Unit 4 - Enzymes

MS. MARTEL

4.1 – ENERGY TRANSFORMATIONS & METABOLISM

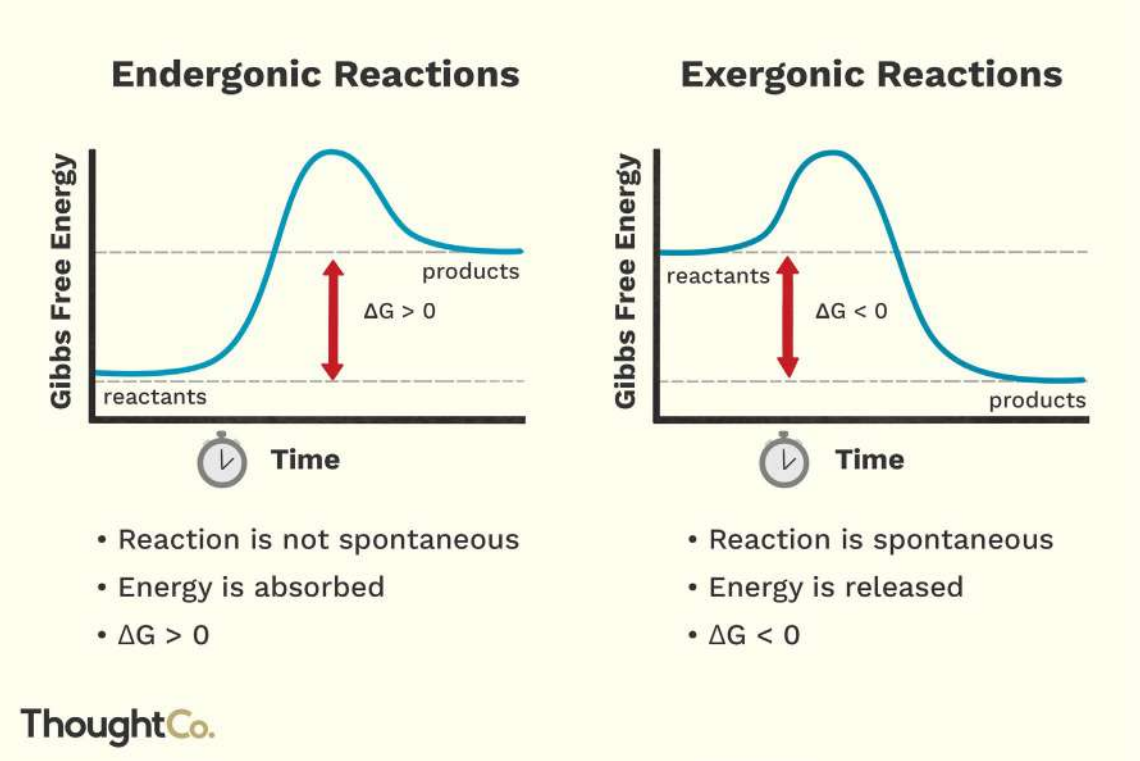
Cellular metabolism is the **sum of all the chemical reactions that occur in a cell.**

- This is largely the breaking down and building up of molecules.

Catabolism is the **breaking down of molecules.**

Anabolism is the **building up of molecules.**

In a chemical reaction, reactants are substances that **participate in a reaction**, products are substances that **form as a result of a reaction.**



Free energy is the **amount of energy available** – or "free" to do work – after a chemical reaction has occurred.

- The change in free energy after a reaction occurs is calculated by **subtracting the free energy content of the reactants from that of the products.**

Exergonic reactions are **spontaneous and release energy**, while endergonic reactions **require an input of energy to occur**

- In the body, many reactions are **endergonic as they require ATP.**

ATP: Energy for Cells

ATP is the common energy currency of cells.

- The more active the organism, **the greater the demand for ATP.**
- A cell is assured a supply of ATP because glucose breakdown during **cellular respiration provides the energy to buildup ATP.**

Biological advantages to using ATP as an energy carrier in living systems:

- It's a universal energy currency because it can be **used in different types of reactions.**
- Little energy is wasted when **ADP is converted into ATP.**
- ATP breakdown can be coupled to reactions in a way that **minimizes energy loss.**

Label the appropriate images in the ATP cycle.

