Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

Enduring understanding 2.A: Growth, reproduction and maintenance of the organization of living systems require free energy and matter.

Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

a. Molecules and atoms from the environment are necessary to build new molecules.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Carbon moves from the environment to organisms where it is used to build carbohydrates, proteins, lipids or nucleic acids. Carbon is used in storage compounds and cell formation in all organisms.

A Little Background First

Ecosystems

Remember: Physical laws control energy flow and chemical cycling.

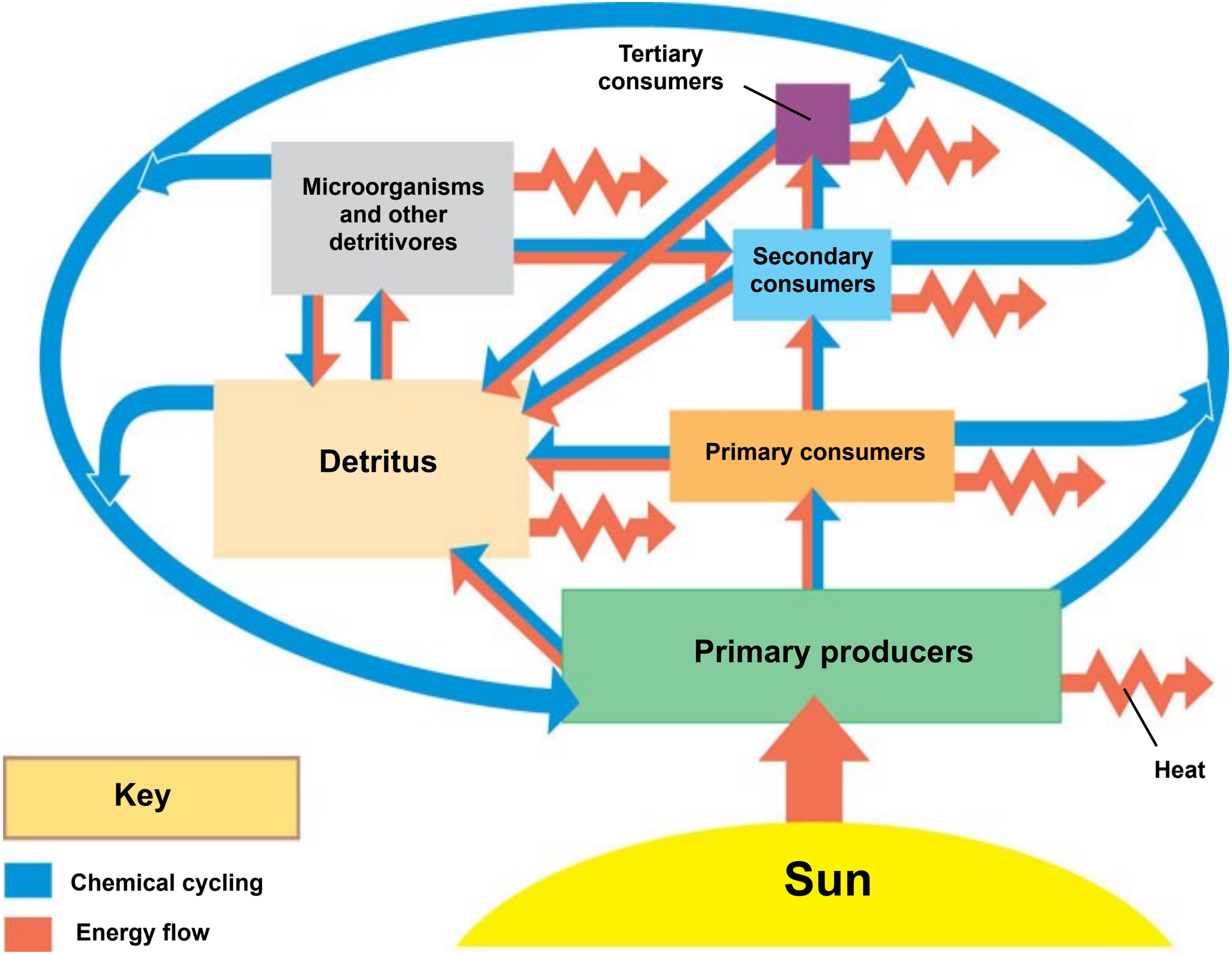
Remember: Energy *flows through* ecosystems.

Main Idea: Chemicals (matter) *cycles within* ecosystems.

PHYSICAL LAWS GOVERN ENERGY FLOW & CHEMICAL CYCLING IN ECOSYSTEMS

Conservation of Mass

- **Law of Conservation of Mass**: like energy, matter can not be created or destroyed.
  - Very little matter enters earth from space.
  - Thus the matter on *earth* is constant. Matter has been, is and will continue to be recycled over time.
  - Be Careful! Matter can be gained and lost from *ecosystems* themselves.


Tertiary consumers
Microorganisms and other detritivores
Secondary consumers
Detritus
Primary consumers
Primary producers
Heat
Sun
Key
Chemical cycling
Energy flow

- **Decomposers/Detrivores** consume **Detritus**, nonliving organic material (dead organisms and feces)

- Two most significant and important decomposers are Fungi and Bacteria

- They play a critical role in recycling matter...decomposers convert organic material into inorganic material that producers can then uptake and reuse. (recycled back into the ecosystem)

  - Consider This! If decomposition stopped detritus would build up and life would not exist


Shelf Fungi


Compost

OK NOW BACK TO THIS IDEA

Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

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Evidence of student learning is a demonstrated understanding of each of the following:

1. Carbon moves from the environment to organisms where it is used to build carbohydrates, proteins, lipids or nucleic acids. Carbon is used in storage compounds and cell formation in all organisms.

Ecosystems

Main Idea: Most ecosystems receive an abundant supply of solar energy but chemical elements are they usually limited.

Main Idea: Solar energy is continually bombarding the earth but chemical elements on earth are finite and must be recycled.

BIOGEOCHEMICAL PROCESSES CYCLE NUTRIENTS AND WATER IN ECOSYSTEMS

- Nutrients are recycled using both *biotic and abiotic* processes together, hence the name *biogeochemical cycles*.

Biogeochemical Cycles

- These cycles occur on both on a local and global level.
- The gaseous forms of nitrogen, oxygen, sulfur and carbon cycle on a more global level.
- A general look at cycles finds two key components:
  - A *Reservoir* (the location of the element)
  - A *Process* (the means of moving the element)

Biogeochemical Cycles

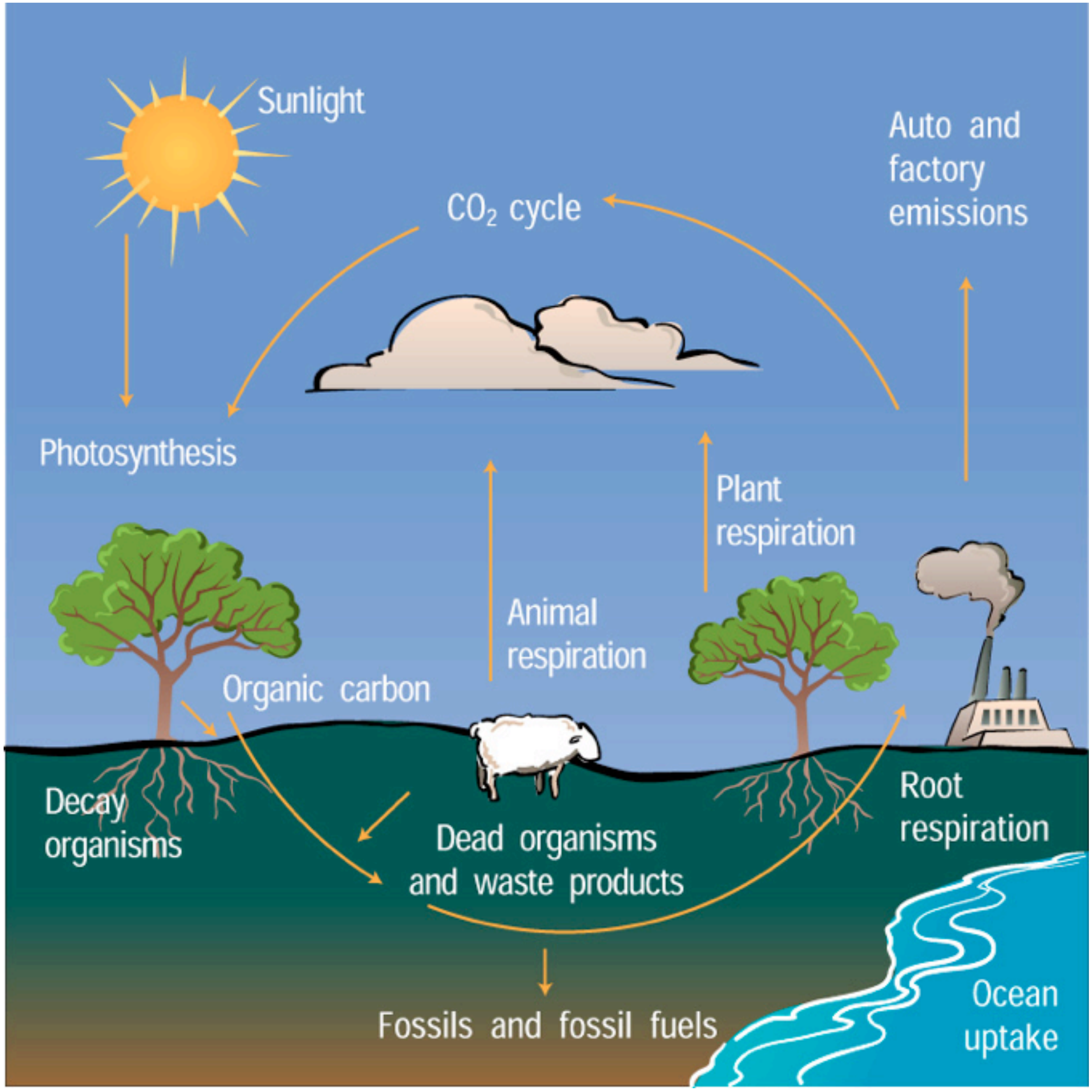
Biogeochemical Cycles

- A biogeochemical cycle is the complete path a chemical takes through the four major components of Earth's system.
  - Atmosphere
  - Hydrosphere
  - Lithosphere
  - Biosphere

Biogeochemical Cycles

- A biogeochemical cycle is the complete path a chemical takes through the four major components of Earth's system.
  - Atmosphere
  - Hydrosphere
  - Lithosphere
  - Biosphere
- Chemicals in the four major components have different average storage time
  - Long in lithosphere (rocks)
  - Short in the atmosphere
  - Intermediate in the hydrosphere and biosphere

CARBON CYCLE



BIOLOGICAL IMPORTANCE

- Carbon is the backbone of all organic compounds essential for life.

FORMS AVAILABLE TO LIFE

- CO_2 used by autotrophs, many other organic forms used by the rest of life.

RESERVOIRS

- Fossil fuels, sediments of aquatic ecosystems, dissolved carbon in oceans, plant/animal biomass, atmosphere, sedimentary rocks (the largest)

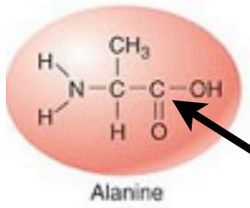
KEY PROCESSES

- Mainly photosynthesis and cellular respiration, burning of fossil fuels, volcanoes

These are the four large molecules that make up living organisms...carbon is the backbone of all of them

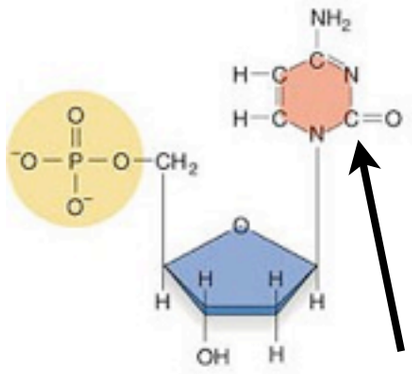
TABLE 4.1 MACROMOLECULES

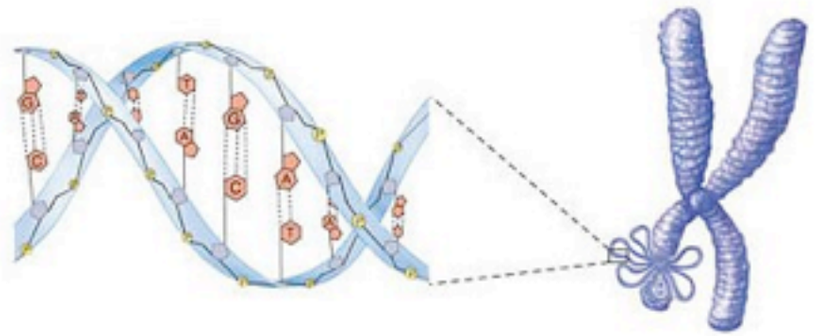
Monomer	Polymer	Cellular structure
Amino Acid	Polypeptide	Intermediate filament



C

Nucleotide	DNA strand	Chromosome





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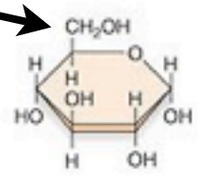
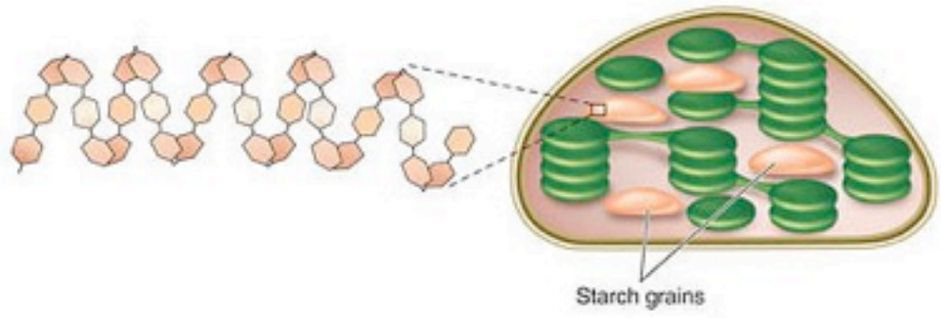
Monosaccharide	Starch	Starch grains in a chloroplast

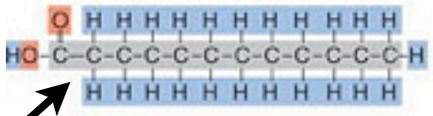
C

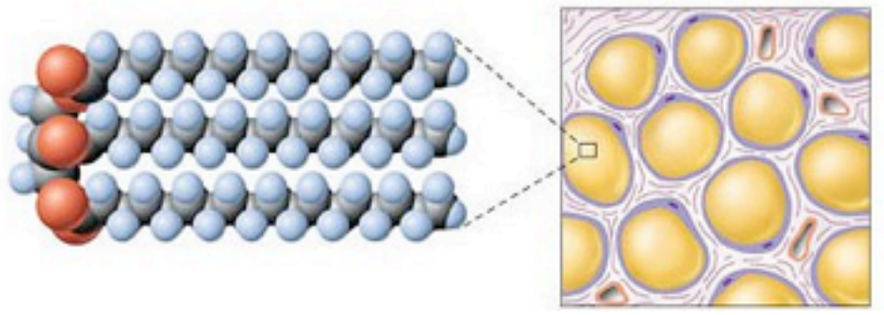




Fatty acid	Fat molecule	Adipose cells with fat droplets

C





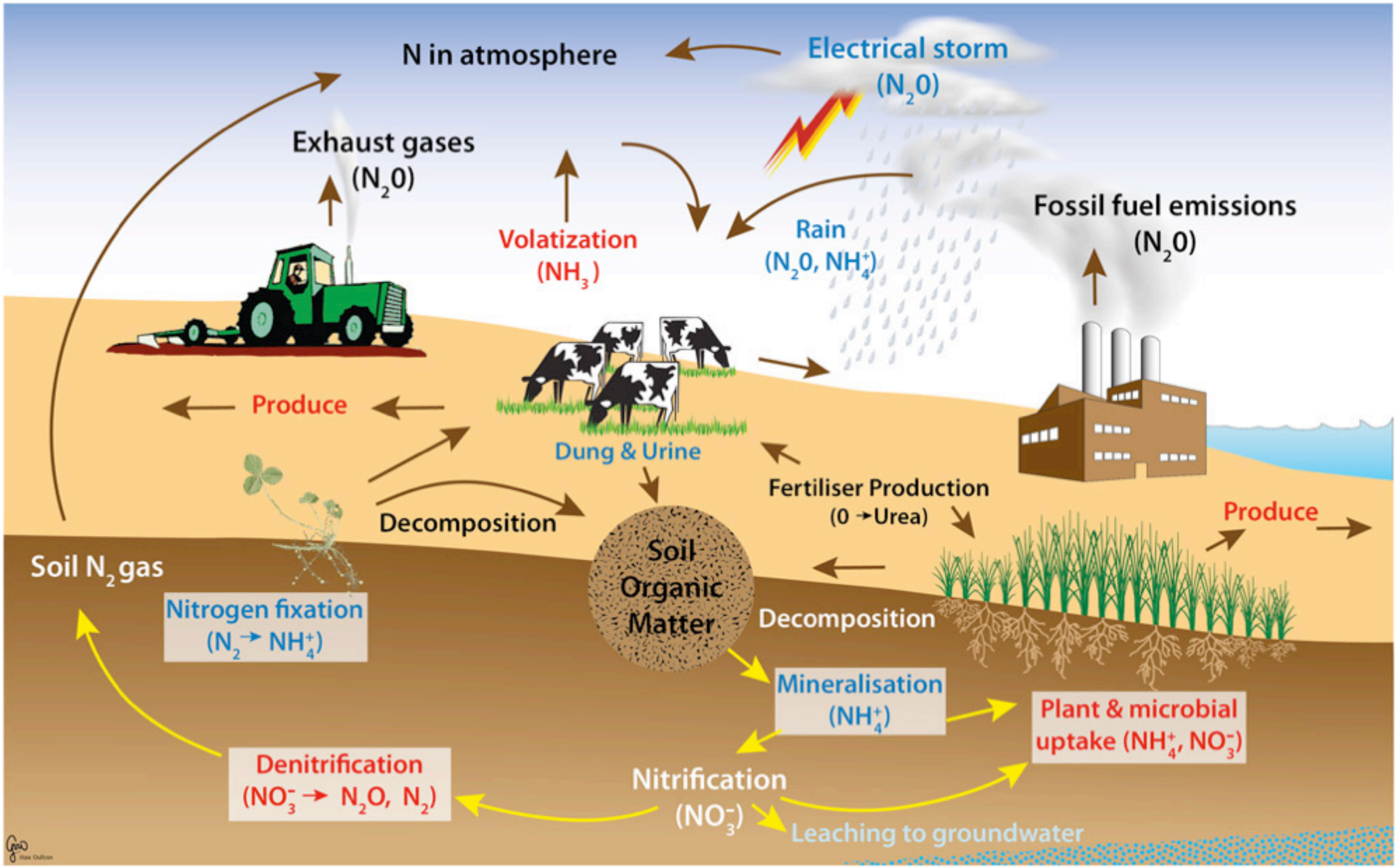
Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

a. Molecules and atoms from the environment are necessary to build new molecules.

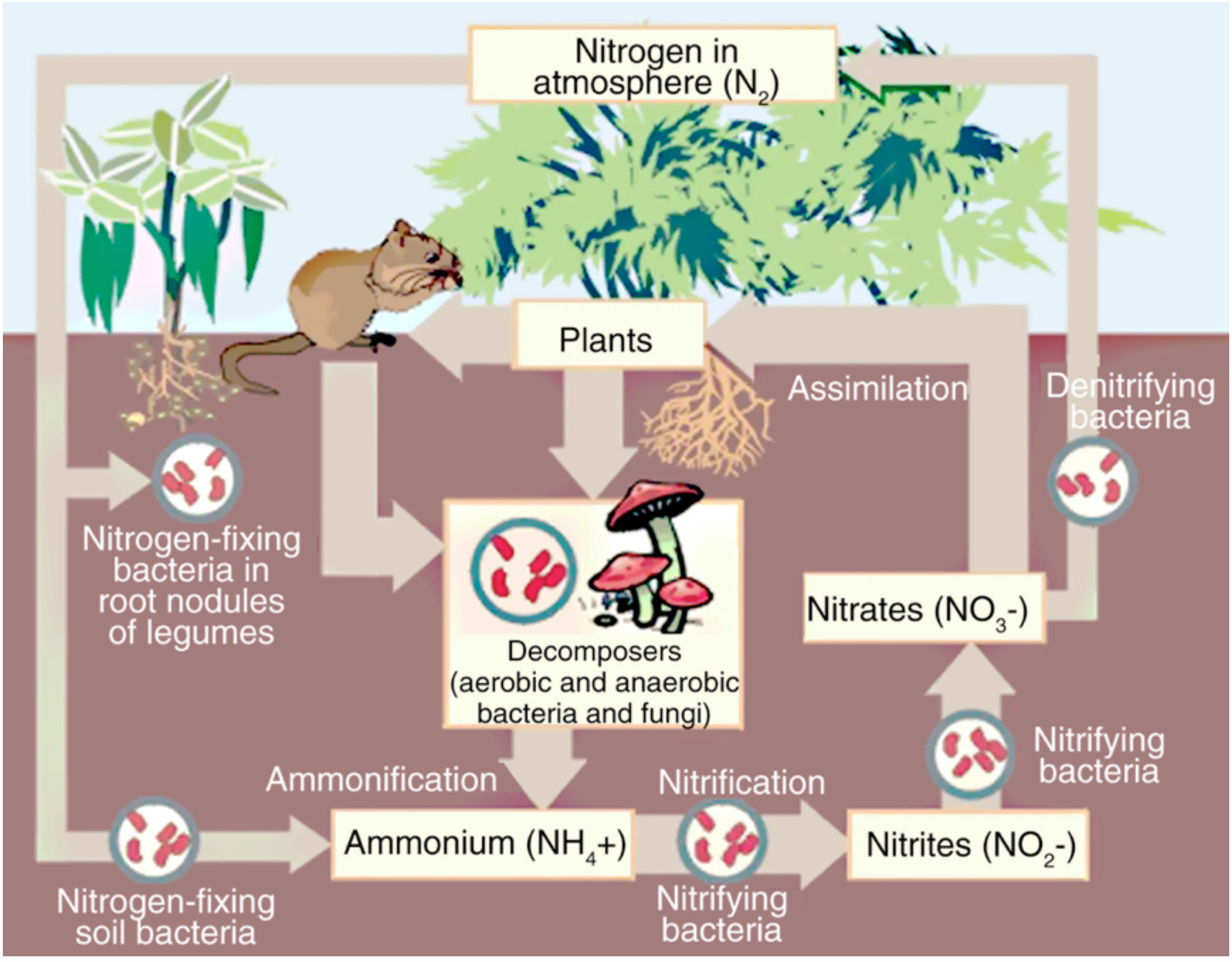
Evidence of student learning is a demonstrated understanding of each of the following:

2. Nitrogen moves from the environment to organisms where it is used in building proteins and nucleic acids. Phosphorus moves from the environment to organisms where it is used in nucleic acids and certain lipids.

NITROGEN CYCLE (abiotic +)



NITROGEN CYCLE (biotic focus)



BIOLOGICAL IMPORTANCE

- Nitrogen is an important part of proteins and nucleic acids.

FORMS AVAILABLE TO LIFE

- Bacteria can use ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-) and some organic forms. Plants use all of the above except nitrites (NO_2^-). Animals can only use organic forms.

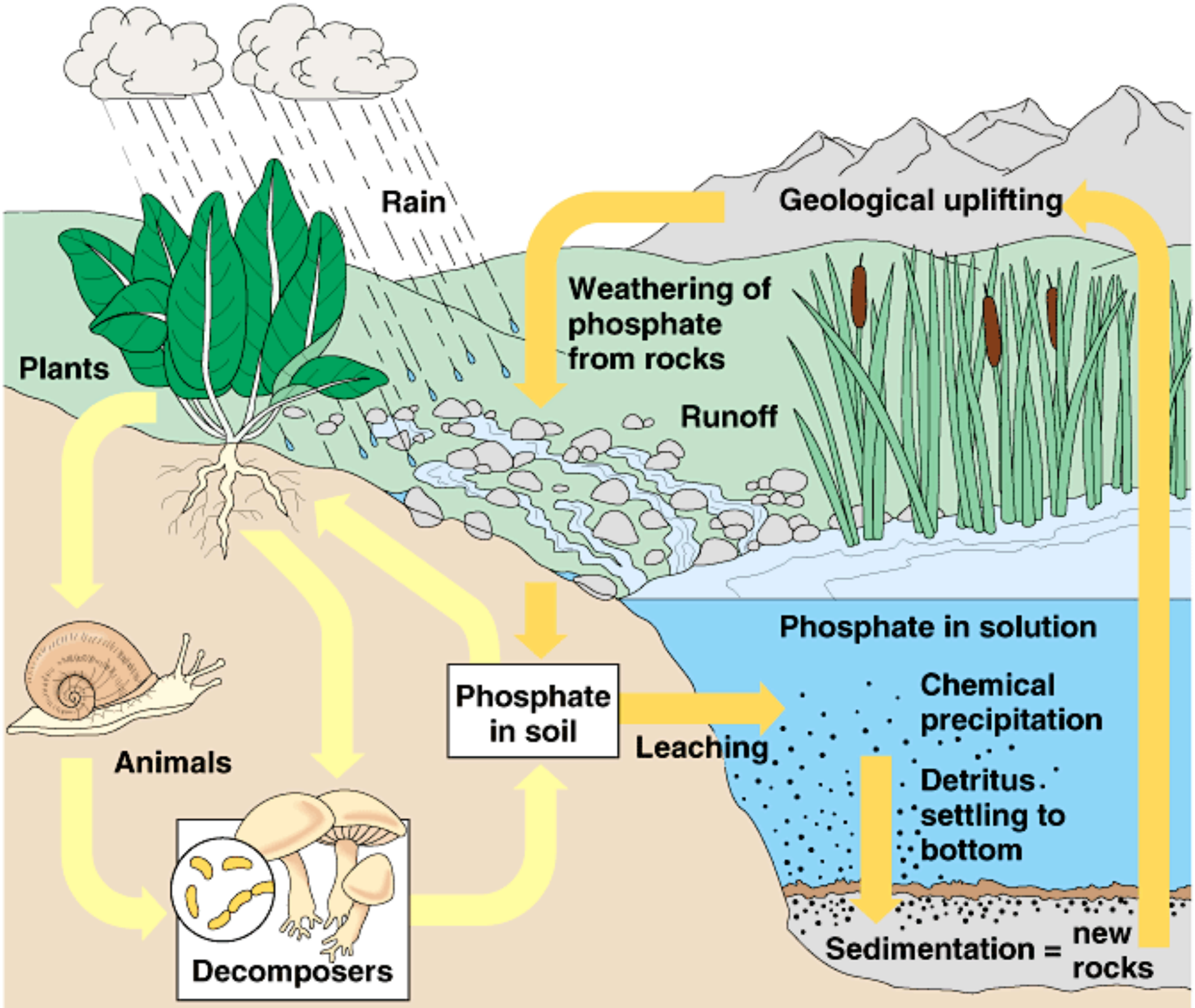
RESERVOIRS

- Atmosphere(the largest), soils, sediments of aquatic ecosystems, dissolved in water and biomass of living organisms

KEY PROCESSES

- Mainly nitrogen fixation, lightning, industrial fertilizers

PHOSPHORUS CYCLE



BIOLOGICAL IMPORTANCE

- Phosphorus is an important part of phospholipids (needed to make cell membranes), nucleic acids and ATP. In addition phosphorus is a mineral constituent of bones and teeth.

