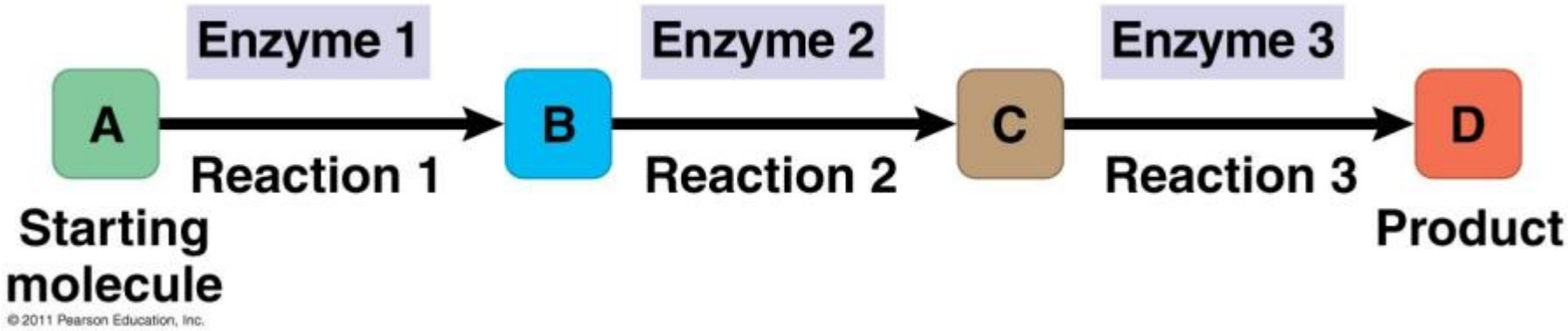
WHAT YOU NEED TO KNOW:

- Examples of endergonic and exergonic reactions.
- The key role of ATP in energy coupling.

- That enzymes work by lowering the energy of activation.
- The catalytic cycle of an enzyme that results in the production of a final product.
- The factors that influence enzyme activity.



Metabolism is the totality of an organism's chemical reactions

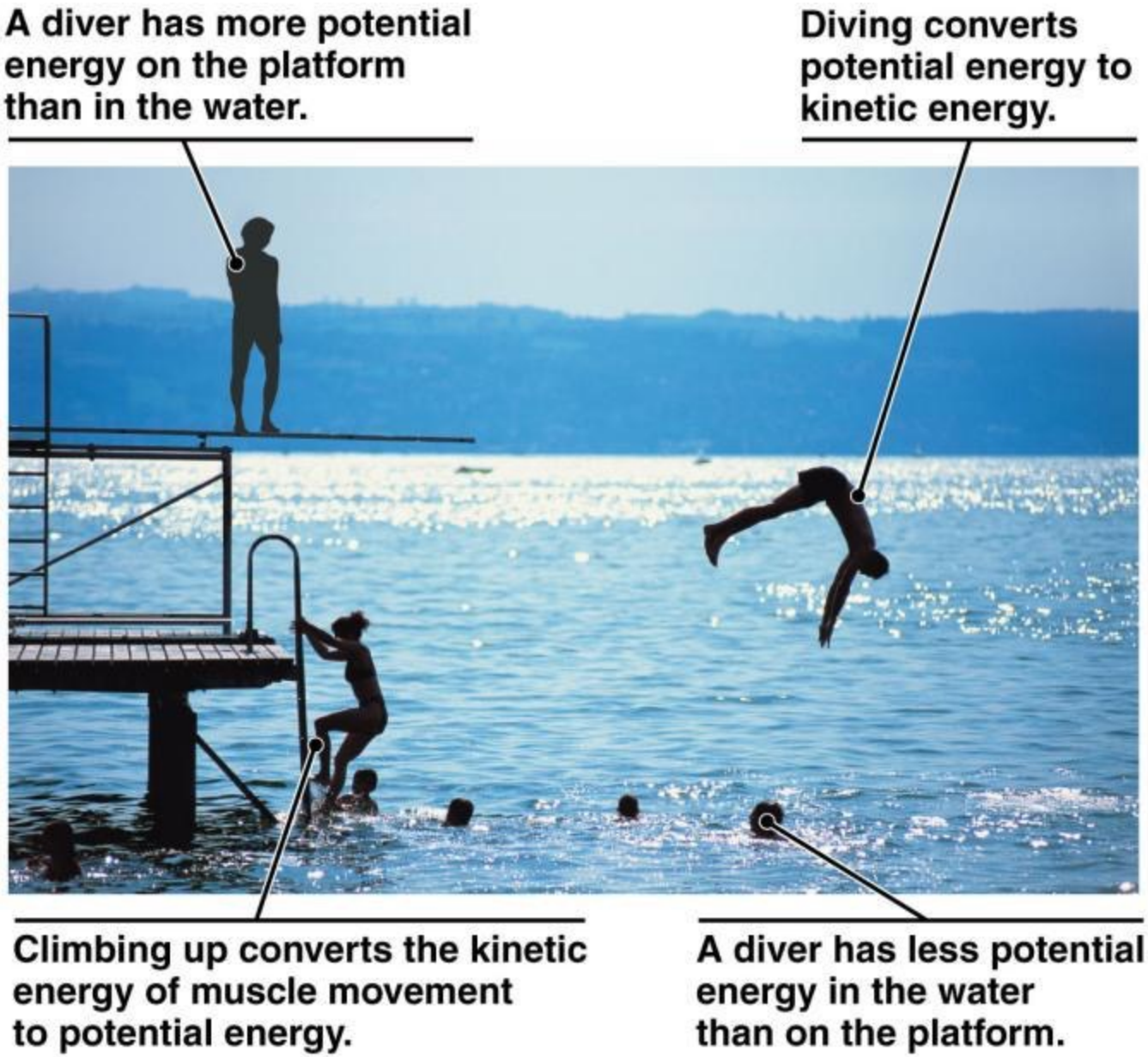
- Manage the materials and energy resources of a cell

- **Catabolic pathways** release energy by breaking down complex molecules into simpler compounds
  - Eg. digestive enzymes break down food → release energy

- **Anabolic pathways** consume energy to build complex molecules from simpler ones
  - Eg. amino acids link to form muscle protein

ENERGY = CAPACITY TO DO WORK

- **Kinetic energy (KE)**: energy associated with motion
  - *Heat* (thermal energy) is KE associated with random movement of atoms or molecules
- **Potential energy (PE)**: stored energy as a result of its position or structure
  - *Chemical energy* is PE available for release in a chemical reaction
- Energy can be converted from one form to another
  - Eg. chemical → mechanical → electrical



THERMODYNAMICS IS THE STUDY OF ENERGY TRANSFORMATIONS THAT OCCUR IN NATURE

- A closed system, such as liquid in a thermos, is isolated from its surroundings
- In an open system, energy and matter can be transferred between the system and its surroundings
- Organisms are open systems

THE FIRST LAW OF THERMODYNAMICS

- The energy of the universe is constant
  - Energy **<u>can</u>** be transferred and transformed
  - Energy **<u>cannot</u>** be created or destroyed

