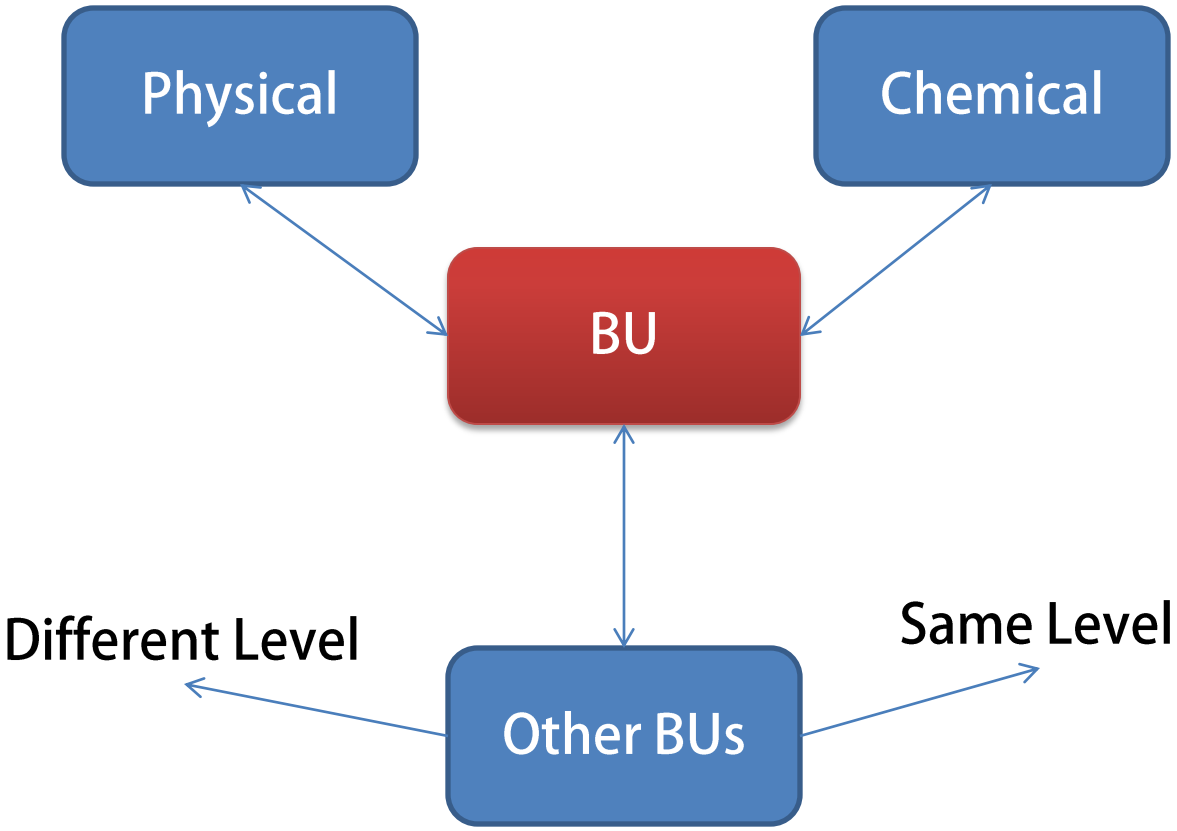
Biology
ES131

Module 4
Biological responses in context
Need for water, oxygen, nutrients

Compiled from Biology for Engineers
& Biology by Campbell

Biological Responses

- Biological units do not exist in isolation



Biological Responses

- The presence of other BU in the same physicochemical environment changes the physicochemical environment for the target BU, so that environmental conditions are constantly changing.

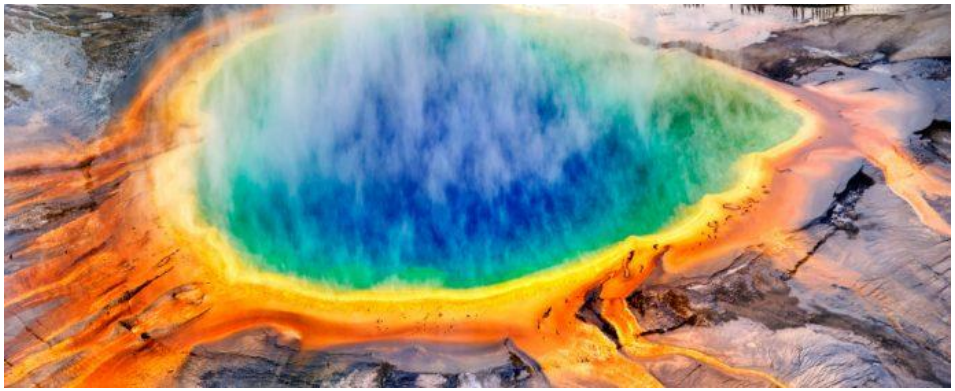
- Equilibrium is never reached, and a true steady-state, where changes over time are nil, is rare and not long-lasting when it does occur.

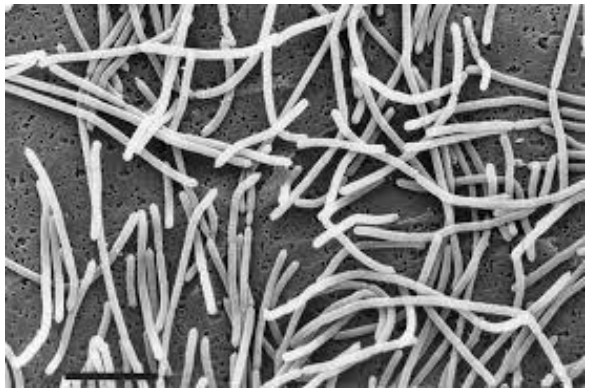
- Thus, being able to predict typical responses is about all that can be expected.