FORMS AVAILABLE TO LIFE

- Phosphates (PO_4^{3-}) absorbed by plants

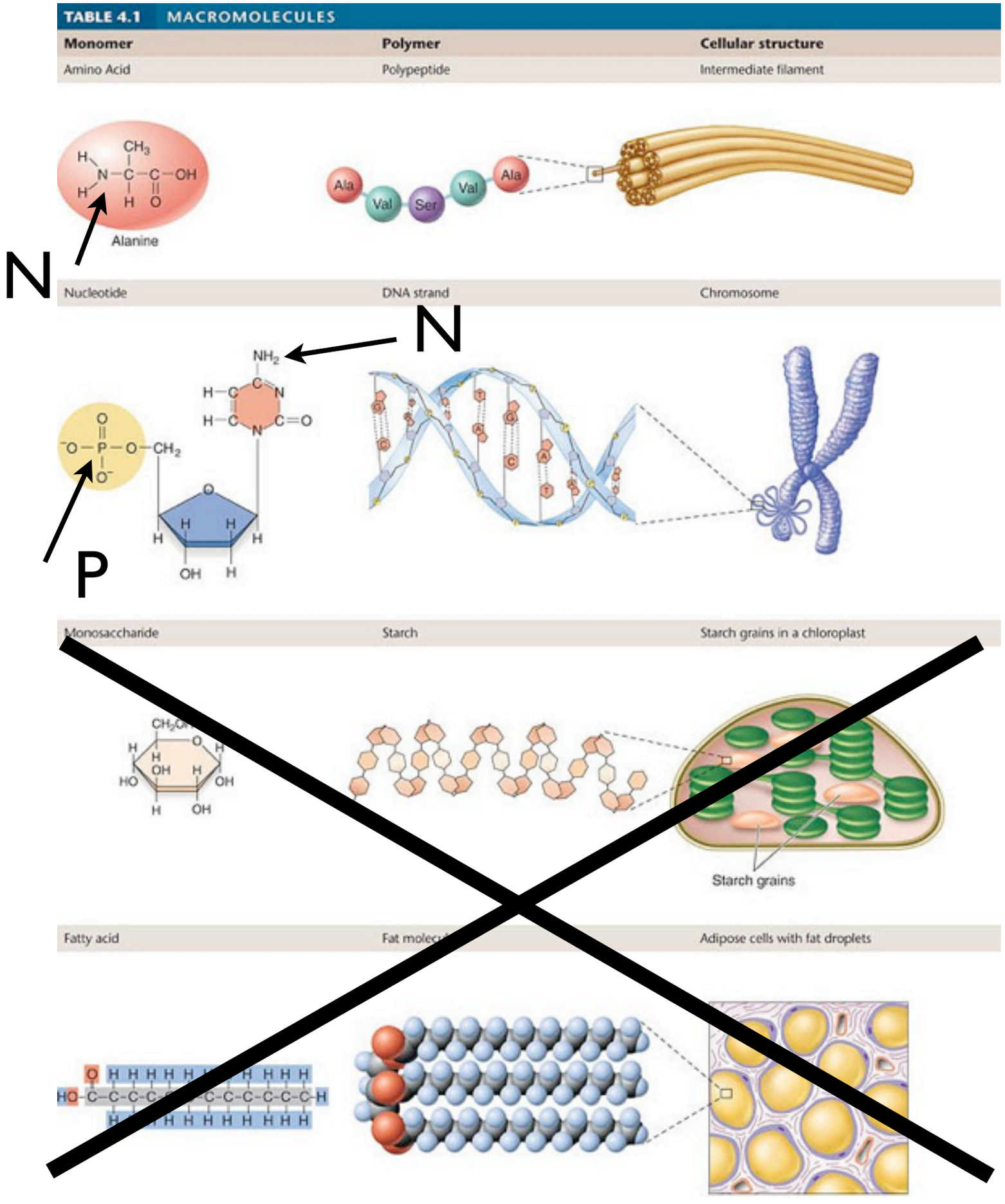
RESERVOIRS

- Sedimentary rocks, soil, dissolved in the ocean and in biomass of organisms.

KEY PROCESSES

- Weathering of rocks, leaching form soil, eaten by consumers, excretion by organisms

These are the four large molecules that make up living organisms...nitrogen and phosphorous are also required elements for proteins and nucleic acids



Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

a. Molecules and atoms from the environment are necessary to build new molecules.

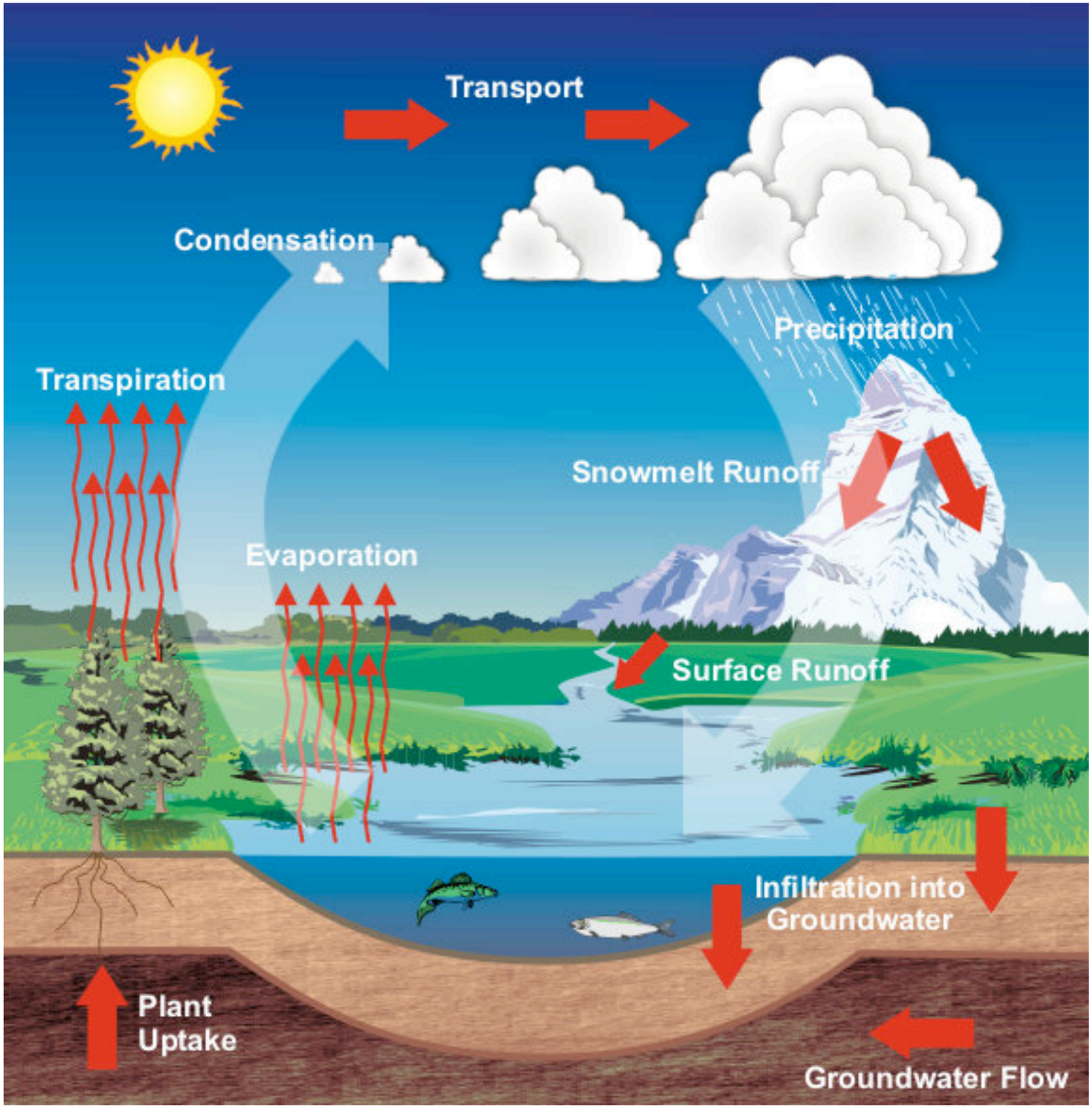
Evidence of student learning is a demonstrated understanding of each of the following:

3. Living systems depend on properties of water that result from its polarity and hydrogen bonding.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

Adhesion, Cohesion, High specific heat capacity, Universal Solvent, High Heat of Vaporization, Heat of Fusion, Thermal Conductivity

WATER CYCLE


Transport
Condensation
Precipitation
Transpiration
Snowmelt Runoff
Evaporation
Surface Runoff
Infiltration into
Groundwater
Plant
Uptake
Groundwater Flow

BIOLOGICAL IMPORTANCE

- Water is essential for all life, water also influences production & decomposition

FORMS AVAILABLE TO LIFE

- Mainly liquid water

RESERVOIRS

- Rough estimations: 97% in oceans, 2% in glaciers and ice caps, 1% in rivers and lakes

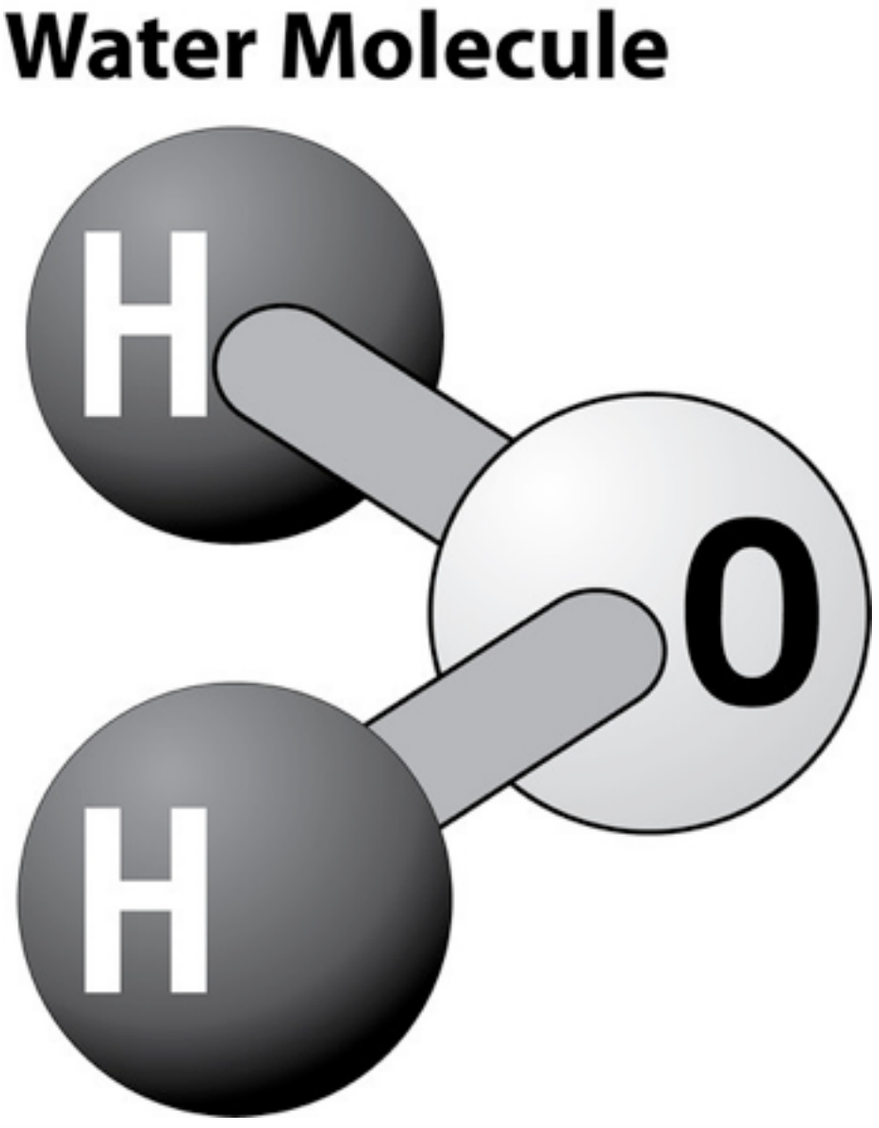
KEY PROCESSES

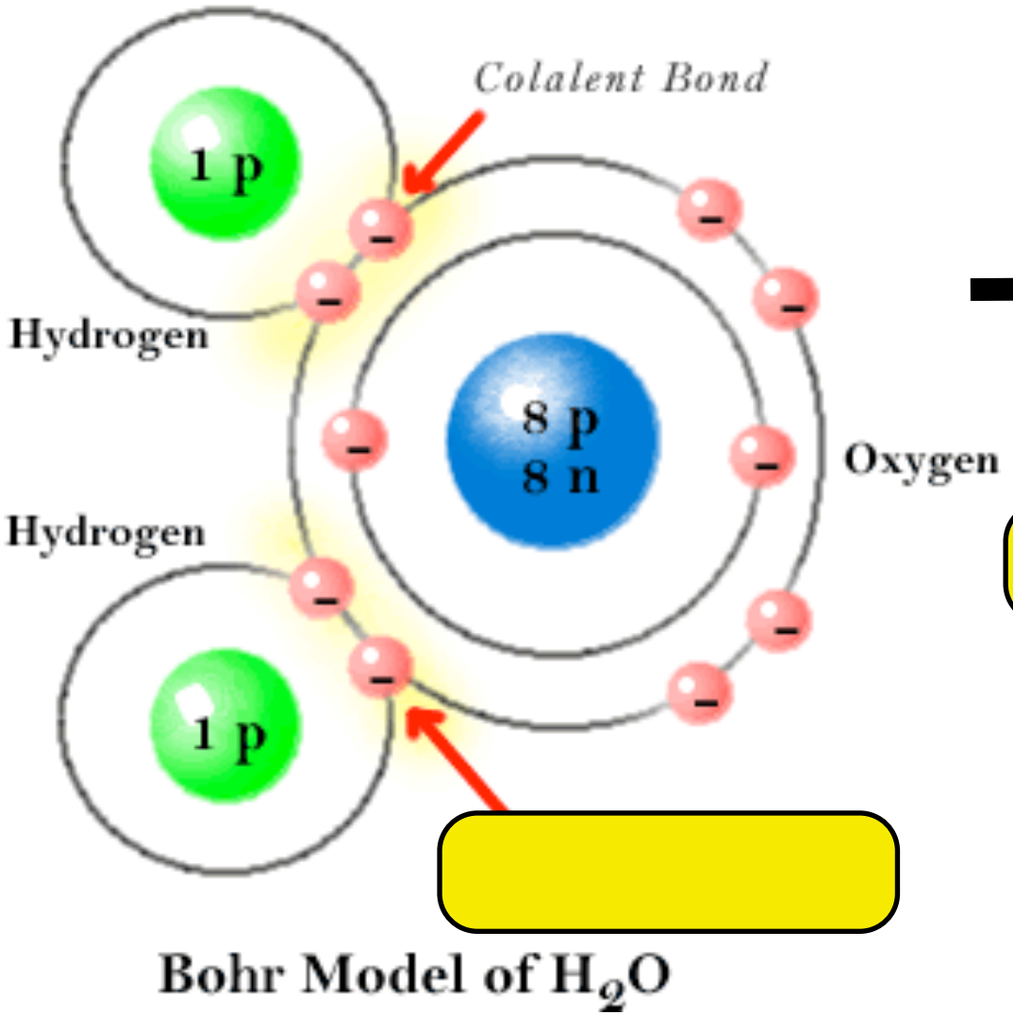
- Evaporation, Condensation and Precipitation

- Water is the substance that makes life possible (as we know it)
- Almost every organism is made of mostly water
- Almost every organism lives in an environment dominated by water.
- Life began in water.
- Most life remains tied to water.
- Living organisms need water more any other substance.
- Water participates in most life sustaining chemical reactions.
- Most cells are bathed in water.
- Most cells are themselves mostly water.
- Water is the substance that makes life possible (as we know it)

POLAR COVALENT BONDS IN WATER MOLECULES RESULT IN HYDROGEN BONDING

- Water is a small, simple "V" shaped molecule.





Bohr Model of H_2O

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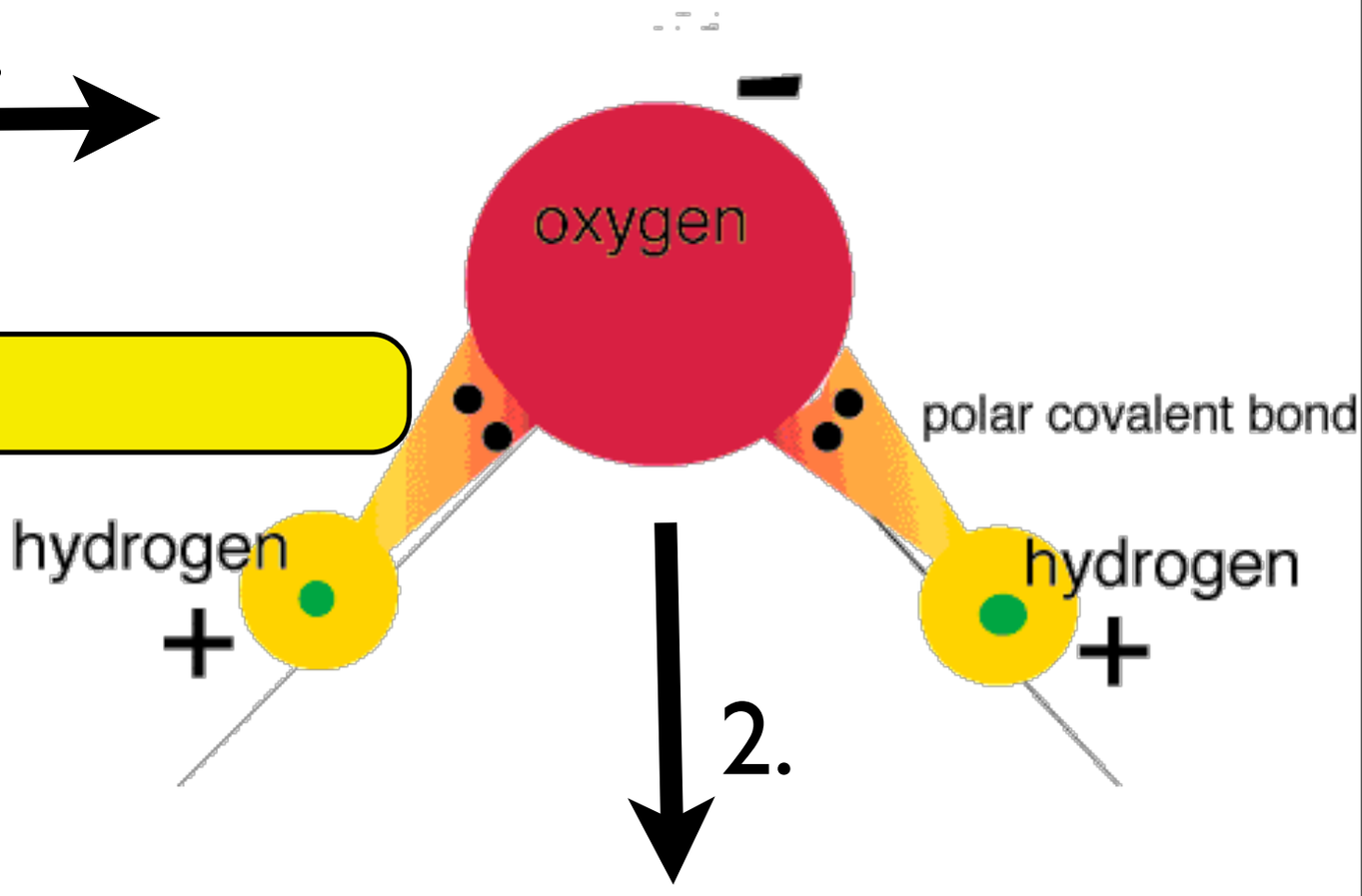

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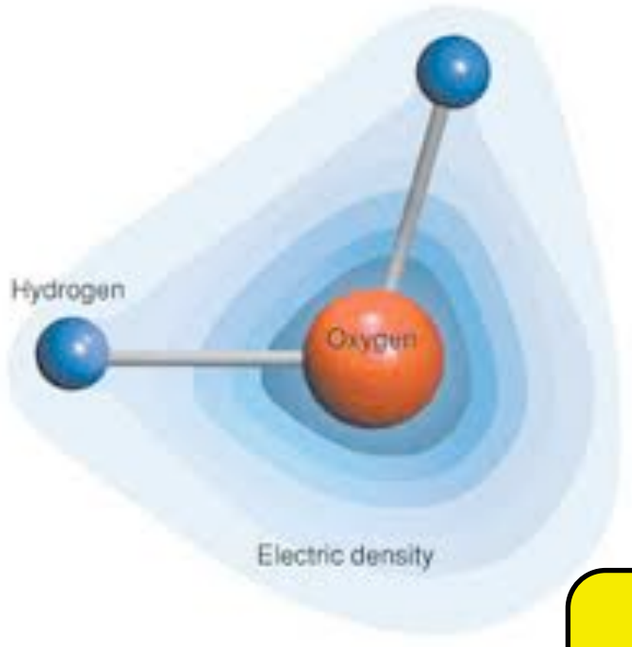

