Chapter 5 The Working Cell

PowerPoint Lectures for

***Campbell Biology: Concepts & Connections,* Seventh Edition**

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Lesson Plans

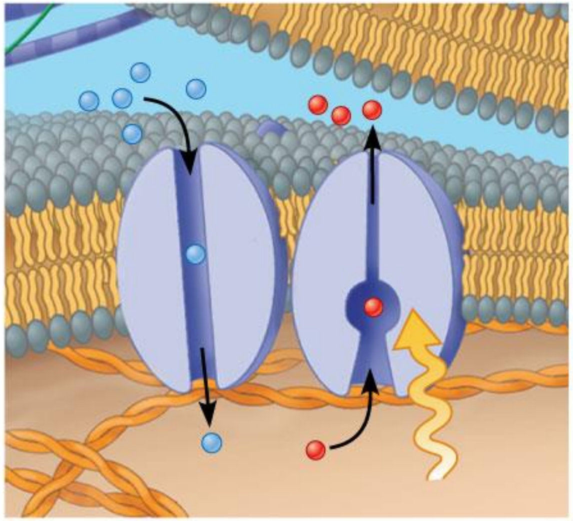
- Flipped Classroom
- HW Day 1Notes outline section 5.1-5.4, review notes, watch examples, do problems in packet
- HW Day 2 Notes 5.5-5.10, Review notes, watch examples, do problems in packet
- HW Day 3 Notes finish chapter, Review notes, watch examples, do problems in packet

Introduction

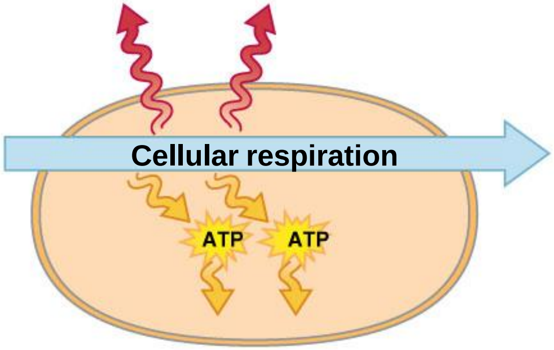
- Some organisms use energy-converting reactions to produce light in a process called bioluminescence.
  - Many marine invertebrates and fishes use bioluminescence to hide themselves from predators.
  - Scientists estimate that 90% of deep-sea marine life produces bioluminescence.
- The light is produced from chemical reactions that convert chemical energy into visible light.

Figure 5.0_1

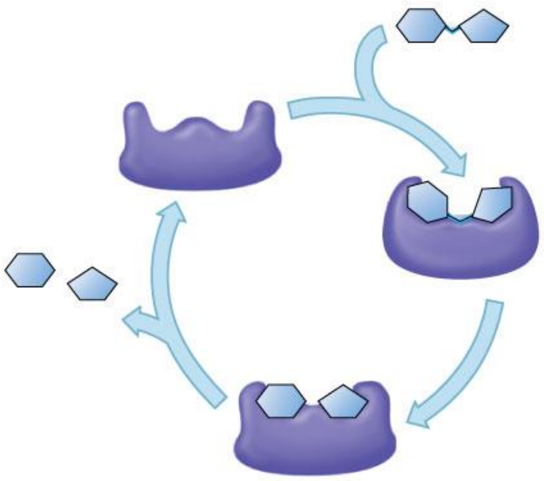
Chapter 5: Big Ideas



Membrane Structure and Function

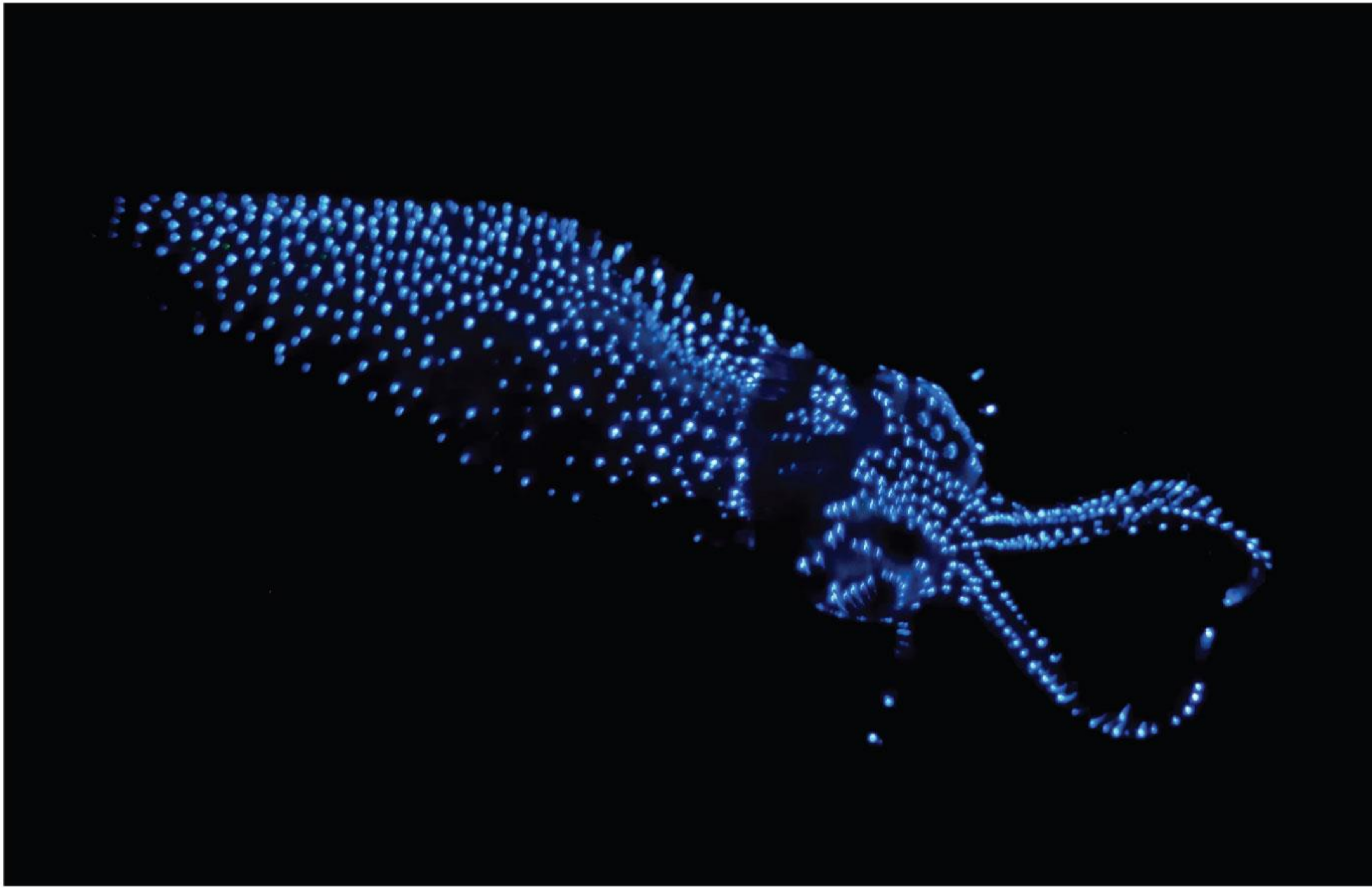


Energy and the Cell



How Enzymes Function

Figure 5.0_2



Introduction

- Bioluminescence is an example of the multitude of energy conversions that a cell can perform.
- Many of a cell's reactions
  - take place in organelles and
  - use enzymes embedded in the membranes of these organelles.
- This chapter addresses how working cells use membranes, energy, and enzymes.

MEMBRANE STRUCTURE AND FUNCTION

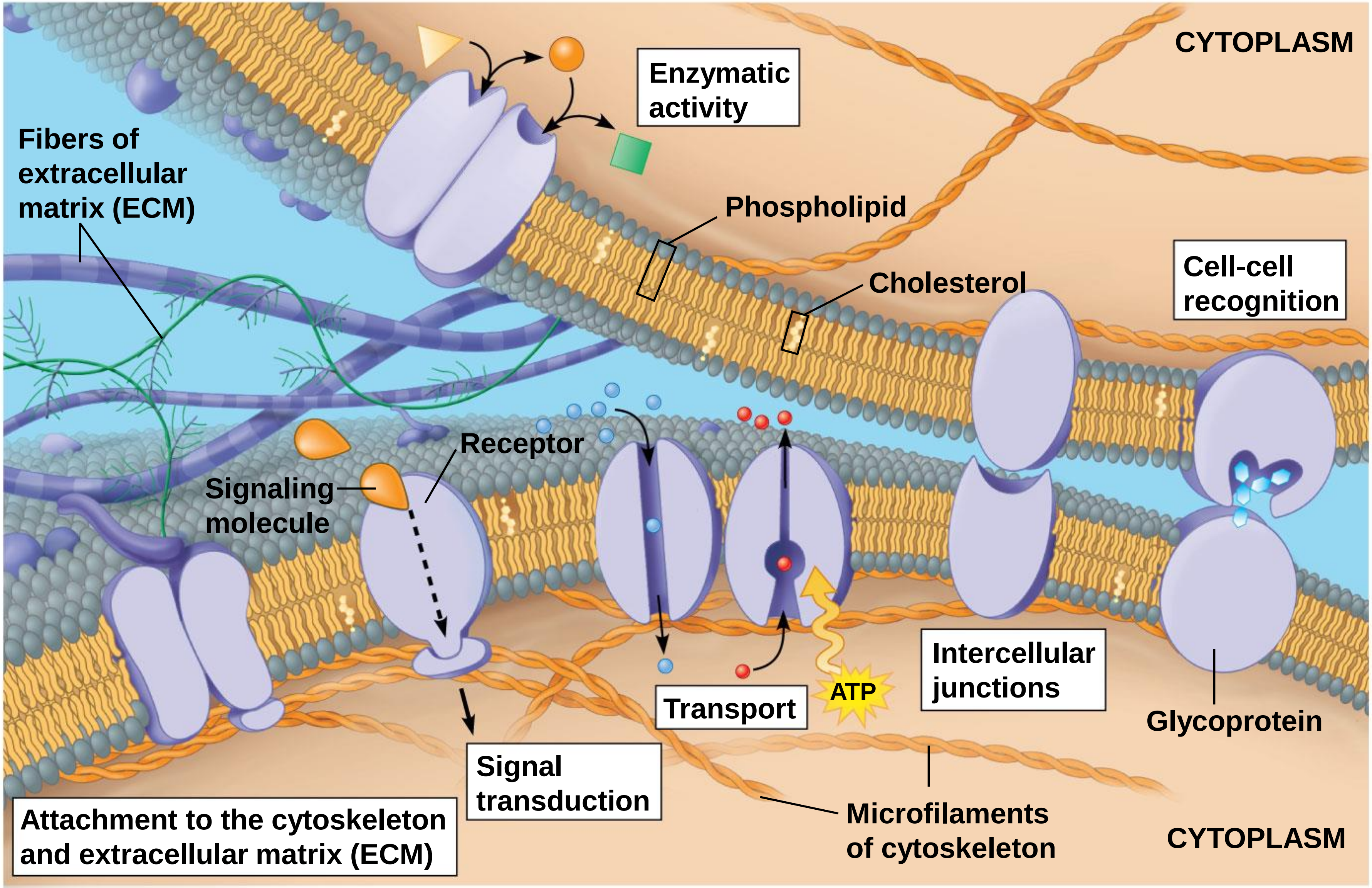
5.1 Membranes are fluid mosaics of lipids and proteins with many functions

- Membranes are composed of
  – a bilayer of phospholipids
  – embedded and attached proteins
  – called a **fluid mosaic**.

5.1 Membranes are fluid mosaics of lipids and proteins with many functions

- Many phospholipids are made from unsaturated fatty acids that have kinks in their tails.
- Kinks prevent phospholipids from packing tightly together, keeping them in liquid form.
- Animal cell membranes, cholesterol helps
  - stabilize membranes at warmer temperatures and
  - keep the membrane fluid at lower temperatures.

Figure 5.1



CYTOPLASM
Enzymatic activity
Fibers of extracellular matrix (ECM)
Phospholipid
Cholesterol
Cell-cell recognition
Receptor
Signaling molecule
ATP
Transport
Intercellular junctions
Glycoprotein
Signal transduction
Attachment to the cytoskeleton and extracellular matrix (ECM)
Microfilaments of cytoskeleton
CYTOPLASM

5.1 Membranes are fluid mosaics of lipids and proteins with many functions

- Membrane proteins perform many functions.

  1. Maintain cell shape and coordinate changes inside and outside.
  2. Receptors for chemical messengers from other cells.
  3. Enzymes.
  4. Some membrane glycoproteins are involved in cell-cell recognition.
  5. Intercellular junctions that attach adjacent cells to each other.
  6. Transport

5.1 Membranes are fluid mosaics of lipids and proteins with many functions

Membranes may exhibit **selective permeability**, allowing some substances to cross more easily than others.

PLAY

Animation: Signal Transduction Pathways

5.3 Passive transport is diffusion across a membrane with no energy investment

- **Diffusion** - particles spread out evenly in an available space.
  - Particles move from an area of more concentrated particles to an area where they are less concentrated.
  - Down their **concentration gradient.**
  - Eventually, the particles reach equilibrium

5.3 Passive transport is diffusion across a membrane with no energy investment

- Diffusion across a cell membrane does not require energy, so it is called **passive transport**.
- The concentration gradient itself represents potential energy for diffusion.