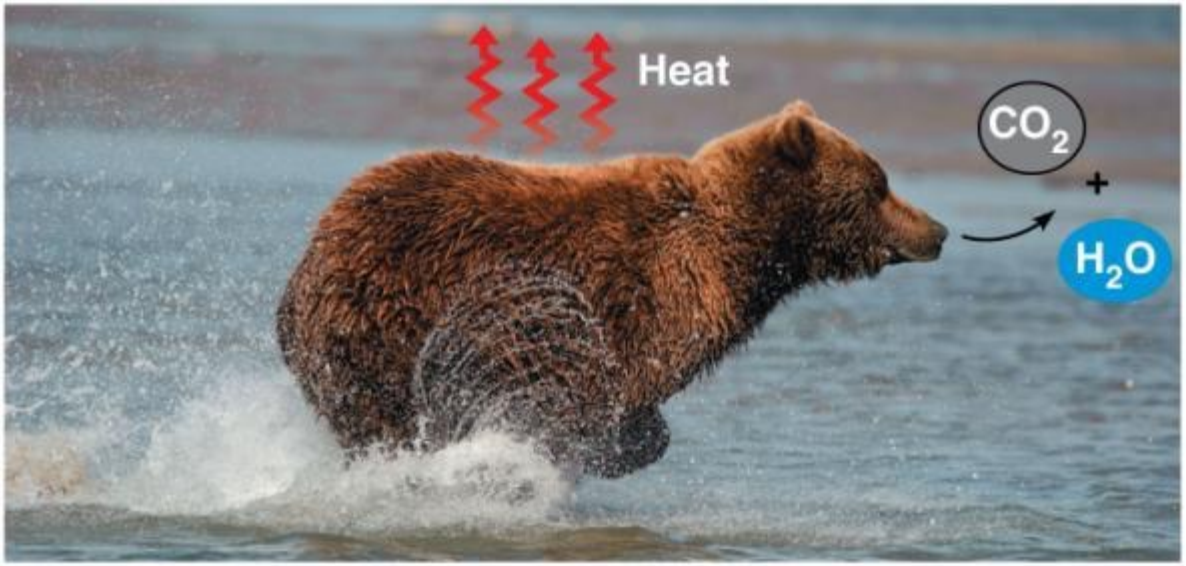
- Also called the principle of **Conservation of Energy**

(a) First law of thermodynamics

THE SECOND LAW OF THERMODYNAMICS

- Every energy transfer or transformation increases the entropy (disorder) of the universe

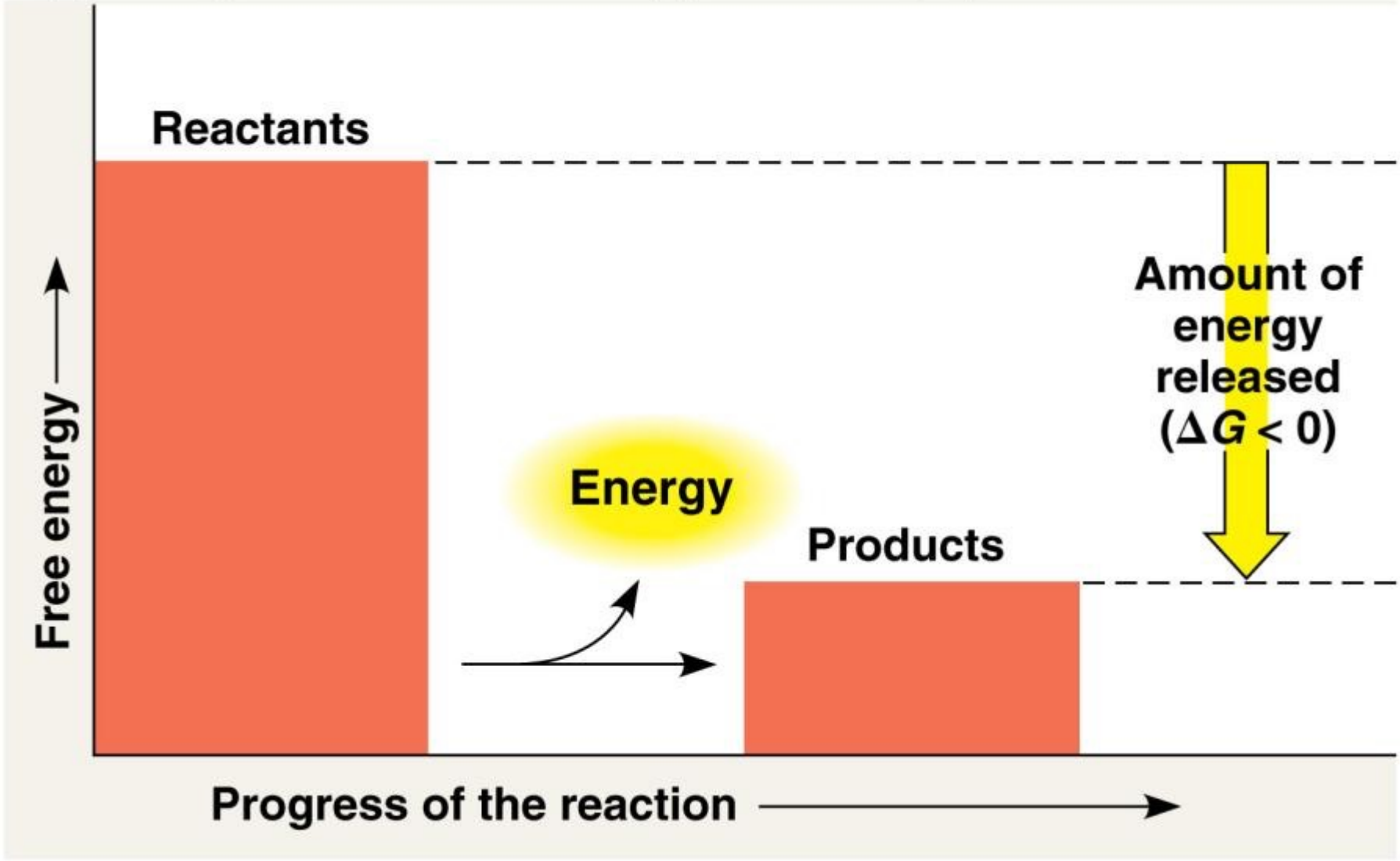
- During every energy transfer or transformation, some energy is *unusable*, often lost as **heat**



