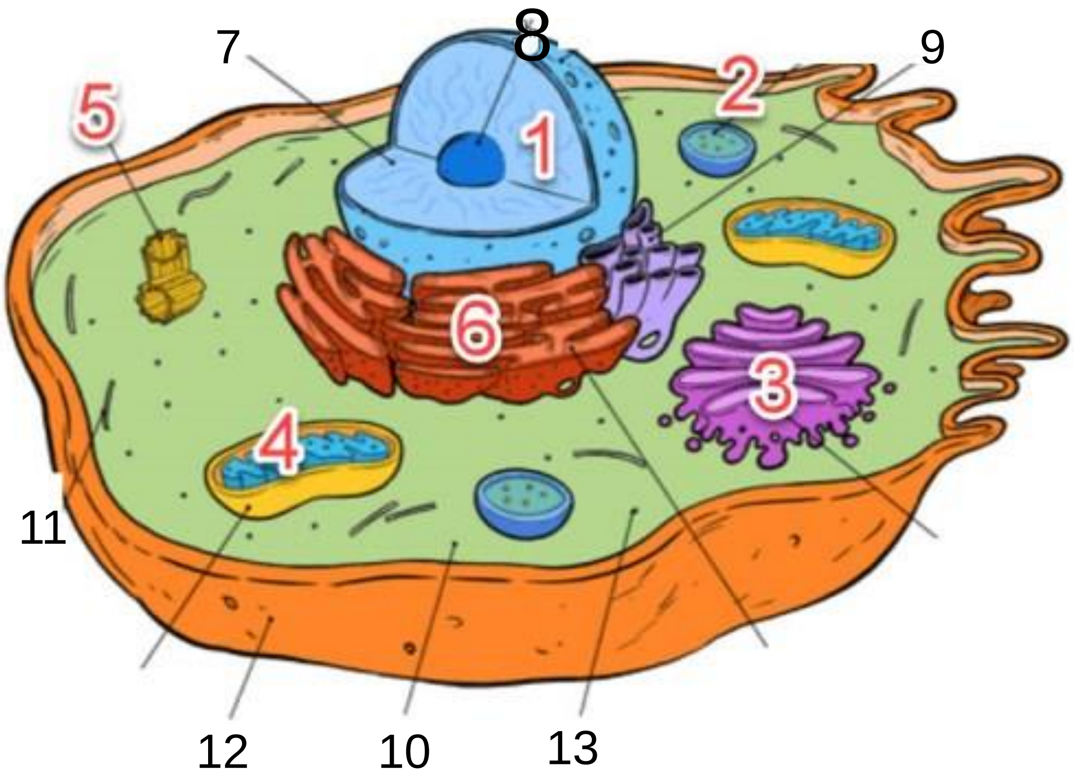
Go to the "Slide Show" shade above

Click on "Play from Beginning"

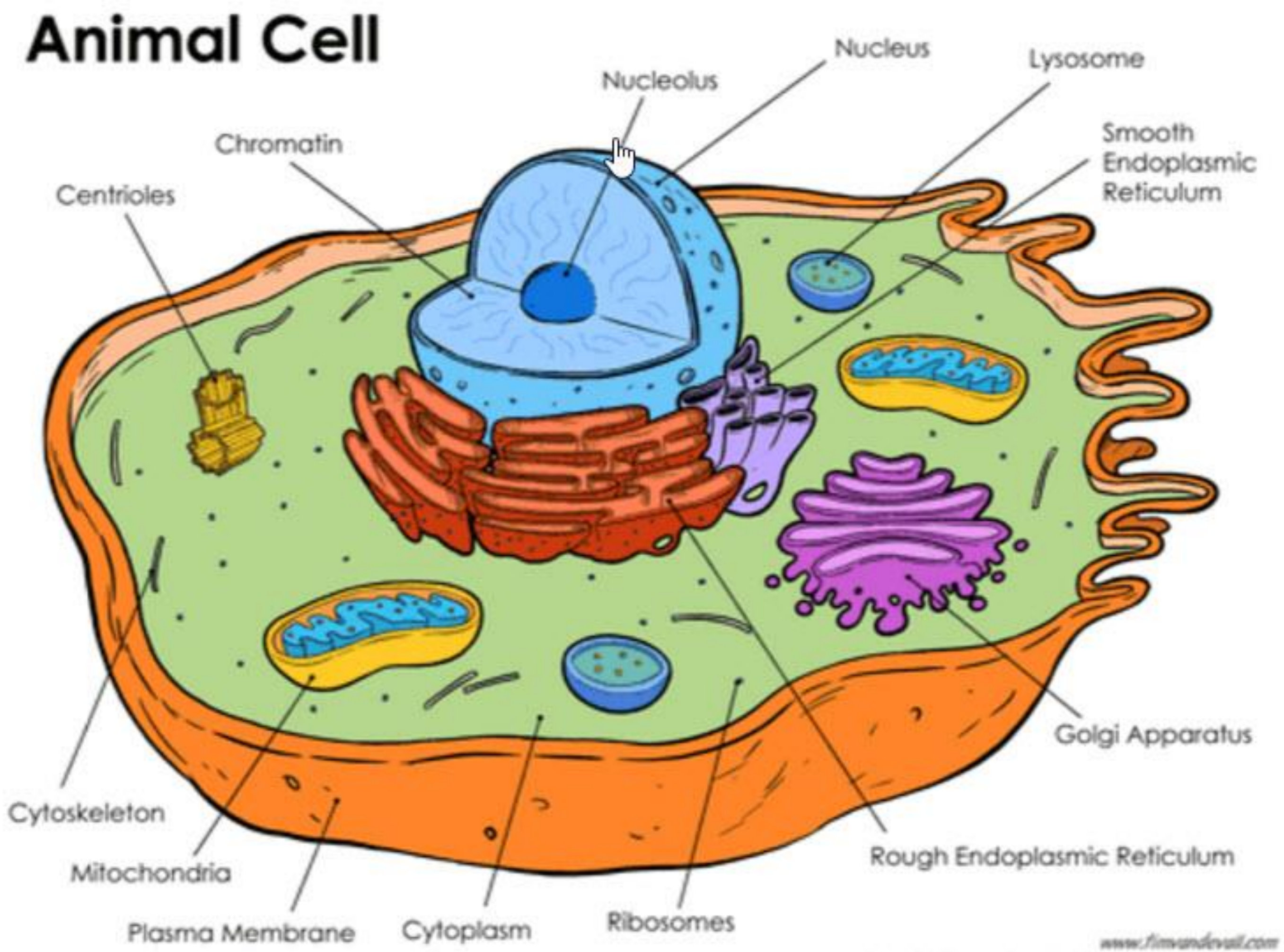
Metabolism Overview and Enzymes

Chapter 6

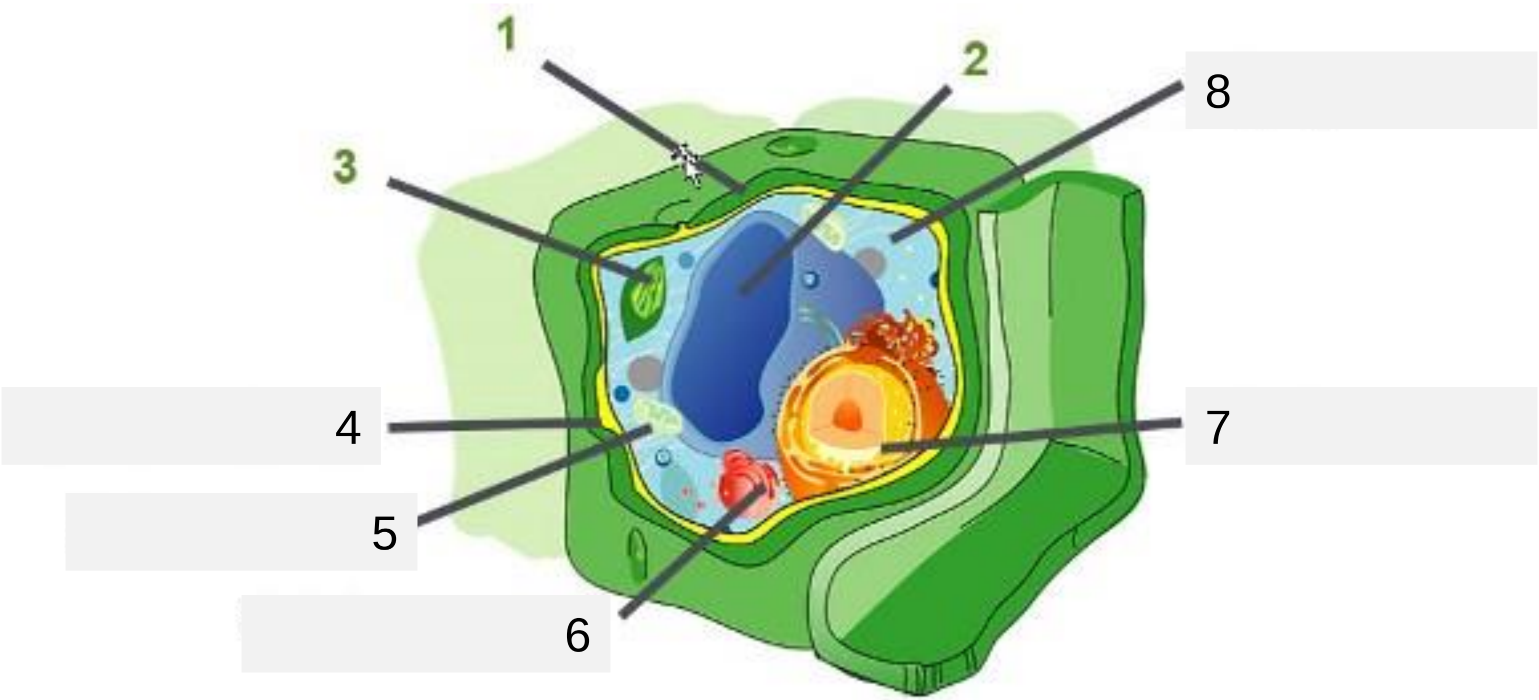
Label the Organelles (Animal or Plant?)



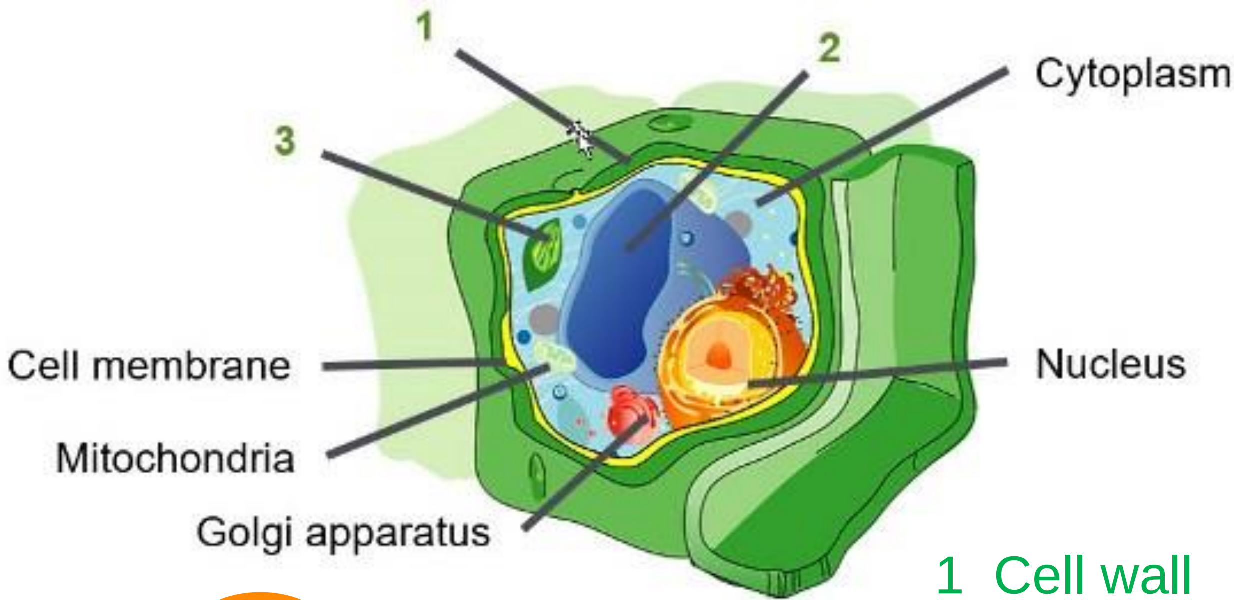
Label the Organelles



Label the Organelles & Name Differences between Plant and Animal Cells



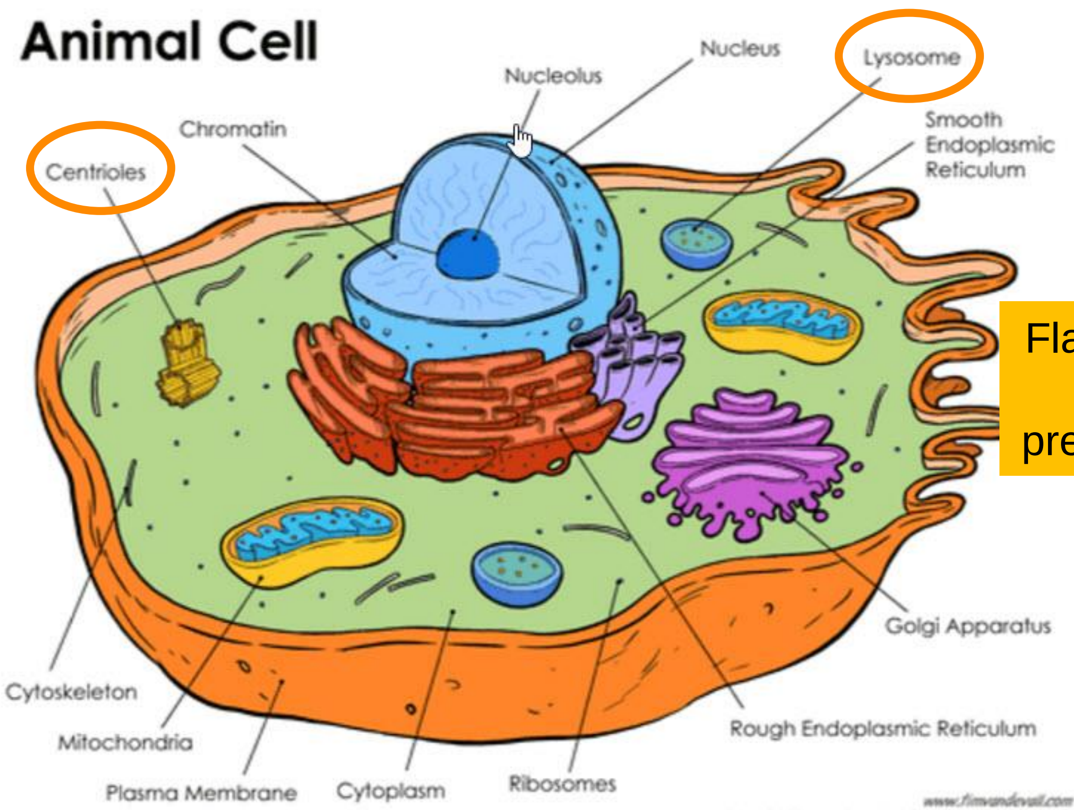
Organelles Differences



1 Cell wall

2 Large Central Vacuole

3 Chloroplast



Flagella (if present)

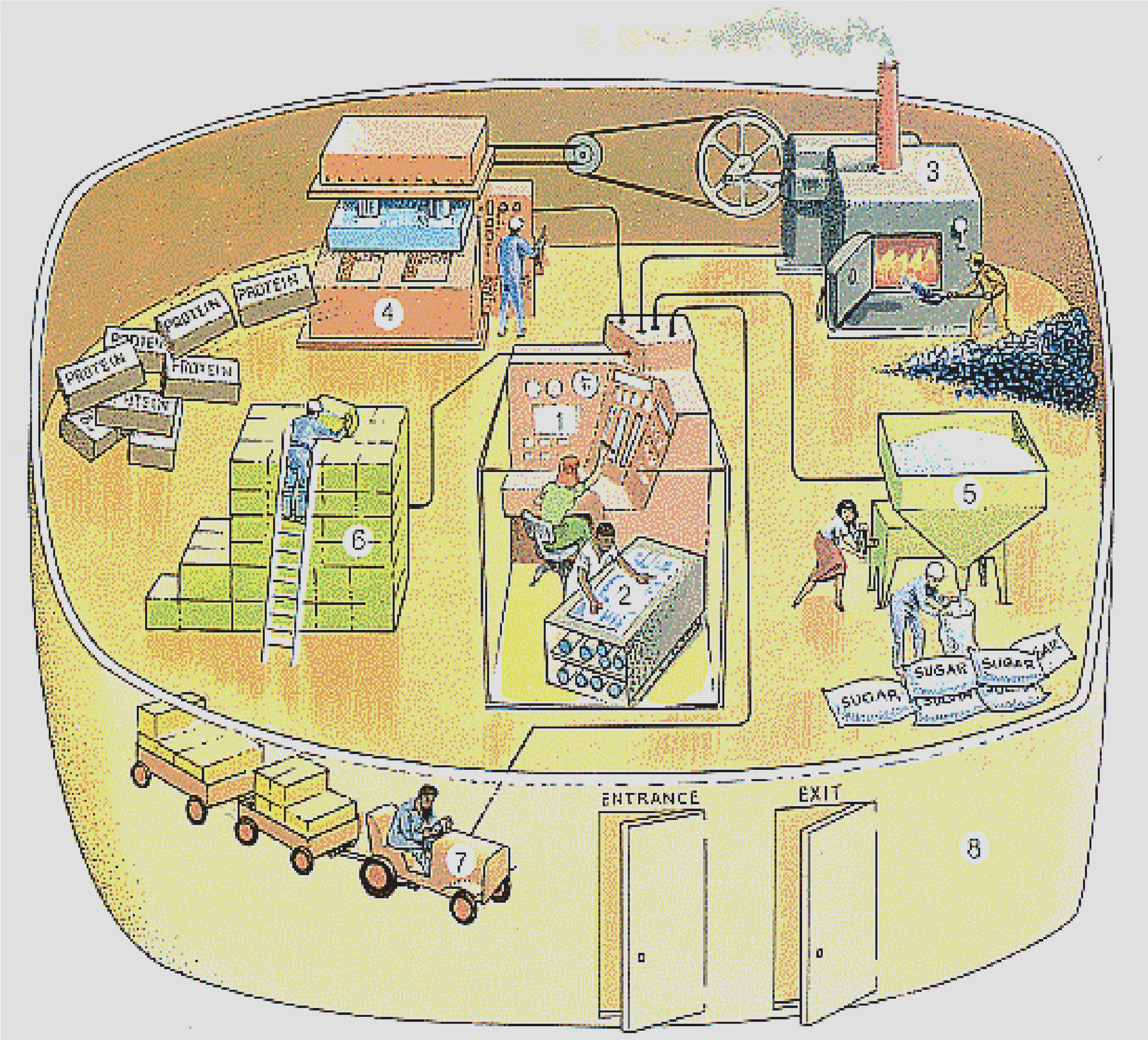
Lesson Objectives

By the end of this lesson, you should be able to:

- Define types of Metabolism.
- Investigate the structure and function of ATP.
- Investigate the properties and actions of Enzymes in living systems.
- **Science Practice:** Enzymes in Pineapple