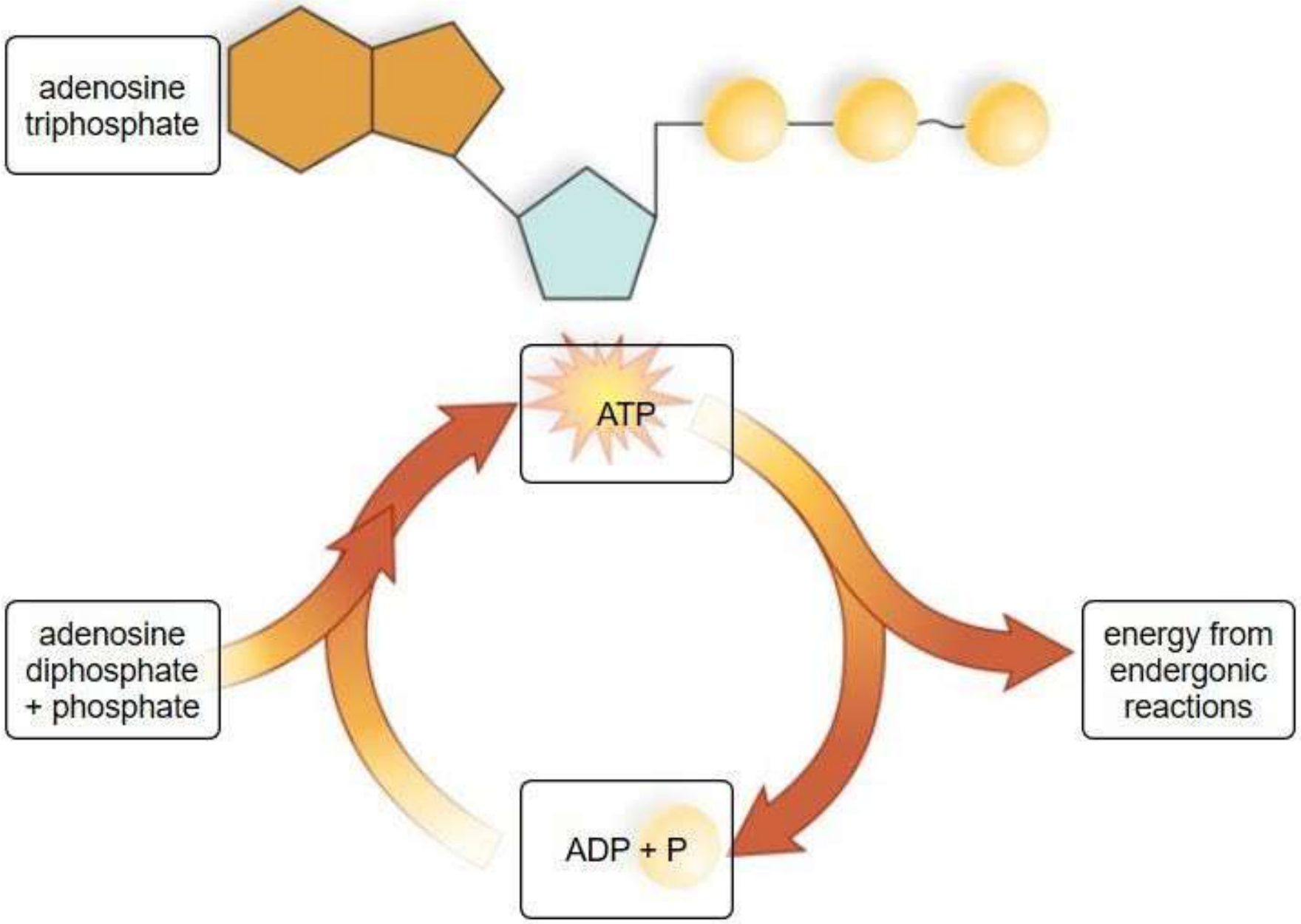
adenosine diphosphate + phosphate

adenosine triphosphate

energy from endergonic reactions

ADP + P

ATP

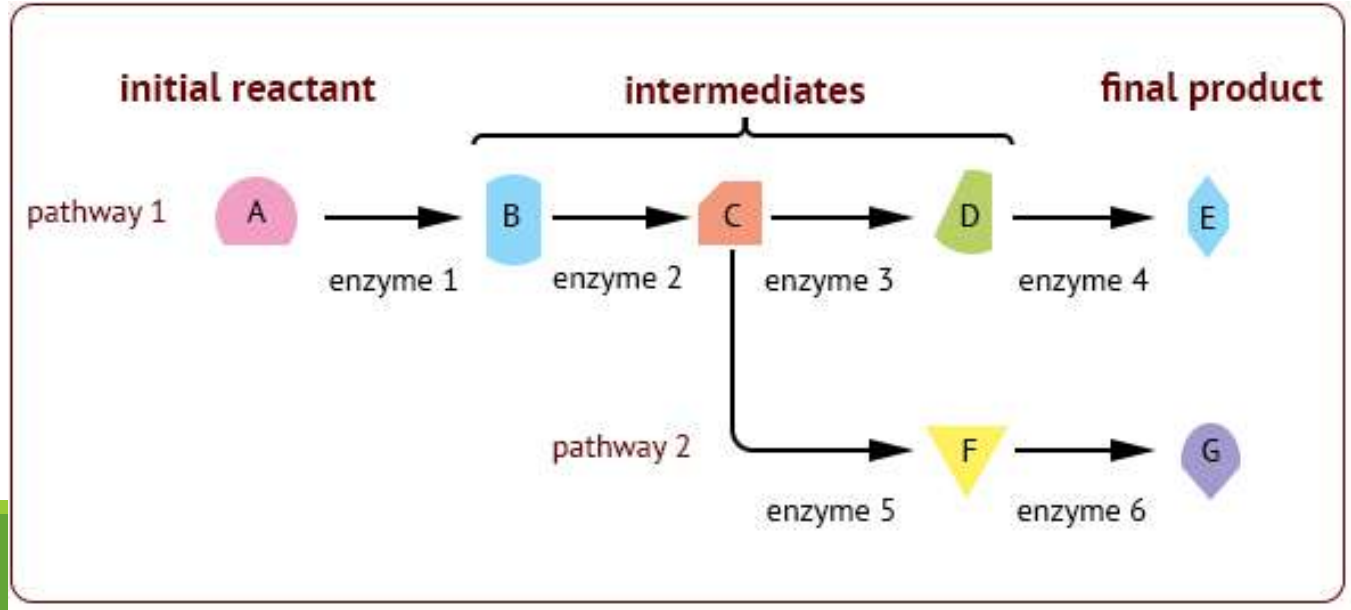


4.2 – ENZYMES & METABOLIC PATHWAYS

Reactions are a part of a metabolic pathway, which is **a series of linked reactions.**

- Metabolic pathways begin with a **particular reactant and terminate with an end product.**
- Some pathways are cyclical, **regenerating the starting material.**
- Its possible for one pathway to lead to several others because various pathways have **several molecules in common.**

- Enzymes are typically proteins that function as **catalysts to speed up chemical reactions.**
  - Catalysts participate in chemical reactions, but are **not used up by the reaction.**
  - Note enzymes do not determine whether a reaction goes forward, that is determined by the **free energy of the reaction.**
  - Enzymes only increase the **RATE of the reaction.**
  - Reactants in an enzymatic reaction are called **substrates for that enzyme.**

