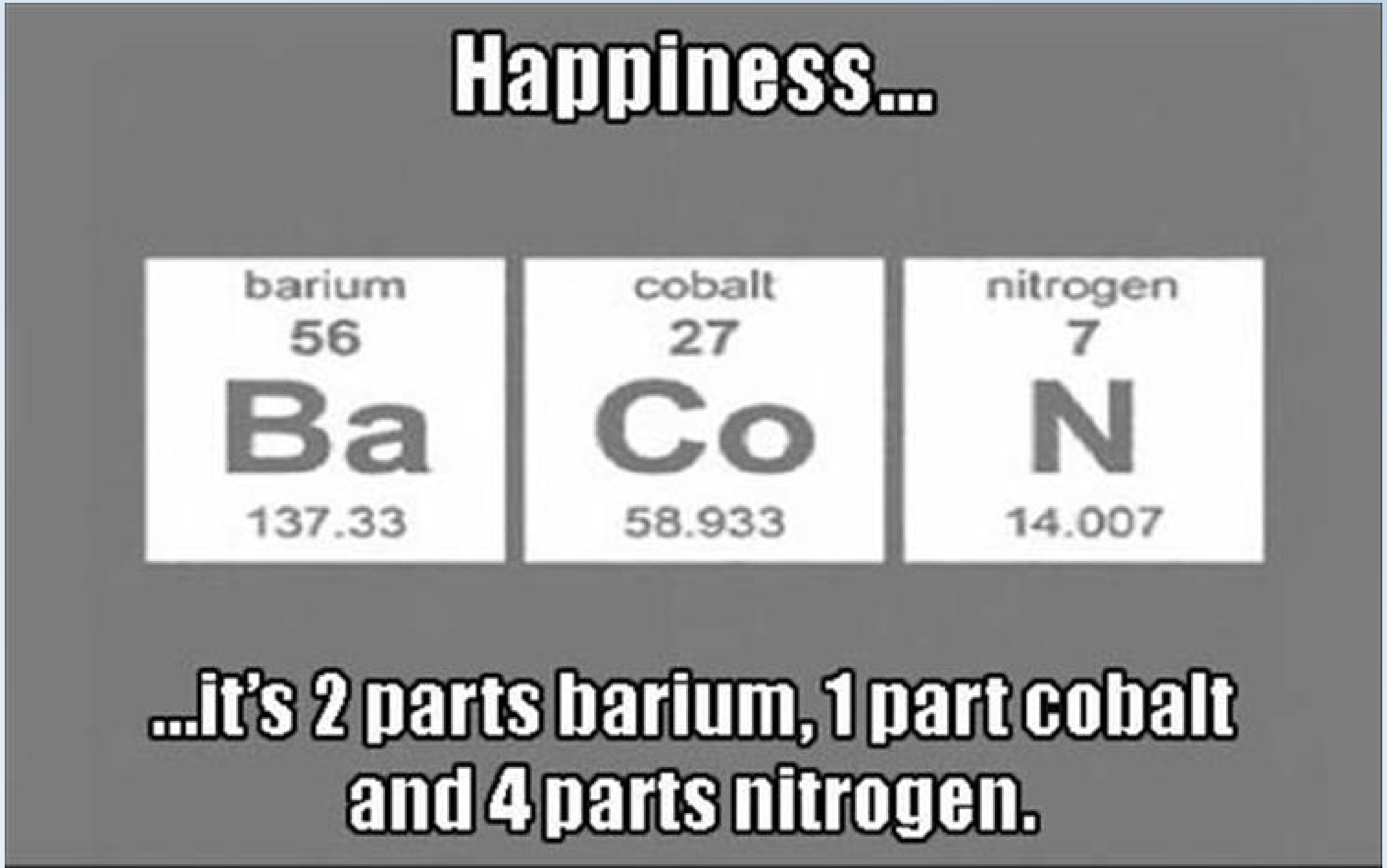

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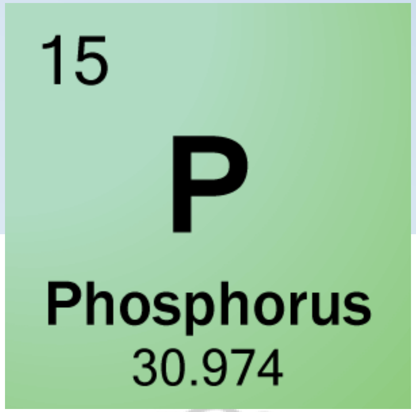

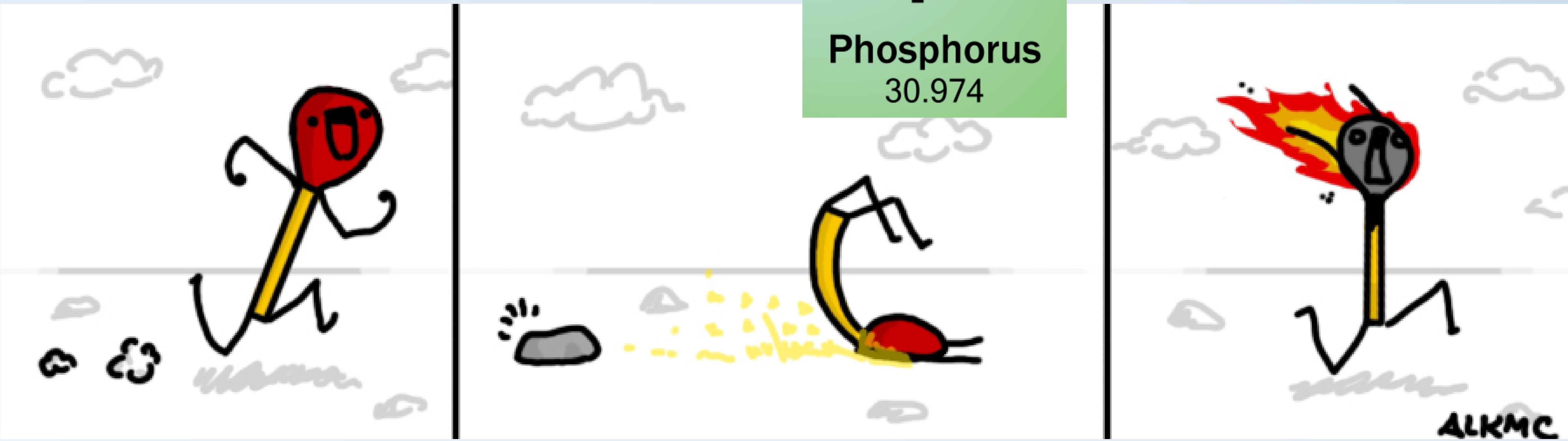

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https://www.youtube.com/watch?v=8Yod31bzmMk

https://www.youtube.com/watch?v=u19QfJWI10Q

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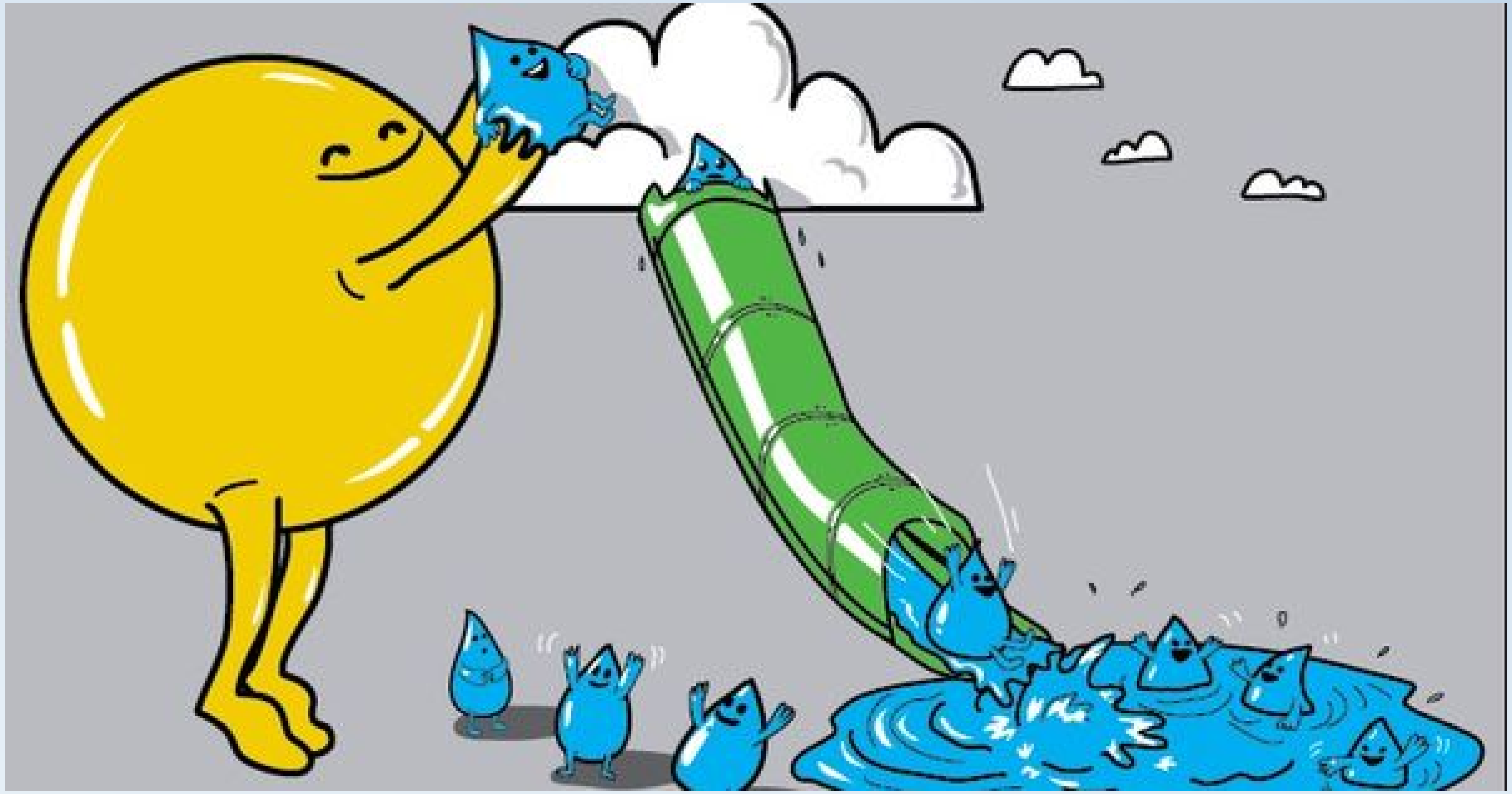
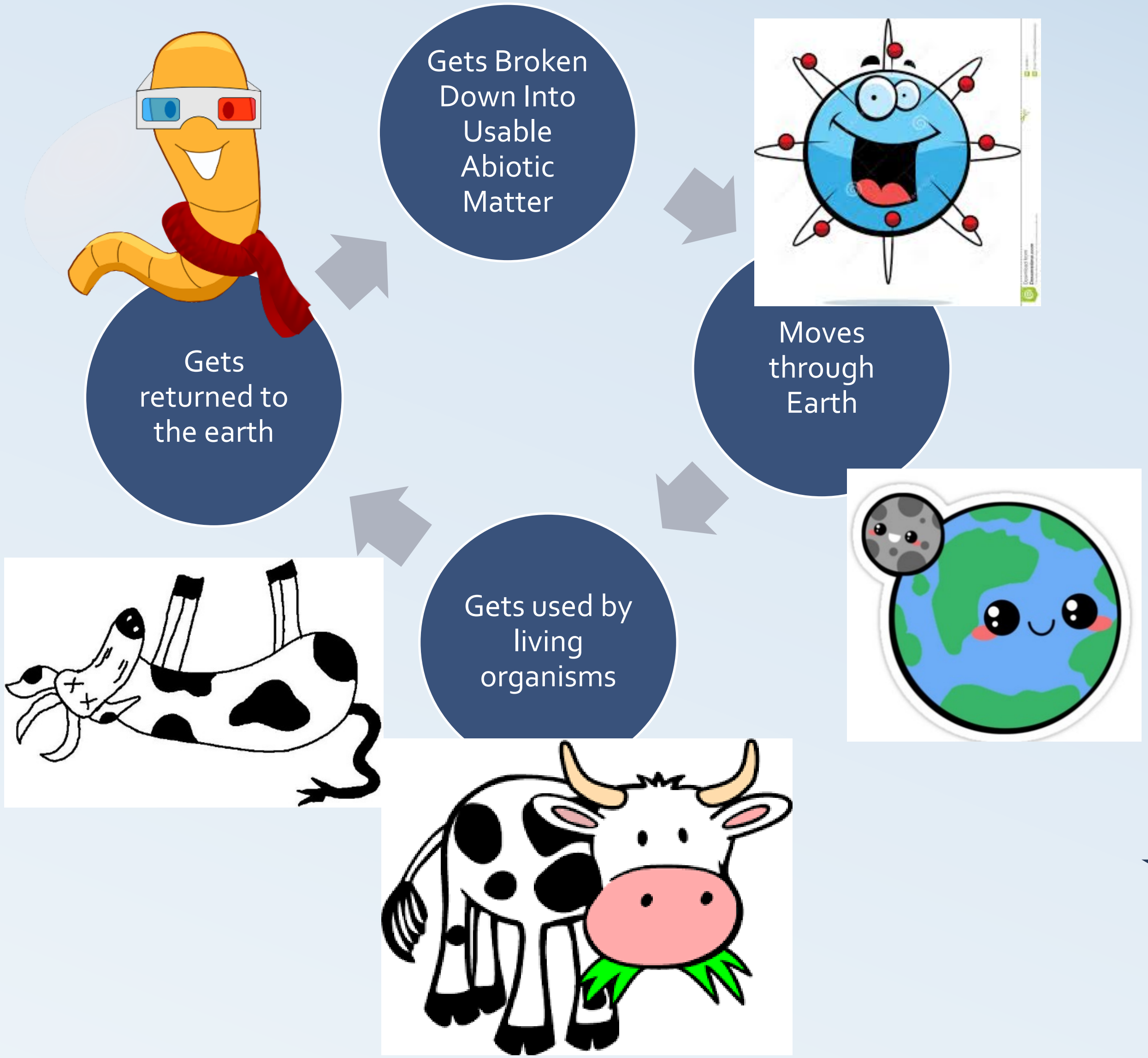