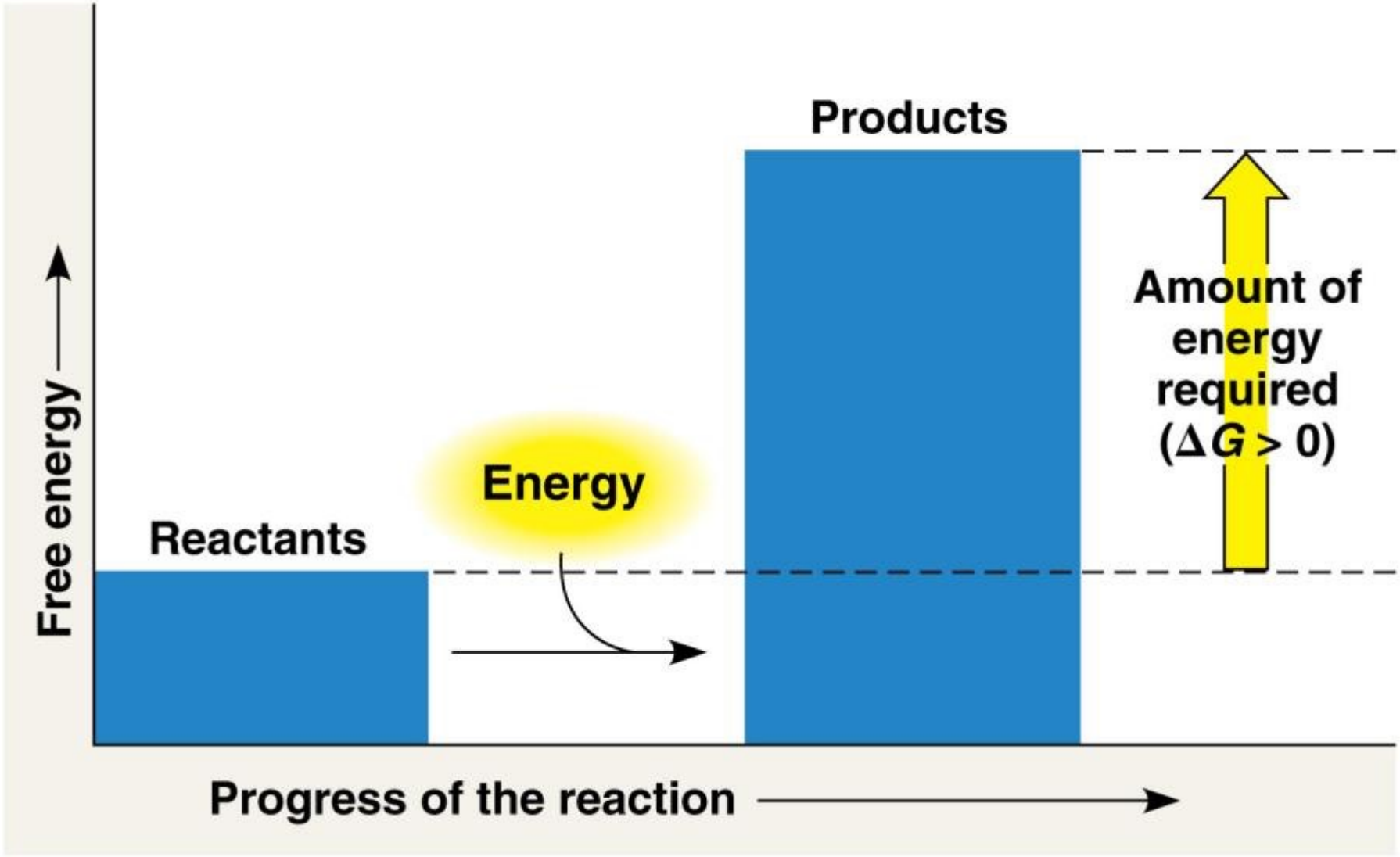
(b) Second law of thermodynamics

- **Free energy**: part of a system's energy available to perform work
  - ΔG = change in free energy
- **Exergonic reaction**: energy is released
  - Spontaneous reaction
  - $\Delta G < 0$
- **Endergonic reaction**: energy is required
  - Absorb free energy
  - $\Delta G > 0$

(a) Exergonic reaction: energy released, spontaneous



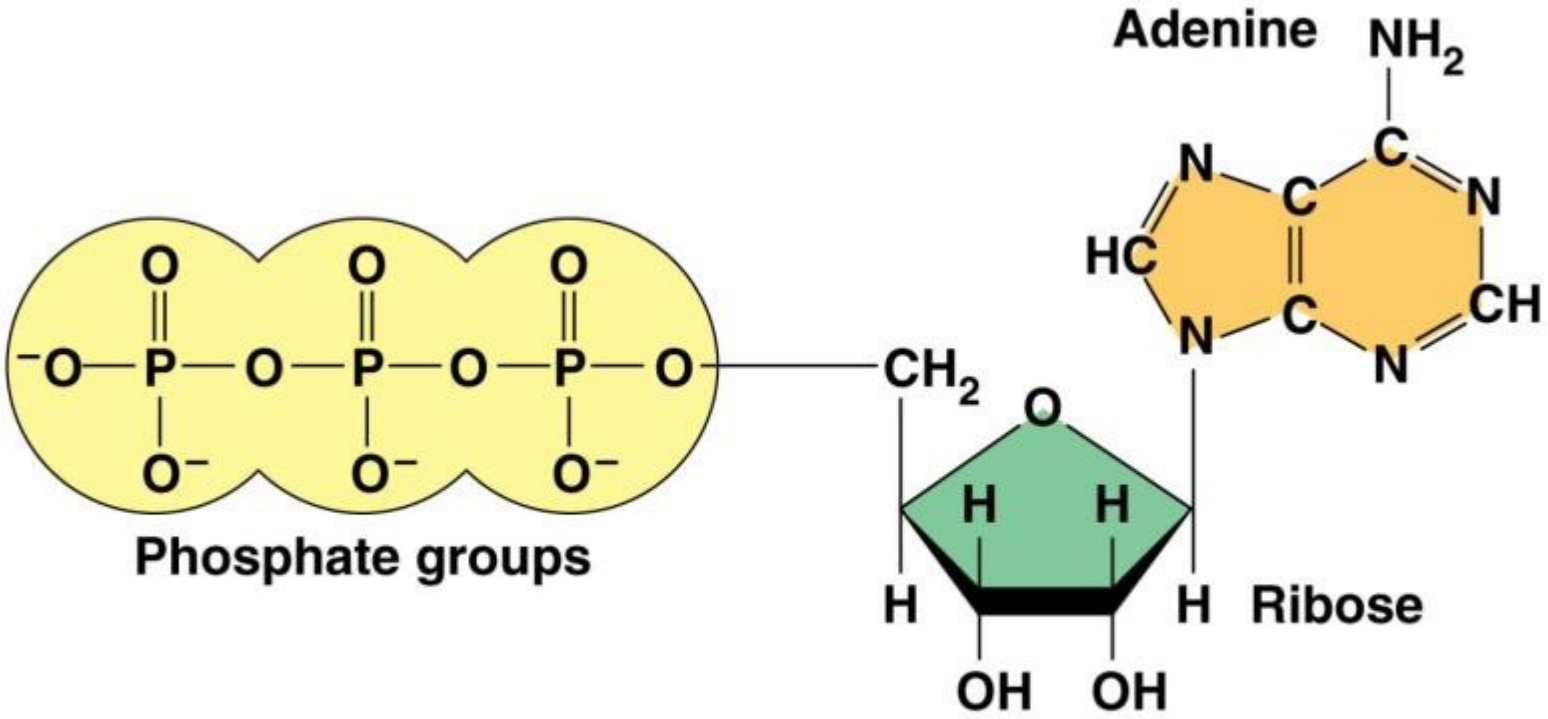
(b) Endergonic reaction: energy required, nonspontaneous



