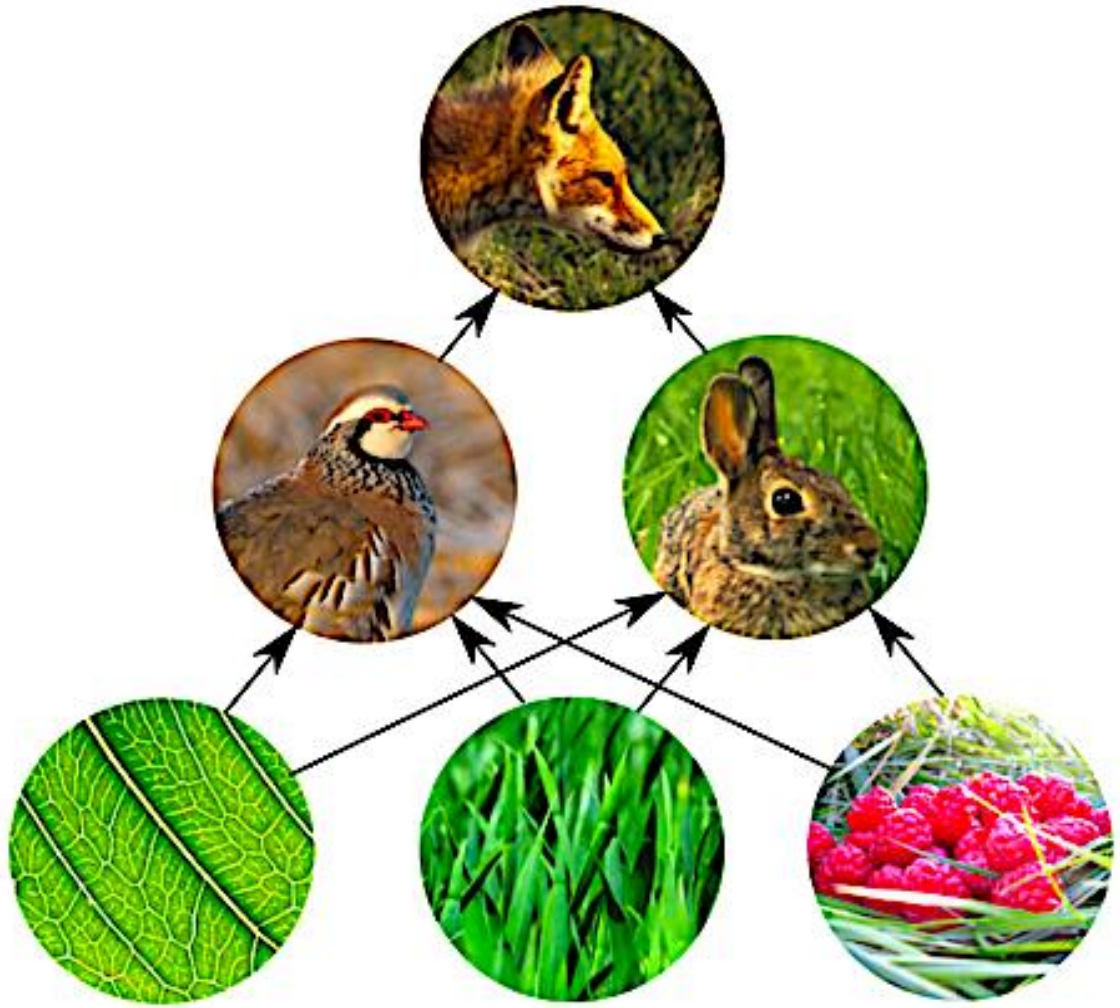
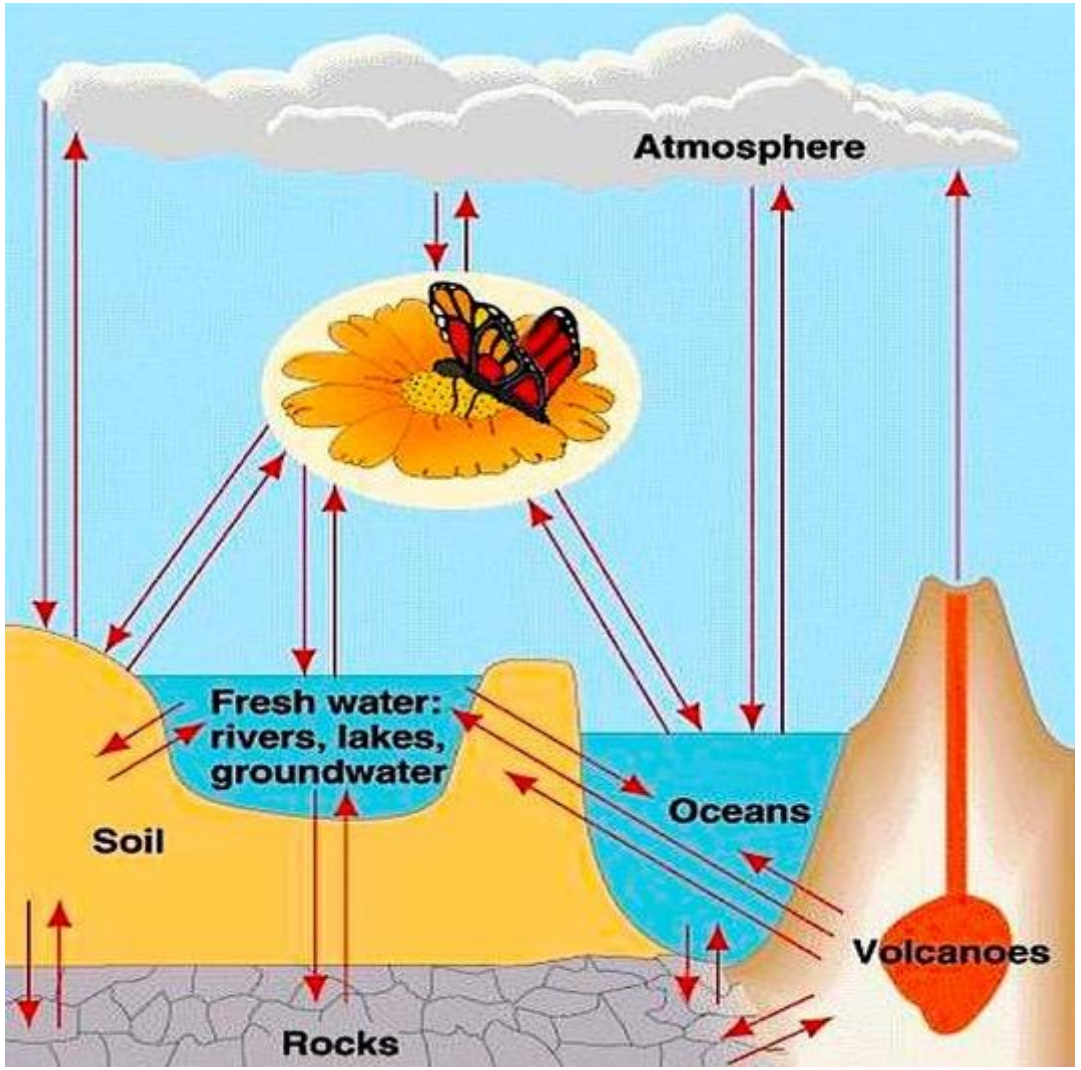
Energy Flow & Biogeochemical Cycling