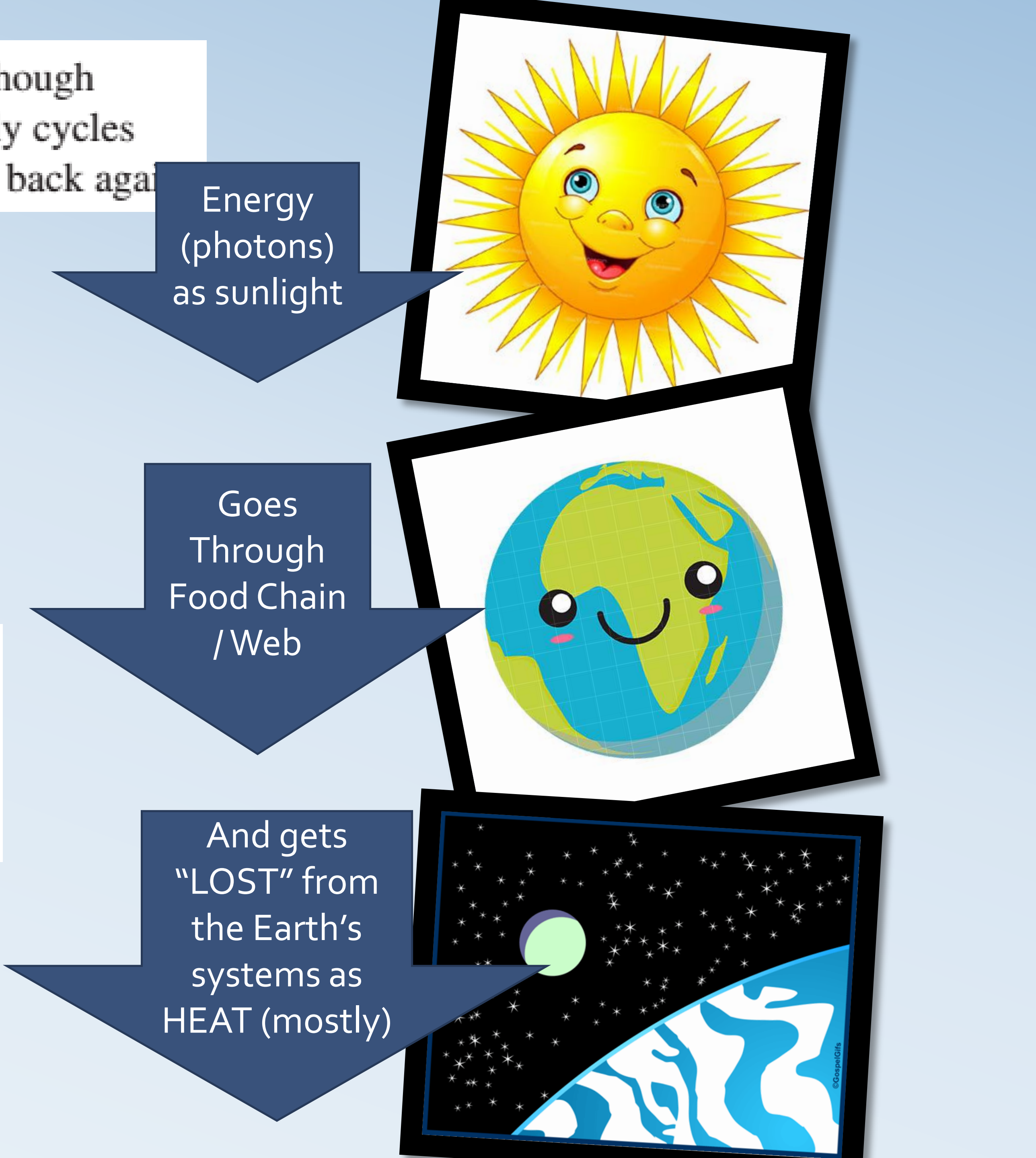
YOU SHOULD BE ABLE TO.. COMPARE AND CONTRAST…

- Energy Flow through the ecosystem – FOOD CHAIN / FOOD WEB
  - Energy flows in ONE DIRECTION
  - Gets lost from “the system” as heat

- Matter Flows through the ecosystem – BIOGEOCHEMICAL RECYCLING
  - Matter refers to the material that make up organisms
  - Looks at how these materials move through the ecosystem
  - Biogeochemical systems in numerous cycles from one part of an ecosystem to another—from one organism to another and from living organisms to the abiotic environment and back again

Figure 4.1 **Earth's system of energy and matter.** Although energy flows one way through ecosystems, matter continually cycles from the abiotic to the biotic components of ecosystems and back agai



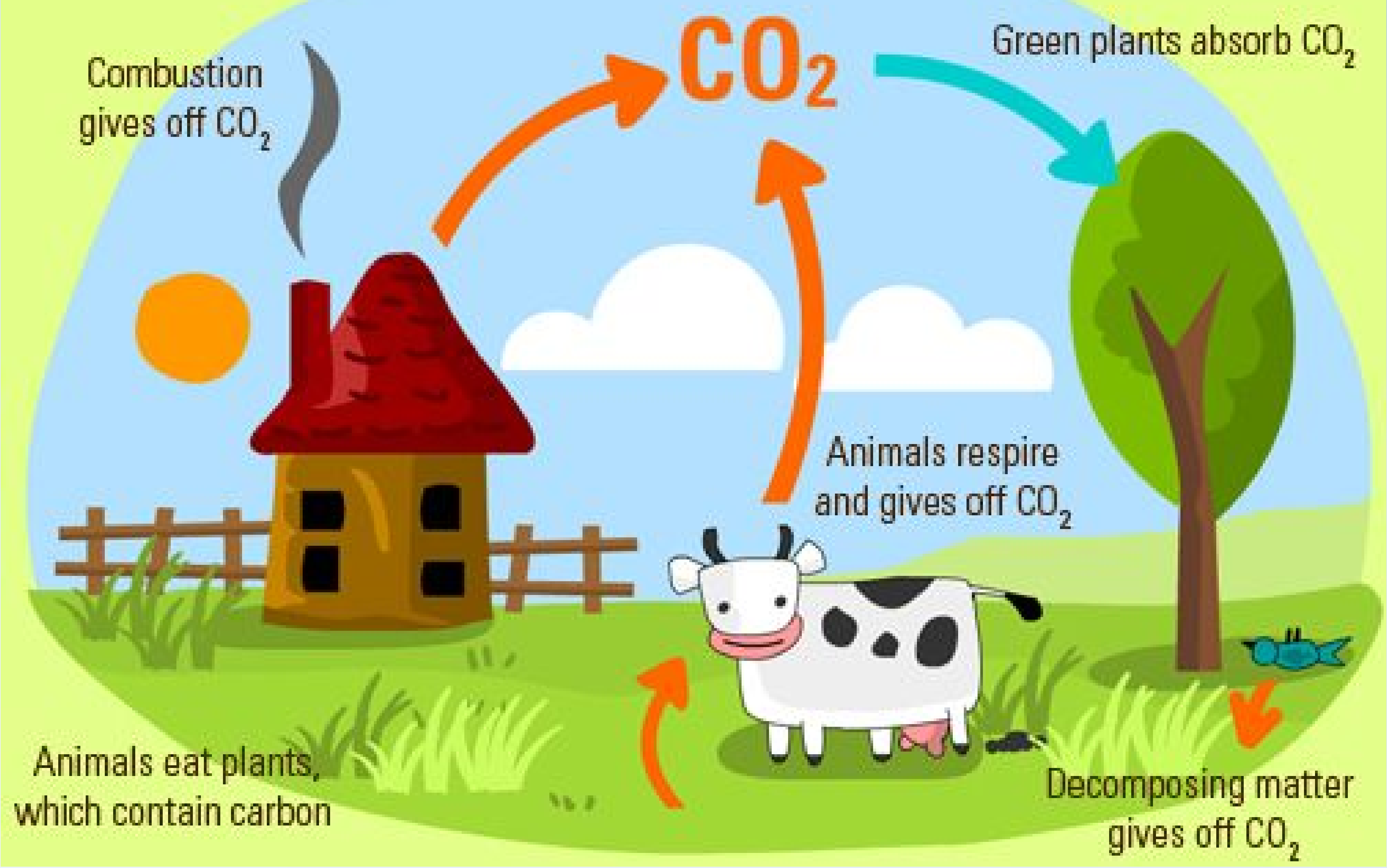


Biogeochemical Cycles

- **These five cycles** are particularly important to organisms because these materials make up the chemical compounds of cells.

1. Carbon
2. Nitrogen
3. Phosphorus
4. Sulfur
5. Hydrologic – This is the Water Cycle

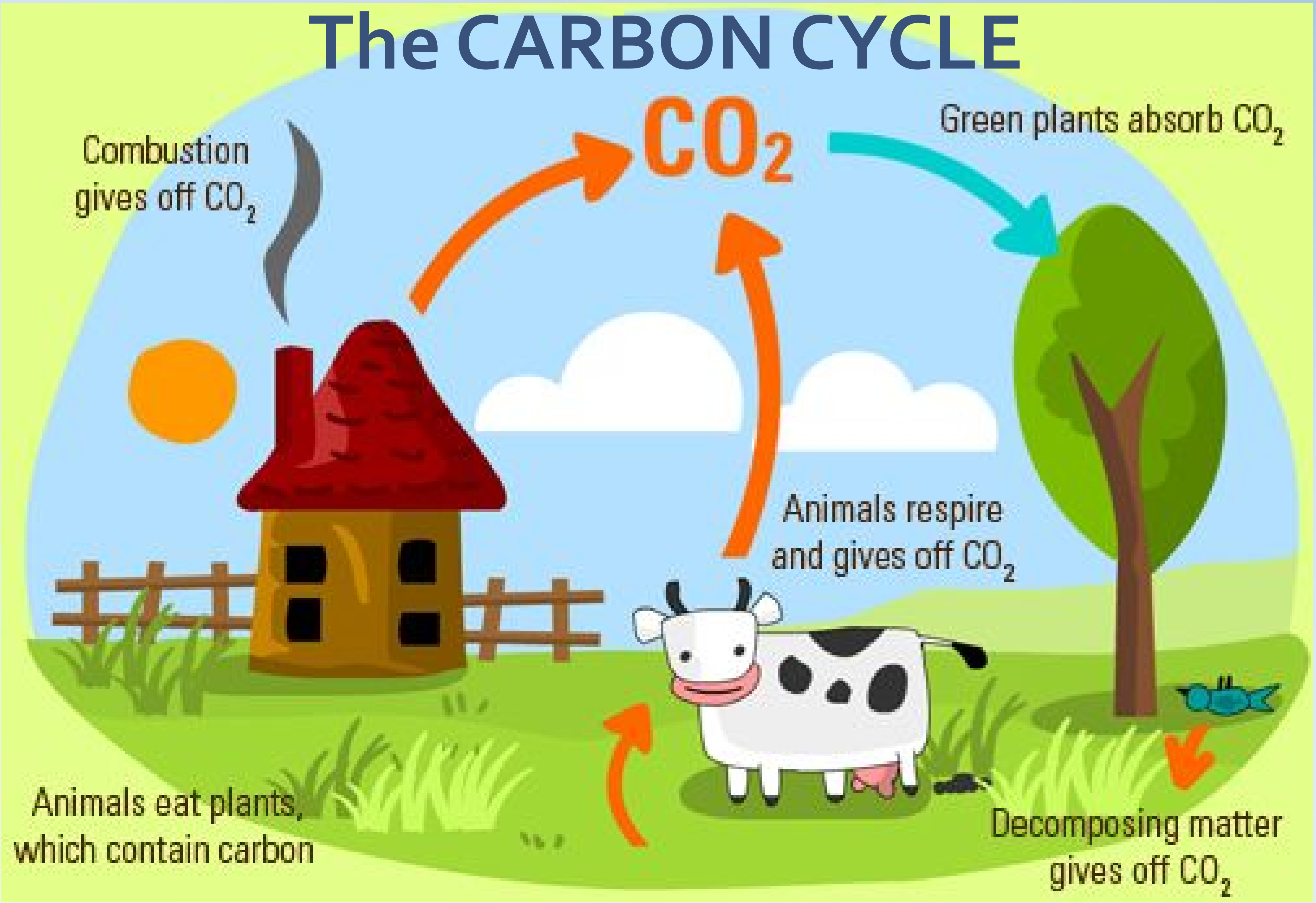
The CARBON CYCLE



Carbon Dioxide is released by…

1. Respiration
2. Combustion
3. Decomposition

The CARBON CYCLE



Carbon Dioxide is used by…

1. Photosynthesis

The CARBON CYCLE

THE CARBON CYCLE is the global circulation of carbon…

1) from the environment to living organisms and…
2) from living organisms back to the environment.