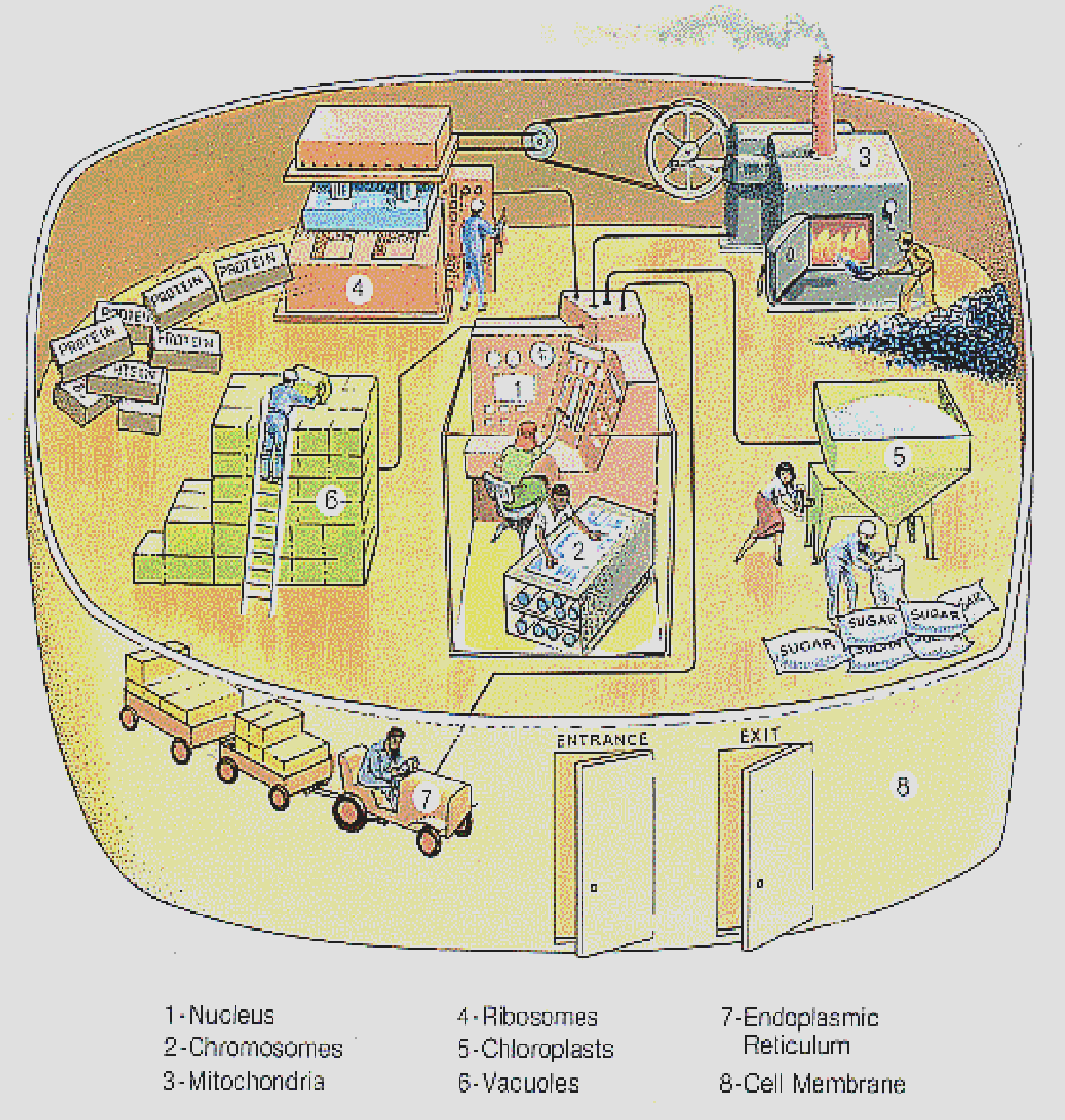
Cells Transform Energy As They Perform Work

- *Picture a cell with its organelles as a manufacturing plant.*
- **What organelles would take on the functions shown in the diagram?**



Cells Transform **Energy** As They Perform **Work**

- Cells are miniature chemical factories, housing thousands of chemical reactions.
- Some of these chemical reactions **release energy**, and others **require energy.**



Energy

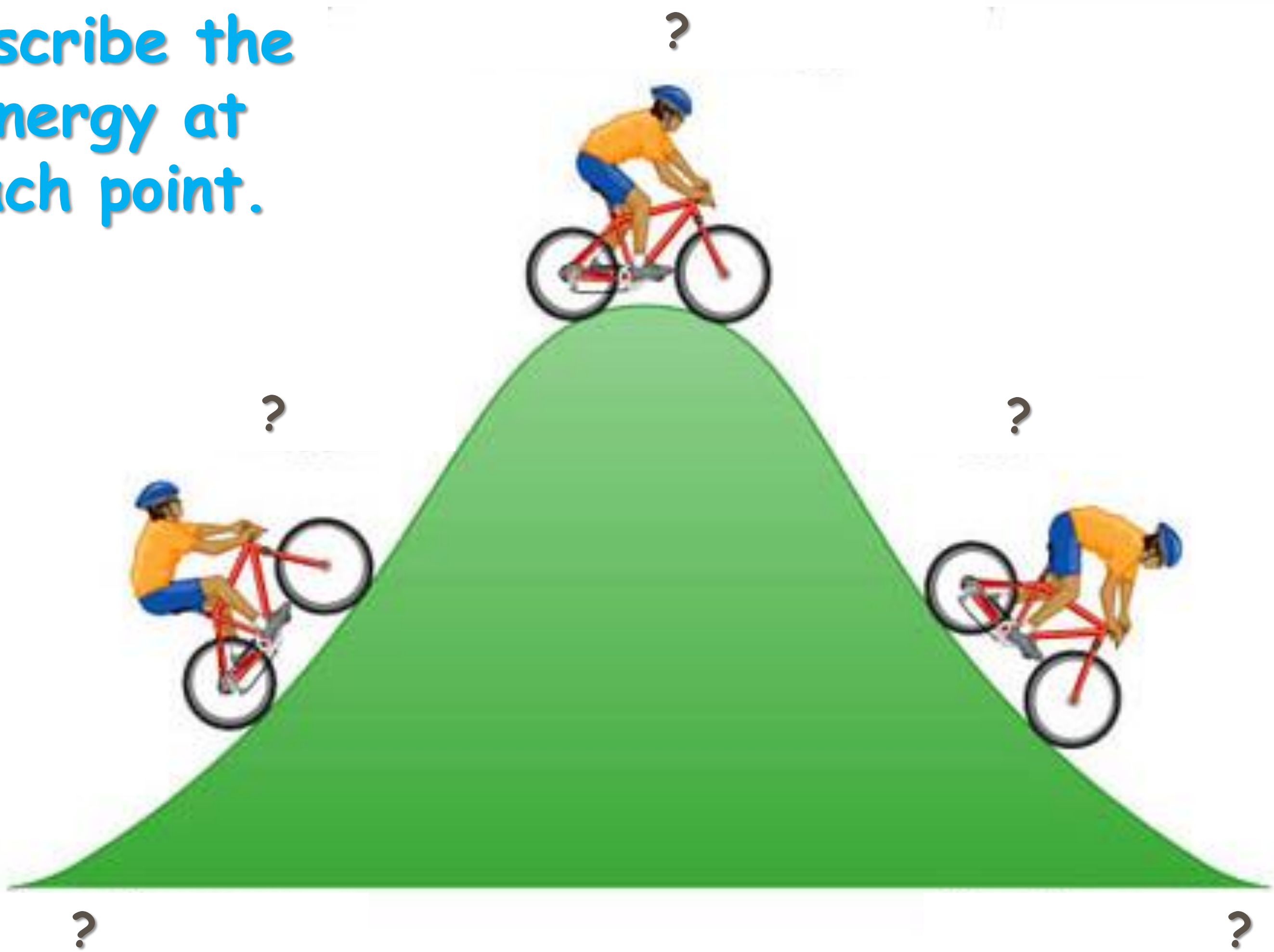
- **Ability to do Work** or **to cause Change.**
- **Two General Types of Energy that exist in all forms of energy:**

  1. **Kinetic energy** is the energy of **motion**
  2. **Potential energy** is **stored** energy that matter possesses as a result of its location or structure.

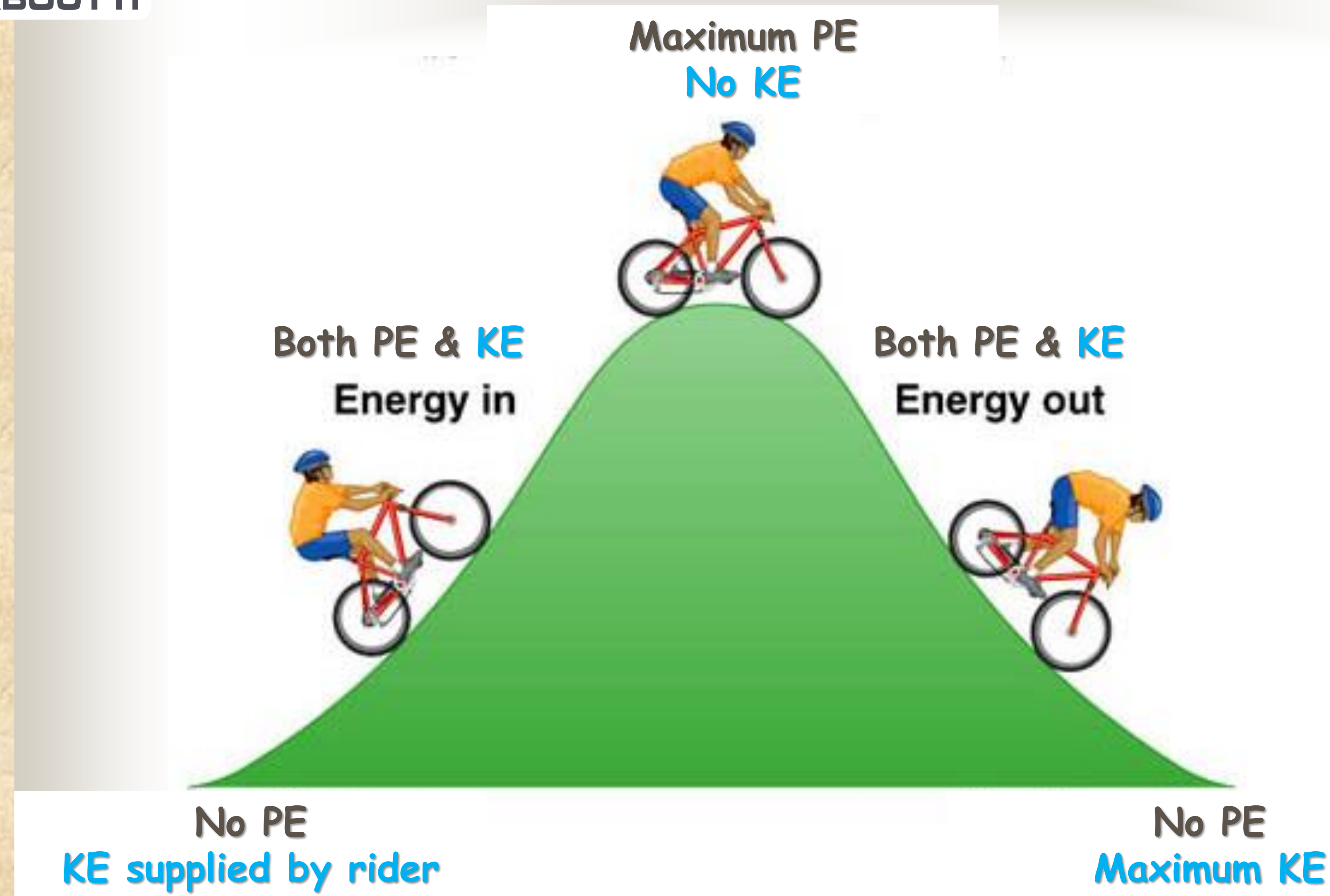
- Energy can be converted from one form to another.

Potential & Kinetic Energy

Describe the energy at each point.



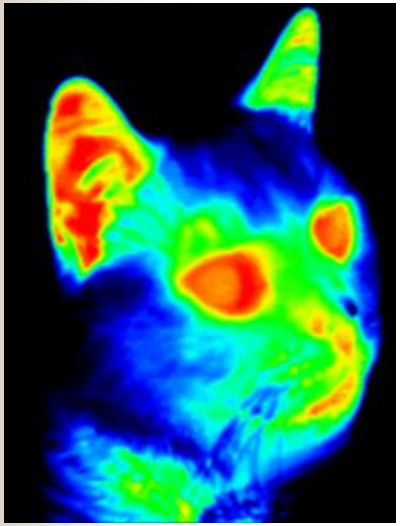
Potential & Kinetic Energy



Kinetic Energy

- Energy of **Motion** or Active Energy.
- **Work being done.**
- **Thermal Energy**

  - Type of kinetic energy associated with **Heat.**
  - Deals with the **amount of matter** and the **random movement of atoms or molecules.**



  - **Heat flows** (transfers thermal energy) from **warmer** to **cooler** (thus, KE).

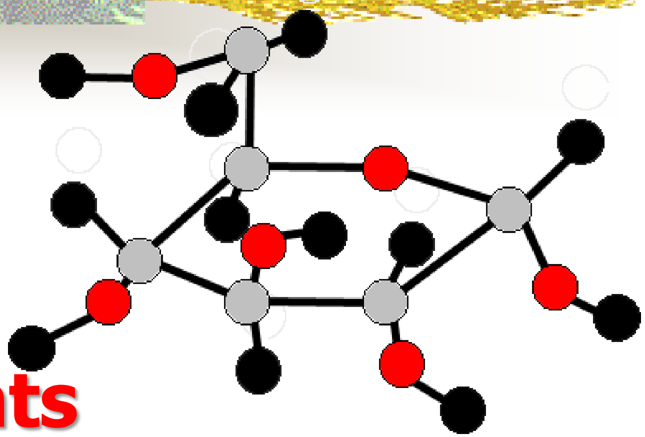
Kinetic Energy

Radiant (Light) Energy

- The kinetic energy of photons or waves of light.
- Light energy is absorbed to power photosynthesis.

- Converted into other forms of energy.
- Stored in chemical bonds (PE).

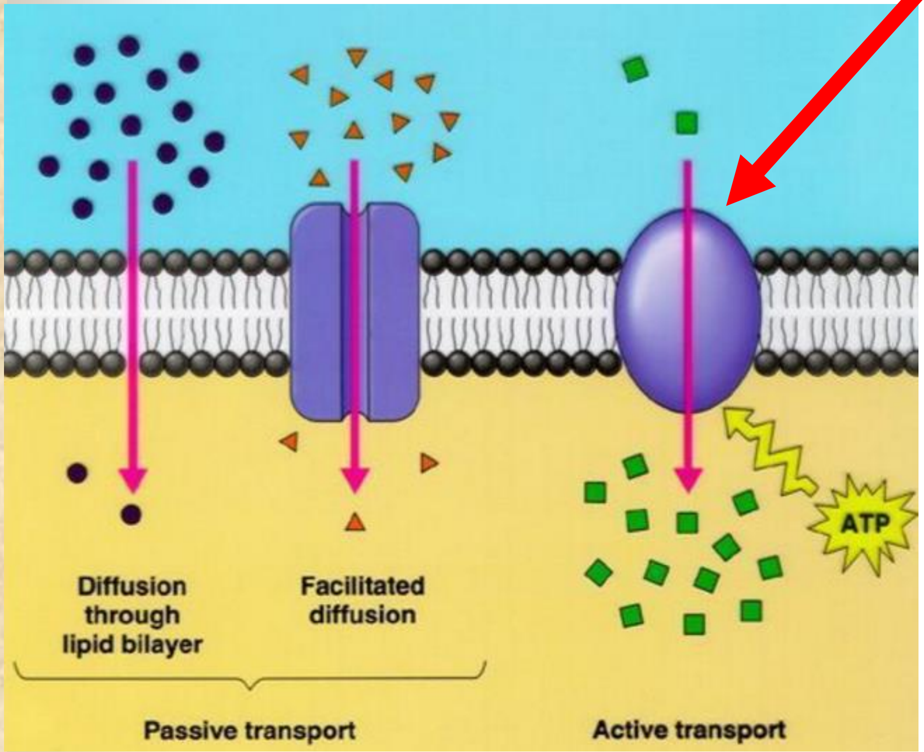
Potential Energy



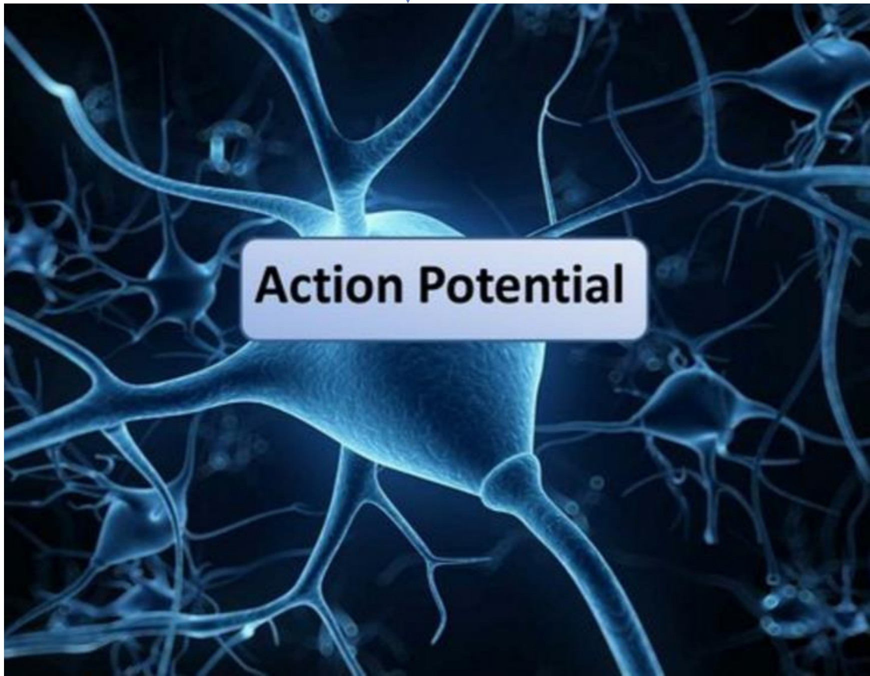
- **Stored** Energy
  - **In chemical bonds**
  - **In concentration gradients**
  - In electric potential (cell membrane)
- **Chemical Energy**
  - Form of potential energy available for release in all chemical reactions .
  - The most important type of energy for living organisms to power the work of the cell.

Potential Energy

In concentration gradients

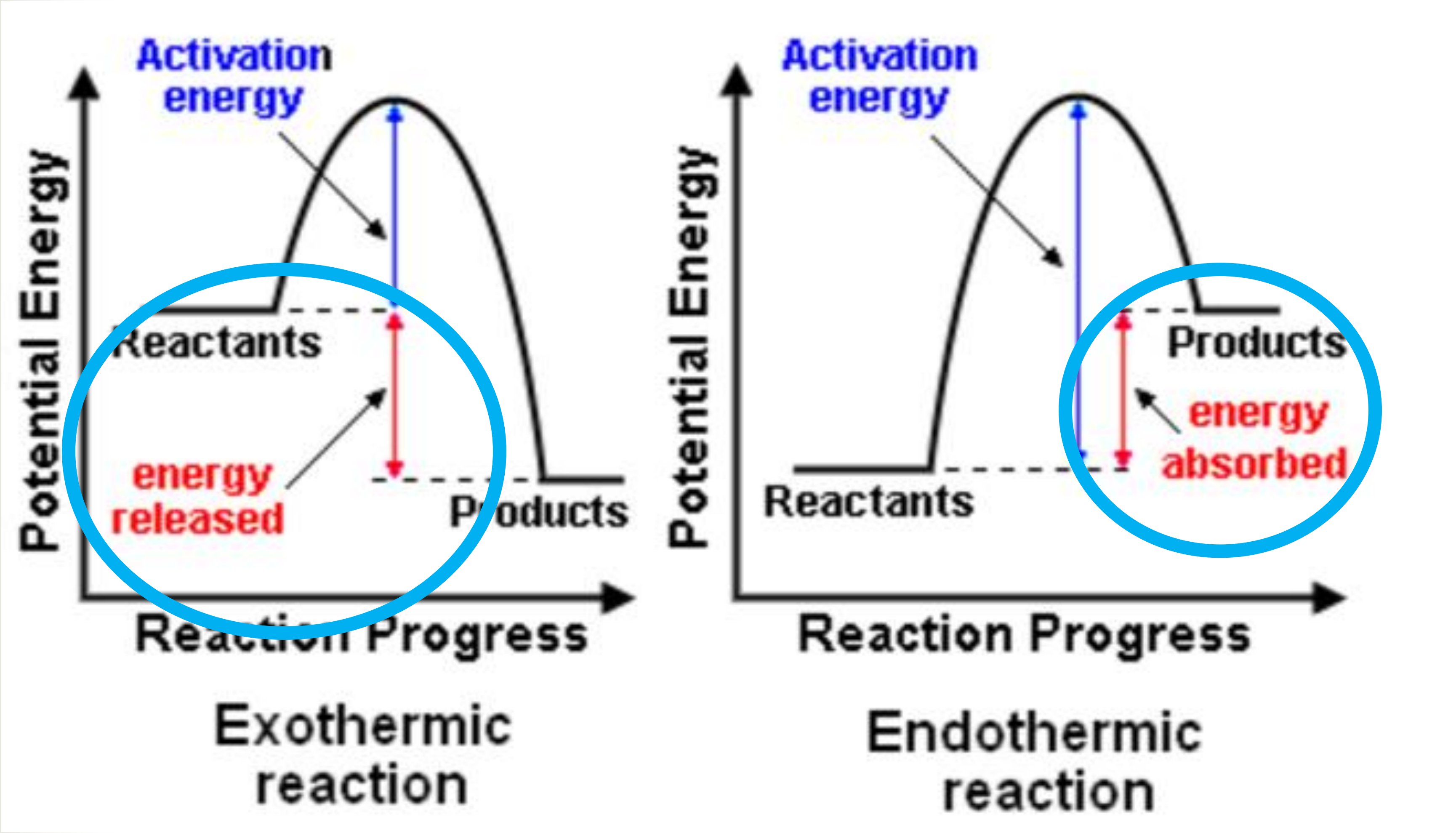


In electric potential (cell membrane)



