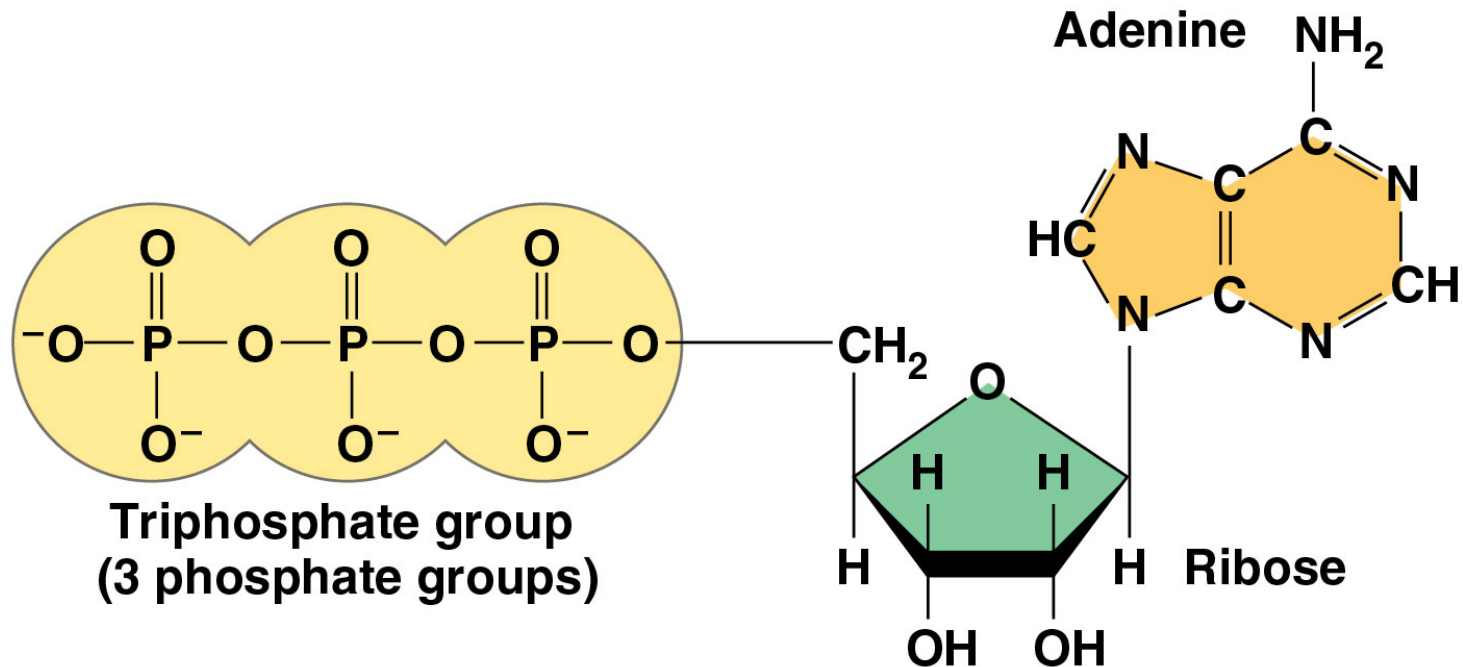


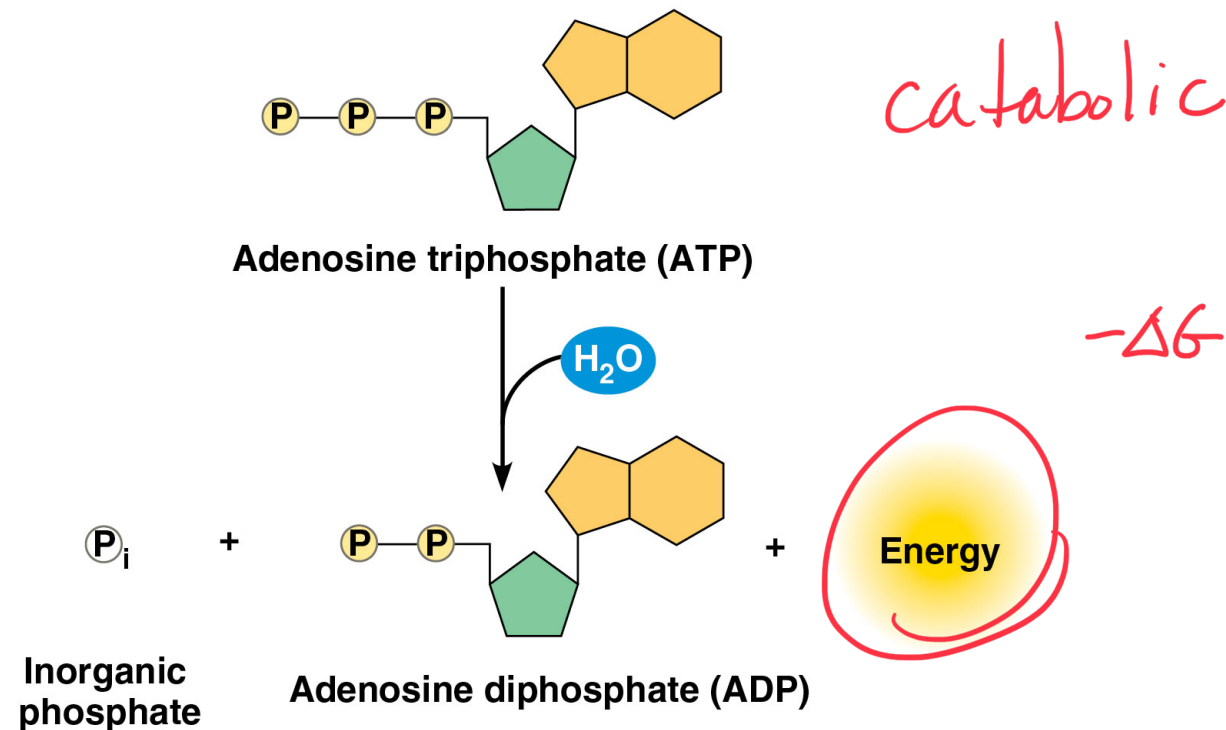
- **ATP** (adenosine triphosphate) is the cell's main energy source in energy coupling
- ATP = adenine + ribose + 3 phosphates



(a) The structure of ATP



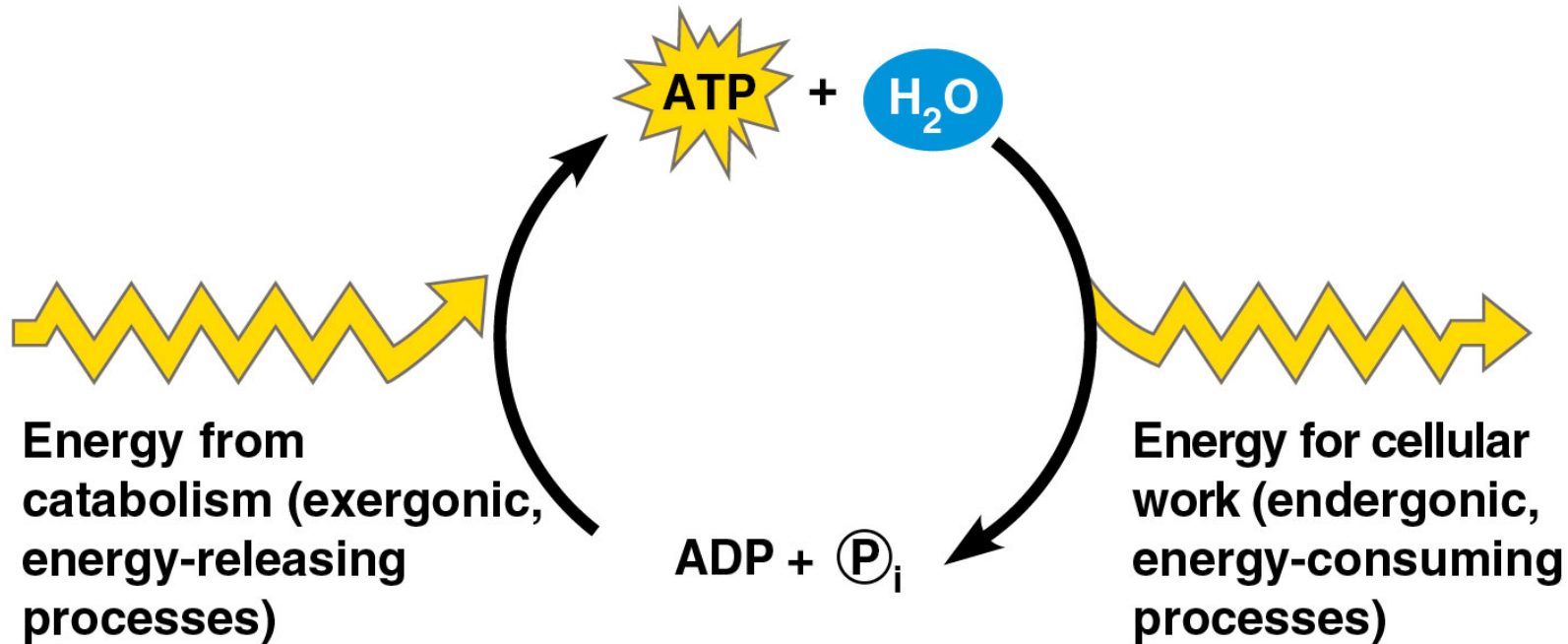
- When the bonds between the phosphate groups are broken by **hydrolysis** → **Energy is released**
- This release of energy comes from the **chemical change to a state of lower free energy**, not in the phosphate bonds themselves