- A cell does three main kinds of work:
  - Mechanical
  - Transport
  - Chemical

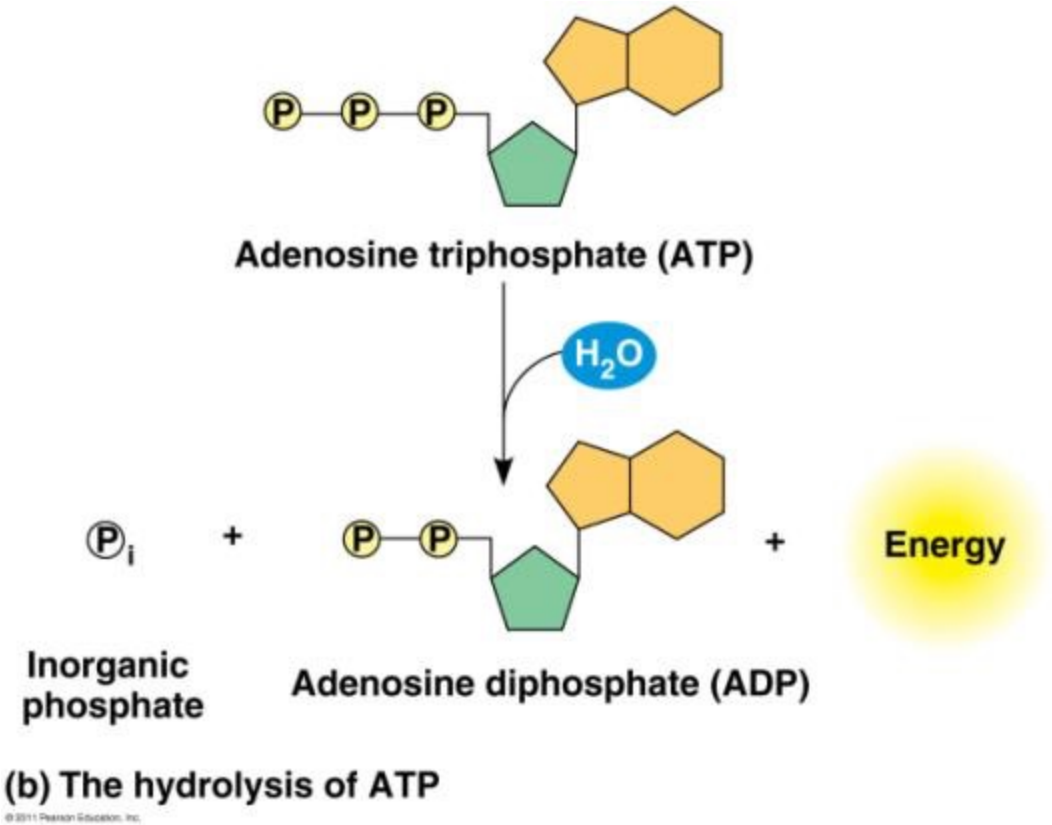
- Cells manage energy resources to do work by energy coupling: using an ***exergonic*** process to drive an ***endergonic*** one

- **ATP** (**adenosine triphosphate**) is the cell's main energy source in energy coupling
- ATP = adenine + ribose + 3 phosphates



(a) The structure of ATP

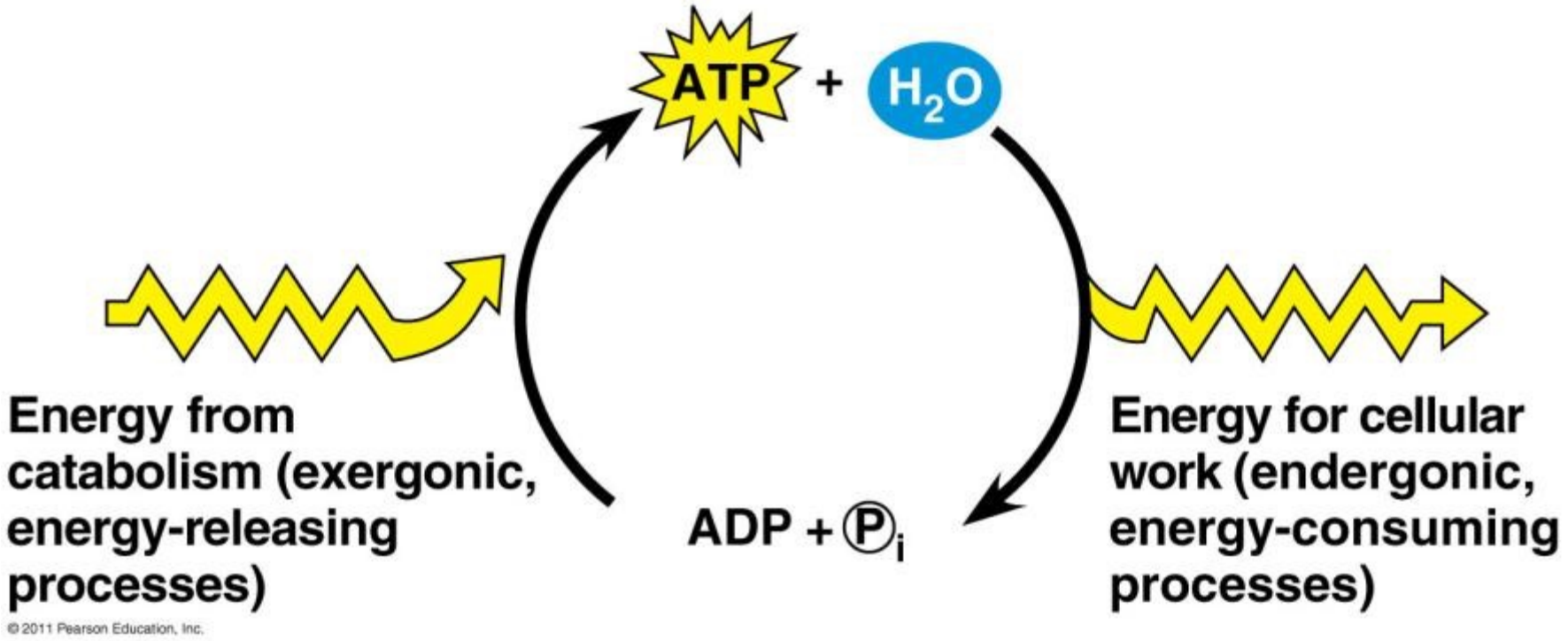
- When the bonds between the phosphate groups are broken by hydrolysis → ***energy is released***
- This release of energy comes from the chemical change to a state of lower free energy, not in the phosphate bonds themselves