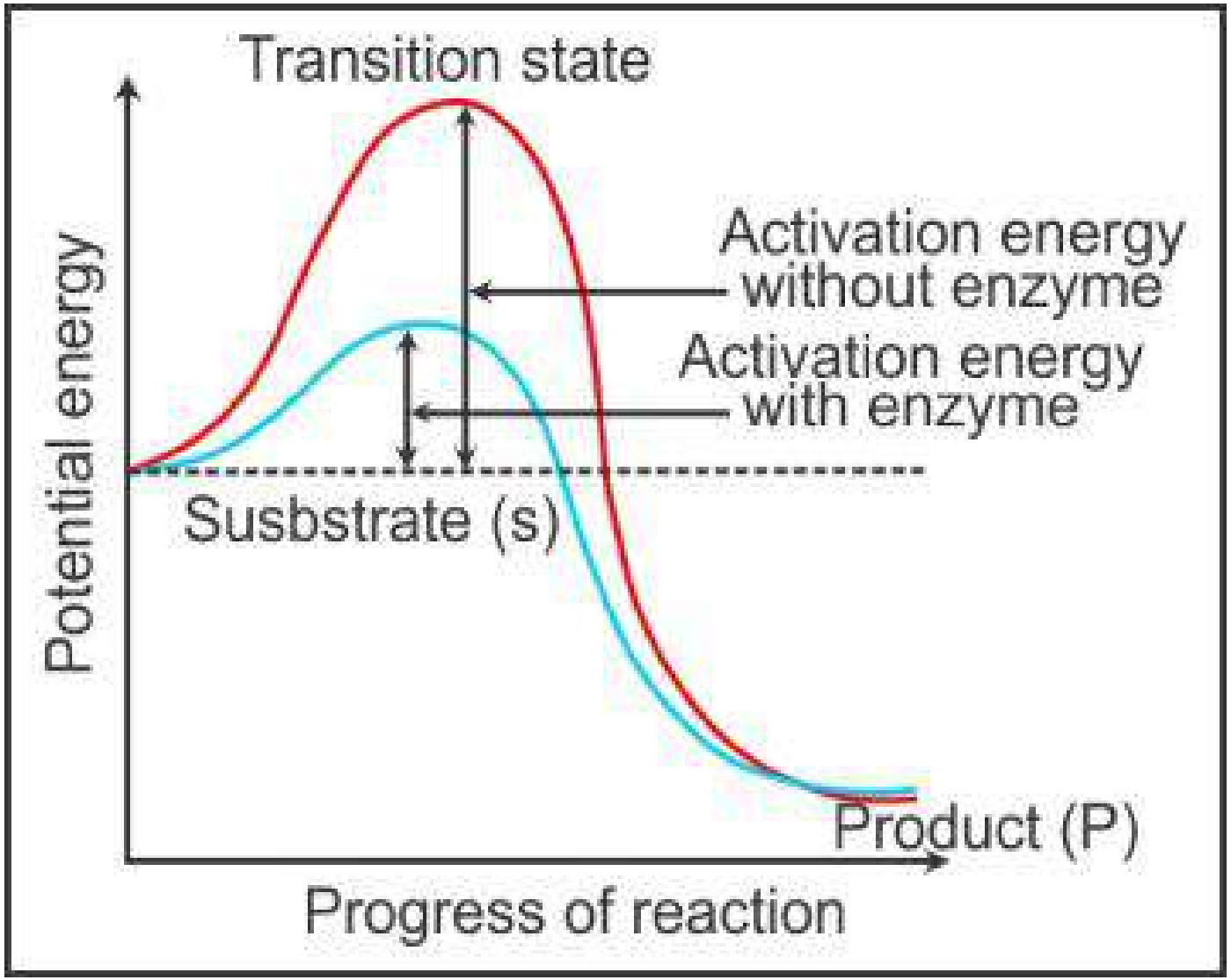


Energy of Activation

Molecules frequently do not react with one another unless they are **activated in some way.**

The energy that must be added to cause molecules to react with one another is called the **energy of activation.**

- **Enzymes lower the amount of energy** required for activation to occur.
- The addition of the enzyme does not **change the end result of the reaction.**
- Without the enzyme, **the reaction rate will be very slow.**