(b) The hydrolysis of ATP

# HOW ATP PERFORMS WORK

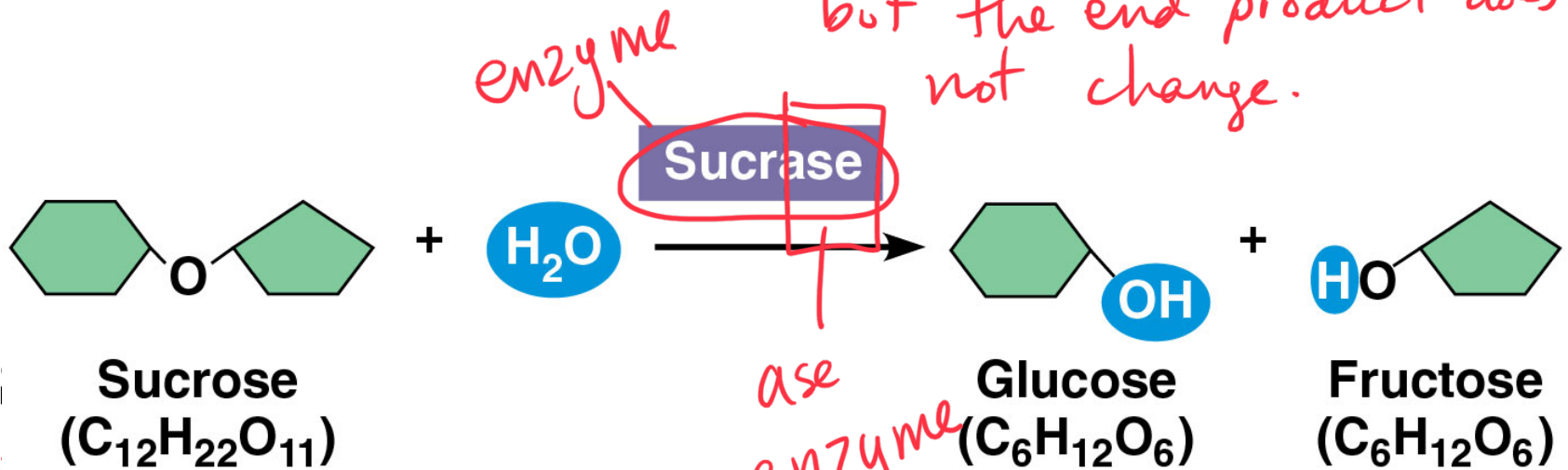
- *Exergonic* release of  $P_i$  is used to do the *endergonic* work of cell
- When ATP is hydrolyzed, it becomes ADP (adenosine diphosphate)



○ **Catalyst**: substance that can change the rate of a reaction without being altered in the process

○ **Enzyme** = biological catalyst

↳ speeds up the reaction but the end product does not change.



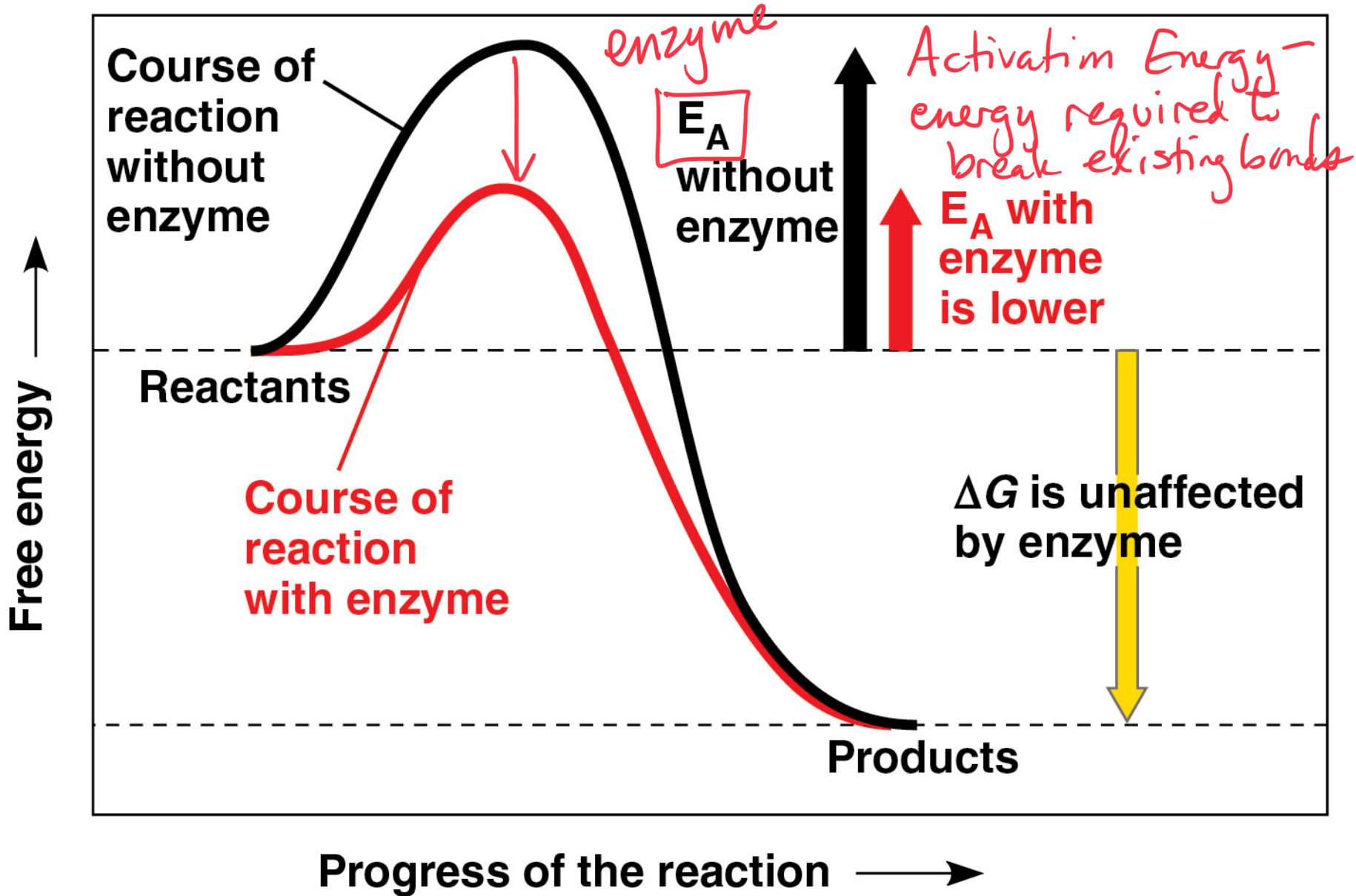
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breaking bonds)