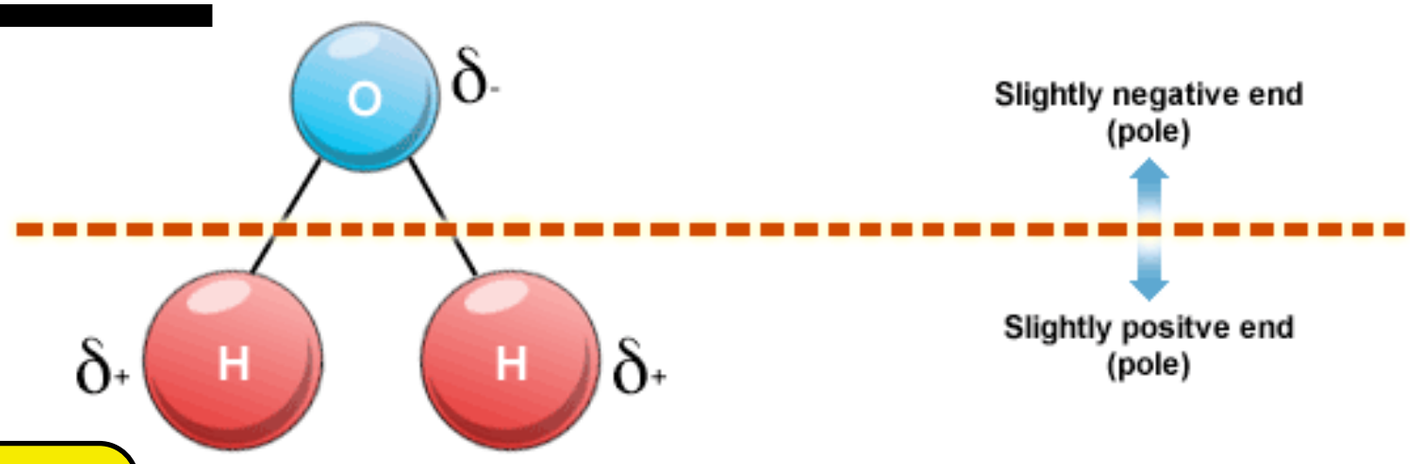

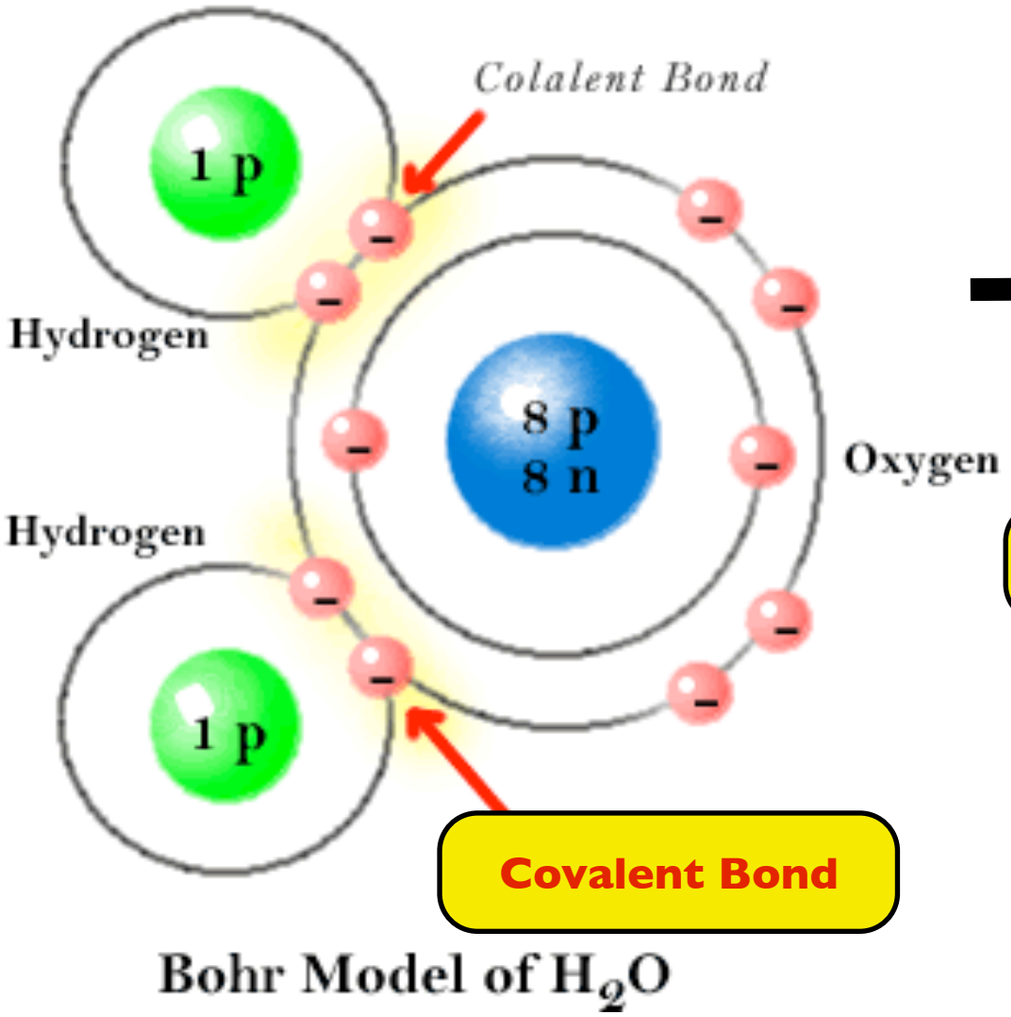

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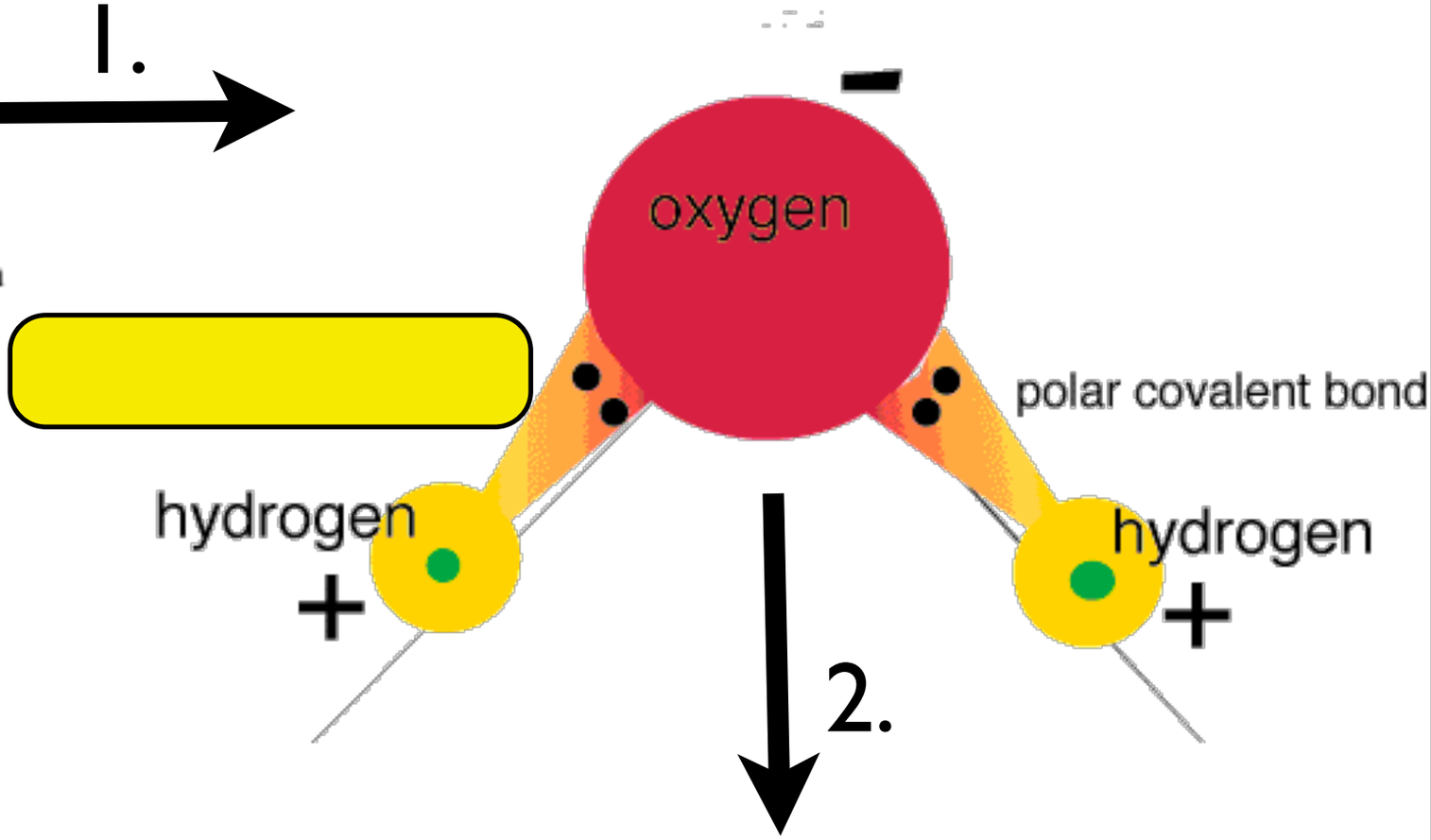

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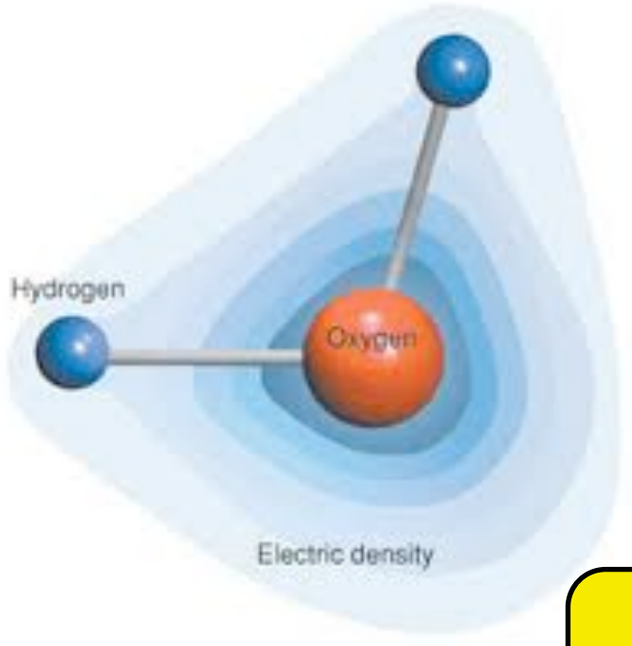

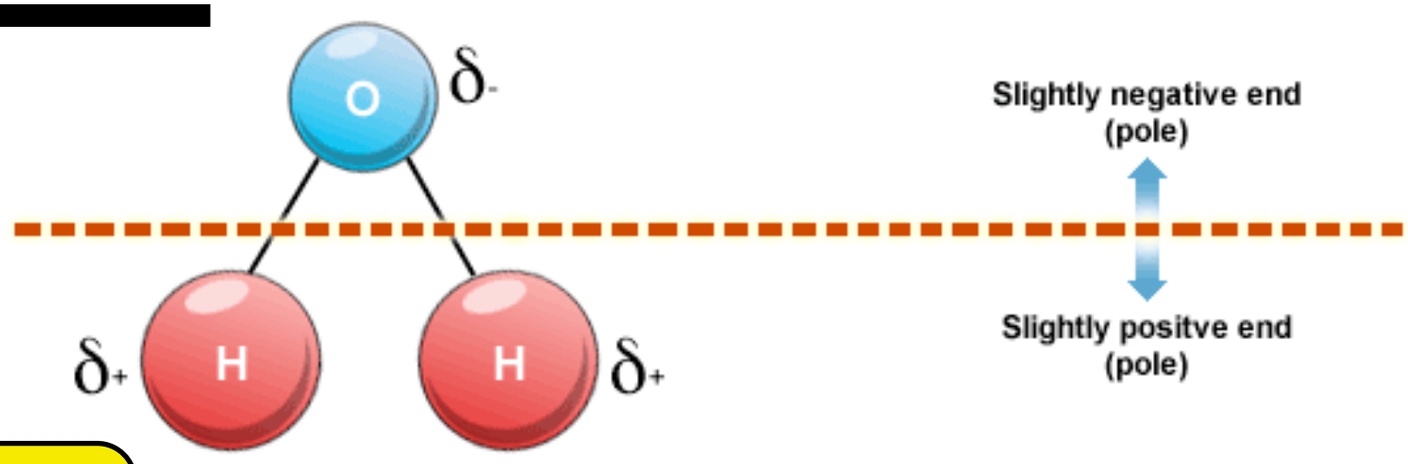

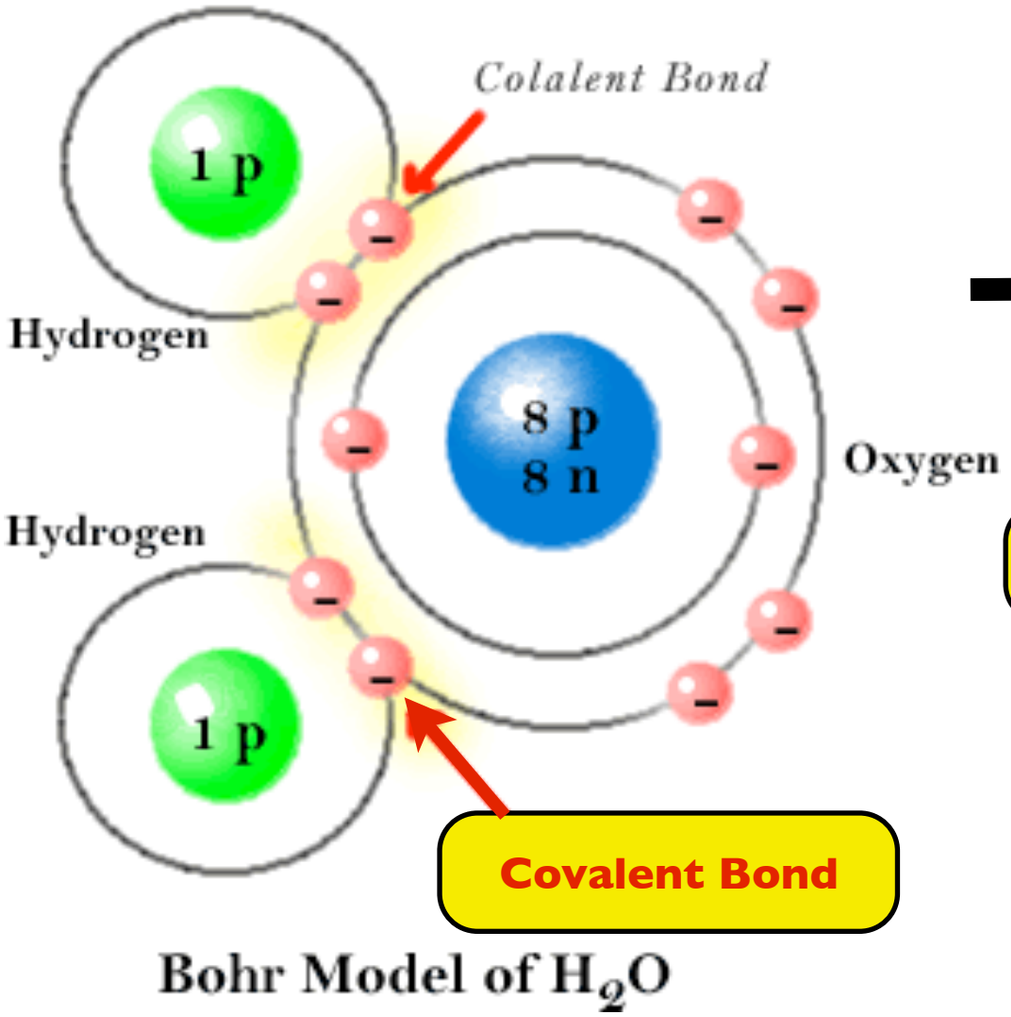

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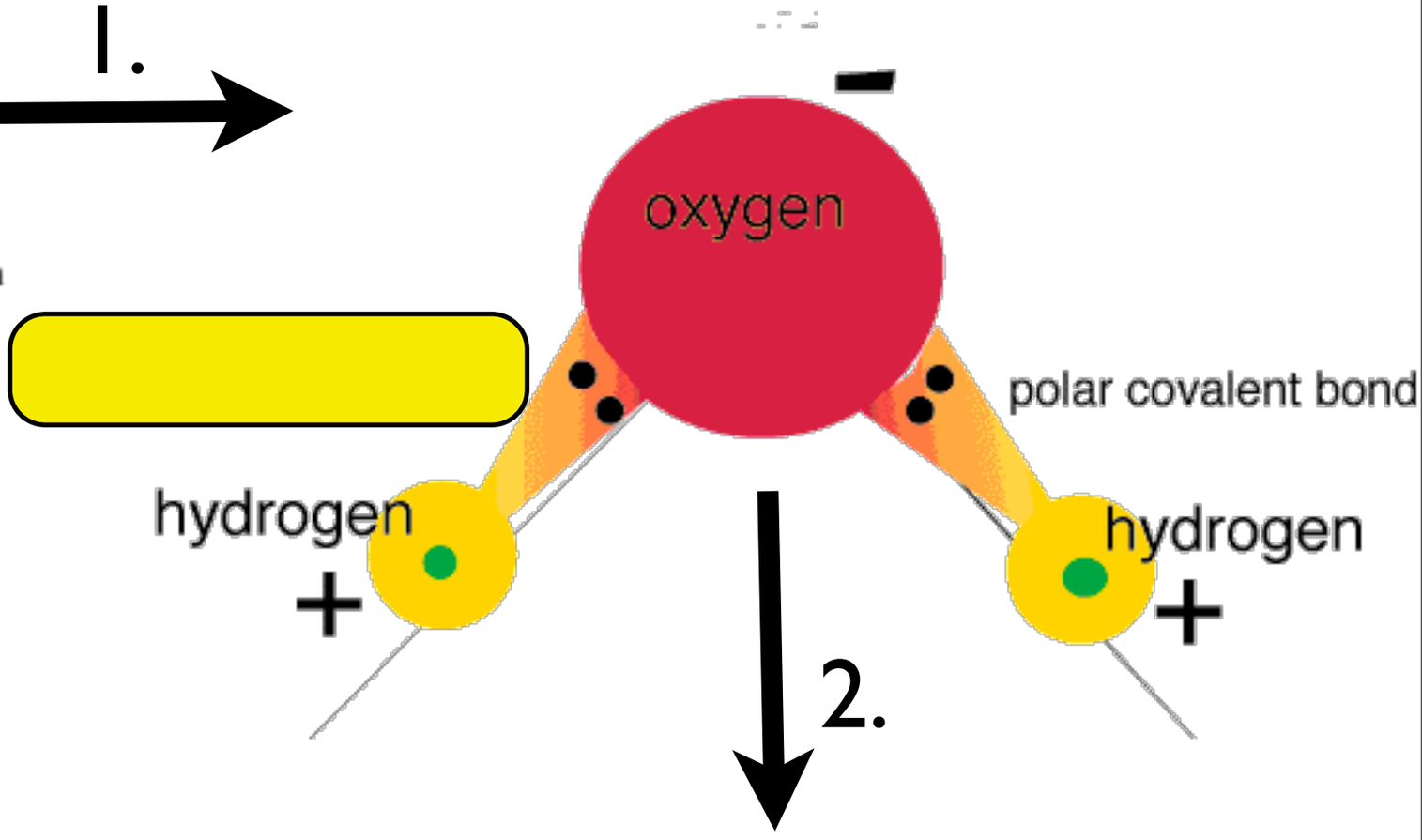

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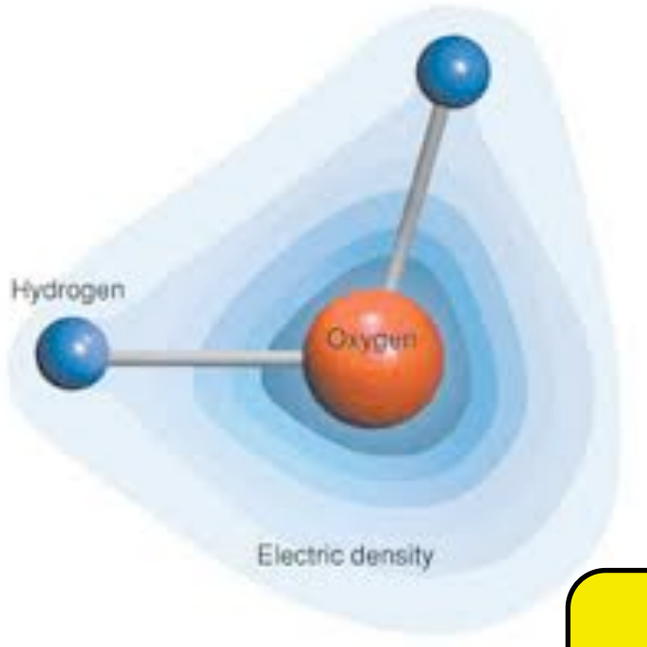
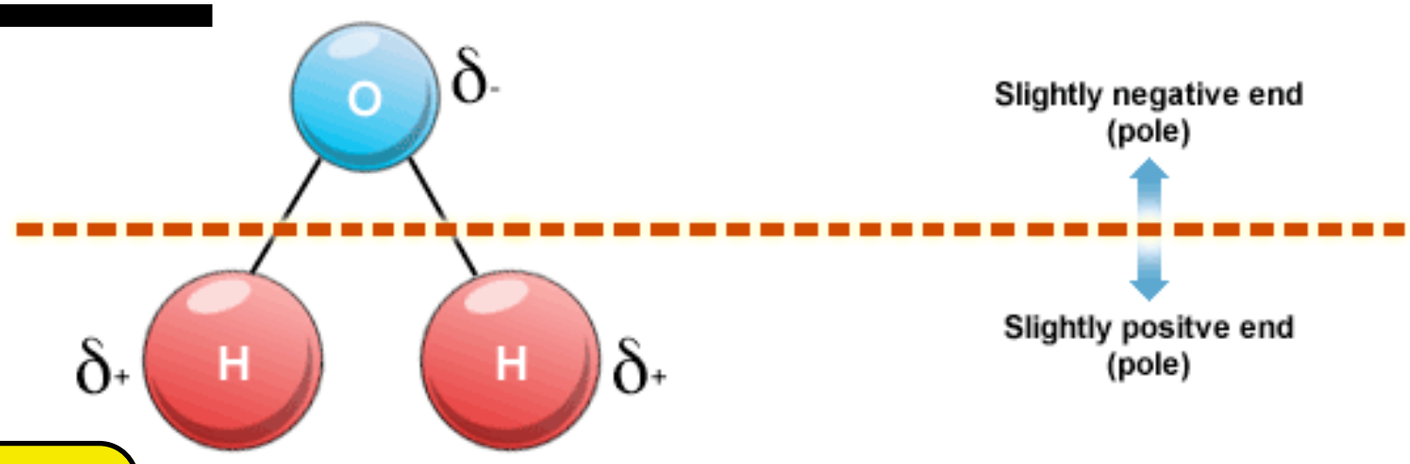
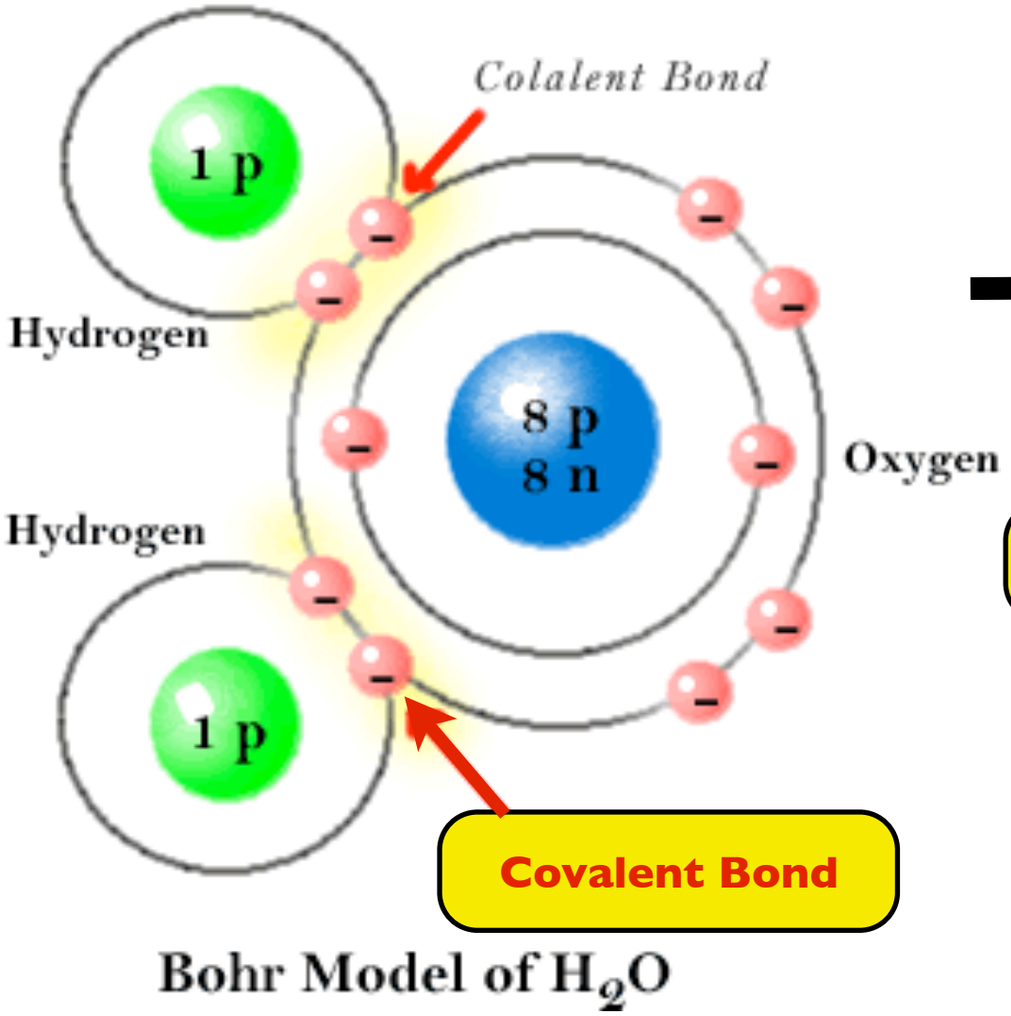


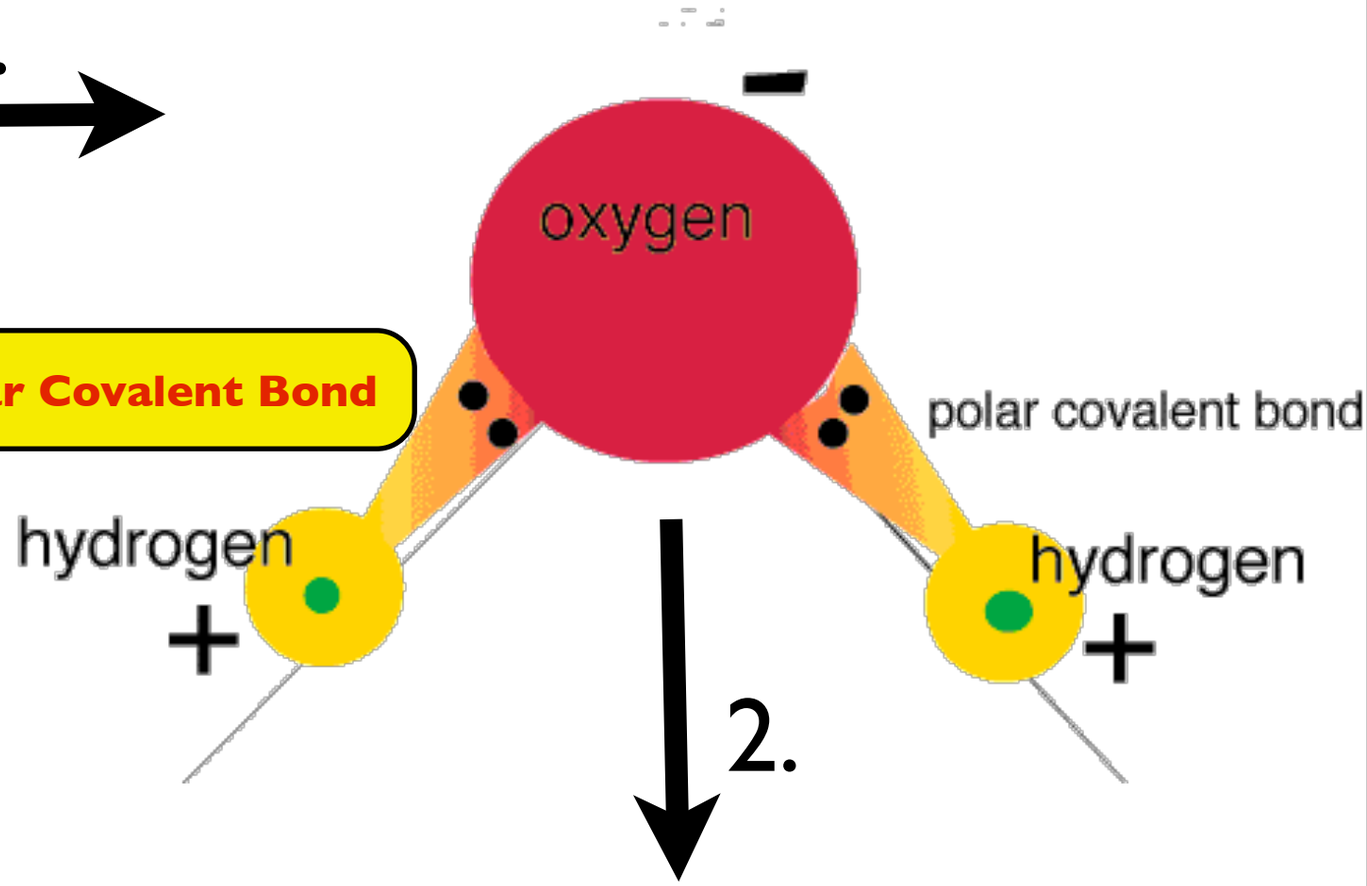




Bohr Model of H_2O

1.