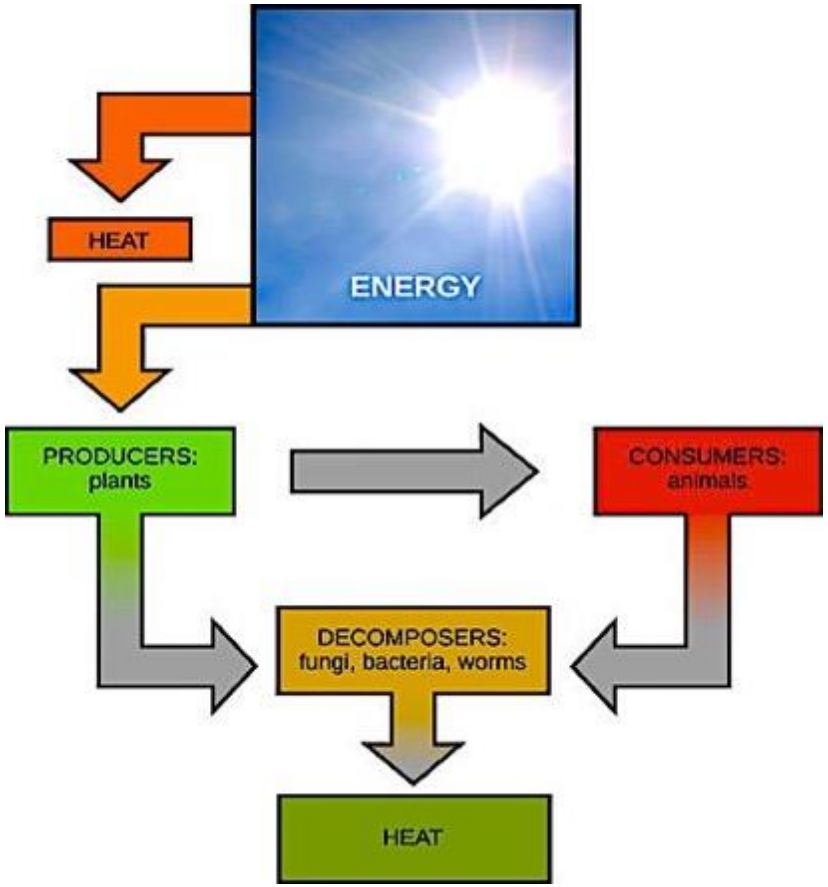




Energy Flow

The matter of life constantly cycles, but the energy from the sun flows in only one direction.

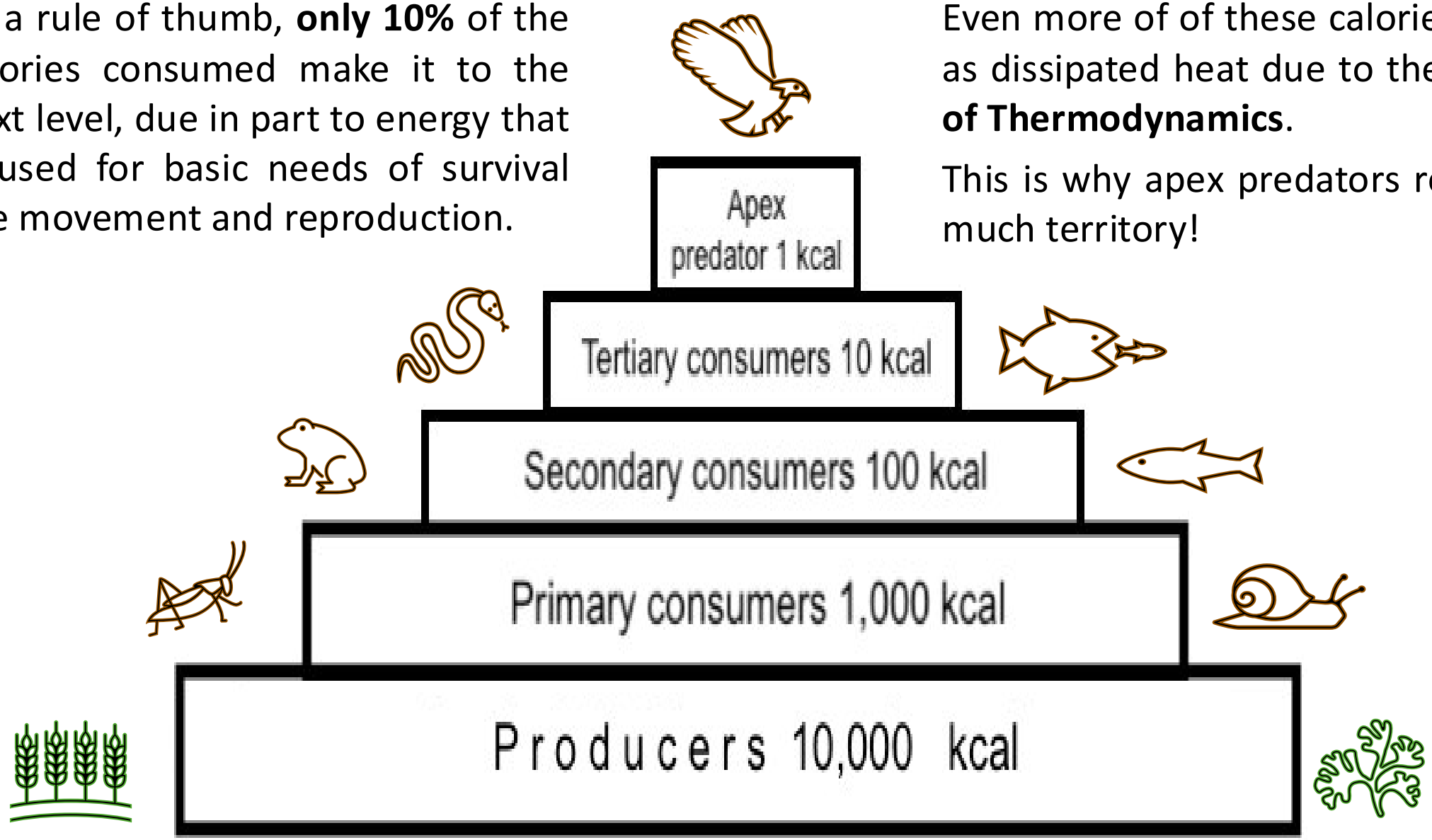
Producers directly use sunlight energy to generate the chemical energy that drives the cycling of matter in the ecosystem.



From “Environmental Issues” by Andrew Frank https://pressbooks.bccampus.ca/environmentalissues/front-matter/introduction/