amylase → cuts amylose

lipase → cuts lipids  
phospholipase

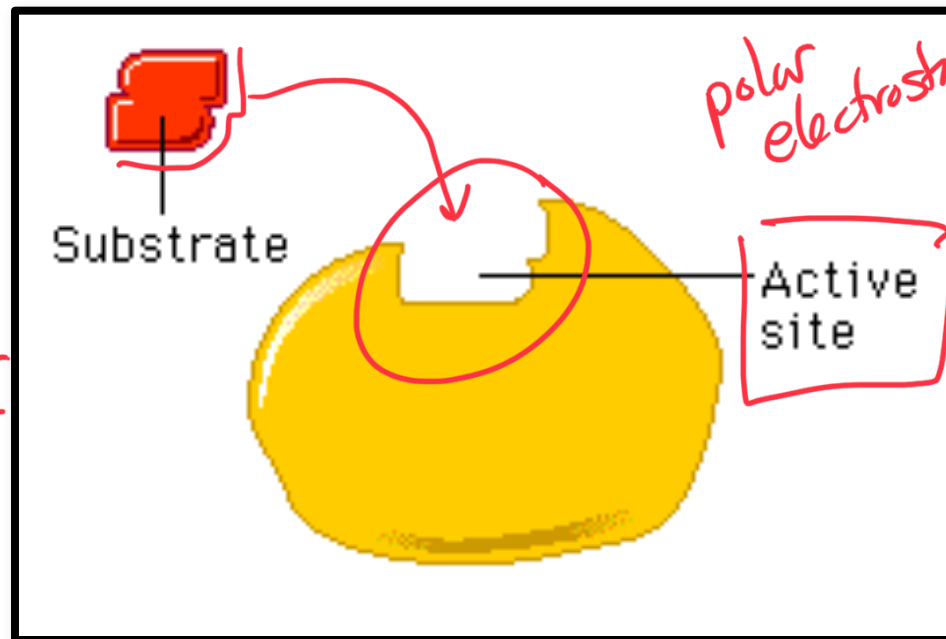




# SUBSTRATE SPECIFICITY OF ENZYMES

- The reactant that an enzyme acts on is called the enzyme's **substrate**
- The enzyme binds to its substrate, forming an **enzyme-substrate complex**
- The **active site** is the region on the enzyme where the substrate binds

Active site is buried deep in the enzyme.  
"quiet" - nonpolar



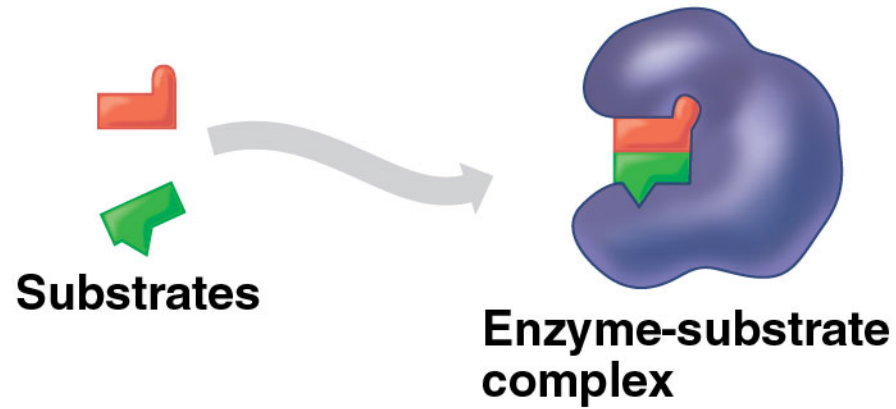
polar  
electrostatic

where the  
reaction  
takes place

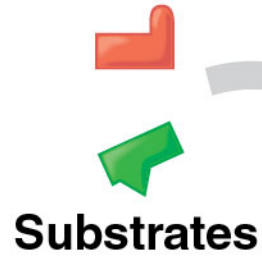


**1** Substrates enter active site.

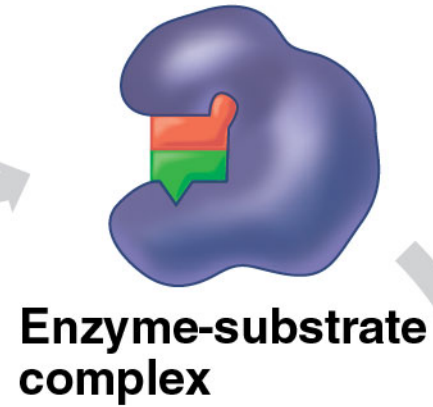
**2** Substrates are held in active site by weak interactions.



**1** Substrates enter active site.



**2** Substrates are held in active site by weak interactions.



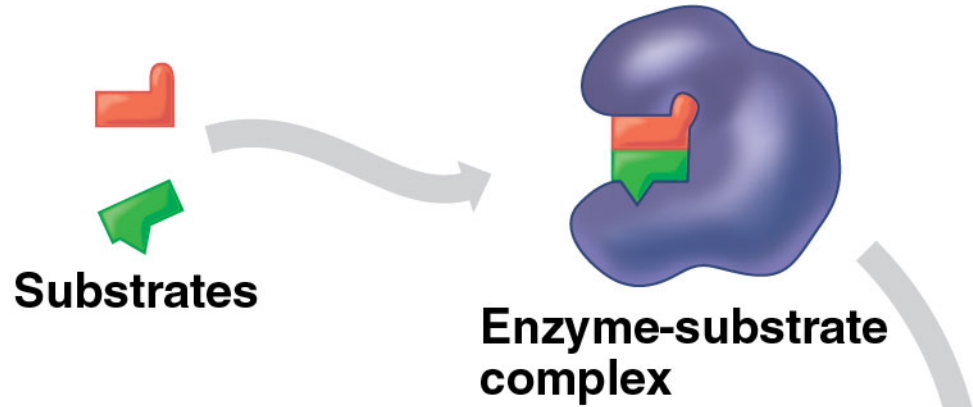
**3** Substrates are converted to products.





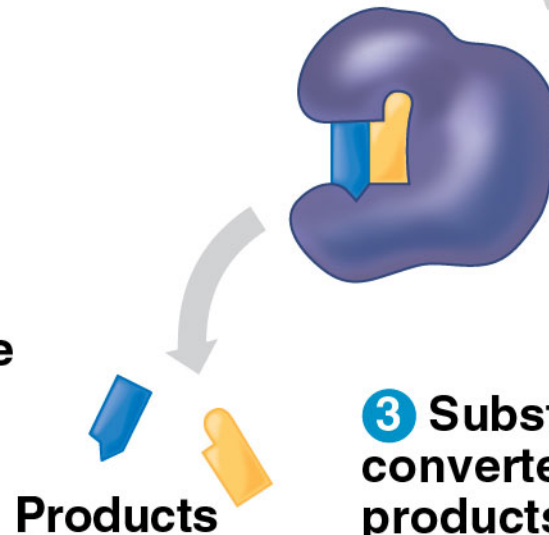
**1** Substrates enter active site.