Potential Energy

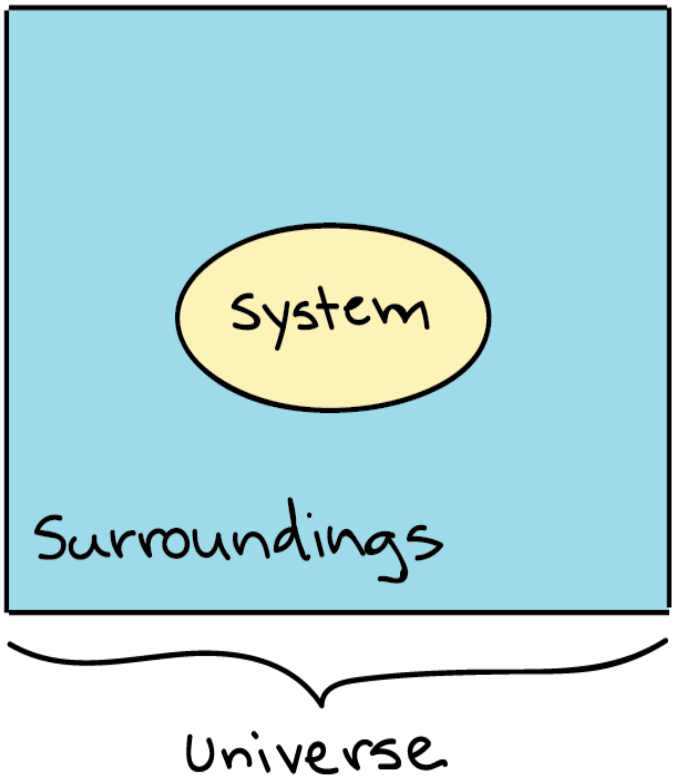
In chemical bonds



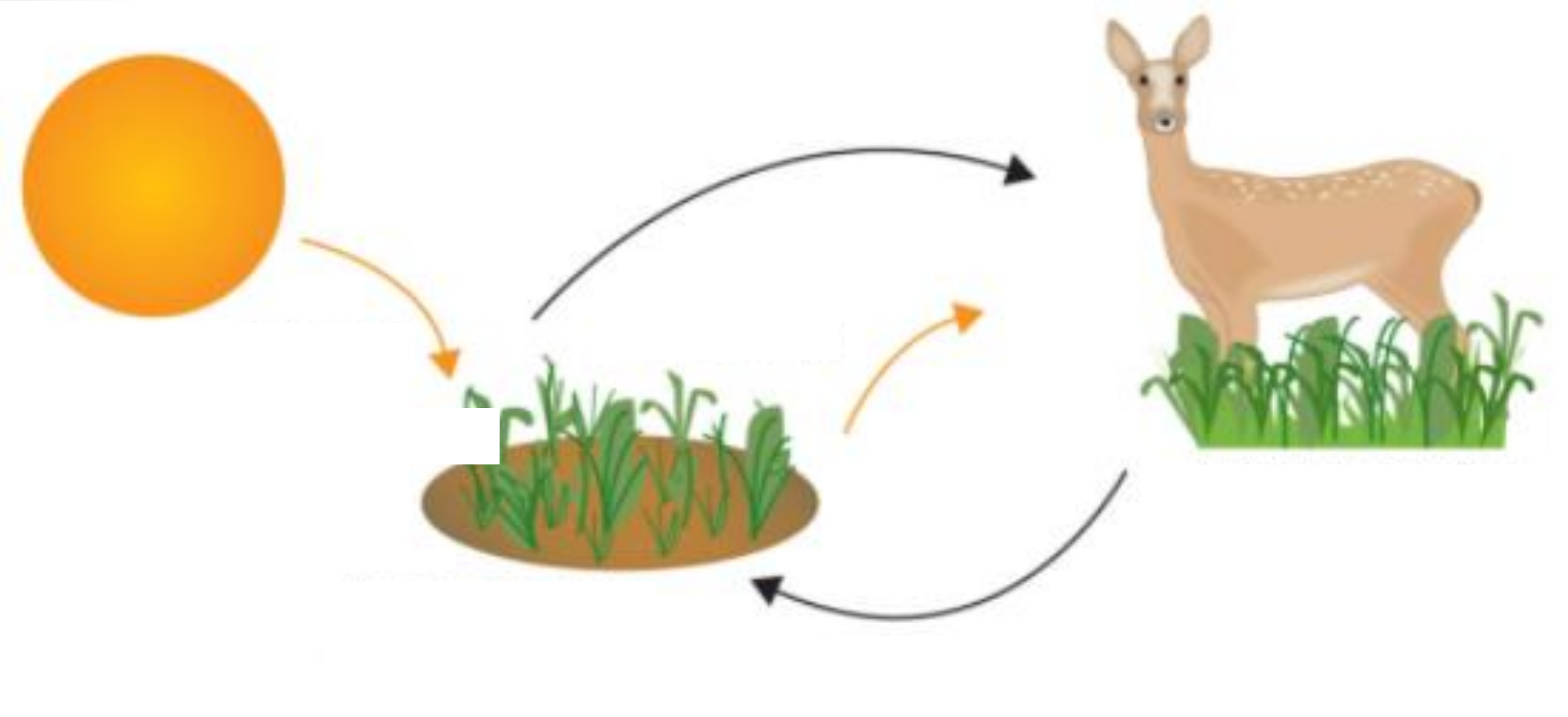
Thermodynamics

The study of **energy transformations** that occur in and between living organisms.

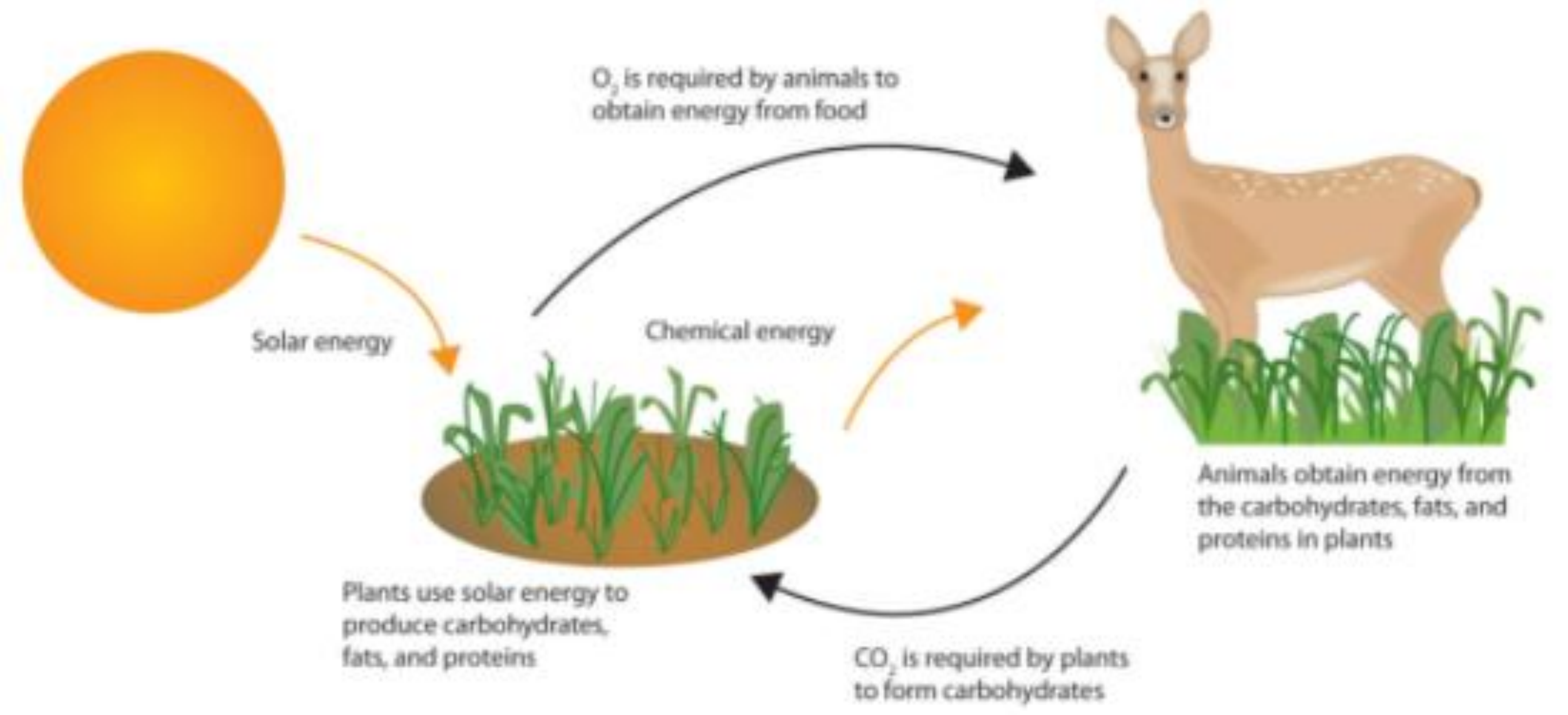
- The word ***system*** is used for the matter under study.
- The word ***surroundings*** is used for everything outside the system; the rest of the universe.



The **LAWS OF THERMODYNAMICS** govern energy transformations in organisms.

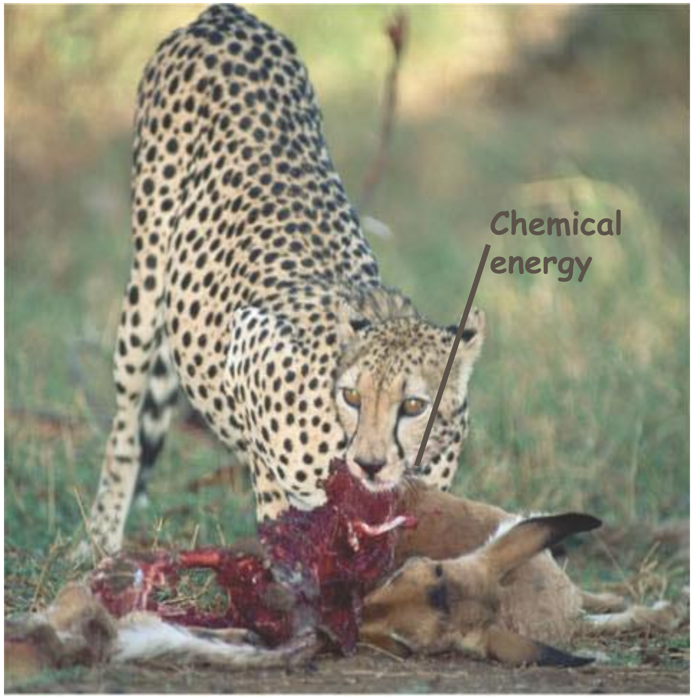


The **LAWS OF THERMODYNAMICS** govern energy transformations in organisms.



First Law of Thermodynamics

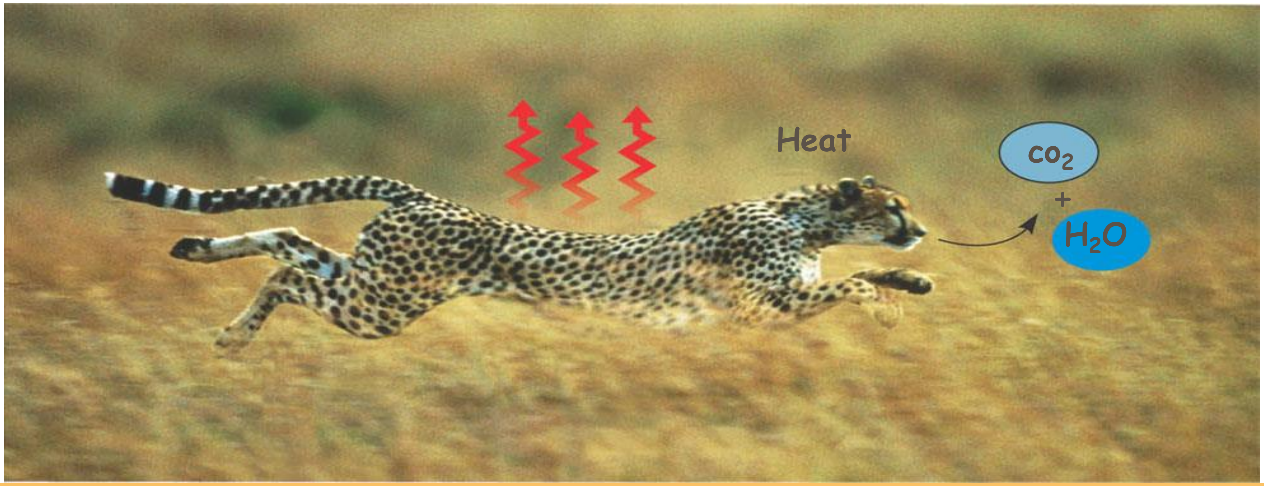
- **Law of Energy Conservation.**
- **Energy can be transferred and transformed.**
- **Energy cannot be created or destroyed.**



Food (PE) will be converted to KE in the Cheetah's movement.

Second Law of Thermodynamics

- **Energy conversions increase the disorder of the universe.**
- **ENTROPY: measure of disorder**



The larger molecules in the Cheetah's cells are broken down by cellular respiration (metabolism) and released into the atmosphere as smaller molecules (this increases disorder).

Endergonic & Exergonic Reactions

Endergonic

Photosynthesis is carried out by plants, algae, and some bacteria.

Exergonic

Cellular respiration is carried out by **ALL** living organisms.

Photos by Walter Simmons and Shane Gorski

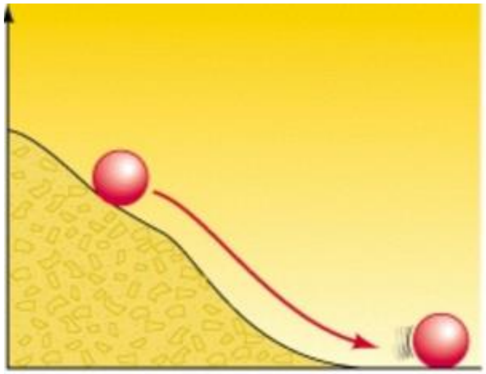
Types of Chemical Reactions:

1) Exergonic Reactions

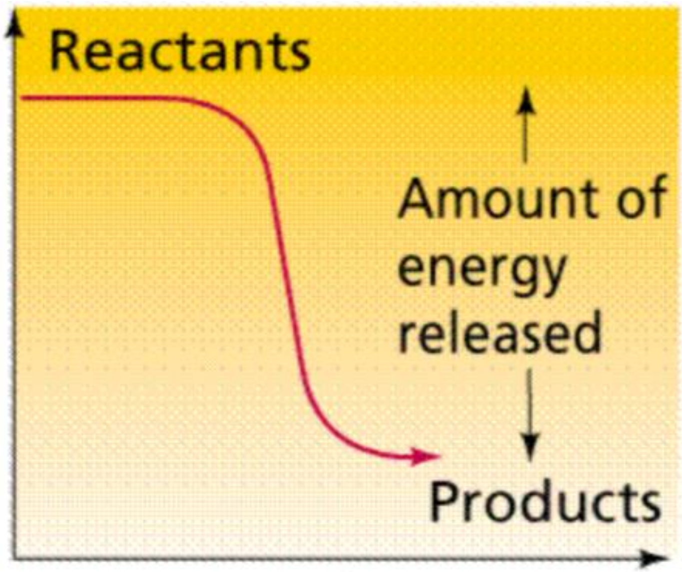
- **RELEASE ENERGY in the form of heat** to the surroundings (*exothermic*).
- Releases the energy stored in the covalent bonds of the **reactants.**
- Burning wood releases the energy in glucose as heat & light.
- **Cellular Respiration**

Types of Chemical Reactions:

1) Exergonic Reactions



- **"DownHill" Reaction**
- Energy of the **reactants** is greater than the energy of the products.

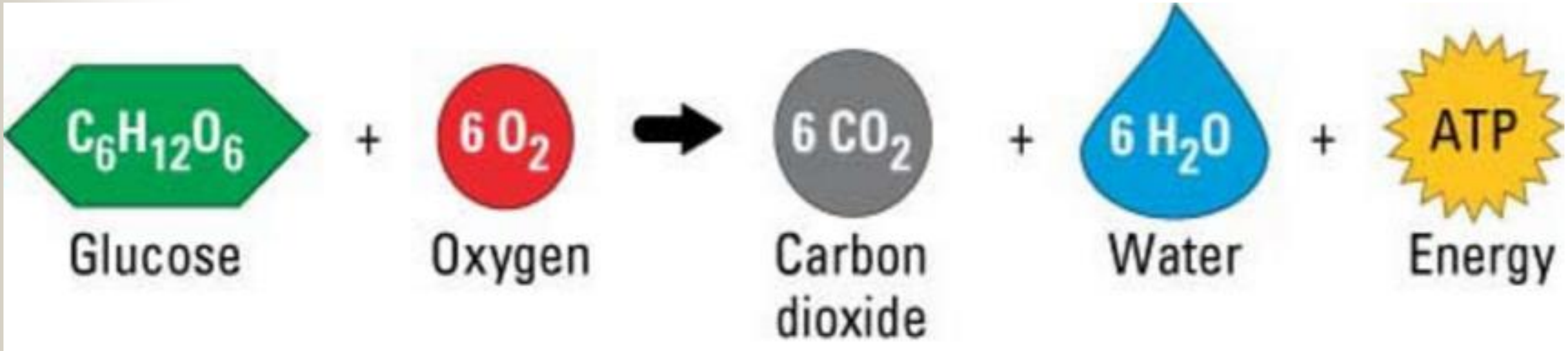


Types of Chemical Reactions:

1) **Exergonic Reactions**

Cellular Respiration

- involves many steps.
- releases energy slowly.
- uses some of the released energy to produce ATP.

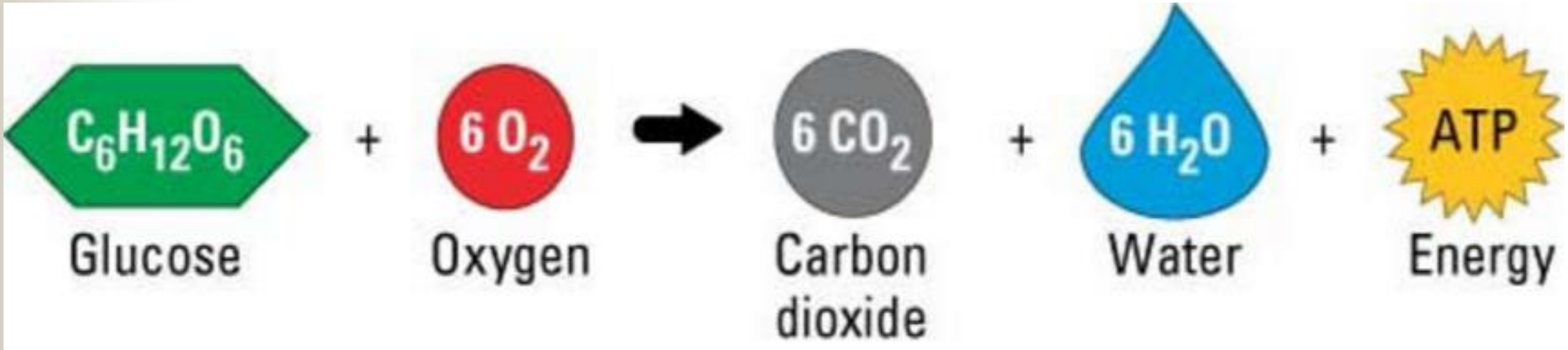


Types of Chemical Reactions:

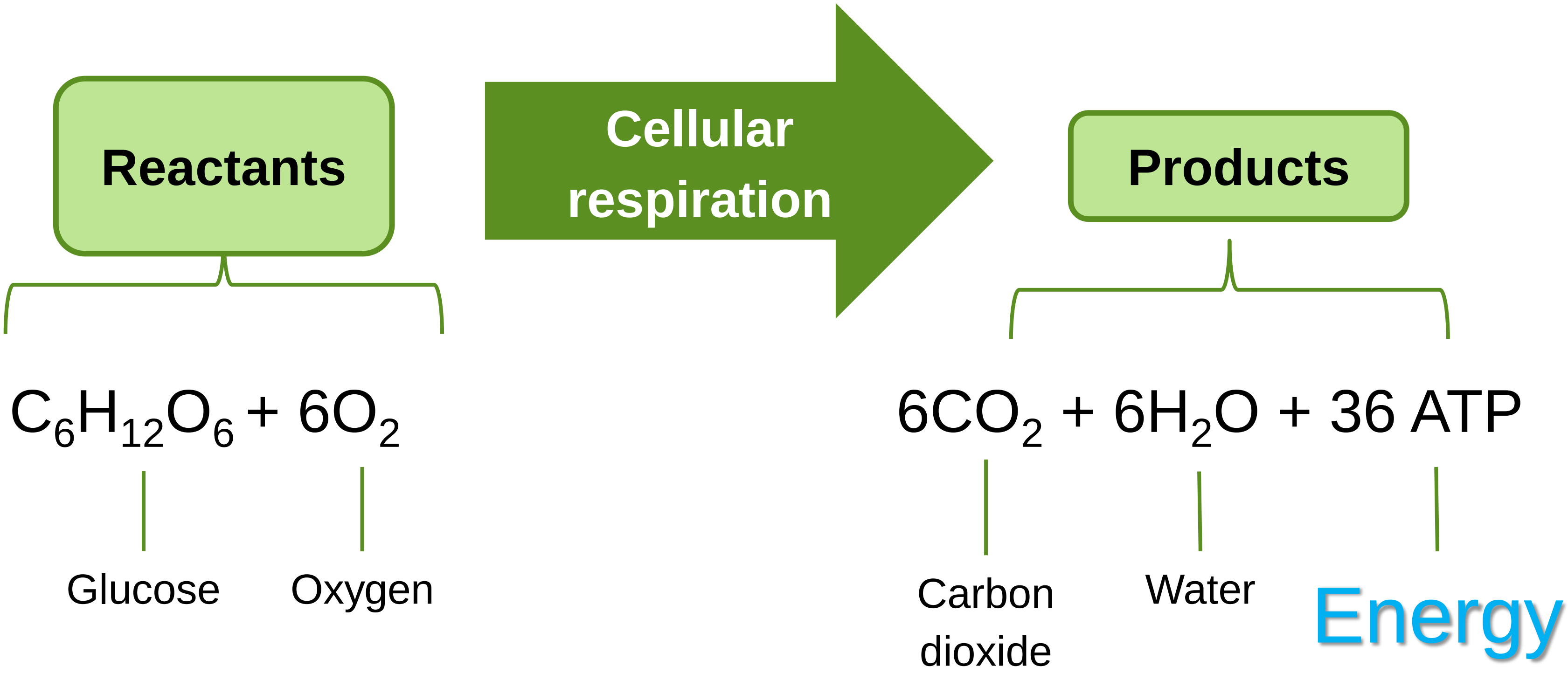
1) Exergonic Reactions

Cellular Respiration

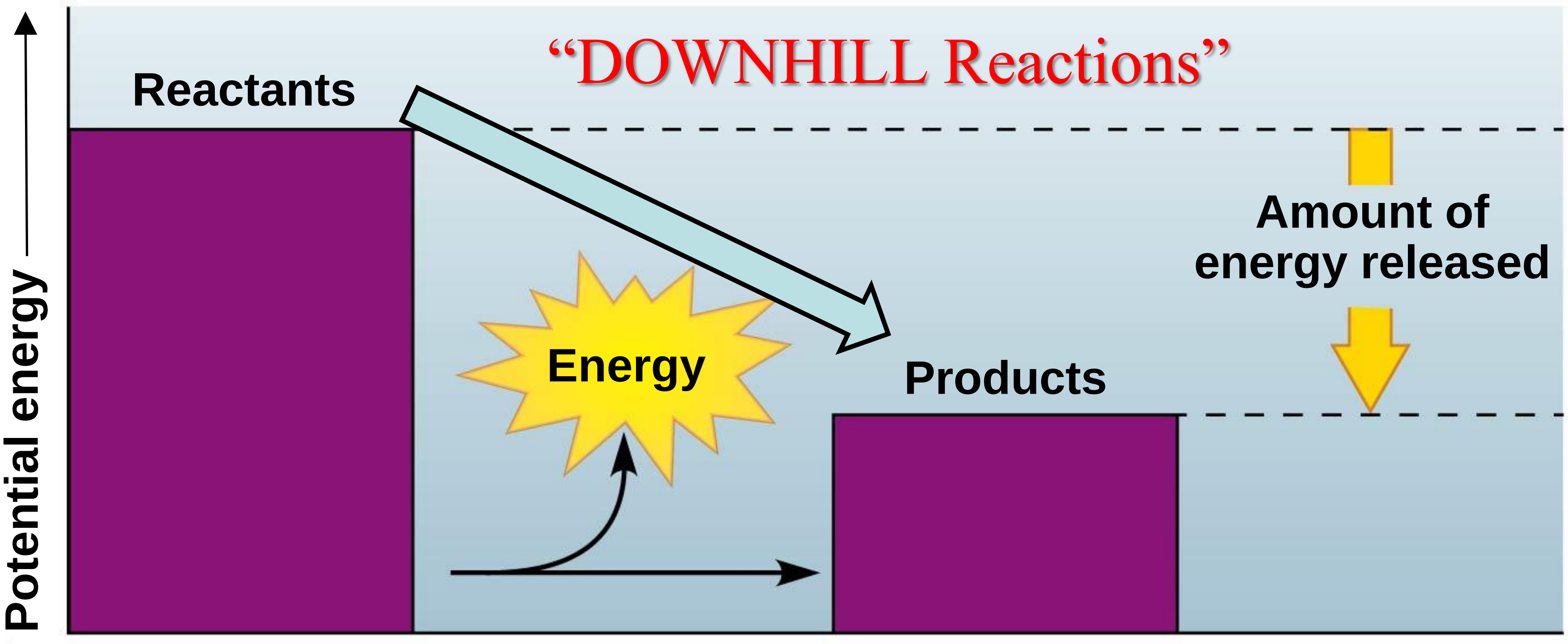
- Occurs in both plants and animal cells (and all living organisms).



Exergonic Reaction: Cellular Respiration

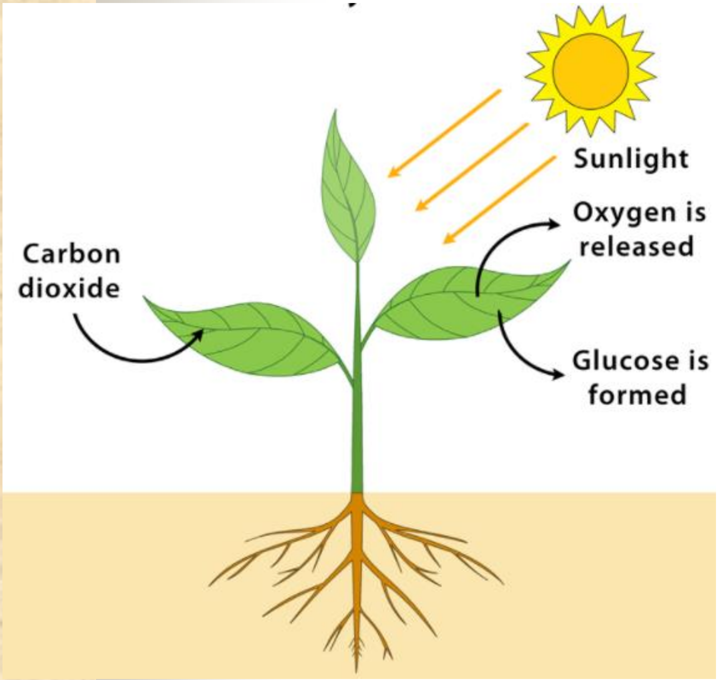


1) Exergonic Reactions: Cellular Respiration



Types of Chemical Reactions:

2) Endergonic Reactions

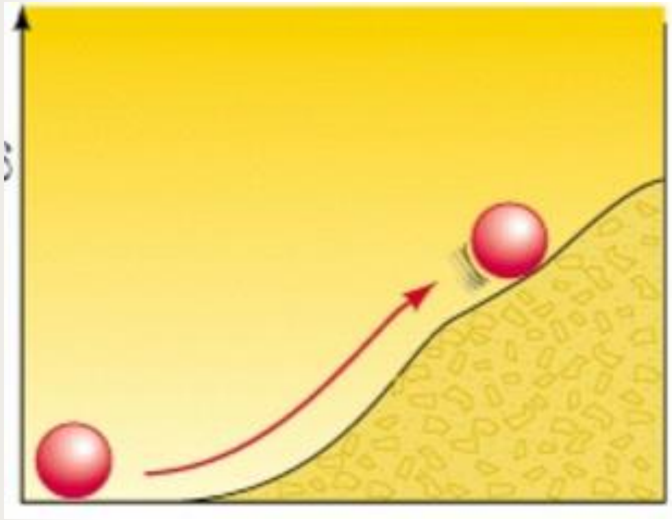


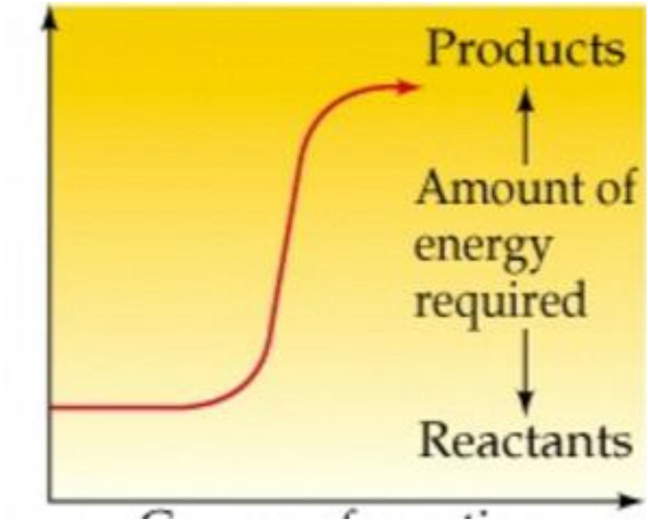
- **Absorb ENERGY** from the surroundings (*endothermic*).
- Yield products rich in potential energy.
- Start with reactant molecules that contain relatively little potential energy.
- End with **products** that contain more chemical energy.

Types of Chemical Reactions:

2) Endergonic Reactions

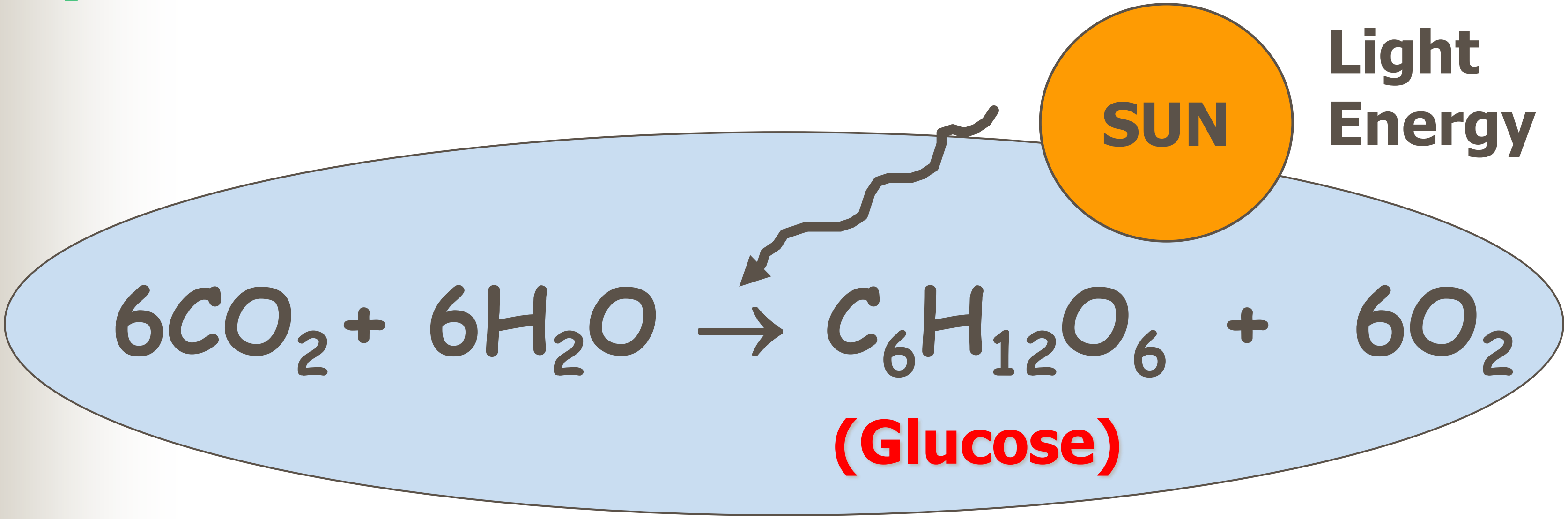
- "UPHill" Reaction
- Energy of the **products** is greater than the energy of the reactants.





Photosynthesis

- Uses energy-poor reactants (carbon dioxide & water).
- Energy is absorbed from sunlight.
- **Energy-rich sugar molecules are produced.**

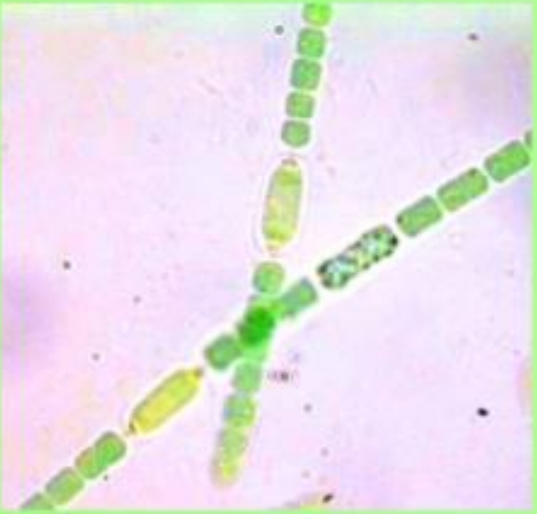


$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

(Glucose)

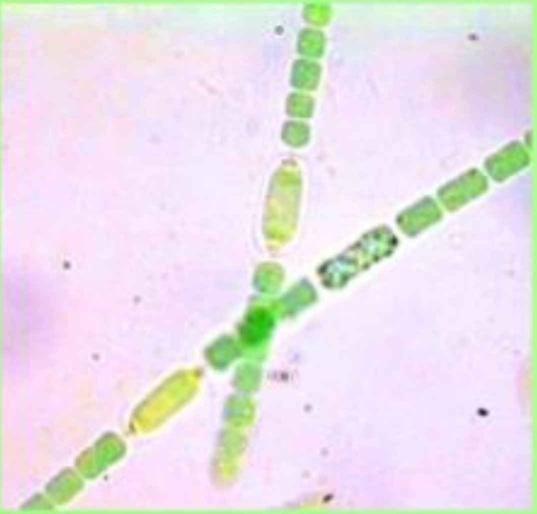
Photosynthesis

- Plants



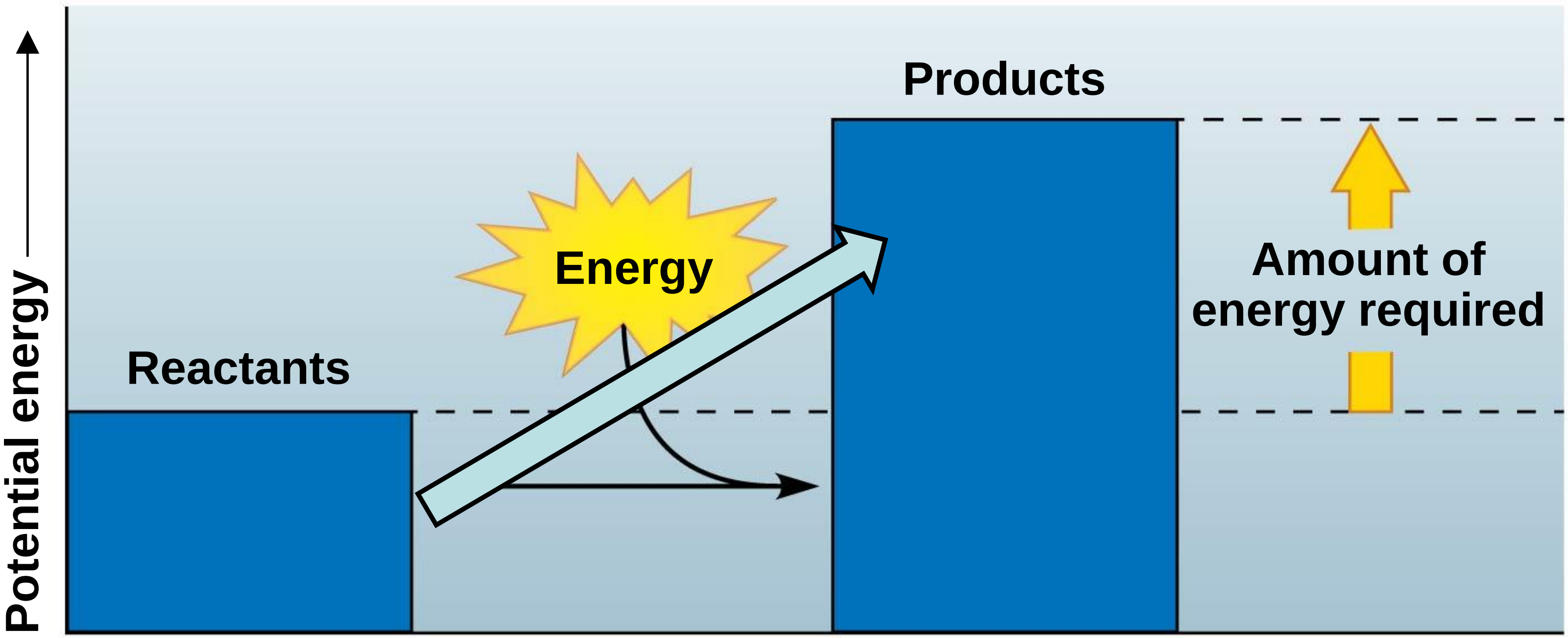
Photosynthesis

- Plants
- Some protists
  - Algae, Euglena
- Some bacteria
  - Cyanobacteria, Purple sulfur bacteria



- Because they make their own "food" they are called **autotrophs**

2) Endergonic Reactions: Photosynthesis



“UPHILL Reactions”

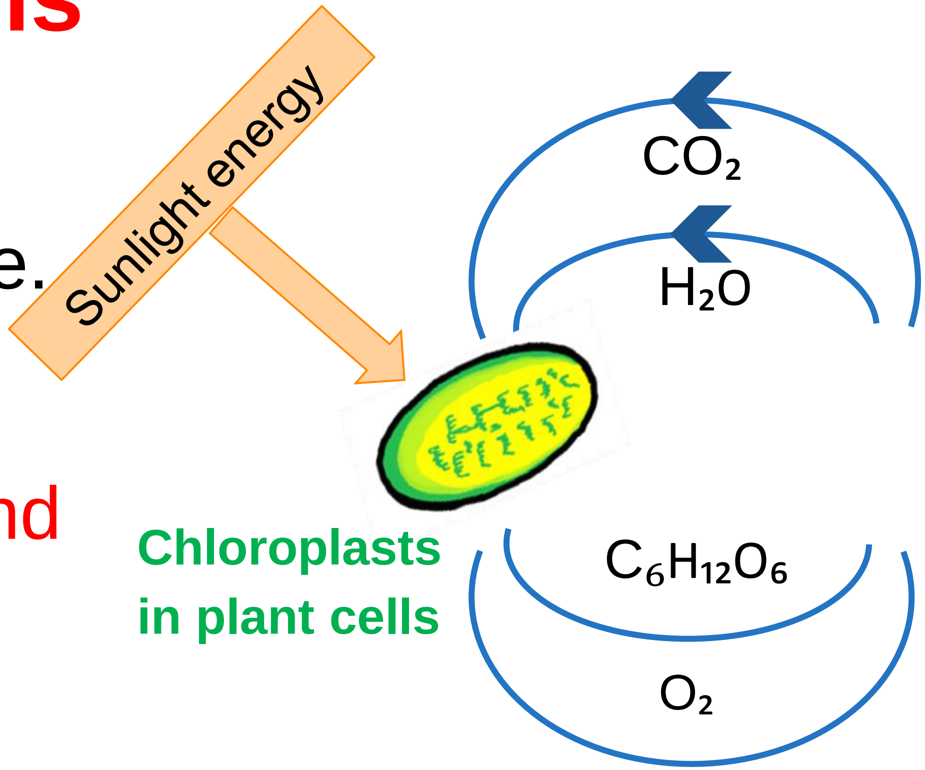
Chemical Reactions:

- A living organism carries out thousands of **endergonic** and **exergonic** chemical reactions.
- The total of an organism's chemical reactions is called **METABOLISM.**
- A **metabolic pathway** is a series of chemical reactions that either …
  - **builds** a complex molecule or
  - **breaks down** a complex molecule into simpler compounds.

Energy Is Cyclic

Photosynthesis

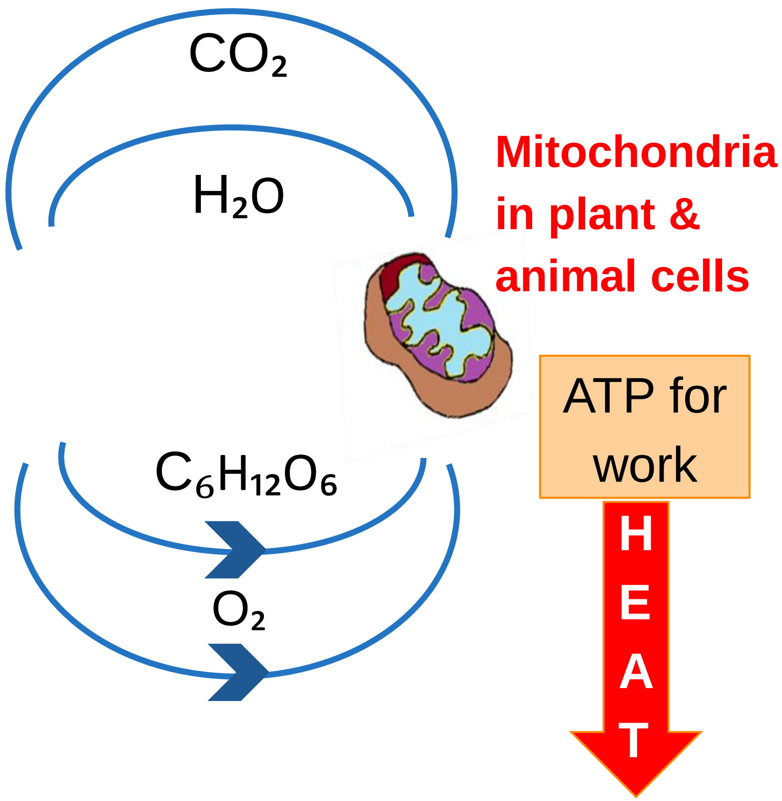
- Uses sunlight as the energy source.
- Chloroplast uses carbon dioxide and water.
- Produces sugar and oxygen.