Biological Responses

- **Biological responses in context (BRIC)** are meant to draw attention to the fact that each BU is not isolated, and that a BU that adapts one way to one type of environment can adapt another way to a different environment

- BRICs can be used as the basis for constructing design solutions to engineering problems utilizing living things





The Molecule That Supports All of Life

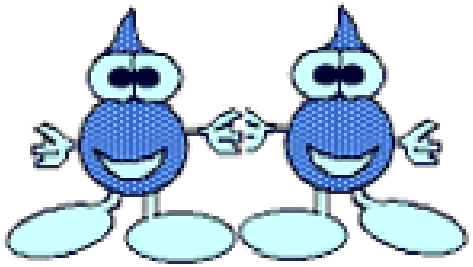
- Water is the biological medium on Earth
- All living organisms require water more than any other substance
- Most cells are surrounded by water, and cells themselves are about 70–95% water
- The abundance of water is the main reason the Earth is habitable

Four emergent properties of water contribute to Earth's fitness for life

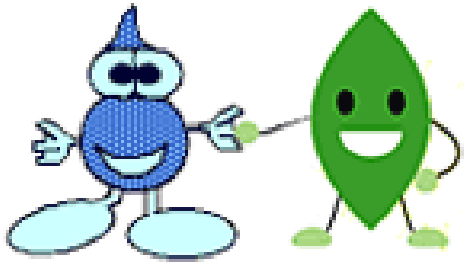
- Four of water's properties that facilitate an environment for life are:
  - Cohesive behavior
  - Ability to moderate temperature
  - Expansion upon freezing
  - Versatility as a solvent

Cohesion

- Collectively, hydrogen bonds hold water molecules together, a phenomenon called **cohesion**
- Cohesion helps the transport of water against gravity in plants
- **Adhesion** is an attraction between different substances, for example, between water and plant cell walls

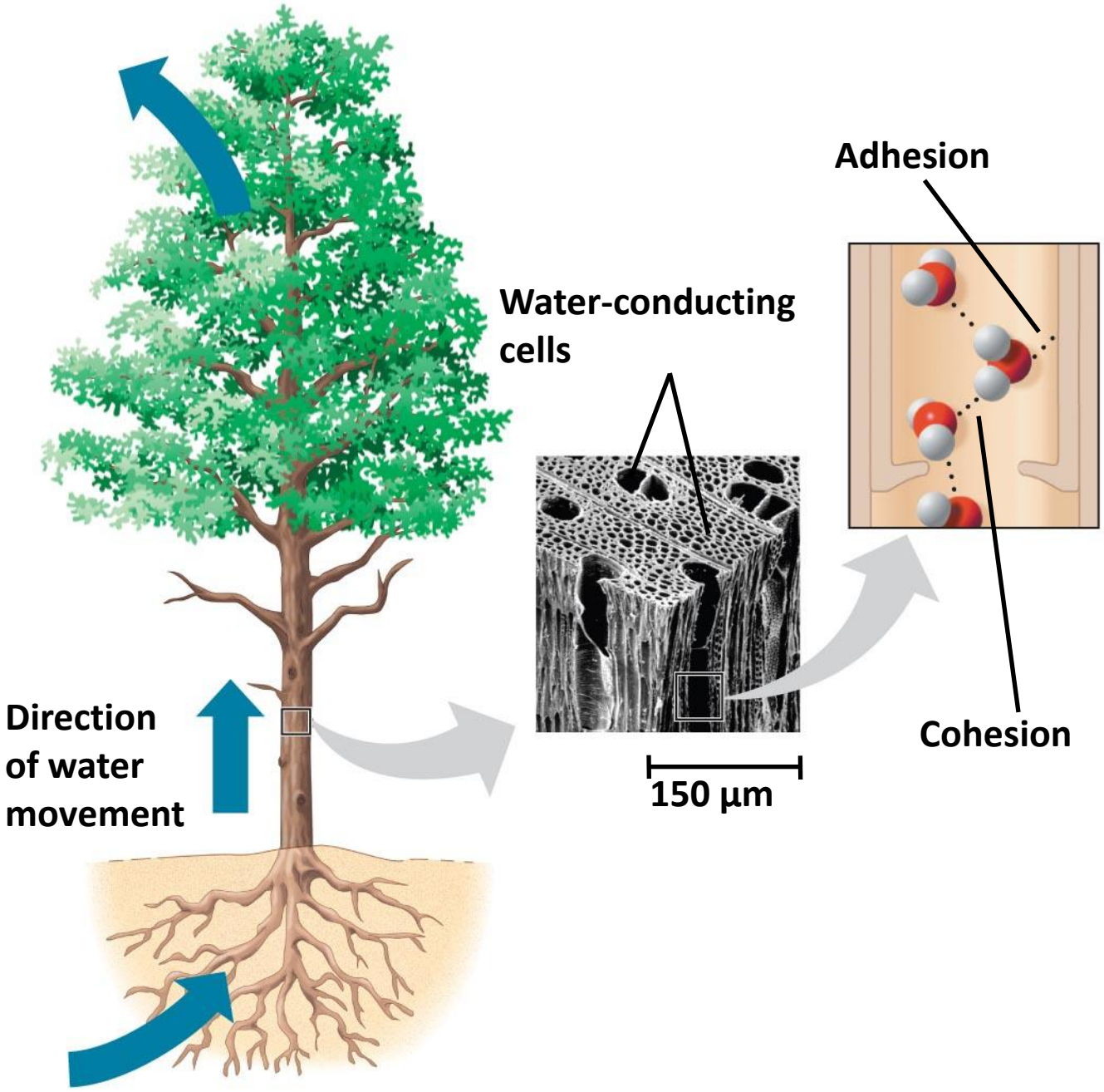


Cohesion



Adhesion

Fig. 3-3



Surface Tension

- **Surface tension** is a measure of how hard it is to break the surface of a liquid
- Surface tension is related to cohesion

Fig. 3-4

Moderation of Temperature

- Water absorbs heat from warmer air and releases stored heat to cooler air
- Water can absorb or release a large amount of heat with only a slight change in its own temperature