3) https://www.youtube.com/watch?v=zrD3tMNPjXU

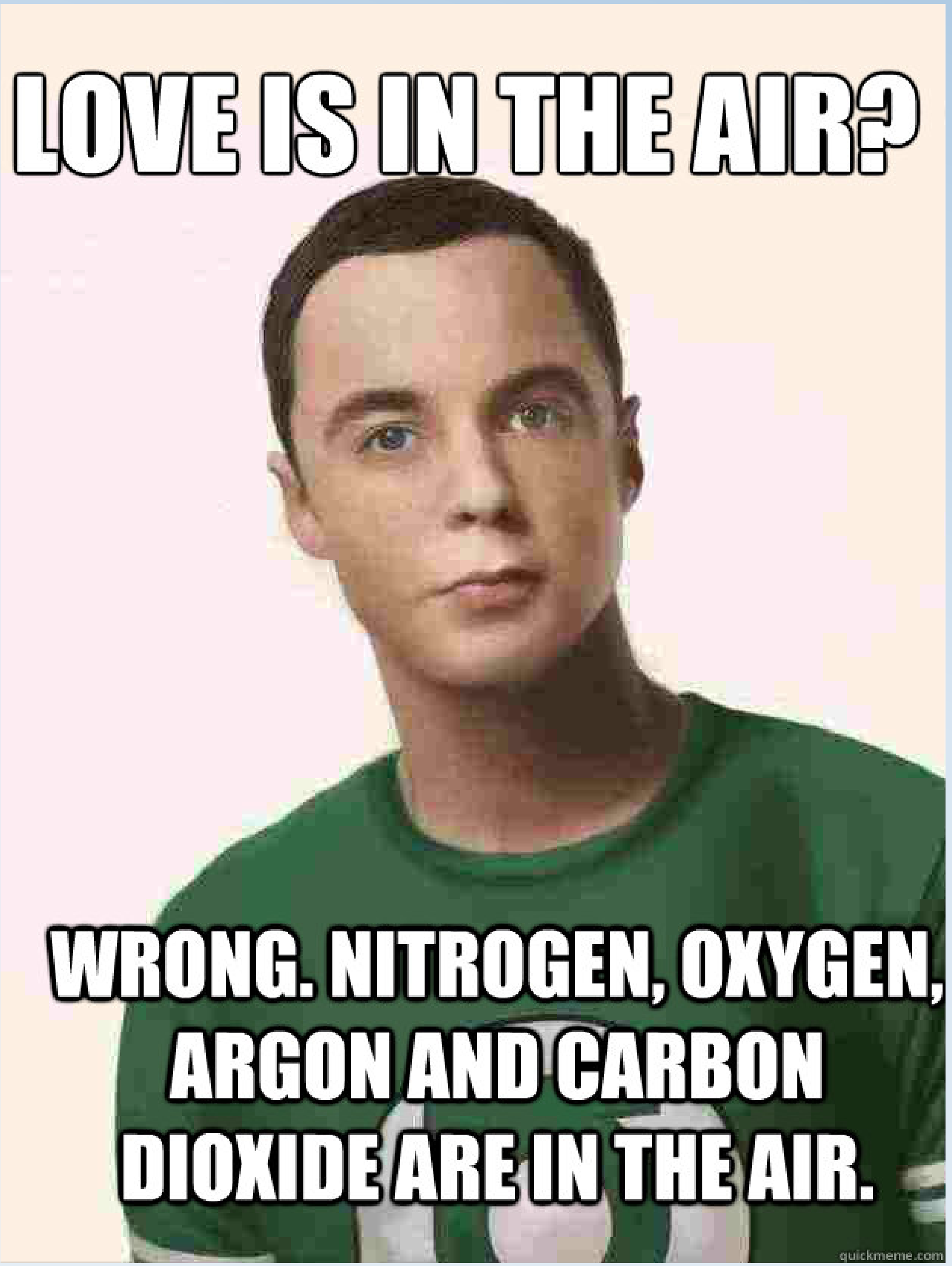
Carbon EXISTS in abiotic environment as:

1. Carbon dioxide [CO_2 (gas)] in the atmosphere
   a. dissolves in H_2O to form HCO_3 (BICARBONATE)

2. Carbonate rocks (limestone & coral = $CaCO_3$ [Calcium Carbonate]

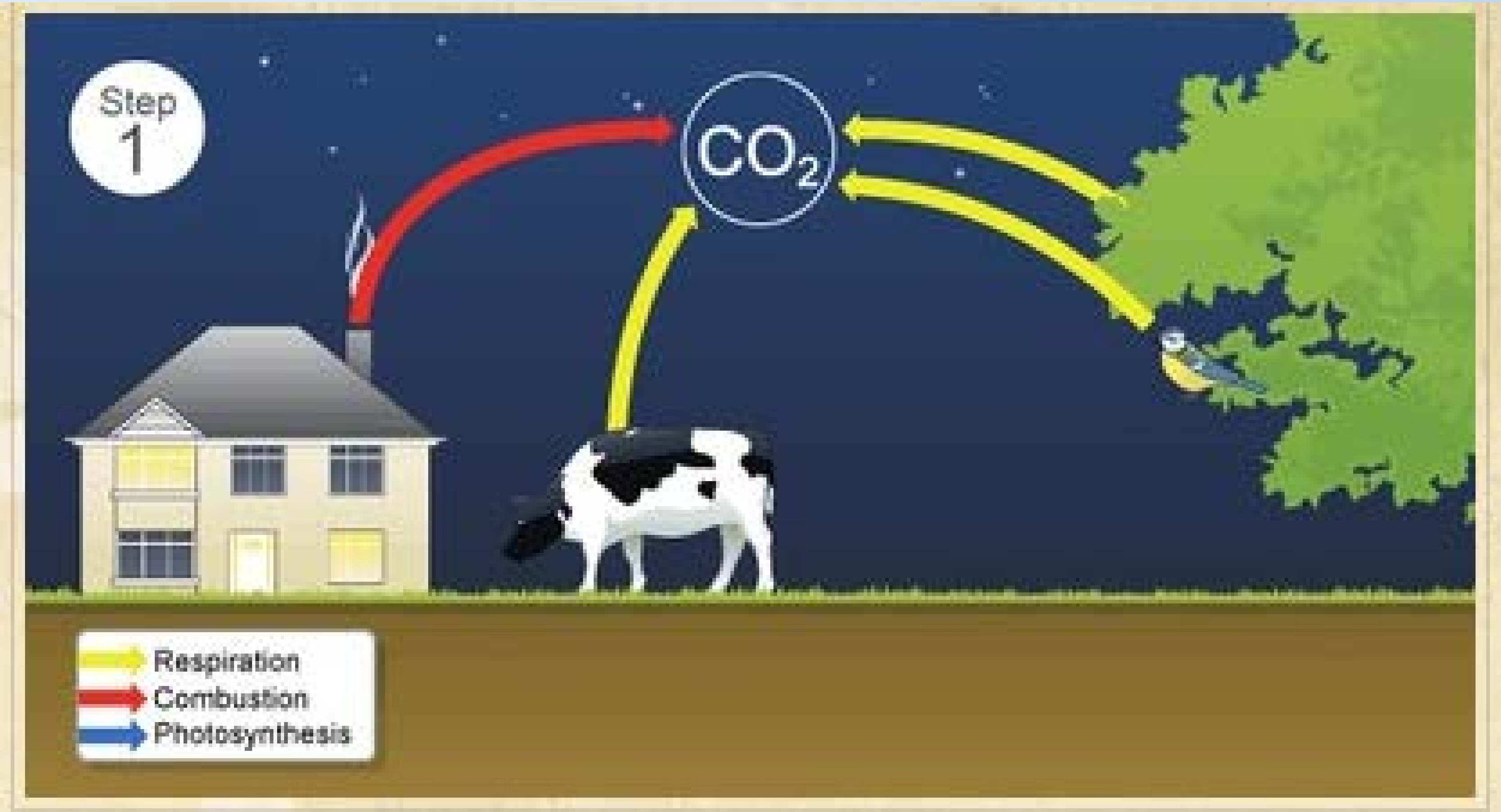
3. Deposits of coal, petroleum, and natural gas
   a. derived from once living things (fossil fuels).

4. Dead organic matter



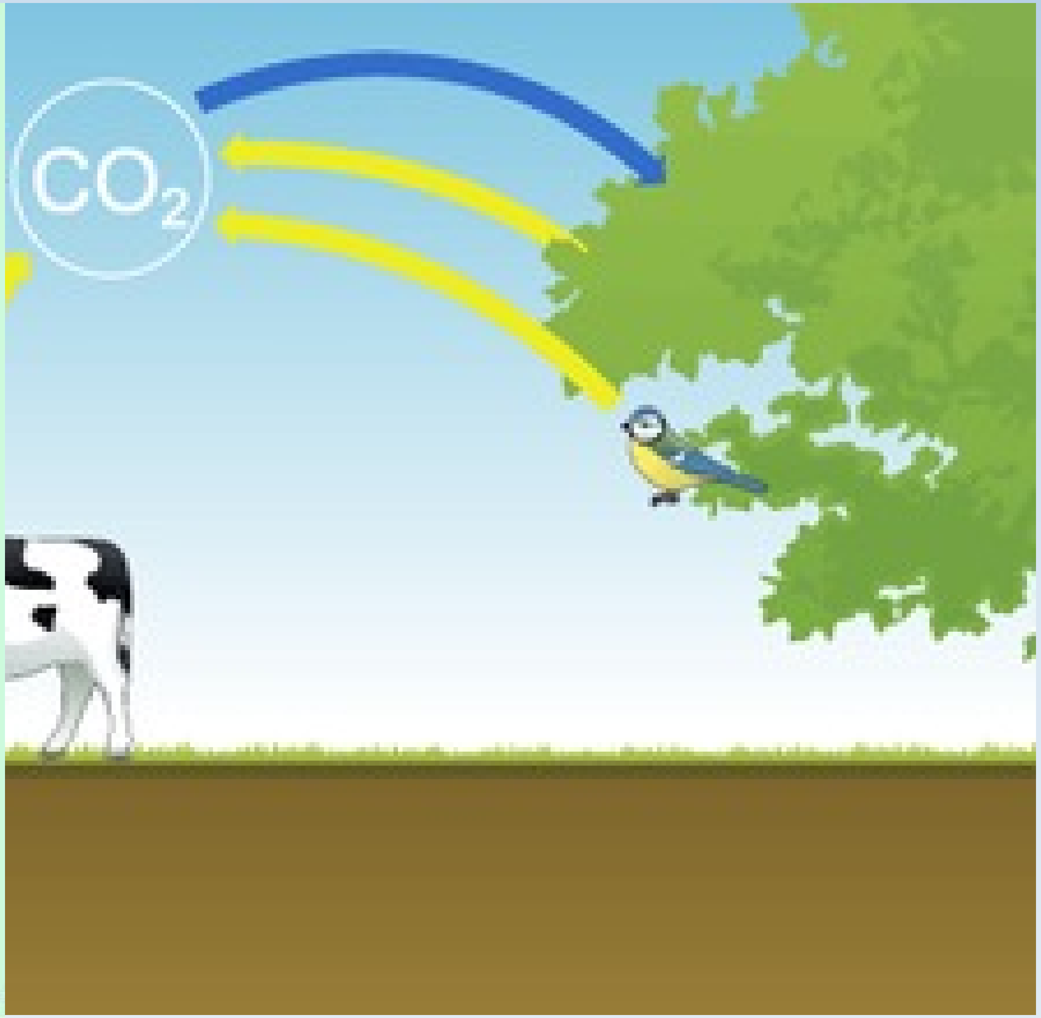
The Carbon Cycle Step 1

- Carbon enters the atmosphere as **carbon dioxide** from respiration (breathing) and combustion (burning).



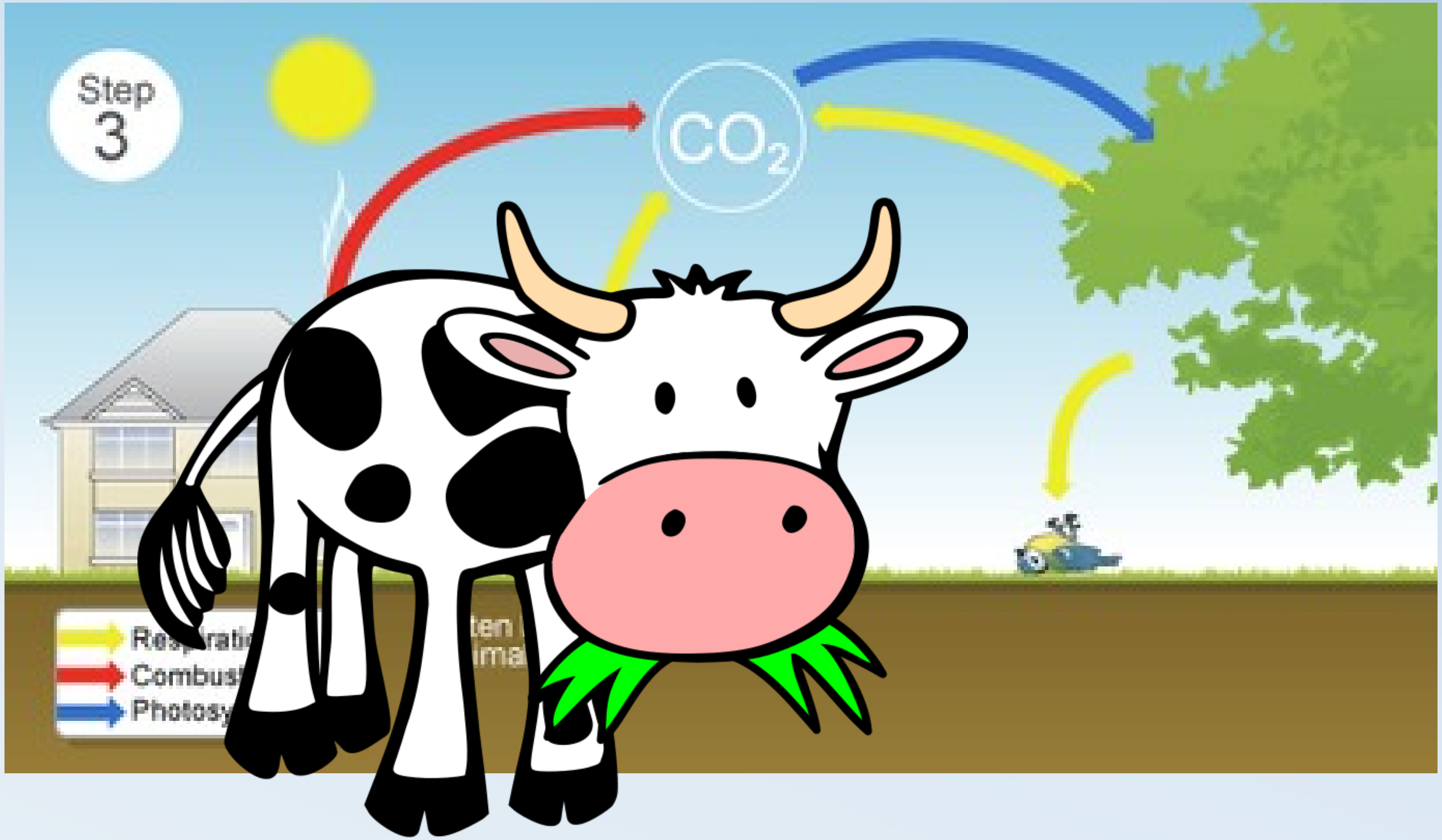
The Carbon Cycle Step 2

- Carbon dioxide is absorbed by producers (life forms that make their own food e.g. plants) to make **carbohydrates** in photosynthesis . These producers then put off oxygen.