Energy Is Cyclic

Cellular respiration

- Mitochondrion uses energy from sugars and other organic molecules.
- **Produces carbon dioxide and water.**
- **Releases energy.**



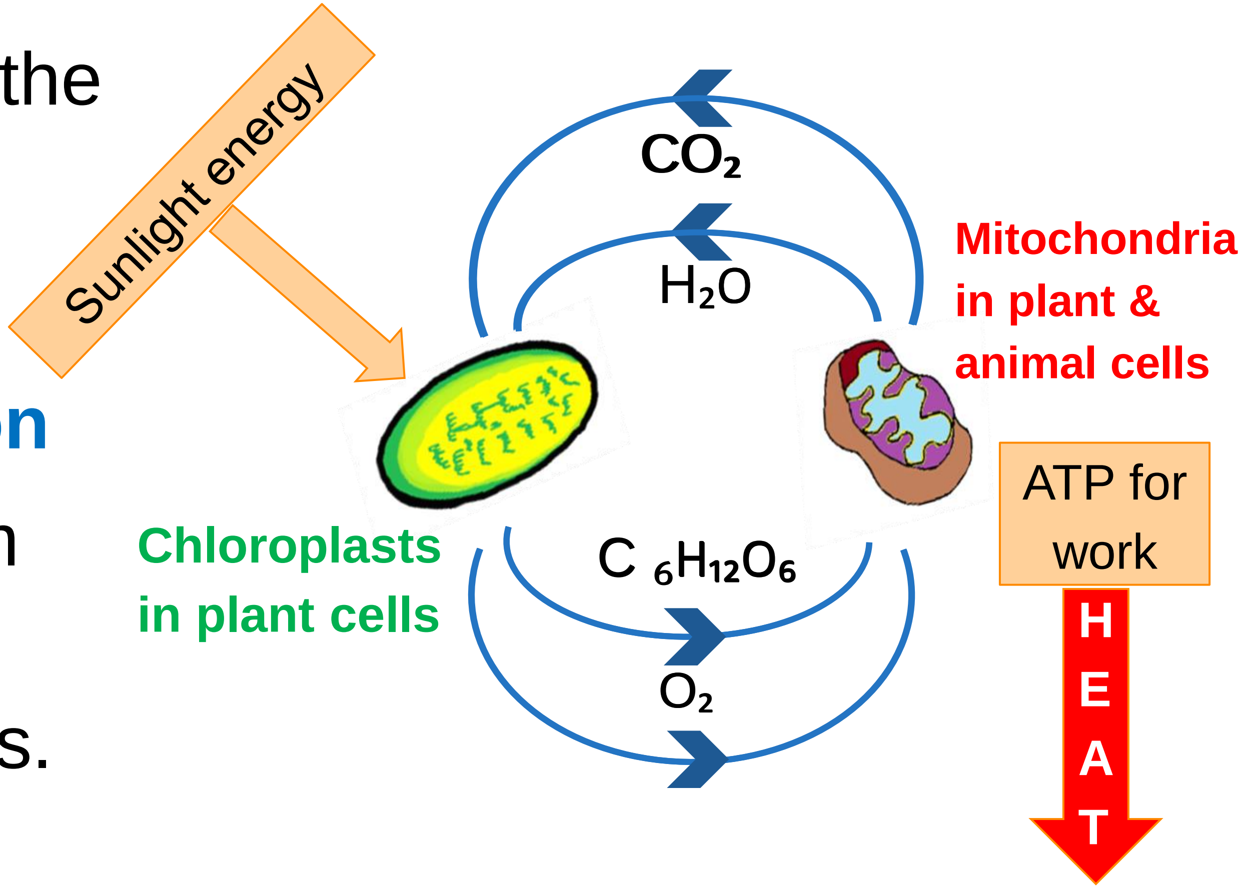
Energy Is Cyclic

Photosynthesis

- Uses sunlight as the energy source.

Cellular respiration

- Uses energy from sugars and other organic molecules.



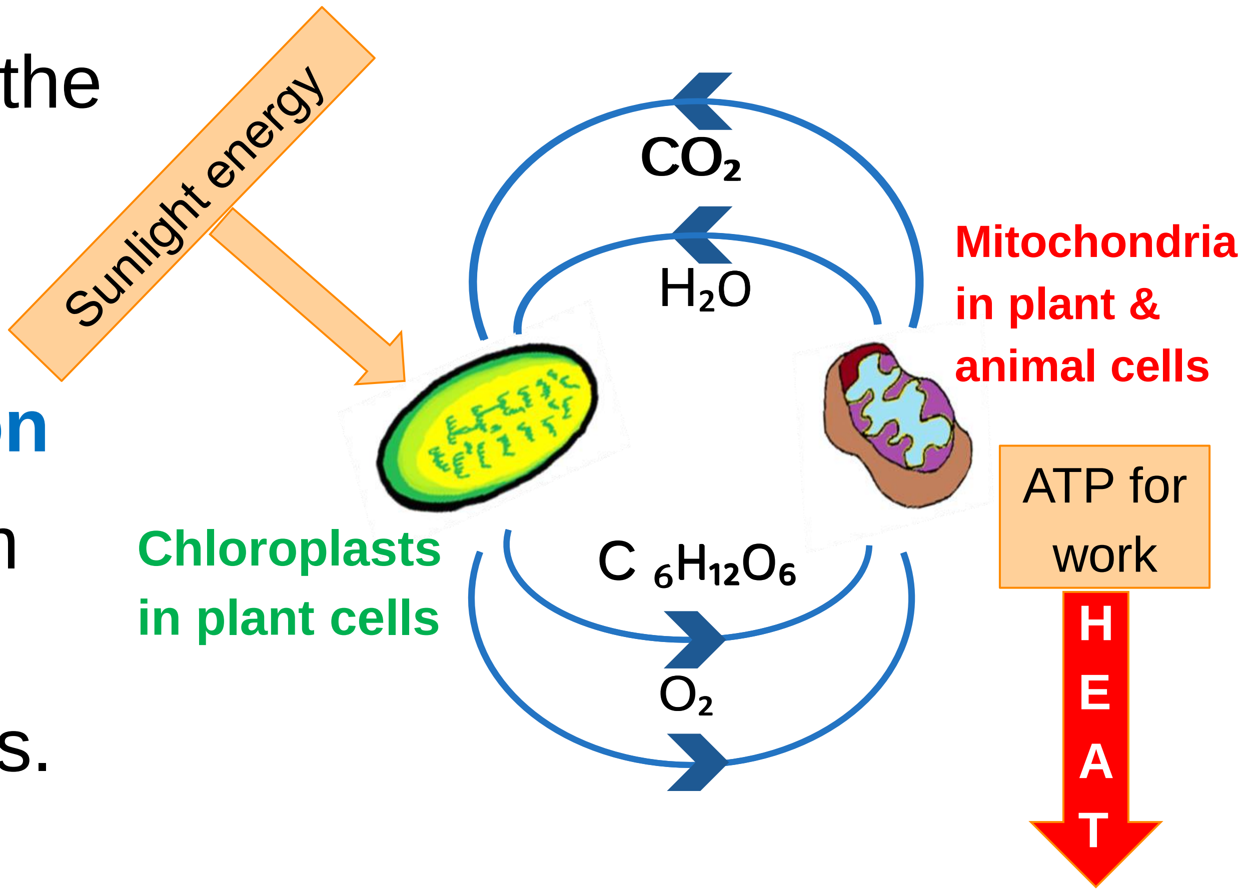
Energy Is Cyclic

Photosynthesis

- Uses sunlight as the energy source.

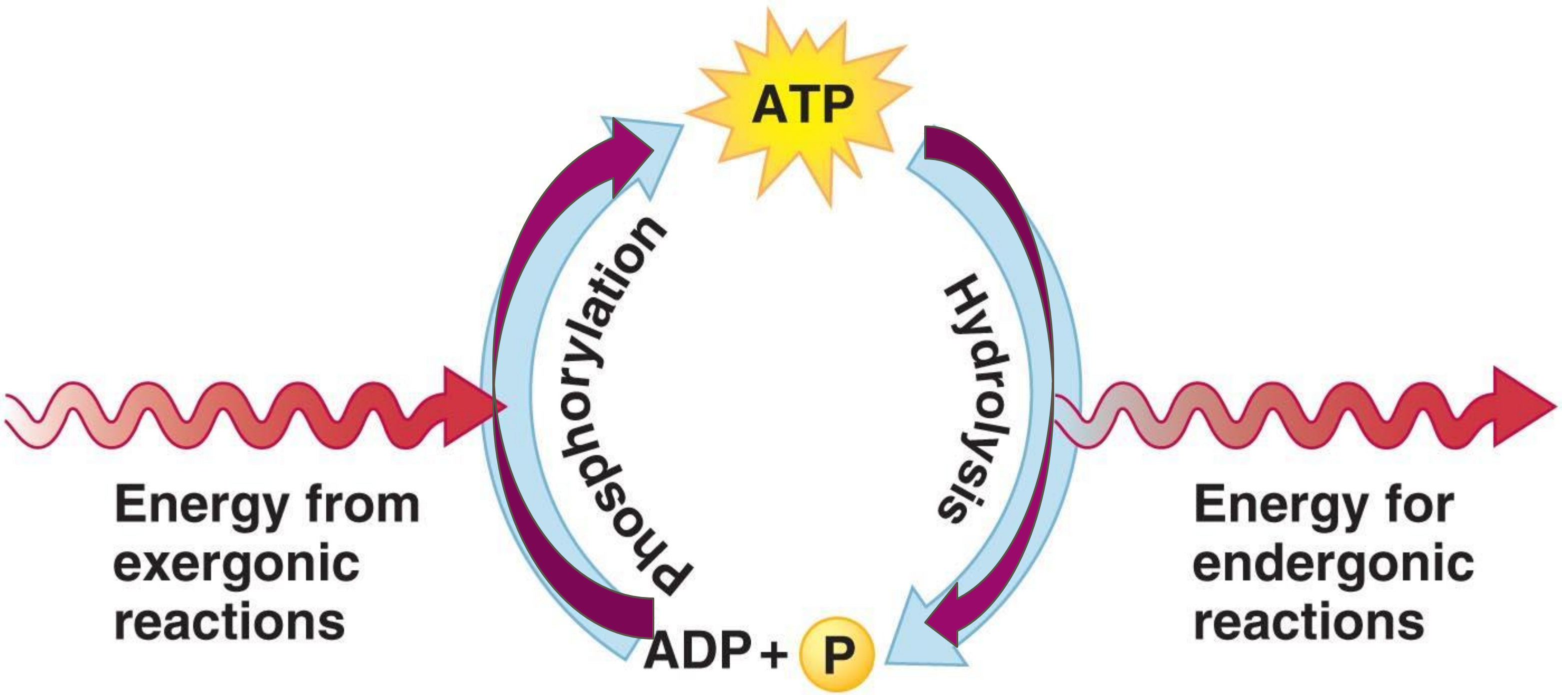
Cellular respiration

- Uses energy from sugars and other organic molecules.



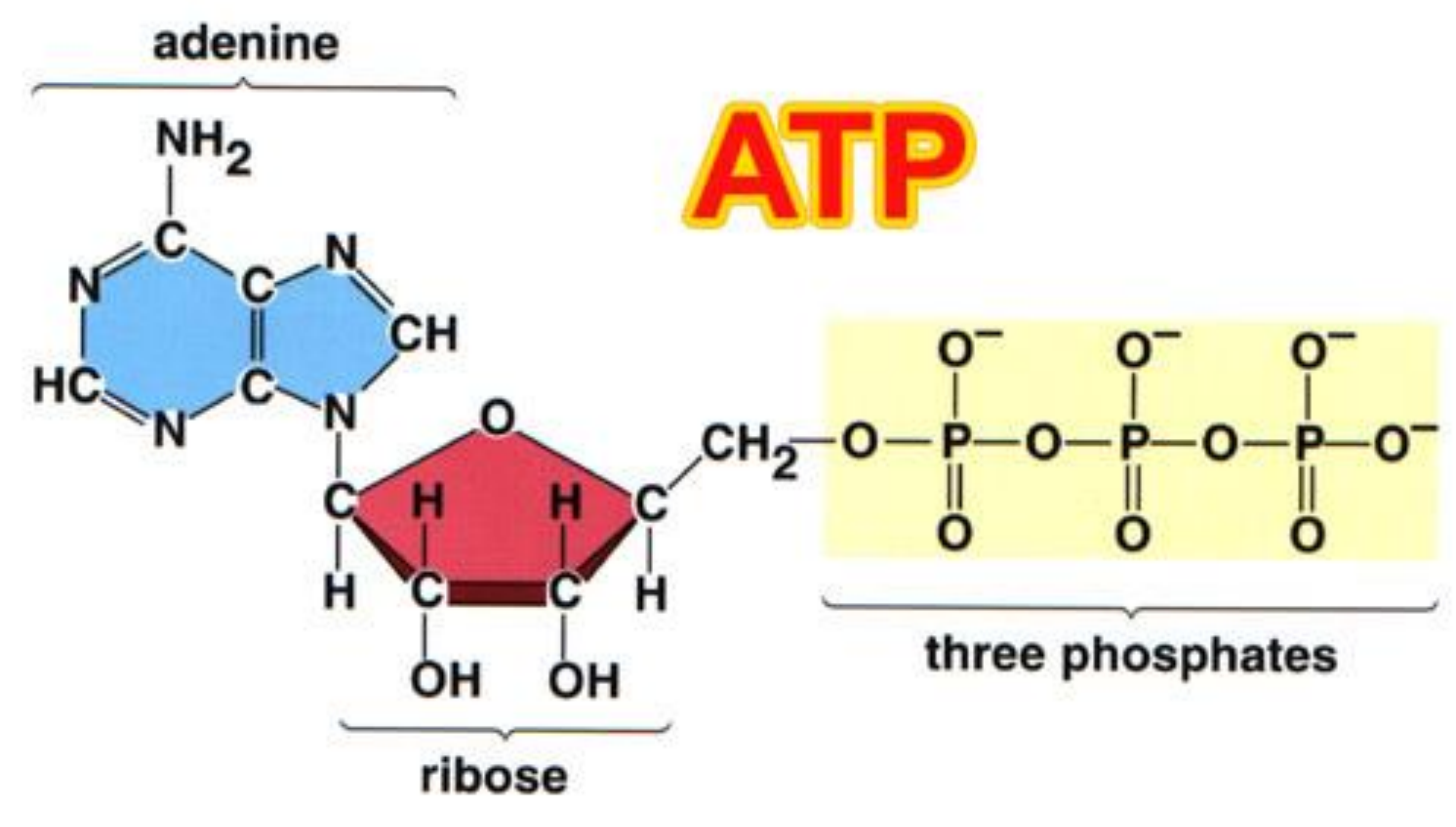
Energy Coupling

- uses the energy released from **exergonic reactions** to drive **endergonic reactions**, typically using the energy stored in **ATP** molecules.



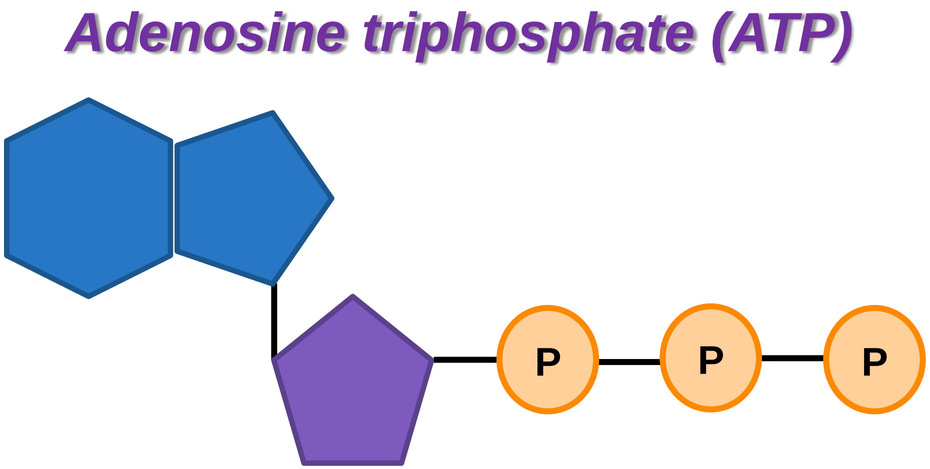
ATP drives Cellular Work by Coupling Exergonic & Endergonic Reactions

- **ATP**, **A**denosine **T**ri**P**hosphate, powers nearly all forms of cellular work.



Structure of ATP

ATP is composed of three parts:



- A base, adenine
- A sugar, ribose
- Tri-phosphate tail

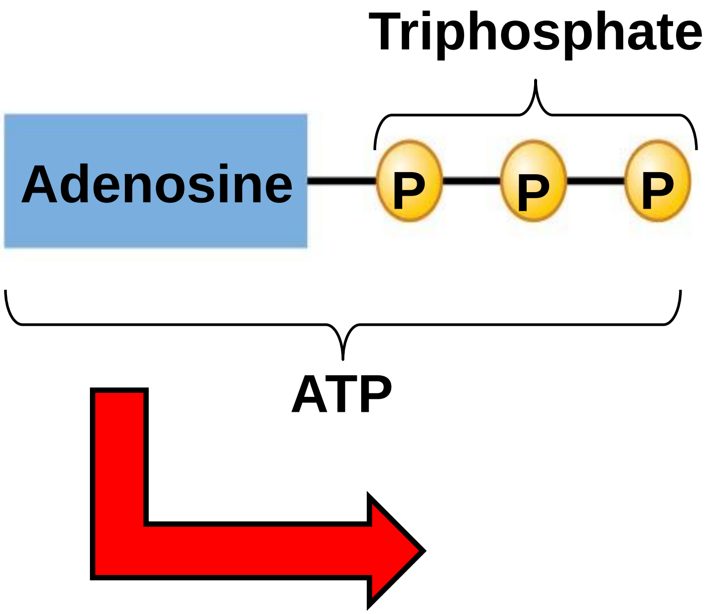
"adenosine **tri**phosphate"

ATP drives Cellular Work by Coupling Exergonic & Endergonic Reactions

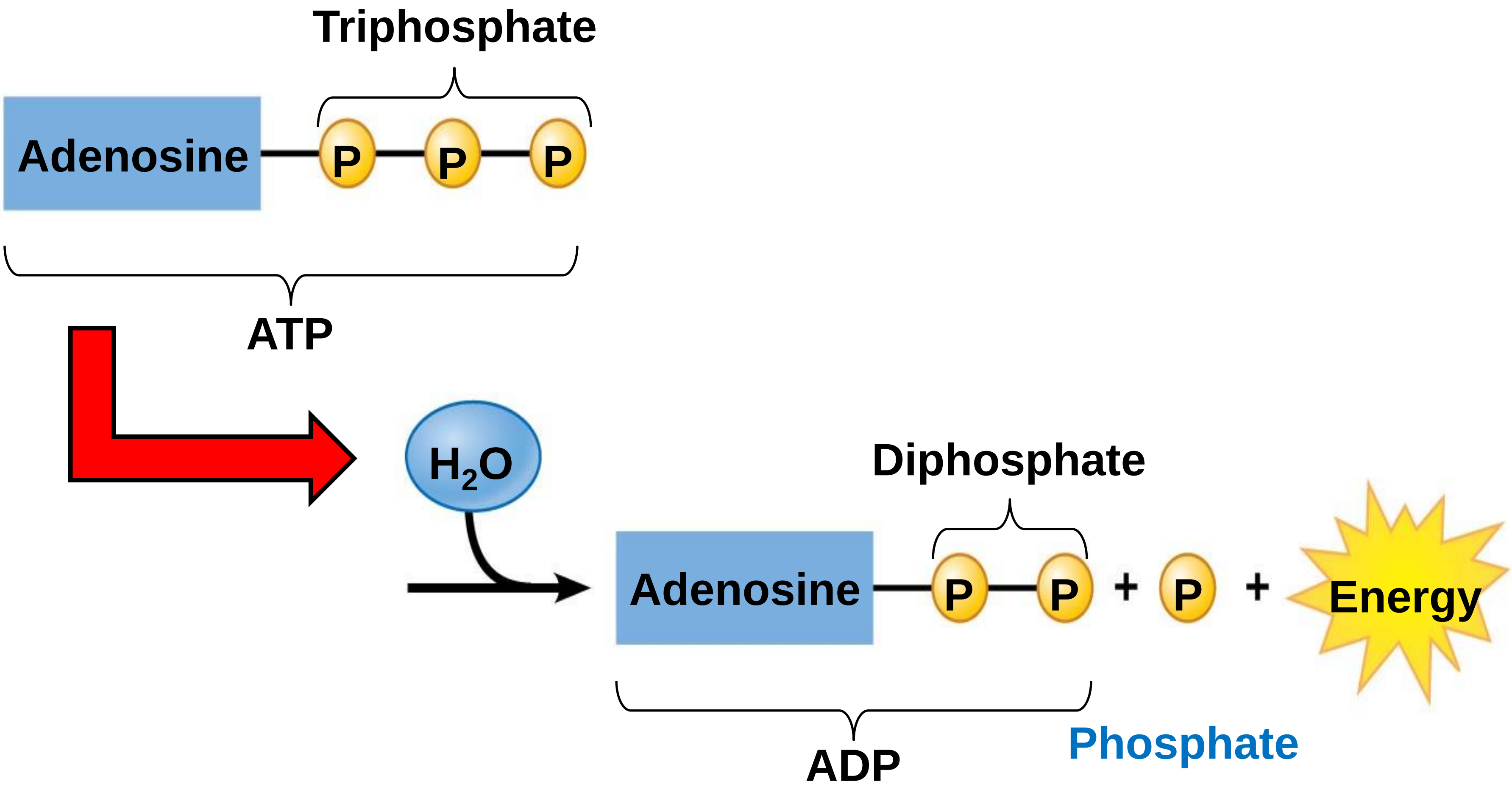
- **Hydrolysis of ATP** releases energy by transferring its third phosphate from ATP to some other molecule in a process called **Phosphorylation.**

- Most cellular work depends on **ATP energizing molecules** by **phosphorylating** them.