PLAY Animation: Diffusion

PLAY Animation: Membrane Selectivity

Figure 5.3A

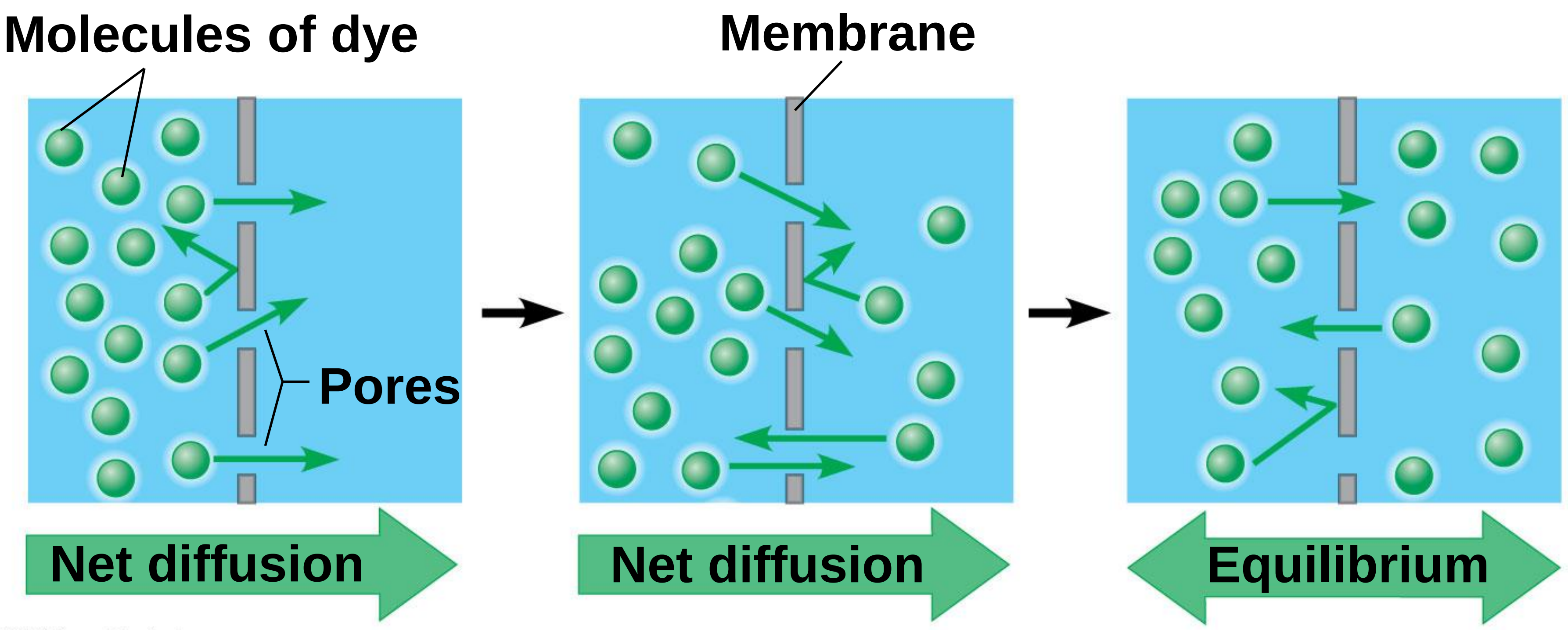
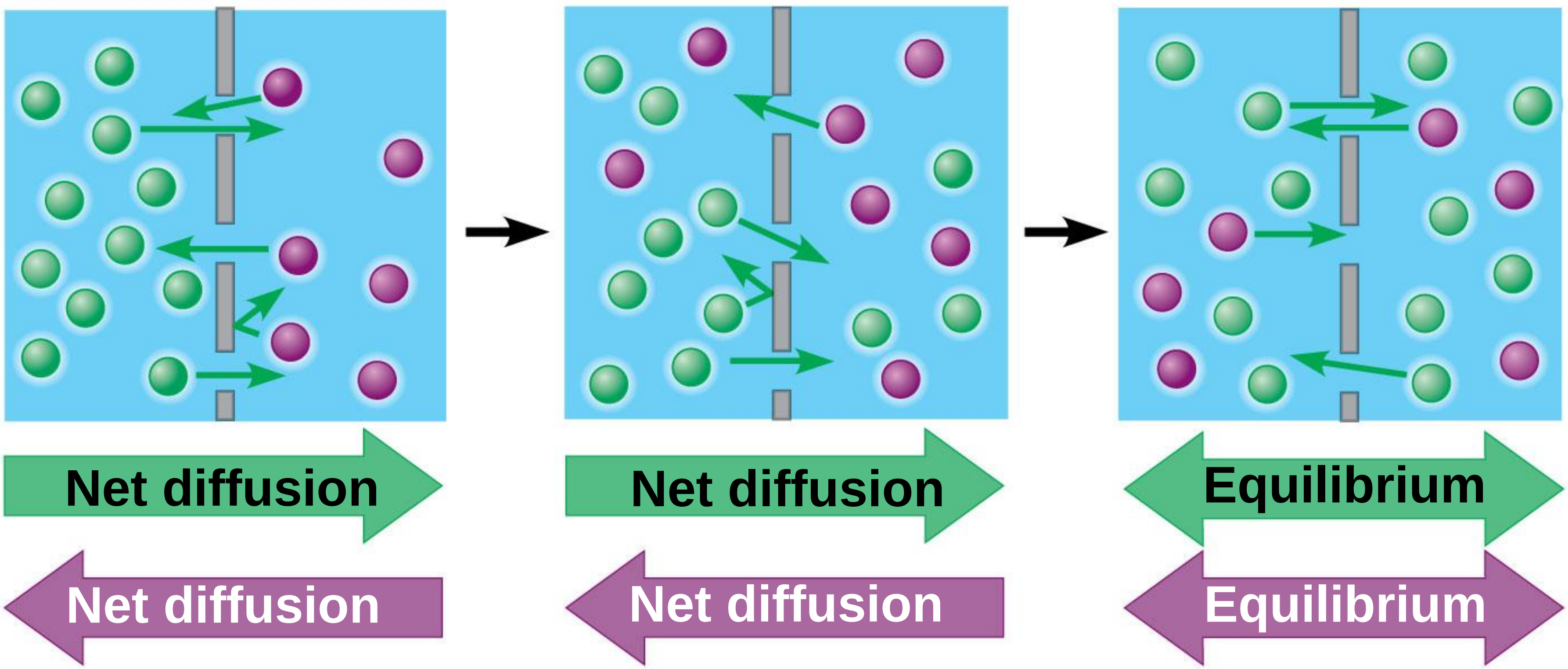

Molecules of dye
Membrane
Pores
Net diffusion
Net diffusion
Equilibrium

Figure 5.3B


Net diffusion
Net diffusion
Net diffusion
Net diffusion
Equilibrium
Equilibrium

5.4 Osmosis is the diffusion of water across a membrane

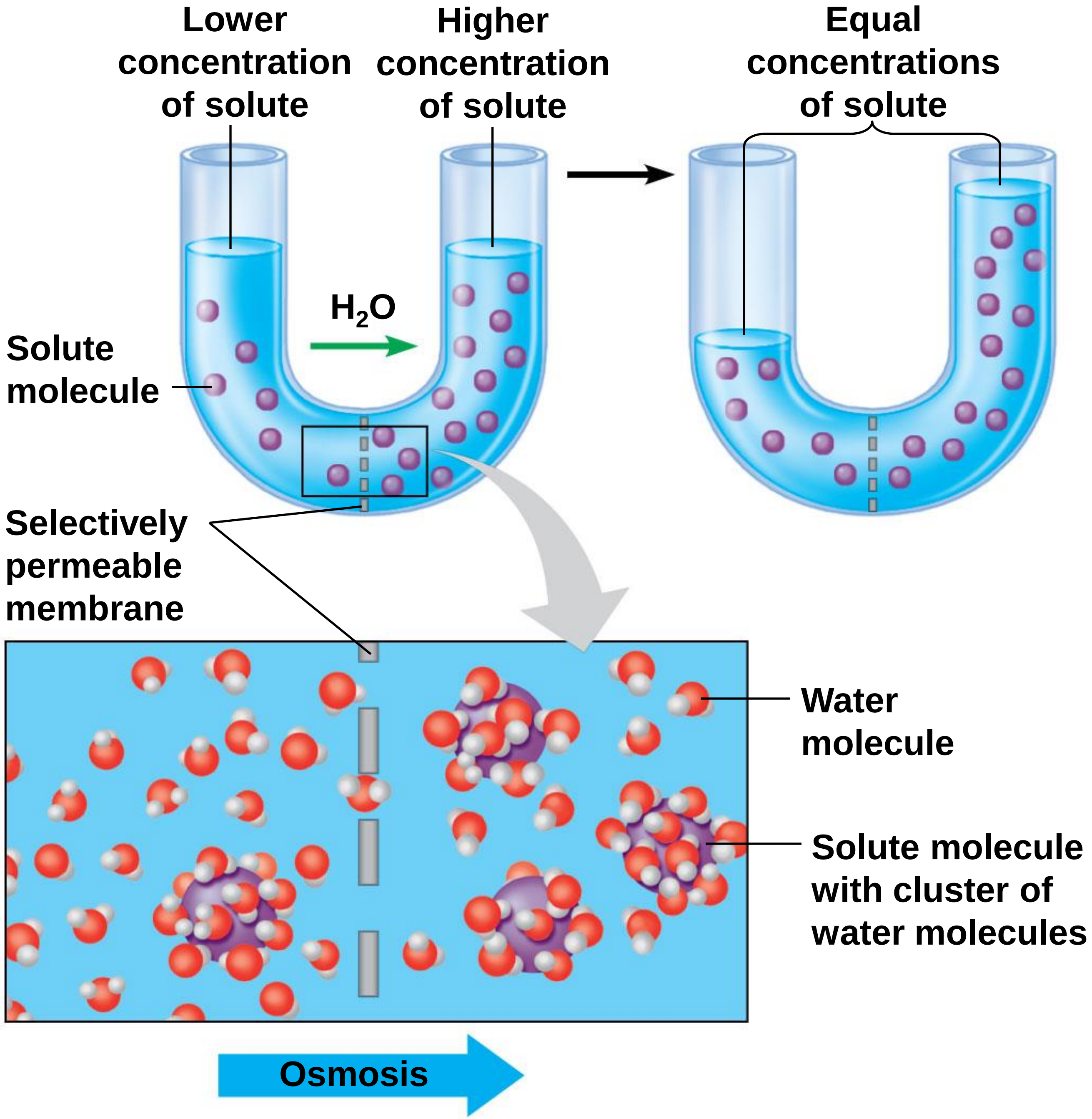
- One of the most important substances that crosses membranes is water.
- The diffusion of water across a selectively permeable membrane is called **osmosis**.

PLAY Animation: Osmosis

5.4 Osmosis is the diffusion of water across a membrane

- If a membrane is permeable to water but not a solute separates two solutions with different concentrations of solute,
  - water will cross the membrane,
  - moving down its own concentration gradient,
  - until the solute concentration on both sides is equal.

Figure 5.4



Lower concentration of solute
Higher concentration of solute
Equal concentrations of solute
H_2O
Solute molecule
Selectively permeable membrane
Water molecule
Solute molecule with cluster of water molecules
Osmosis

5.5 Water balance between cells and their surroundings is crucial to organisms

- **Tonicity -** describes the ability of a solution to cause a cell to gain or lose water.
- Tonicity mostly depends on the concentration of a solute on both sides of the membrane.

5.5 Water balance between cells and their surroundings is crucial to organisms

- When an animal cell is placed into
  - **an isotonic** solution, the concentration of solute is the same on both sides of a membrane, and the cell volume will not change,
  - **a hypotonic** solution, the solute concentration is lower outside the cell, water molecules move into the cell, and the cell will expand and may burst, or
  - **a hypertonic** solution, the solute concentration is higher outside the cell, water molecules move out of the cell, and the cell will shrink.

5.5 Water balance between cells and their surroundings is crucial to organisms

- Animal cell - to survive in a hypotonic or hypertonic environment, it must engage in **osmoregulation**, the control of water balance.

5.5 Water balance between cells and their surroundings is crucial to organisms

- The cell walls of plant cells, prokaryotes, and fungi make water balance issues somewhat different.
  - The cell wall of a plant cell exerts pressure that prevents the cell from taking in too much water and bursting when placed in a hypotonic environment.
  - But in a hypertonic environment, plant and animal cells both shrivel.

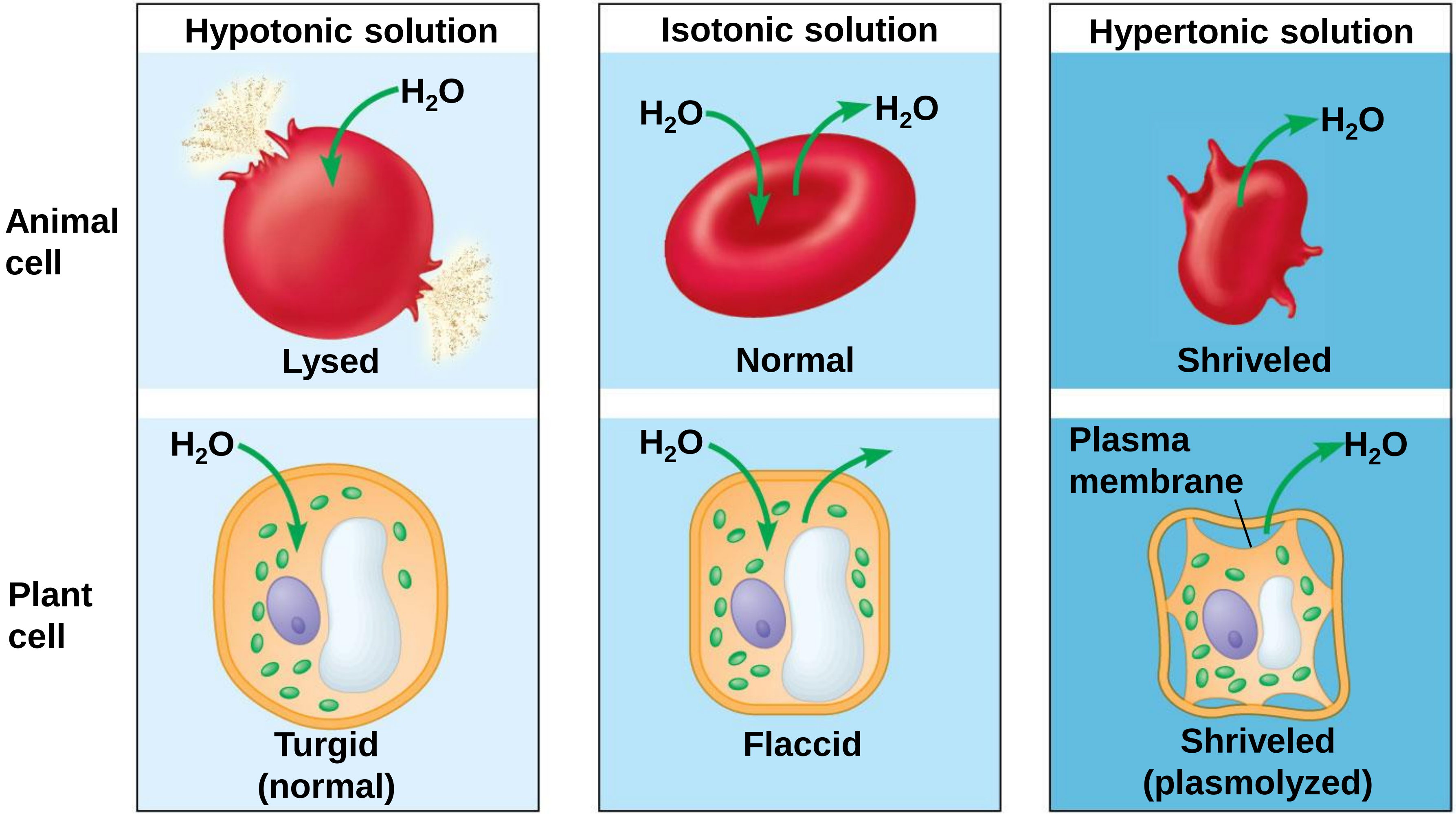
PLAY Video: *Chlamydomonas*

PLAY Video: Plasmolysis

PLAY Video: *Paramecium* Vacuole

PLAY Video: Turgid *Elodea*

Figure 5.5



Hypotonic solution
Isotonic solution
Hypertonic solution
Animal cell
Plant cell
H_2O
H_2O
H_2O
H_2O
Lysed
Normal
Shriveled
H_2O
H_2O
Plasma membrane
H_2O
Turgid (normal)
Flaccid
Shriveled (plasmolyzed)

5.6 Transport proteins can facilitate diffusion across membranes

- Hydrophobic substances easily diffuse across a cell membrane.
- Polar or charged substances do not easily cross cell membranes, instead, move across membranes with the help of specific transport proteins in a process called **facilitated diffusion**, which
  - does not require energy and
  - relies on the concentration gradient.

5.6 Transport proteins can facilitate diffusion across membranes

- Some proteins function by becoming a hydrophilic tunnel for passage of ions or other molecules.
- Other proteins bind their passenger, change shape, and release their passenger on the other side.
- In both of these situations, the protein is specific for the substrate, which can be sugars, amino acids, ions, and even water.

5.6 Transport proteins can facilitate diffusion across membranes

- Water is polar, its diffusion through a membrane's hydrophobic interior is slow.
- The very rapid diffusion of water into and out of certain cells is made possible by a protein channel called an **aquaporin**.

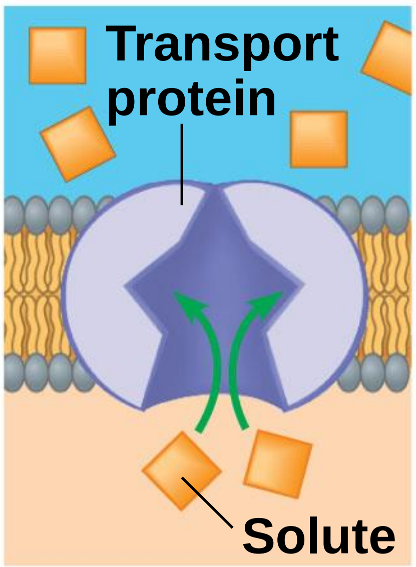
5.8 Cells expend energy in the active transport of a solute

- In active transport, a cell
  - must expend energy to
  - move a solute against its concentration gradient.
- The following figures show the four main stages of active transport.