Transition state
Activation energy without enzyme
Activation energy with enzyme
Susbstrate (s)
Potential energy
Product (P)
Progress of reaction

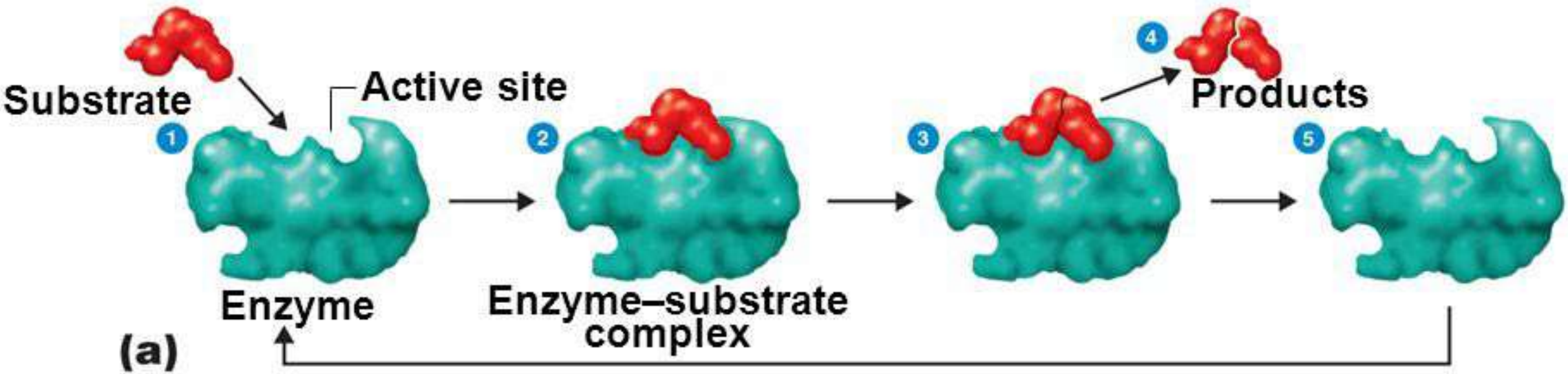
How Enzymes Function

In most instances, only one small part of the enzyme, called the **active site, complexes with the substrate**(s).

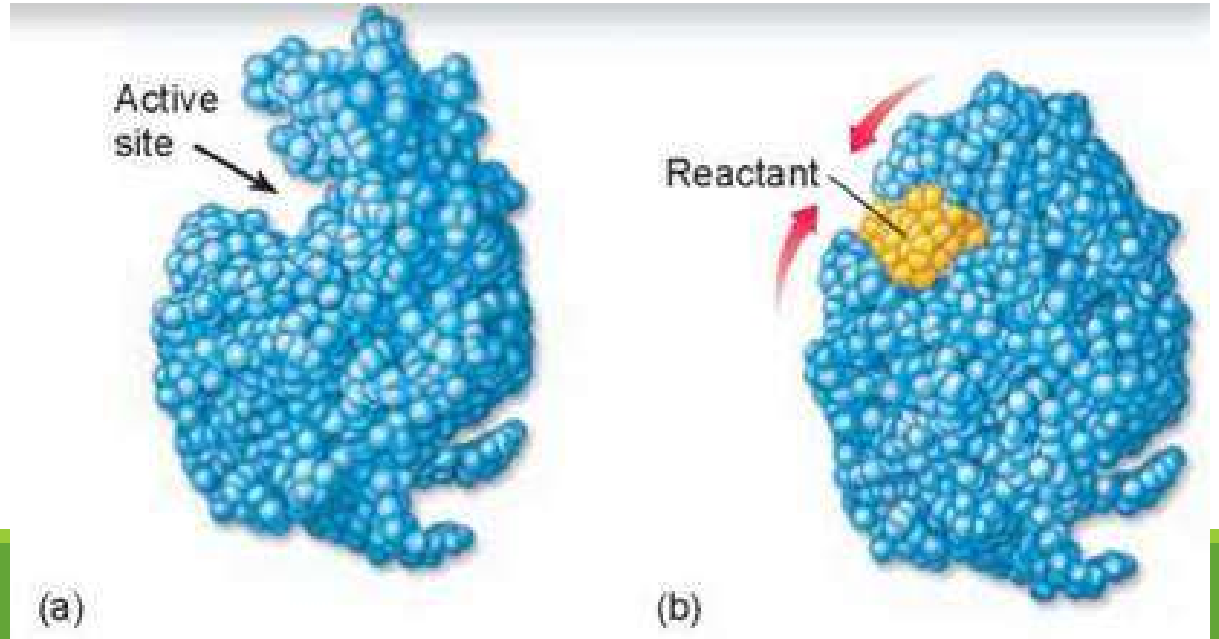
- This forms the enzyme substrate complex, **seemingly like a key fits a lock.**