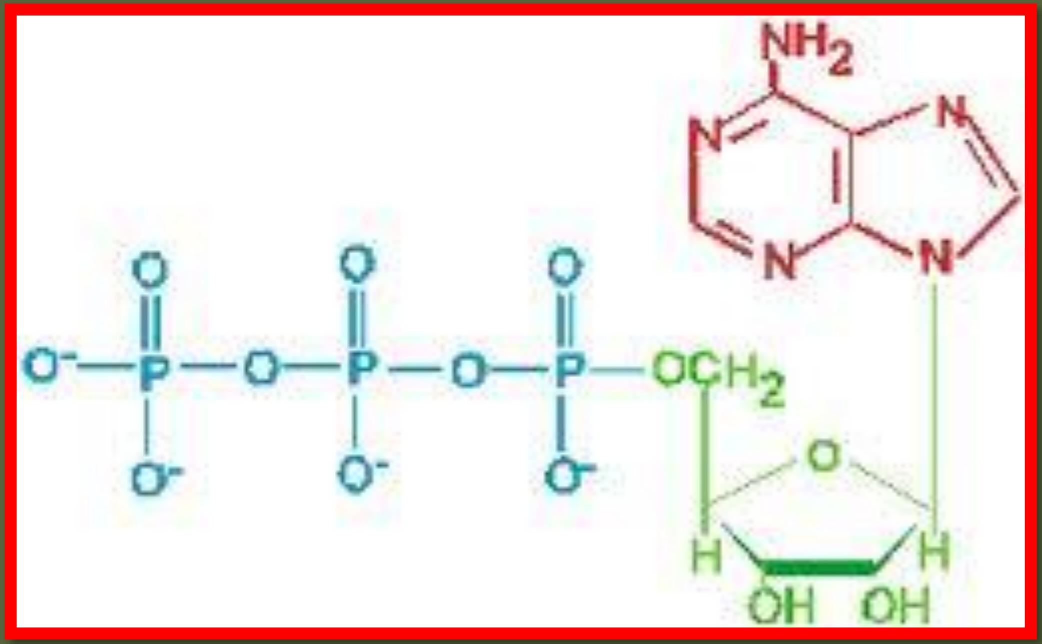
Hydrolysis of ATP



Hydrolysis of ATP



ATP has enough stored energy to power a variety of cellular activities such as…



1. Photosynthesis
2. Protein synthesis
3. Muscle contraction
4. Active transport across the cell membrane
5. Growth & repair
6. Reproduction

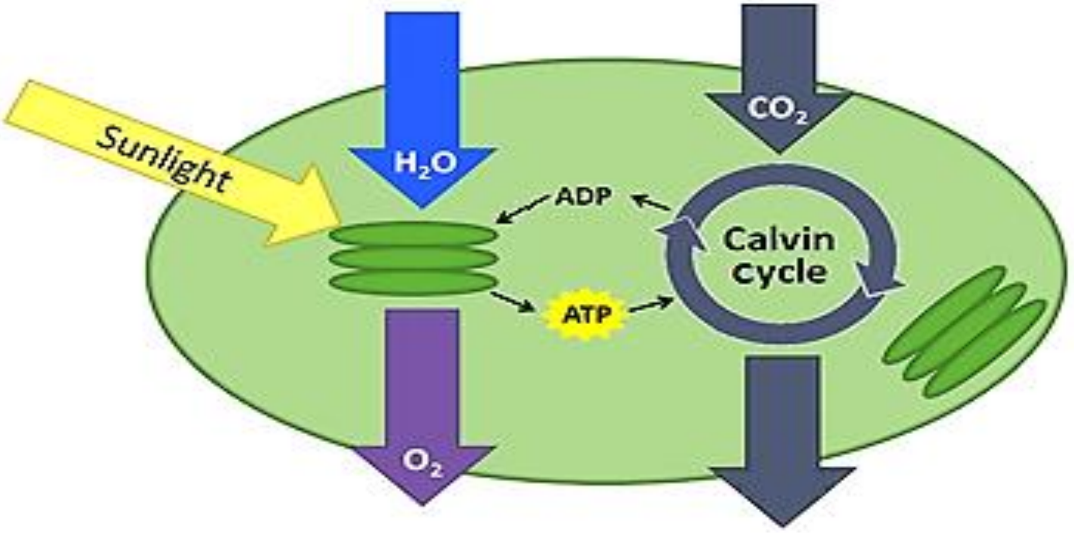
How do cells receive the energy they need to function?

The ATP molecule is the basic energy source of all living cells.

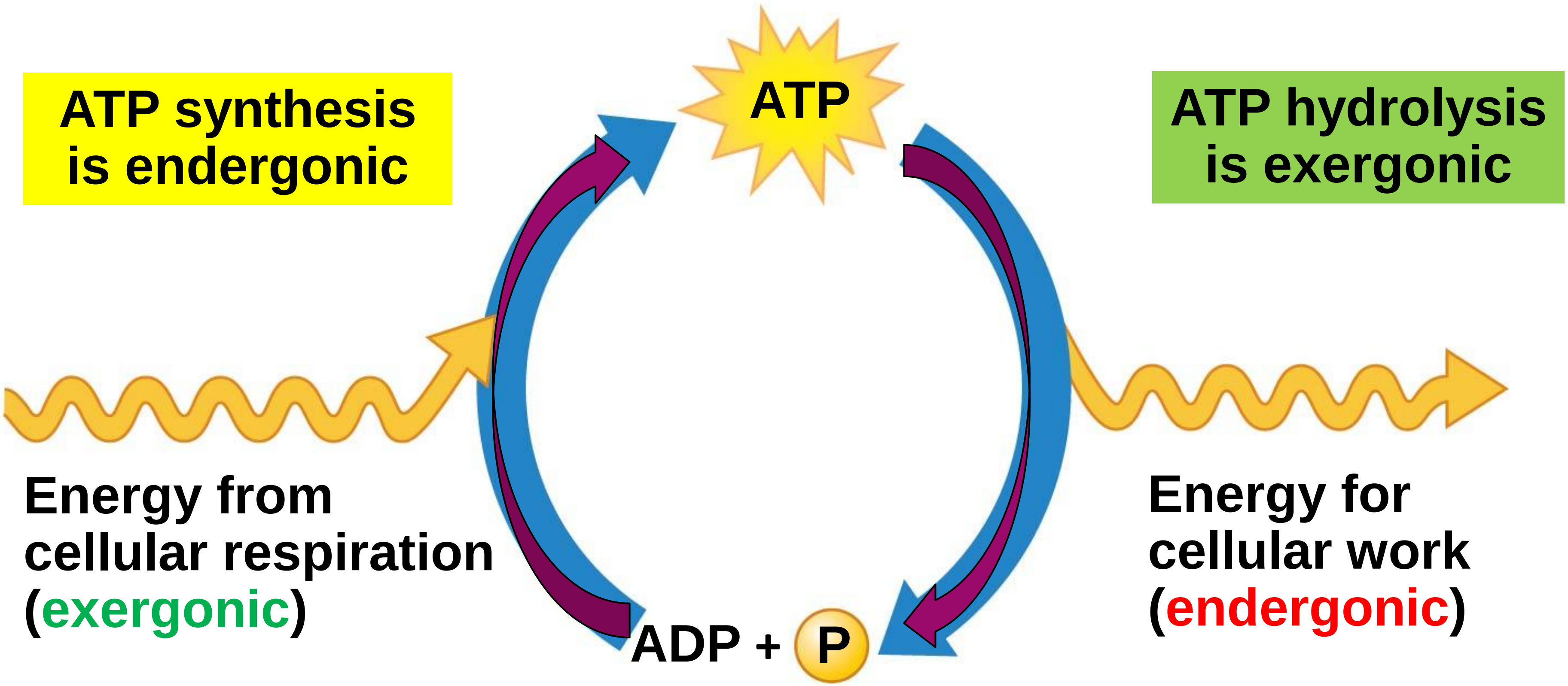
In a cell, ATP is used continuously and must be regenerated continuously. In a working muscle cell, 10 million ATP are consumed & regenerated per sec!!

ATP drives Cellular Work by Coupling Exergonic and Endergonic Reactions

- A cell uses & regenerates ATP continuously.
- In the **ATP Cycle**, energy released in an **exergonic** reaction, *such as the breakdown of glucose during cellular respiration*, is used in an **endergonic** reaction *to generate ATP from ADP.*



ATP drives Cellular Work by Coupling Exergonic and Endergonic Reactions



ADP and ATP Recycling

ATP → ADP + P + energy

ADP + P + energy → ATP

Review of Energy & ATP

QUICK CHECK

Which pathway shows the hydrolysis of ATP ?

[ ] ATP + P + energy → ADP

[ ] ATP → ADP + P + energy

[ ] ADP → ATP + P + energy

[ ] ADP + P + energy → ADP

Label each item exergonic or endergonic.

1. Cellular Respiration
2. Phosphorylation of ATP
3. Photosynthesis
4. Hydrolysis of ATP

Label each item Potential Energy (PE) or Kinetic Energy (KE).

1. Chemical Bonds
2. Radiant Energy shining
3. Heat flowing
4. Concentration gradients

Review of Energy & ATP

QUICK CHECK

Which pathway shows the hydrolysis of ATP ?

[ ] ATP + P + energy → ADP

[X] ATP → ADP + P + energy

[ ] ADP → ATP + P + energy

[ ] ADP + P + energy → ADP

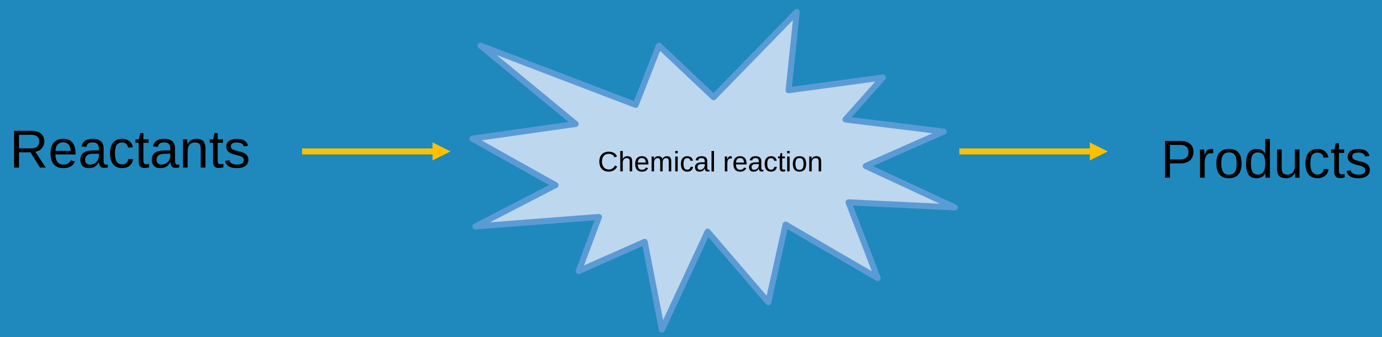
Label each item exergonic or endergonic.

1. Cellular Respiration …exergonic
2. Phosphorylation of ATP…endergonic
3. Photosynthesis …endergonic
4. Hydrolysis of ATP … exergonic

Label each item Potential Energy (PE) or Kinetic Energy (KE).

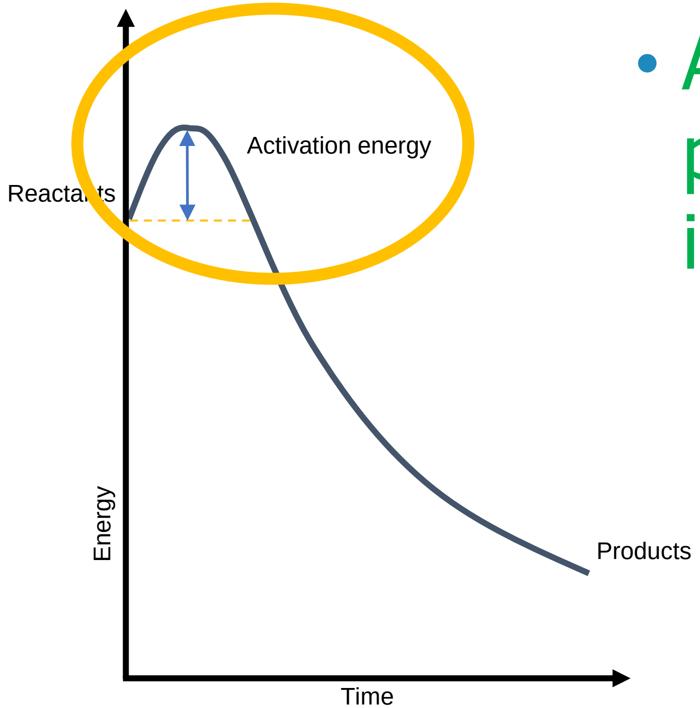
1. Chemical Bonds PE
2. Radiant Energy shining KE
3. Heat flowing KE
4. Concentration gradients PE

The Importance of Enzymes And How They Function



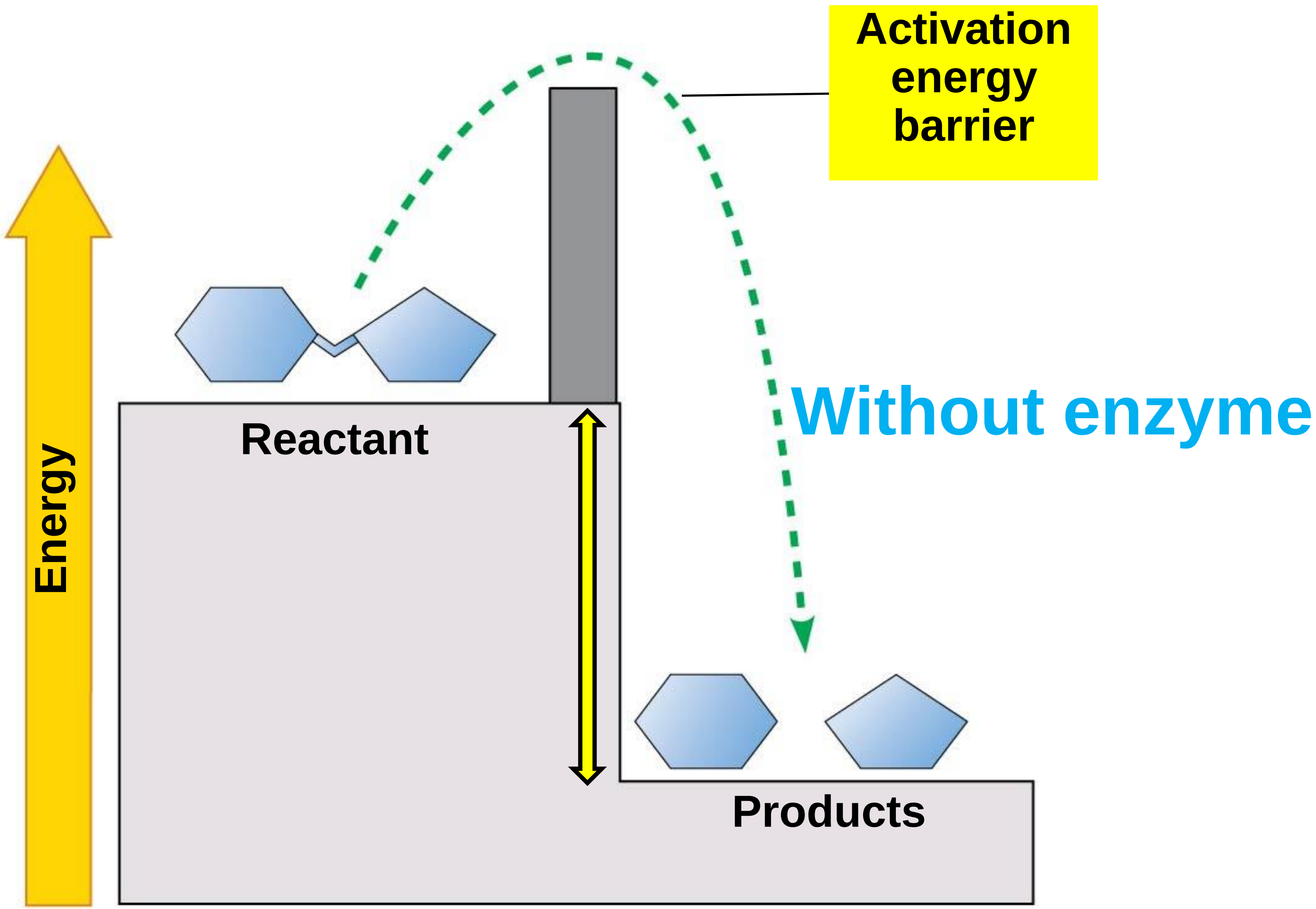
Chemical Reactions are influenced by Enzymes.

Enzymes Speed Up the Cell's Chemical Reactions by Lowering Energy Barriers



- Although biological molecules possess much potential energy, it is not released spontaneously.
  - An energy barrier must be overcome before a chemical reaction can begin.
  - This energy is called the **Activation Energy** (because it activates the reactants).

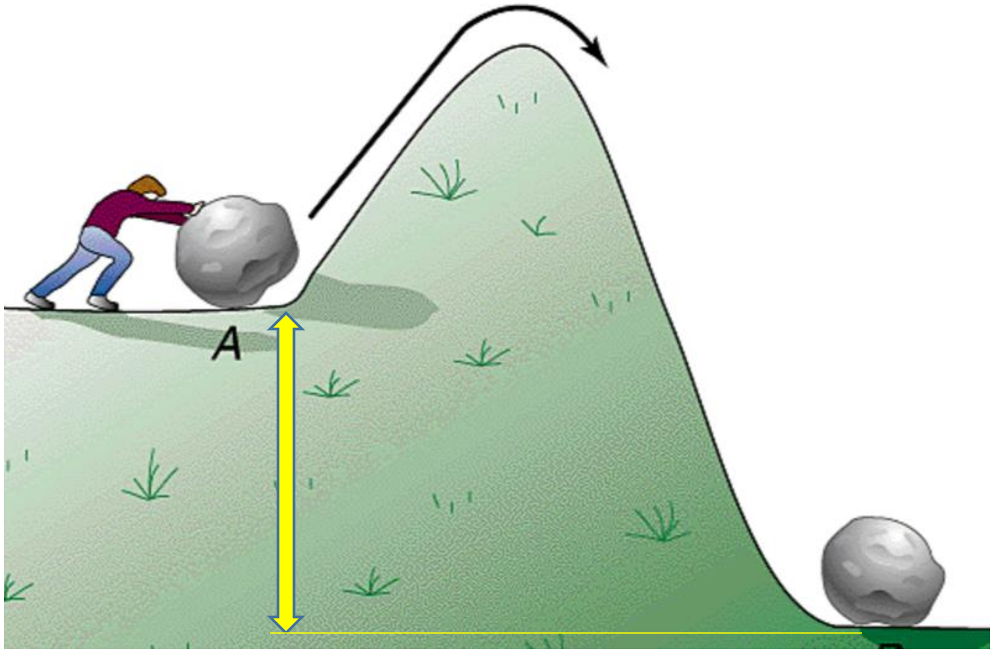
Enzymes Speed Up the Cell's Chemical Reactions by Lowering Energy Barriers



Activation energy

The energy needed for a reactant molecule to move "uphill" to a higher-energy (*although an unstable state*) so that the "downhill" part of the reaction can begin.