PLAY

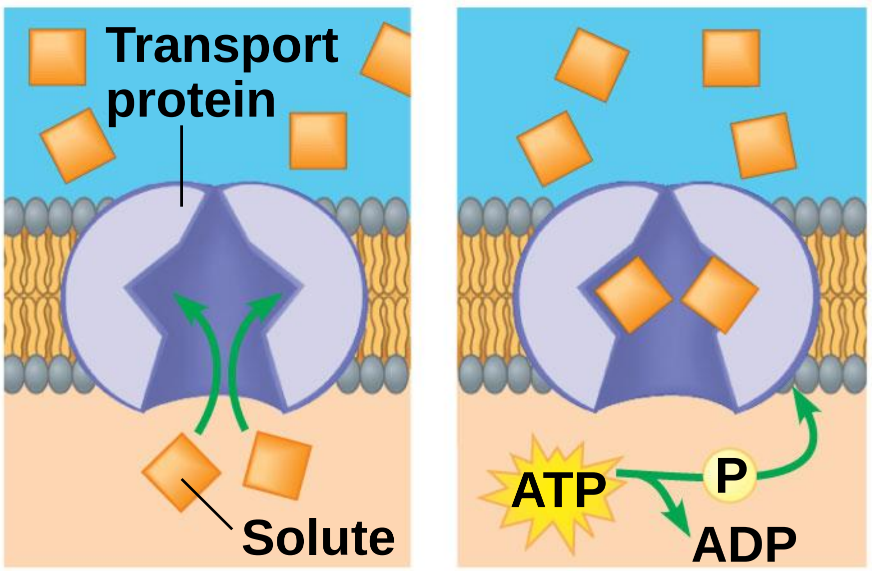
Animation: Active Transport

Figure 5.8_s1



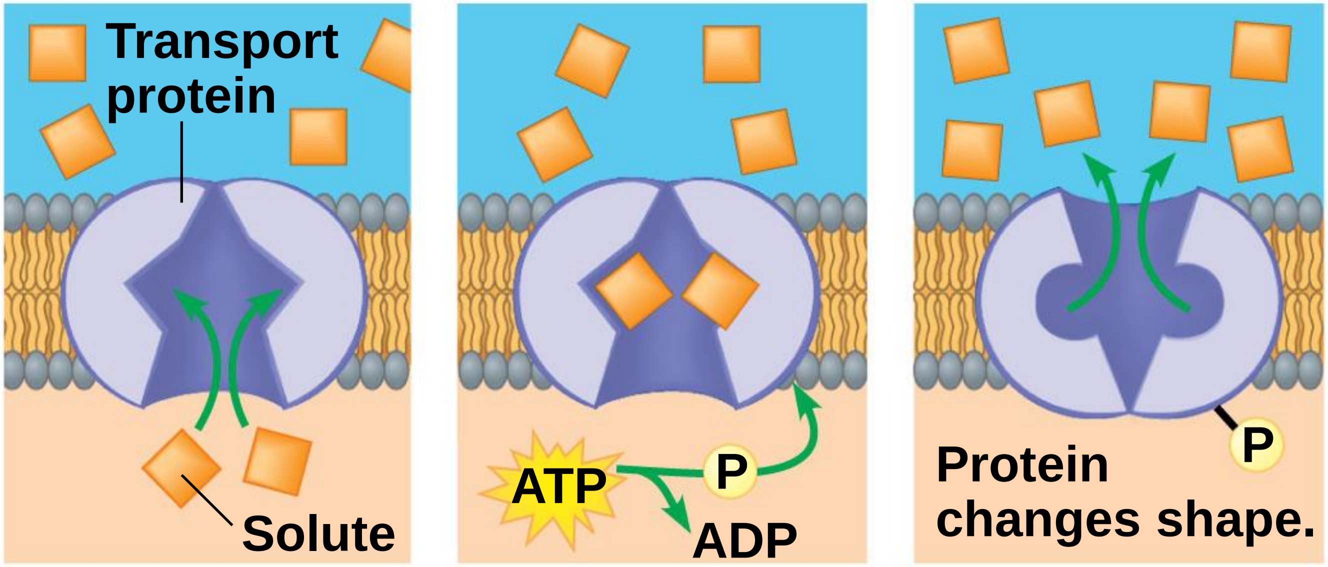
1 **Solute binding**

Figure 5.8_s2



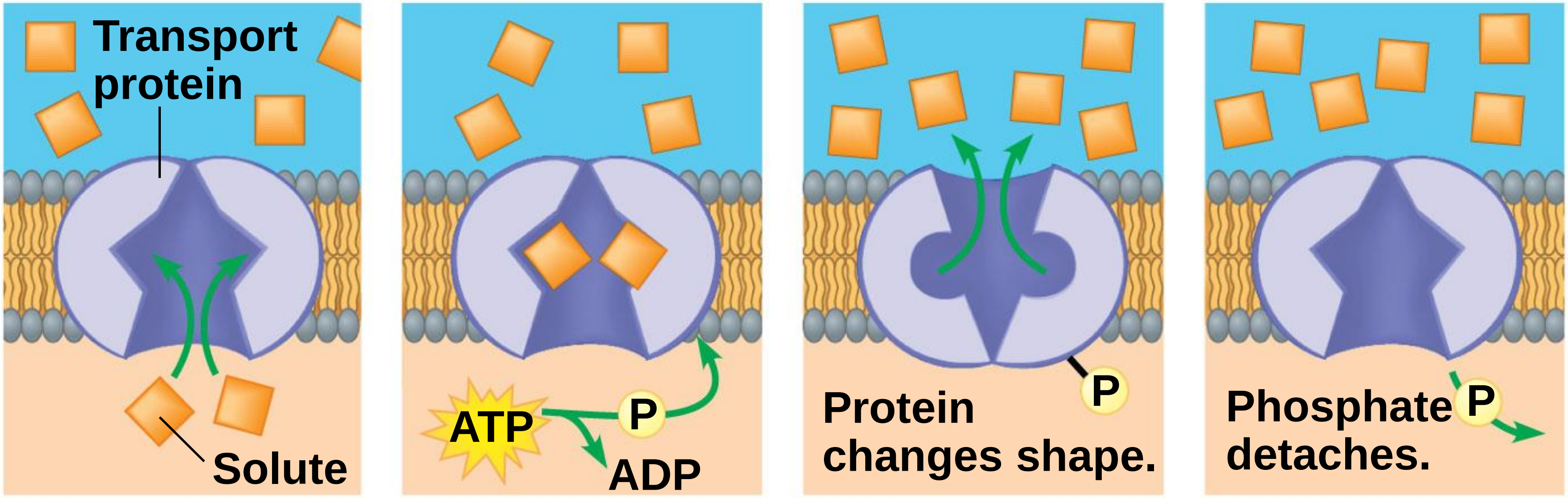
❶ Solute binding ❷ Phosphate attaching

Figure 5.8_s3



❶ Solute binding ❷ Phosphate attaching ❸ Transport

Figure 5.8_s4



1 Solute binding

2 Phosphate attaching

3 Transport

4 Protein reversion

5.9 Exocytosis and endocytosis transport large molecules across membranes

- Two mechanisms to move large molecules across membranes.
  - **Exocytosis** is used to export bulky molecules, such as proteins or polysaccharides.
  - **Endocytosis** is used to import substances useful to the livelihood of the cell.
- In both cases, material to be transported is packaged within a vesicle that fuses with the membrane.

5.9 Exocytosis and endocytosis transport large molecules across membranes

- There are three kinds of endocytosis.
  1. **Phagocytosis** is the engulfment of a particle by wrapping cell membrane around it, forming a vacuole.
  2. **Pinocytosis** is the same thing except that fluids are taken into small vesicles.
  3. **Receptor-mediated endocytosis** uses receptors in a receptor-coated pit to interact with a specific protein, initiating the formation of a vesicle.

PLAY Animation: Exocytosis and Endocytosis Introduction

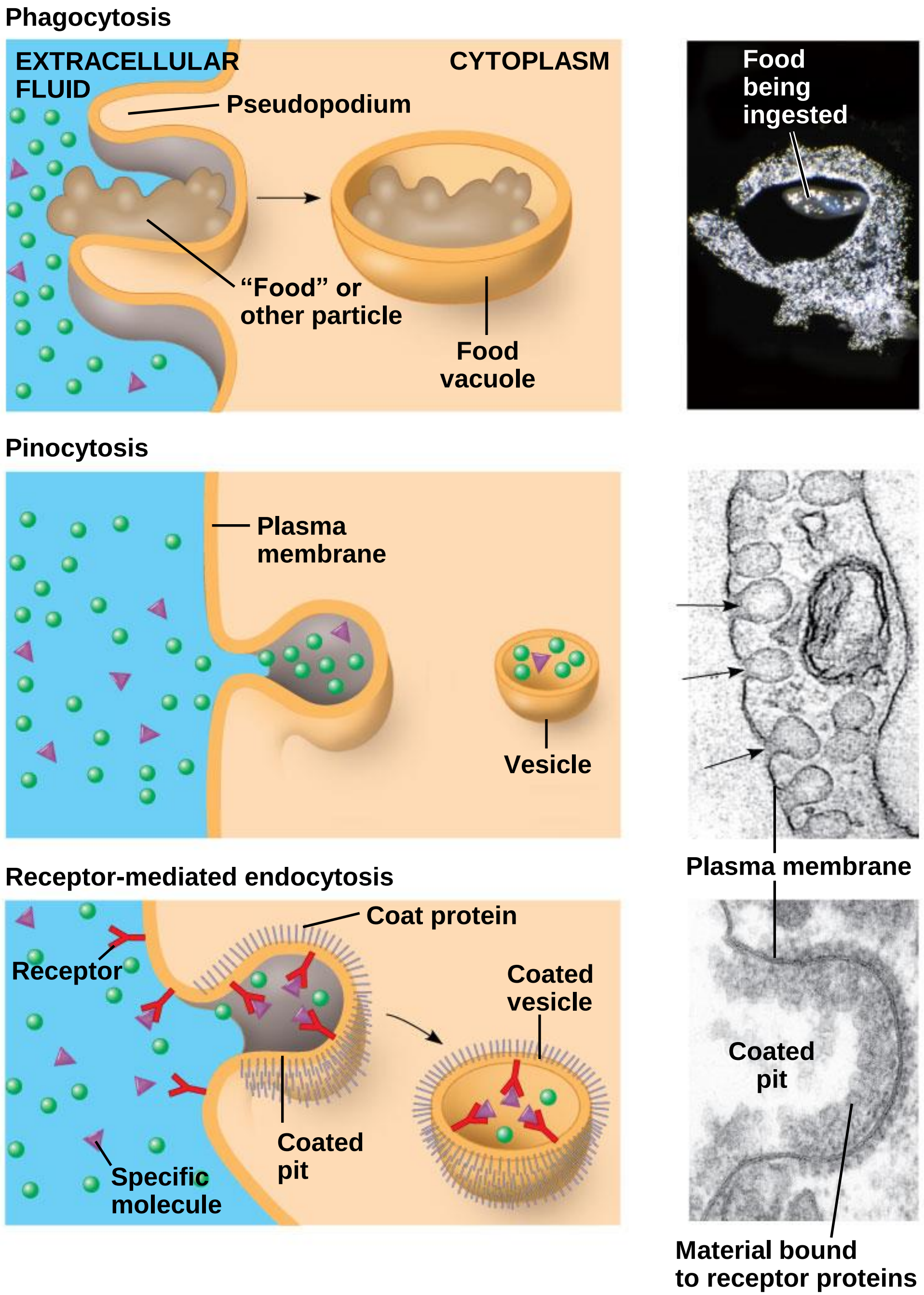
PLAY Animation: Exocytosis

PLAY Animation: Pinocytosis

PLAY Animation: Phagocytosis

PLAY Animation: Receptor-Mediated Endocytosis

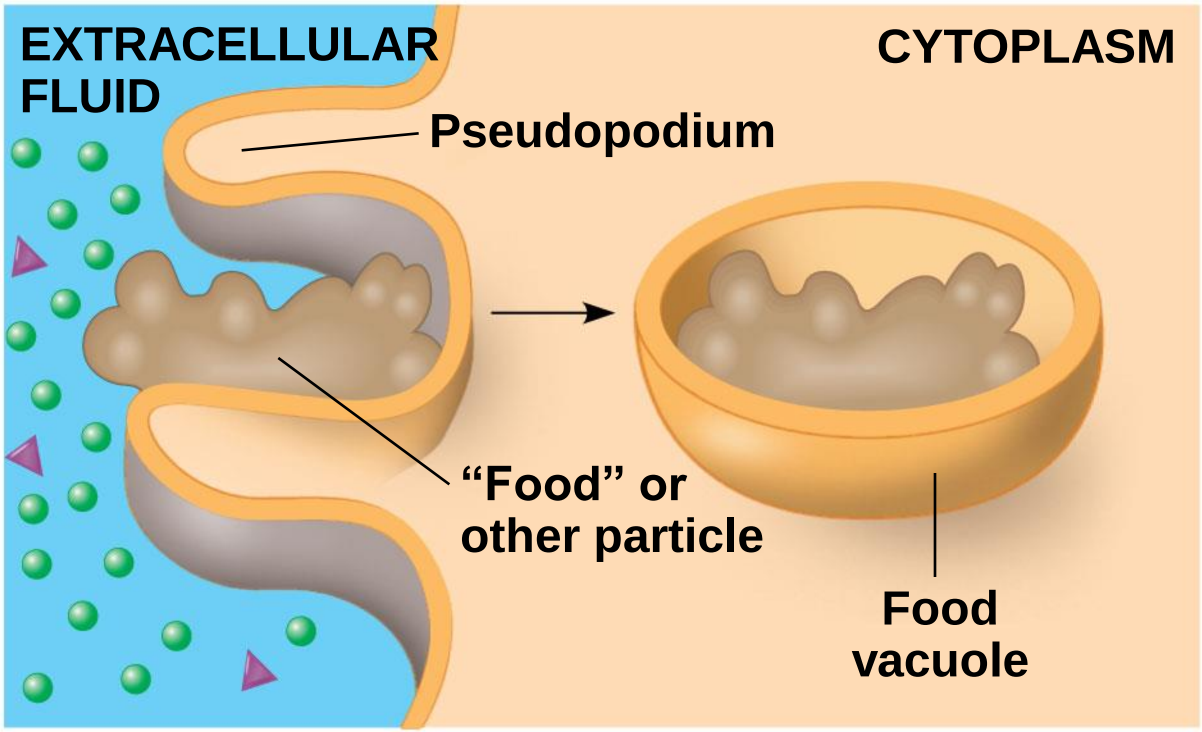
Figure 5.9

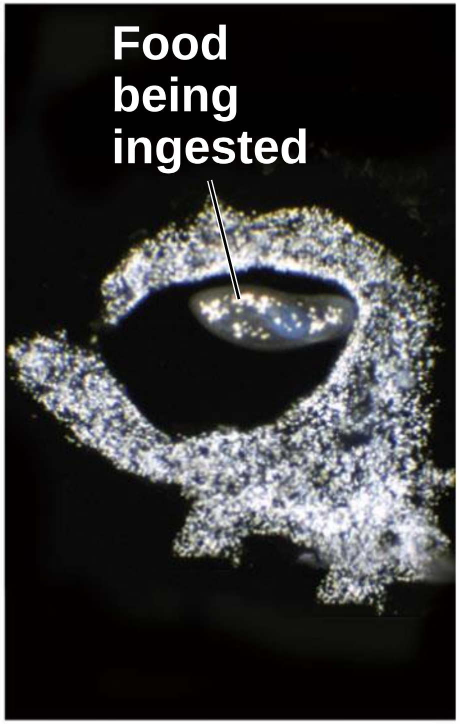


Phagocytosis
EXTRACELLULAR FLUID
CYTOPLASM
Pseudopodium
"Food" or other particle
Food vacuole
Food being ingested
Pinocytosis
Plasma membrane
Vesicle
Plasma membrane
Receptor-mediated endocytosis
Coat protein
Receptor
Coated vesicle
Coated pit
Specific molecule
Coated pit
Material bound to receptor proteins