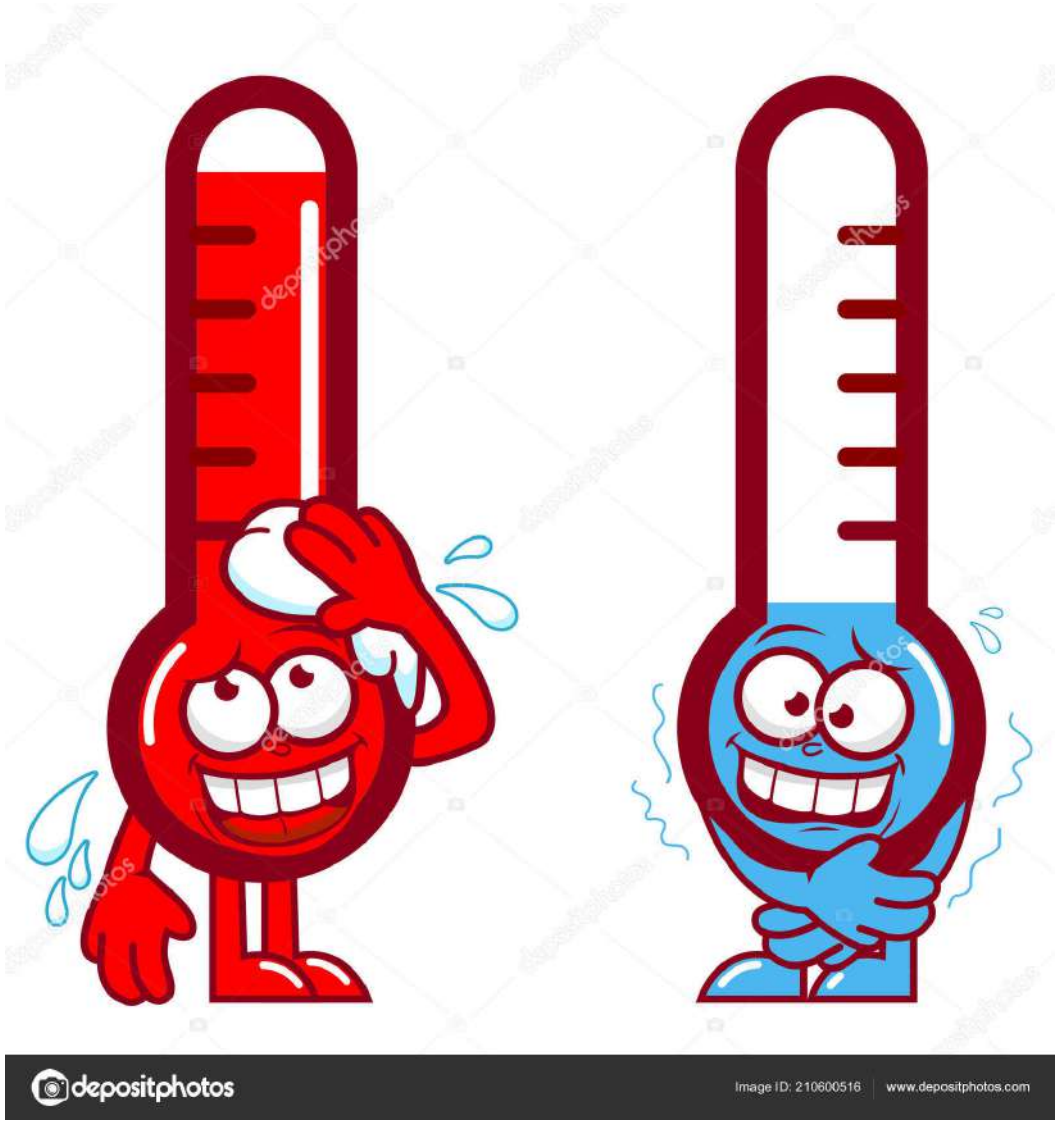
However, cell biologists now know that the active site **undergoes a slight change in shape to accommodate the substrate**(s).