Polar Covalent Bond



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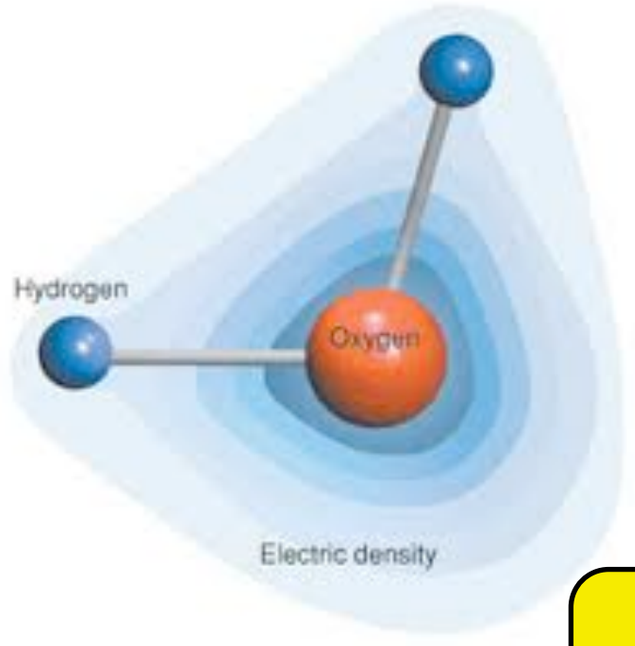

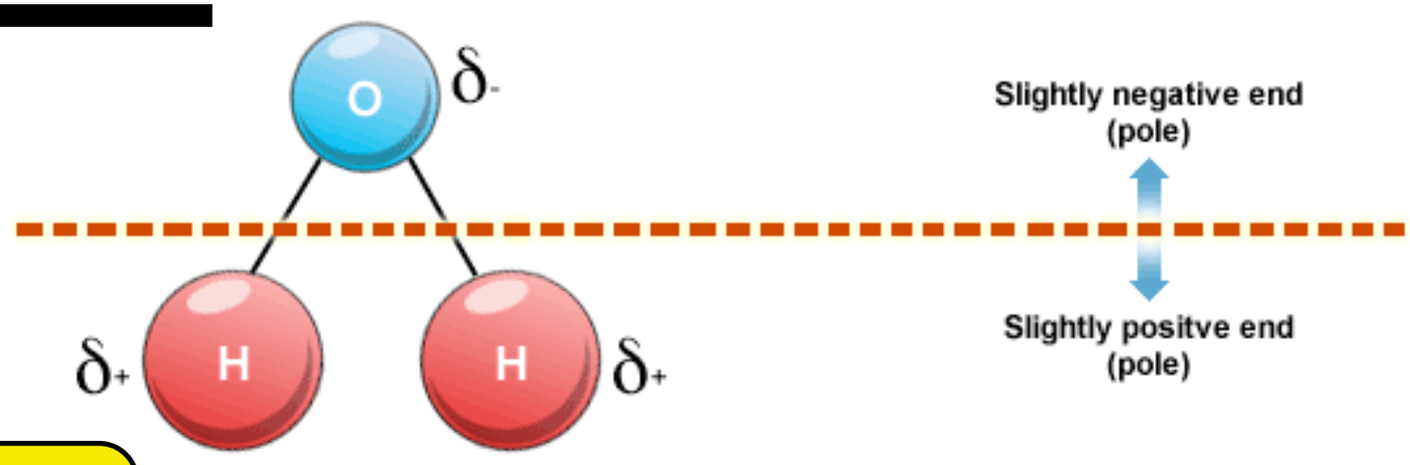

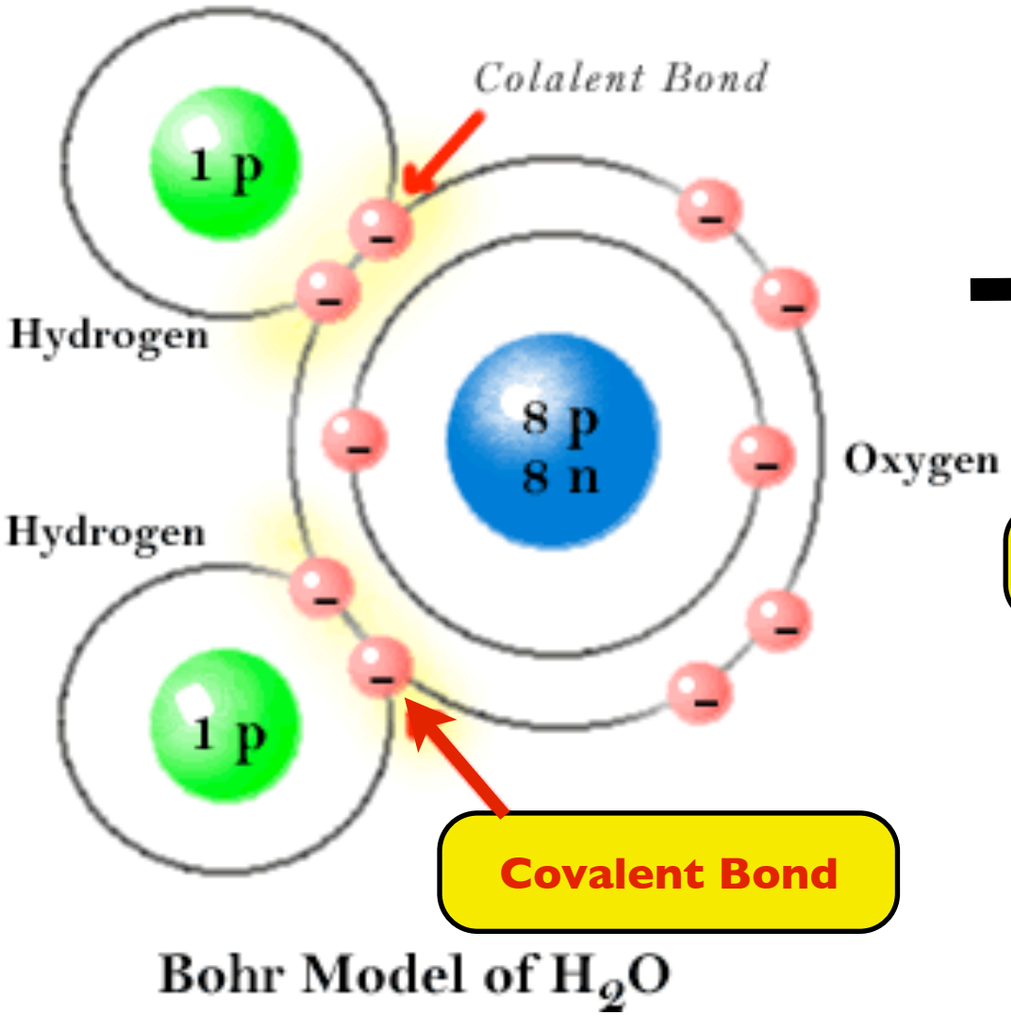

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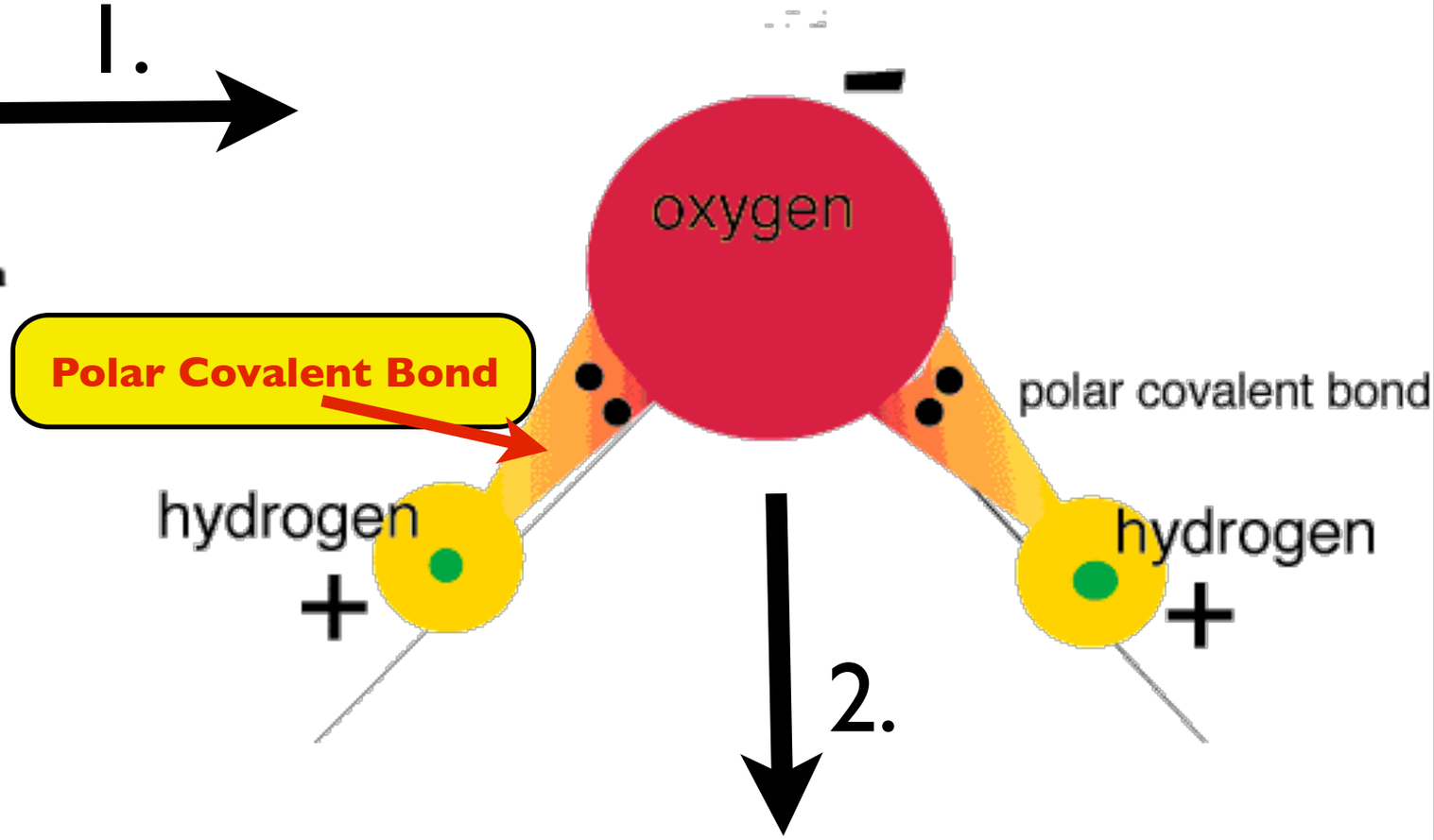

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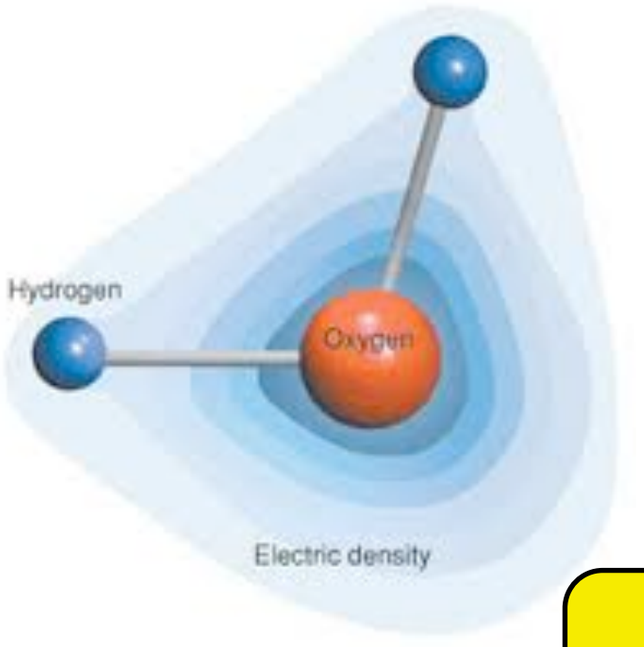

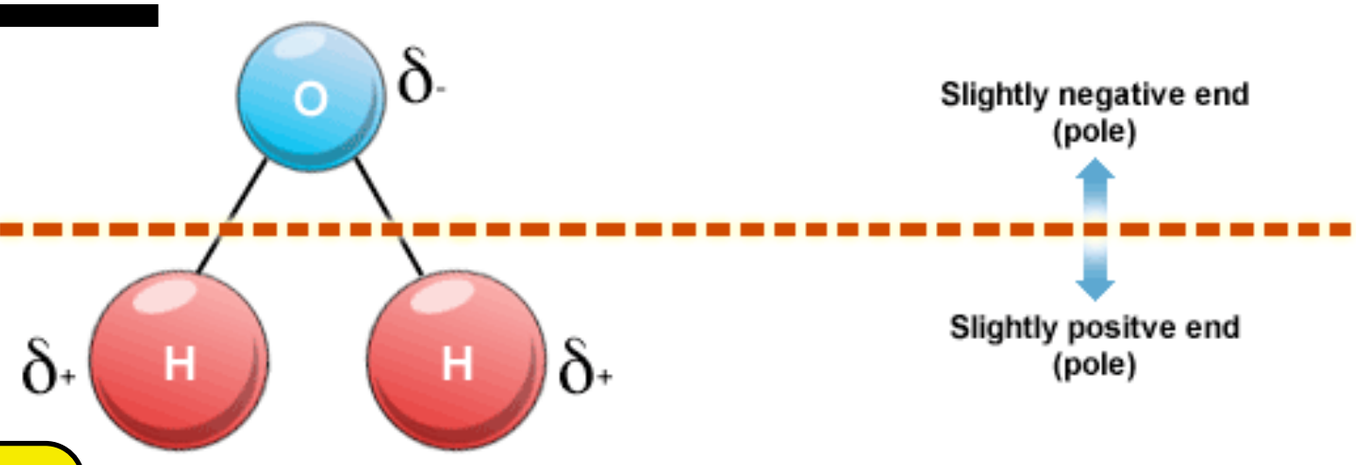

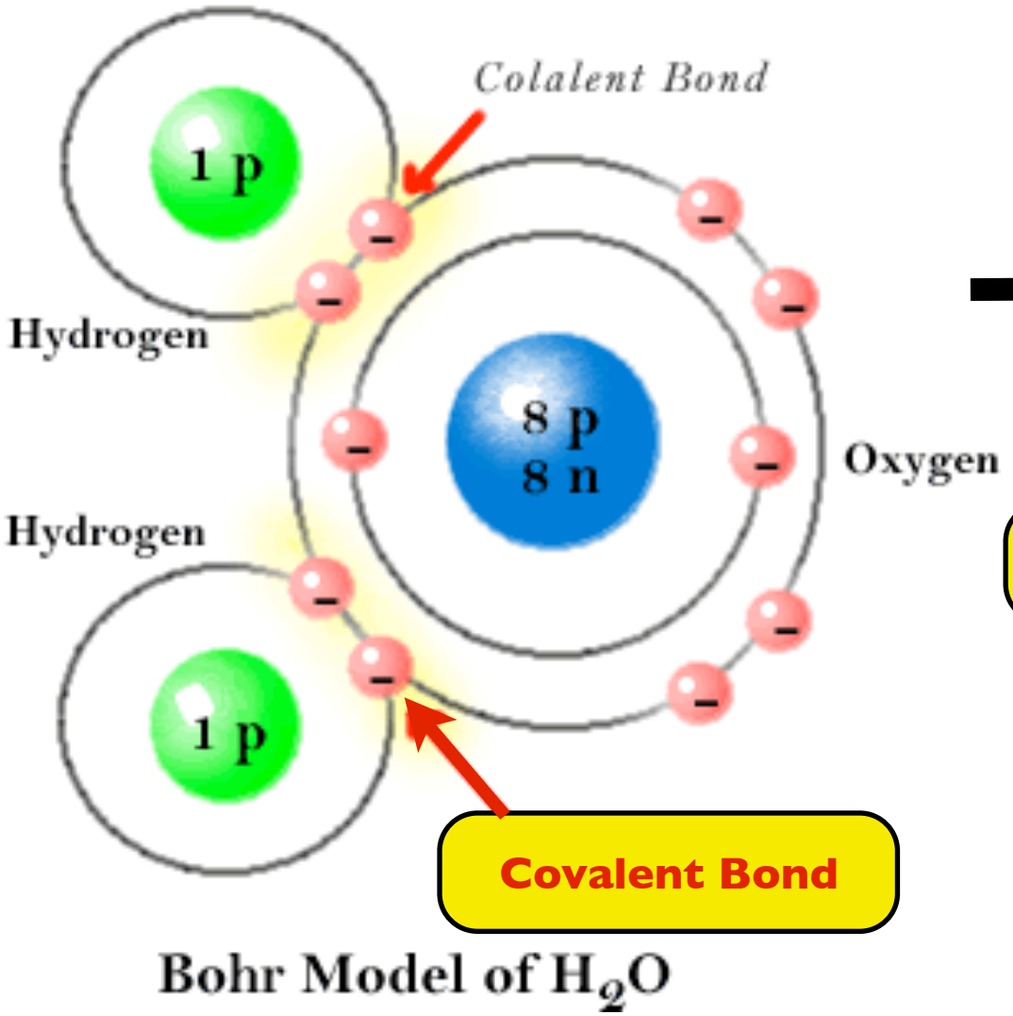

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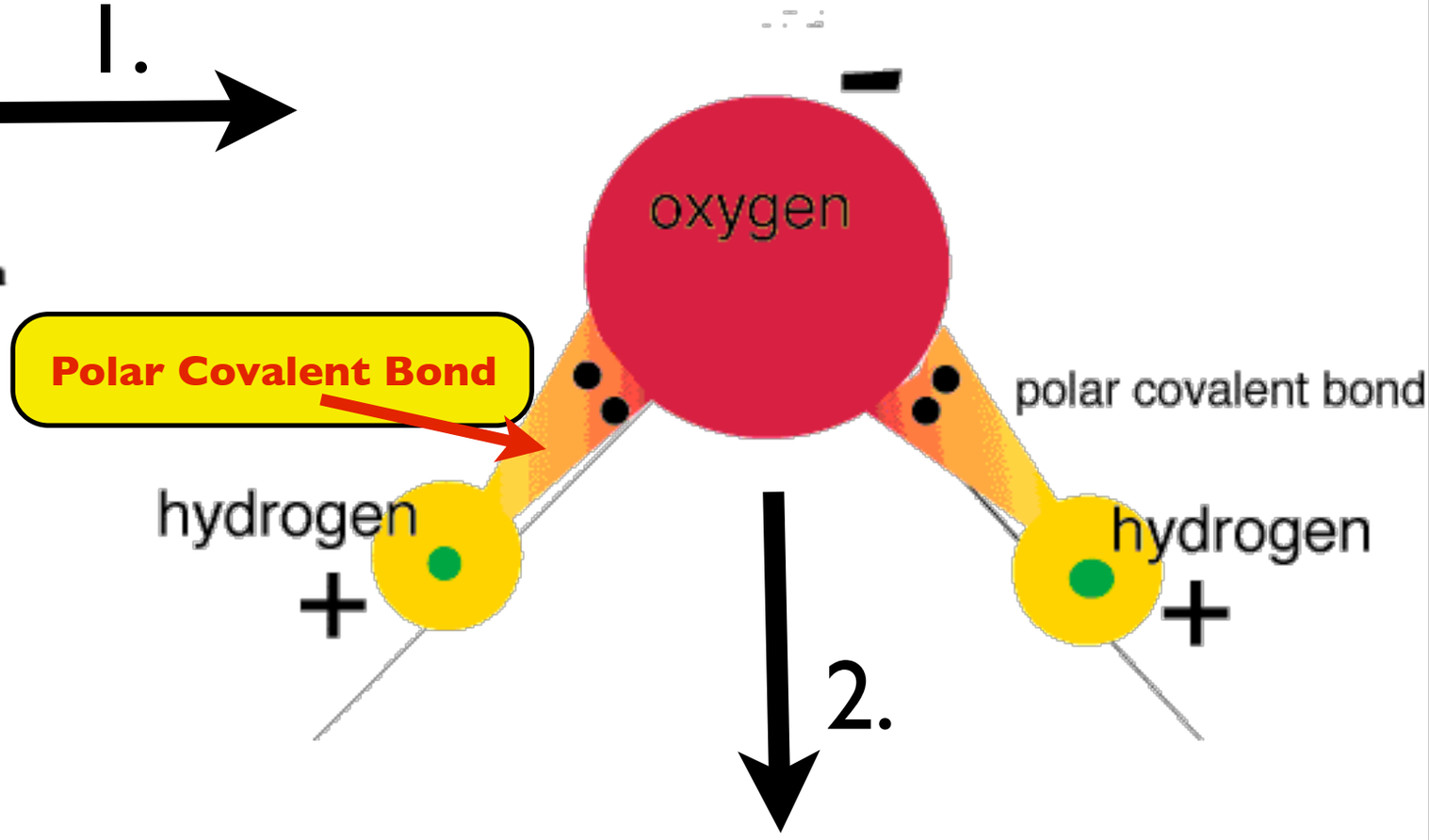

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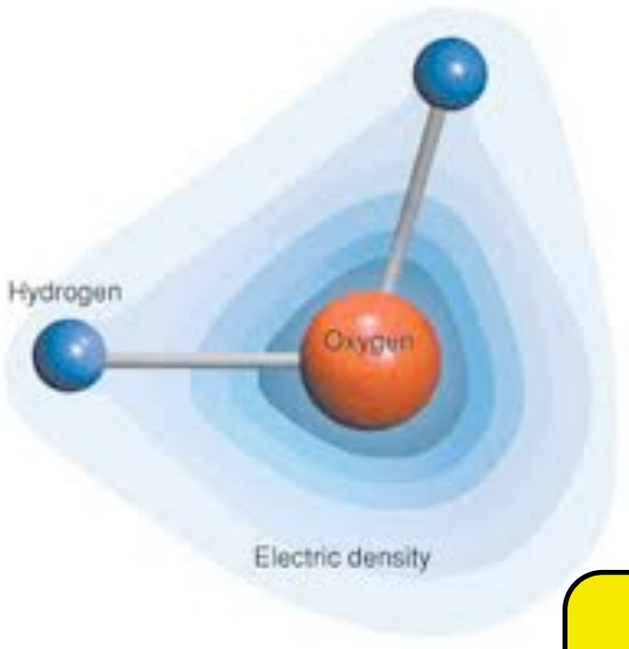
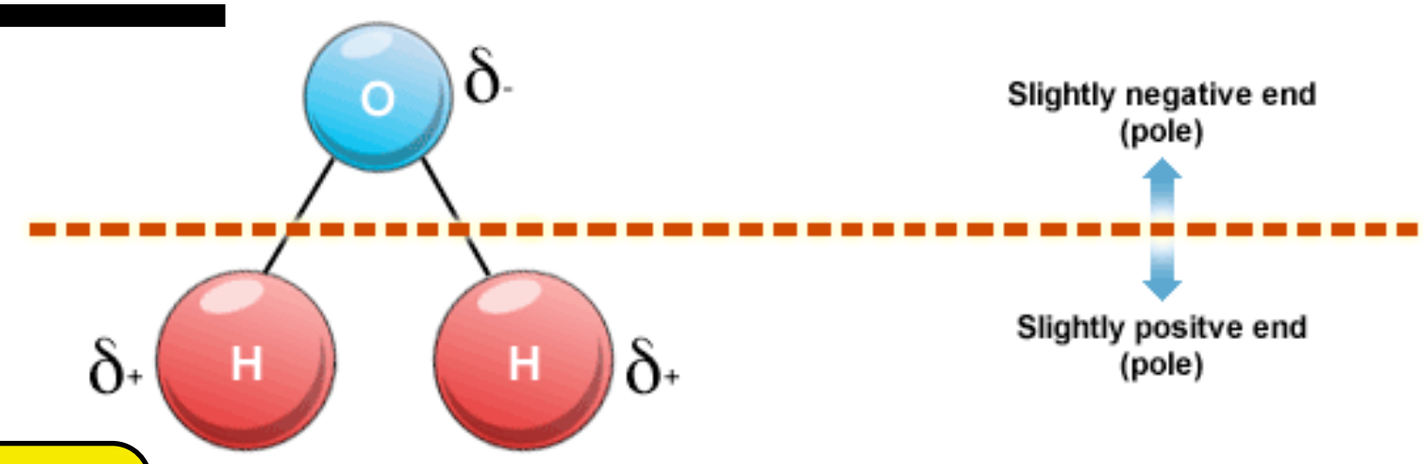
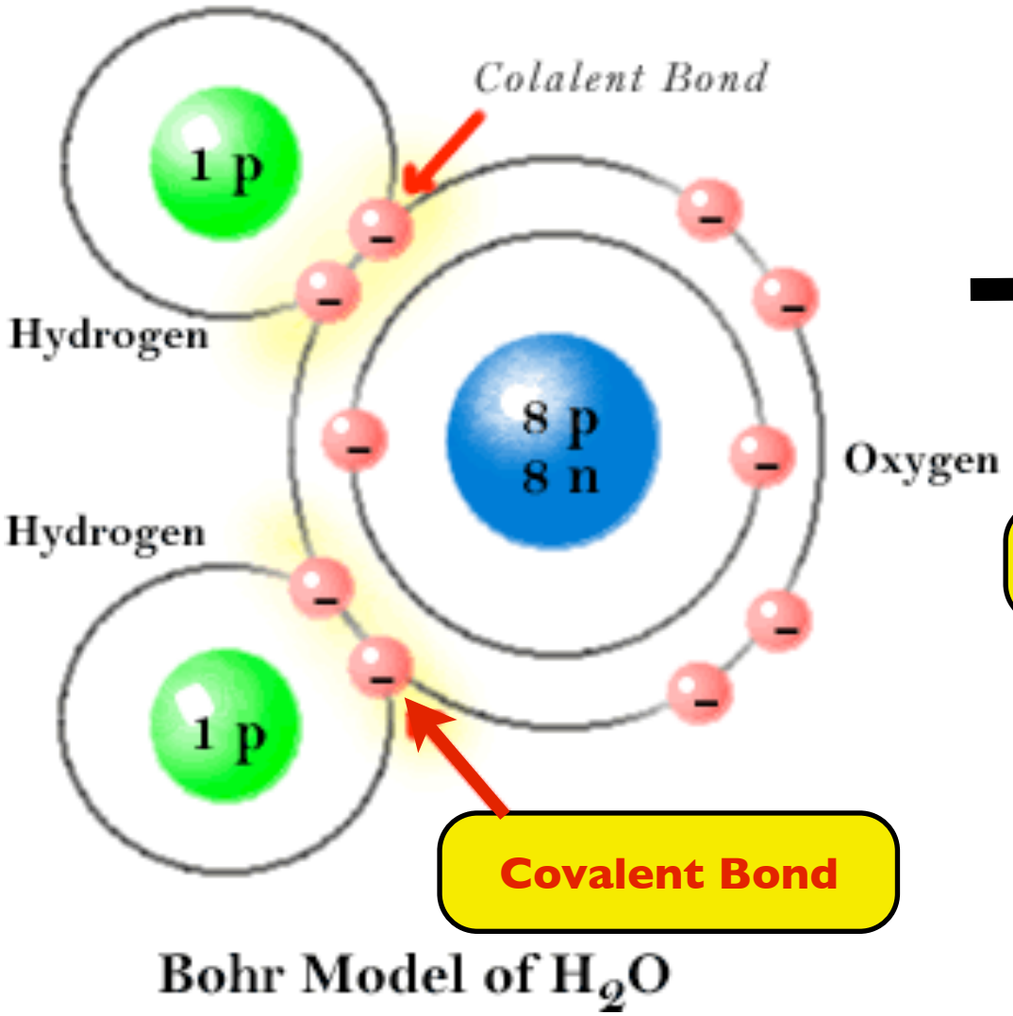