The Carbon Cycle Step 3

- Animals feed on the plants. Thus passing the carbon compounds along the food chain.
- Most of the carbon these animals consume however is exhaled as **carbon dioxide.**
- This is through the process of respiration. The animals and plants then eventually die.

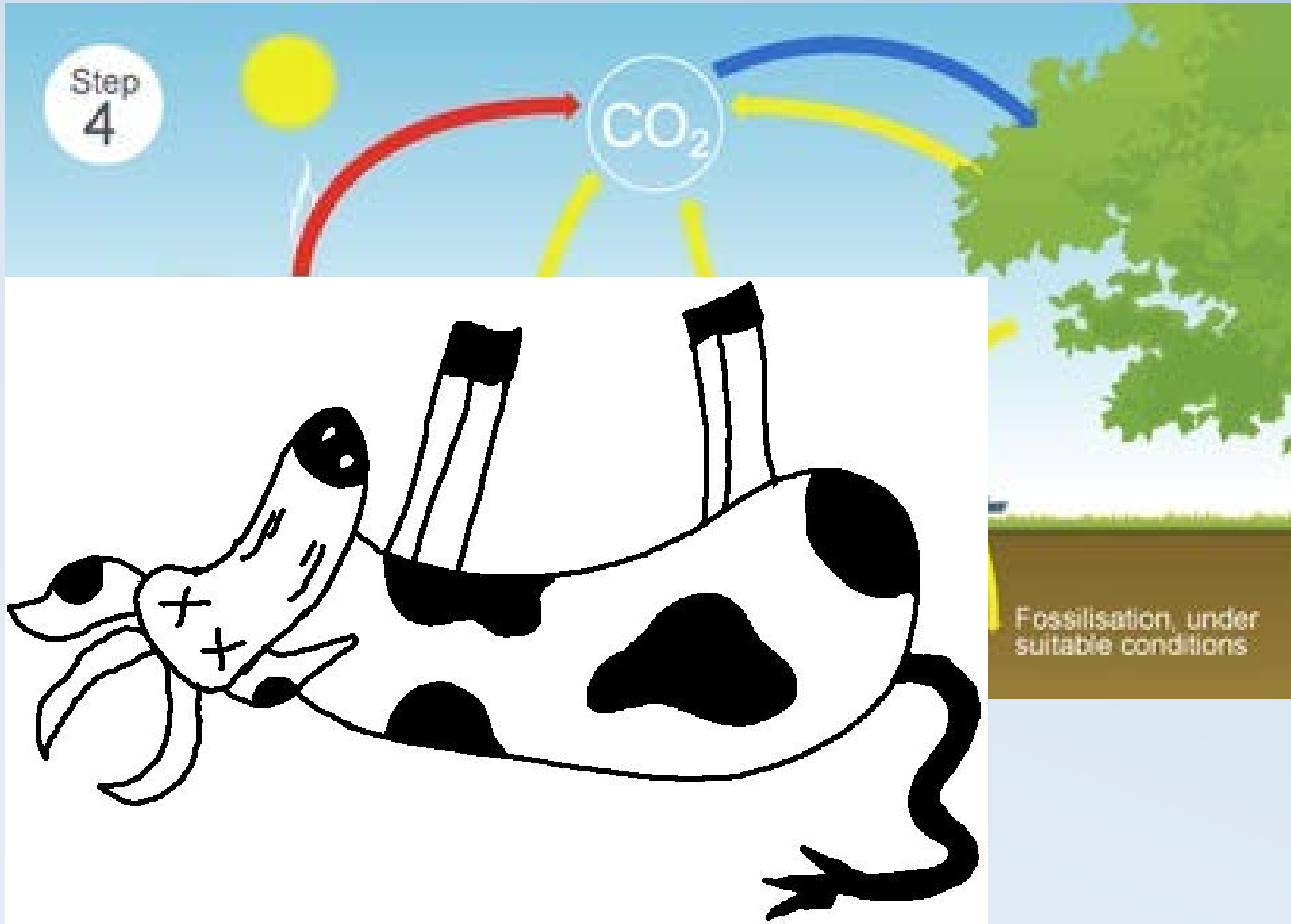


The Carbon Cycle Step 4

The dead organisms (dead animals and plants) are eaten by **decomposers** in the ground.

The carbon that was in their bodies is then returned to the atmosphere as carbon dioxide. In some circumstances the process of decomposition is **prevented**.

The decomposed plants and animals may then be available as **fossil fuel** in the future for combustion.



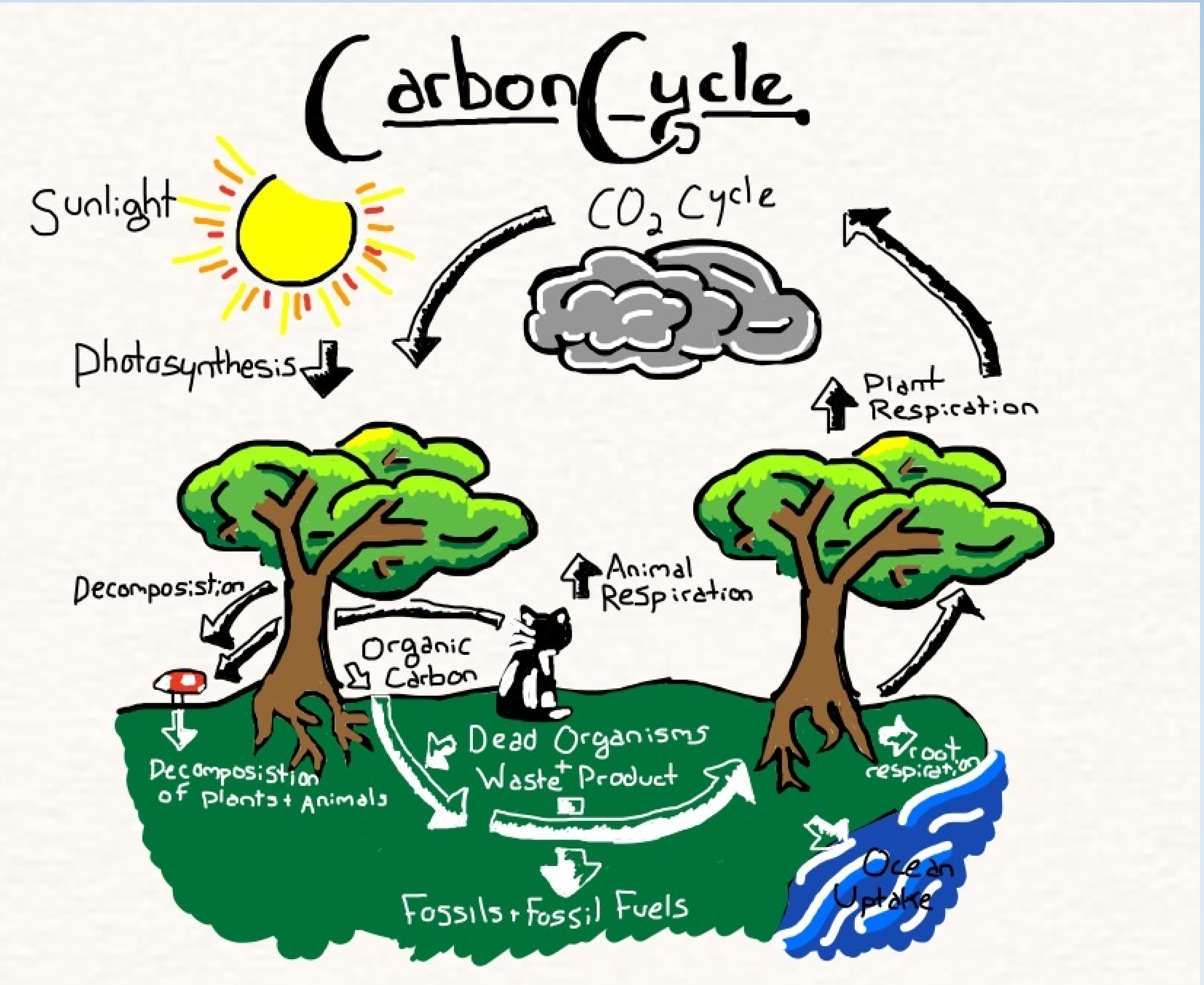
The CARBON CYCLE

Living Organisms must have a consistent supply of carbon.

Carbon is found in the atmosphere as a gas, carbon dioxide (CO_2).

Carbon can be present in water (dissolved) as carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) and dissolved organic carbon from decaying biotic material.

Carbon is also present in sedimentary rocks such as limestone, which consists primarily of calcium carbonate, $CaCO_3$


Carbon Cycle
Sunlight
CO2 Cycle
Photosynthesis
Plant Respiration
Animal Respiration
Decomposistion
Organic Carbon
Dead Organisms
Waste + Product
root respiration
Decomposistion of Plants + Animals
Fossils + Fossil Fuels
Ocean Uptake

http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php

The Effects of too much CARBON DIOXIDE in our atmosphere

According to NASA

- land plants and the ocean have taken up about 55 percent of the extra carbon people have put into the atmosphere.
- 45 percent of the extra carbon has stayed in the atmosphere.
- Eventually, the land and oceans will take up most of the extra carbon dioxide, but as much as 20 percent may remain in the atmosphere for many thousands of years.

http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php

The Effects of too much CARBON DIOXIDE in our atmosphere

According to NASA

- Excess carbon in the atmosphere warms the planet and helps plants on land grow more.
- Excess carbon in the ocean makes the water more acidic, putting marine life in danger.

http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php

GREEN-HOUSE GASES

According to NASA

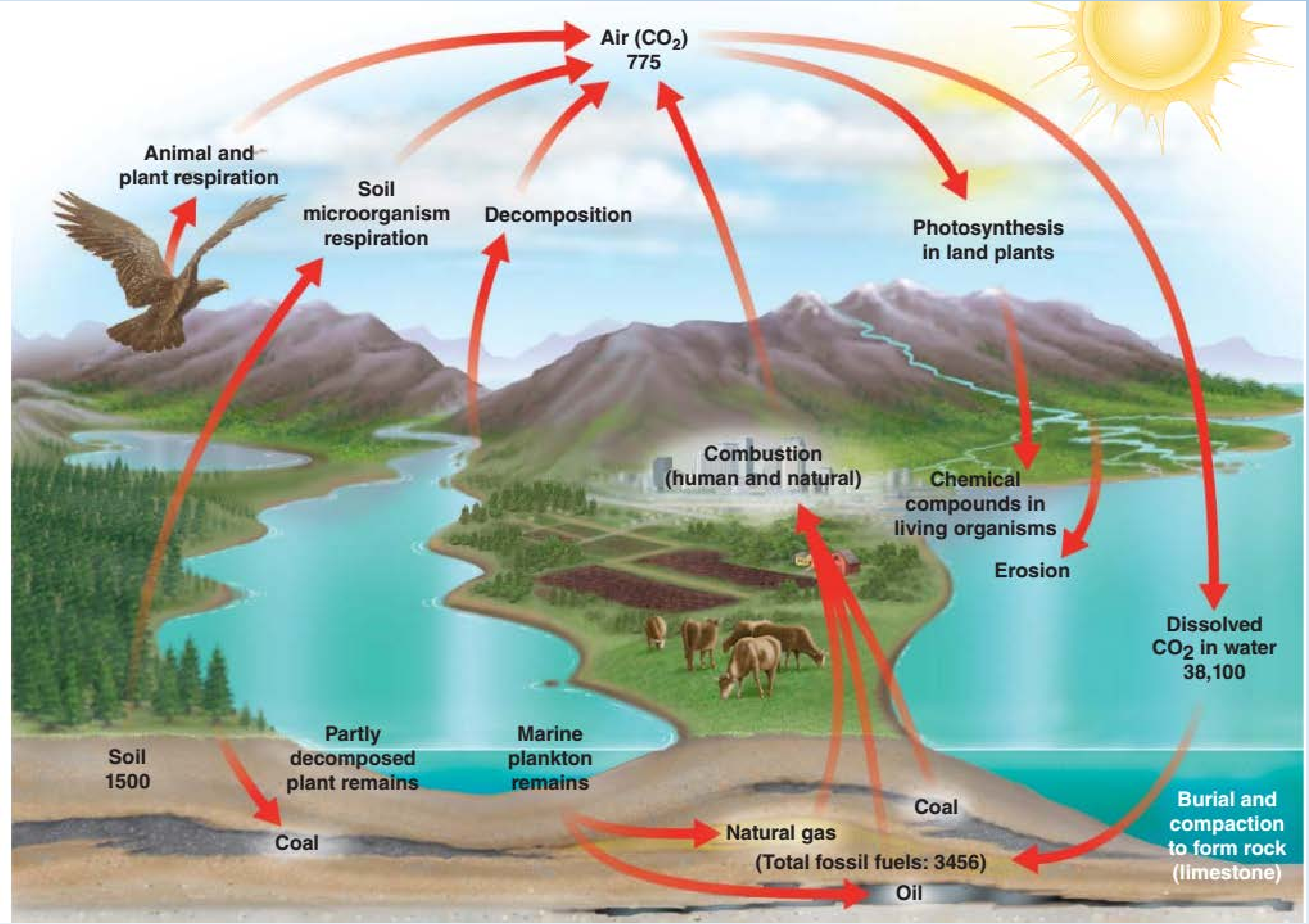
- CO_2 is the most important gas for controlling Earth's temperature.
- Carbon dioxide, methane, and halocarbons are greenhouse gases that absorb a wide range of energy—including infrared energy (heat) emitted by the Earth—and then re-emit it.

http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php

GREEN-HOUSE GASES

According to NASA

- The re-emitted energy travels out in all directions, but some returns to Earth, where it heats the surface.
- Without greenhouse gases, Earth would be a frozen at around zero degrees Fahrenheit.
- With too many greenhouse gases, Earth would be like Venus, where the greenhouse atmosphere keeps temperatures around 750 degrees Fahrenheit.