**2** Substrates are held in active site by weak interactions.



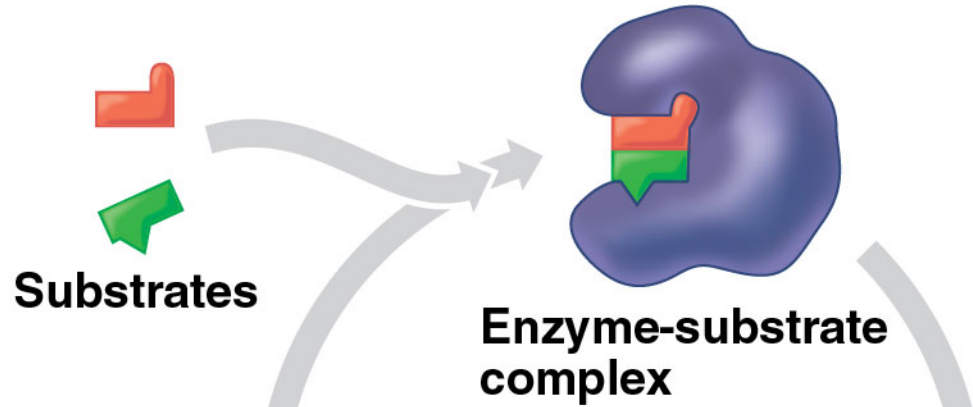
**4** Products are released.

**3** Substrates are converted to products.



**1** Substrates enter active site.

**2** Substrates are held in active site by weak interactions.



Substrates

Enzyme-substrate complex

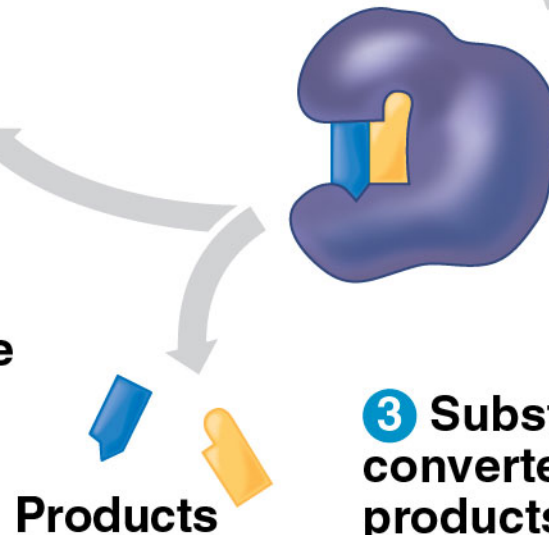
**5** Active site is available for new substrates.