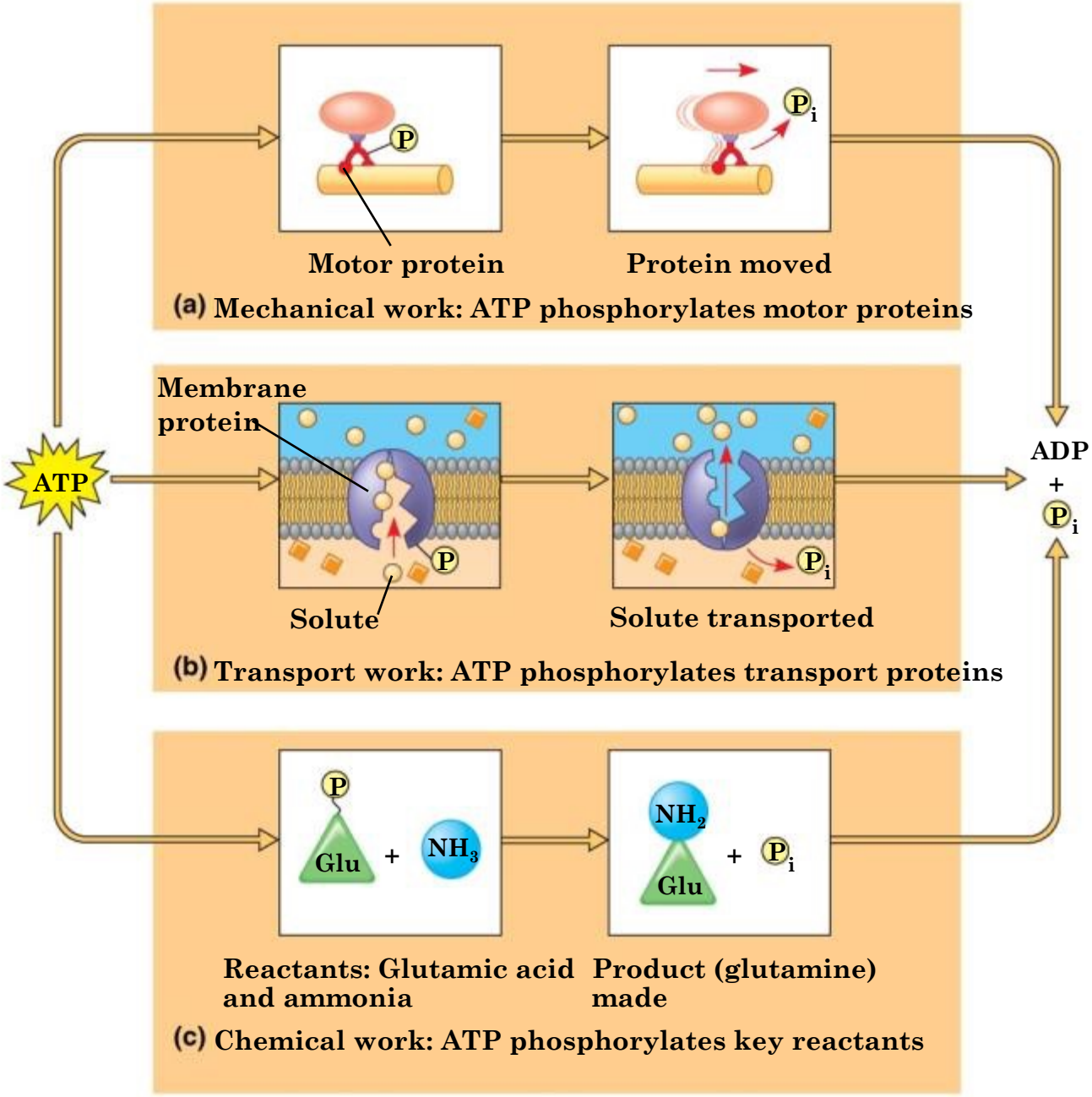


(b) The hydrolysis of ATP

HOW ATP PERFORMS WORK

- ***Exergonic*** release of P_i is used to do the ***endergonic*** work of cell
- When ATP is hydrolyzed, it becomes ADP (adenosine diphosphate)





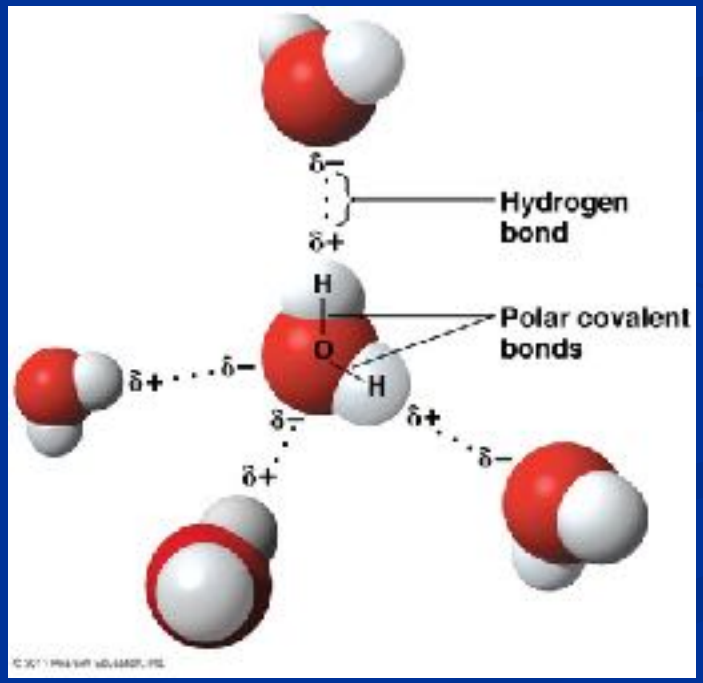
Water and the Fitness of the Environment

You Must Know

- The importance of hydrogen bonding to the properties of water.
- Four unique properties of water, and how each contributes to life on Earth.
- How to interpret the pH scale.
- The importance of buffers in biological systems.

1. Polarity of H_2O

- O^- will bond with H^+ on a different molecule of H_2O = **hydrogen bond**
- H_2O can form up to 4 hydrogen bonds



2. Properties of H_2O

A. **Cohesion** = H-bonding between like molecules

(ex: water bonding to water)

- **Surface Tension** = measure of how difficult it is to break or stretch surface of liquid

2. Properties of H_2O

B. **Adhesion** = bonding between unlike molecules

(ex: water bonding to something else)