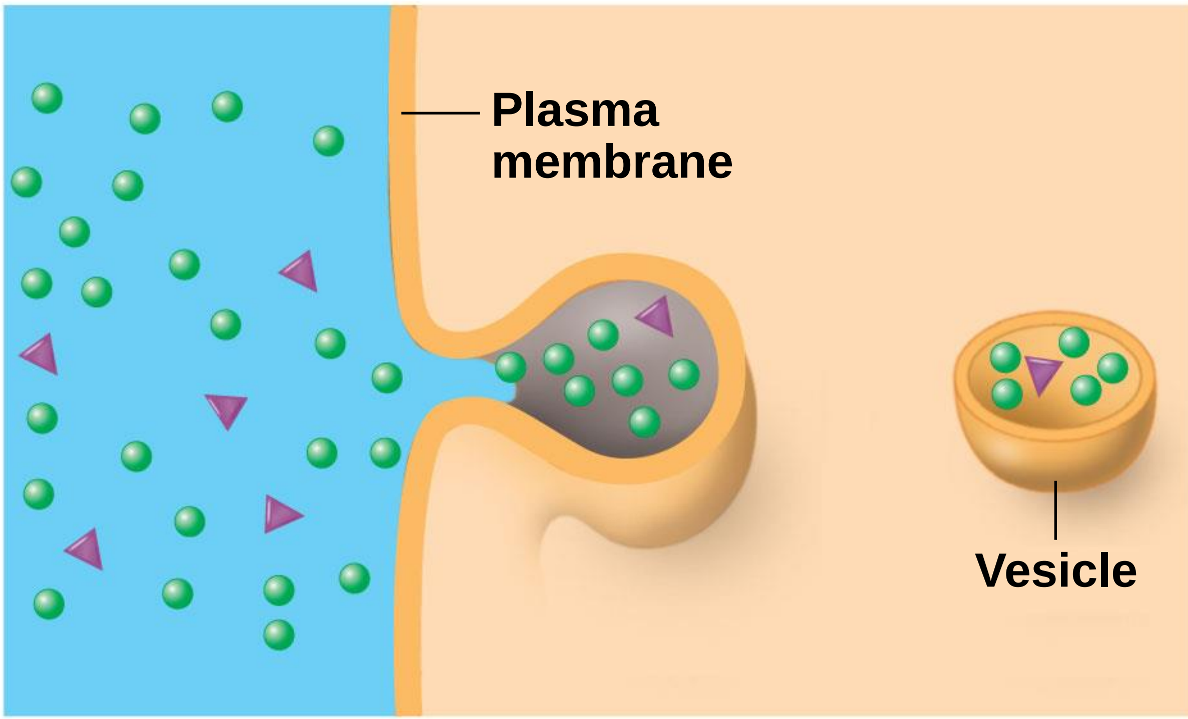
Figure 5.9_1

Phagocytosis





Pinocytosis



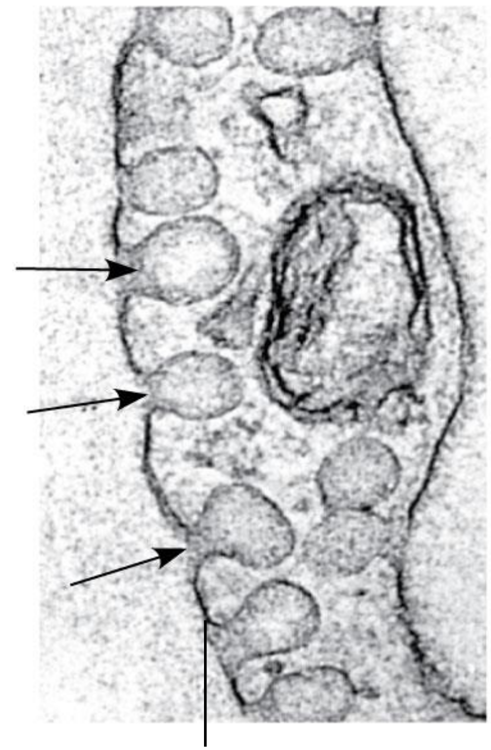
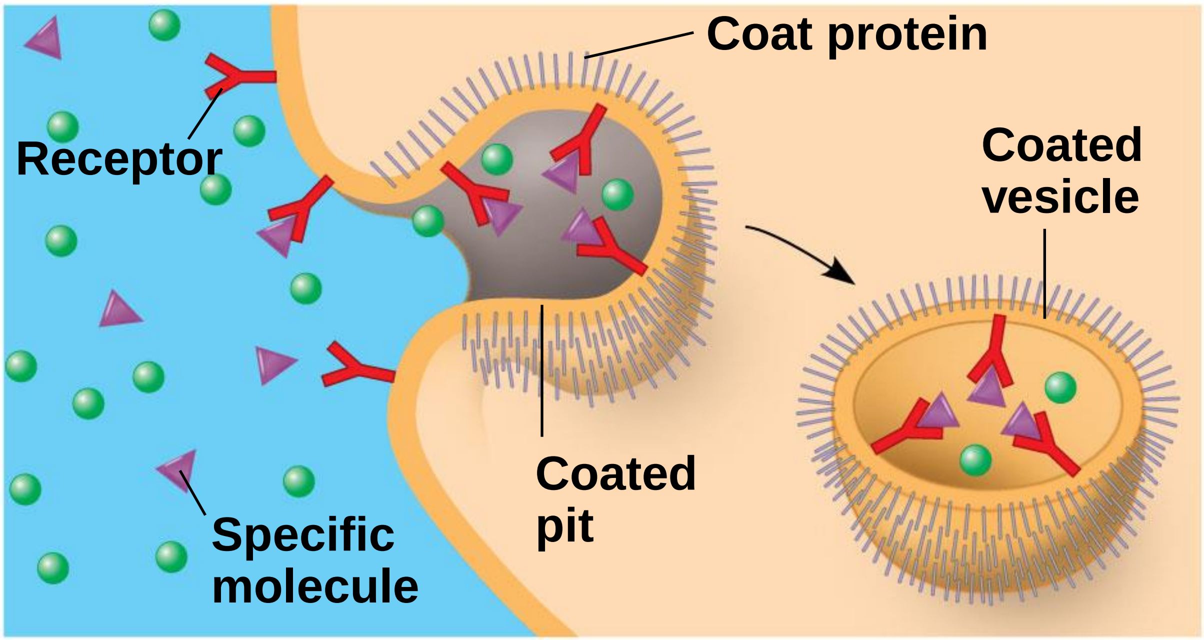


Figure 5.9_3

Receptor-mediated endocytosis



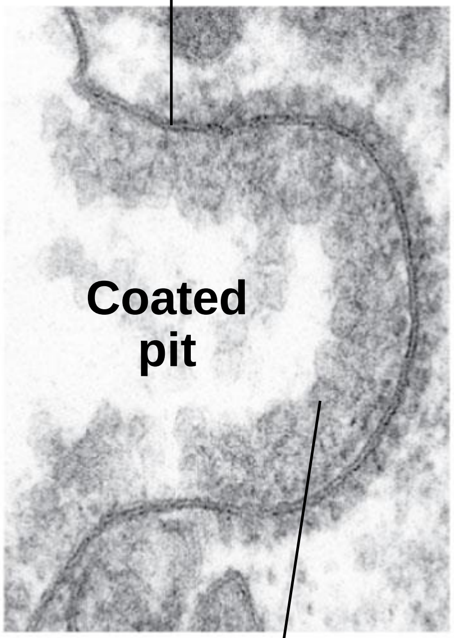


Figure 5.9_4

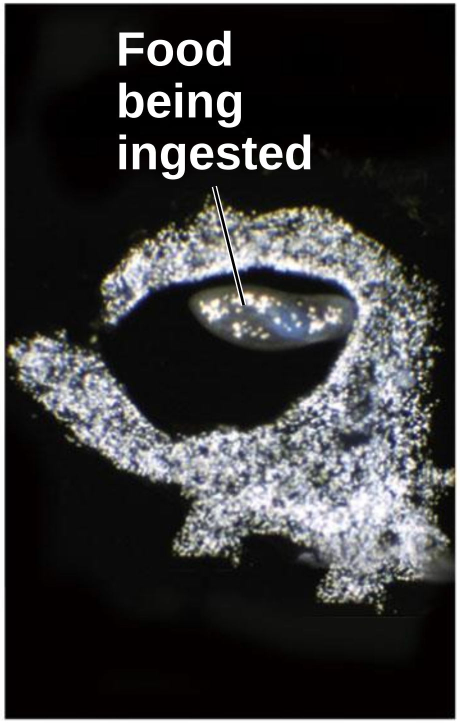


Figure 5.9_5

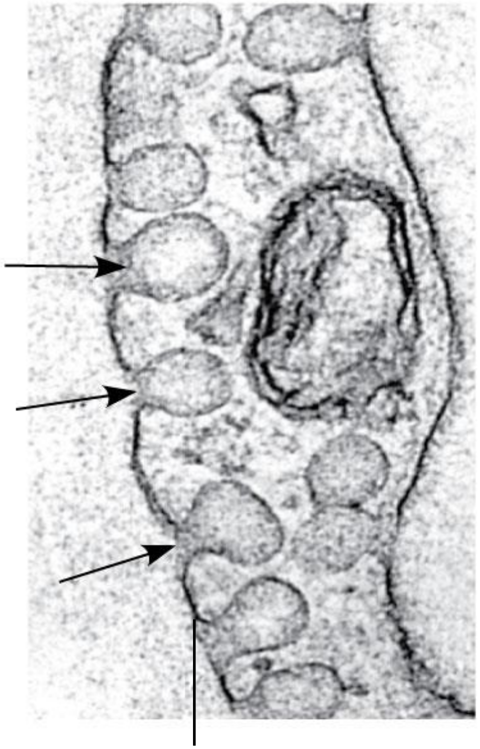
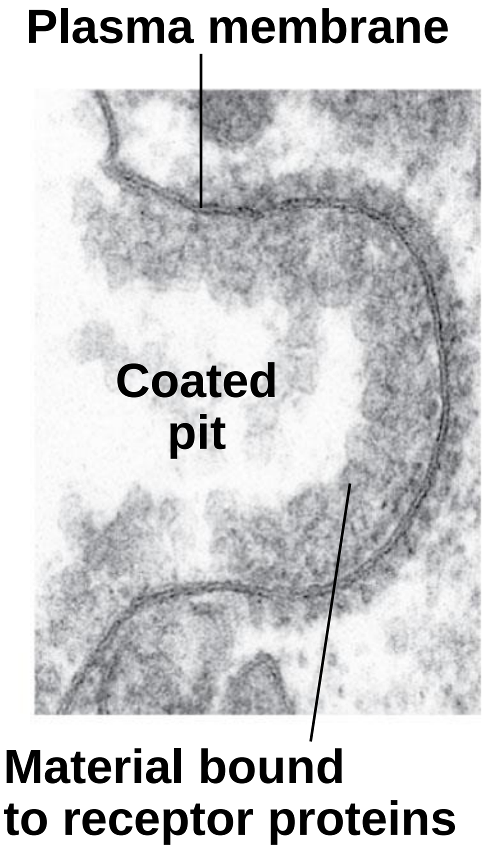


Figure 5.9_6



Plasma membrane
Coated pit
Material bound to receptor proteins

ENERGY AND THE CELL

5.10 Cells transform energy as they perform work

- Cells perform thousands of chemical reactions.
  - Use for:
    - cell maintenance,
    - manufacture of cellular parts, and
    - cell replication.

5.10 Cells transform energy as they perform work

- **Energy** - capacity to cause change or to perform work.
- 2 kinds of energy.
  1. **Kinetic energy** - energy of motion.
  2. **Potential energy** – stored energy.

Figure 5.10

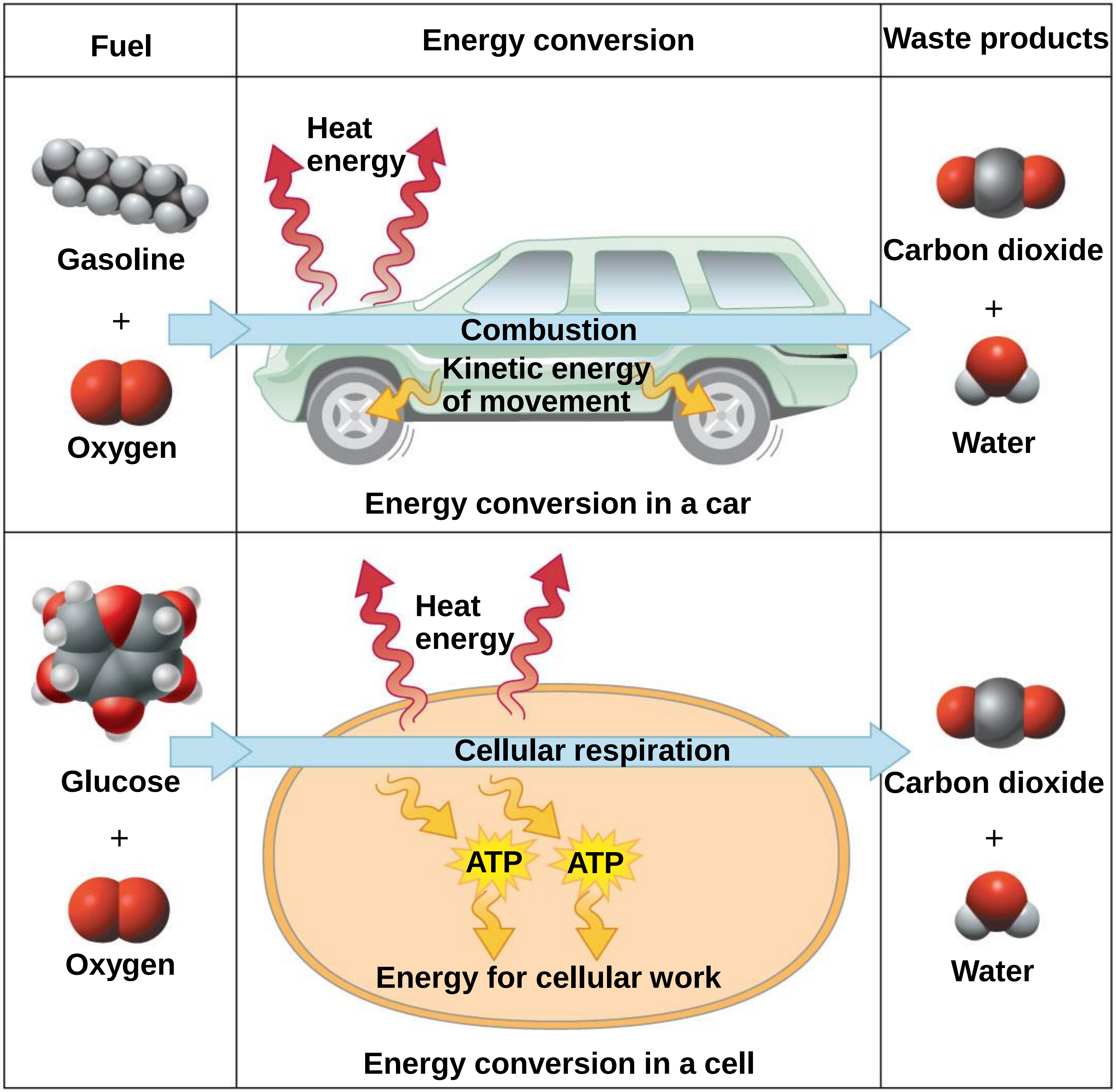

Fuel
Energy conversion
Waste products
Gasoline
+
Oxygen
Heat energy
Combustion
Kinetic energy of movement
Energy conversion in a car
Carbon dioxide
+
Water
Glucose
+
Oxygen
Heat energy
Cellular respiration
ATP
ATP
Energy for cellular work
Energy conversion in a cell
Carbon dioxide
+
Water