- This is called the induced fit model, where the **enzyme alters slightly to achieve optimum fit.**


Substrate
Active site
1
2
3
4
Products
5
Enzyme
Enzyme–substrate complex
(a)

- The change in shape of the active site forms the **enzyme substrate complex.**
  - After the reaction has been completed, the product(s) is released, and **the active site returns to its original state.**
  - Some enzymes **participate in the reaction.**
  - Every reaction in a cell requires that its **specific enzyme be present.**
  - Enzymes complex only with their substrates, therefore, they are often **named for their substrate with the suffix** – ase.





Factors Affecting Enzymatic Speed

Substrate Concentration

Temperature & pH

Enzyme Activation

Enzyme Inhibition

Enzyme Cofactors

Substrate Concentration

Generally, enzyme activity increases as substrate concentration increases because there are **more collisions between substrate molecules and the enzyme.**

- When the enzyme's active sites are filled continuously with substrate, **the enzyme's rate of activity cannot increase any more.**
- The **maximum rate has been reached.**

Temperature & pH

As the temperature rises, **enzyme activity increases.**

- This occurs because higher temperatures cause **more effective collisions between enzyme and substrate.**
- If the temperature rises beyond a certain point, enzyme activity levels out and **then declines rapidly because the enzyme is denatured.**

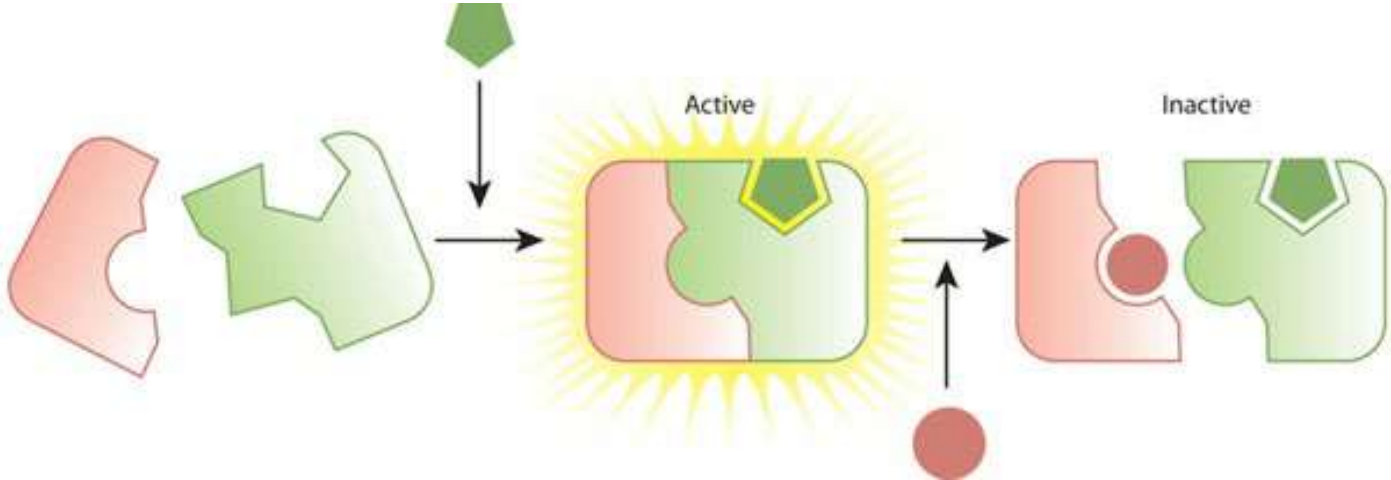
Each enzyme has an **optimal pH.**

- The globular structure of an enzyme is dependent on interactions, such as **hydrogen bonding.**
- A change in pH can alter the ionization of R groups, and **disrupt normal interactions.**
- Under extreme pH conditions, **denaturation eventually occurs.**

Enzyme Activation

Not all enzymes are needed by the cell all the time.

- Genes can be **turned on to increase the concentration of the enzyme, or turned off to decrease the concentration.**
- Enzymes can also be present in the cell in an inactive form.
- Enzyme activity in a cell often **changes in response to the action of messengers and hormones in a cell.**