Enzyme

*enzyme must be regenerated*

**4** Products are released.



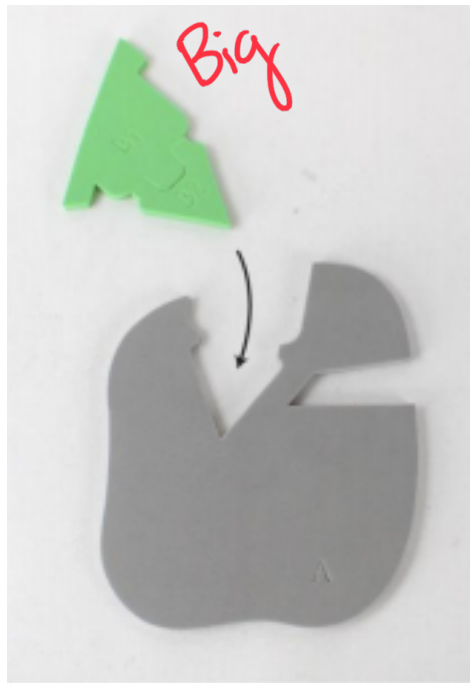
Products

**3** Substrates are converted to products.



# ENZYMES ACTION: CATABOLISM

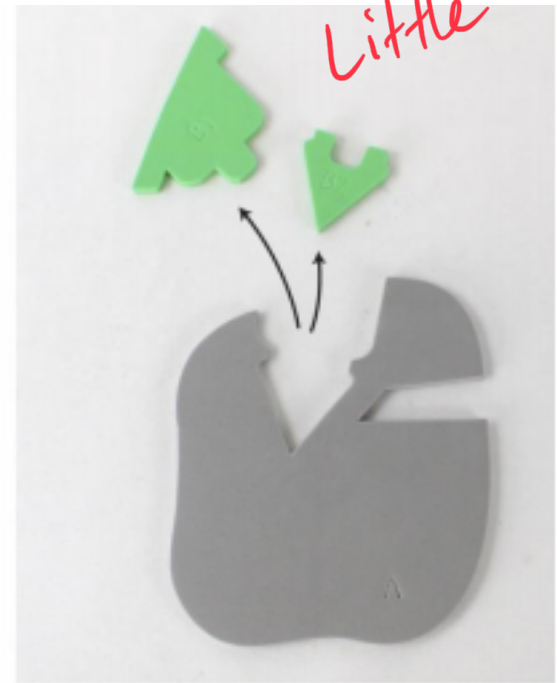
catabolic energy released



Step 1



Step 2



Step 3



# ENZYME ACTION:

## ANABOLISM

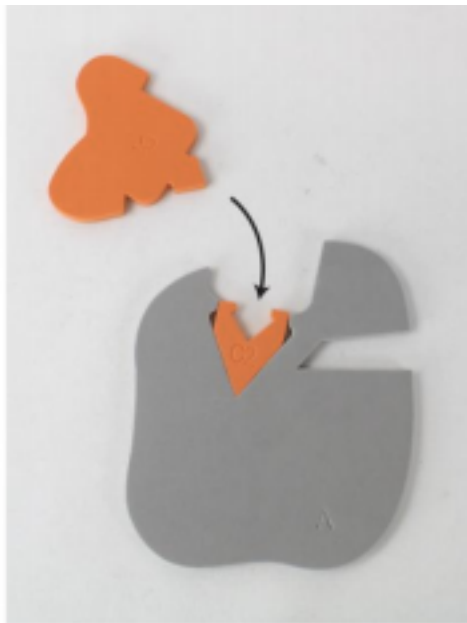
Absorb energy

+ΔG

Big



Step 1



Step 2



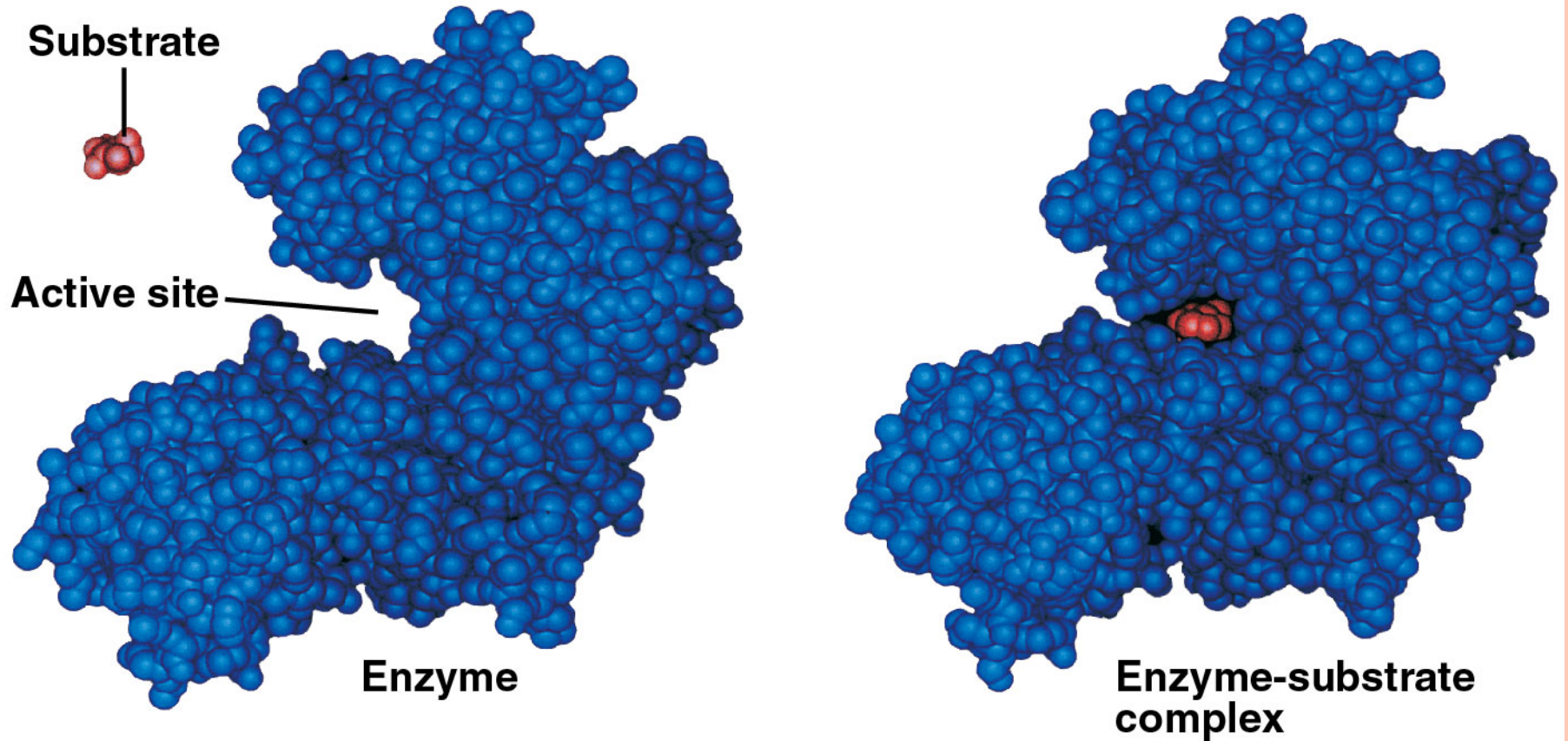
Step 3



Step 4



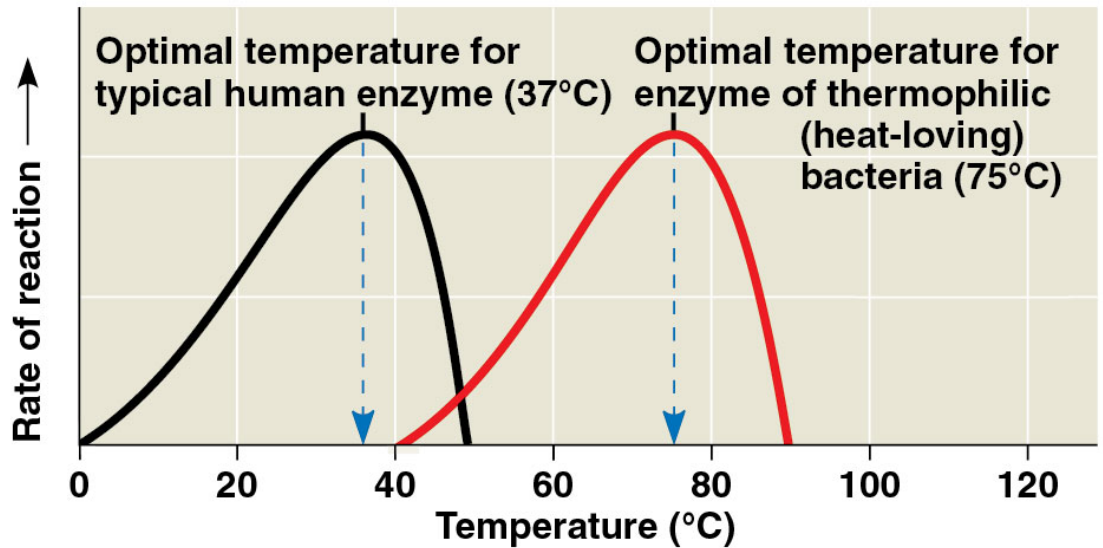
**INDUCED FIT:** ENZYME FITS SNUGLY AROUND  
SUBSTRATE -- “CLASPING HANDSHAKE”



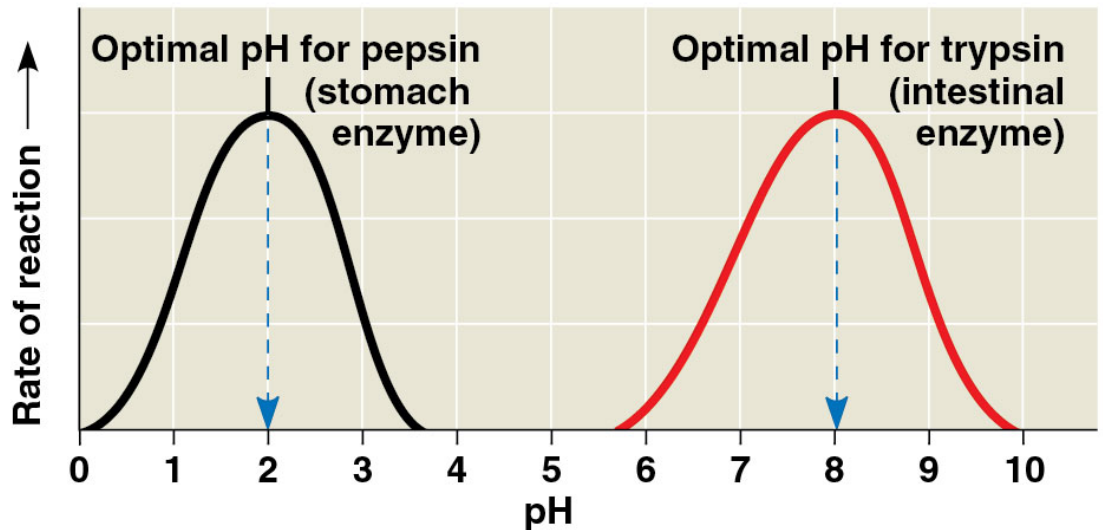
An enzyme's activity can be affected by:

- Temperature ✓
- pH ✓
- Chemicals

denatured



(a) Optimal temperature for two enzymes



(b) Optimal pH for two enzymes

# ENZYME STRUCTURE & FUNCTION

- Change to the **molecular structure** of a component in an enzymatic system may result in a change of **function** or **efficiency** of the system
- **Denaturation**: disrupt protein structure  
→ reduce enzymatic activity
- **Environmental pH**: alter efficiency of enzyme activity; disruption of H-bonds
- In some cases, enzyme denaturation is *reversible* → enzyme regains activity



# COFACTORS

- Cofactors: nonprotein enzyme helpers such as minerals (eg. Zn, Fe, Cu)
- Coenzymes: organic cofactors (eg. vitamins)

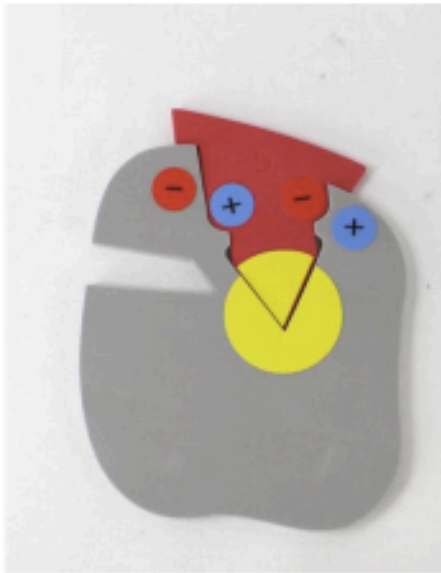
## Enzyme Inhibitors

- Competitive inhibitor: binds to the *active site* of an enzyme, competes with substrate
- Noncompetitive inhibitor: binds to *another part* of an enzyme → enzyme changes shape → active site is **nonfunctional**