- Adhesion of H_2O to vessel walls counters ↓ pull of gravity

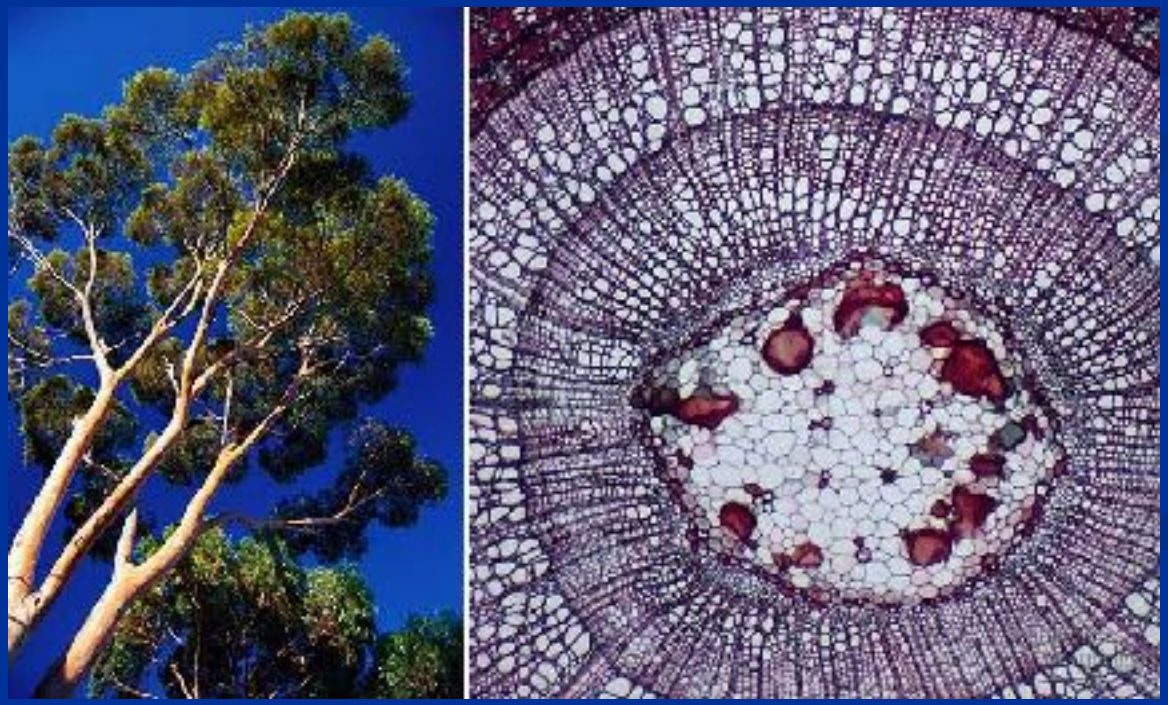
Surface Tension Challenge

1. Using the materials provided, or anything else you want, figure out what solution will have the highest surface tension (able to float the most paper clips
2. Explain why this solution works best

2. Properties of H_2O

C. <u>Transpiration</u> = movement of H_2O up plants

- H_2O clings to each other by **<u>cohesion</u>**; cling to xylem tubes by **<u>adhesion</u>**



3. Moderation of temperature

Heat = Total amount of Kinetic Energy (KE) in system

Temperature = measure intensity of heat due to average KE of molecules

Which has higher temp?

More heat?

3. Moderation of temperature

A. Water's **high specific heat**

- Change temp less when absorbs/loses heat
  - Large bodies of water absorb and store more heat → warmer coastal areas
- Create stable marine/land environment
- Humans ~65% H_2O → stable temp, resist temp. change

3. Moderation of temperature

B. Evaporative Cooling

- Water has high heat of vaporization
- Molecules with greatest KE leave as gas
- Stable temp in lakes & ponds
- Cool plants
- Human sweat

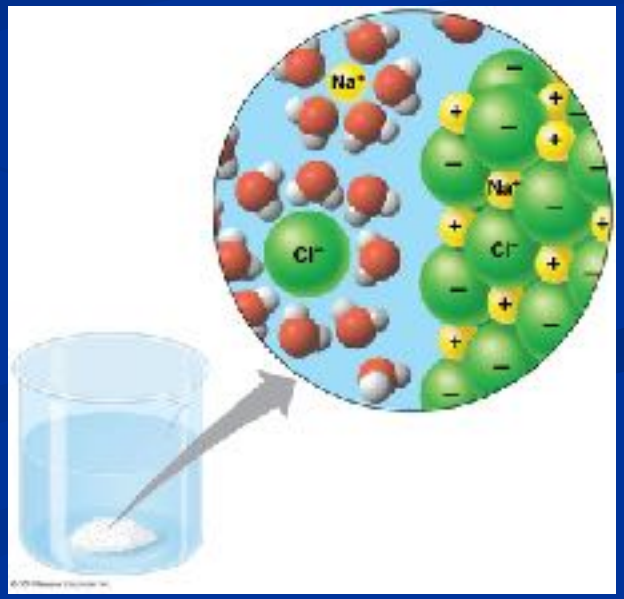
3. Moderation of temperature

C. **Insulation by ice** – less dense, floating ice insulates liquid H_2O below

- Life exists under frozen surface (ponds, lakes, oceans)
- Ice = solid habitat (polar bears)

4. Solvent of life

- **Solution** = liquid, homogeneous mixture of 2+ substances
- **Solvent** = dissolving agent (liquid)
- **Solute** = dissolved substance
- **Water = versatile solvent**