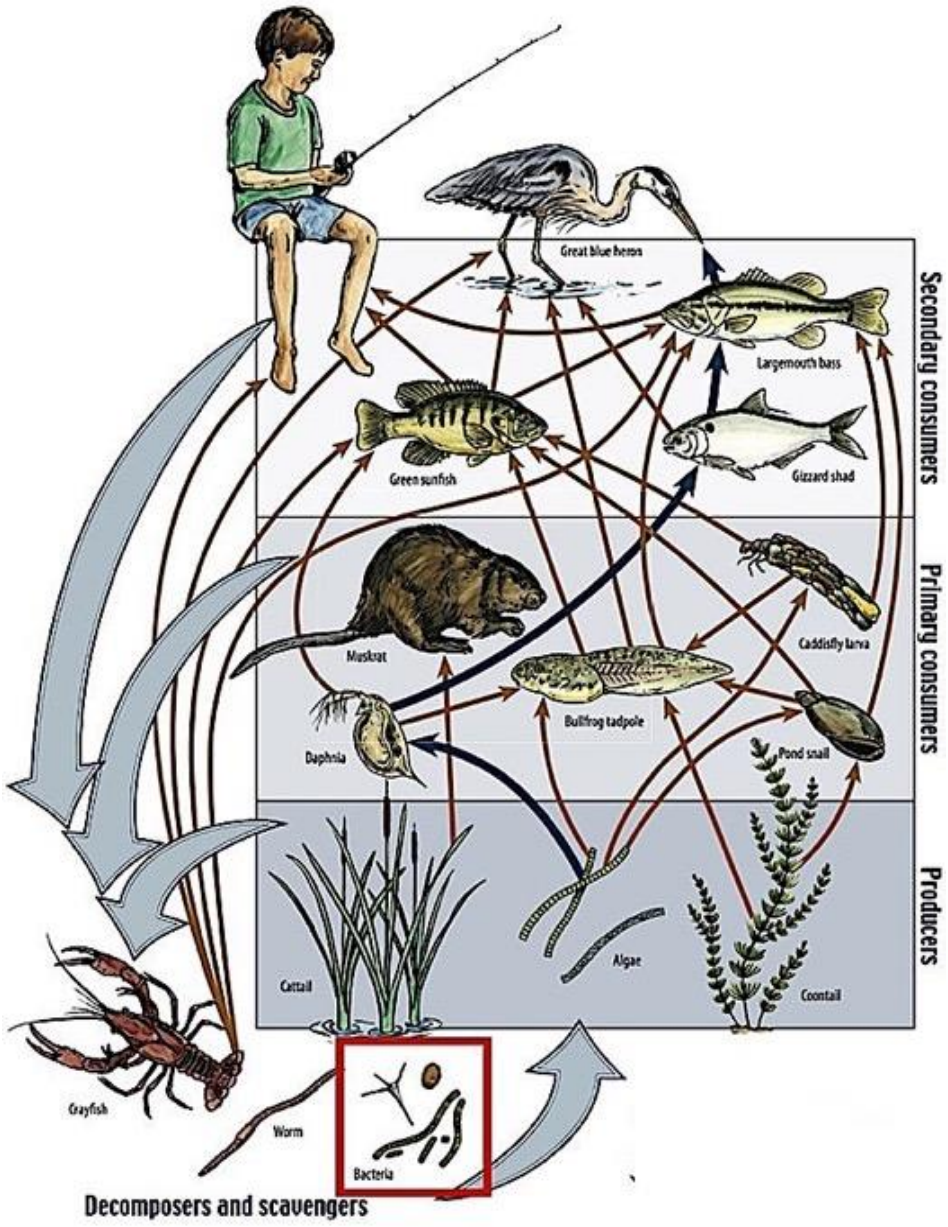
The Trophic Pyramid

As a rule of thumb, **only 10%** of the calories consumed make it to the next level, due in part to energy that is used for basic needs of survival like movement and reproduction.



Even more of of these calories end up as dissipated heat due to the **2nd Law of Thermodynamics**.

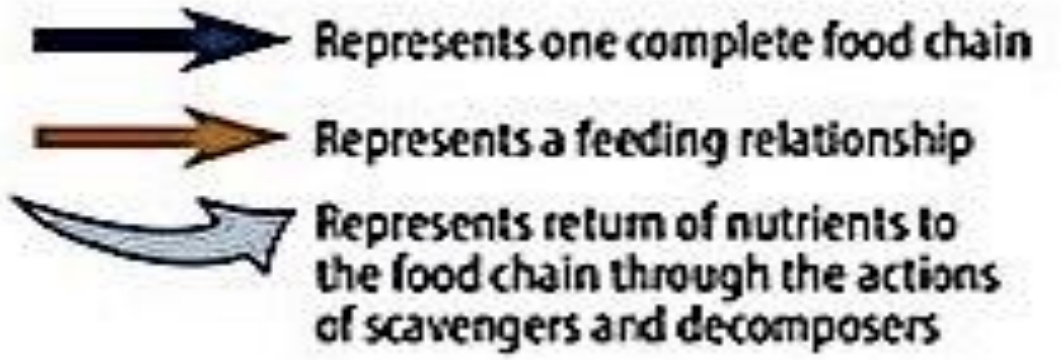
This is why apex predators require so much territory!



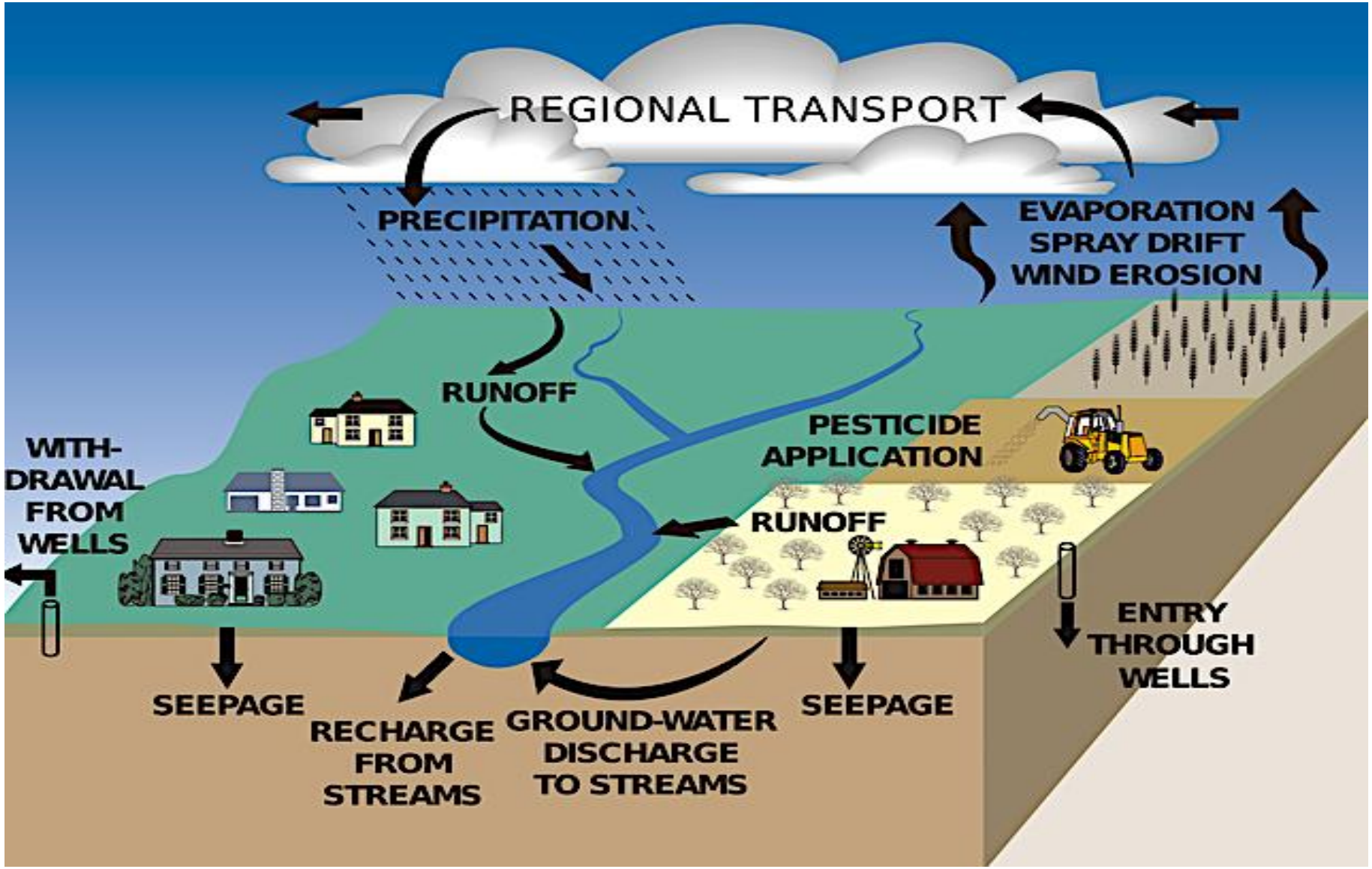
The trophic pyramid is useful for determining how much producers need to produce in order to maintain a diverse ecosystem that can accommodate apex predators.