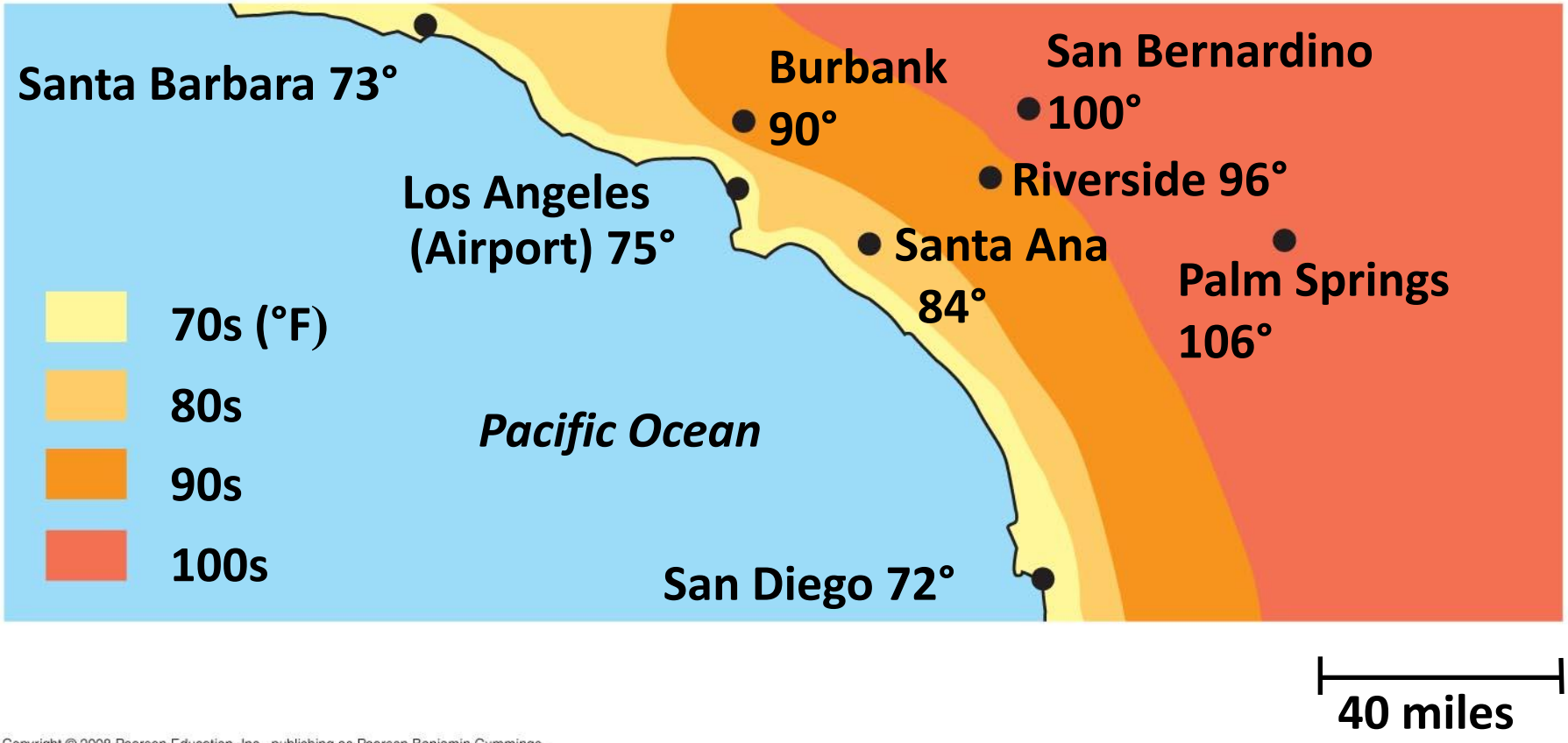
Water's High Specific Heat

- The **specific heat** of a substance is the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1ºC
- The specific heat of water is 1 cal/g/ºC
- Water resists changing its temperature because of its high specific heat

Water's High Specific Heat

- Water's high specific heat can be traced to hydrogen bonding
  - Heat is absorbed when hydrogen bonds break
  - Heat is released when hydrogen bonds form
- The high specific heat of water minimizes temperature fluctuations to within limits that permit life

Fig. 3-5



Evaporative Cooling

- *Evaporation* is transformation of a substance from liquid to gas
- **Heat of vaporization** is the heat a liquid must absorb for 1 g to be converted to gas
- As a liquid evaporates, its remaining surface cools, a process called **evaporative cooling**
- Evaporative cooling of water helps stabilize temperatures in organisms and bodies of water

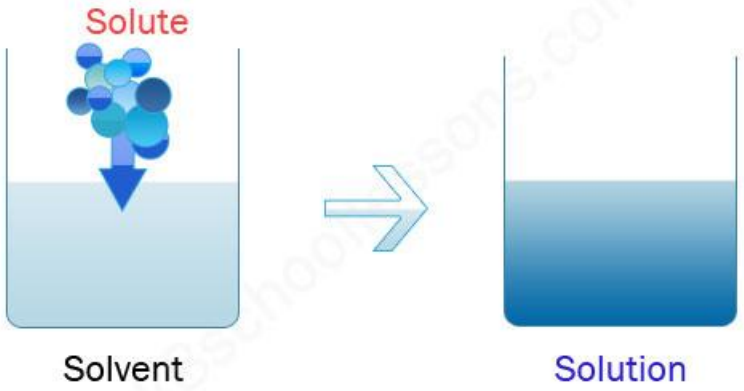
Insulation of Bodies of Water by Floating Ice

- Ice floats in liquid water because hydrogen bonds in ice are more "ordered," making ice less dense
- Water reaches its greatest density at 4°C
- If ice sank, all bodies of water would eventually freeze solid, making life impossible on Earth