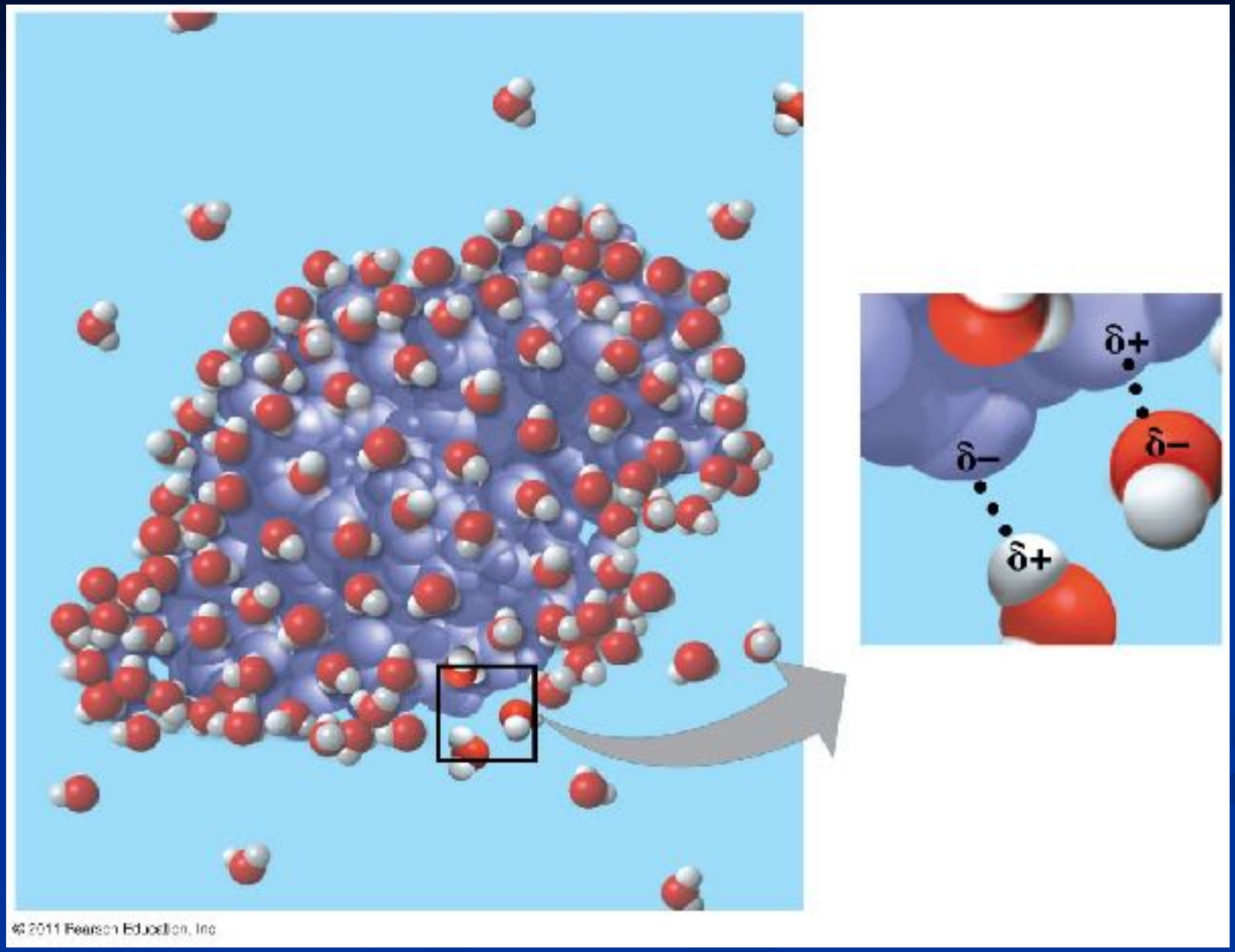


4. Solvent of life

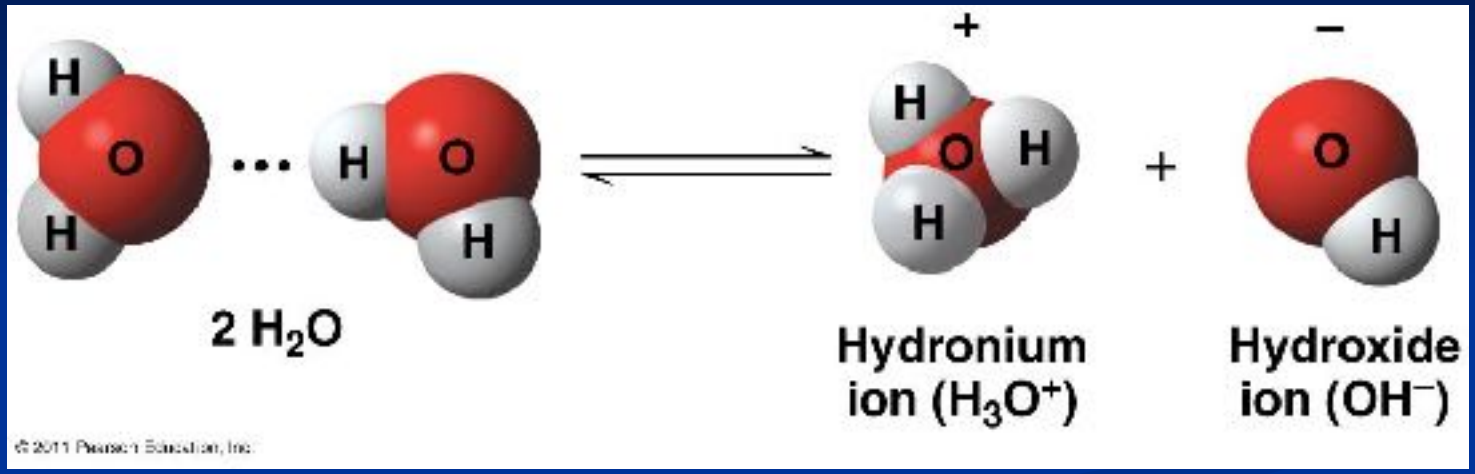
- "like dissolves like"

Hydrophilic	Hydrophobic
Affinity for H_2O	Repel H_2O
Polar, ions	Nonpolar
Cellulose, sugar, salt	Oils, lipids
Blood	Cell membrane

Figure 3.8 A water-soluble protein



5. Acids and Bases



$$H_2O \rightleftharpoons H^+ + OH^-$$

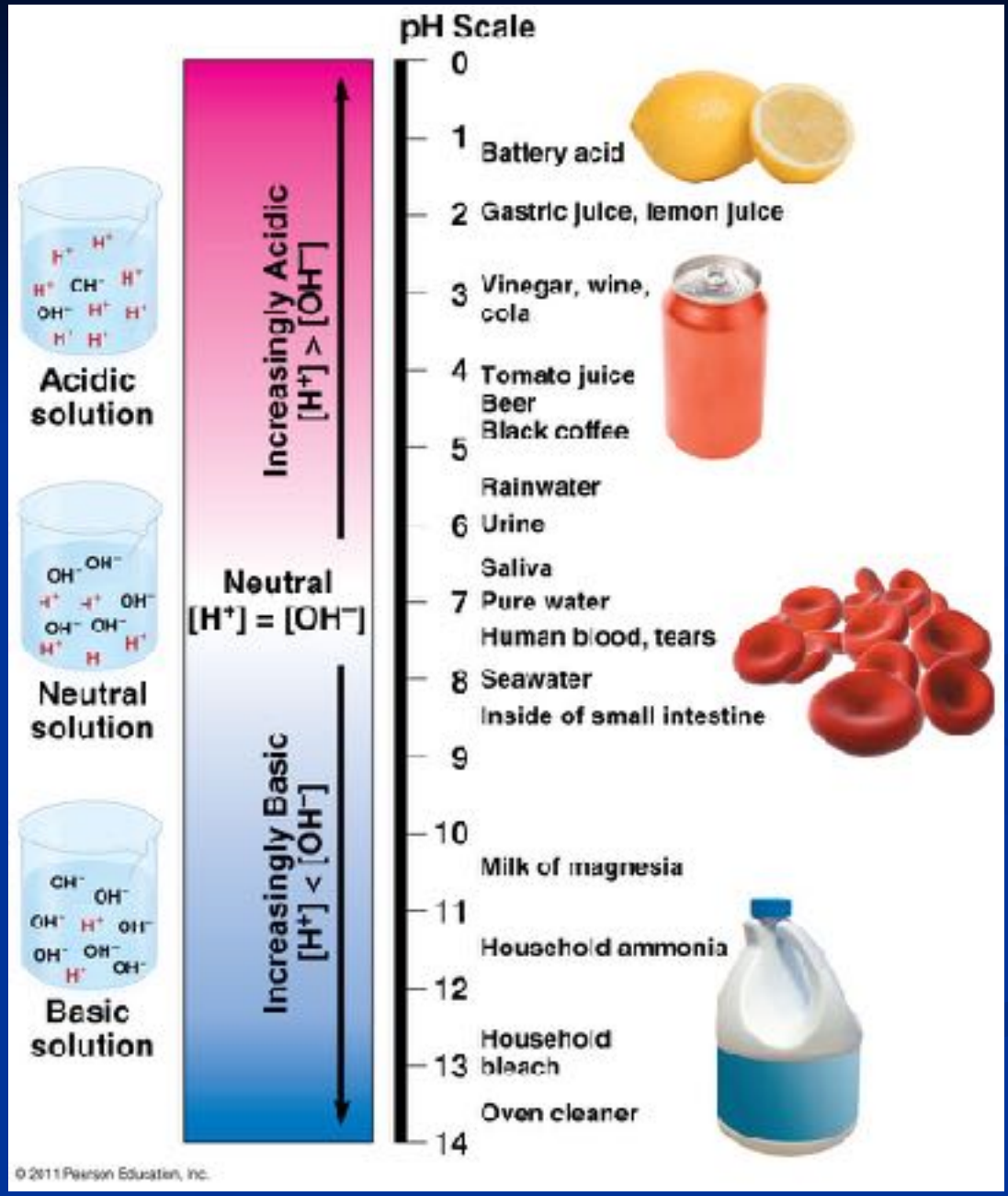
(gains proton) $H^+ + H_2O \rightarrow \mathbf{H_3O^+}$ (hydronium ion)