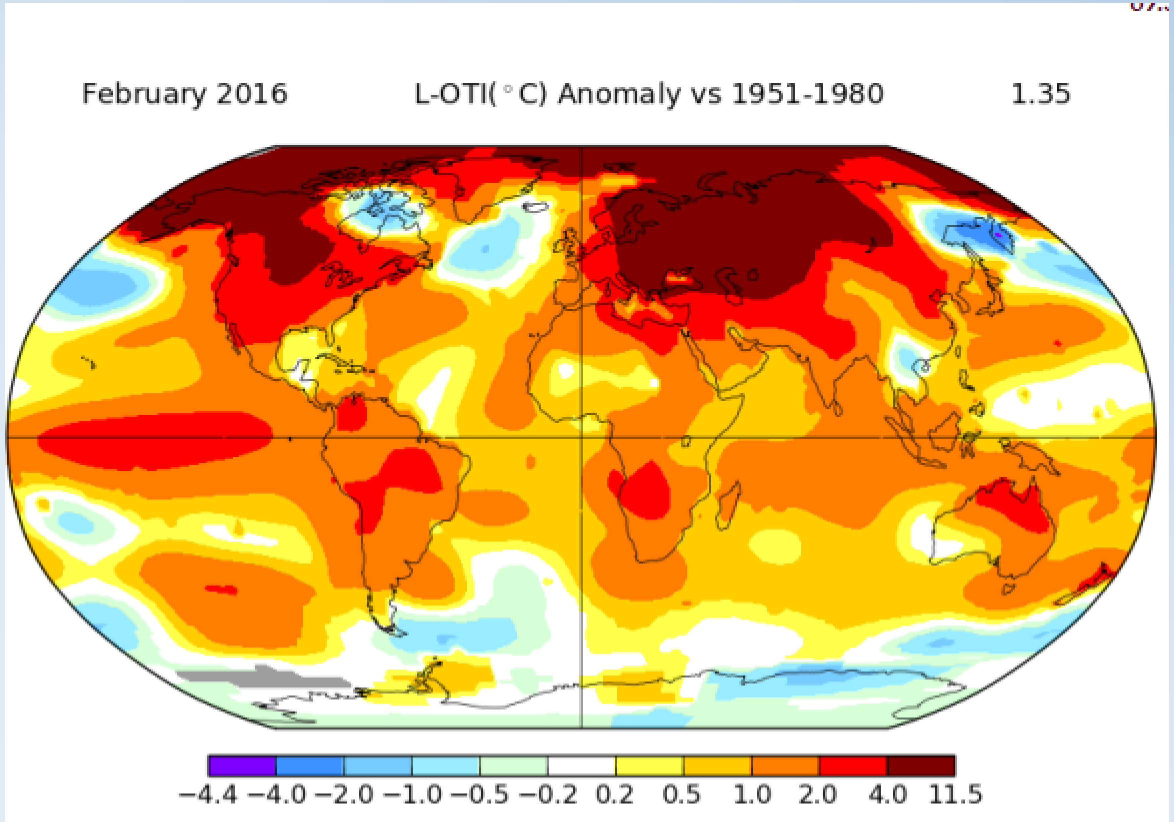
Air (CO_2)
775
Animal and plant respiration
Soil microorganism respiration
Decomposition
Photosynthesis in land plants
Combustion (human and natural)
Chemical compounds in living organisms
Erosion
Dissolved CO_2 in water
38,100
Soil
1500
Partly decomposed plant remains
Marine plankton remains
Coal
Coal
Natural gas
(Total fossil fuels: 3456)
Oil
Burial and compaction to form rock (limestone)

Global Warming

- Rising carbon dioxide concentrations are already causing the planet to heat up.
- Greenhouse gases continue to increase in our atmosphere.
- The average global temperatures have risen 1.4 degrees Fahrenheit since 1880.

Global Warming

- ***Update, March 12, 2016***: Data **released** from NASA confirm that February 2016 was not only the most unusually warm month ever measured globally, at 1.35 degrees Celsius above the long-term average—it was more than 0.2 degrees Celsius warmer than the previously most unusually warm month ever measured: January 2016.



NASA has confirmed that our planet's temperature surged in February 2016—past a major milestone.

NASA

The Carbon Cycle

- Carbon is fixed by plants
  - $6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$
- Carbon is given off by consumers
  - $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$
- Organisms containing carbon form fossil fuels
- Burning fossil fuels releases carbon
  - $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

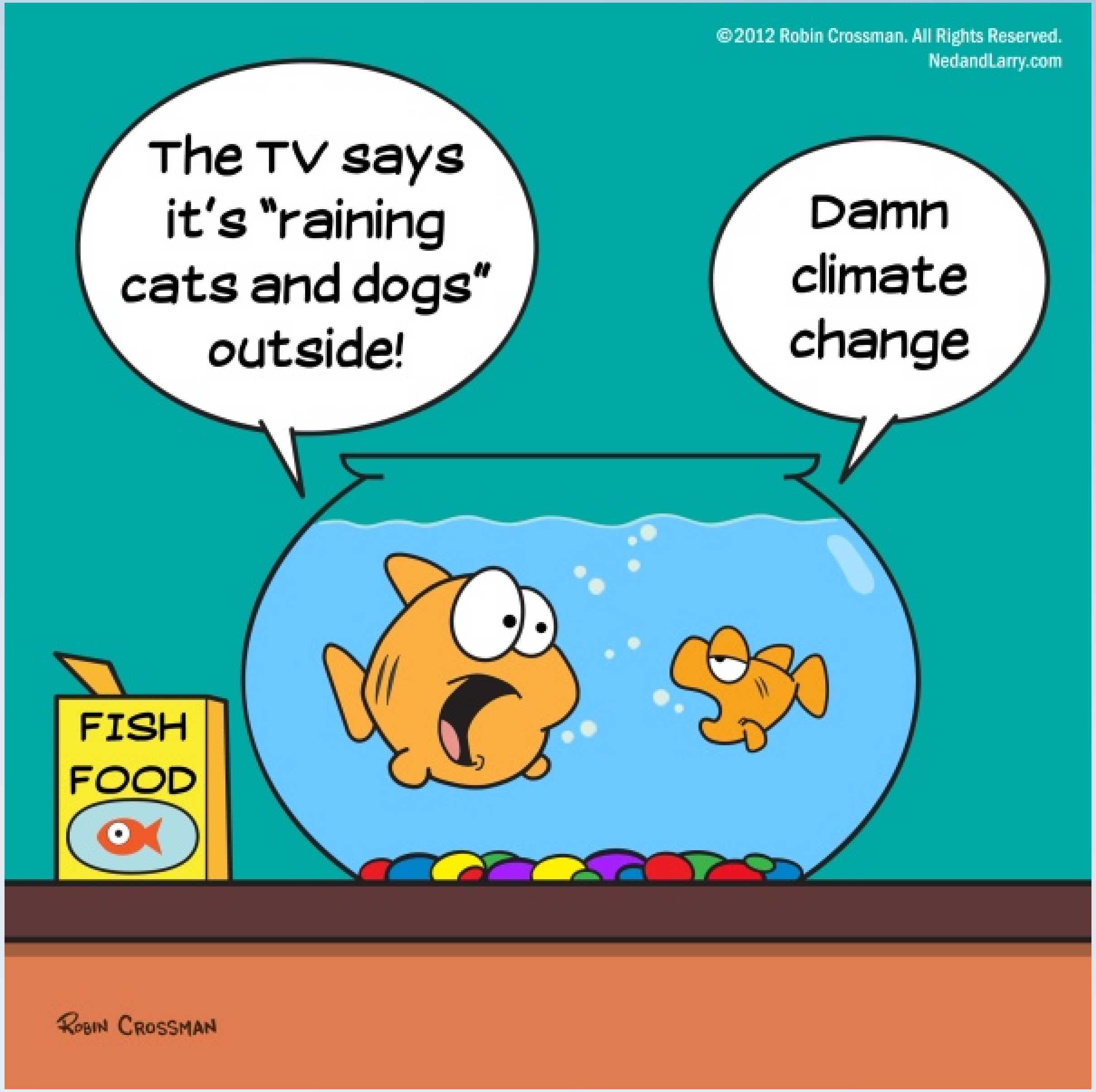
Human-Induced Changes to the Carbon Cycle

- Human activities are increasingly disturbing the balance of biogeochemical cycles, including the carbon cycle.
- Since the end of the 18th century, the advent of the Industrial Revolution, industrial society has used a lot of energy, most of which we have obtained by burning increasing amounts of fossil fuels—coal, oil, and natural gas.

- This trend, along with a greater combustion of wood as a fuel and the burning of large sections of tropical forests, has shifted carbon from underground deposits to the atmosphere.
- In the 1700s, CO_2 made up 0.029% of the atmosphere; it now makes up 0.04%, and some scientists project it will be up to 0.06% (double the preindustrial level) by the end of this century.

Human-Induced Changes to the Carbon Cycle

- Numerous studies indicate that the increase of CO_2 in the atmosphere is causing human-induced global climate change.

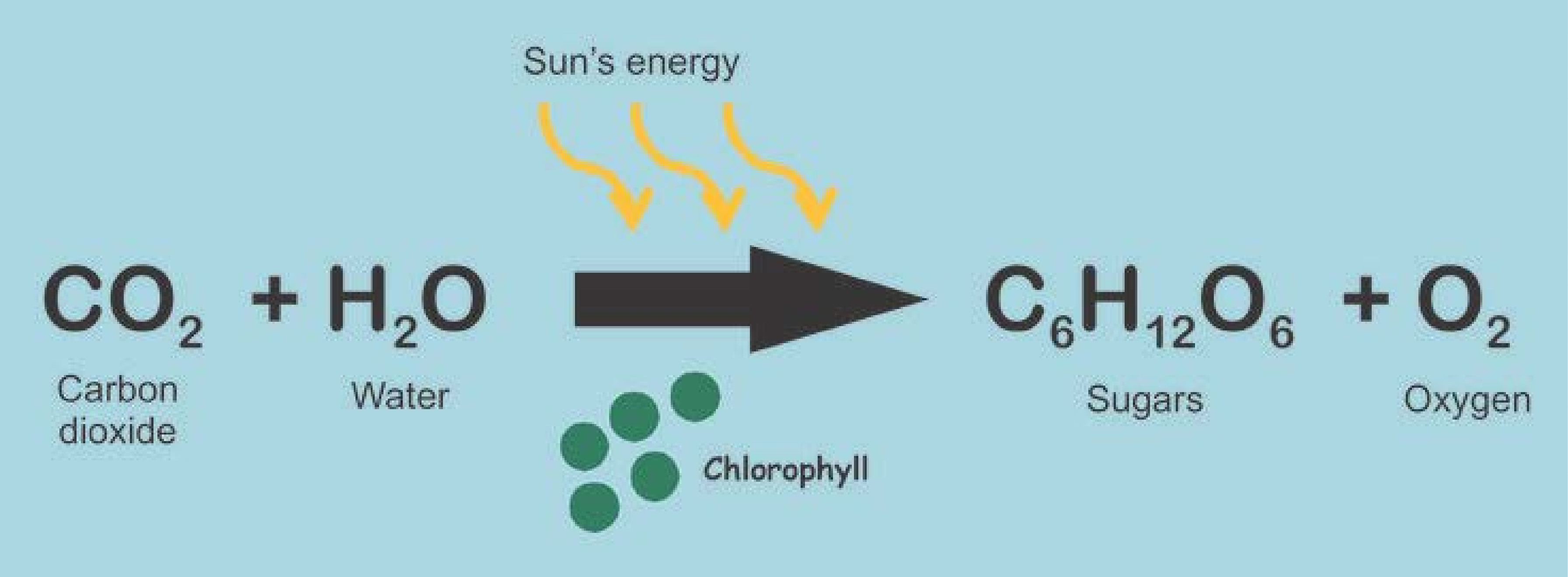


Human-Induced Changes to the Carbon Cycle

- Global climate changes include
  - Increasing Temperatures
  - A Rise In Sea Level
  - Altered Precipitation Patterns
  - Increased Wildfires
  - Flooding
  - Drought
  - Heat Waves (global warming)
  - Extinctions Of Organisms
  - Agricultural Disruption