But the reality is more complicated because many participants (like the bullfrog tadpole) consume at multiple levels of the pyramid. Consequently, the "**food web**" provides a more comprehensive image of energy flow in the ecosystem.

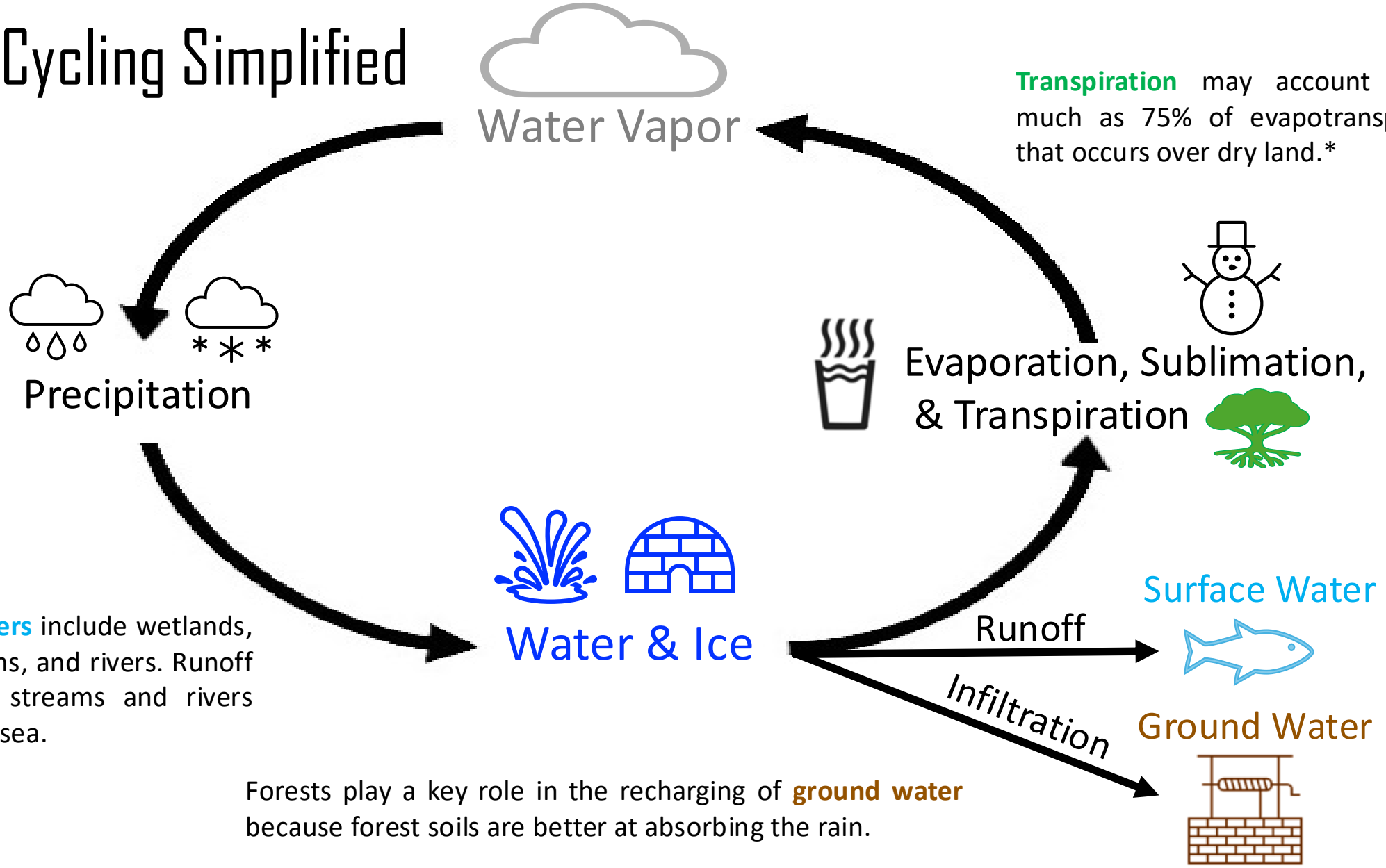
All nutrients are eventually broken down and "recycled" with the help of decomposers and scavengers.



The Biogeochemical Cycling of Water



Water Cycling Simplified



Transpiration may account for as much as 75% of evapotranspiration that occurs over dry land.*

Surface waters include wetlands, lakes, streams, and rivers. Runoff that enters streams and rivers flows to the sea.

Forests play a key role in the recharging of **ground water** because forest soils are better at absorbing the rain.

*Information from CID Bio-Science: https://cid-inc.com/blog/transpiration-in-plants-its-importance-and-applications/

Changes to the Earth's surface such as deforestation and the laying down of pavement **increases runoff at the expense of infiltration**.

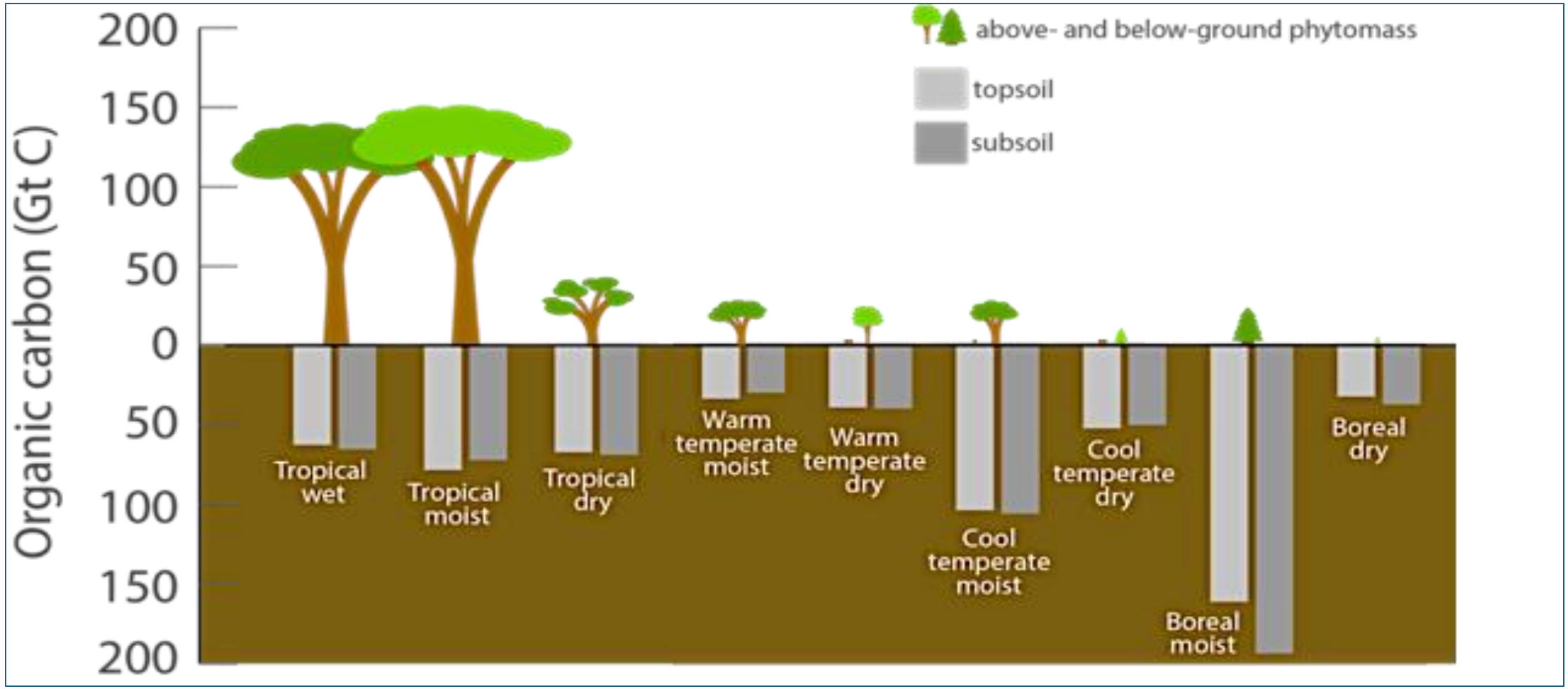
In the short run, this causes **erosion and flooding**.