Fig. 3-6

The Solvent of Life

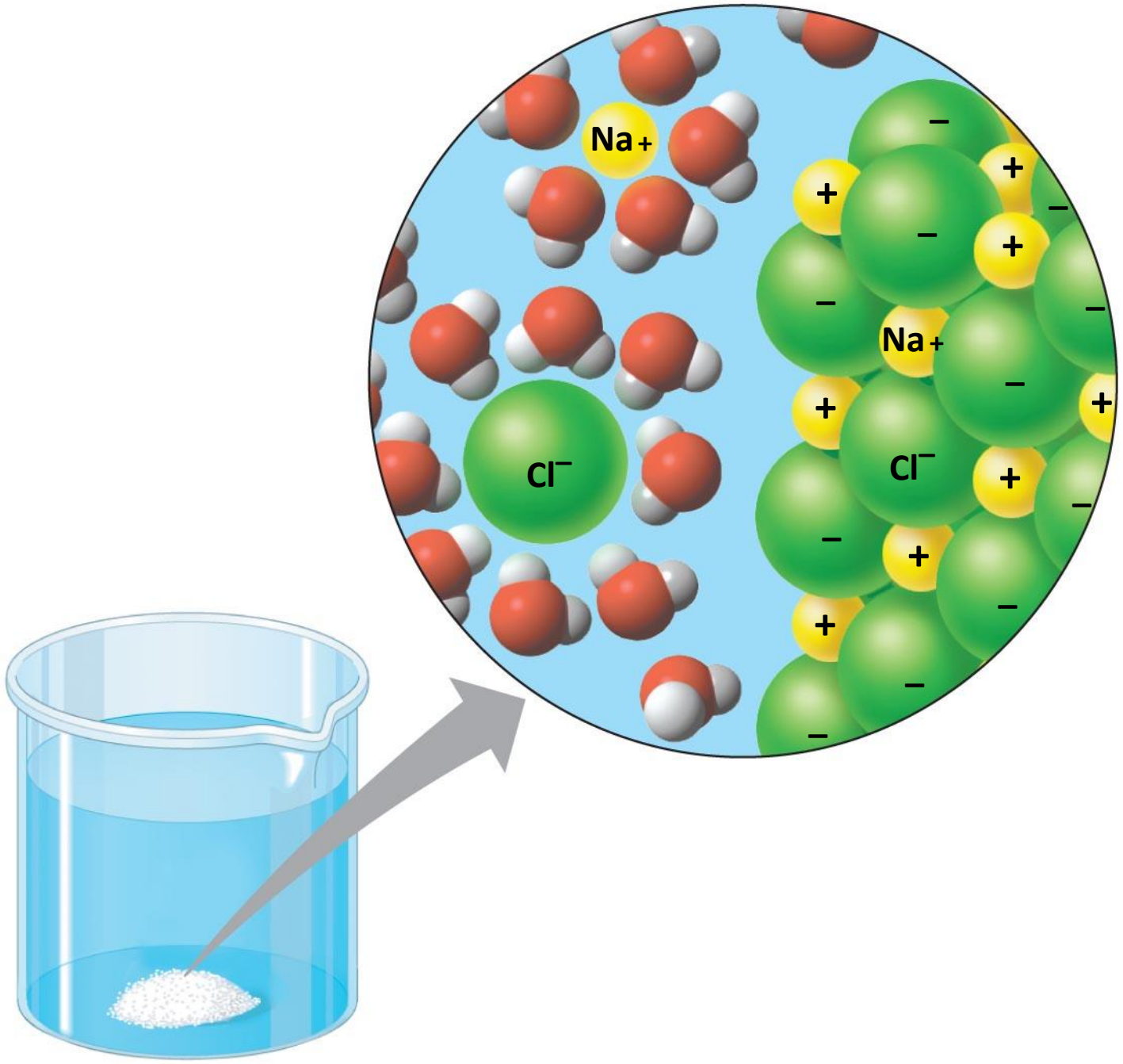
- A **solution** is a liquid that is a homogeneous mixture of substances
- A **solvent** is the dissolving agent of a solution
- The **solute** is the substance that is dissolved
- An **aqueous solution** is one in which water is the solvent



The Solvent of Life

- Water is a versatile solvent due to its polarity, which allows it to form hydrogen bonds easily
- When an ionic compound is dissolved in water, each ion is surrounded by a sphere of water molecules called a **hydration shell**

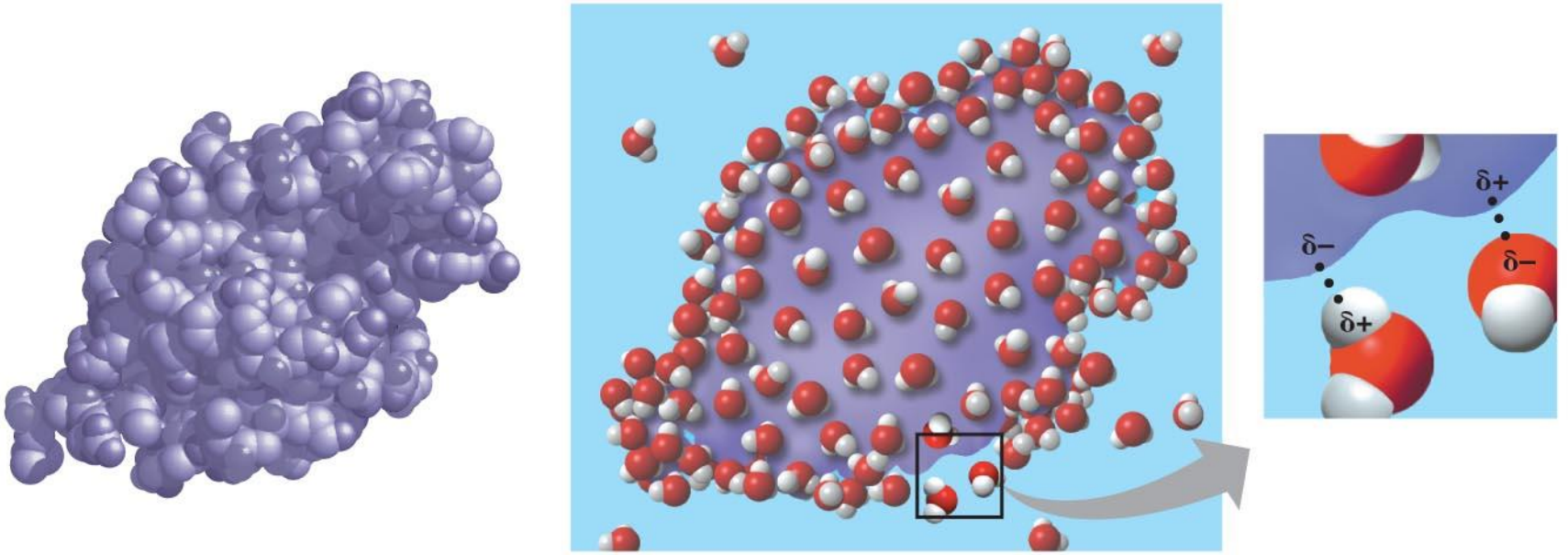
Fig. 3-7



The Solvent of Life

- Water can also dissolve compounds made of nonionic polar molecules
- Even large polar molecules such as proteins can dissolve in water if they have ionic and polar regions

Fig. 3-8



(a) Lysozyme molecule in a nonaqueous environment

(b) Lysozyme molecule (purple) in an aqueous environment

(c) Ionic and polar regions on the protein's surface attract water molecules.