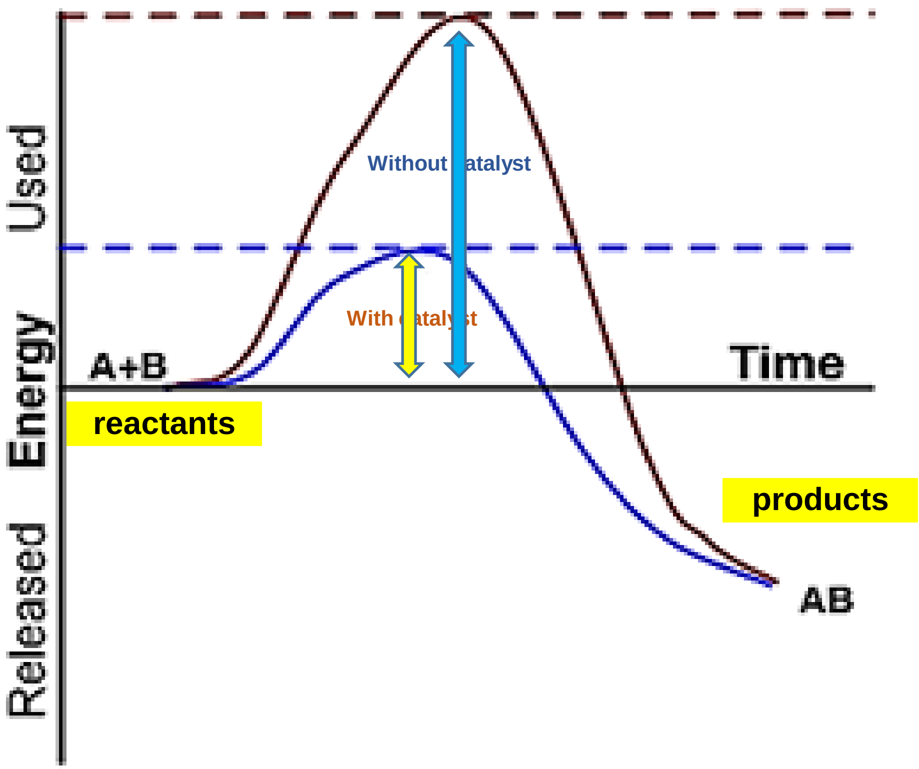
e.g. use a ski lift to get to the top of the hill.



One way to speed up a reaction is to add heat, which agitates atoms so that bonds break more easily and reactions can proceed, **but too much heat will kill a cell.**

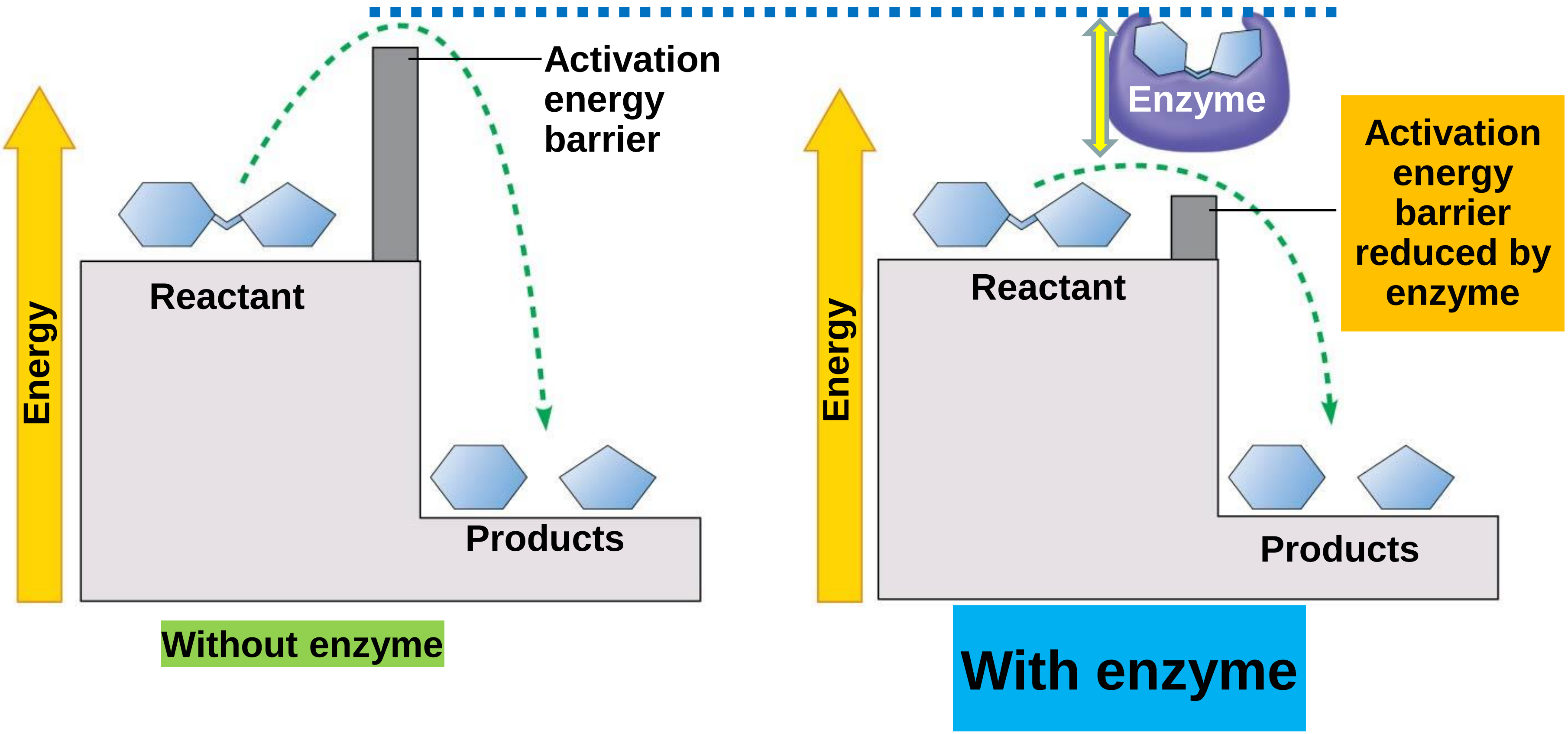
ENZYMES

- function as biological **catalysts.**
- speeds up a reaction without being consumed by the reaction.
- are usually proteins.



Enzymes speed up a reaction by lowering the activation energy needed for a reaction to begin.

Enzymes Speed Up the Cell's Chemical Reactions by Lowering Energy Barriers



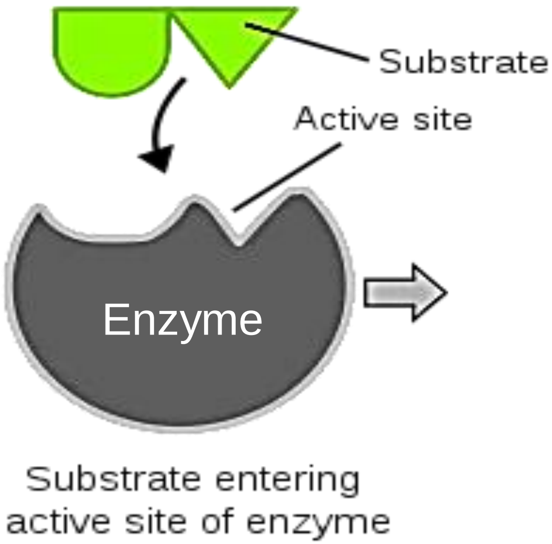
A Specific Enzyme Catalyzes Each Cellular Reaction

- An **Enzyme**
  - is very selective in the reaction it catalyzes.
  - has a **shape** that determines the **enzyme's specificity.**
- The specific reactant that an enzyme acts on is called the enzyme's **substrate.**
- A substrate fits into a region of the enzyme called the **active site.**
- Enzymes are specific because **only specific substrate molecules fit into their active site.**

Enzymes at Work

Substrate: is a reactant that is catalyzed by an enzyme

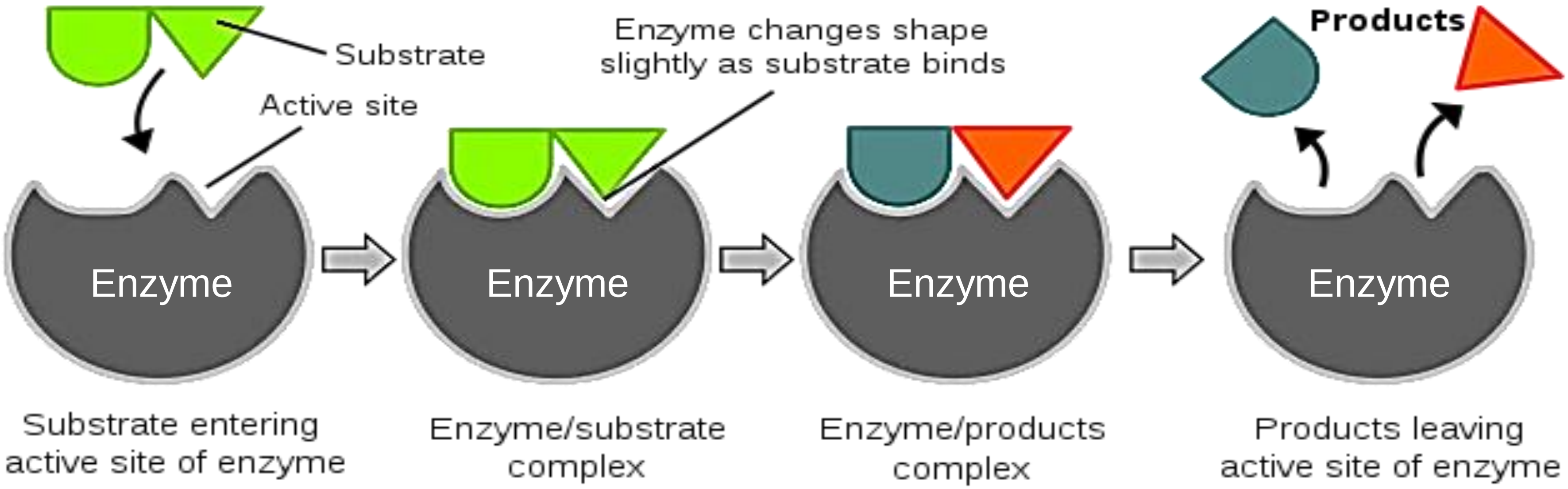
One enzyme and one substrate fit together like a lock and key.



Enzymes at Work

Substrate: is a reactant that is catalyzed by an enzyme

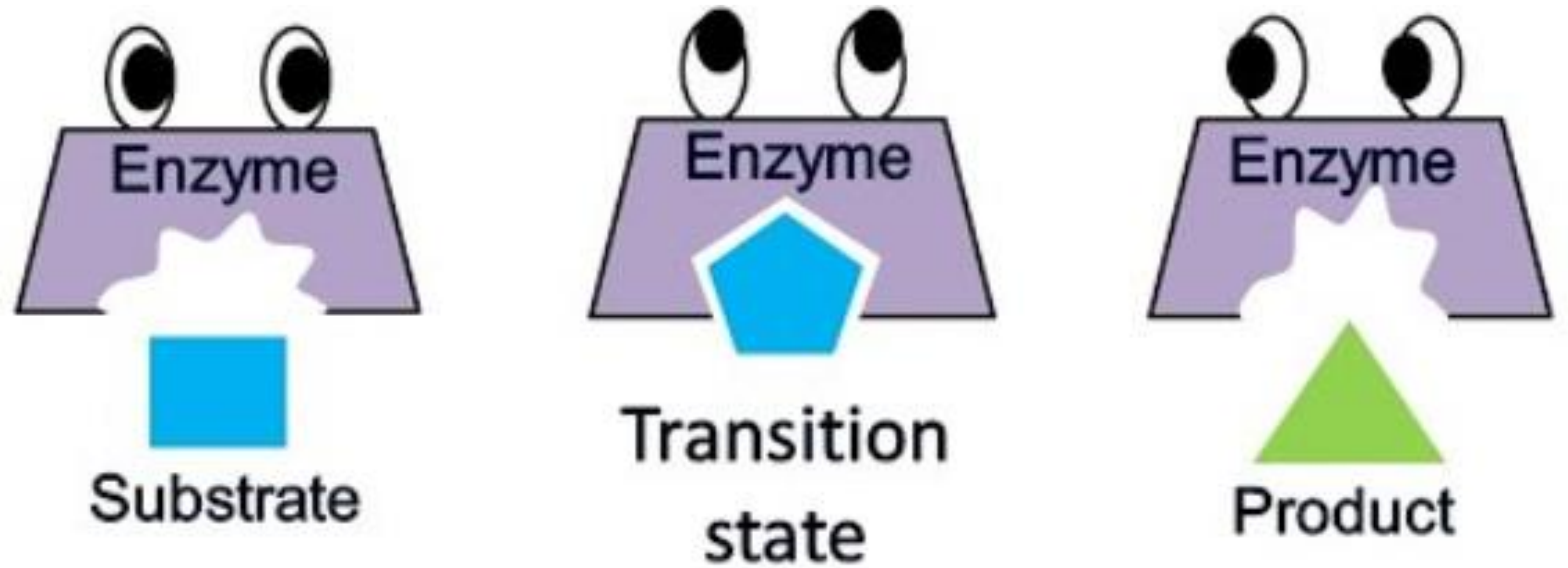
One enzyme and one substrate fit together like a lock and key.



- **Induced Fit Model → the enzyme/substrate changes shape**

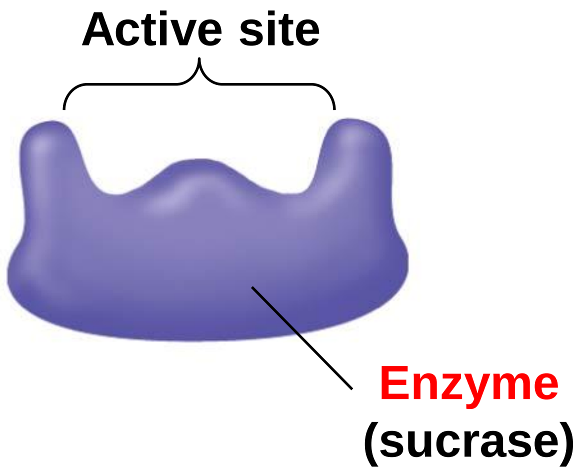
Induced Fit Model of Enzyme Action

The enzyme/substrate intermediate induces a changed shape.

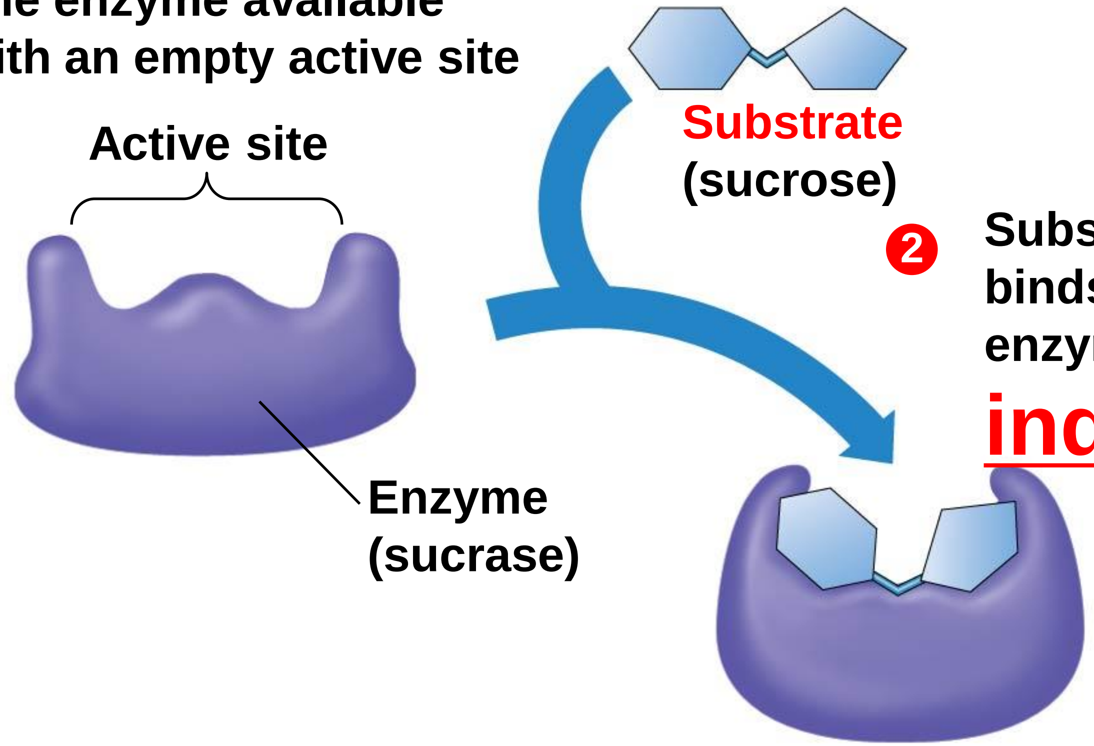


square **pentagon** **triangle**

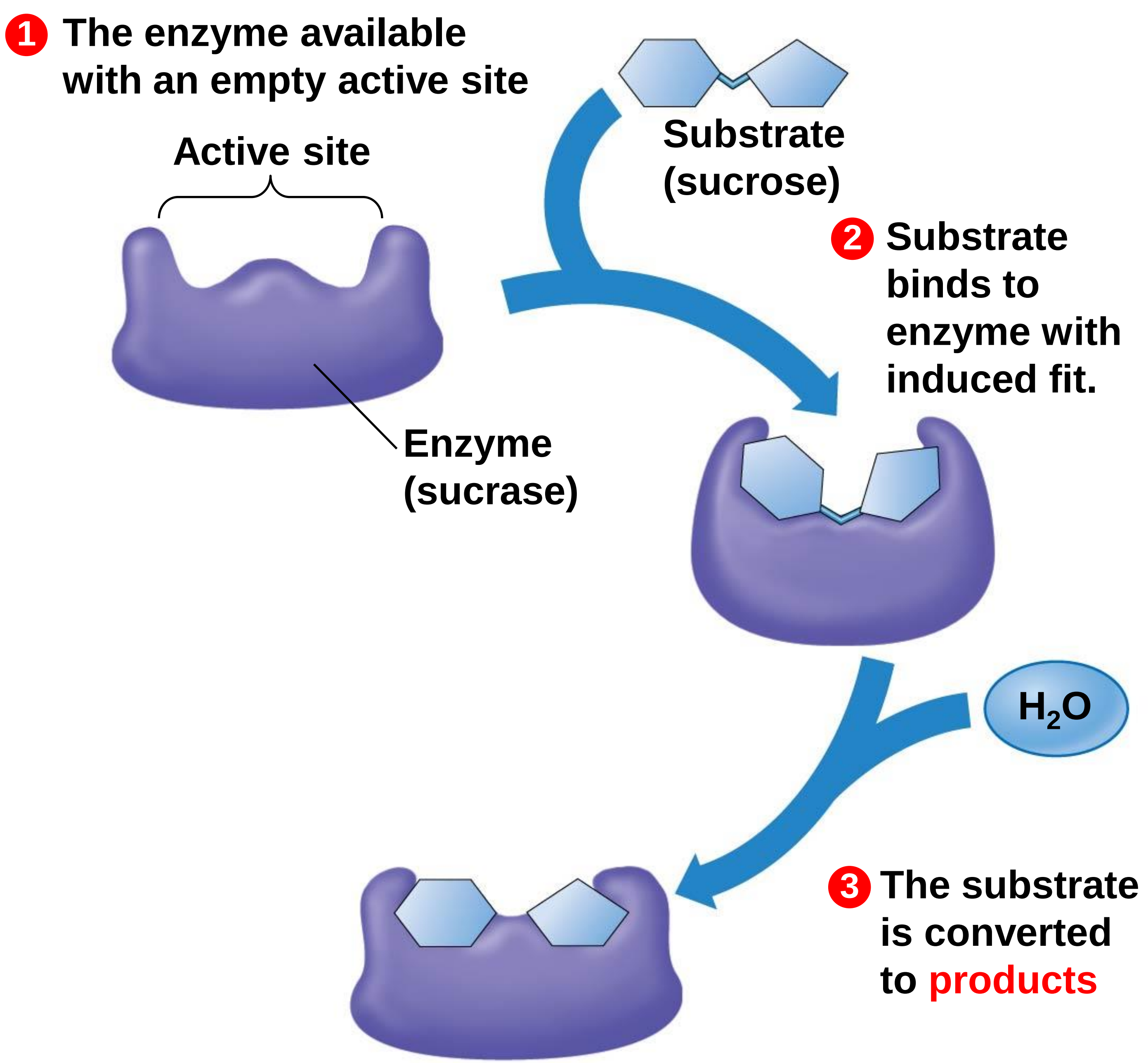
1 The enzyme available with an empty active site