(loses proton) $H_2O - H^+ \rightarrow \mathbf{OH^-}$ (hydroxide ion)

5. Acids and Bases

- **Acid** = increases H^+ concentration (HCl)
- **Base** = reduces H^+ concentration (NaOH)
- Most biological fluids are pH 6-8

Figure 3.10 The pH scale and pH values of some aqueous solutions



Calculating pH

$[H^+][OH^-] = 10^{-14}$

1. If $[H^+] = 10^{-6}$ M, then $[OH^-] = 10^{-8}$

$pH = -\log [H^+]$

n. If $[H^+] = 10^{-2}$
   - $-\log 10^{-2} = -(-2) = 2$
   1. Therefore, pH = 2

1. If $[OH^-] = 10^{-10}$
   1. $[H^+] = 10^{-4}$
   2. $-\log 10^{-4} = -(-4) = 4$
   - Therefore, pH = 4

5. Acids and Bases

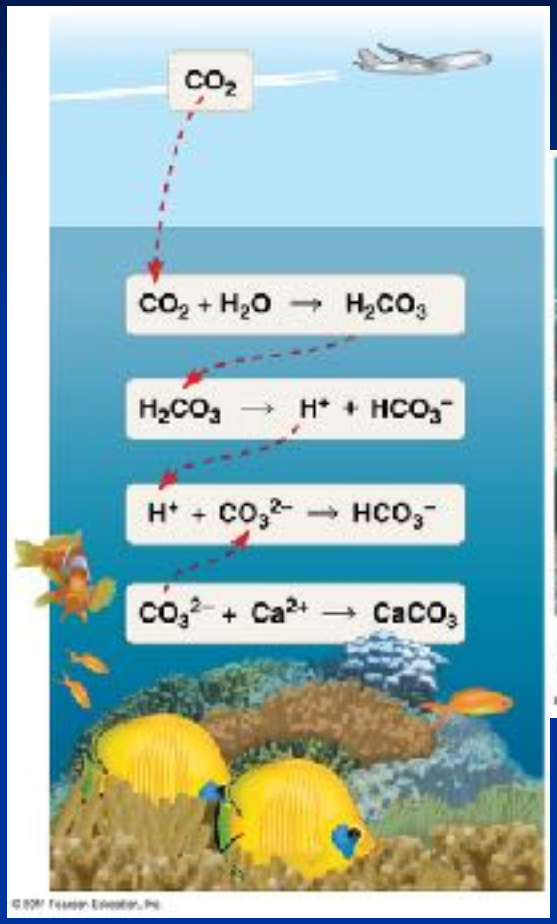
Buffers: minimize changes in concentration of H^+ and OH^- in a solution (weak acids and bases)

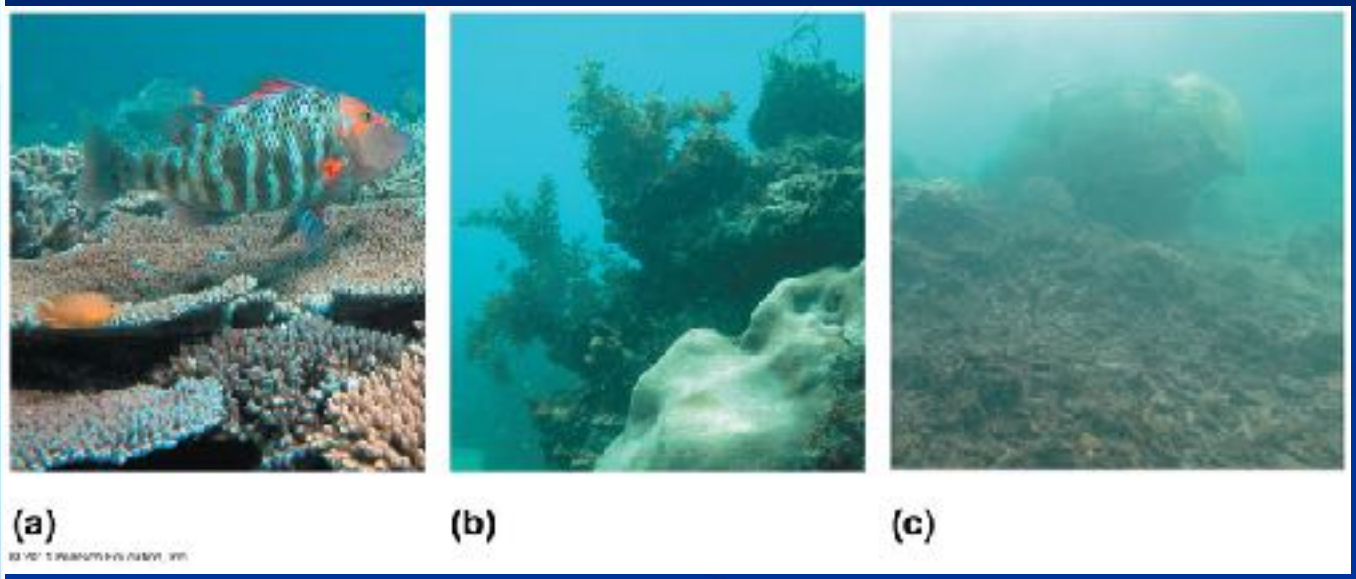
- Buffers keep blood at pH ~7.4
- If blood drops to 7 or up to 7.8, then death

Carbonic Acid – Bicarbonate System: important buffers in blood plasma

H_2CO_3 (carbonic acid) → HCO_3^- (bicarbonate) + H^+

Ocean acidification threatens coral reef ecosystems





CO_2 mixed with seawater → Carbonic acid (lowers ocean pH)

The effects of acid precipitation on a forest

H_2O Property	Chemical Explanation	Examples of Benefits to Life
Cohesion	•polar •H-bond •like-like	↑gravity plants, trees
Adhesion	•H-bond •unlike-unlike	plants→ xylem blood→veins
Surface Tension	•diff. in stretch •break surface •H-bond	bugs→water
Specific Heat	•Absorbs & retains E •H-bond	ocean→mod temp →protect marine life
Evaporation	•liquid→gas •KE	Cooling Homeostasis
Universal Substance	•Polarity→ionic •H-bond	Good dissolver solvent