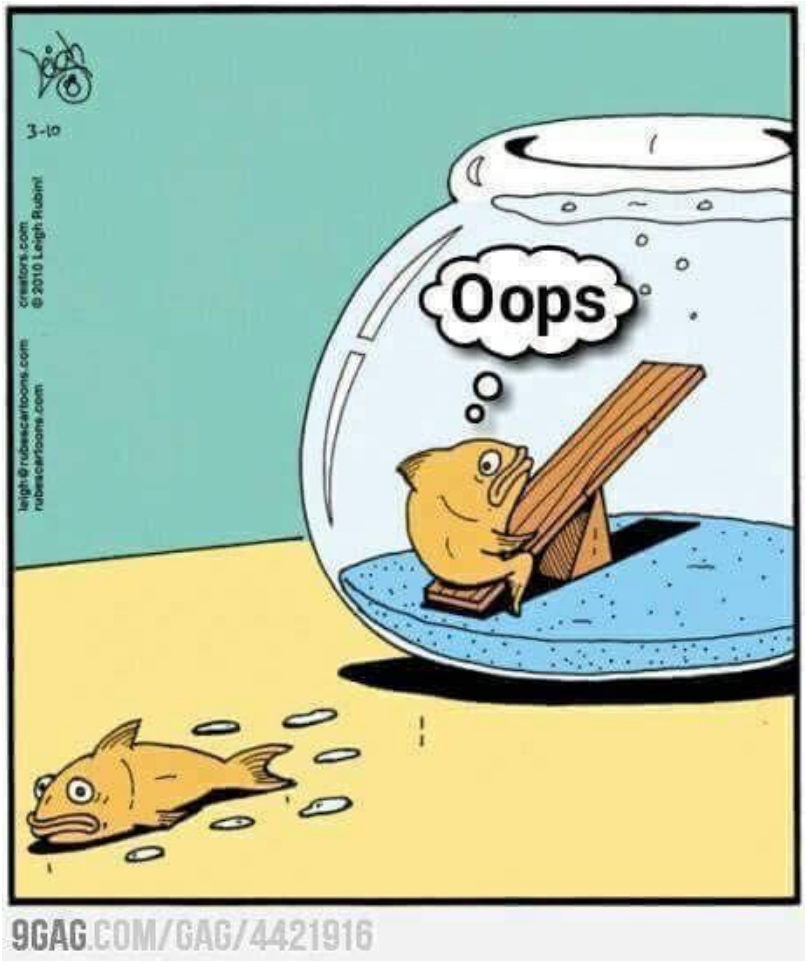
Application: Monitoring Almond Tree Trunk Diameter

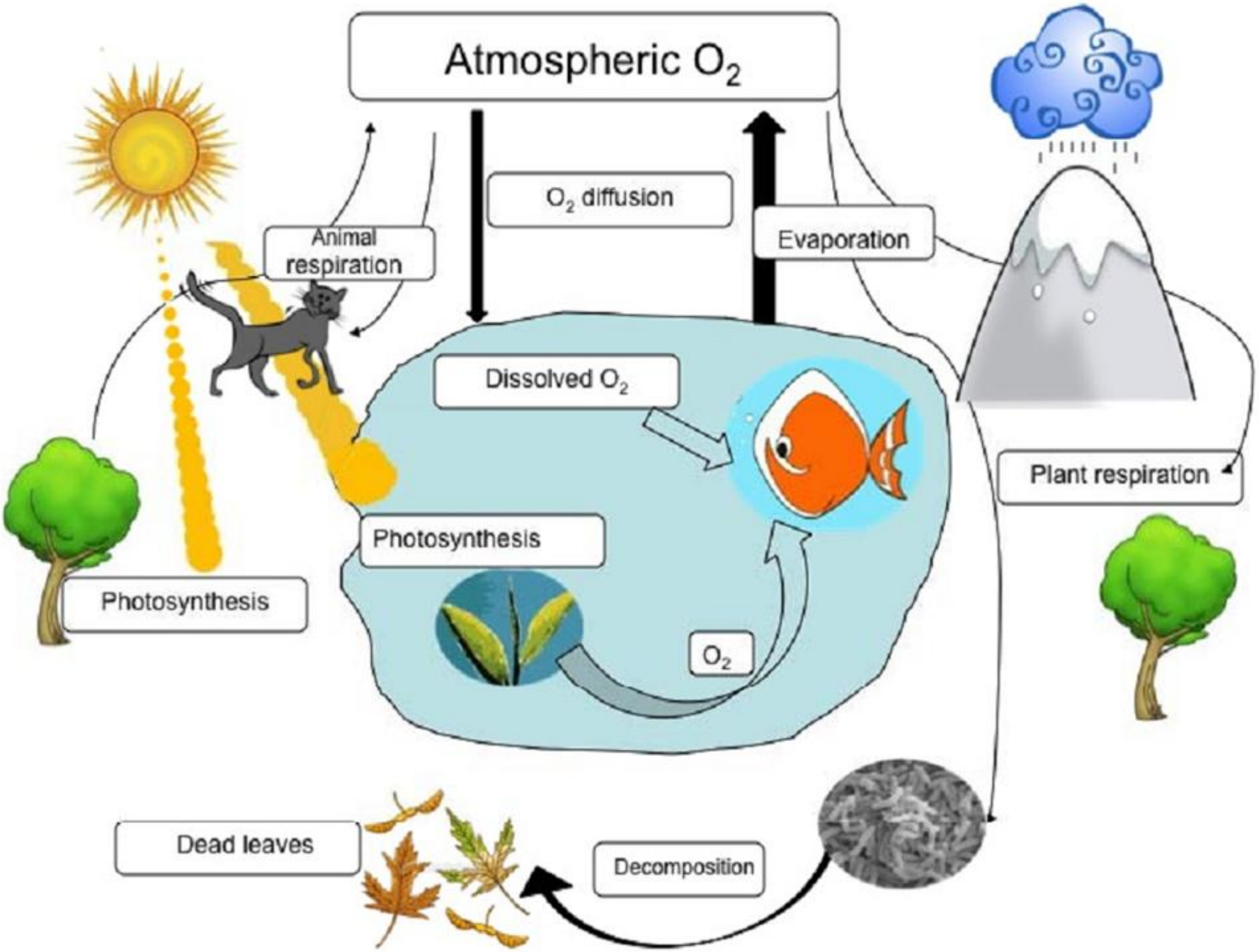
- Linear variable differential transformers
- Continuously monitored the diameters of tree trunks.