In the long run, the **decline in ground water recharge** from forest soils combined with **transpiration** losses from a lack of trees results in drier climate and **lower water table**.

The Biogeochemical Cycling of Carbon

The Joseph Priestley experiment demonstrating the relationship between respiration and photosynthesis in the 1770's.

Most of the world's total carbon is stored in rocks and marine sediments, but most *organic* carbon comes from the biomass of producers.



Organic Carbon Storage by Different Terrestrial Ecosystems https://www.fs.usda.gov/research/treesearch/54316

Biological Cycling of Carbon

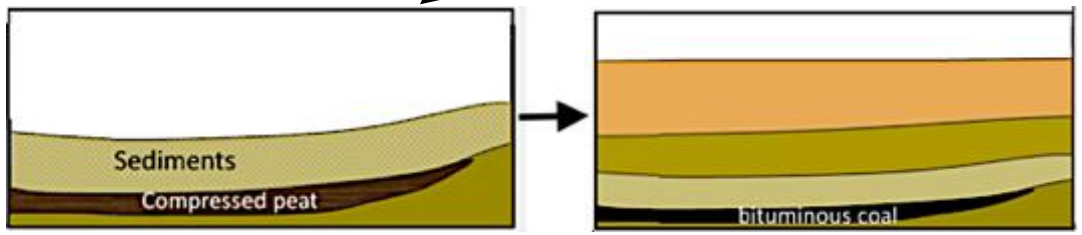

Respiration & Combustion

CO_2

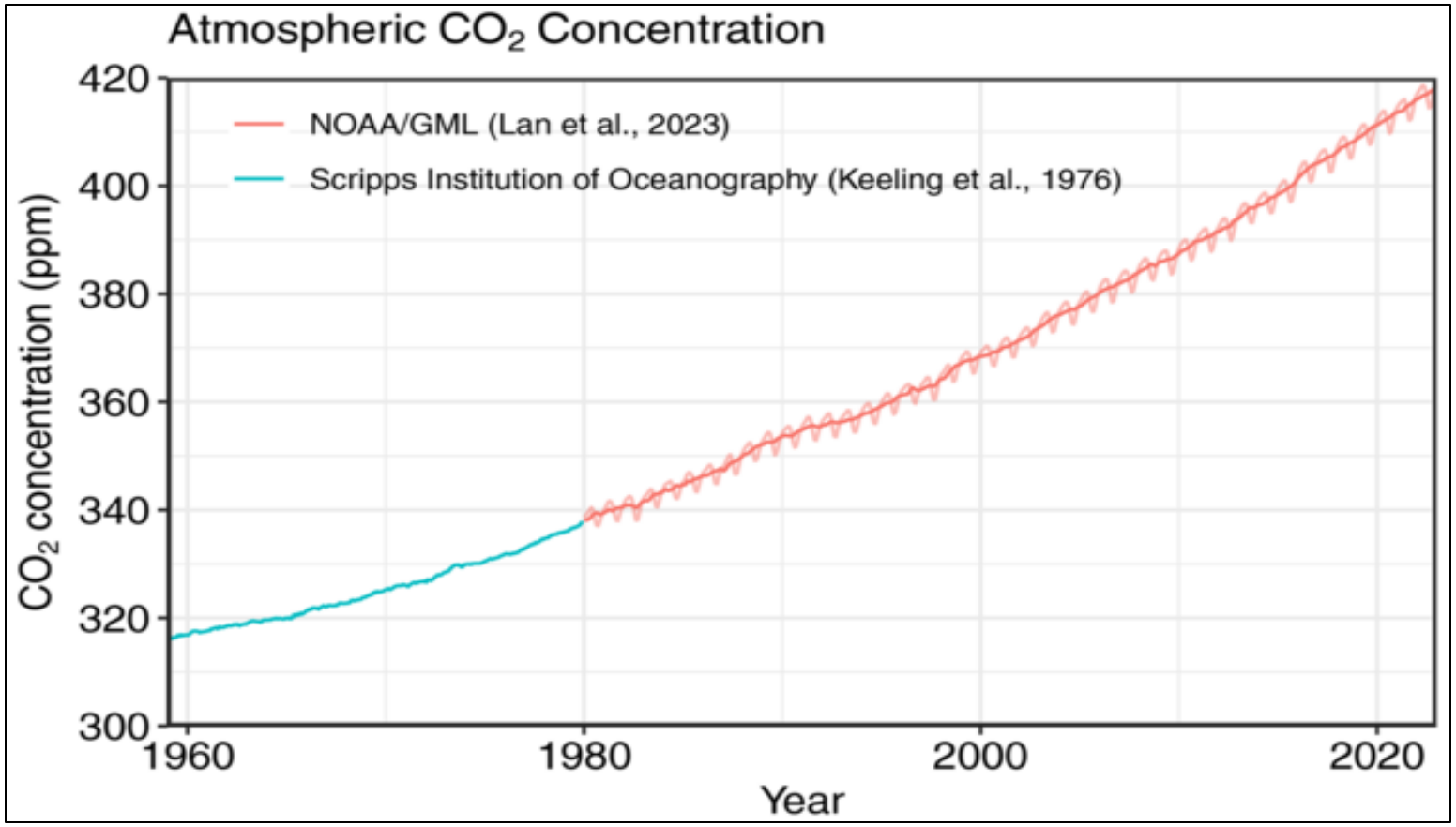

Photosynthesis

Organic Molecules

Over millions of years and under the right conditions, a small portion of this biomass is transformed into fossil fuels.