Polar Molecule



Bohr Model of H_2O

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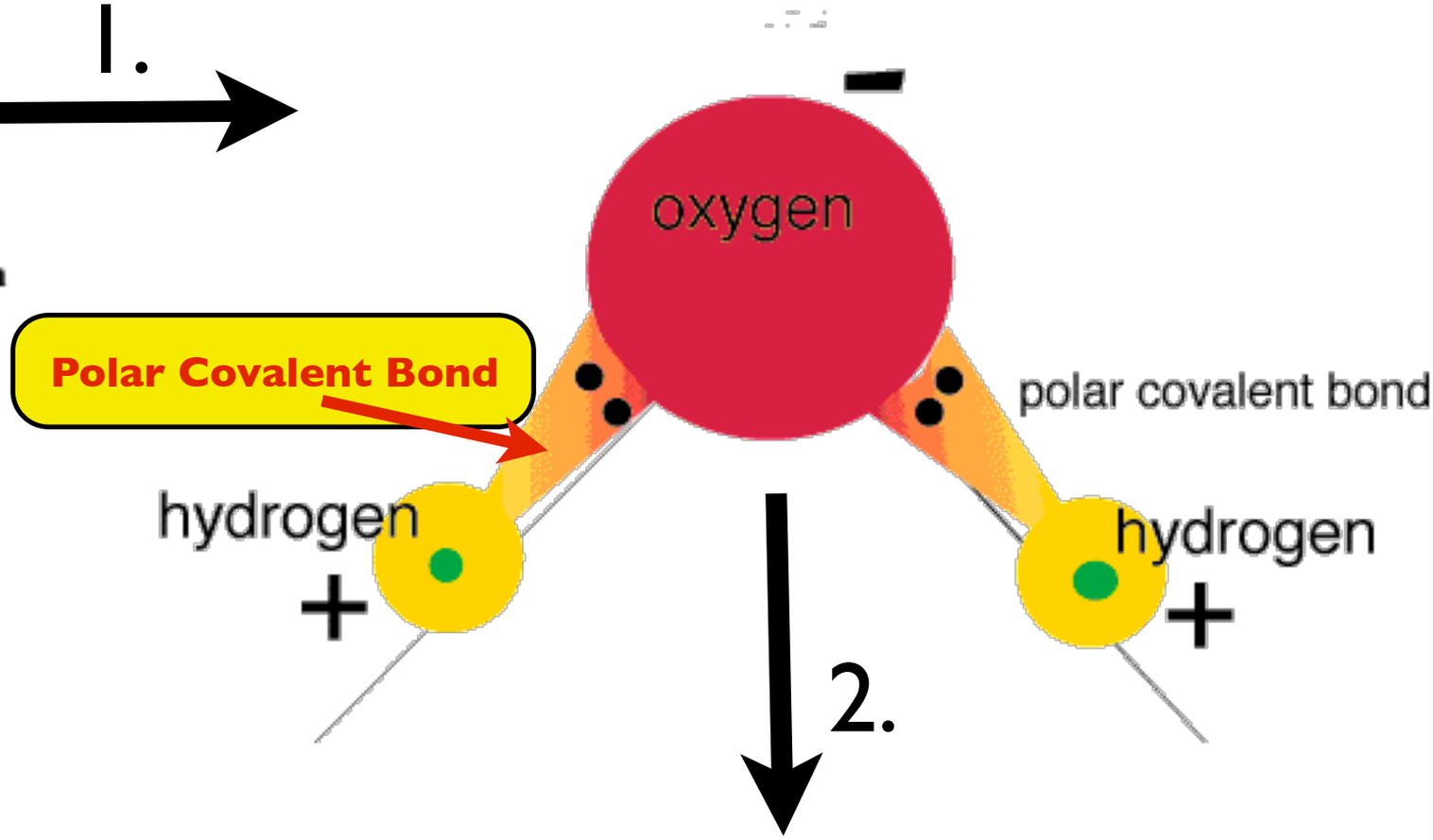

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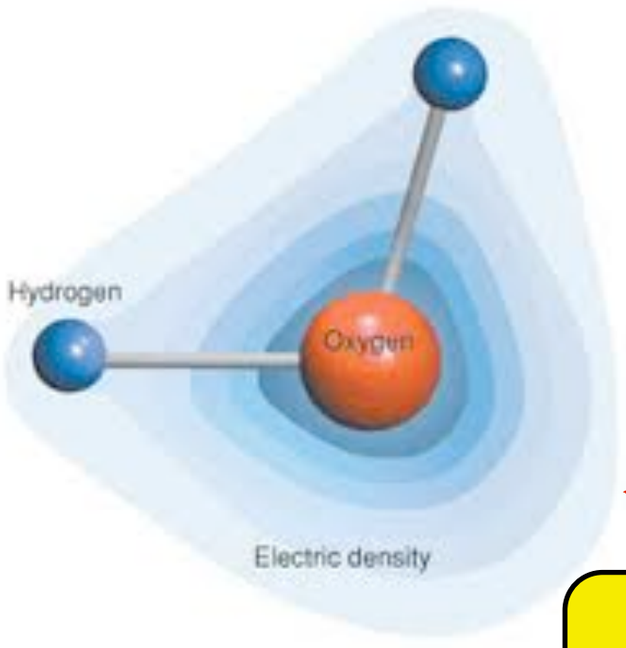
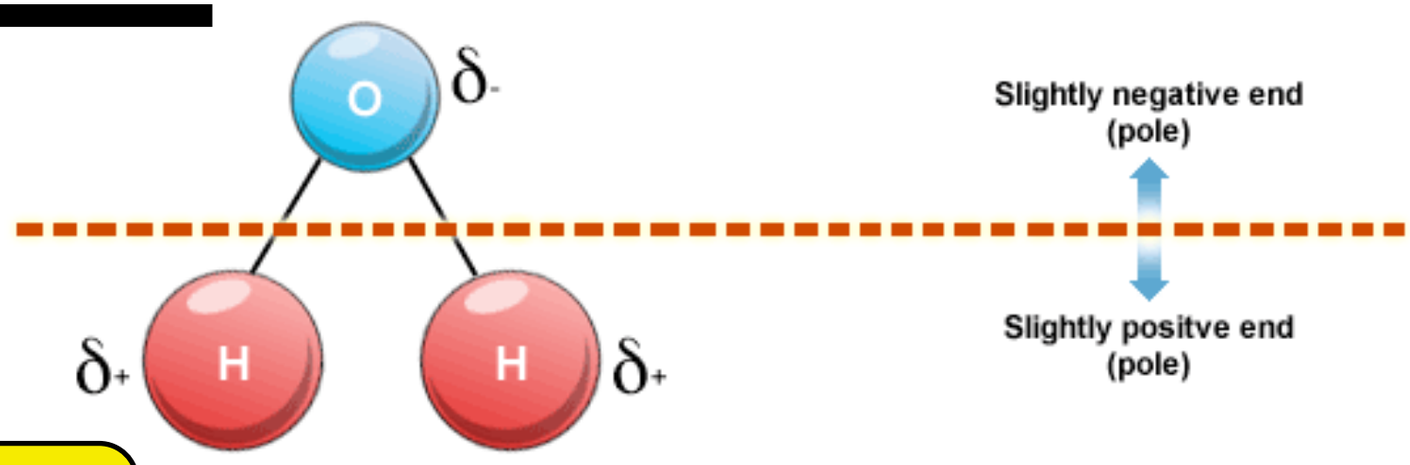
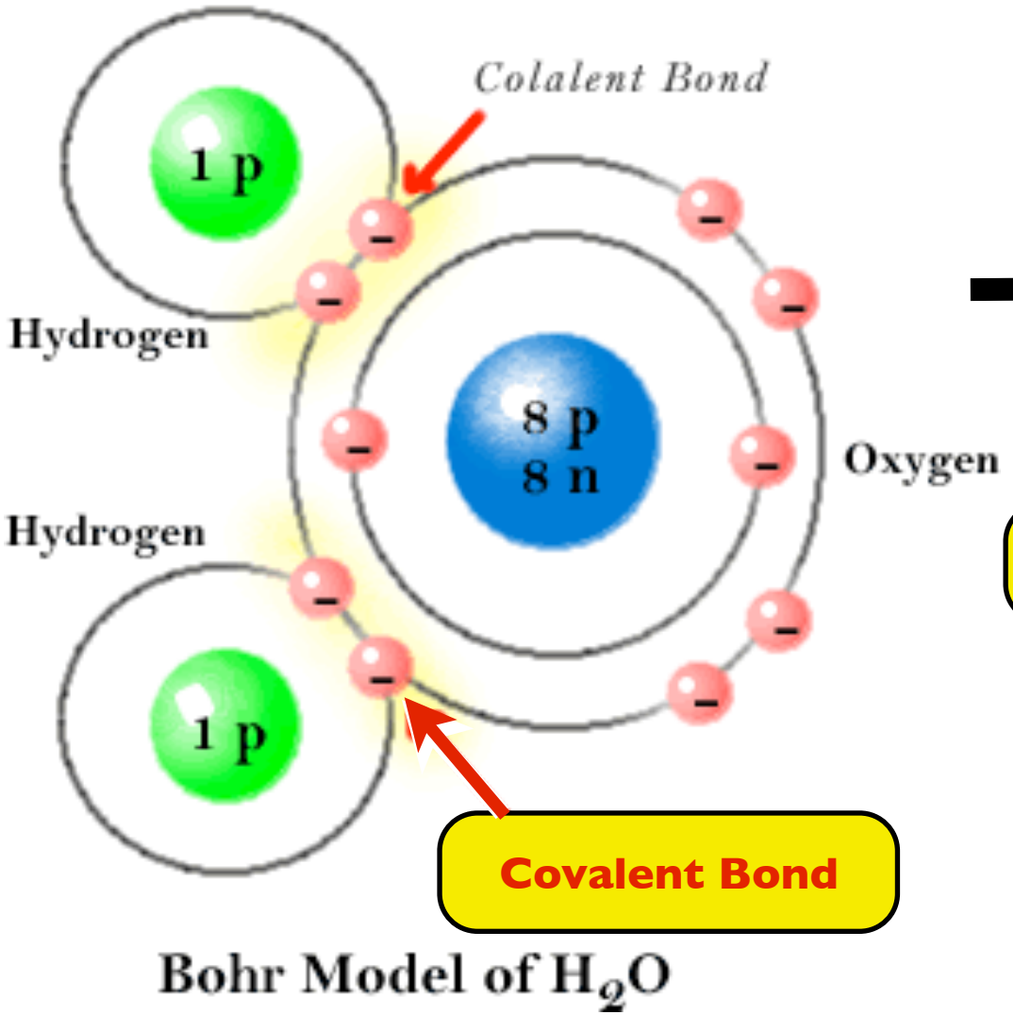




Polar Molecule



Bohr Model of H_2O

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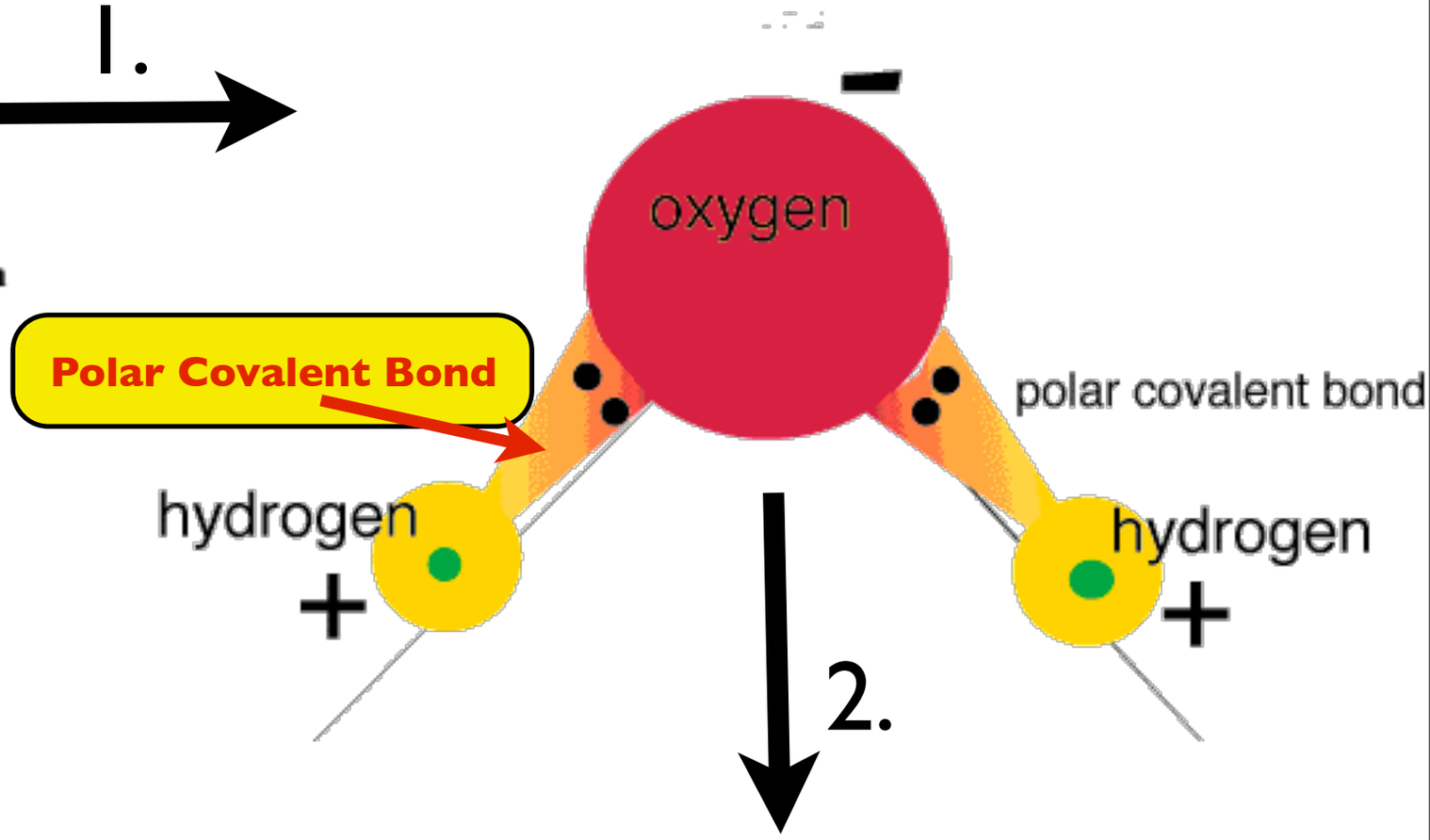
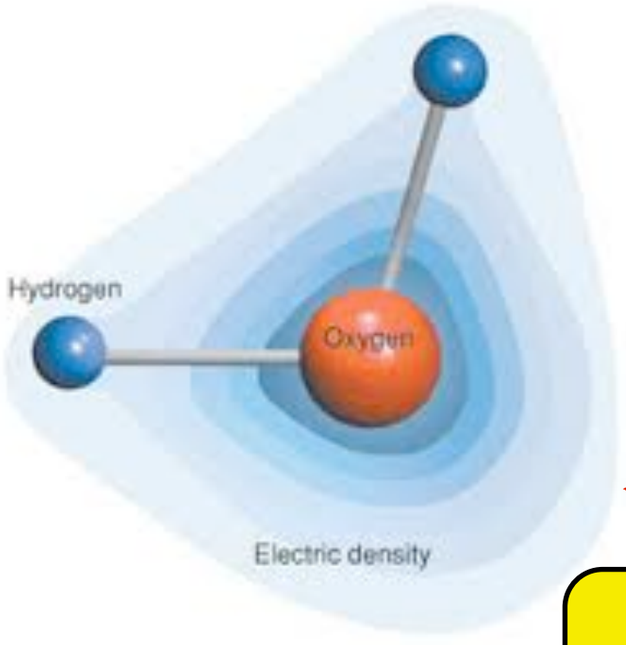
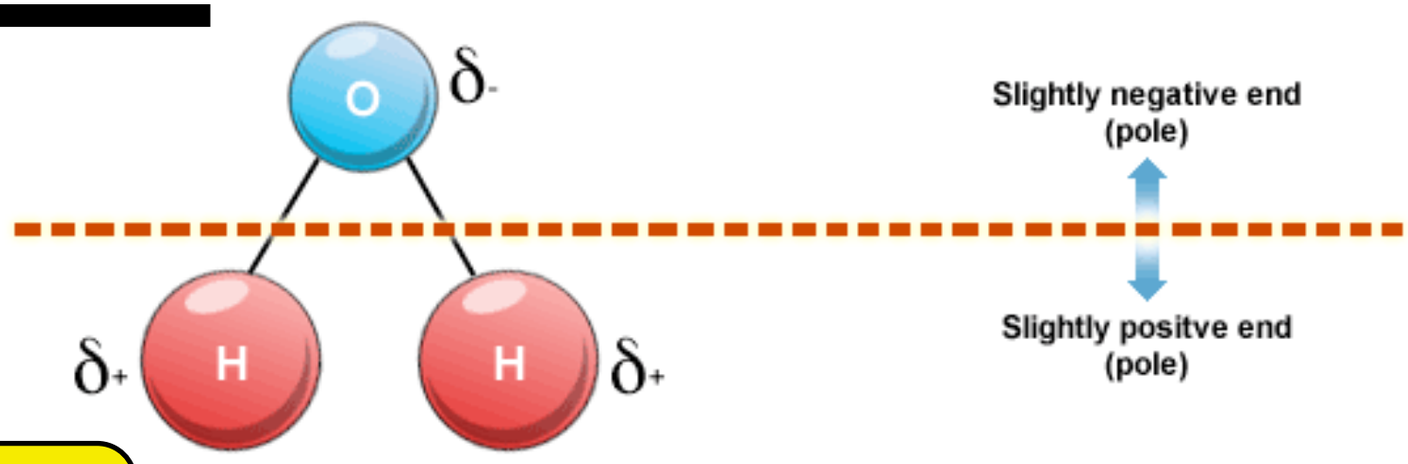


2.

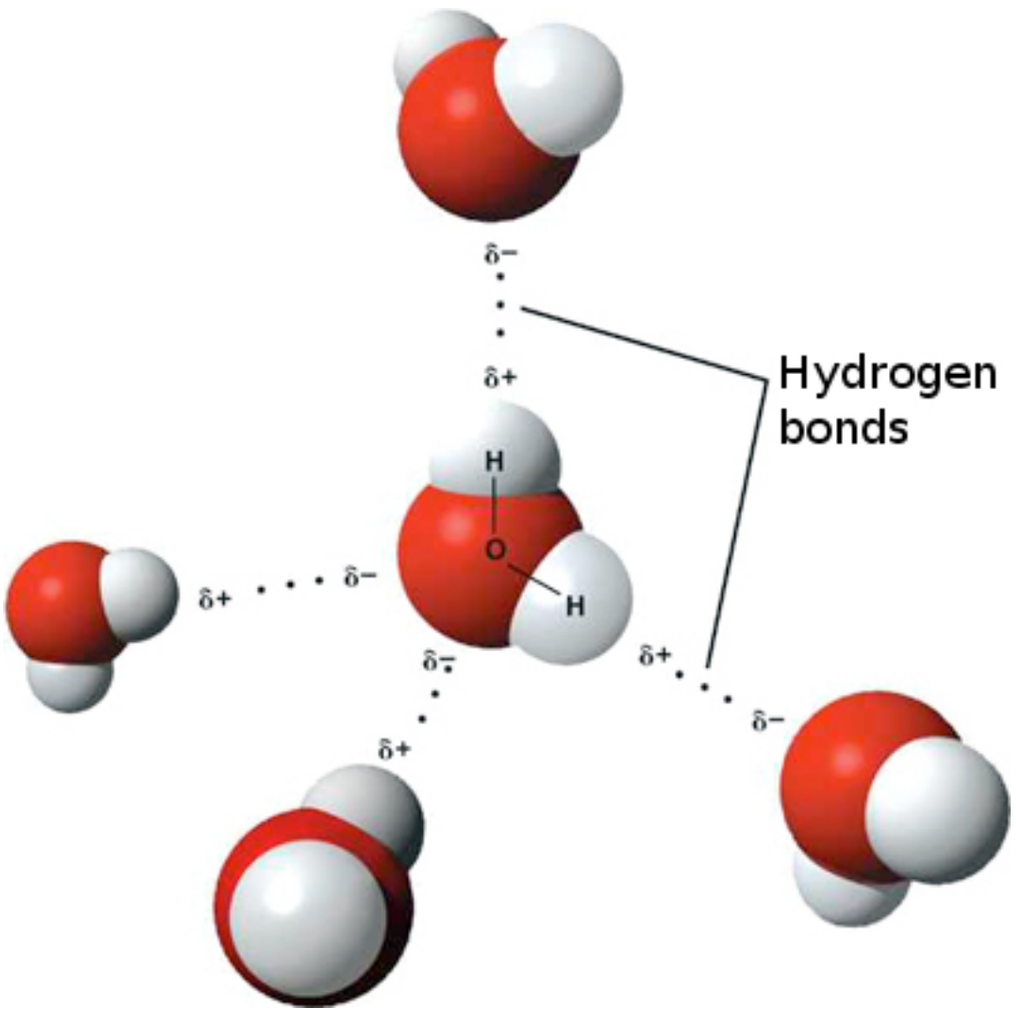
3.