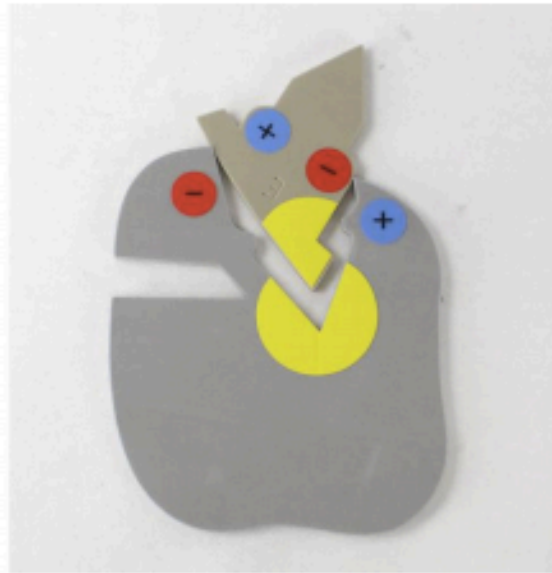




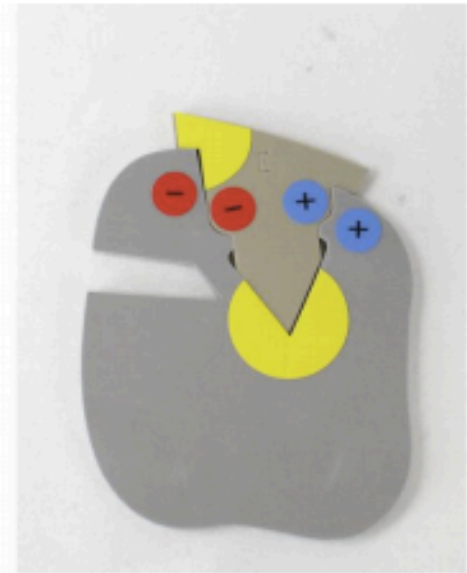
# ENZYME SPECIFICITY



**Figure 1:** Enzyme-substrate complex



**Figure 2:** The charges align between the enzyme and the substrate; however, the enzyme's shape will not "fit".



**Figure 3:** The shape of the substrate appears to fit but the charges do not align in the active site of the enzyme.

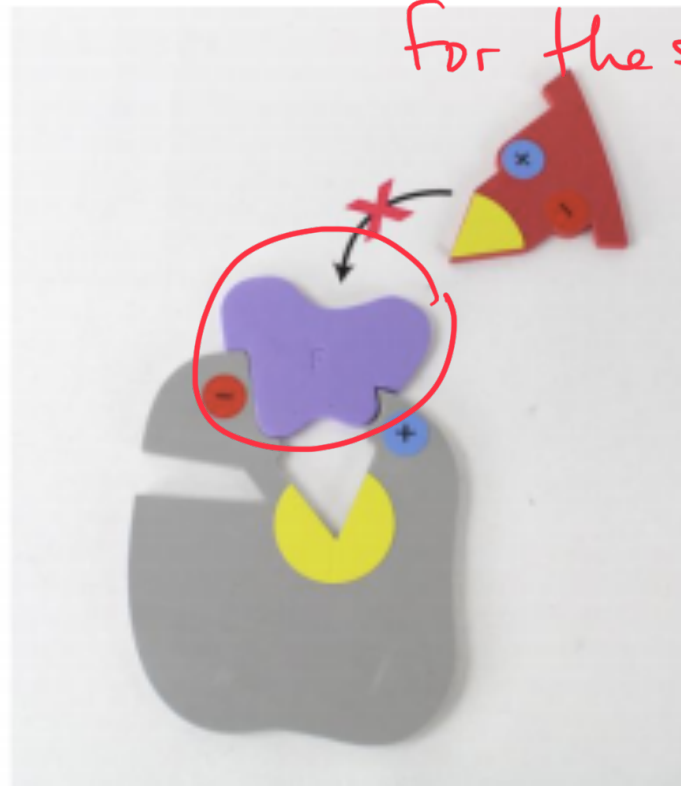
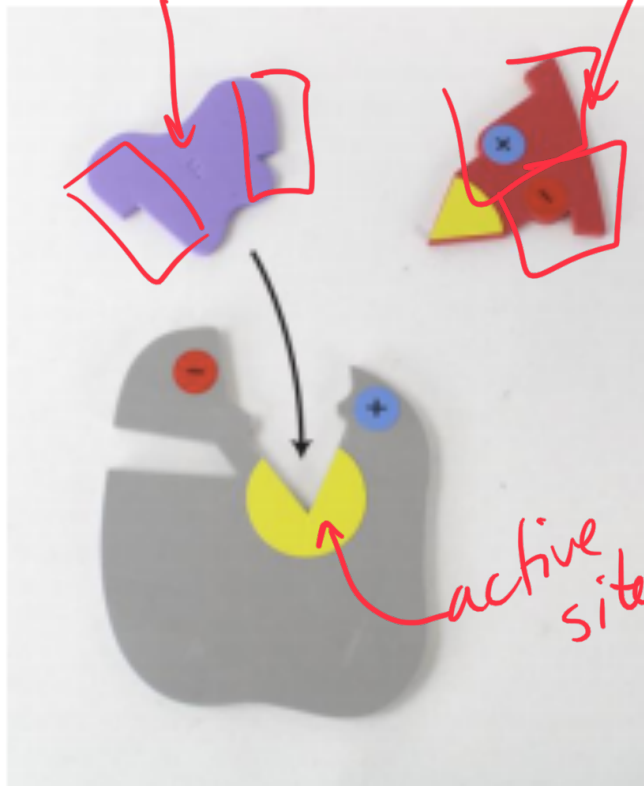