Figure 5.10_1

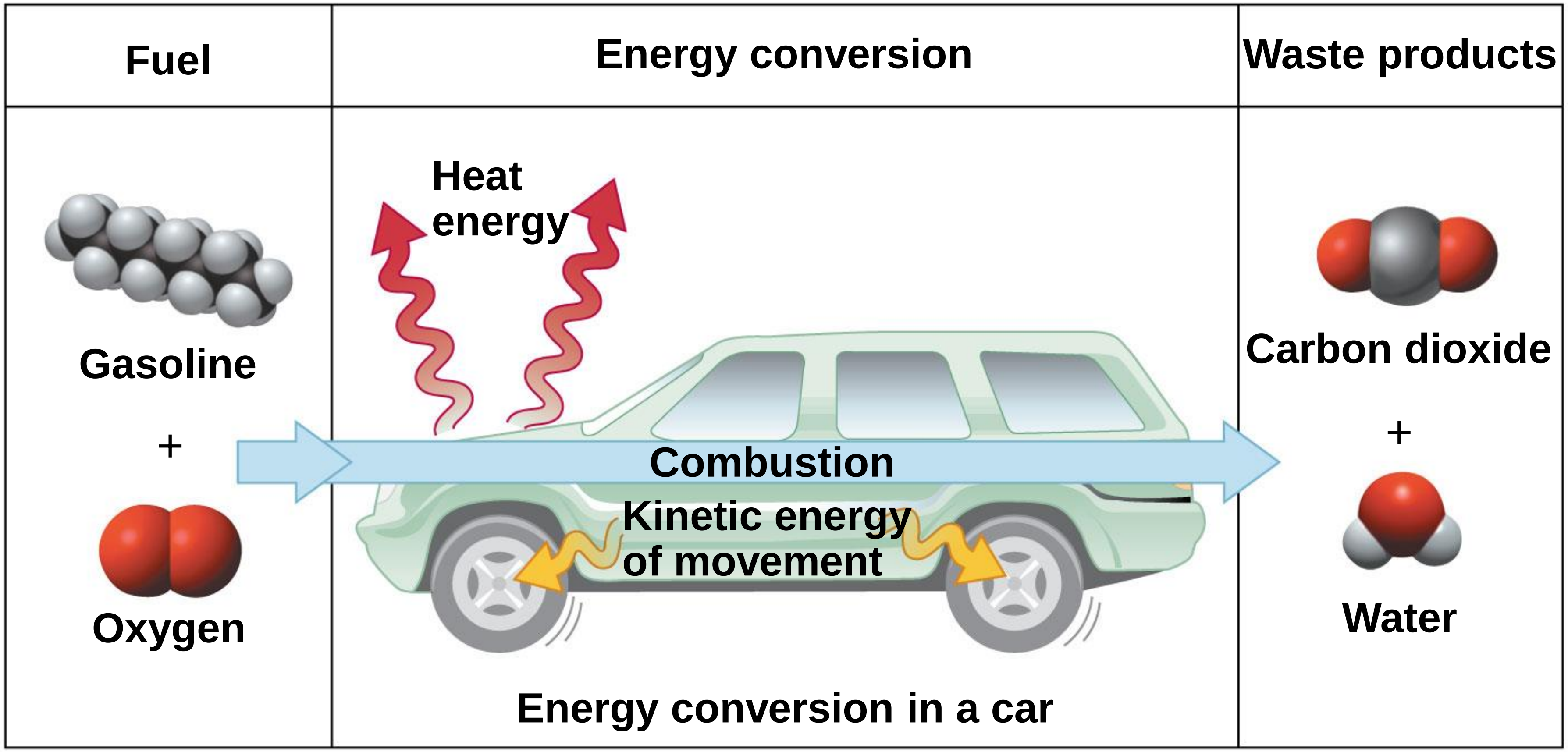
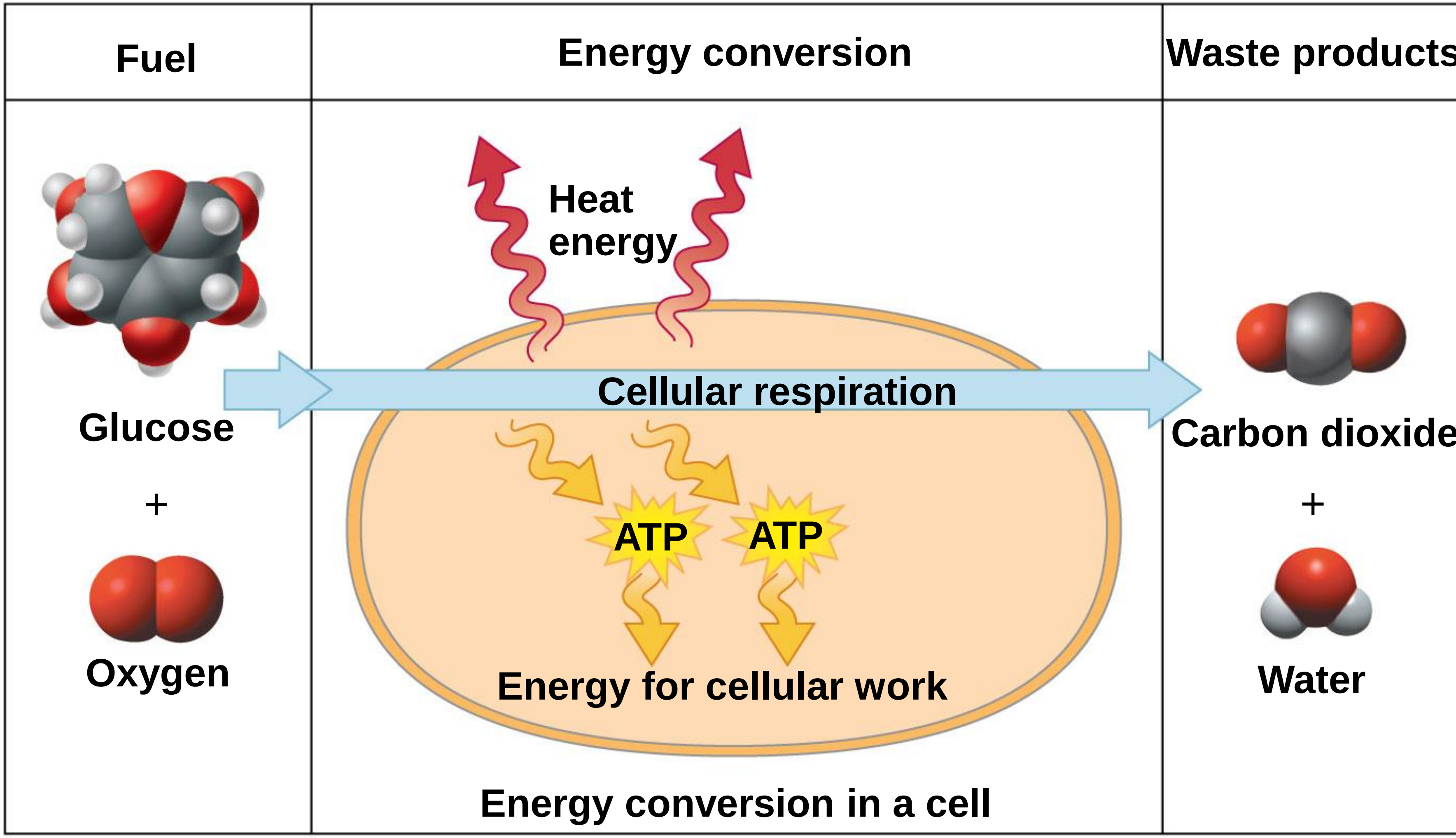

Fuel
Energy conversion
Waste products
Gasoline
+
Oxygen
Heat
energy
Combustion
Kinetic energy
of movement
Energy conversion in a car
Carbon dioxide
+
Water

Figure 5.10_2



Fuel
Energy conversion
Waste products
Heat
energy
Cellular respiration
Glucose
+
Oxygen
ATP
ATP
Energy for cellular work
Carbon dioxide
+
Water
Energy conversion in a cell

5.10 Cells transform energy as they perform work

- **Kinetic Energy**
  - **Heat –** energy associated with the random movement of atoms or molecules.
  - **Light** - can be harnessed to power photosynthesis
- **Potential Energy**
  - **Chemical** - energy available for release in a chemical reaction. It is the most important type of energy for living organisms to power the work of the cell.

5.10 Cells transform energy as they perform work

- **Thermodynamics** - the study of energy transformations that occur in a collection of matter.
- Two laws
  - **first law of thermodynamics**, energy in the universe is constant, and
  - **second law of thermodynamics**, energy conversions increase the disorder (entropy) of the universe.
- **Entropy** is the measure of disorder, or randomness.

5.10 Cells transform energy as they perform work

- Cells use oxygen in reactions that release energy from fuel molecules.
- In **cellular respiration**, the chemical energy stored in organic molecules is converted to a form that the cell can use to perform work.

5.11 Chemical reactions either release or store energy

- Chemical reactions either
  - release energy (**exergonic reactions**) ex: cellular respiration or
  - require an input of energy and store energy (**endergonic reactions**). Ex: photosynthesis

Figure 5.11A

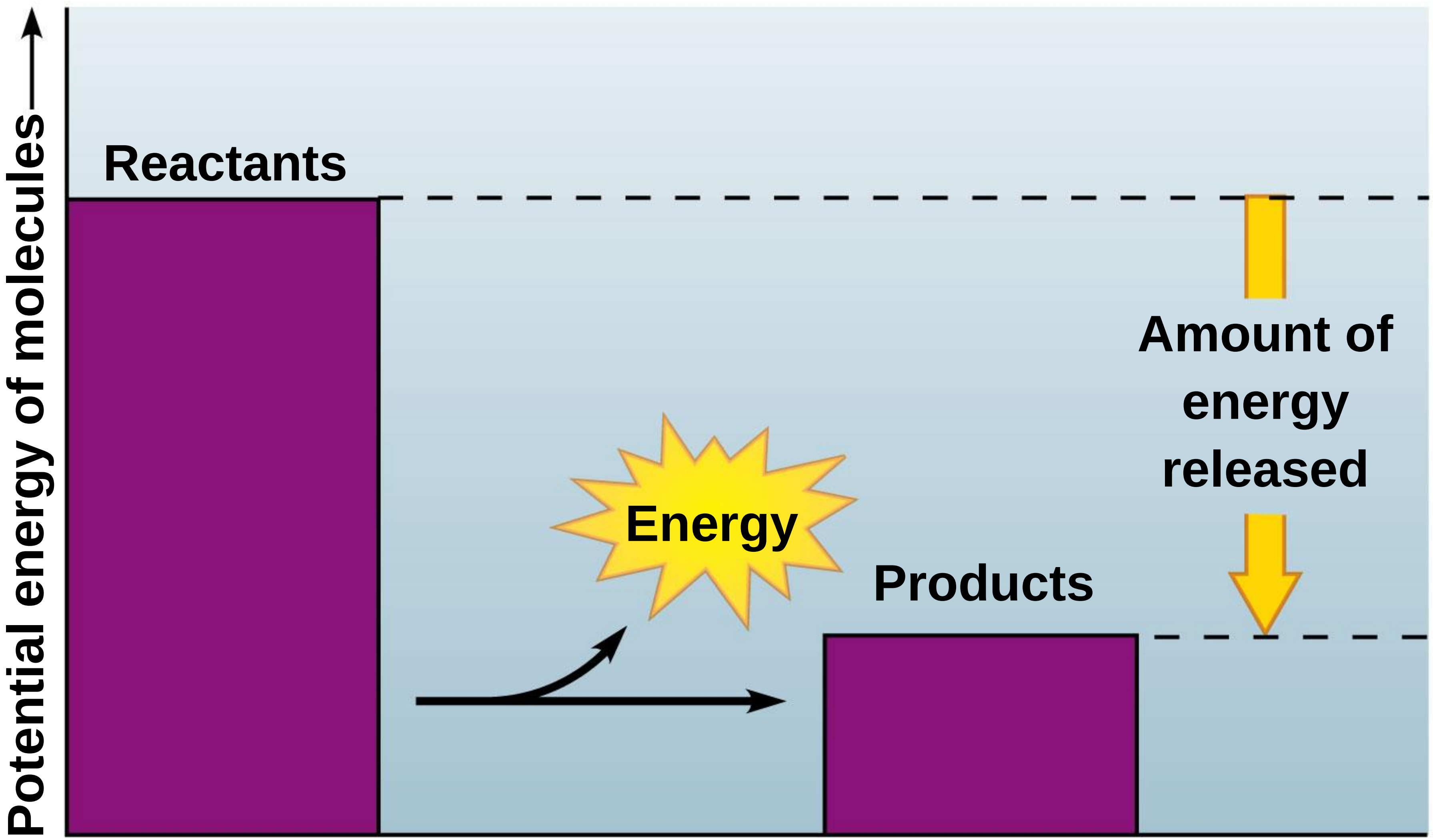
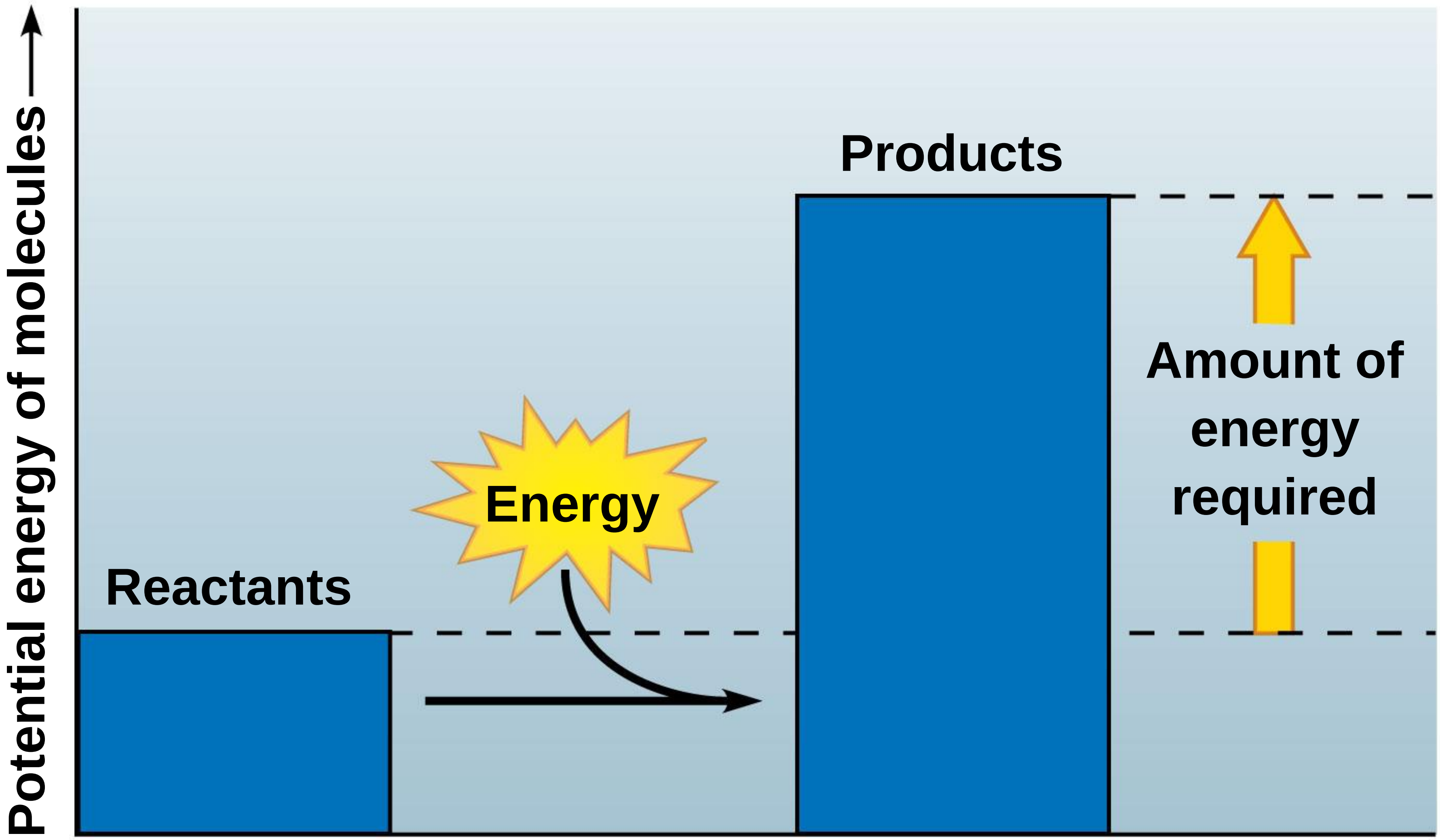

Potential energy of molecules
Reactants
Energy
Products
Amount of energy released

Figure 5.11B


Potential energy of molecules
Products
Amount of energy required
Energy
Reactants

5.11 Chemical reactions either release or store energy

- **Metabolism** - The total of an organism's chemical reactions.
- **Metabolic pathway** - series of chemical reactions that either
  - builds a complex molecule or
  - breaks down a complex molecule into simpler compounds.

5.11 Chemical reactions either release or store energy

- **Energy coupling** uses the
  - energy released from exergonic reactions to drive
  - essential endergonic reactions,
  - usually using the energy stored in ATP molecules.

5.12 ATP drives cellular work by coupling exergonic and endergonic reactions

- **ATP**, adenosine triphosphate, powers nearly all forms of cellular work.
- ATP consists of
  - the nitrogenous base adenine,
  - the five-carbon sugar ribose, and
  - three phosphate groups.

5.12 ATP drives cellular work by coupling exergonic and endergonic reactions

- Hydrolysis of ATP releases energy by transferring its third phosphate from ATP to some other molecule in a process called **phosphorylation**.
- Most cellular work depends on ATP energizing molecules by phosphorylating them.