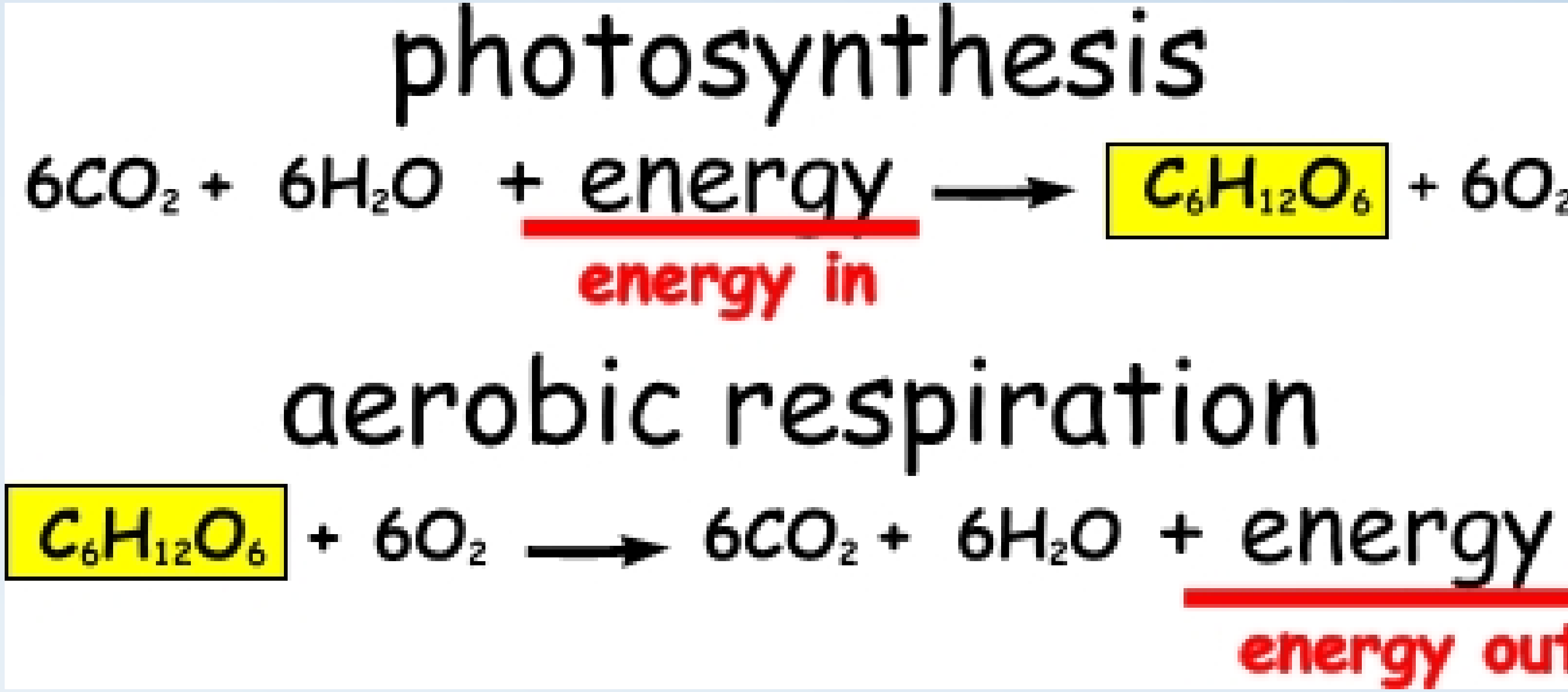
Human-Induced Changes to the Carbon Cycle

- During photosynthesis, plants, algae, and certain bacteria remove CO_2 from the air and fix (incorporate) it into chemical compounds such as sugar.



The Carbon Cycle

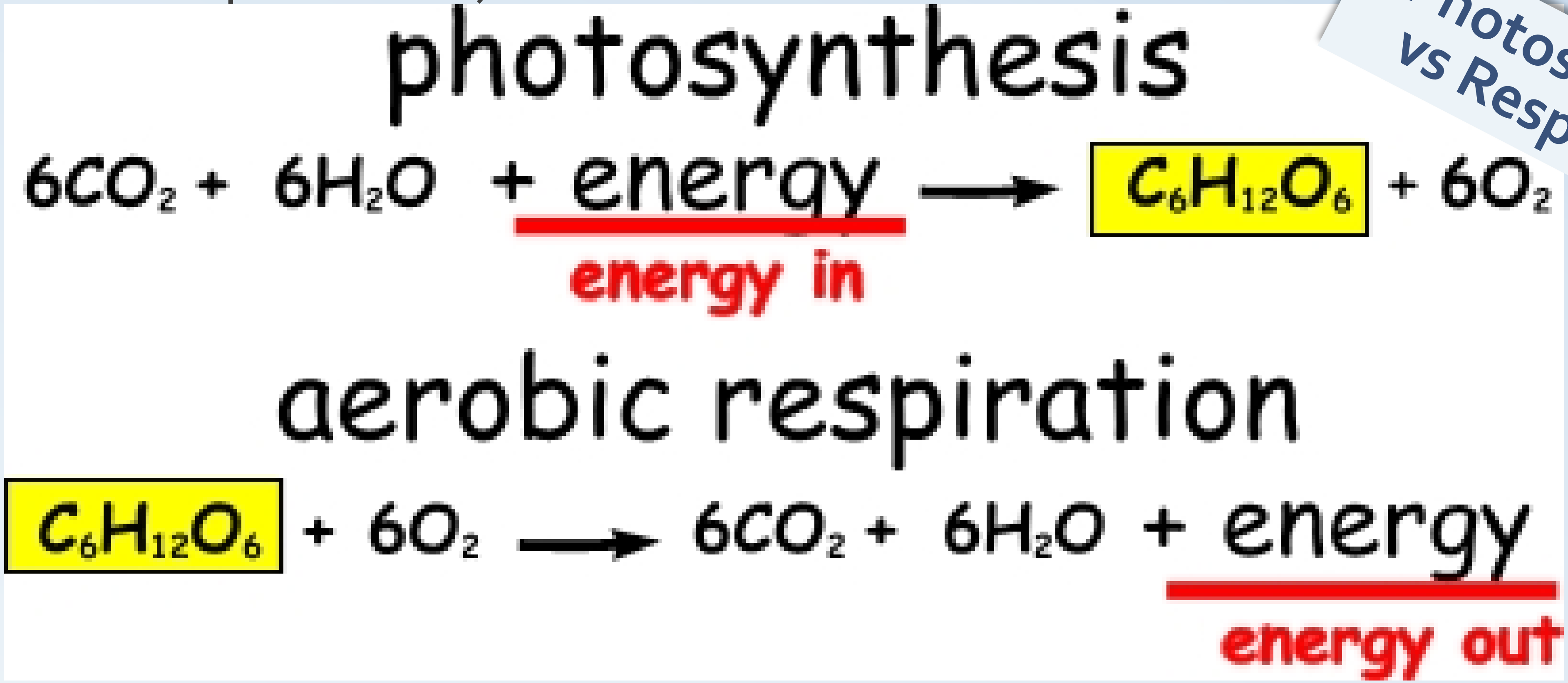
- Photosynthesis incorporates carbon from the abiotic environment into the biological compounds of producers.
- Those compounds are usually used as fuel for cellular respiration by the producer.



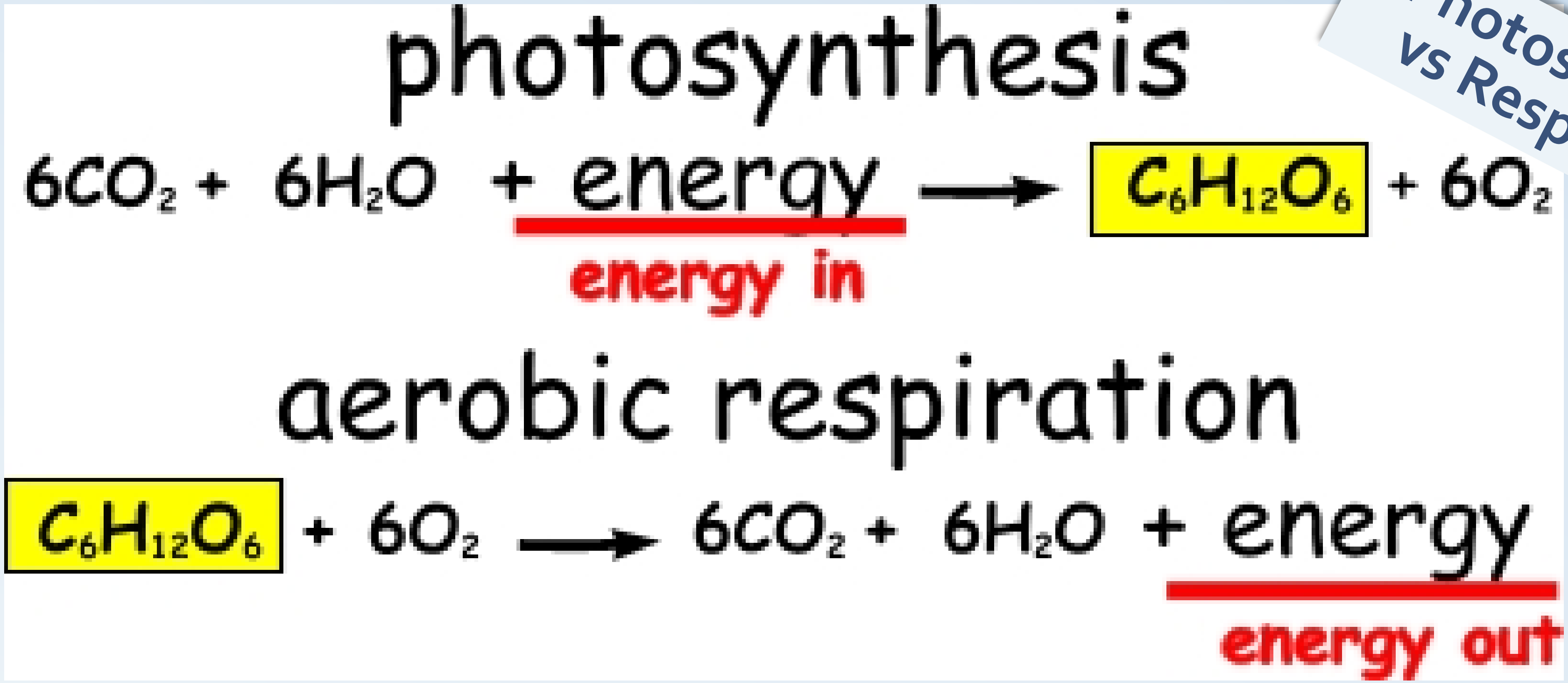
The Carbon Cycle

Photosynthesis vs Respiration

- In green plants both photosynthesis and respiration occur.
- In relatively bright light photosynthesis is the dominant process (meaning that the plant produces more food than it uses during respiration).
- At night, or in the absence of light, photosynthesis essentially ceases, and respiration is the dominant process; the plant consumes food (for growth and other metabolic processes).



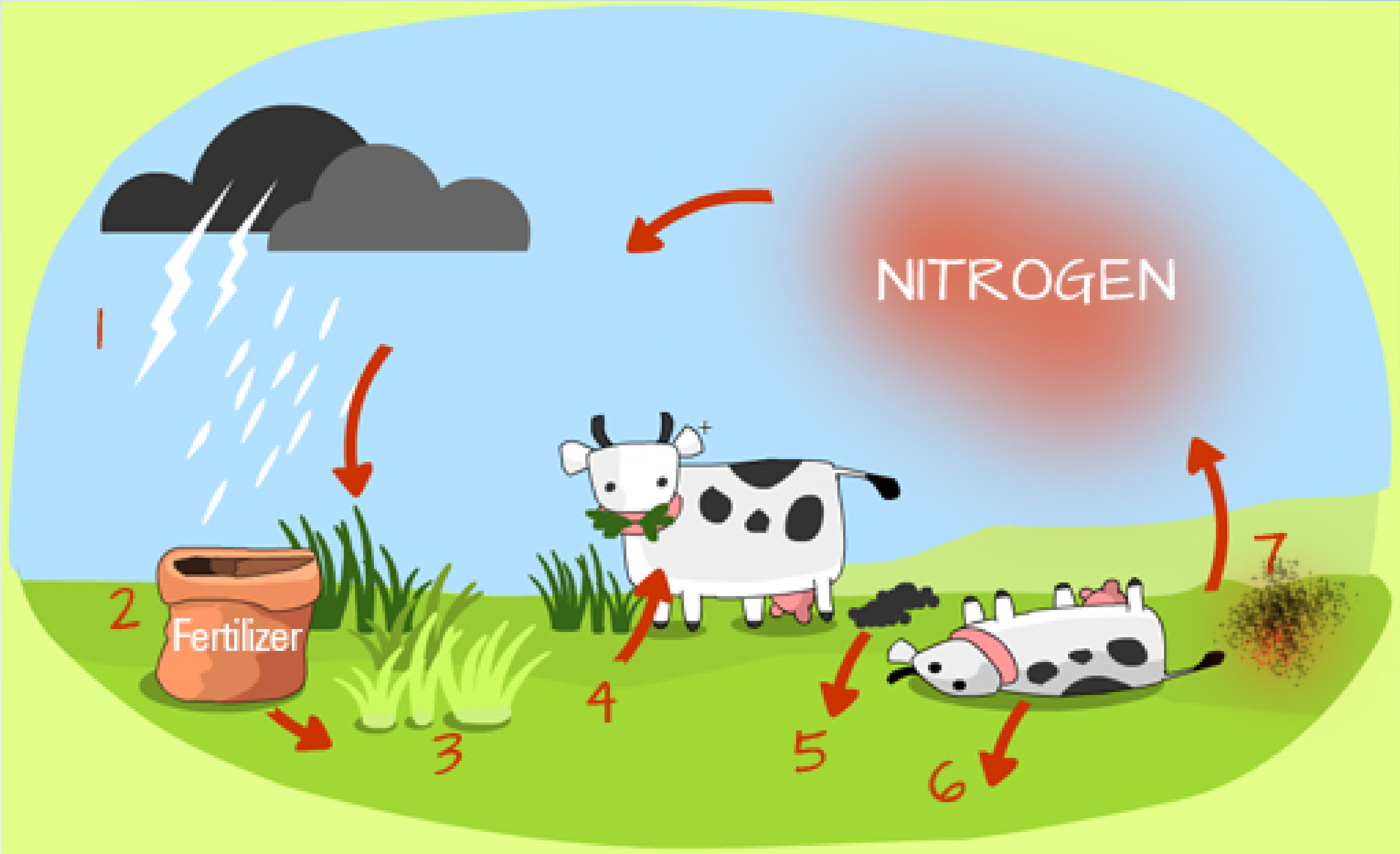
- The two processes are shown in the simplified equation below. Photosynthesis absorbs energy (from sunlight) whereas aerobic respiration yields energy (as a result of the oxidation of glucose, the carbohydrate molecule shown here).
- Note that these are essentially "competing" processes, one producing glucose (photosynthesis) and the other consuming glucose (respiration).