Enzyme Inhibition

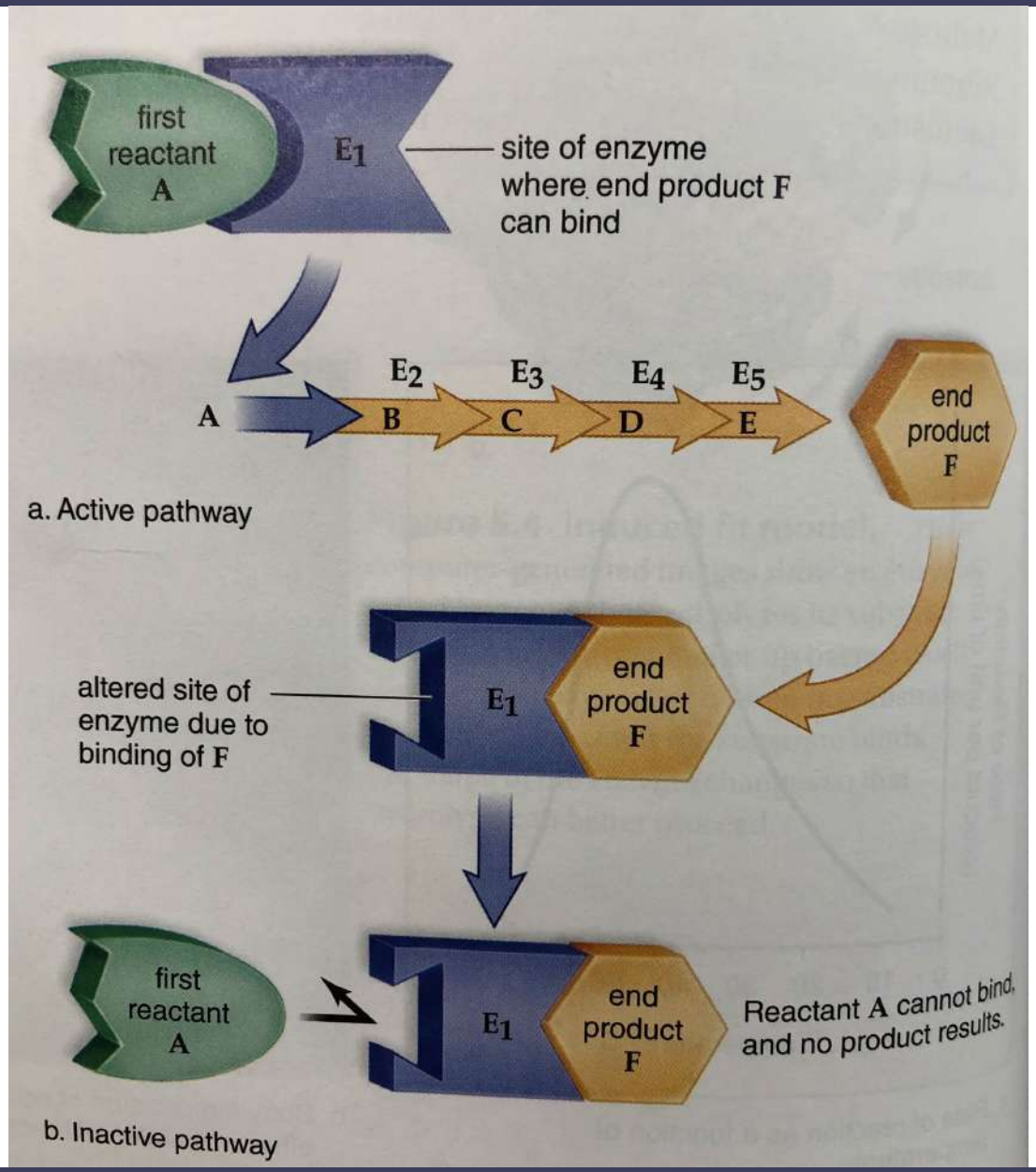
Enzyme inhibition occurs when the **substrate is unable to bind to the active site of an enzyme**. This is **competitive inhibition.**

- The activity of almost every enzyme is regulated by **feedback inhibition.**
- For example, when there is plenty of product, it binds to the enzyme's active site, and **the substrate is unable to bind.**

Most metabolic pathways are regulated by **non-competitive inhibition.**

- The **end product binds to a site other than the active site of the enzyme and changes the shape of the active site**, preventing the substrate to bind to the enzyme.

Poisons are often inhibitors.