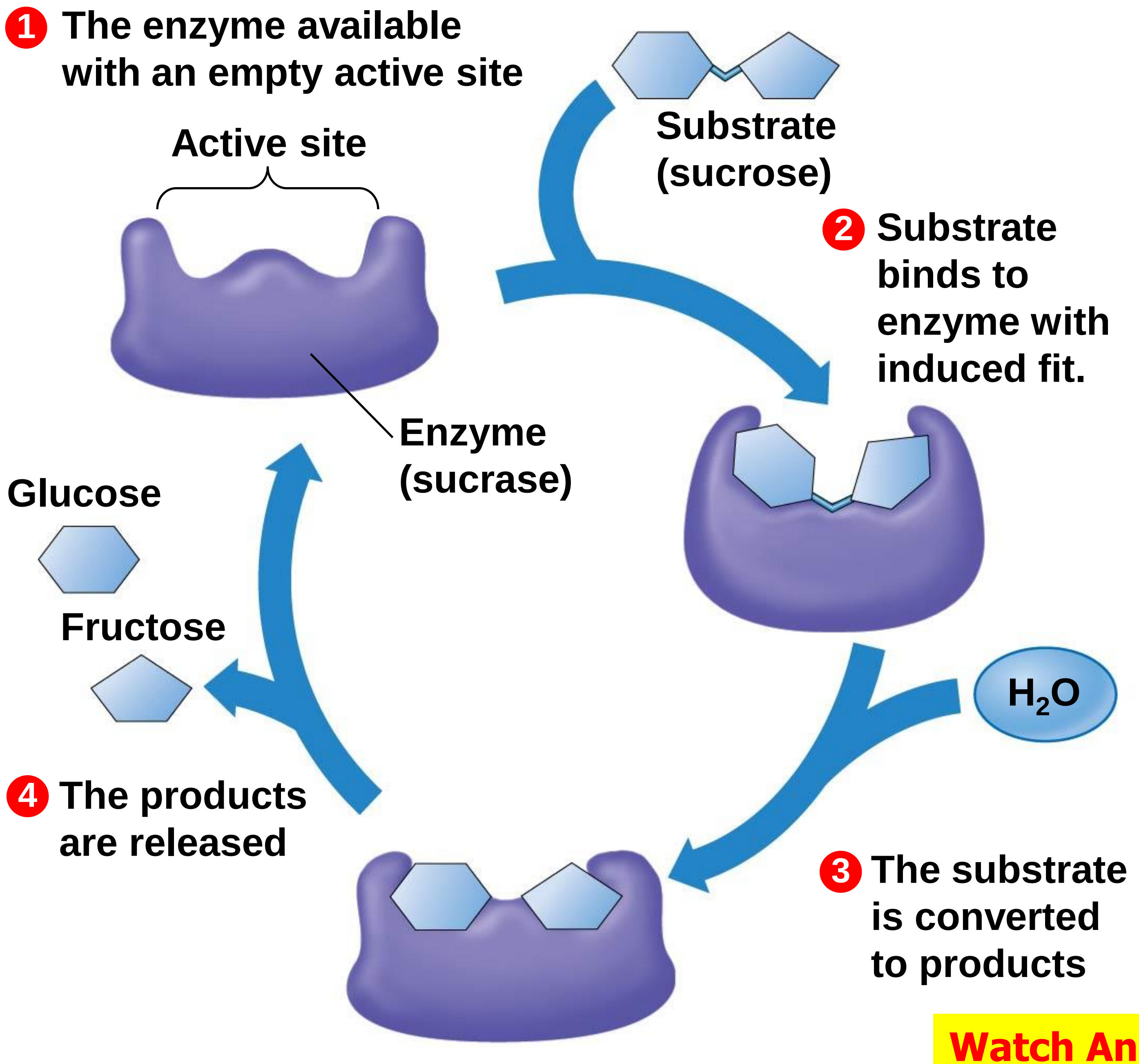


1 The enzyme available with an empty active site



2 Substrate binds to enzyme with **induced fit**.


1 The enzyme available with an empty active site
Active site
Enzyme (sucrase)
Substrate (sucrose)
2 Substrate binds to enzyme with induced fit.
H_2O
3 The substrate is converted to products



Watch Animation

A Specific Enzyme Catalyzes Each Cellular Reaction

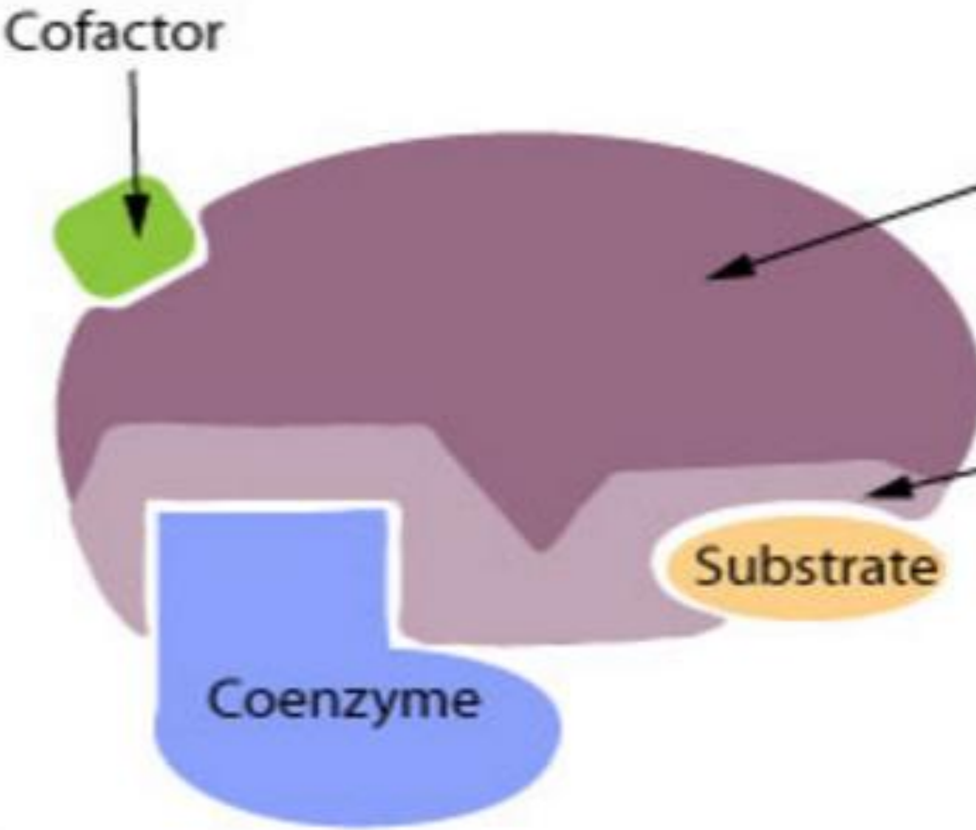
- For every enzyme, there are optimal conditions under which it is most effective.
- **Temperature** affects molecular motion.
  - An enzyme's optimal temperature produces the highest rate of contact between the reactants and the enzyme's active site.
  - Most human enzymes work best at 35–40°C.
- The optimal **pH** for most enzymes is near neutrality (about 7).

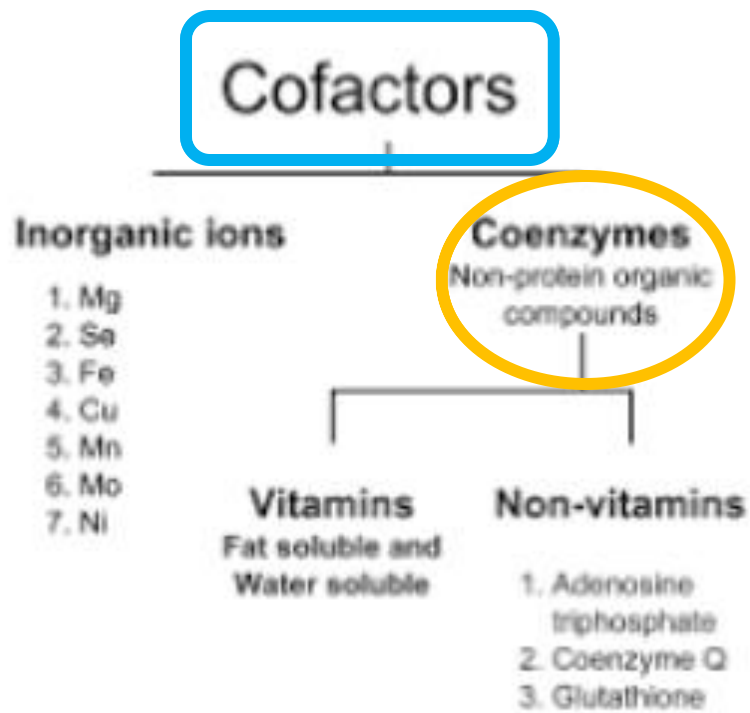
Some Enzyme "Helpers":

- Coenzymes and Cofactors
- Necessary for some enzymes to function properly.

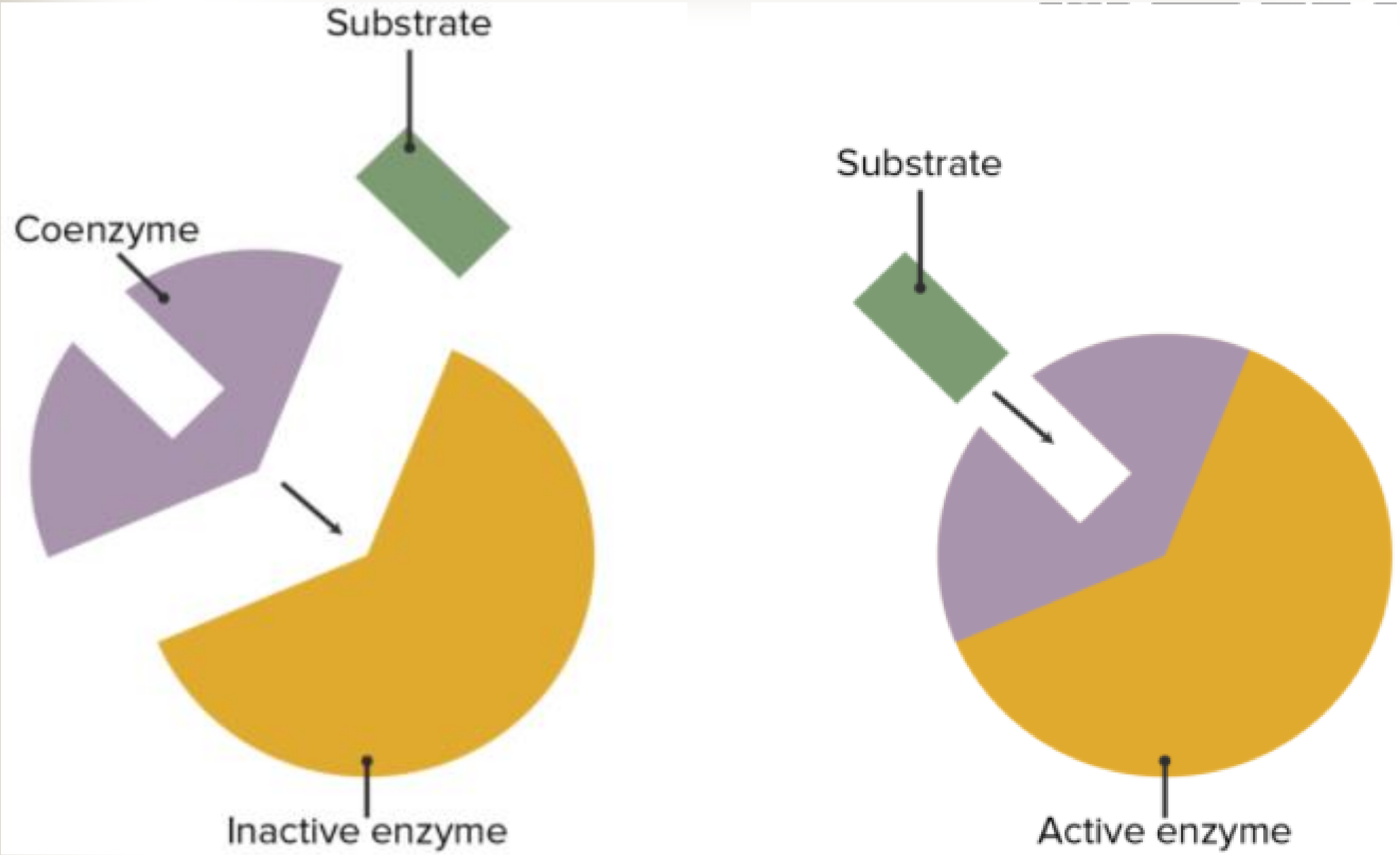
Cofactors: inorganic (Mg^{+2}, Cu^{+2}, Zn^{+2}, Fe^{+2}, Ca^{+2}) or organic

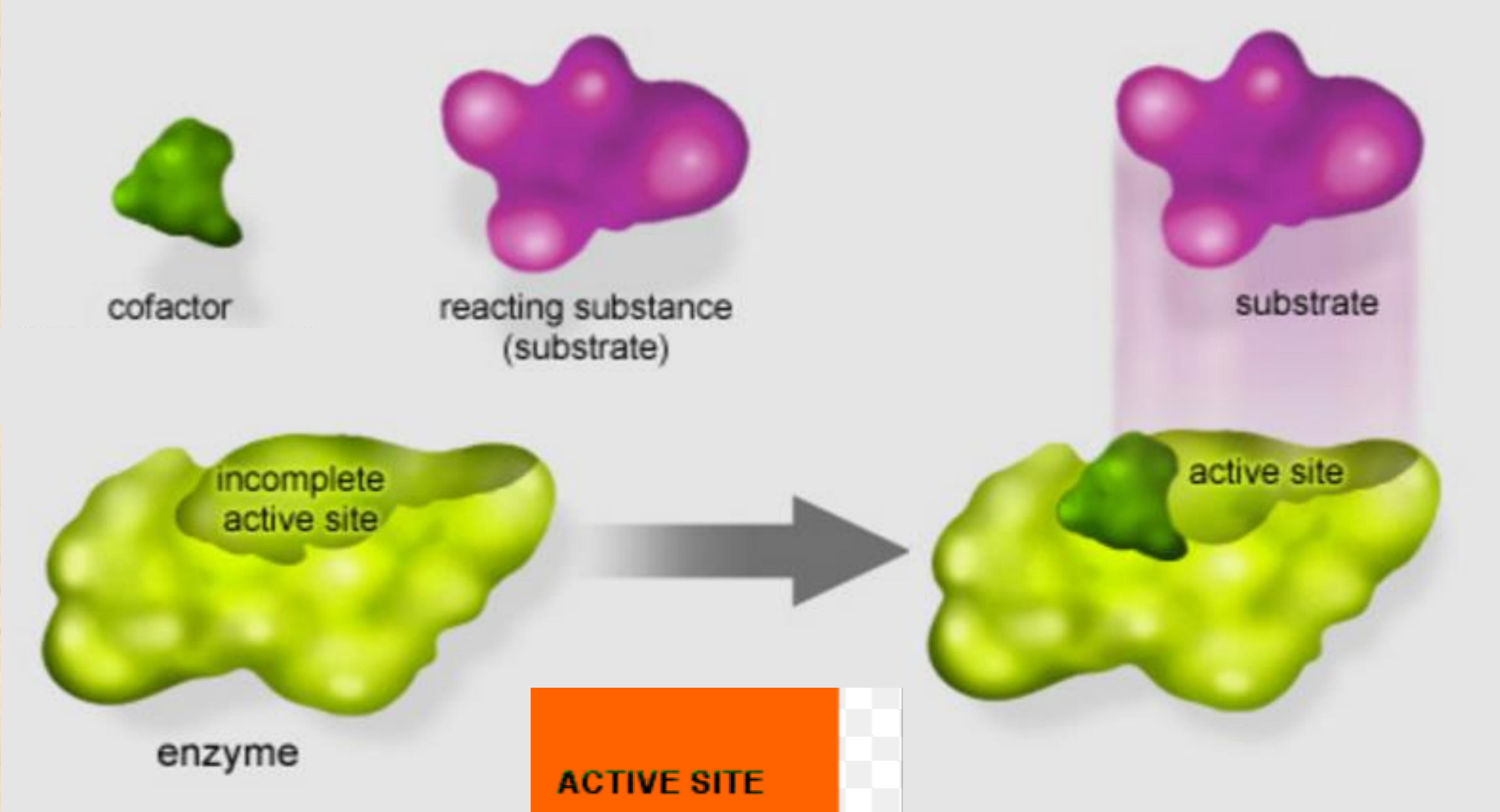
Coenzymes: organic; most **Vitamins; NAD, FAD**





Coenzymes are Cofactors


Substrate
Coenzyme
Inactive enzyme
Substrate
Active enzyme


cofactor
reacting substance
(substrate)
substrate
incomplete
active site
active site
enzyme


ACTIVE SITE
SUBSTRATE
COENZYME

Enzymes

QUICK CHECK

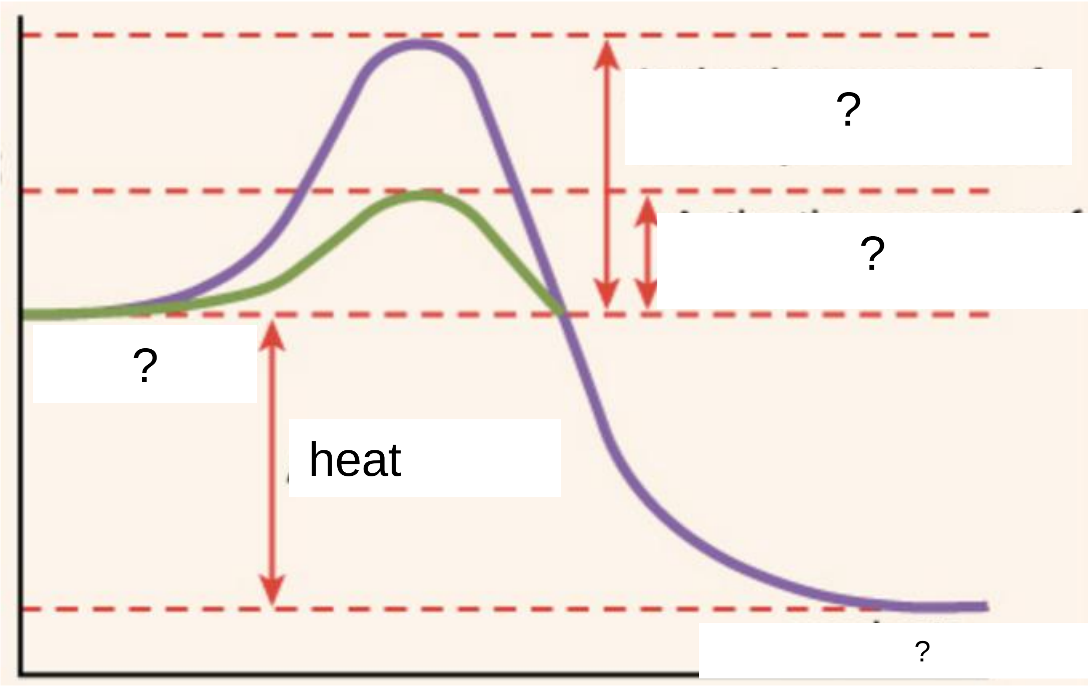
Put the steps of enzyme activity in order from first (1) to last (4).

[ ] The chemical reaction occurs.

[ ] A substrate enters the active site of enzyme.

[ ] New substances called “products” are formed.

[ ] The enzyme and the substrate bind to form the enzyme-substrate complex.



Label the diagram

Enzymes

QUICK CHECK

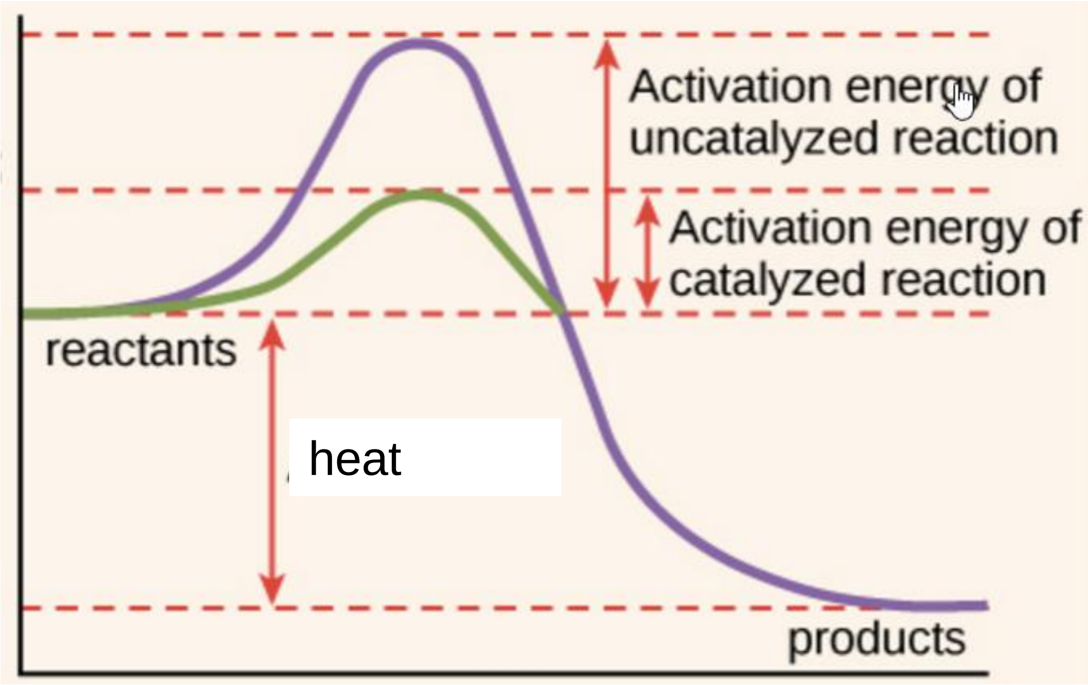
Put the steps of enzyme activity in order from first (1) to last (4).

[3] The chemical reaction occurs.

[1] A substrate enters the active site of enzyme.

[4] New substances called “products” are formed.

[2] The enzyme and the substrate bind to form the enzyme-substrate complex.



Label the diagram