Almond trees in arid California require irrigation water to survive and produce crops. However, with the increased competition for water supplies because of continuing urban development, there is pressure to decrease the water ration for agriculture. Tree water status has been found to be able to be used for tree-based irrigation scheduling,

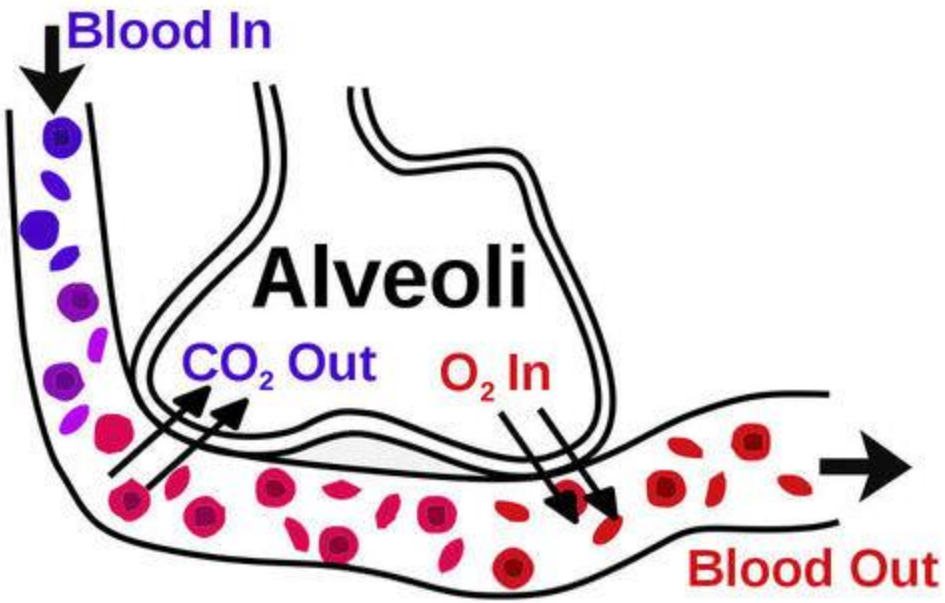
The Need of Oxygen

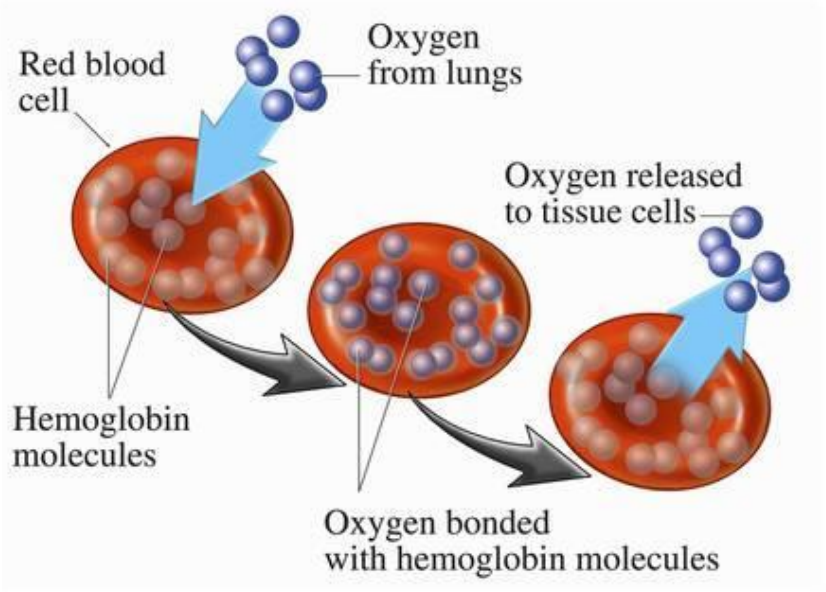
- Oxygen is a key molecule in life
- Its terminal electron acceptor in energy generation
- Aerobic and Anaerobic forms of life
- It plays a role in metabolism




Atmospheric O_2
O_2 diffusion
Evaporation
Animal respiration
Dissolved O_2
Photosynthesis
Photosynthesis
O_2
Plant respiration
Dead leaves
Decomposition

Getting Oxygen Into the Body





Aerobic Respiration is Highly Efficient

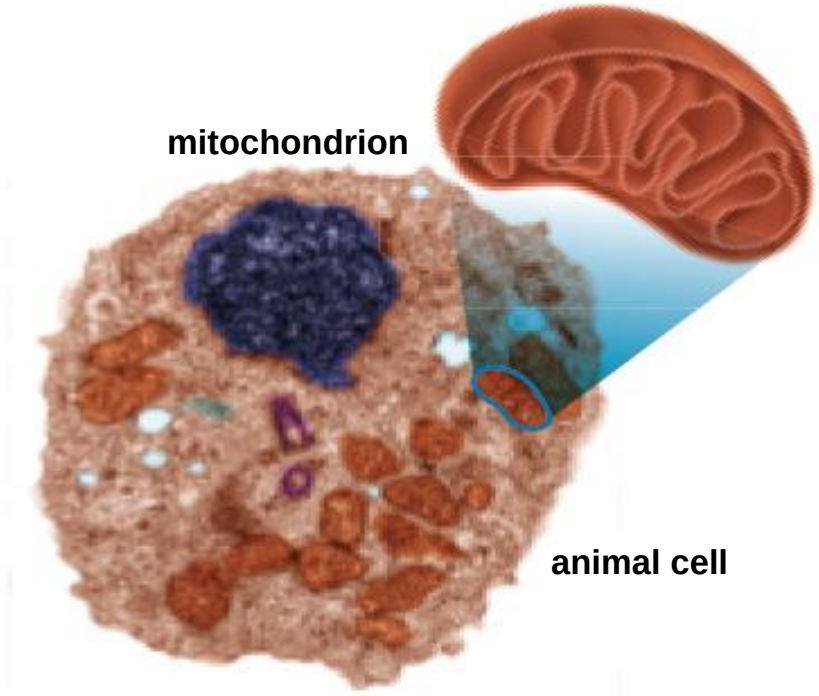
- Oxidative metabolism gives more energy
- Oxidative catabolism of Glucose yields 18 times more ATP as compared to non oxidative process
- Oxidation of fatty acids: 64.5 times more ATP
- Thus there is advantage to have life with oxygen

Aerobic Respiration

- Glucose enters cells from the bloodstream and is broken down in a series of reactions collectively called glycolysis.
- These reactions result in the production of pyruvate, which then enters cell organelles known as mitochondria.
- Here, the pyruvate enters the TCA or citric acid cycle, which culminates in something called the electron-transport chain.
- This chain relies on oxygen for the production of energy in the form of adenosine triphosphate, or ATP.