Photosynthesis vs Respiration

THE **NITROGEN** CYCLE

- https://www.youtube.com/watch?v=zrD3tMNPjXU



The NITROGEN CYCLE

1. ~79% of air is N_2 gas (nitrogen gas)
2. N (nitrogen) is essential to plants and animals
3. Plants and animals can't use the N (nitrogen) when it is on the gaseous form of N_2 gas
4. Therefore, organisms must CONVERT nitrogen gas into usable nitrogenous compounds such as ammonia (NH_3) or nitrate (NO_3^-)

The NITROGEN CYCLE – HOW DO ORGANISMS CONVERT N_2?

The goal here is to convert atmospheric N_2 to NH_3 and NO_3 :

$$N_2 \rightarrow NH_3 + NO_3$$

Nitrogen Gas (N_2) gets converted in biological systems into ammonia (NH_3) and nitrates (NO_3).

BUT HOW?

The 4 important processes in the nitrogen cycle include

- fixation
- ammonification
- nitrification
- denitrification

This is a TATTOO! →
NOT RECOMMENDED.

The NITROGEN CYCLE – HOW DO ORGANISMS CONVERT N_2?

Nitrogen fixation

1. Aquatic ecosystems: blue-green algae

2. Terrestrial ecosystems: bacteria on root nodules of legumes (peas, beans, alfalfa, clover)

3. Lightening

The NITROGEN CYCLE – HOW DO ORGANISMS CONVERT N_2?

Nitrogen RETURNS to soil by:

1. decomposition of once living things

   → ammonifying bacteria + fungi

2. exists in soil as nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3)

The NITROGEN CYCLE –
HOW DO ORGANISMS CONVERT N_2?

Nitrogen RETURNS to the atmosphere by:

1. denitrifying bacteria

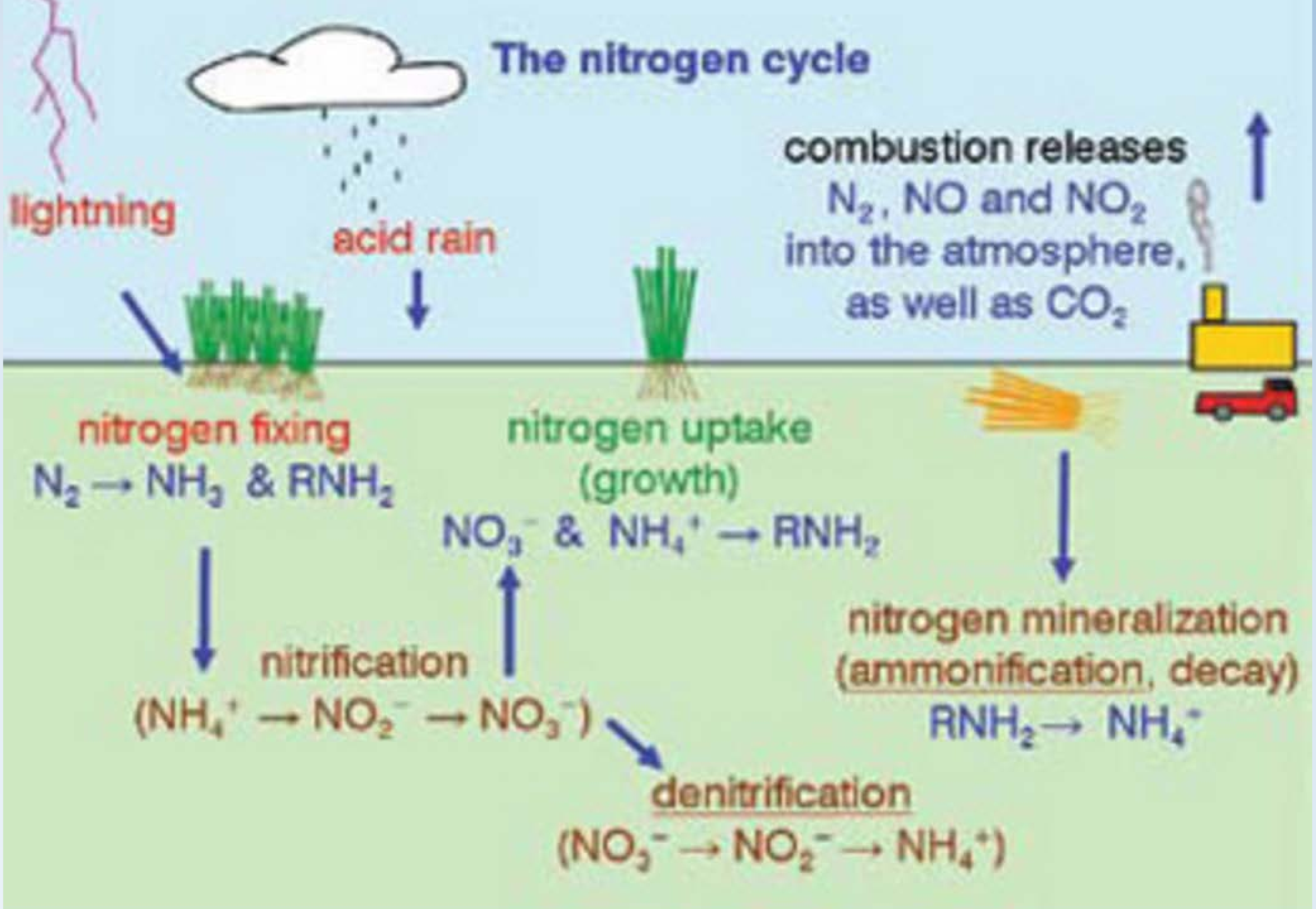
Denitrifying bacteria form a necessary part of the process known as denitrification as part of the nitrogen cycle which consists of the ongoing processes that Nitrogen has to undertake as it is the largest gas compound in the atmosphere.

The NITROGEN CYCLE – HOW DO ORGANISMS CONVERT N_2?

Nitrogen RETURNS to the atmosphere by:

1. denitrifying bacteria

Their primary purpose being to metabolize nitrogenous compounds, with the assistance of the *nitrate reductase* enzyme, to turn oxides back to nitrogen gas or nitrous oxides for energy generation.



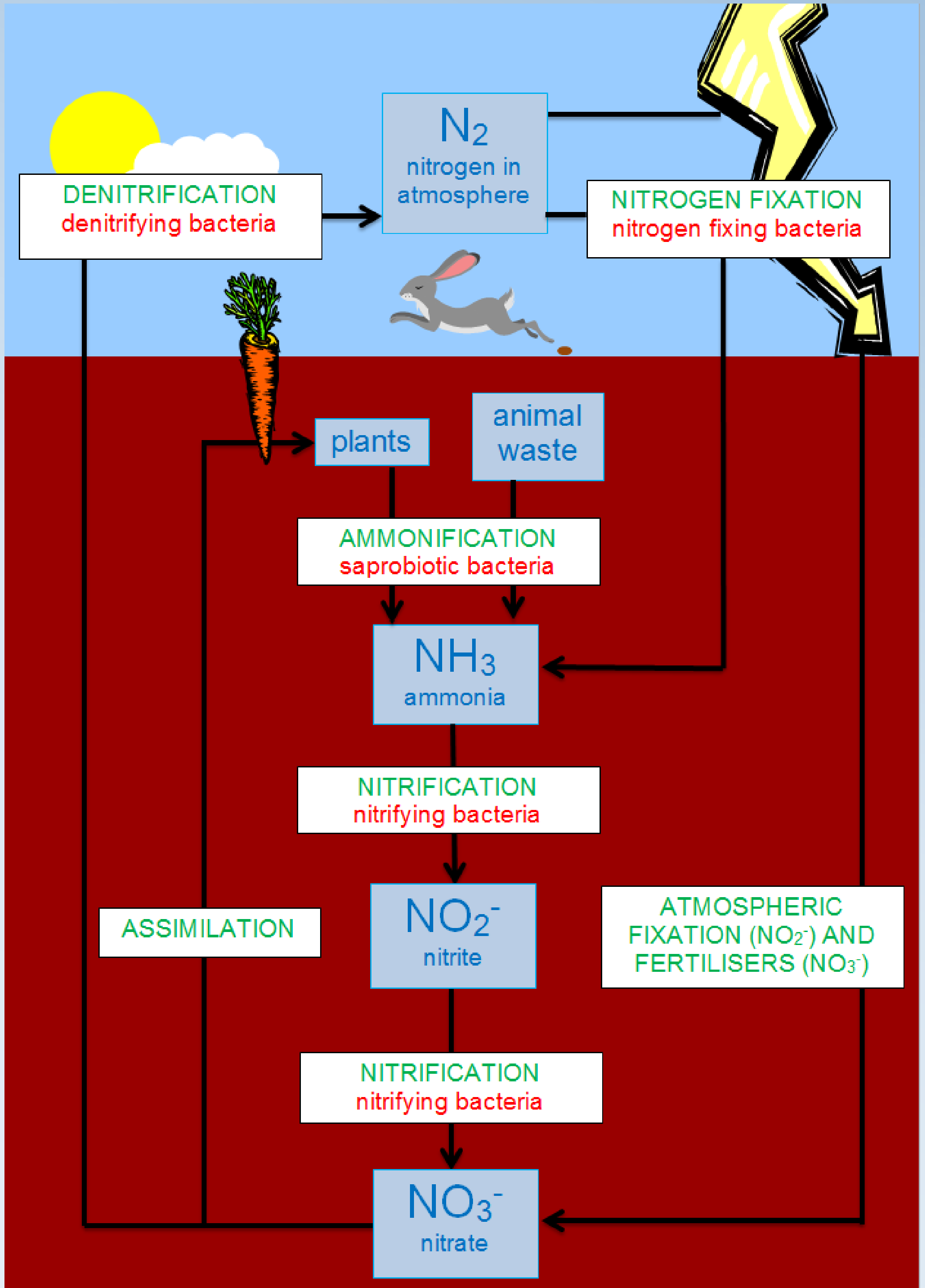
The nitrogen cycle
lightning
acid rain
combustion releases
N2, NO and NO2
into the atmosphere,
as well as CO2
nitrogen fixing
N2 → NH3 & RNH2
nitrogen uptake
(growth)
NO3- & NH4+ → RNH2
nitrogen mineralization
(ammonification, decay)
RNH2 → NH4+
nitrification
(NH4+ → NO2- → NO3-)
denitrification
(NO3- → NO2- → NH4+)

- The **nitrogen cycle** is the biogeochemical cycle by which nitrogen is converted into various chemical forms as it circulates among atmosphere and land (terrestrial) and marine ecosystems.
- The conversion of nitrogen can be carried out through both biological and physical processes.

The Nitrogen Cycle

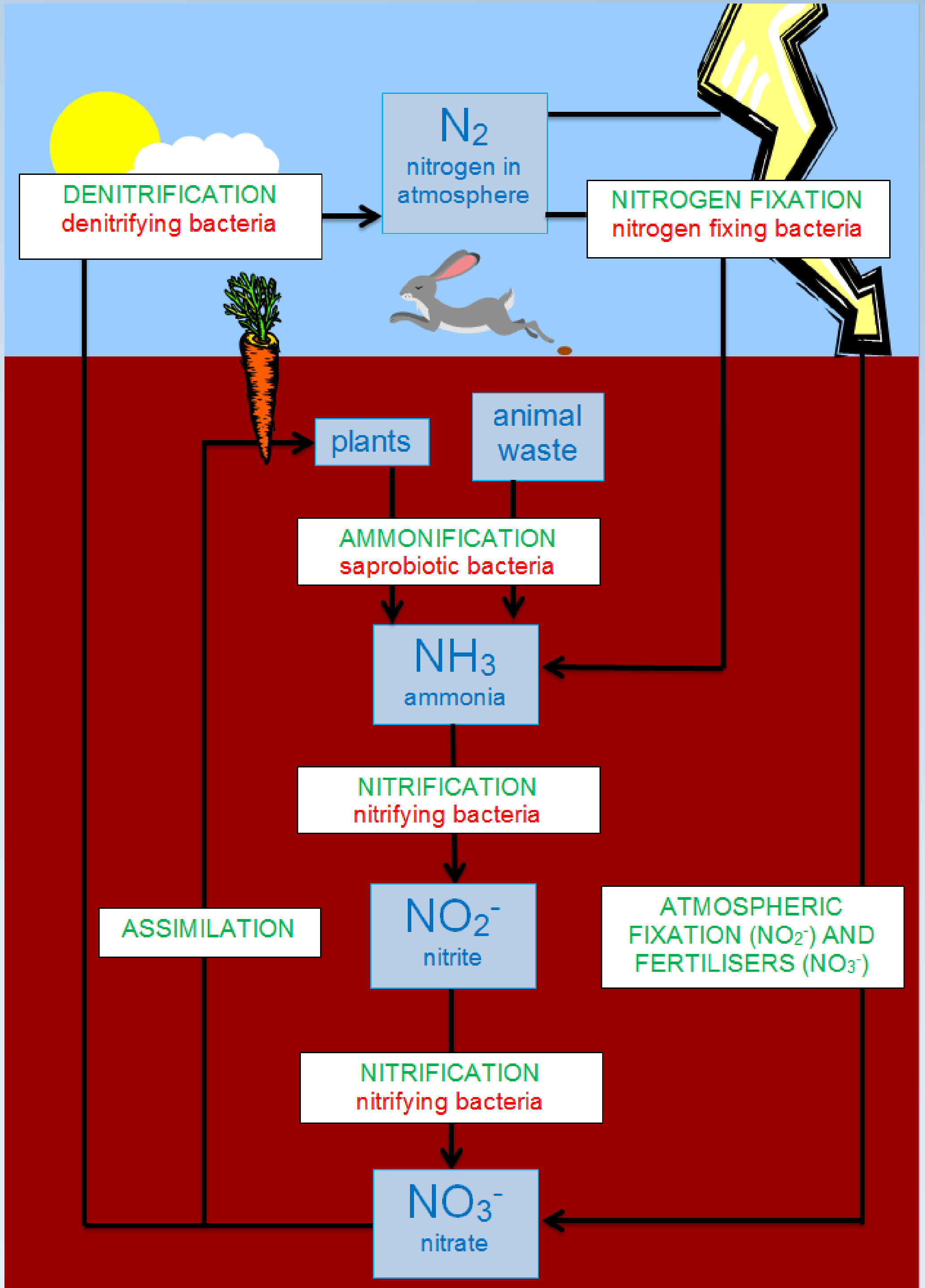
The Nitrogen Cycle

- The majority of Earth's atmosphere (78%) is nitrogen, making it the largest pool of nitrogen.
- However, atmospheric nitrogen has limited availability for biological use, leading to a scarcity of usable nitrogen in many types of ecosystems.