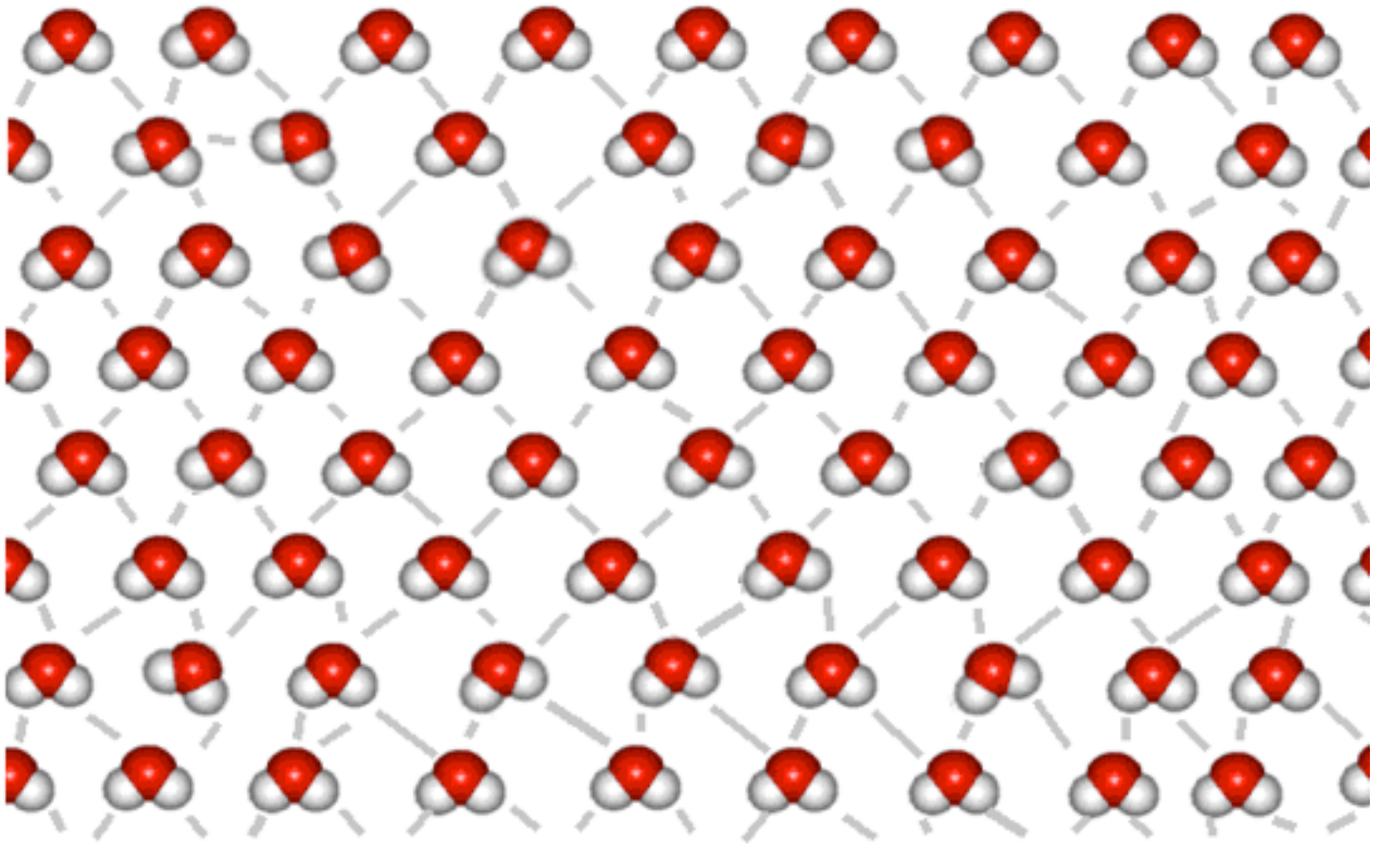




Polar Molecule

- The properties of water arise from attractions between oppositely charged atoms of different water molecules.
- Two molecules are held together by hydrogen bonds.
  - H bonds are fragile,
  - They form, break and re-form with great frequency





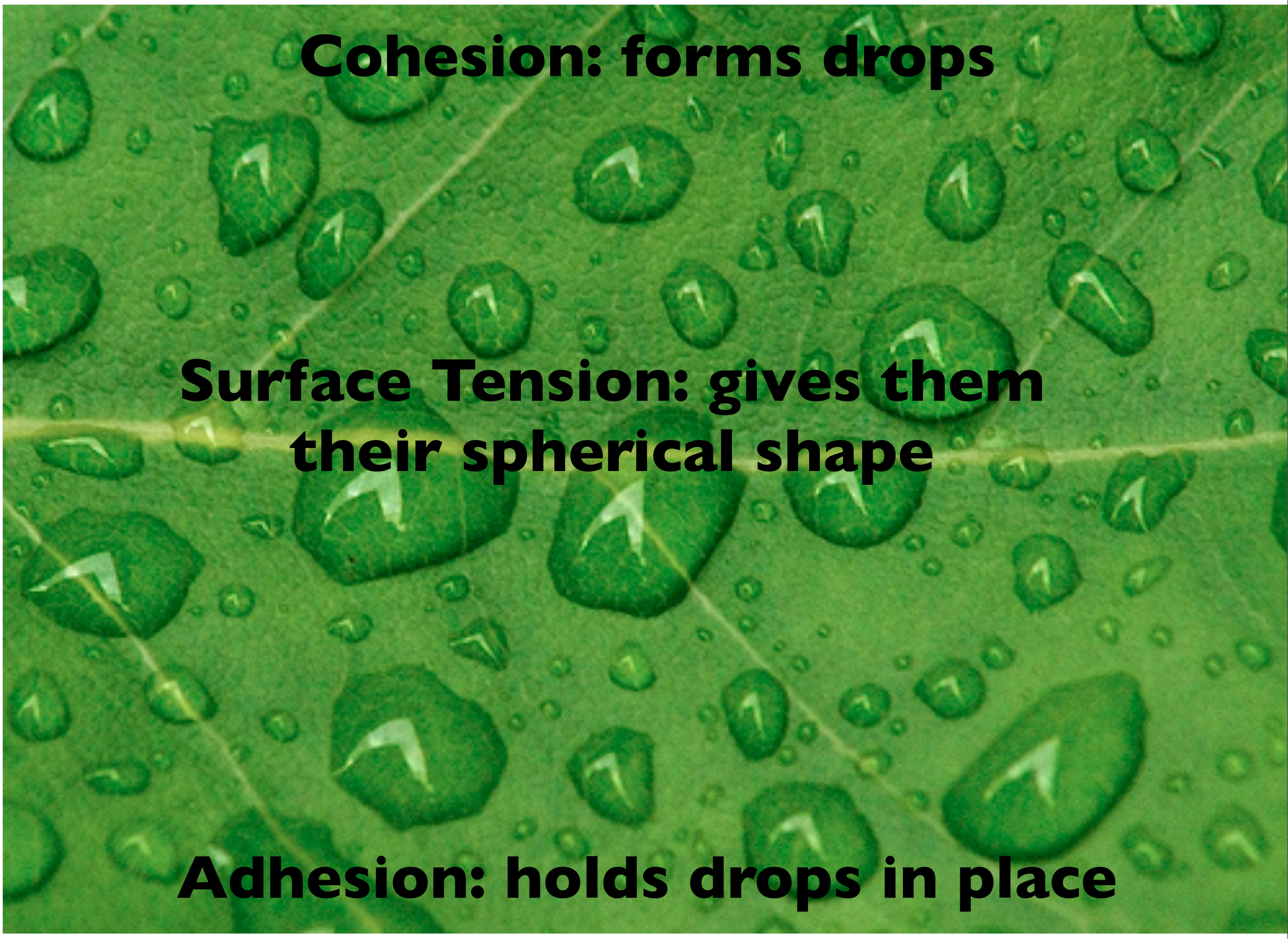
An idealized 2-dimensional view

FOUR EMERGENT PROPERTIES OF WATER CONTRIBUTE TO EARTH'S SUITABILITY FOR LIFE

- Cohesive Behavior
- Ability to moderate temperature
- Expansion upon freezing
- Versatility as a solvent (can dissolve a lot

Cohesion of Water Molecules

- Hydrogen bonds give water more structure than most other liquids
- Cohesion is the bonding of water molecules to each other through hydrogen bonds
  - Surface tension is (related to cohesion) a measure of how difficult it is to stretch or break the surface of a liquid
    - Water has one of the highest surface tensions!
- Adhesion is the bonding of water molecules to other substances through hydrogen bonds
- Water would not move through plants if not for cohesion and adhesion


Cohesion: forms drops
Surface Tension: gives them their spherical shape
Adhesion: holds drops in place

Moderation of Temperature

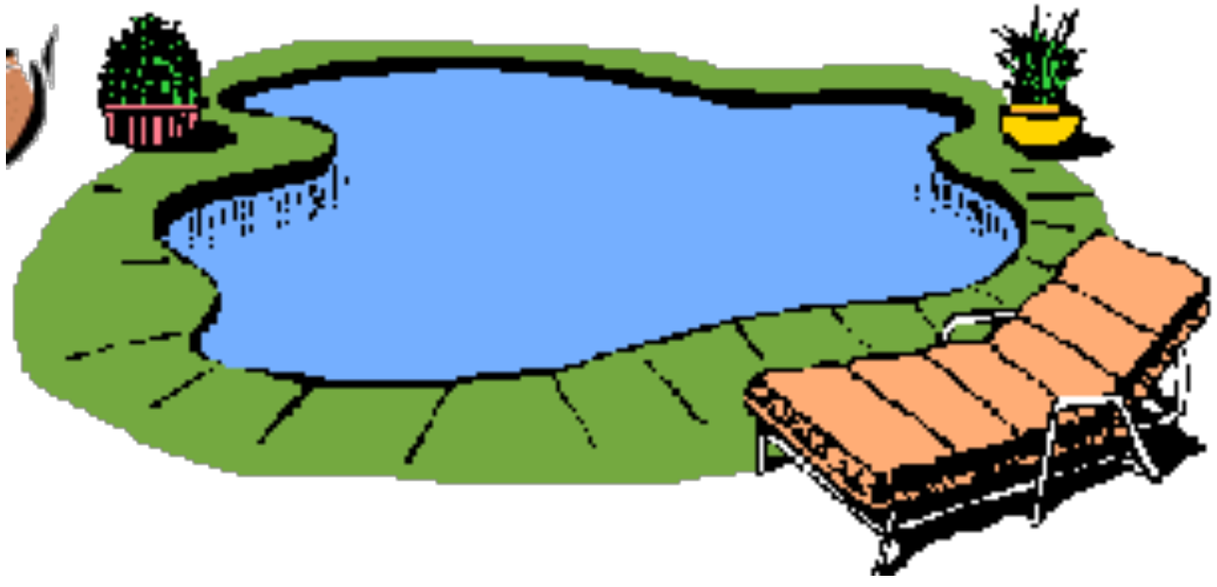
- Water can absorb heat from warmer air OR release heat to cooler air
- Water can absorb or release a relatively large amount of heat with only a slight change to its own temperature

Heat and Temperature

- *Kinetic Energy* is the energy of motion, anything moving has kinetic energy
  - atoms & molecules are constant random motion

Heat and Temperature (cont.)

- *Heat* is a form of energy
  - amount of heat is a measure of the matter's kinetic energy
    - heat depends somewhat on its volume of the matter
- *Temperature* is a measure of heat intensity, it represents the average kinetic energy, regardless of volume!



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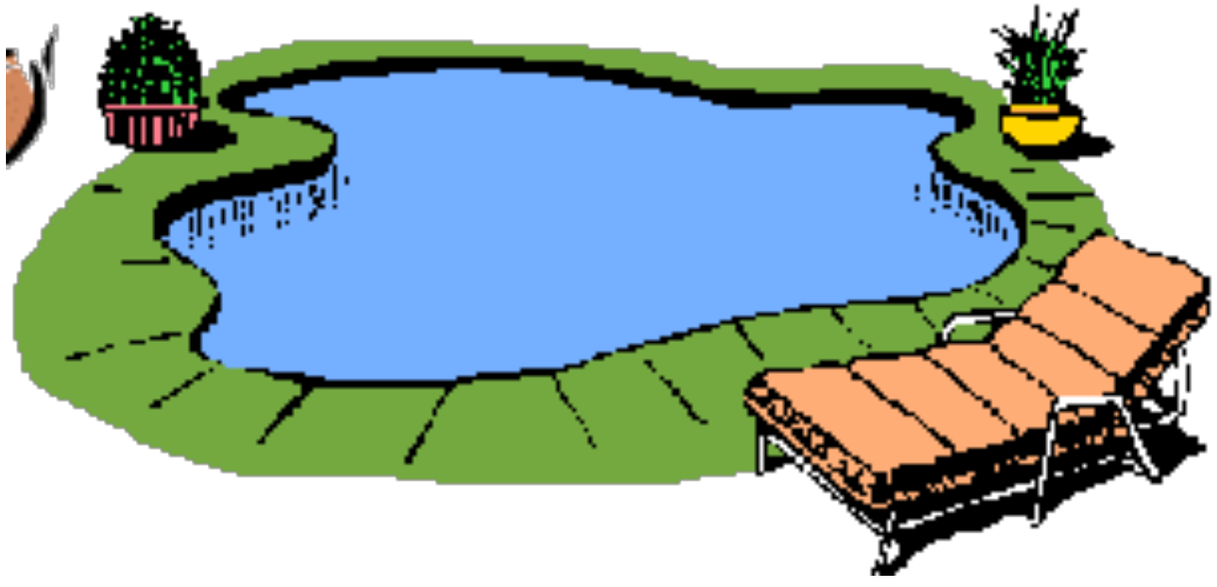

Which has higher temperature?
Which has more heat?

Heat and Temperature (cont.)

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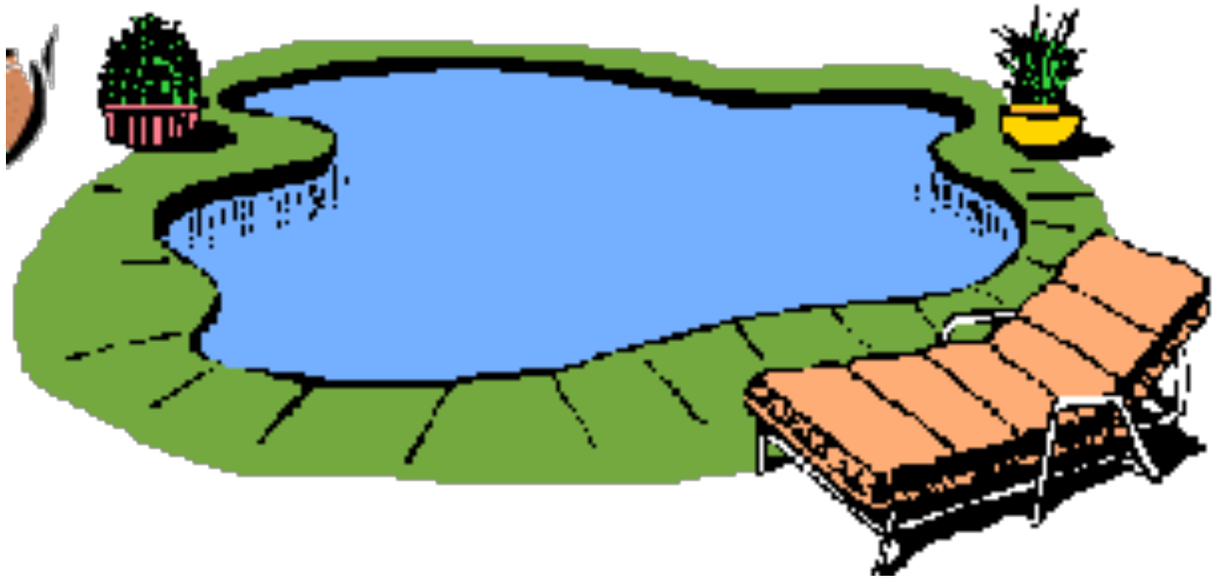

Which has higher temperature?
Which has more heat?

...the coffee

Heat and Temperature (cont.)

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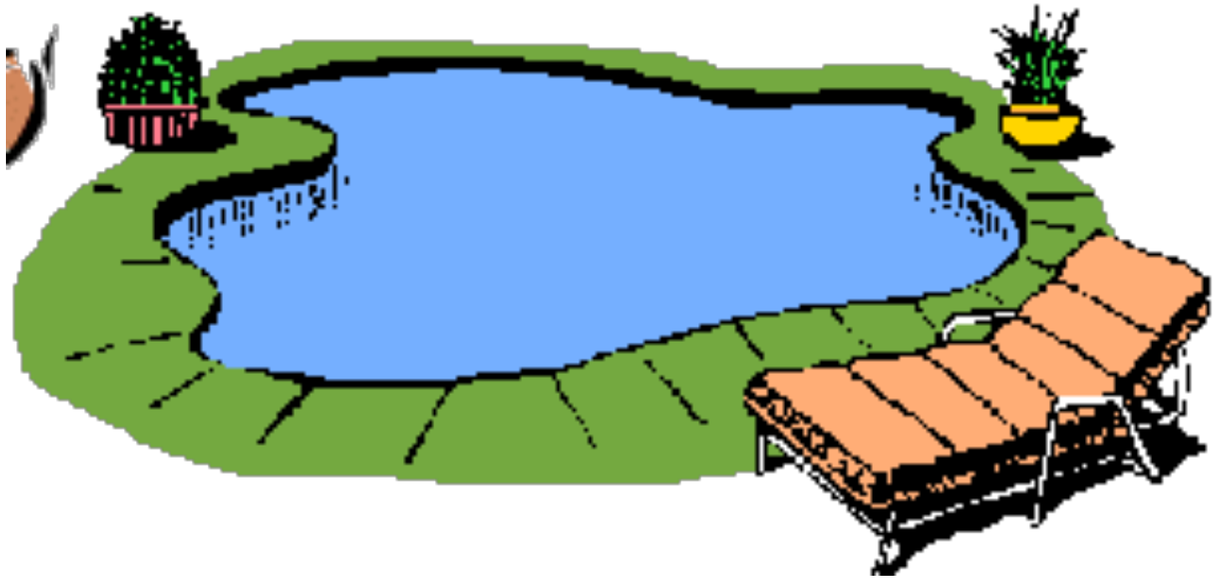


Which has higher temperature?
Which has more heat?

...the coffee
...the pool

Heat and Temperature (cont.)

- *Heat* moves from warmer object to a cooler one

Heat and Temperature (cont.)

- *Heat* moves from warmer object to a cooler one

How then does ice make water colder?

Heat and Temperature (cont.)

- *Heat* moves from warmer object to a cooler one

How then does ice make water colder?

Ice does not add coldness, it absorbs heat from water, thus melts

Heat and Temperature (cont.)

- *Heat* moves from warmer object to a cooler one

How then does ice make water colder?

Ice does not add coldness, it absorbs heat from water, thus melts

- *Celcius scale* indicates temperature
  - Water freezes at 0°C, Boils at 100°C, Body temp 37°
- *Temperature* is a measure of heat intensity, it represents the average kinetic energy, regardless of volume!

Water's High Specific Heat

- *Specific Heat* is the amount of heat that must be absorbed or lost for 1g of a substance to change temp. by 1 °C
  - is a measure of well a substance resists changing its temp.
- Water has a unusually high specific heat
  - this property results from water's hydrogen bonding

Review...Relevance?

- ***Moderates both sea and land temperatures***
- ***Allows organisms to resist change in body temperatures***

Evaporative Cooling

- *Evaporation (vaporization)* is the transformation from a liquid to a gas
  - some evaporation occurs at any temperature.
- *Heat of Vaporization* is the amount of heat a liquid must absorb for 1g to be converted from liquid to gas
- *Evaporative cooling* occurs because "hottest" molecules (most energy) are most likely to leave and the liquid left behind becomes cooler.

Global Relevance

- ***Water evaporates at equator, water contains heat, moves towards poles, condenses and releases heat***

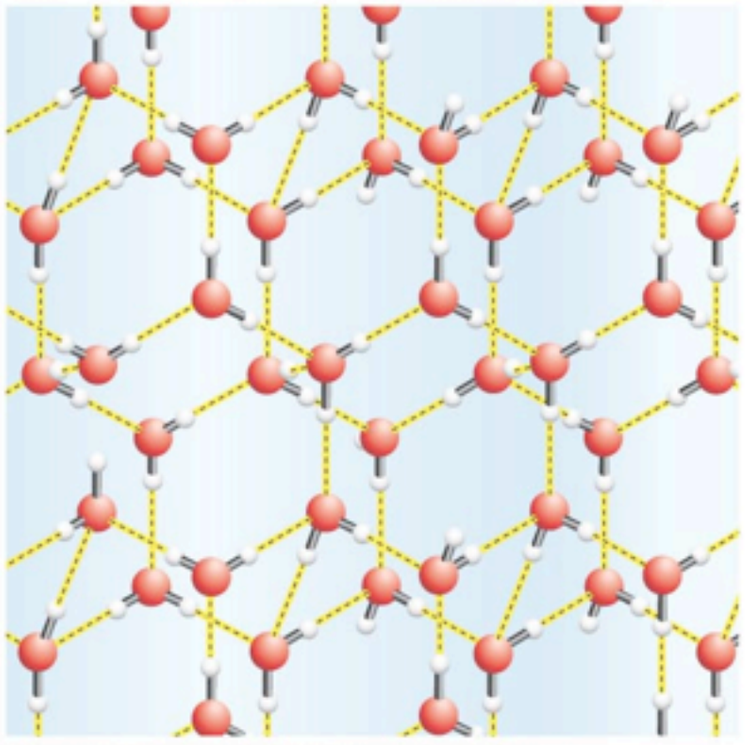
Organismal Relevance

- ***A mechanism that prevents terrestrial organisms from over heating***

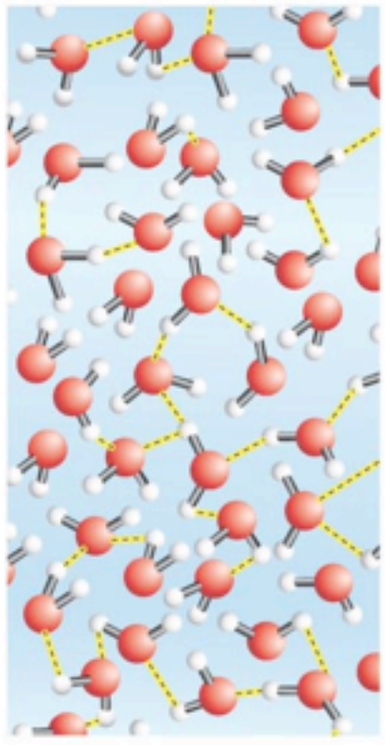
Ice Floats on Liquid Water

- *Water is one of the only substances that is less dense as a solid than as a liquid.*
  - most substances contract as they get colder, BUT water expands as it gets colder.
  - the cause is once again the unique hydrogen bonding

(a) In ice, water molecules form a crystal lattice.



(b) In liquid water, no crystal lattice forms.



(c) Liquid water is denser than ice. As a result, ice floats.

Relevance

-prevents bodies of water from freezing solid

-solid habitat

-insulation

Water the Solvent of Life

- *Solution*- a liquid homogenous mixture of two or more substances
  - *Solvent*- is the dissolving agent of the solution
  - *Solute*- the substance that is dissolved
  - *Aqueous Solution*- one where water is the solvent

***Water is a versatile solvent BUT it is NOT the universal solvent!**

Water dissolves Ionic compounds &
Nonionic Polar Compounds

Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

b. Surface area-to-volume ratios affect a biological system's ability to obtain necessary resources or eliminate waste products.

Evidence of student learning is a demonstrated understanding of each of the following:

1. As cells increase in volume, the relative surface area decreases and demand for material resources increases; more cellular structures are necessary to adequately exchange materials and energy with the environment. These limitations restrict cell size.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

root hairs,
cells of aveoli,
cells of villi,
microvilli

Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

b. Surface area-to-volume ratios affect a biological system's ability to obtain necessary resources or eliminate waste products.

Evidence of student learning is a demonstrated understanding of each of the following:

2. The surface area of the plasma membrane must be large enough to adequately exchange materials; smaller cells have a more favorable surface area-to-volume ratio for exchange of materials with the environment.

EXCHANGING WITH THE ENVIRONMENT

- Molecules need to imported and exported across the membrane.
- Cells are filled with water and cells are surrounded by water.
  - Not pure water but rather a solution.
- Water is the medium that imports and exports molecules across the membrane.
- Small cells can import and export molecules more efficiently than larger cells. All cells are small.

Molecules need to imported and exported across the membrane.

FOR STARTERS

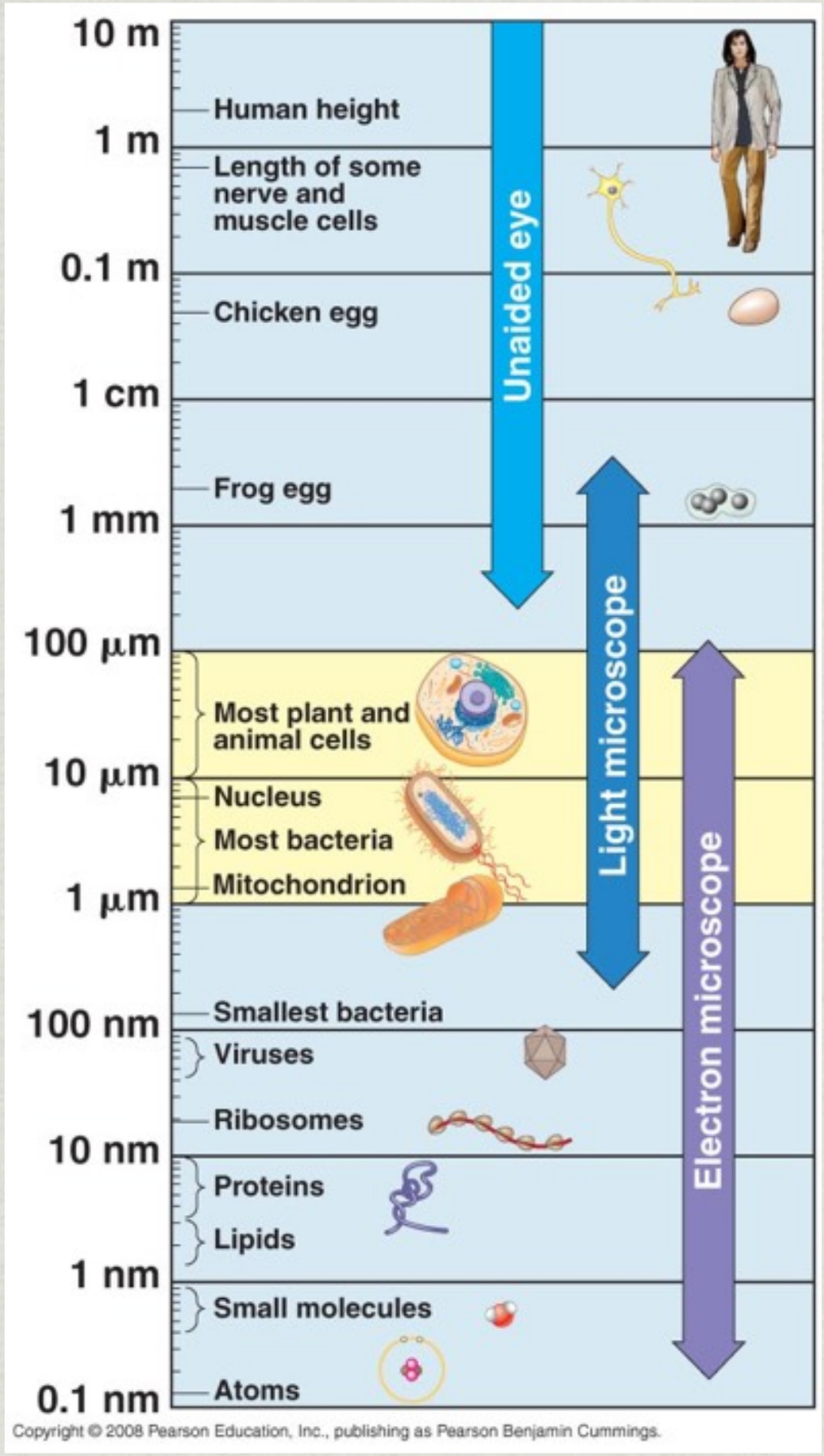
- Nutrients and oxygen need to be imported.
- Waste and carbon dioxide need to be exported.