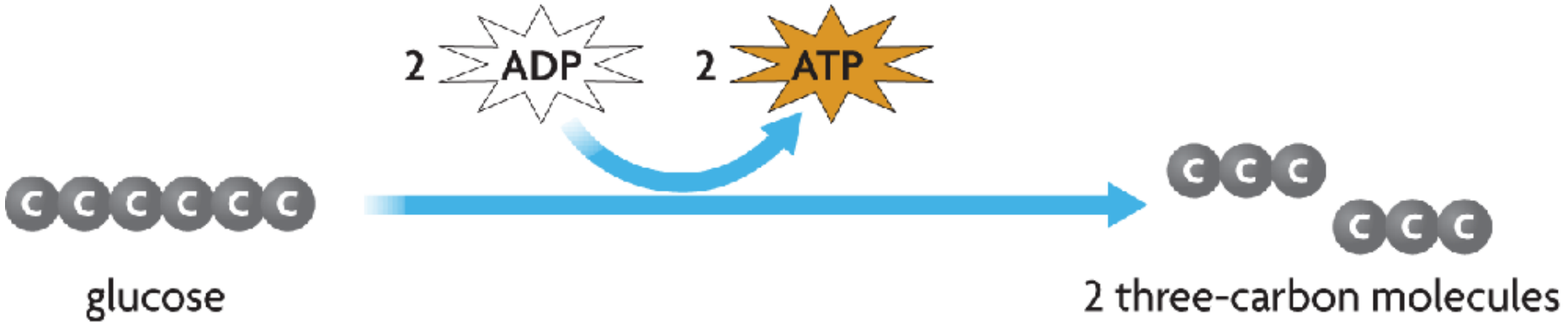
Cellular Respiration

- Cellular respiration is aerobic, or requires oxygen
- Cellular respiration makes ATP by breaking down sugars
- Aerobic stages take place in mitochondria



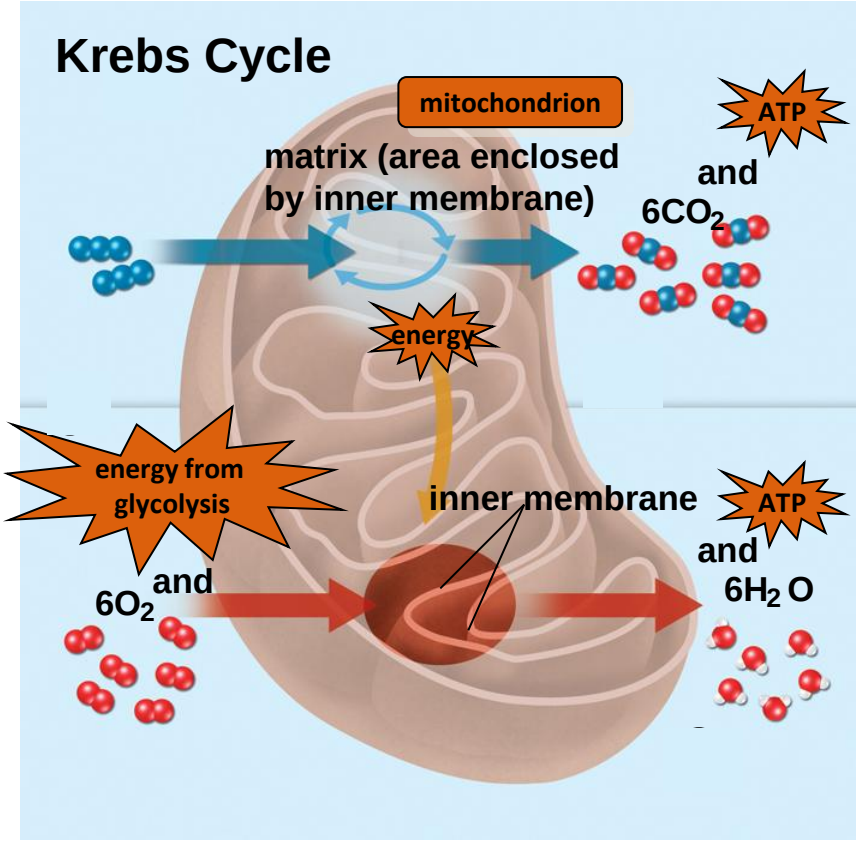
Cellular Respiration

- Glycolysis must take place first
  - anaerobic process (does not require oxygen)
  - takes place in cytoplasm
  - splits glucose into two three-carbon molecules
  - produces two ATP molecules