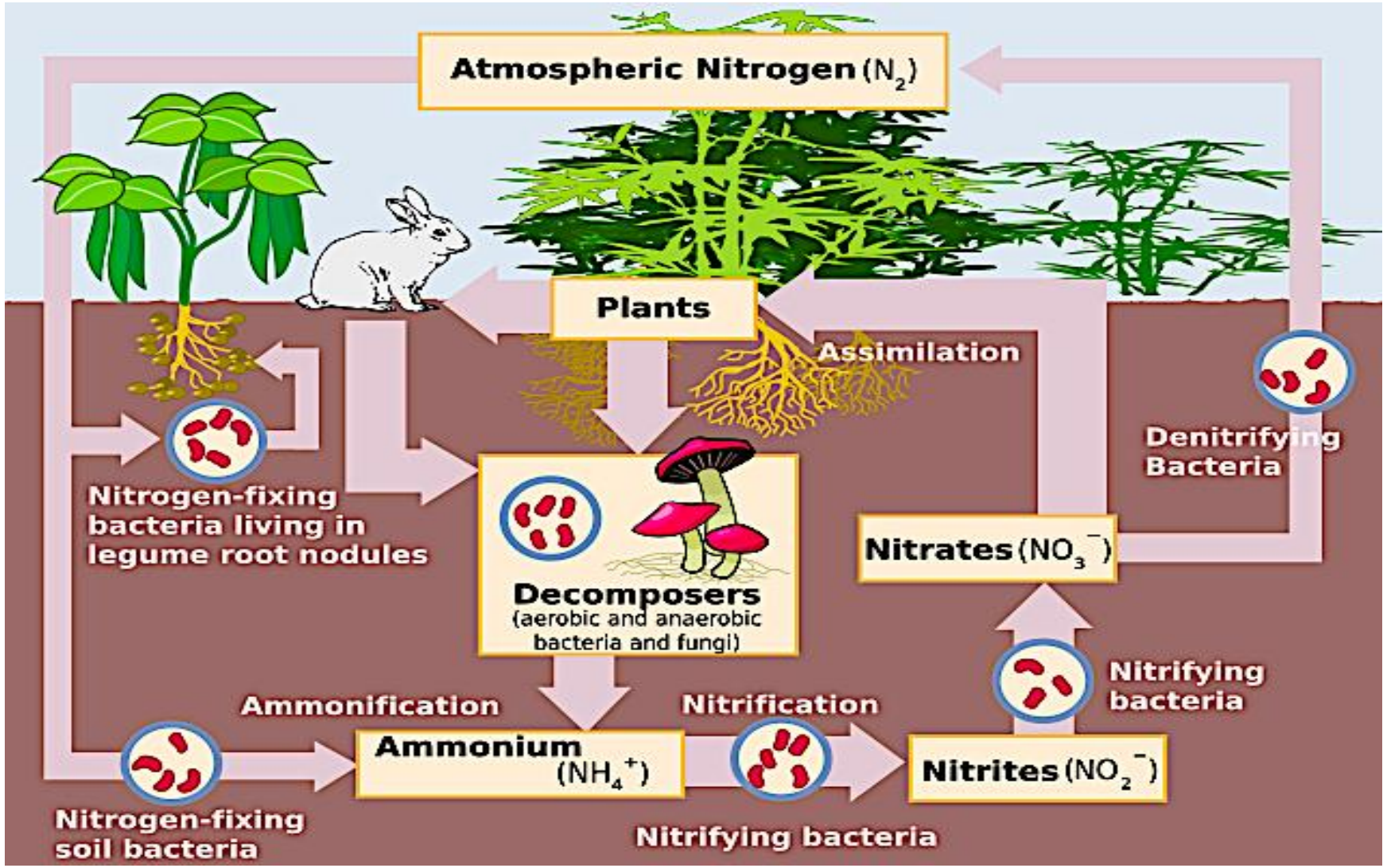


Is human activity now affecting the *global* climate?



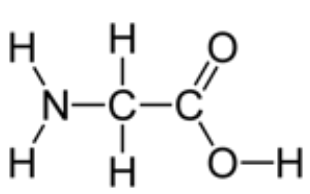
There are concerns that burning of fossil fuels and deforestation are contributing to rising levels of carbon dioxide, and that this greenhouse gas is playing a significant role in overall warming of the climate. This is addressed in greater depth in a later chapter.

The Biogeochemical Cycling of Nitrogen

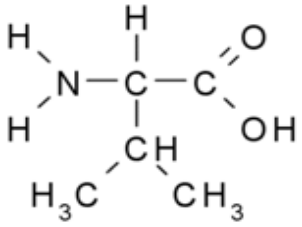


Nitrogen enters the ecosystem from above.

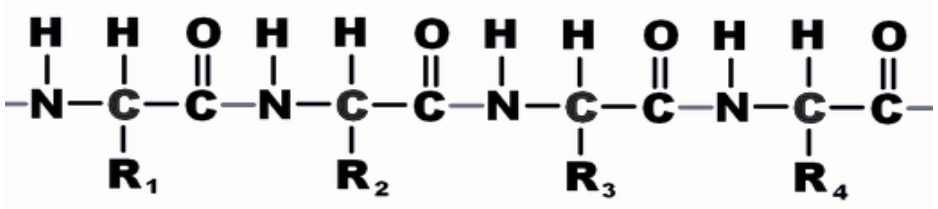
- The main source of nitrogen is the atmosphere.
- Nitrogen is a key element in organic molecules like amino acids and **proteins**.



Glycine

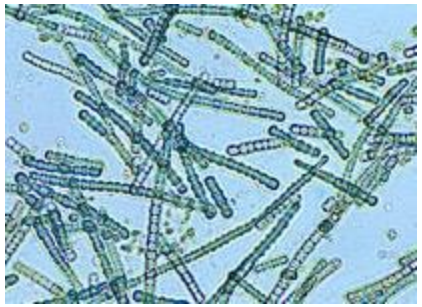


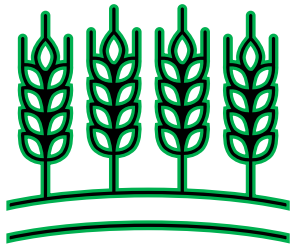
Valine

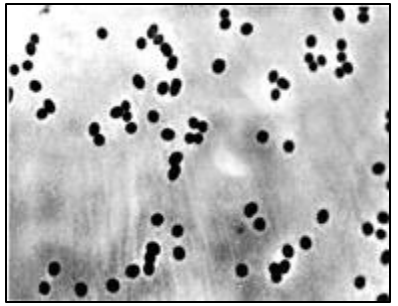


Amino Acid Chain

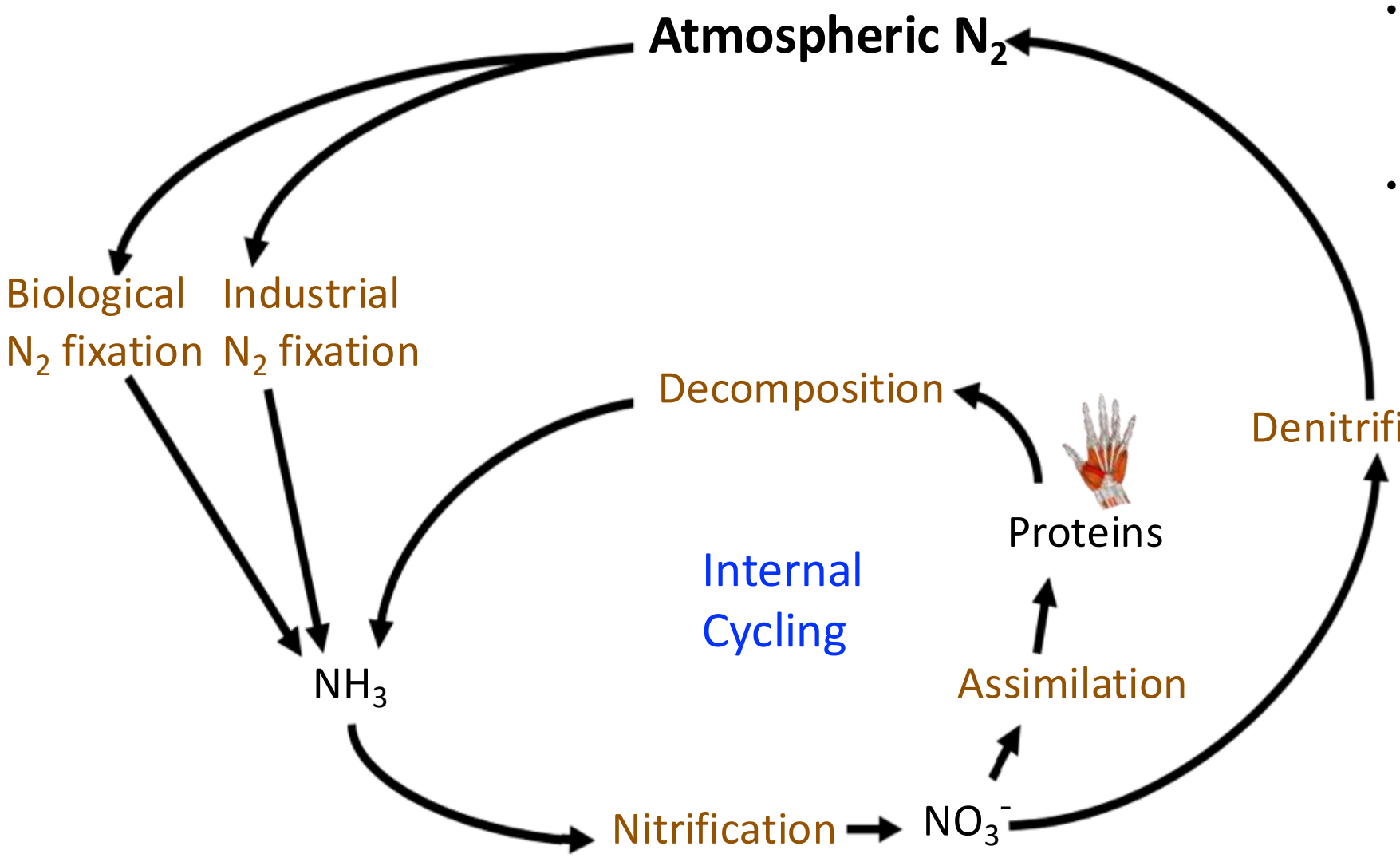
- Nitrogen enters the ecosystem **via nitrogen-fixing bacteria** and blue-green algae that use it to make **ammonia** (NH_3).
- Producers assimilate the nitrogen from this compound into their macromolecules after the NH_3 is chemically transformed into **nitrate** (NO_3^-) by **nitrifying bacteria**.