Cells are filled with water and cells are surrounded by water.

- The inside of a cell is 70-95% water, more specifically called cytosol.
  - *The cytosol is a complex mixture of substances dissolved in water.*
- A unicellular organism is surrounded lives an aquatic environment.
- The cells of a multicellular organism are bathed in extracellular fluid.
  - *denotes all body fluid outside of cells*

Water is the medium that imports and exports molecules across the membrane.

- Life began in water.
- Life remains tied to water, organisms require water more than any other substance.
- Important cellular substances and molecules are dissolved in water.
- Water molecules participate in many chemical reactions necessary to sustain life.



Small cells can import and export molecules more efficiently than larger cells. All cells are small.

SIZE MATTERS

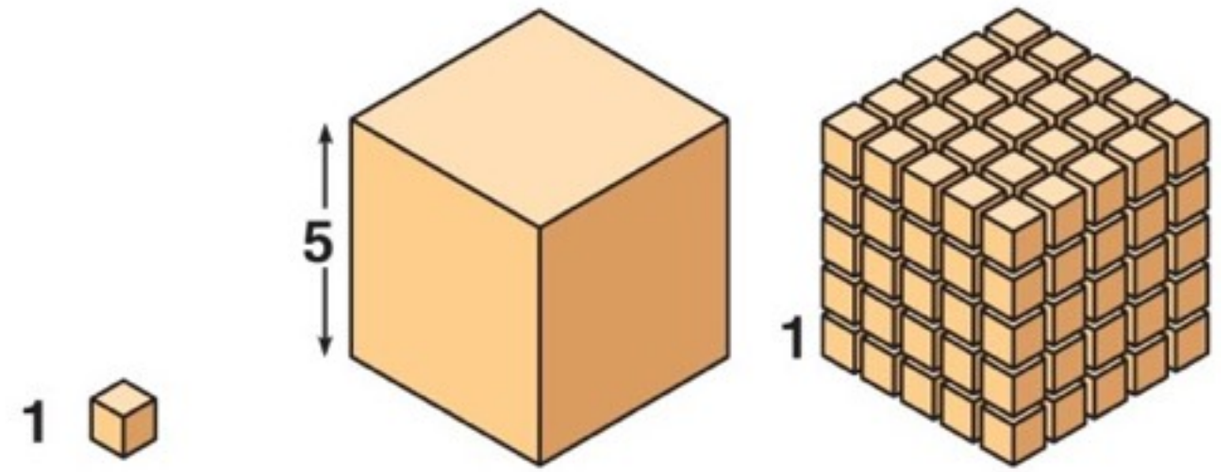
The logistics to carry out metabolism sets the lower limit on cell size

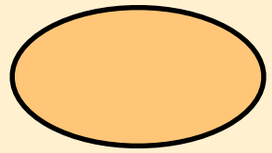
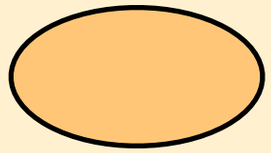
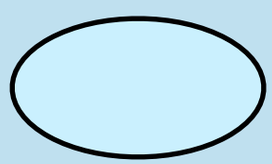
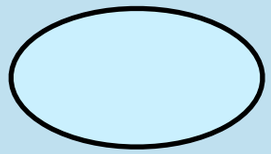
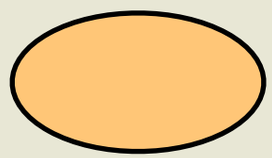
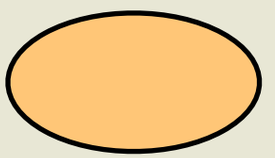
The requirements for metabolism set the upper limit on cell size

The ratio of surface area to volume is critical

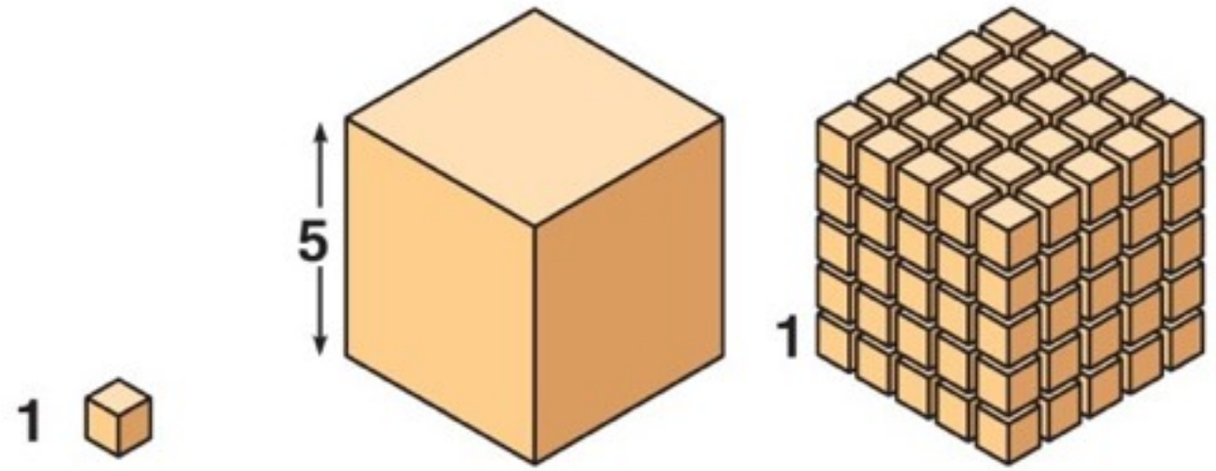
Volume (cubed function) grows proportionately more than its surface area (squared function)

Surface area increases while total volume remains constant



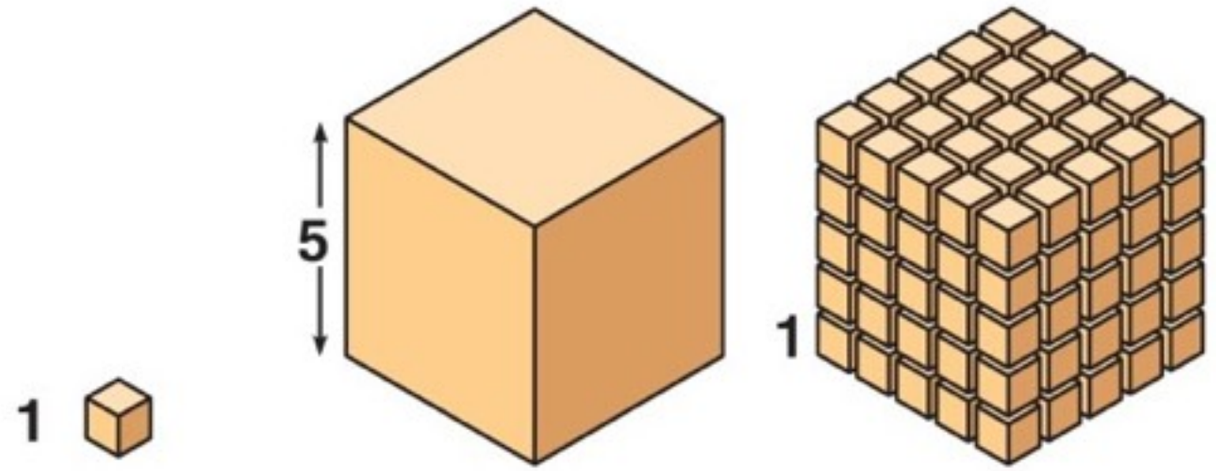
Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6		
Total volume [height × width × length × number of boxes]	1		
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6		

Surface area increases while total volume remains constant



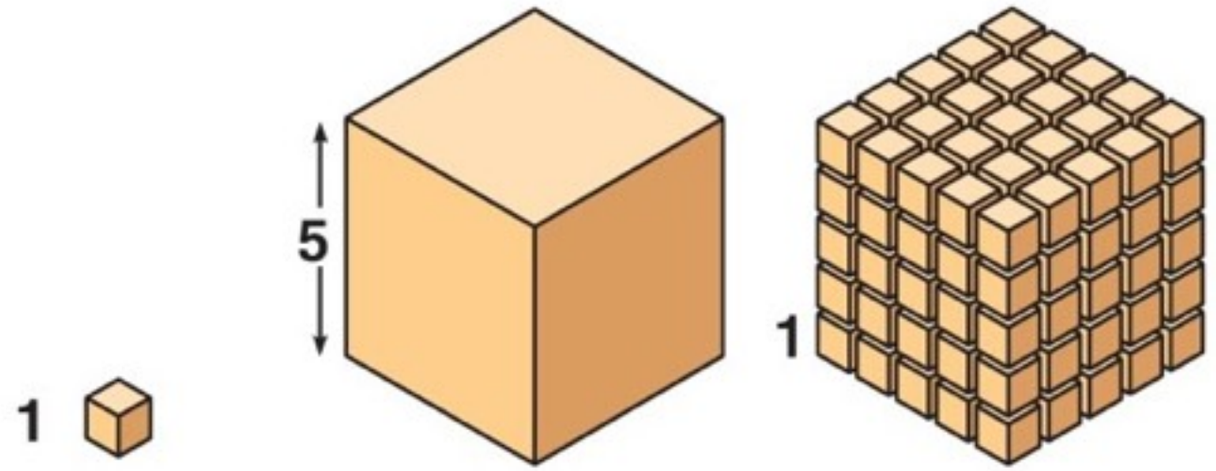
Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	
Total volume [height × width × length × number of boxes]	1		
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6		

Surface area increases while total volume remains constant



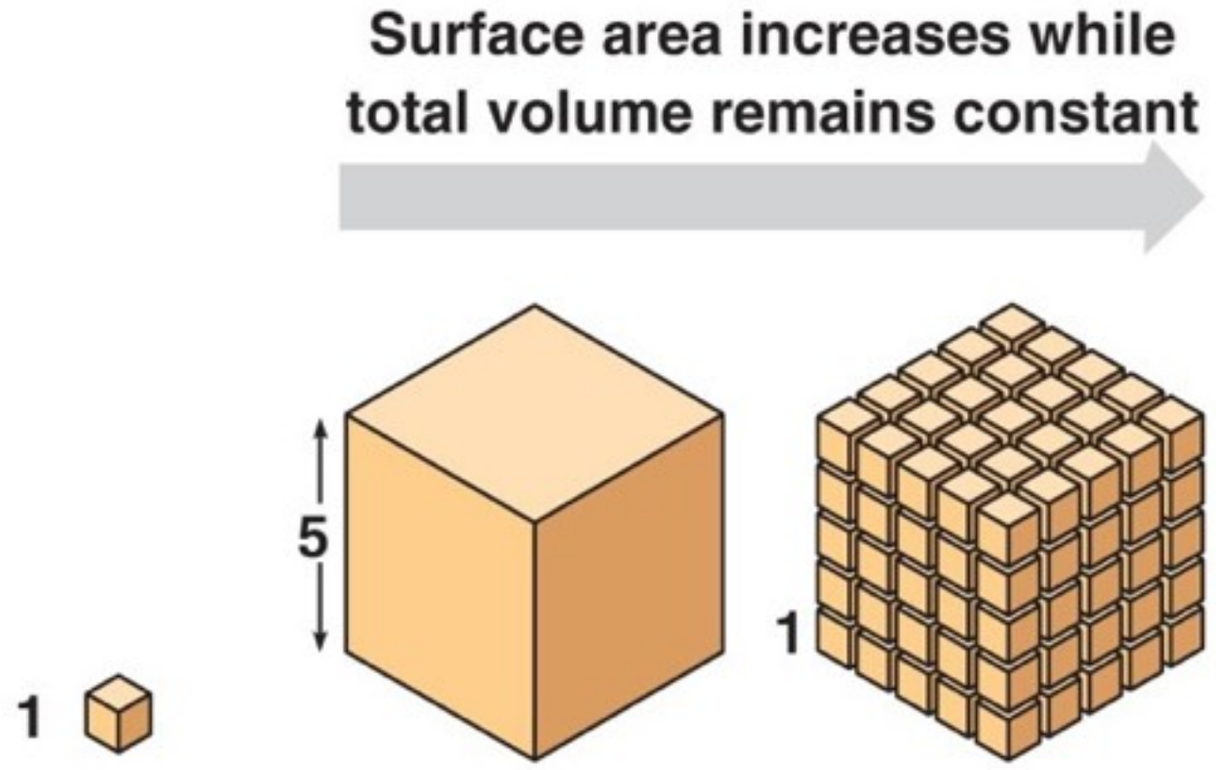
Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	
Total volume [height × width × length × number of boxes]	1	125	
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6		

Surface area increases while total volume remains constant



Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	
Total volume [height × width × length × number of boxes]	1	125	
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	

Thus a smaller object has a greater SA:V ratio



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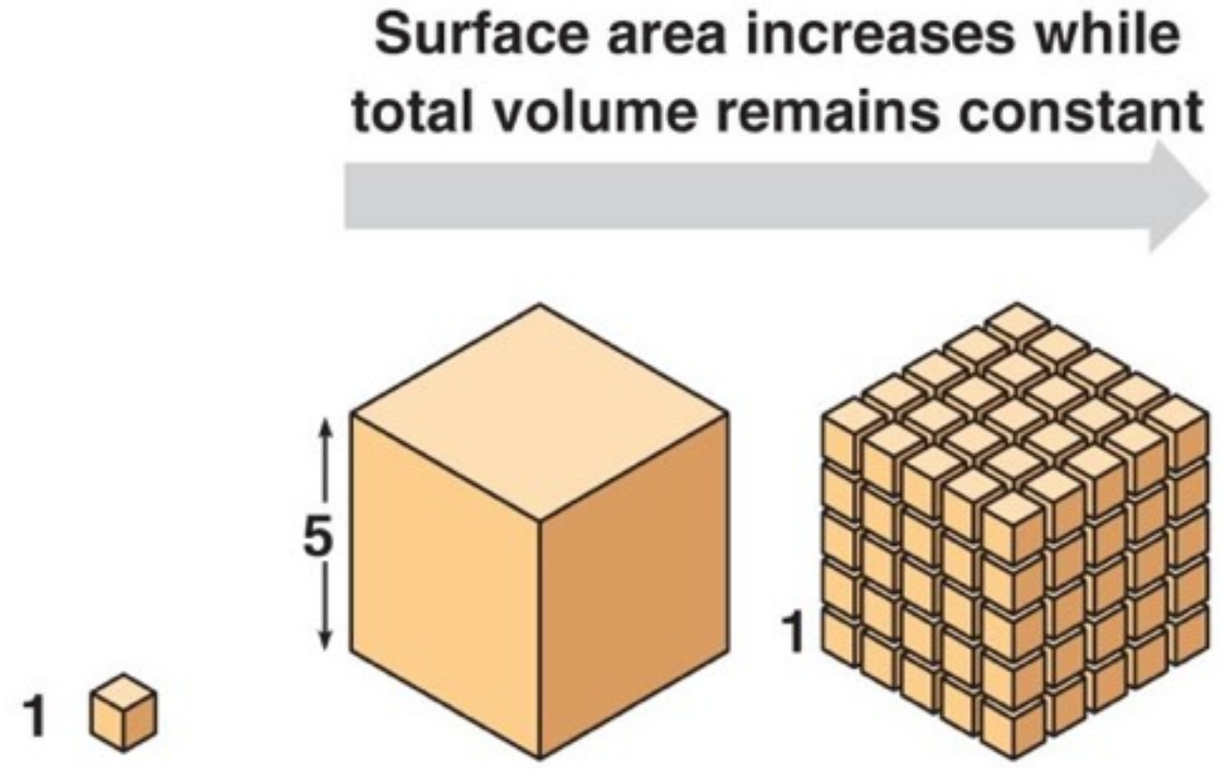

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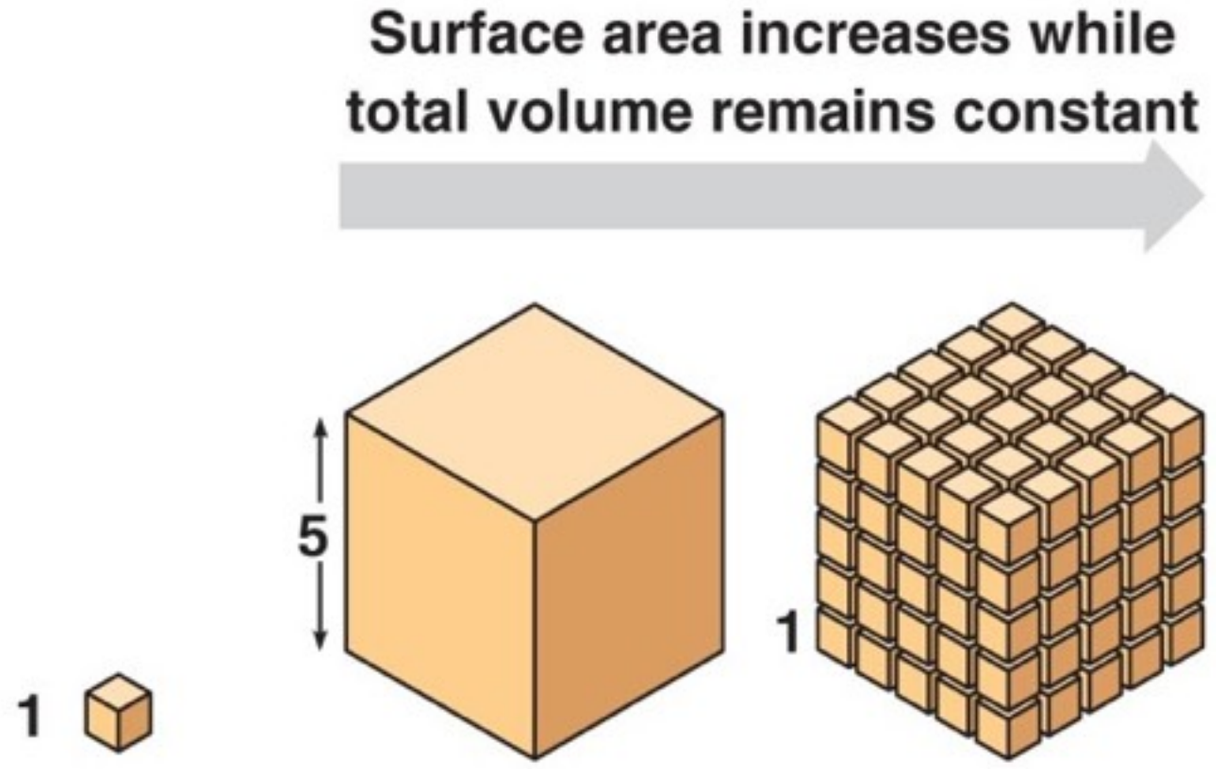
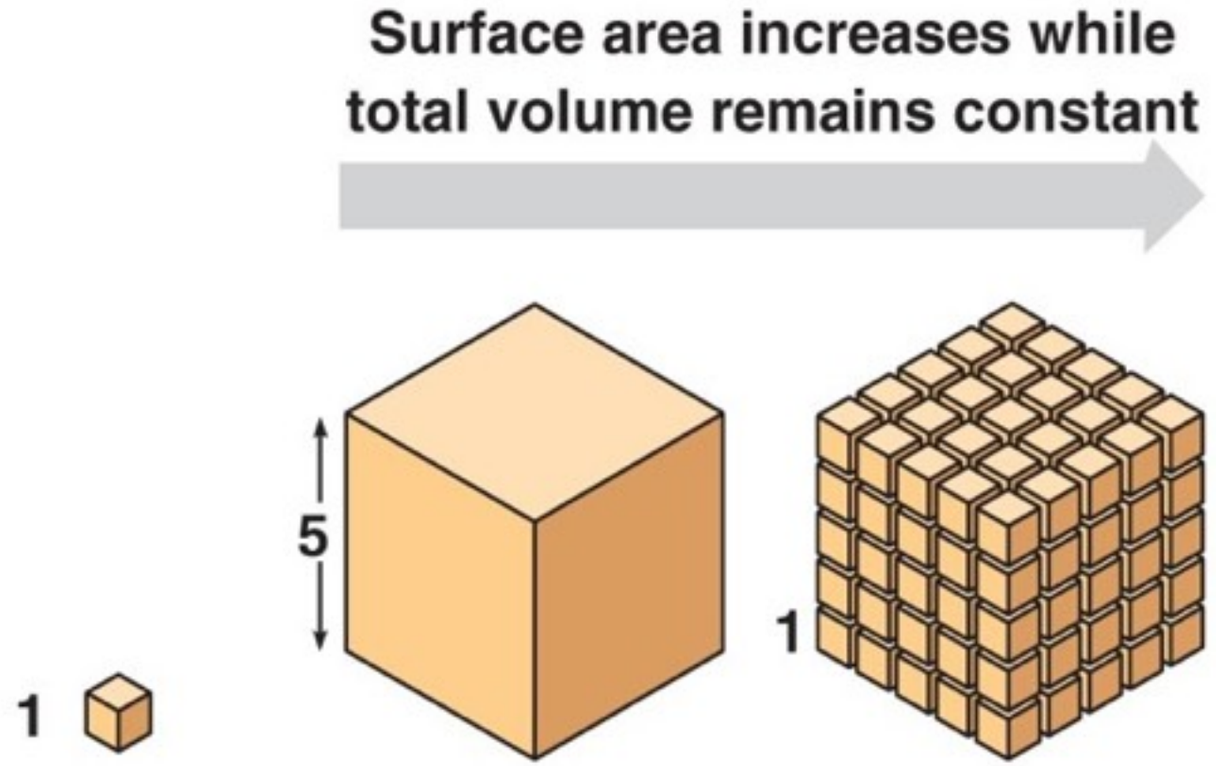


Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	
Total volume [height × width × length × number of boxes]	1	125	
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	

Bigger is Better!

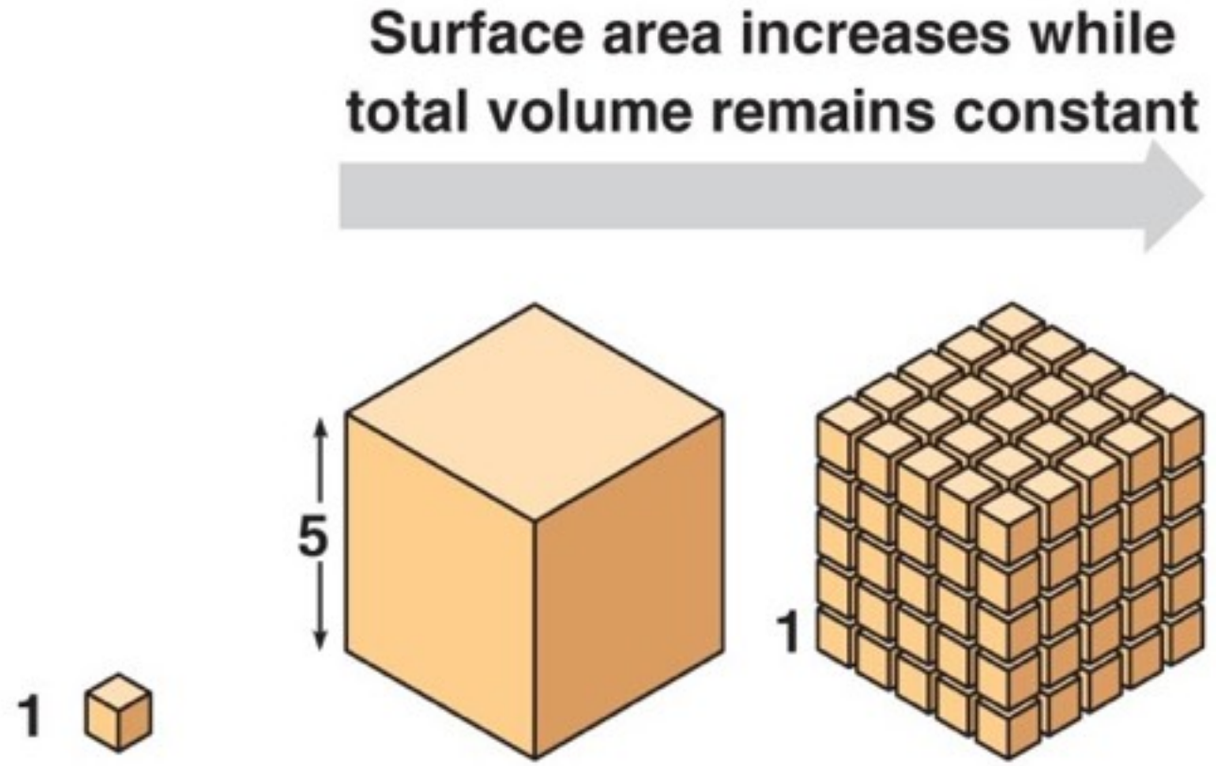
Thus a smaller object has a greater SA:V ratio



Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	

Bigger is Better!