Figure 5.12A_s1

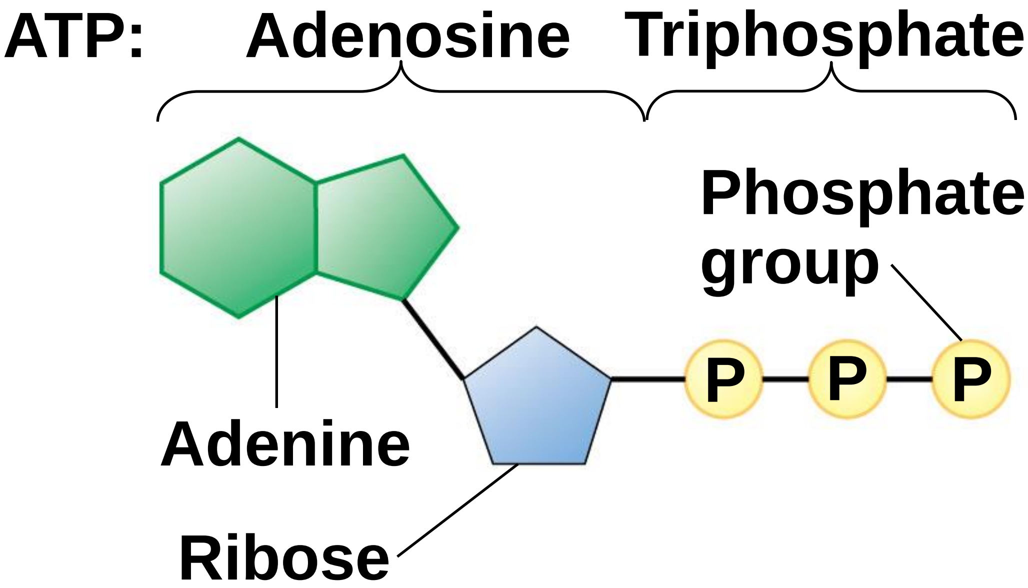
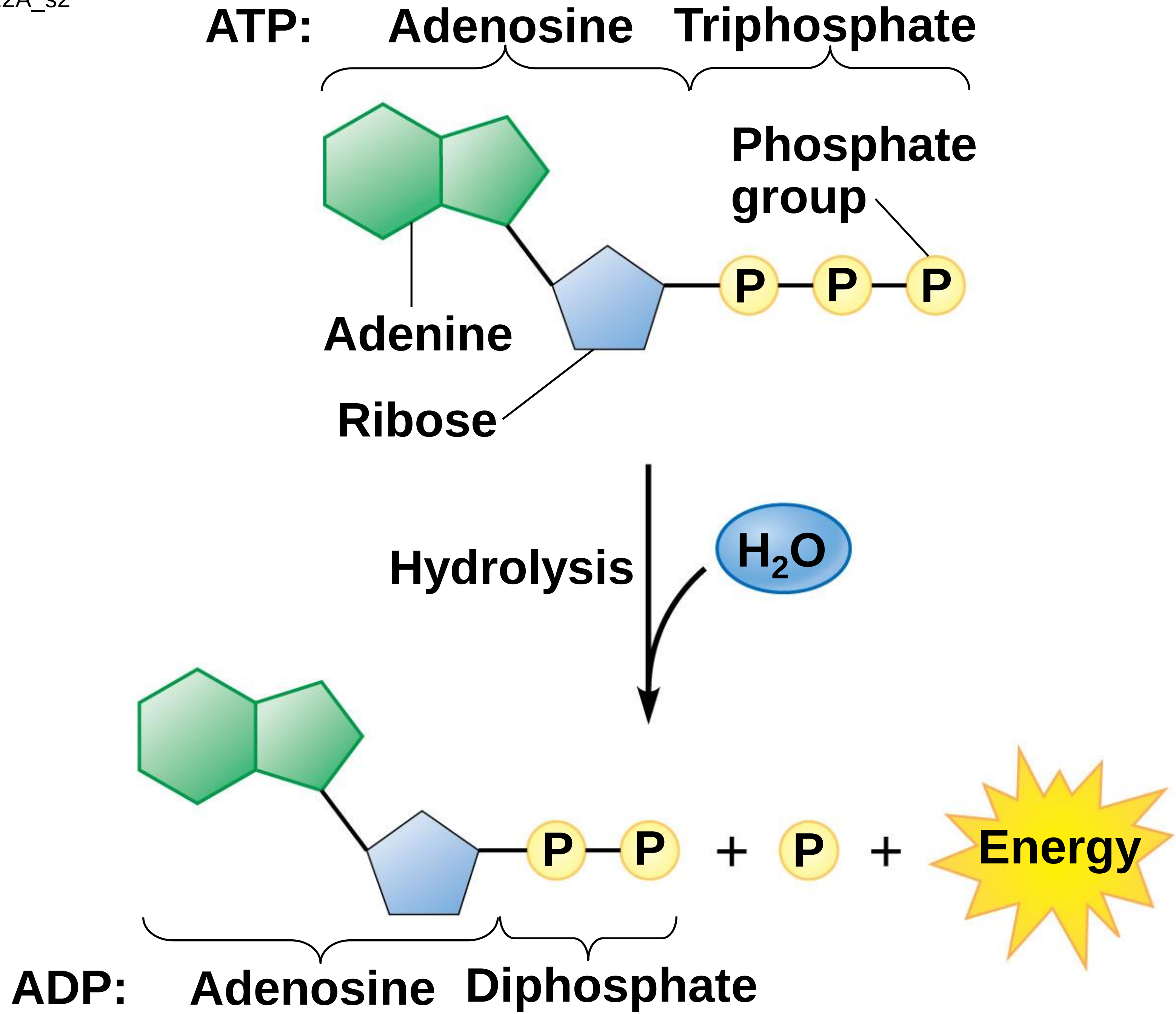


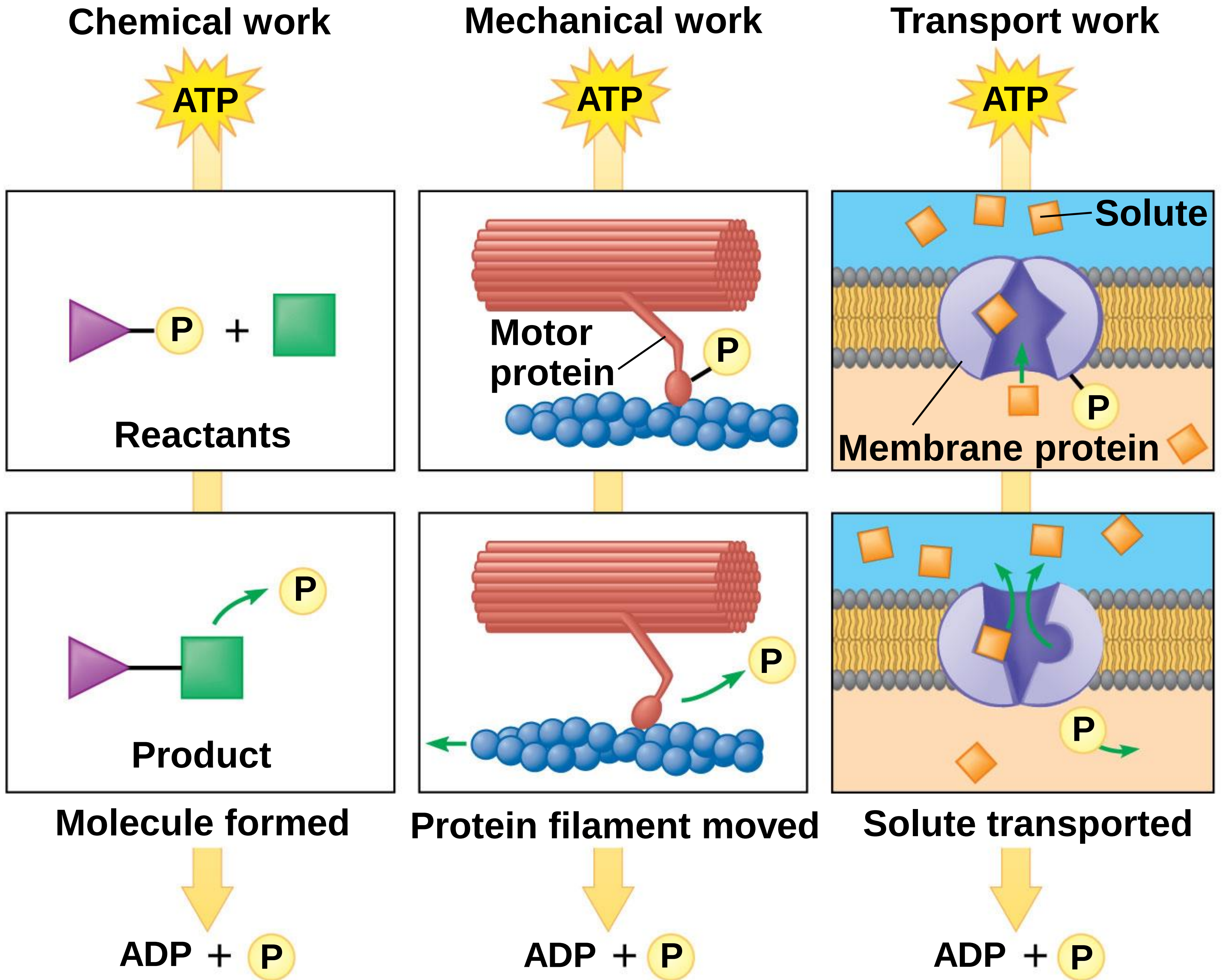
Figure 5.12A_s2



5.12 ATP drives cellular work by coupling exergonic and endergonic reactions

- There are three main types of cellular work:
  1. chemical,
  2. mechanical, and
  3. transport.
- ATP drives all three of these types of work.

Figure 5.12B

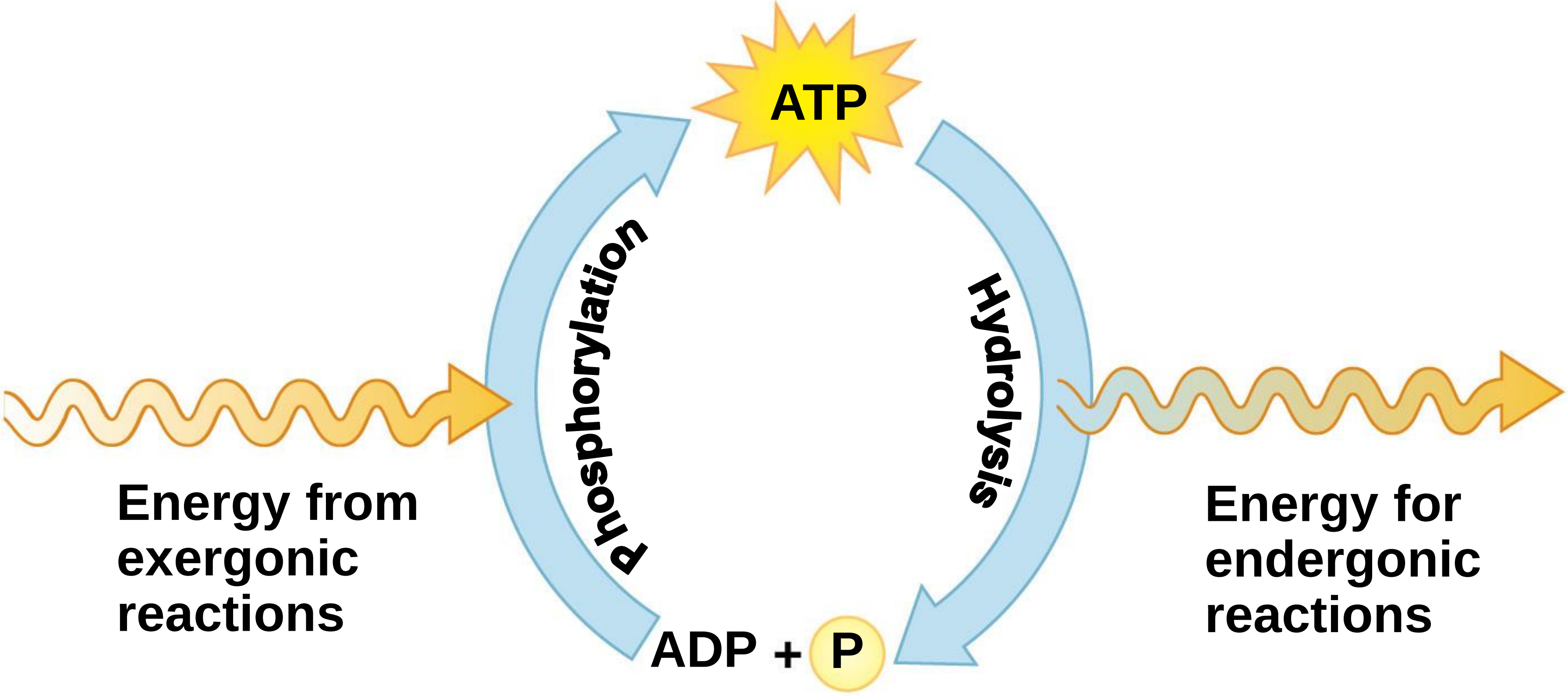


Chemical work
Mechanical work
Transport work
ATP
ATP
ATP
P
Reactants
Motor protein
P
Solute
Membrane protein
P
P
Product
P
P
Molecule formed
Protein filament moved
Solute transported
ADP + P
ADP + P
ADP + P

5.12 ATP drives cellular work by coupling exergonic and endergonic reactions

- ATP is a renewable source of energy for the cell.
- ATP cycle - energy released in an exergonic reaction (ex. breakdown of glucose), then energy is used in an endergonic reaction to generate ATP.

Figure 5.12C


ATP
Phosphorylation
Hydrolysis
Energy from exergonic reactions
Energy for endergonic reactions
ADP + P

HOW ENZYMES FUNCTION

5.13 Enzymes speed up the cell's chemical reactions by lowering energy barriers

- An energy barrier must be overcome before a chemical reaction can begin.
- This energy is called the **activation energy** (E_A).

5.13 Enzymes speed up the cell's chemical reactions by lowering energy barriers

- We can think of Energy of Activation, E_A
  - amount of energy needed for a reactant molecule to move "uphill" to a higher energy but an unstable state
  - so that the "downhill" part of the reaction can begin.
- One way to speed up a reaction is to add heat,
  - agitates atoms so that bonds break more easily and reactions can proceed but
  - could kill a cell.

Figure 5.13A

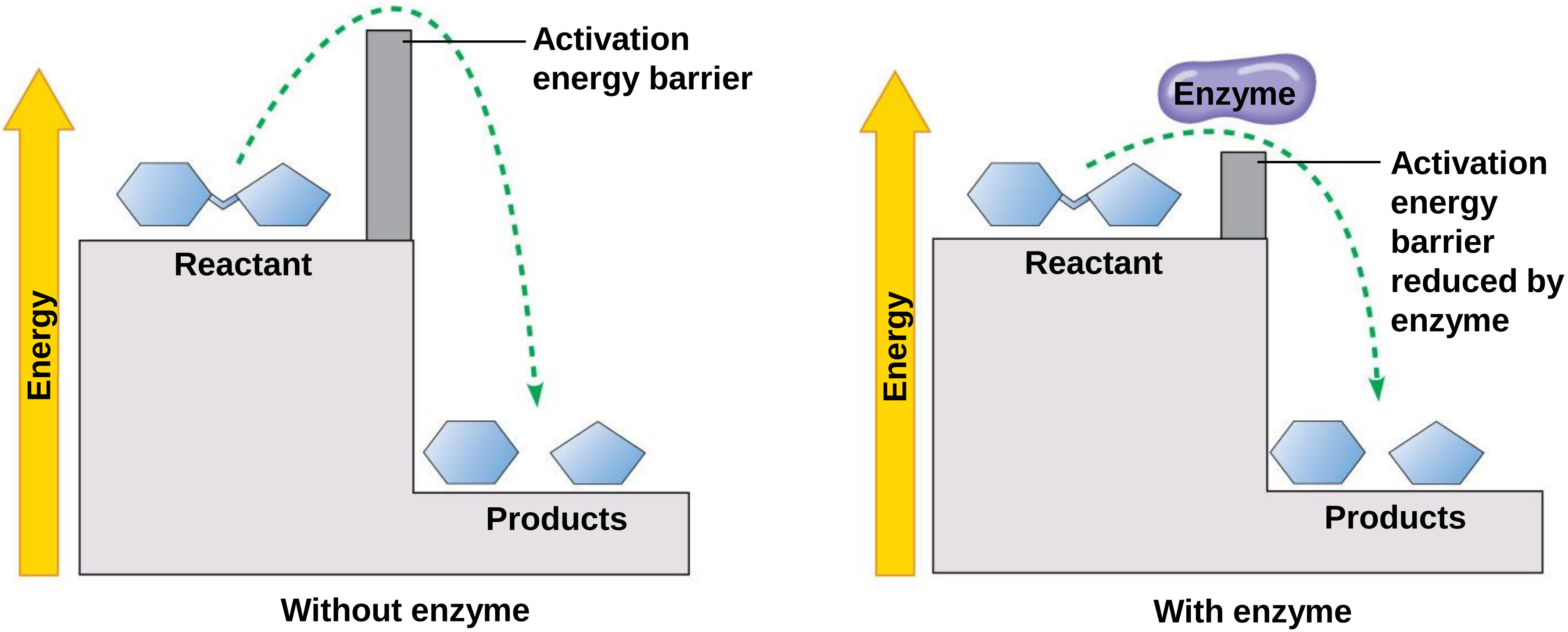

Activation energy barrier
Energy
Reactant
Products
Without enzyme
Enzyme
Activation energy barrier reduced by enzyme
Energy
Reactant
Products
With enzyme