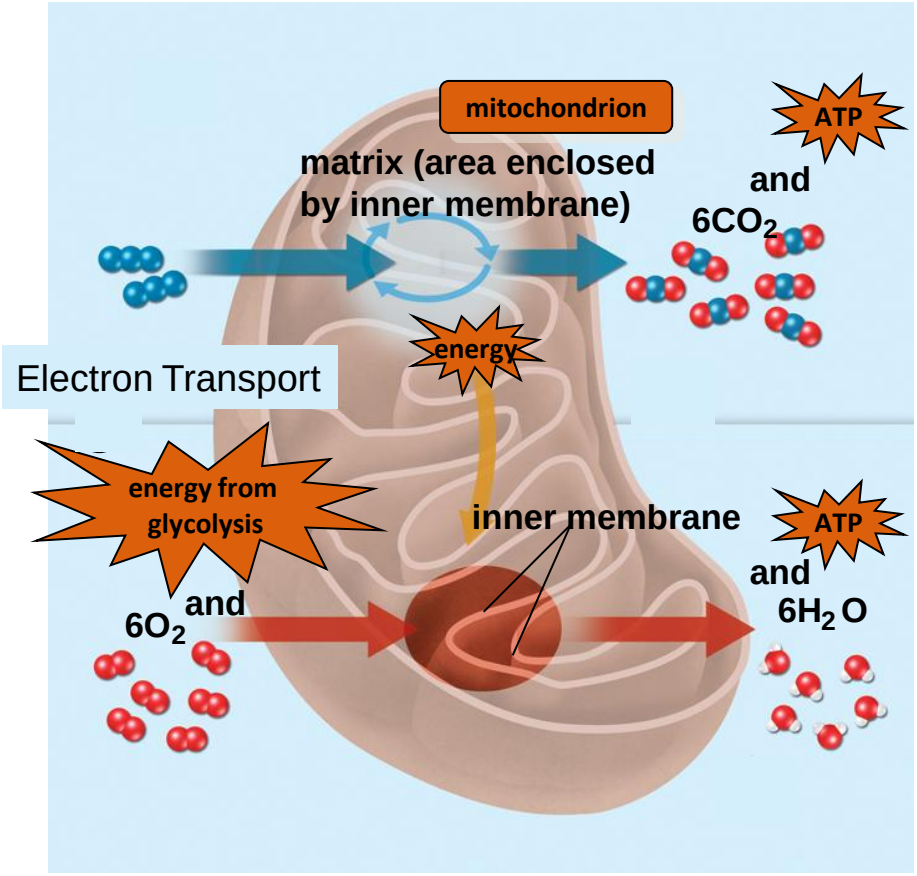
Cellular Respiration is Mirror Image of Photosynthesis

- The Krebs cycle transfers energy to an electron transport chain.
  - takes place in mitochondrial matrix
  - breaks down three-carbon molecules from Glycolysis
  - makes a small amount of ATP
  - releases carbon dioxide
  - transfers energy-carrying molecules

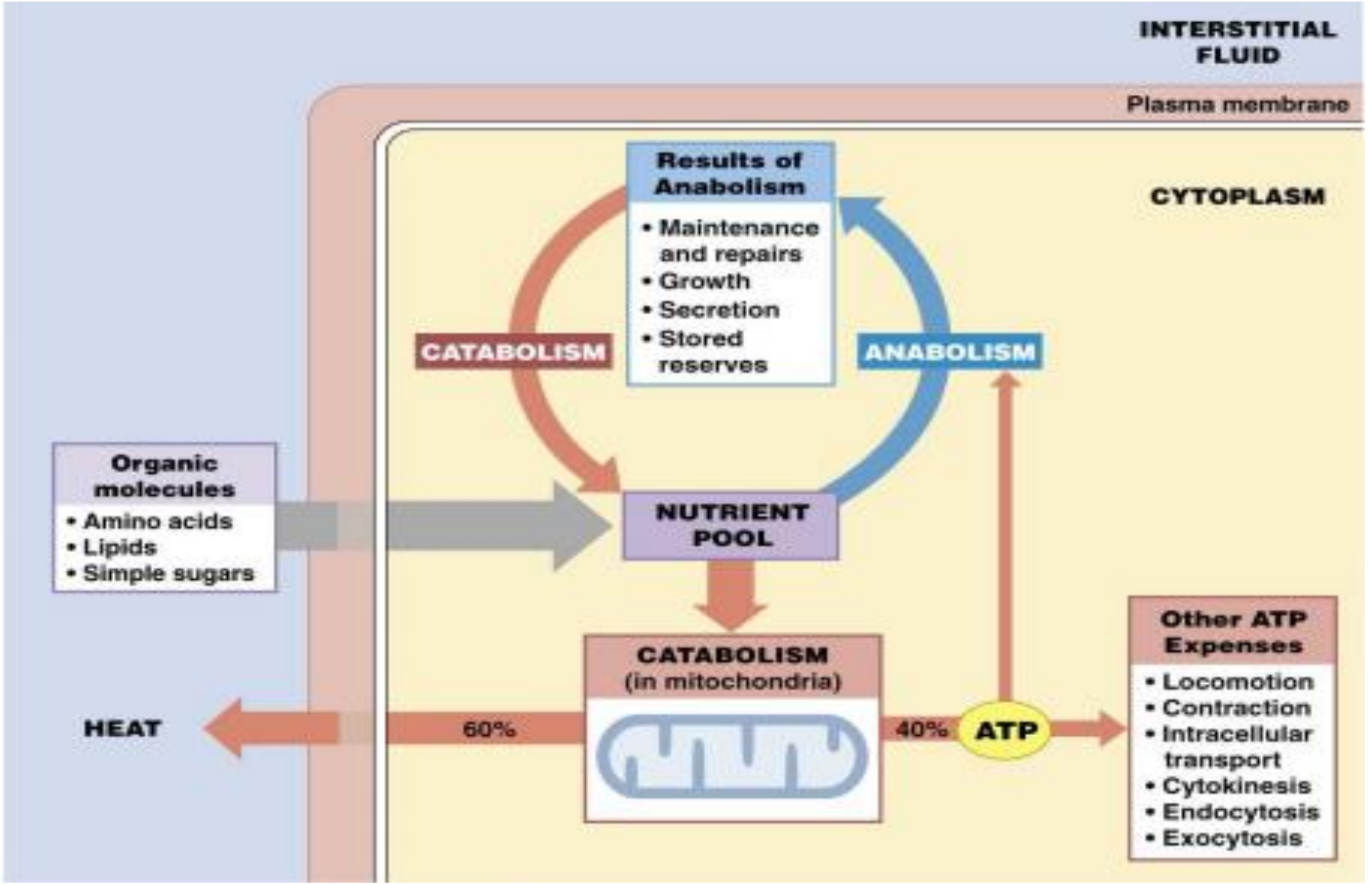


Cellular Respiration is Mirror Image of Photosynthesis

- The electron transport chain produces a large amount of ATP.
  - takes place in inner membrane
  - energy transferred to electron transport chain
  - oxygen enters process
  - ATP produced
  - water released as a waste product



Nutrient Metabolism



Nutrient Use in Cellular Metabolism