# COMPETITIVE INHIBITION

inhibitor

substrate

competitive inhibitor  
is an analog  
for the substrate

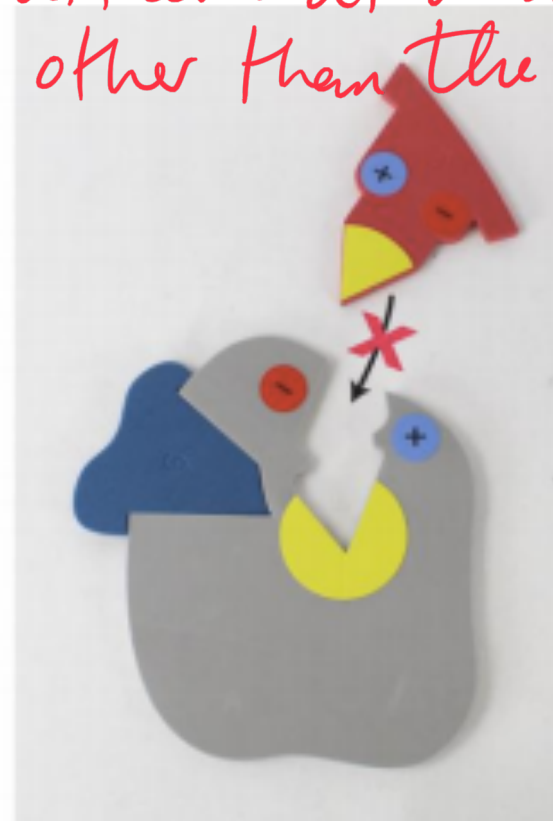


same  
shape



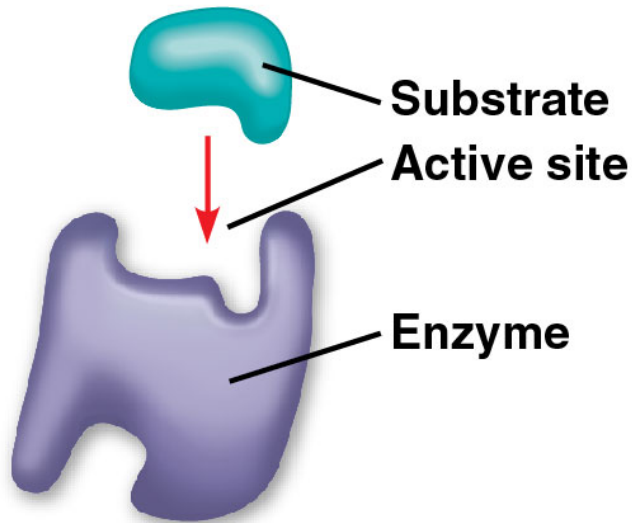
# NONCOMPETITIVE INHIBITION

*not same shape,  
attaches at a site  
other than the active  
site*

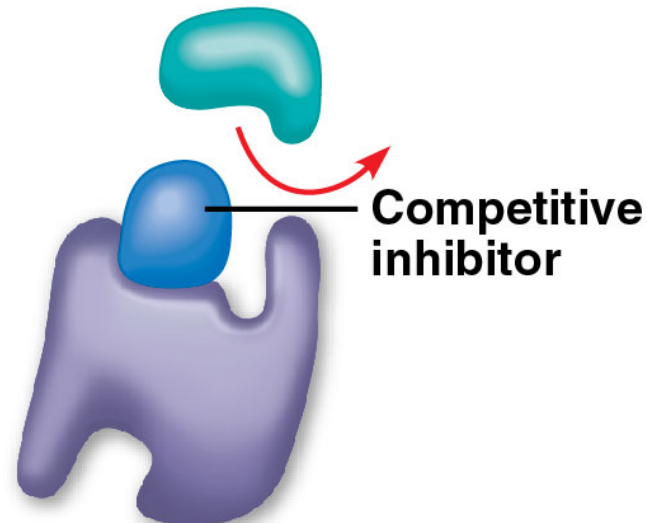


# INHIBITION OF ENZYME ACTIVITY

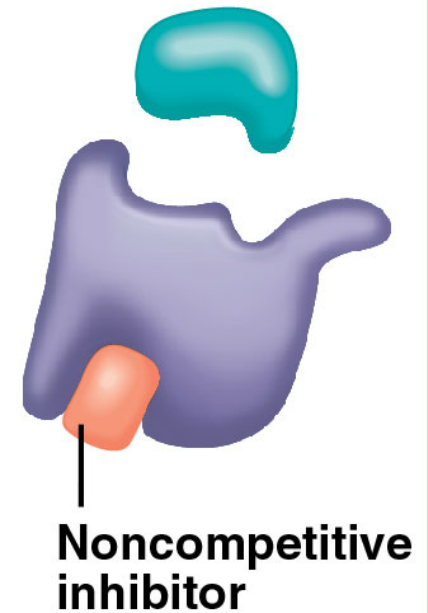
(a) Normal binding



(b) Competitive inhibition



(c) Noncompetitive inhibition

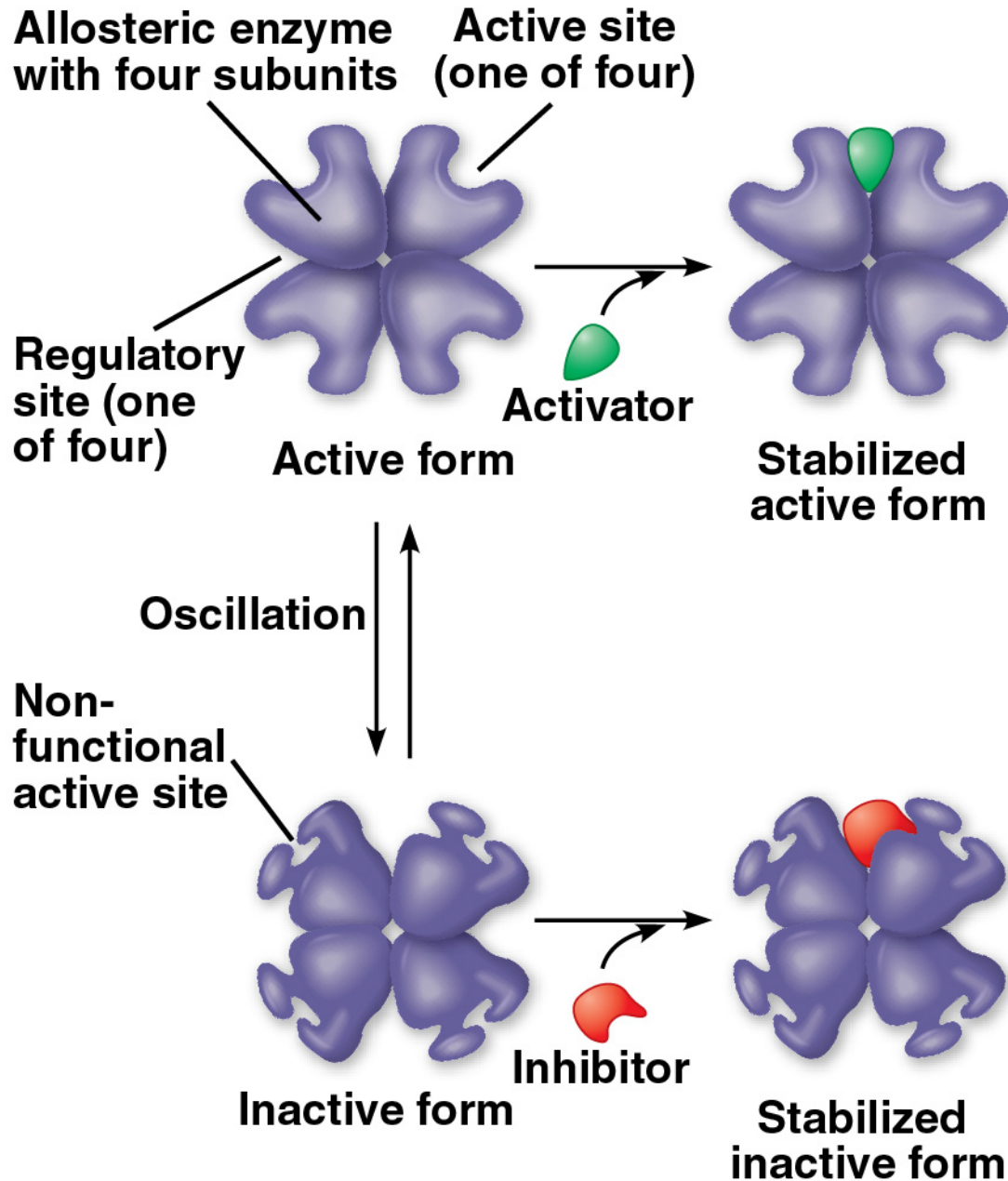


# REGULATION OF ENZYME ACTIVITY

- To regulate metabolic pathways, the cell switches on/off the genes that encode specific enzymes
- **Allosteric regulation**: protein's function at one site is affected by binding of a **regulatory molecule** to a separate site (allosteric site)
  - **Activator** – stabilizes active site
  - **Inhibitor** – stabilizes inactive form
  - **Cooperativity** – one substrate triggers shape change in other active sites → increase catalytic activity