Nitrogen Cycling Simplified



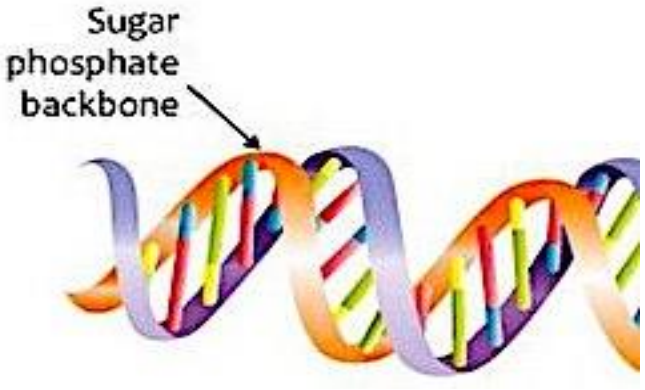
- Nitrogen is used to generate ammonia through both natural and industrial processes.
- Ammonia is toxic to most organisms, so it must be converted into nitrate before it can be assimilated by the producers.

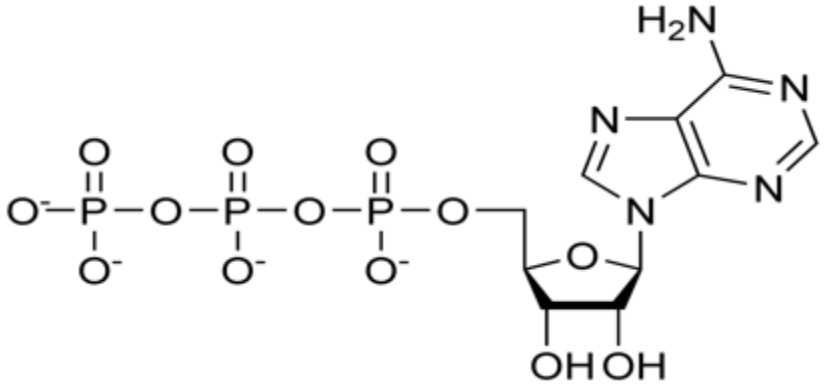
- The protein building blocks in all consumers originally came from producers.
- Ammonia is a by-product of protein decomposition.
- Denitrification breaks down nitrate and returns the nitrogen to the air. This is done by anaerobic bacteria.

The Biogeochemical Cycling of Phosphorous

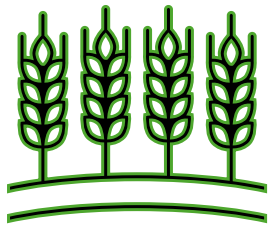
Phosphorus enters the ecosystem from below.

- The main sources of phosphorous are **rocks and sediments**.
- Phosphorus is a key element in macromolecules like **nucleic acids** and **ATP**.

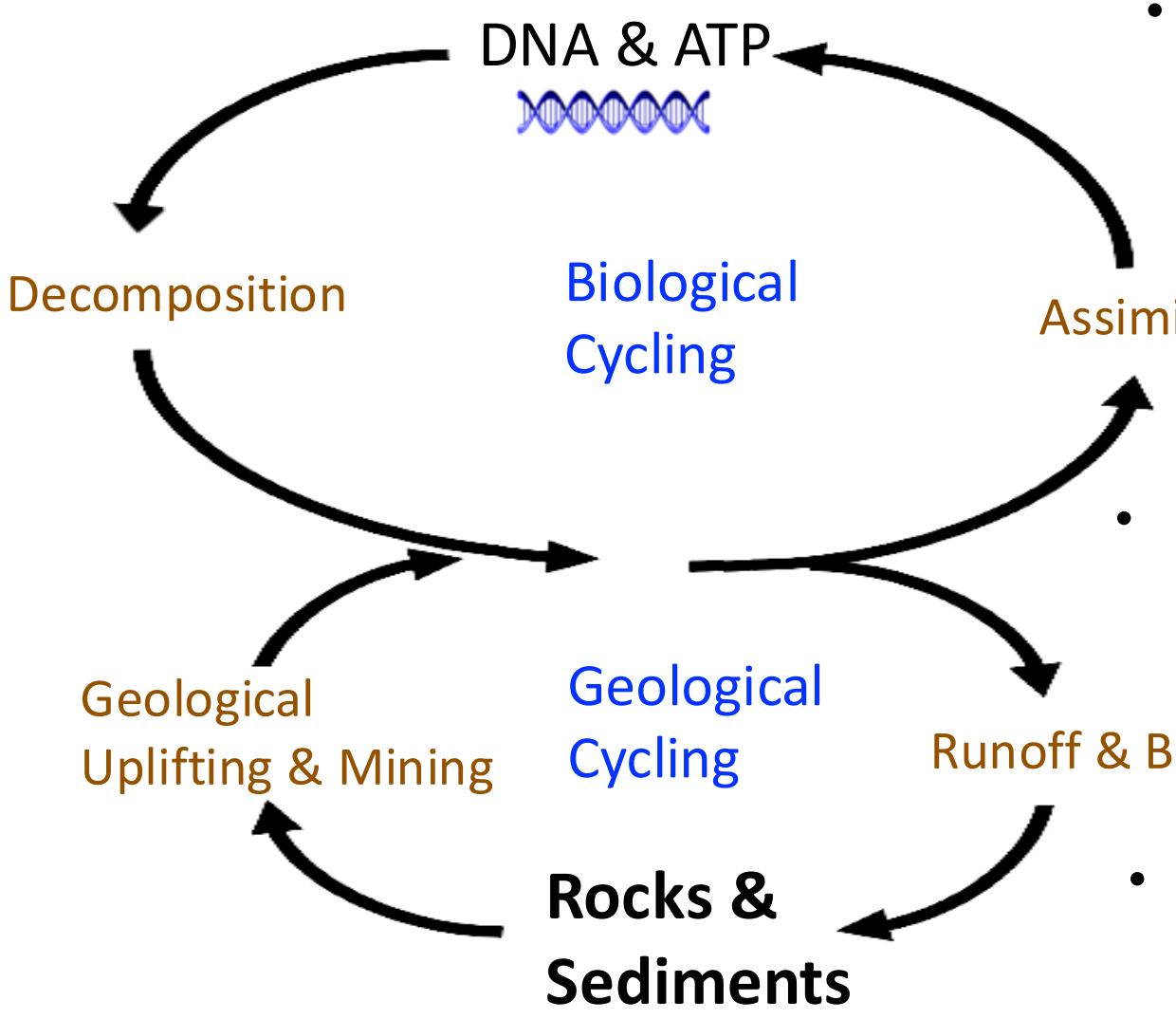




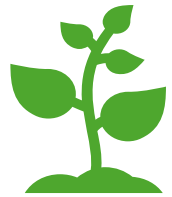
- **Phosphorous enters the ecosystem via producers** that directly assimilate phosphorous from the soil or water into their macromolecules.