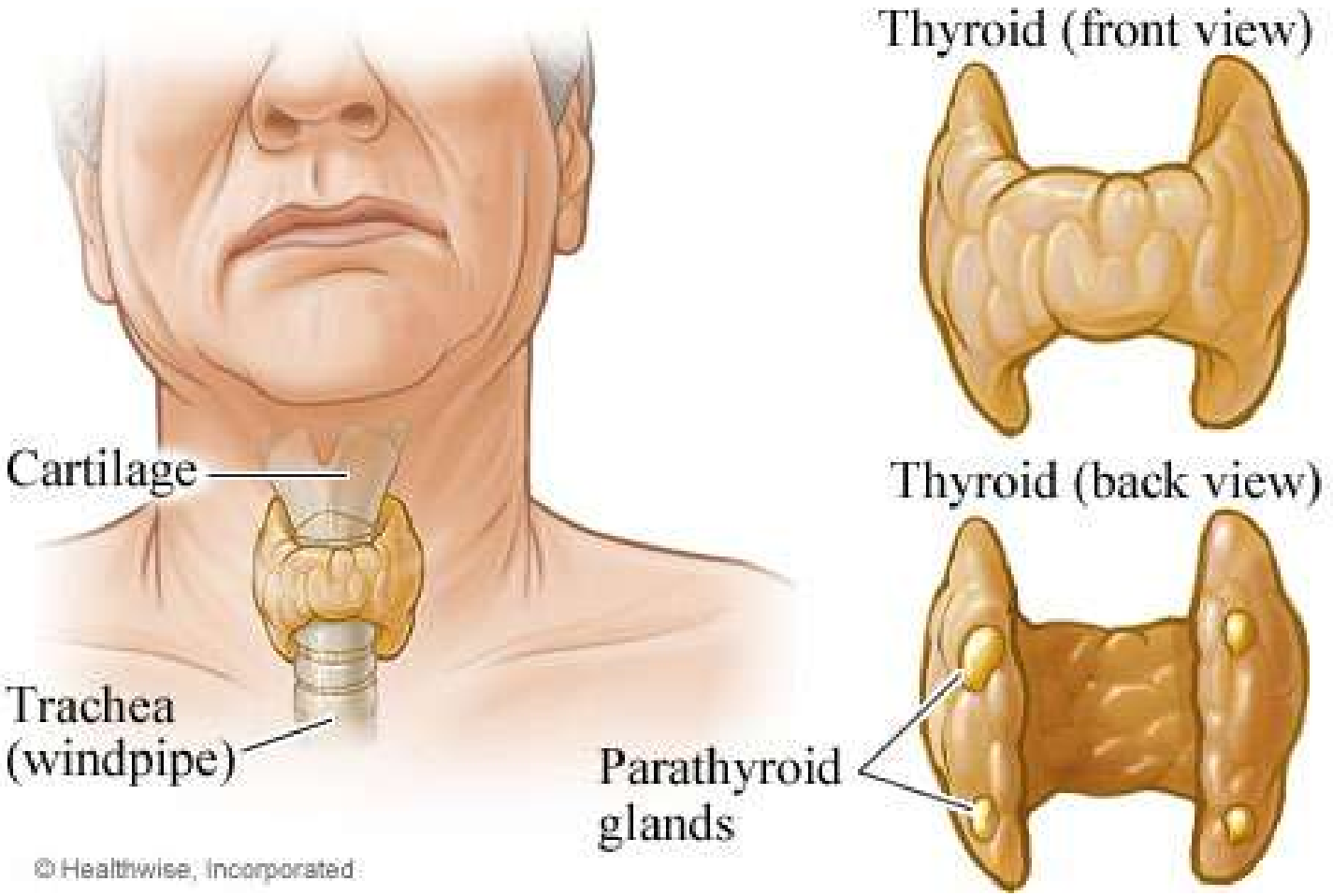

first reactant A
E1
site of enzyme where end product F can bind
A
E2
B
E3
C
E4
D
E5
E
end product F
a. Active pathway
altered site of enzyme due to binding of F
E1
end product F
first reactant A
E1
end product F
Reactant A cannot bind, and no product results.
b. Inactive pathway

Enzyme Cofactors

Many enzymes require an **inorganic ion or an organic nonprotein, helper to function properly.**

- These helpers are called **cofactors.**
- The organic nonprotein molecules are called **coenzymes.**
- **Vitamins** are often components of coenzymes.
- We acquire vitamins in our diets.
- **A deficiency of any particular vitamin can result in a lack of coenzyme**, and therefore a lack of certain enzymatic actions.
- For example a lack of vitamin C can result in scurvy.

4.3 – METABOLIC RATE AND THE THYROID AND PARATHYROID GLANDS



The thyroid gland is a large gland **located in the neck.**

The parathyroid glands are **embedded behind the thyroid gland.**

Thyroid Gland

The thyroid gland contains a large number of follicles, these produce **triiodothyronine (T3), and thyroxine (T4).**

- To produce T3 and T4, the thyroid gland actively **acquires iodine from the bloodstream.**
- The thyroid hormones T3 and T4, increase the metabolic rate.
- They stimulate most cells of the body to **metabolize more glucose and use more energy.**
- The liver is able to convert most of the T4 into T3 because the **thyroid produces too much of it.**

The thyroid gland also produces a hormone called calcitonin, which **helps control blood calcium levels.**

Calcium plays a significant role in many processes including **nerve conduction, muscle contraction, and blood clotting.**

The thyroid gland secretes calcitonin when blood calcium levels rise.

- The primary effect of calcitonin is to **deposit calcium in the bones.**

Parathyroid Glands

Years ago, the parathyroid glands were sometimes mistakenly removed during thyroid surgery because they are so small.

Parathyroid hormone (PTH) causes the blood phosphate level to decrease and the **blood calcium level to increase.**

- PTH promotes the activity of bone cells and the **release of calcium from the bones.**
- PTH also promotes the reabsorption of calcium by the kidneys, which activates vitamin D, which in turn **stimulates the absorption of calcium from the intestines.**