Figure 5.13A_1

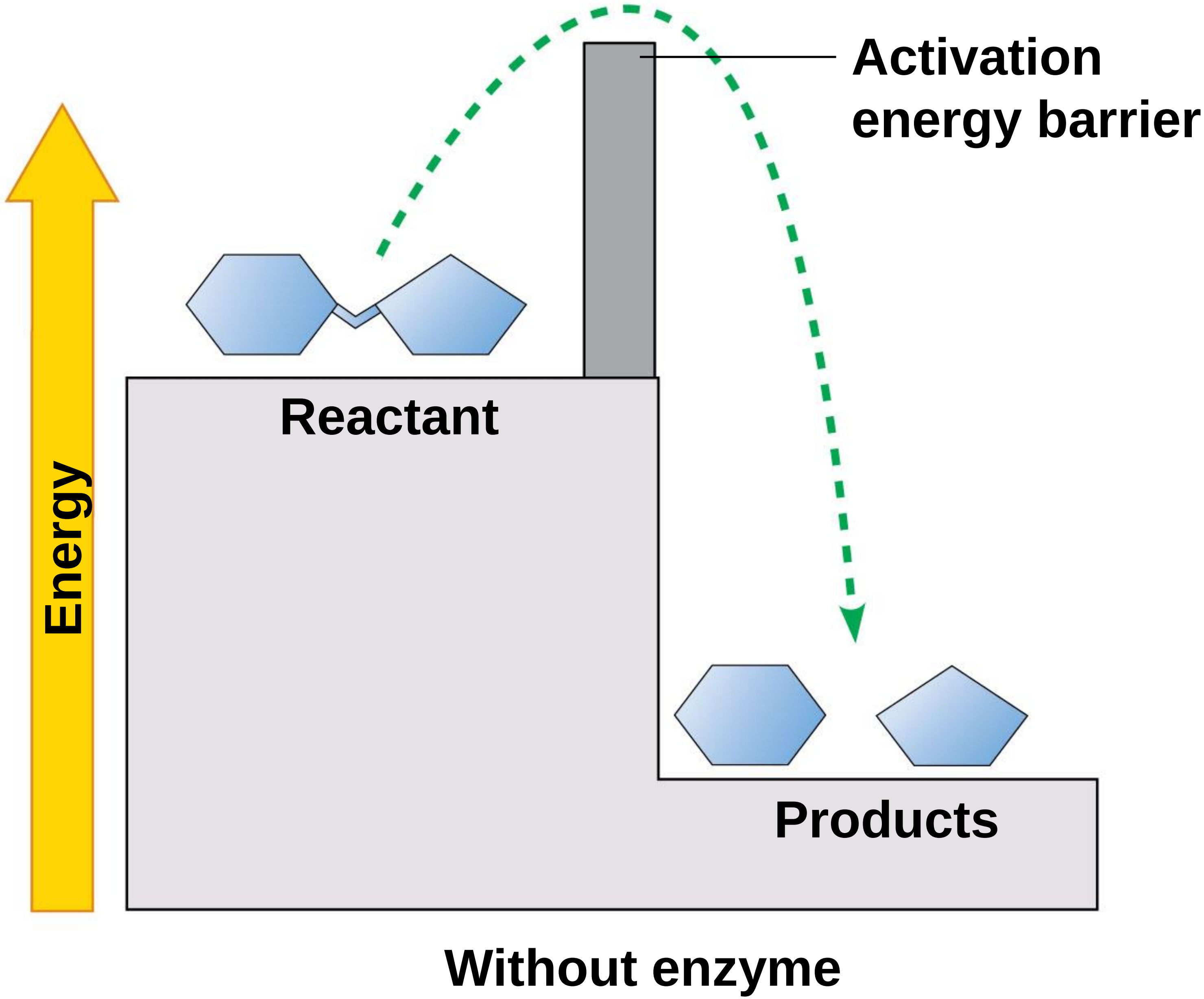


Figure 5.13A_2

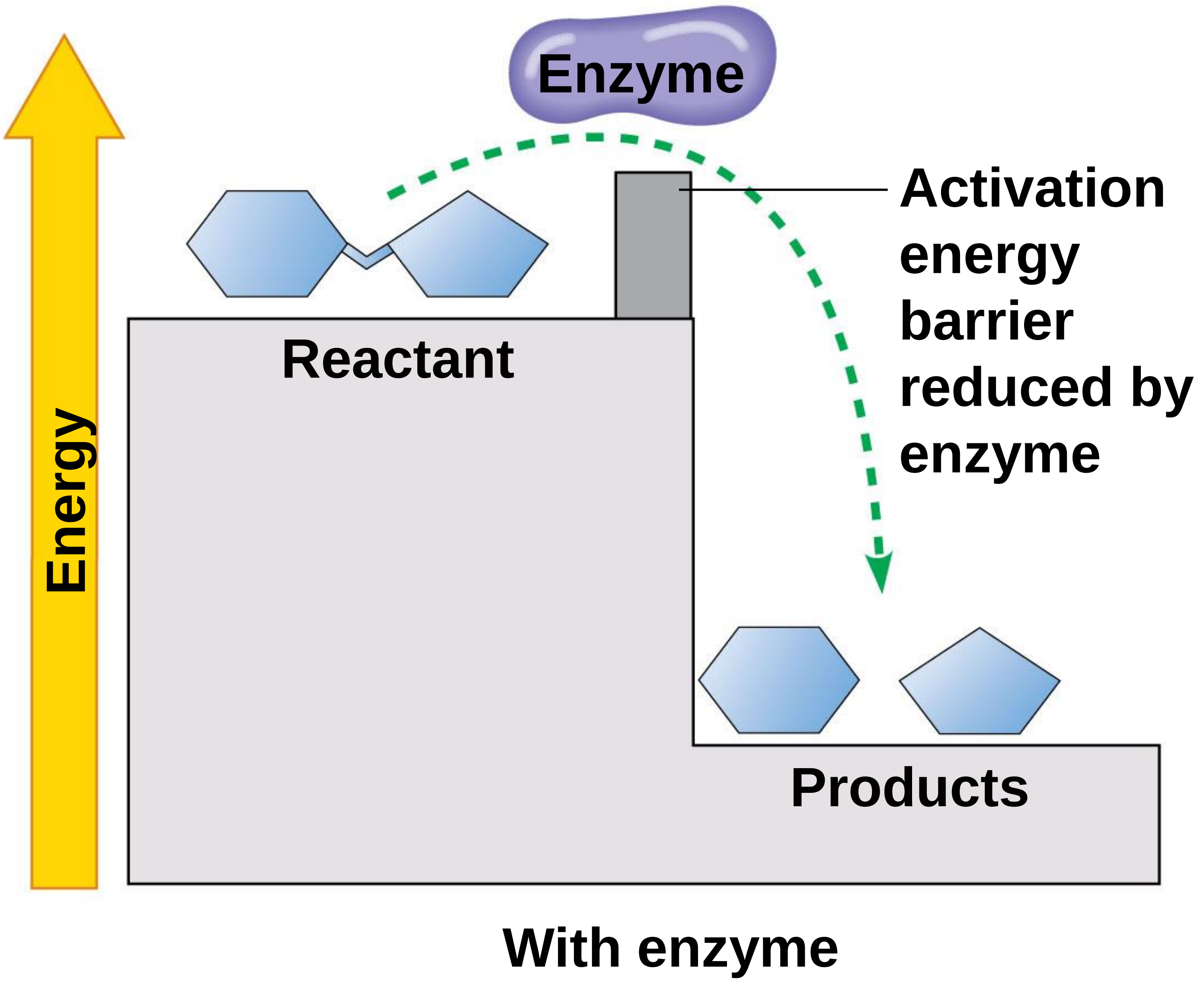
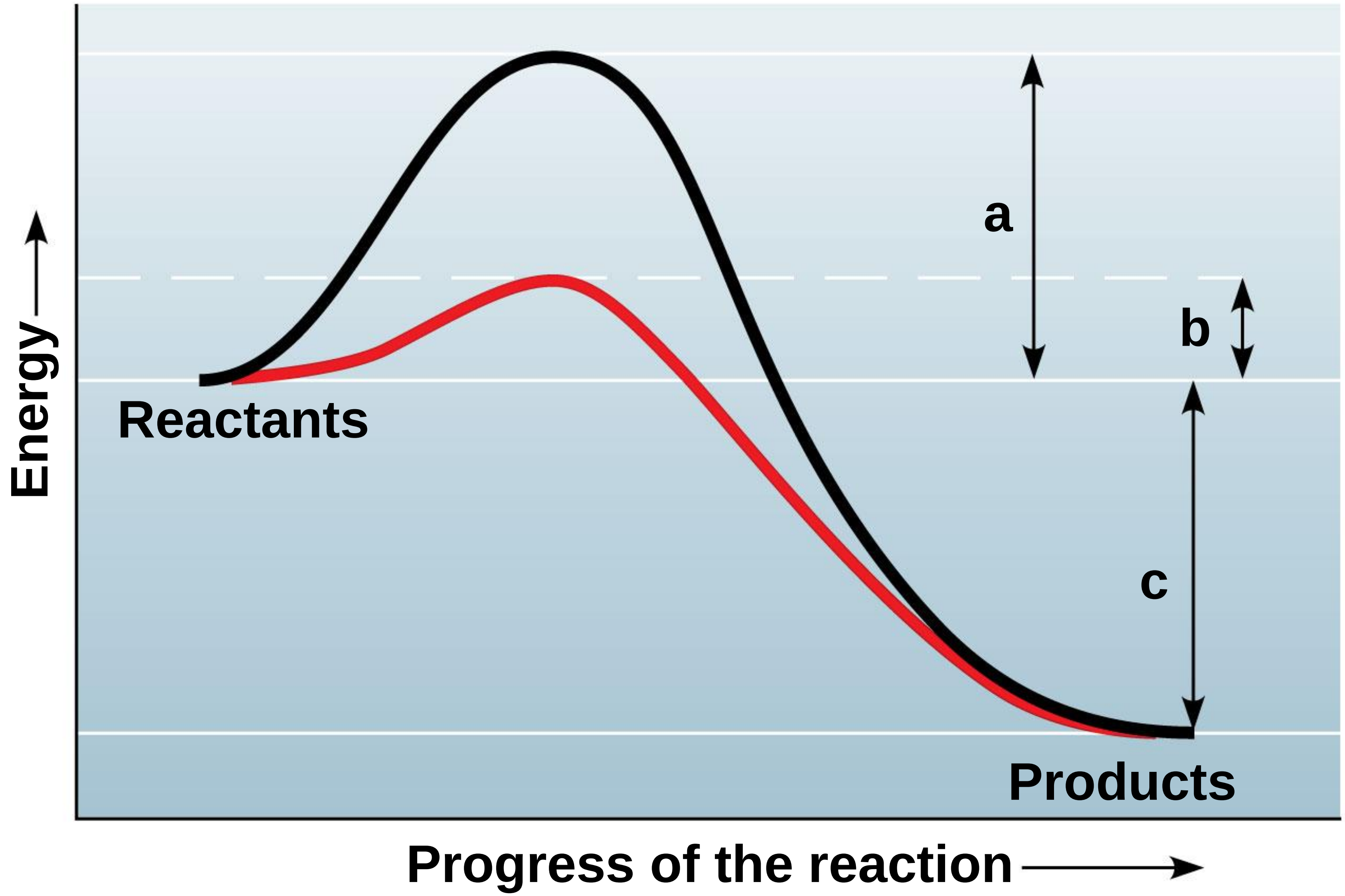


Figure 5.13Q



5.13 Enzymes speed up the cell's chemical reactions by lowering energy barriers

- Enzymes
  - a biological catalysts, lowers E_A
  - increase the rate of a reaction
  - Not consumed by the reaction, and
  - are usually proteins

PLAY Animation: How Enzymes Work

5.14 A specific enzyme catalyzes each cellular reaction

- An enzyme
  - is very selective in the reaction it catalyzes and
  - has a shape that determines the enzyme's specificity.
- Specific reactant - **substrate**.
- Substrate fits into the enzyme's **active site**.