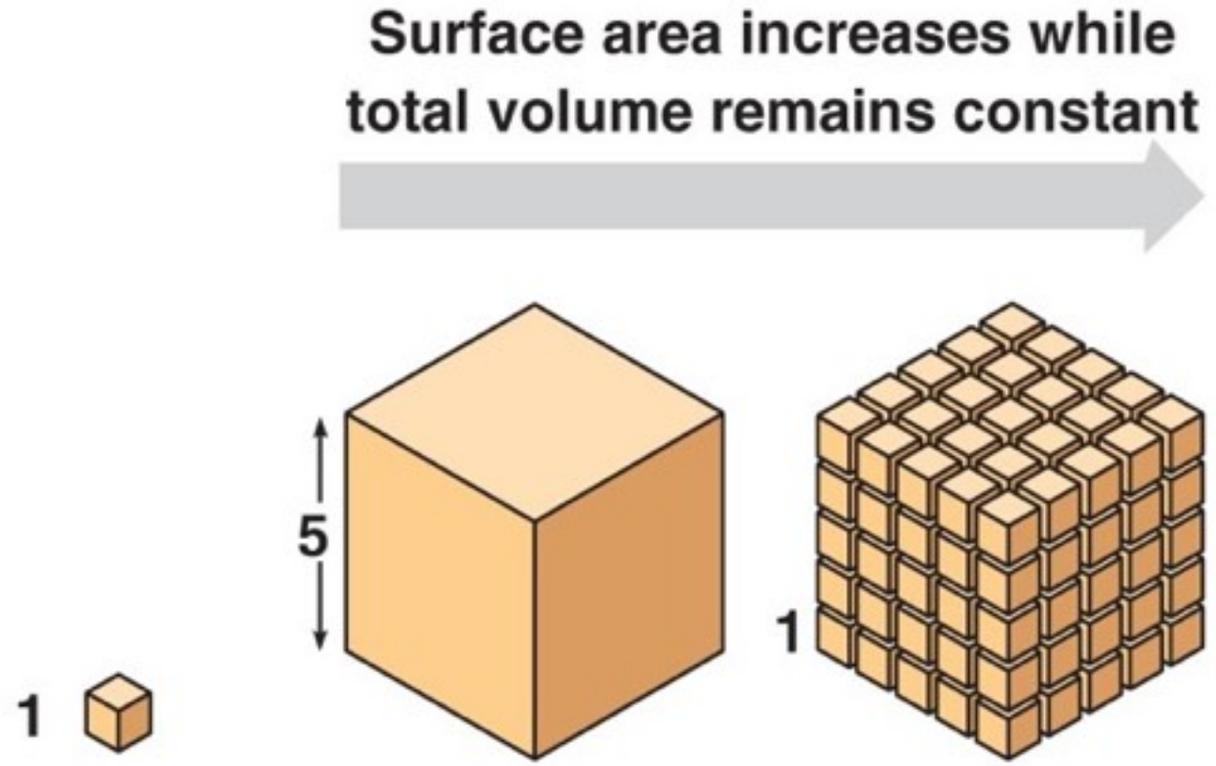
Thus a smaller object has a greater SA:V ratio



Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	

Bigger is Better!

Thus a smaller object has a greater SA:V ratio



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Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

Bigger is Better!

Can think of any cells or tissues that continually exchange with its environment?

A Big SA:V ratio is especially important for cells that continually exchange with its surroundings

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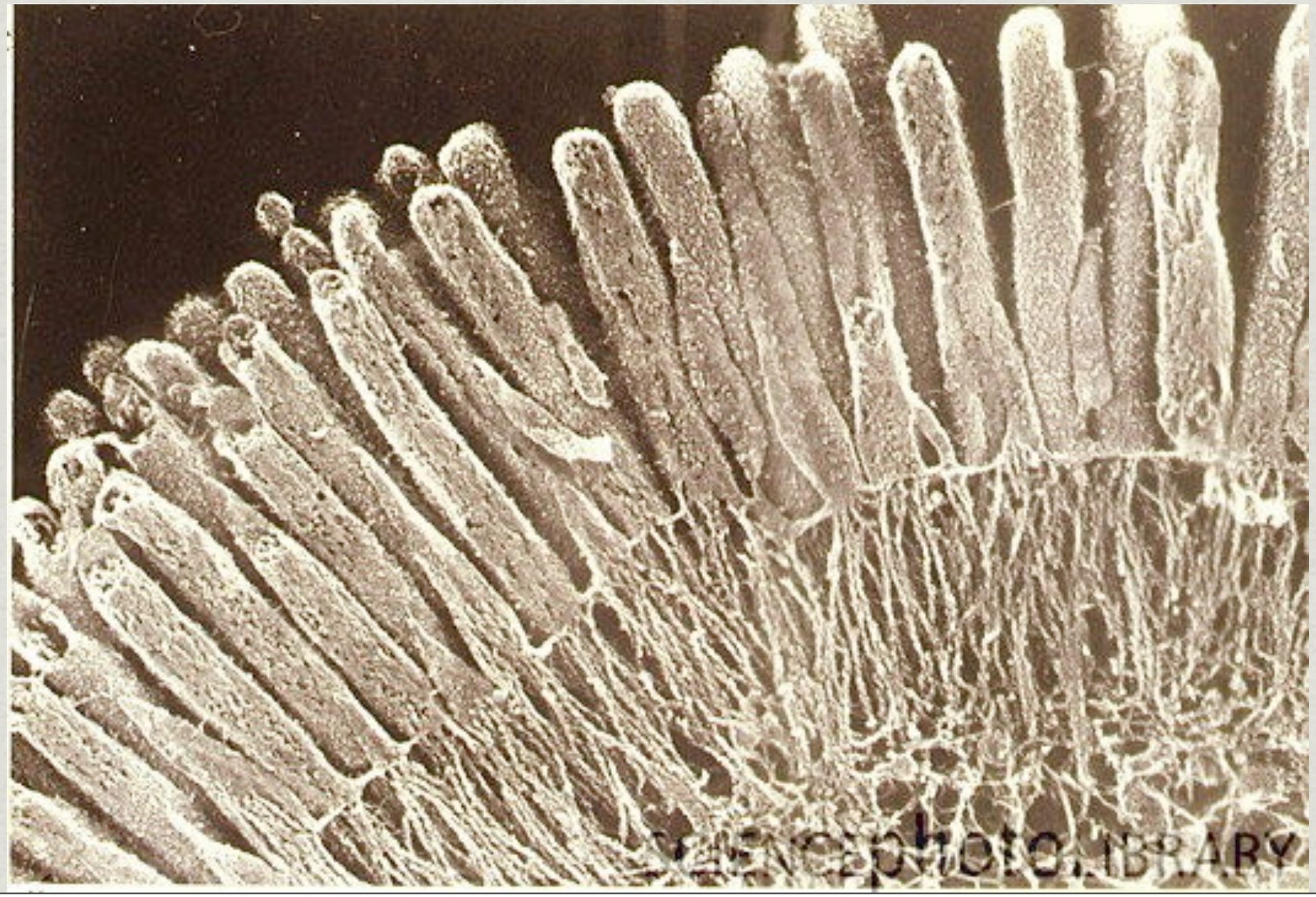

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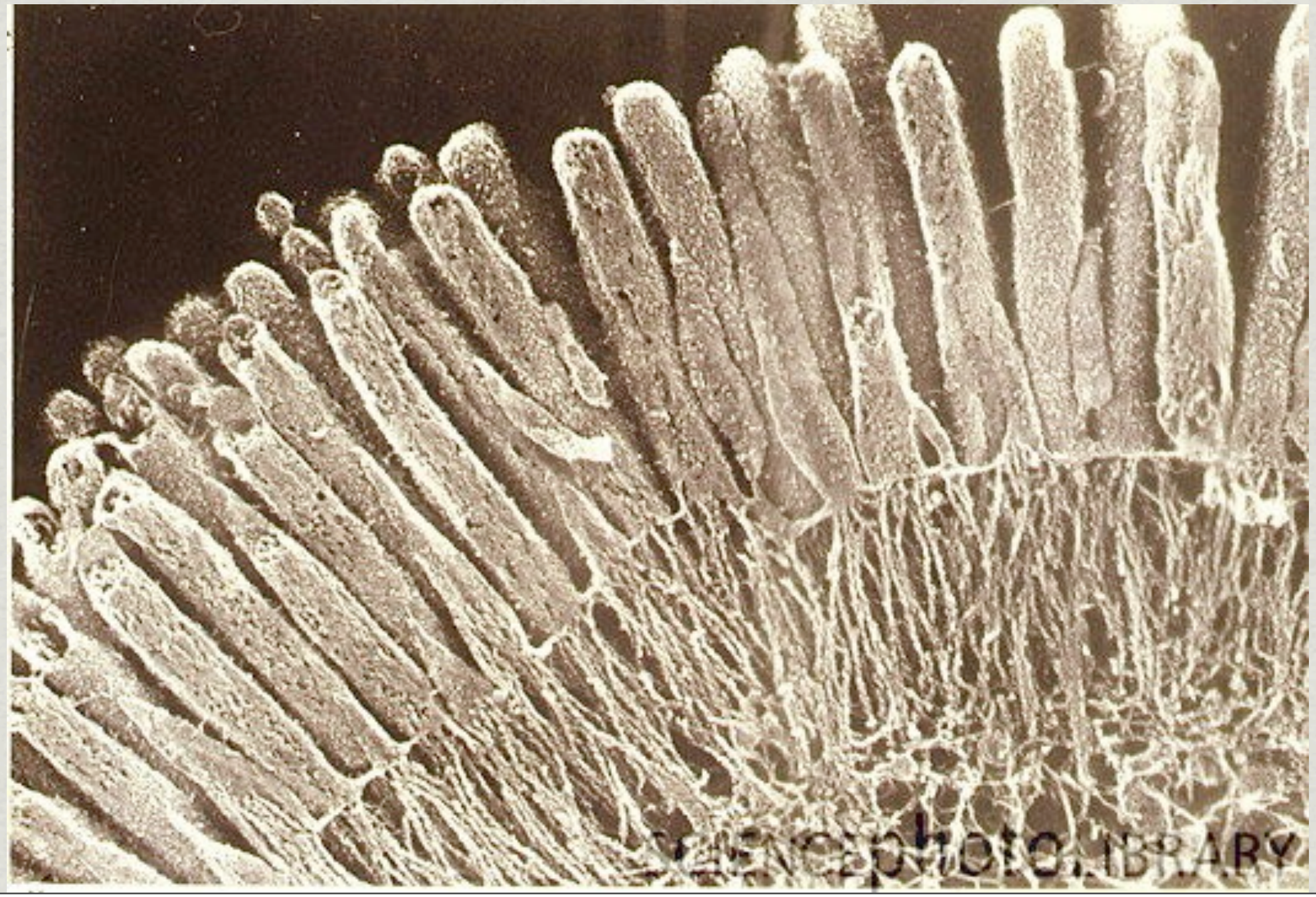

Intestine

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Can think of any cells or tissues that continually exchange with its environment?

Intestine

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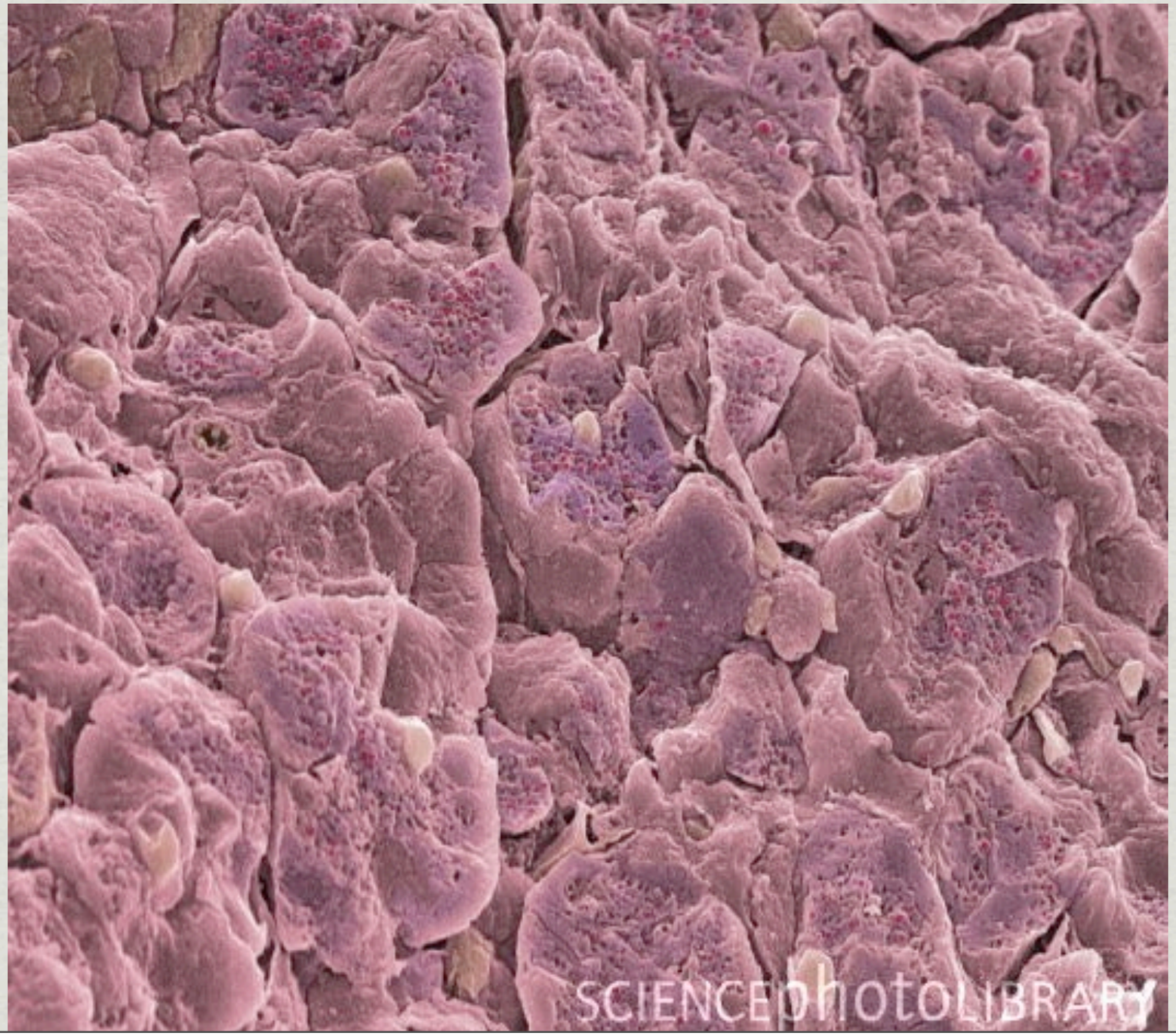

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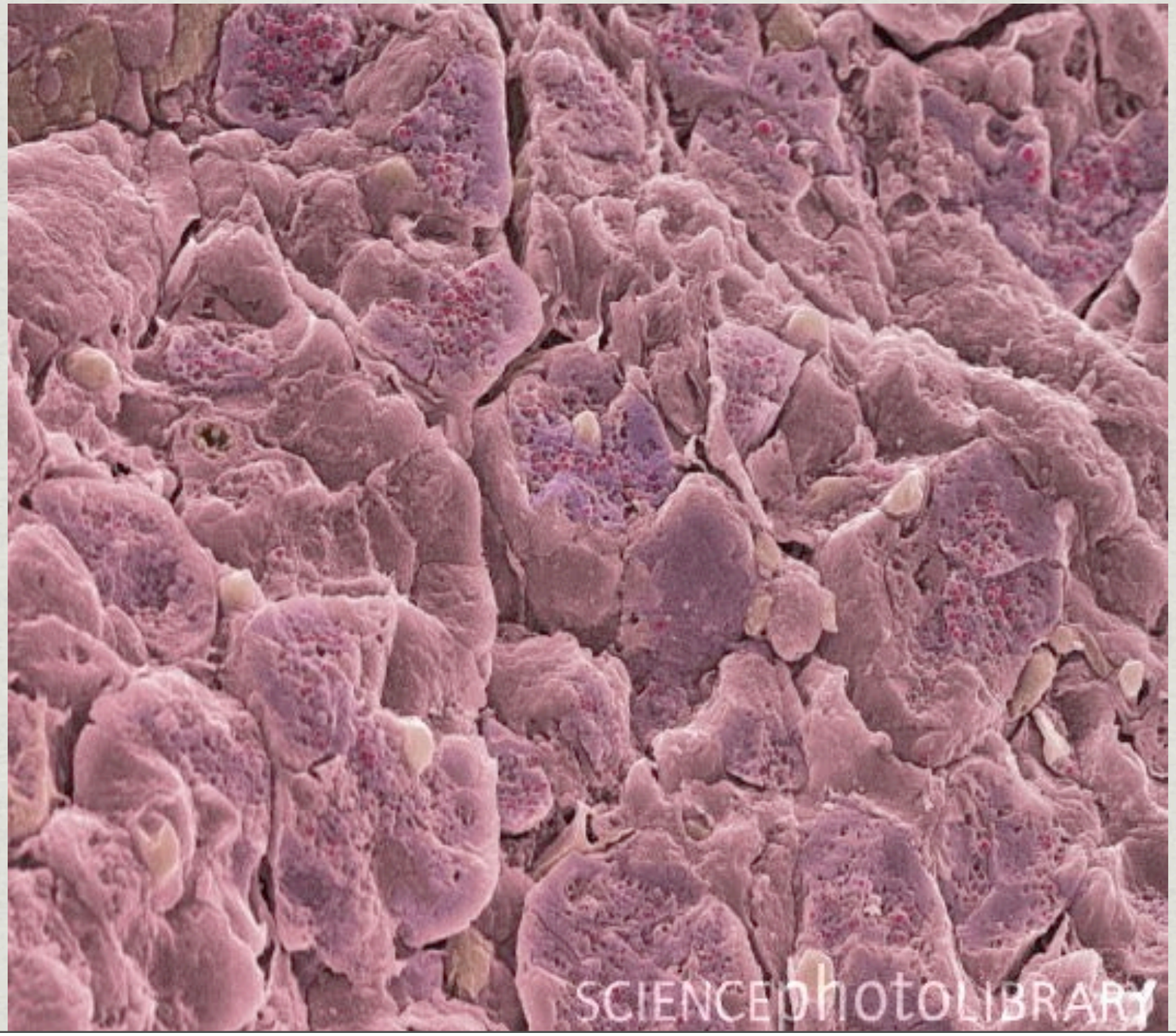

Pancreas

A Big SA:V ratio is especially important for cells that continually exchange with its surroundings

Can think of any cells or tissues that continually exchange with its environment?

Pancreas

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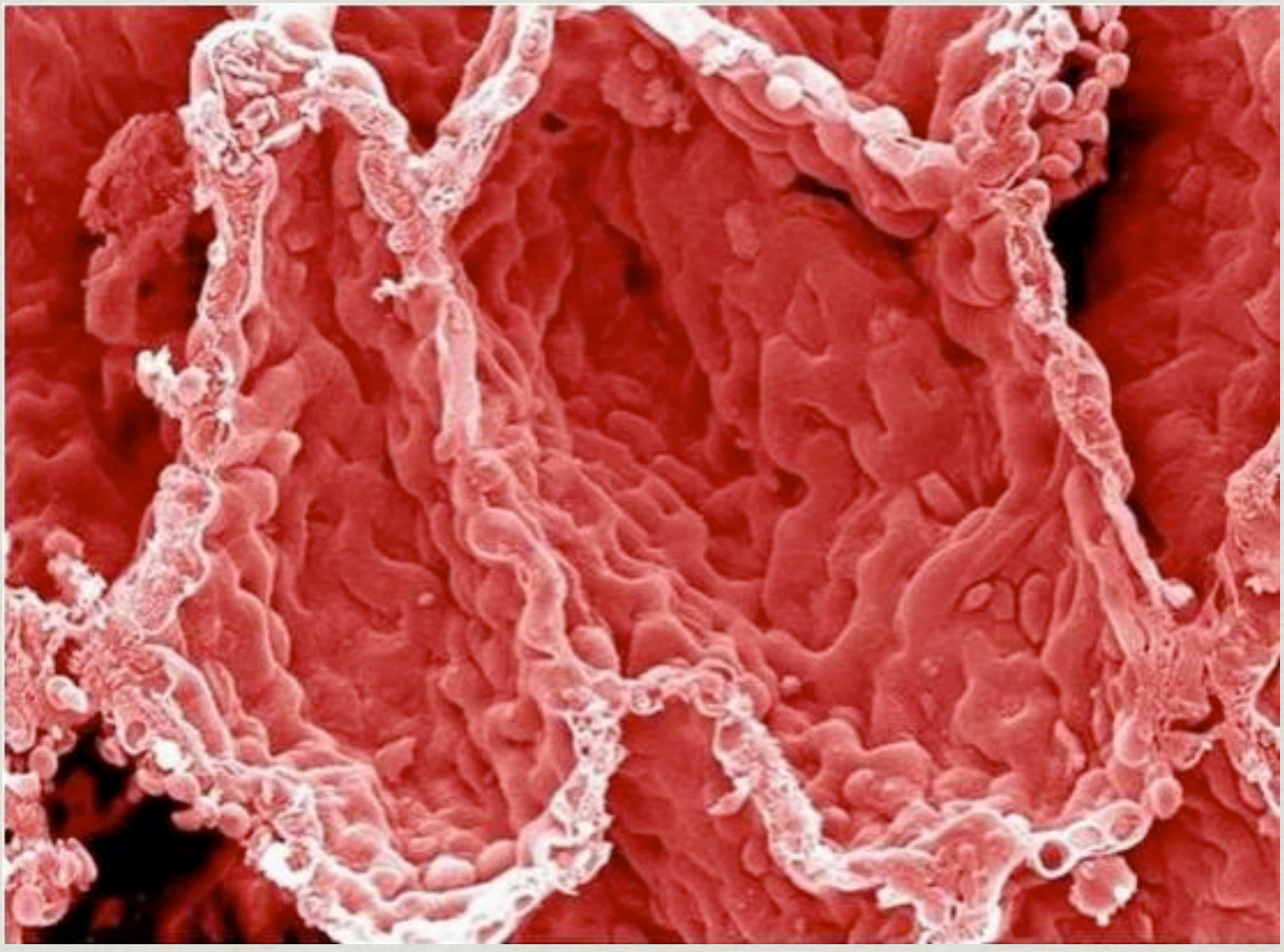

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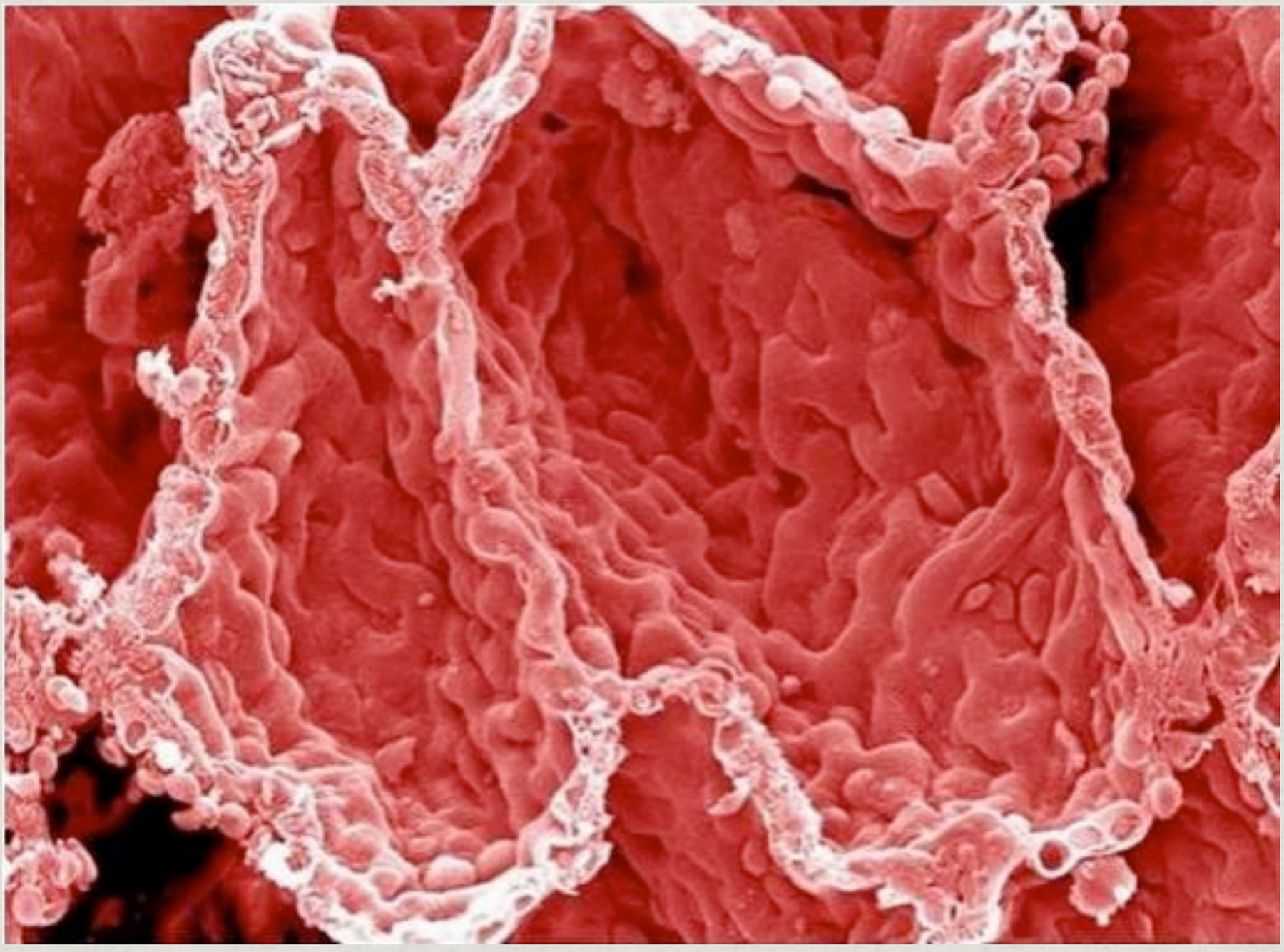

Alveoli

Learning Objectives:

LO 2.6 The student is able to use calculated surface area-to-volume ratios to predict which cell(s) might eliminate wastes or procure nutrients faster by diffusion. [See SP 2.2]

LO 2.7 Students will be able to explain how cell size and shape affect the overall rate of nutrient intake and the rate of waste elimination. [See SP 6.2]

LO 2.8 The student is able to justify the selection of data regarding the types of molecules that an animal, plant or bacterium will take up as necessary building blocks and excrete as waste products. [See SP 4.1]

LO 2.9 The student is able to represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth and reproduction. [See SP 1.1, 1.4]