- The nitrogen cycle is of particular interest to ecologists because nitrogen availability can affect the rate of key ecosystem processes, including primary production and decomposition.
- Human activities such as fossil fuel combustion, use of artificial nitrogen fertilizers, and release of nitrogen in wastewater have dramatically altered the global nitrogen cycle.

The Nitrogen Cycle



- Fixation - **Nitrogen fixation**

Atmospheric nitrogen must be processed, or "fixed", in a usable form to be taken up by plants.

Between $5x10^{12}$ and $10x10^{12}$ g per year are fixed by lightning strikes, but most fixation is done by free-living orsymbiotic bacteria known as diazotrophs.

These bacteria have the nitrogenase enzyme that combines gaseous nitrogen with hydrogen to produce ammonia, which is converted by the bacteria into other organic compounds.

fixation, ammonification, nitrification, and denitrification.

- Fixation - **Nitrogen fixation**

Most biological nitrogen fixation occurs by the activity of Mo-nitrogenase, found in a wide variety of bacteria and some Archaea. Mo-nitrogenase is a complex two component enzyme that has multiple metal-containing prosthetic groups.[3] An example of the free-living bacteria is *Azotobacter*. Symbiotic nitrogen-fixing bacteria such as *Rhizobium* usually live in the root nodules of legumes (such as peas, alfalfa, and locust trees).

fixation, ammonification, nitrification, and denitrification.

- **ammonification –**
- When a plant or animal dies or an animal expels waste (in the form of gas), the initial form of nitrogen is organic.
- Bacteria or fungi convert the organic nitrogen within the remains back into ammonium (NH_4^+), a process called ammonification or mineralization.
- Enzymes involved are:
  - GS: Gln Synthetase (Cytosolic & Plastic)
  - GOGAT: Glu 2-oxoglutarate aminotransferase (Ferredoxin & NADH dependent)
  - GDH: Glu Dehydrogenase:
    - Minor Role in ammonium assimilation.
    - Important in amino acid catabolism.

fixation, ammonification, nitrification, and denitrification.

- The conversion of ammonium to nitrate is performed primarily by soil-living bacteria and other nitrifying bacteria.
- In the primary stage of nitrification, the oxidation of ammonium (NH_4^+) is performed by bacteria such as the *Nitrosomonas* species, which converts ammonia to nitrites (NO_2^-). Other bacterial species such as *Nitrobacter*, are responsible for the oxidation of the nitrites into nitrates (NO_3^-).[5] It is important for the ammonia to be converted to nitrates or nitrites because ammonia gas is toxic to plants.

Nitrification

- Due to their very high solubility and because soils are highly unable to retain anions, nitrates can enter groundwater.
- Elevated nitrate in groundwater is a concern for drinking water use because nitrate can interfere with blood-oxygen levels in infants and cause methemoglobinemia or blue-baby syndrome.[7][8]

Nitrification

- Where groundwater recharges stream flow, nitrate-enriched groundwater can contribute to eutrophication, a process that leads to high algal population and growth, especially blue-green algal populations.
- While not directly toxic to fish life, like ammonia, nitrate can have indirect effects on fish if it contributes to this eutrophication.

Nitrification

- Nitrogen has contributed to severe eutrophication problems in some water bodies.
- Since 2006, the application of nitrogen fertilizer has been increasingly controlled in Britain and the United States.
- This is occurring along the same lines as control of phosphorus fertilizer, restriction of which is normally considered essential to the recovery of contaminated waterbodies.

Nitrification

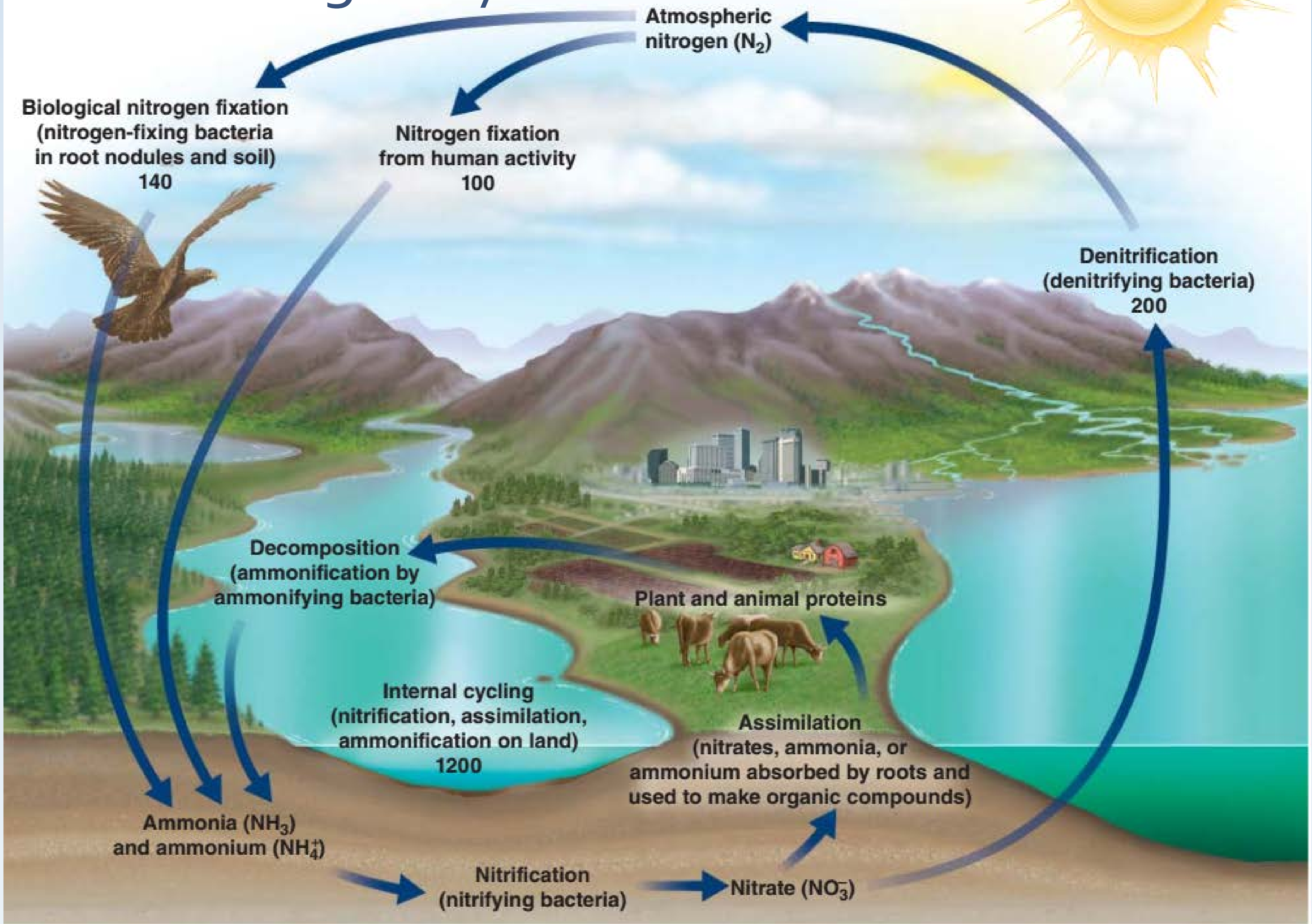
- Denitrification is the reduction of nitrates back into nitrogen gas (N_2), completing the nitrogen cycle.
- This process is performed by bacterial species such as *Pseudomonas* and *Clostridium* in anaerobic conditions.
- They use the nitrate as an electron acceptor in the place of oxygen during respiration.

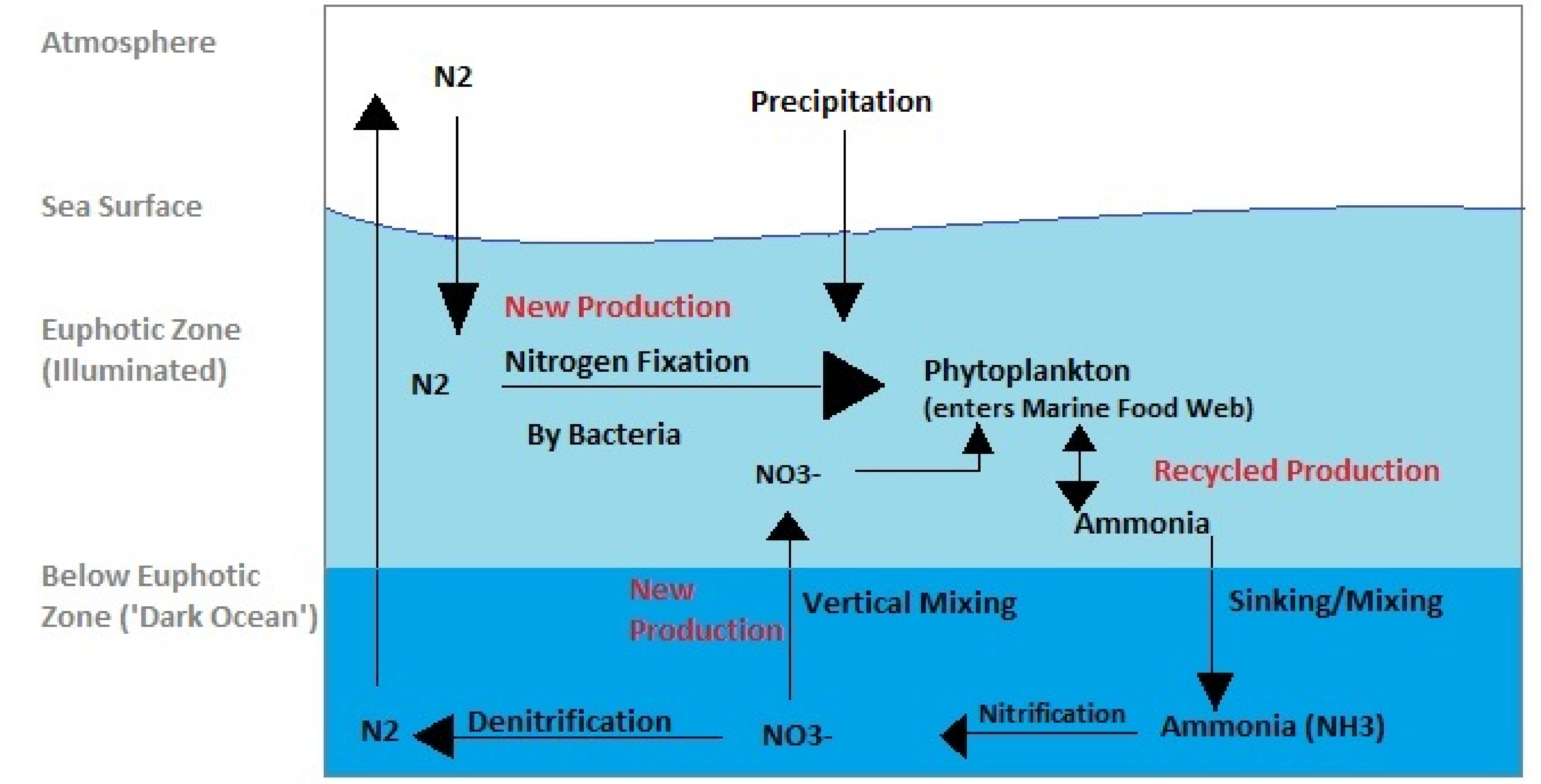
Denitrification

- These facultatively anaerobic bacteria can also live in aerobic conditions.
- Denitrification happens in anaerobic conditions e.g. waterlogged soils.
- The denitrifying bacteria use nitrates in the soil to carry out respiration and consequently produce nitrogen gas, which is inert and unavailable to plants.

Denitrification

The Nitrogen Cycle





The Nitrogen Cycle in the Ocean

- From a systems perspective, human activities have disturbed the balance of the global nitrogen cycle.
- During the 20th century, humans doubled the amount of fixed nitrogen entering the global nitrogen cycle, primarily through the application of fertilizer composed of fixed nitrogen.
- Several lines of scientific evidence suggest that terrestrial ecosystems enriched with nitrogen have fewer plant species than unenriched terrestrial ecosystems.

Human-Induced Changes to the Nitrogen Cycle

- Precipitation washes nitrogen fertilizer into rivers, lakes, and coastal areas, where it stimulates the growth of algae.
- As these algae die, their decomposition by bacteria robs the water of dissolved oxygen, which in turn causes many fishes and other aquatic organisms to die of suffocation.
- An excess of nitrogen and other nutrients from fertilizer runoff has caused large oxygen-depleted dead zones in about 150 coastal areas around the world.

Human-Induced Changes to the Nitrogen Cycle

- In addition, nitrates from fertilizer can leach (dissolve and wash down) through the soil and contaminate groundwater.
- Many people drink groundwater, and nitrate-contaminated groundwater is dangerous to drink, particularly for infants and small children.

Human-Induced Changes to the Nitrogen Cycle

- Nitrate reduces the oxygen-carrying capacity of a child’s blood.
- Another human activity that affects the nitrogen cycle is the combustion of fossil fuels. When fossil fuels are burned—in automobiles, for example—the high temperatures of combustion convert some atmospheric nitrogen to nitrogen oxides, which produce photochemical smog, a mixture of air pollutants that injures plant tissues, irritates eyes, and causes respiratory problems.

Human-Induced Changes to the Nitrogen Cycle

- Nitrogen oxides react with water in the atmosphere to form acids that leave the atmosphere as acid deposition and cause the pH of surface waters (lakes and streams) and soils to decrease.
- Acid deposition is linked to declining plant and animal populations in aquatic ecosystems and altered soil chemistry on land.

Human-Induced Changes to the Nitrogen Cycle