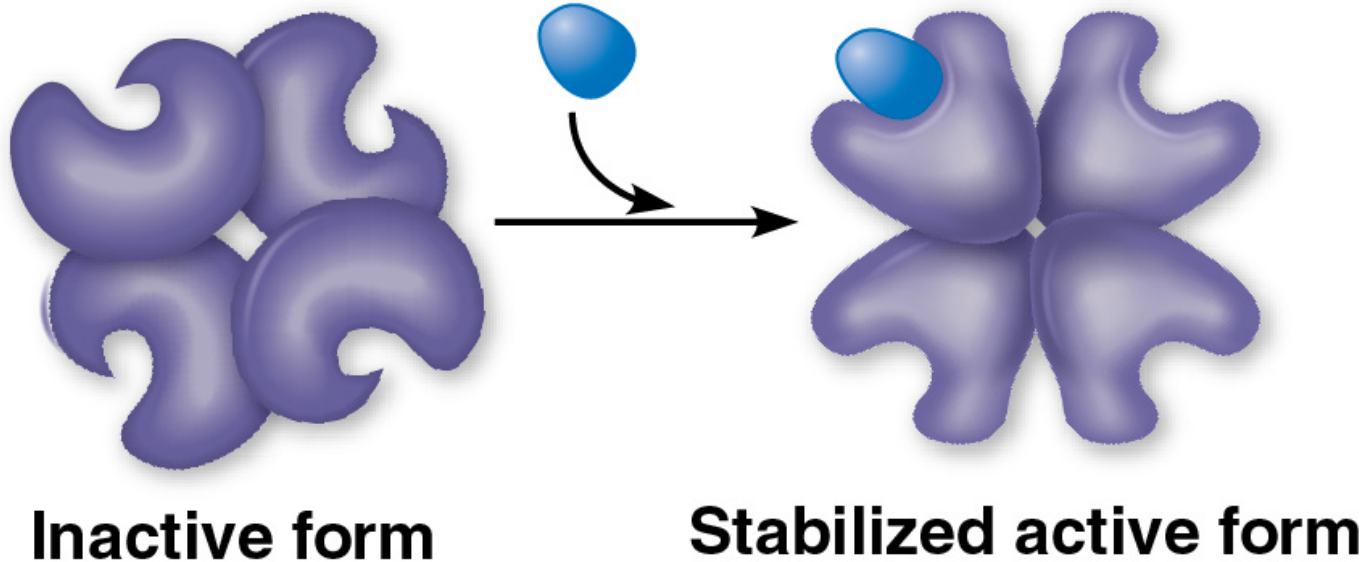


# (a) Allosteric activators and inhibitors



**(b) Cooperativity: another type of allosteric activation**

**Substrate**



# *FEEDBACK INHIBITION*

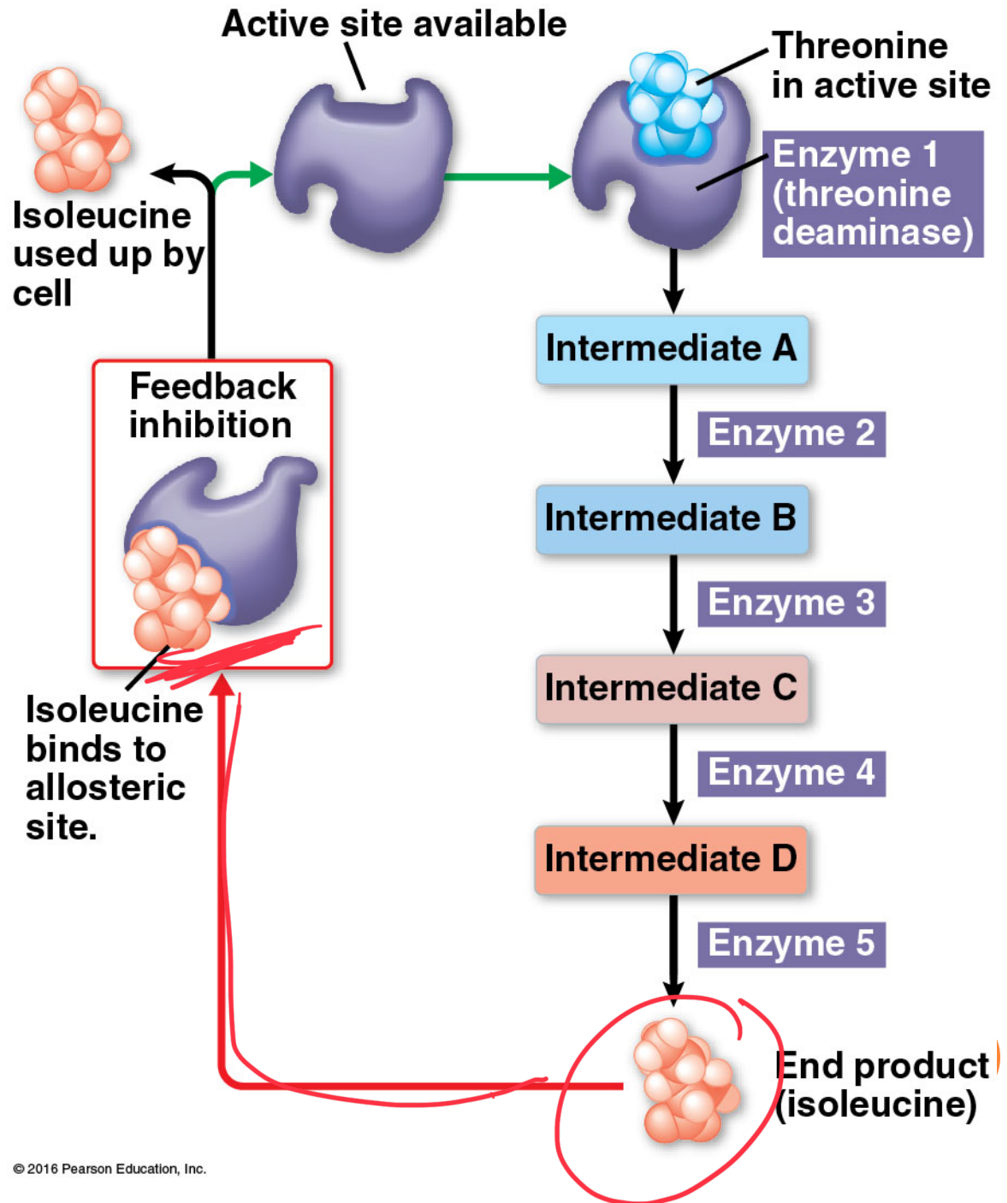
- End product of a metabolic pathway shuts down pathway by binding to the allosteric site of an enzyme
- Prevent wasting chemical resources, increase efficiency of cell



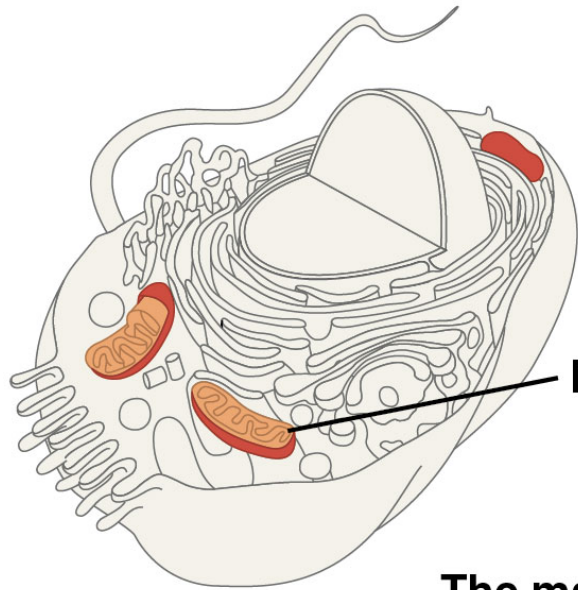


# FEEDBACK INHIBITION

*conserve energy*



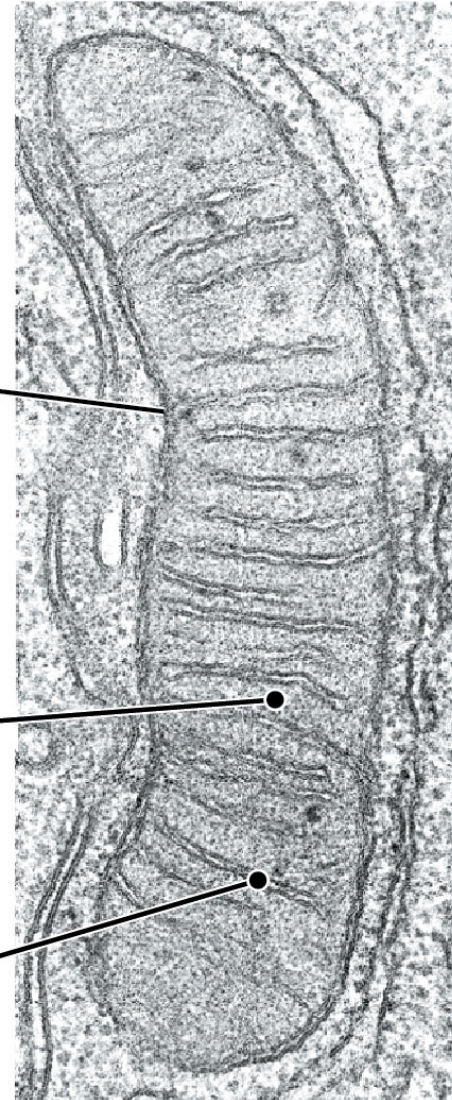
# ORGANIZATION OF ENZYMES WITHIN A CELL



Mitochondrion

The matrix contains enzymes in solution that are involved in one stage of cellular respiration.

Enzymes for another stage of cellular respiration are embedded in the inner membrane.



1  $\mu\text{m}$