Figure 5.14_s1

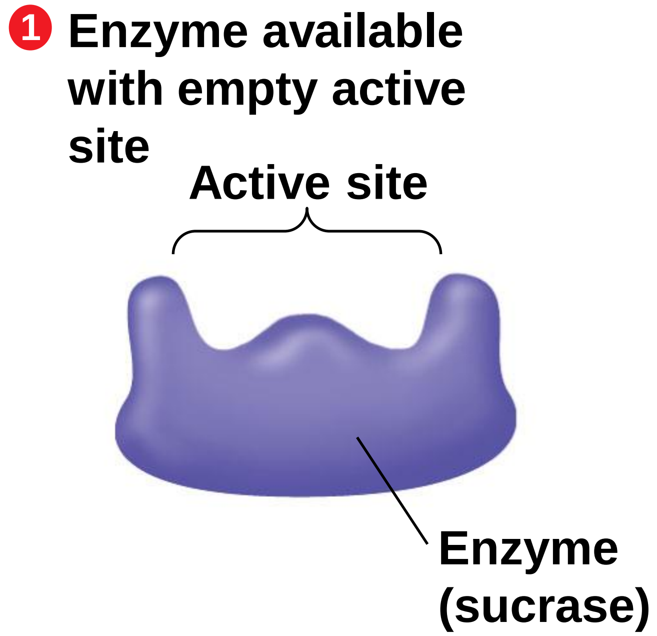


Figure 5.14_s2

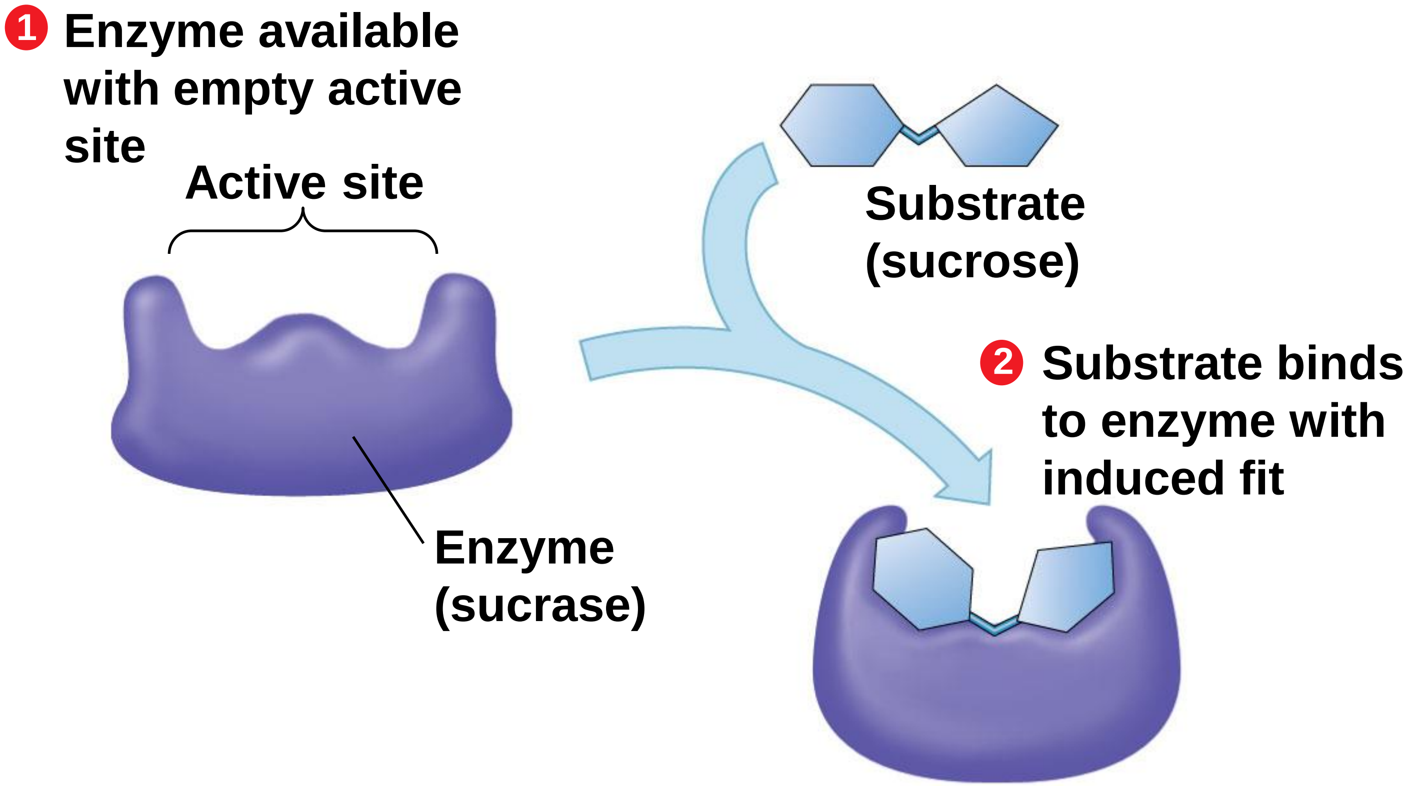


Figure 5.14_s3

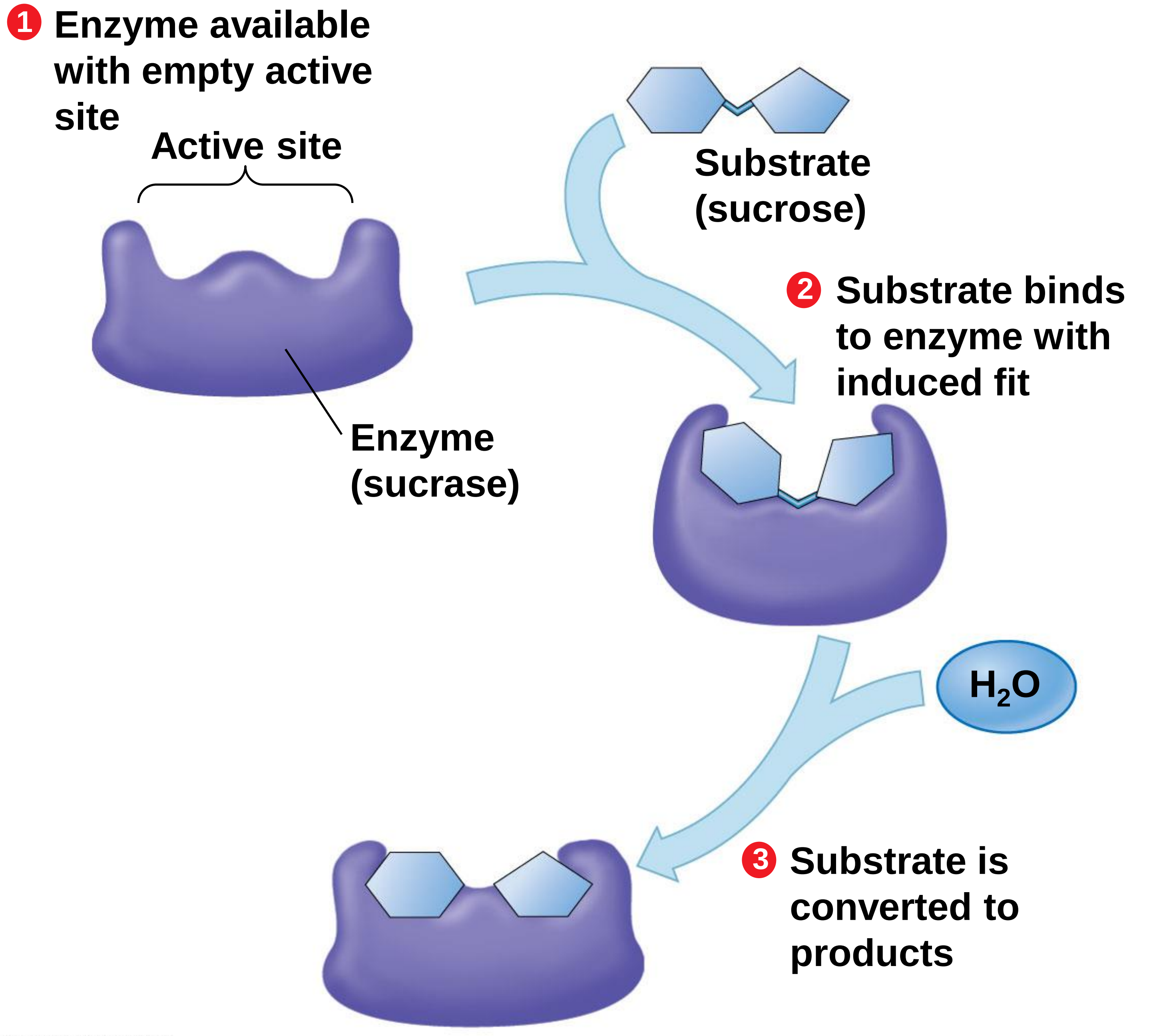
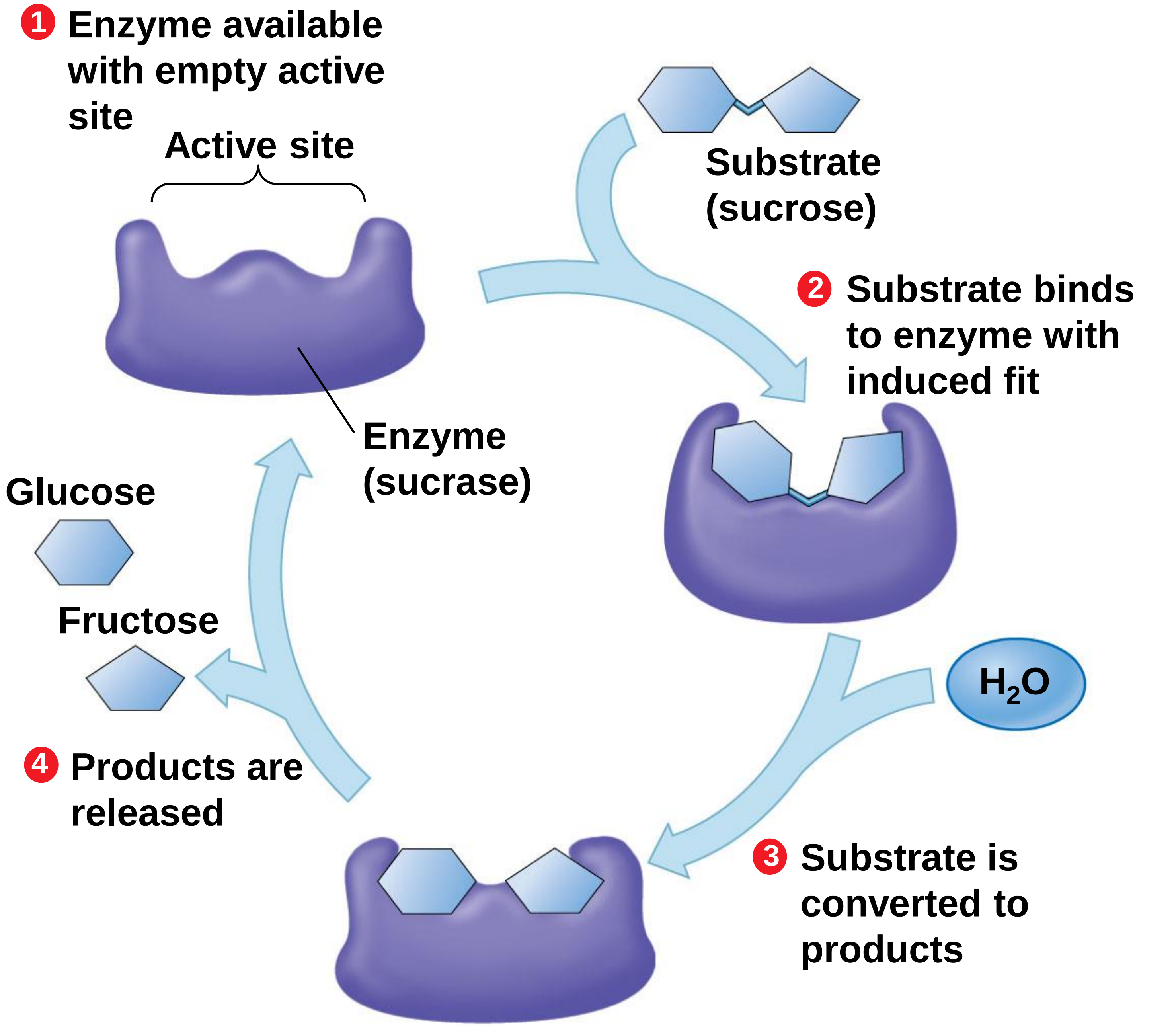


Figure 5.14_s4



5.14 A specific enzyme catalyzes each cellular reaction

- Optimal conditions for enzymes.
- Temperature Ex. Most human enzymes work best at 35–40ºC.
- pH - most enzymes near neutrality.

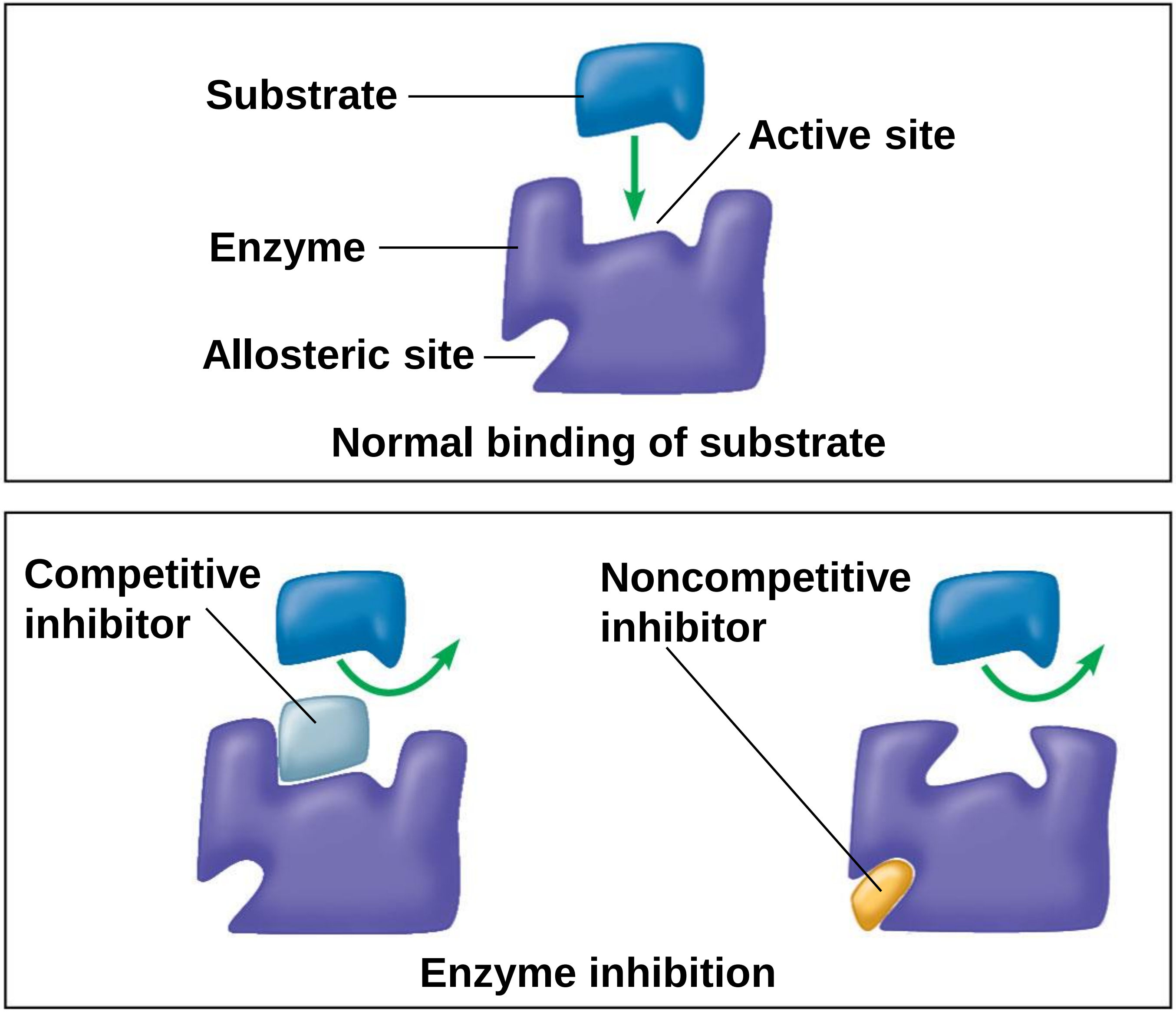
5.14 A specific enzyme catalyzes each cellular reaction

- **Cofactors-** nonprotein helpers, which
  - bind to the active site and
  - function in catalysis.
  - Can be inorganic, such as zinc, iron, or copper.
    - If organic, such as most vitamins, it is called a **coenzyme**.

5.15 Enzyme inhibitors can regulate enzyme activity in a cell

- **Inhibitor** - A chemical that interferes with an enzyme's activity.
  - **Competitive inhibitors**
  - block substrates from entering the active site and
  - reduce an enzyme's productivity.
- **Noncompetitive inhibitors**
  - bind to the enzyme somewhere other than the active site,
  - change the shape of the active site, and
  - prevent the substrate from binding.

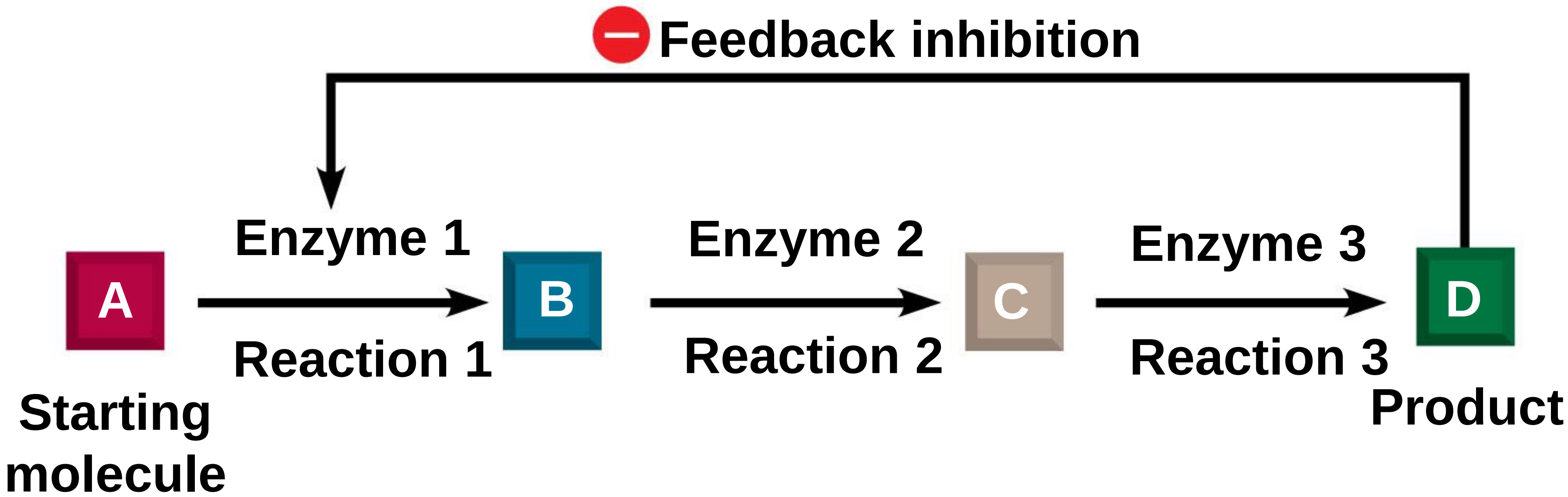
Figure 5.15A


Substrate
Active site
Enzyme
Allosteric site
Normal binding of substrate
Competitive inhibitor
Noncompetitive inhibitor
Enzyme inhibition

5.15 Enzyme inhibitors can regulate enzyme activity in a cell

- Enzyme inhibitors are important in regulating cell metabolism.
- **Feedback inhibition -** the product in some reactions may act as an inhibitor of one of the enzymes in the pathway that produced it.
  - Ibuprofen, inhibiting the production of prostaglandins,
  - some antidepressants,
  - many antibiotics, and
  - protease inhibitors used to fight HIV.

Figure 5.15B


Feedback inhibition
Enzyme 1
Enzyme 2
Enzyme 3
A
B
C
D
Reaction 1
Reaction 2
Reaction 3
Starting molecule
Product