Phosphorous Cycling Simplified



- Phosphorous enters the ecosystem through volcanic emissions, Earthquakes, and phosphate mining.



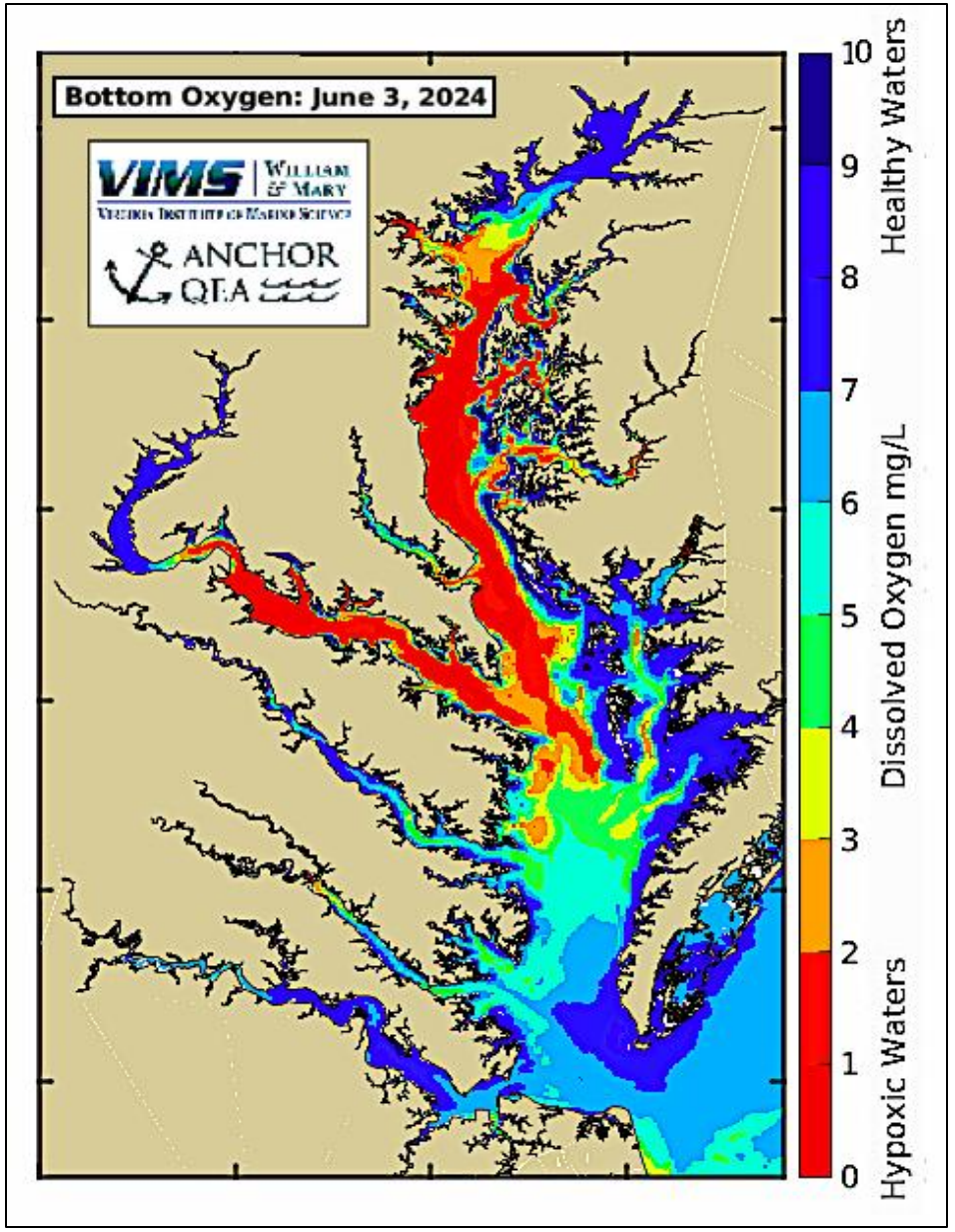
- The phosphorous in all consumers originally came from producers.

- Phosphorous can leave the ecosystem through soil erosion.

Early explorers to the New World marveled at the biodiversity and transparency of the Chesapeake. Shortly after his arrival in 1607 Englishman George Percy described oyster reefs "as thick as stones," and in 1608 Captain John Smith described this estuary as "full of "*sturgeon, grampus, porpoise, seals, stingrays … brits, mullets, white salmon [rockfish], trouts, soles, perch of three sorts*."*

We know today that oysters played a central role maintaining the water clarity that allowed seagrasses to thrive and support the diverse community described by Captain John Smith.

* Incolarum Virginiae piscandi ratio (The Method of Fishing of the Inhabitants of Virginia), c. 1590.
https://encyclopediavirginia.org/wp-content/uploads/2020/11/213hpr_c527f0b8feabb40.jpg



Today Chesapeake waters are murky due to overharvesting of oysters and nutrient pollution from chemical fertilizers and urban runoff.

These excess levels of phosphate and nitrates result in algae blooms that generate “dead zones” of low dissolved oxygen during the summer months. Making matters worse, oyster populations are now less than 1% of original levels. This greatly limits their role in curbing these population explosions of phytoplankton.

Map downloaded from the Virginia Institute of Marine Science: https://www.vims.edu/research/products/cbefs/cbay/
Map based on research by Beaver et al., 2021: https://www.sciencedirect.com/science/article/pii/S136481522100079?via%3Dihub

Review Questions

1. What process makes atmospheric nitrogen available to plants?

   a) Nitrification
   b) Denitrification
   c) Nitrogen fixing
   d) Assimilation

Review Questions

2. What process involves the uptake of nitrate by plants?

a) Nitrification
b) Denitrification
c) Nitrogen fixing
d) Assimilation

Review Questions

3. Which organic molecule releases ammonia when it decomposes?

a) Nitrate
b) Protein
c) ATP
d) DNA

Review Questions

4. What process makes inorganic phosphorus (from rocks) available for biological cycling?

a) Geological uplifting
b) Decomposition
c) Runoff
d) Assimilation

Review Questions

5. Which macromolecule contains phosphorus?

a) DNA
b) Starch
c) Protein
d) Fat

Review Questions

7. What cycle can take place in the absence of decomposers?

a) Phosphorous Cycle
b) Nitrogen Cycle
c) Carbon Cycle
d) None of these

Review Questions

8. What cycle can take place in the absence of producers?

a) Phosphorous Cycle
b) Nitrogen Cycle
c) Carbon Cycle
d) None of these

Acknowledgement:

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