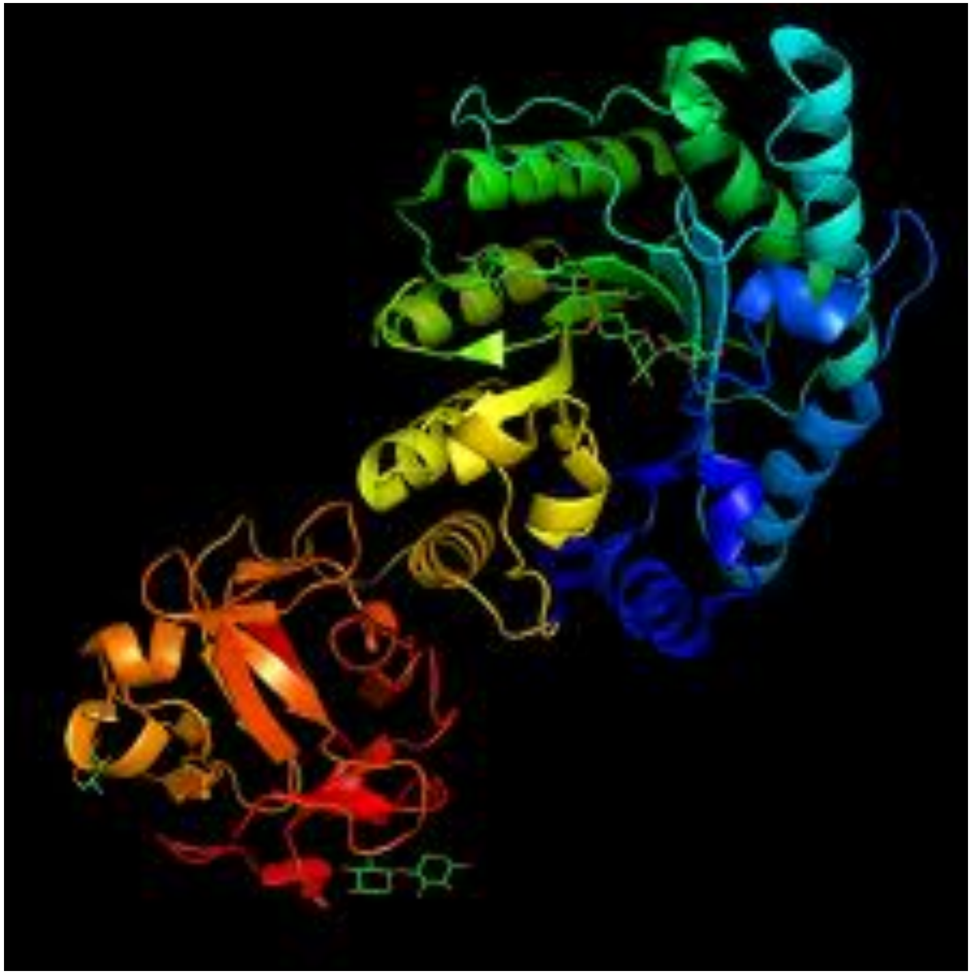
Enzymes



Enzymes: Important Terminology

I. **Metabolism** Ted-ed Speeding up Rxn’s

A. In order for cells to maintain homeostasis, they must constantly convert chemicals from one form to another, in order to produce necessary molecules, obtain usable molecules from food, and produce energy rich molecules

B. These constantly occurring chemical reactions are collectively known as metabolism

C. **METABOLISM** a term to collectively describe **all** the **chemical reactions** occurring constantly in the cell that maintain **homeostasis** in a cell or organism

D. **METABOLIC PATHWAYS** are the orderly **step-wise** series of chemical reactions from the **initial** reactants to the **final** products

E. One reaction **leads** to the next; highly **structured reaction**

F. Ex. **photosynthesis, cellular respiration**

G. It is controlled by **enzymes**

1. Each **step** (i.e. each chemical reaction) within the metabolic pathway requires a **specific enzyme**

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6	
A	→	B	→	C	→	D	→	E	→	F	→	G
Reactant	Enz. 1		Enz. 2		Enz. 3		Enz. 4		Enz. 5		Enz. 6	Product

H. There are reasons why metabolic pathways exist:

1. **It is not possible in biological systems to have a single reaction that could produce complex molecules from simple reactants**

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

would never happen in a cell in one step (photosynthesis requires many intermediate steps)

2. One pathway can lead to several others.

a. intermediate products of one pathway can be starting reactant for another pathway

b. Ex. A → B C
D

3. Having more than one step means that there are more places where the overall reaction can be controlled

				β		Y	→	Z	→	AA	→	BB
				↑		↑						
				α		X						
				↑		↑						
		A	→	B	→	C	→	D	→	E		
		↓						↓		↓		
		L	←	φ	←	δ	←	H		Q		
		↓						↓		↓		
		M						I		R	→	X
		↓						↓		↑		
O	←	N	→	P	←	K	←	J	→	S		

II. Enzyme = Biological Catalysts

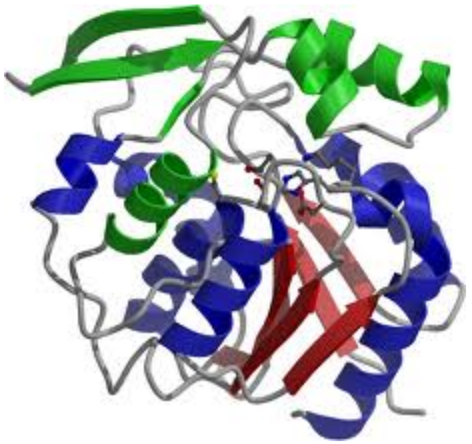
A. A protein that can speed up a chemical reaction without being consumed that speeds up a chemical reaction

B. Enzymes are the sites of chemical reactions, but aren't used up in the reaction or permanently changed by the reaction

C. E.g. They can hold reactant molecules together long enough for them to react

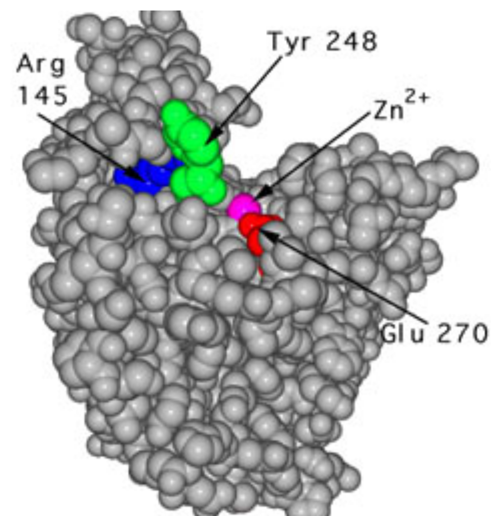
D. Enzymes are highly specific (each enzyme speeds up only one reaction)

1. Specificity arises from the protein's complex three-dimensional structure



2. No cellular reaction will occur without its specific enzyme to act as catalyst

3. Enzymes have a groove/dimple into which only specific reactant molecules may enter called the ACTIVE SITE



E. Enzyme names usually end with the suffix "ase" or sometimes "sin"

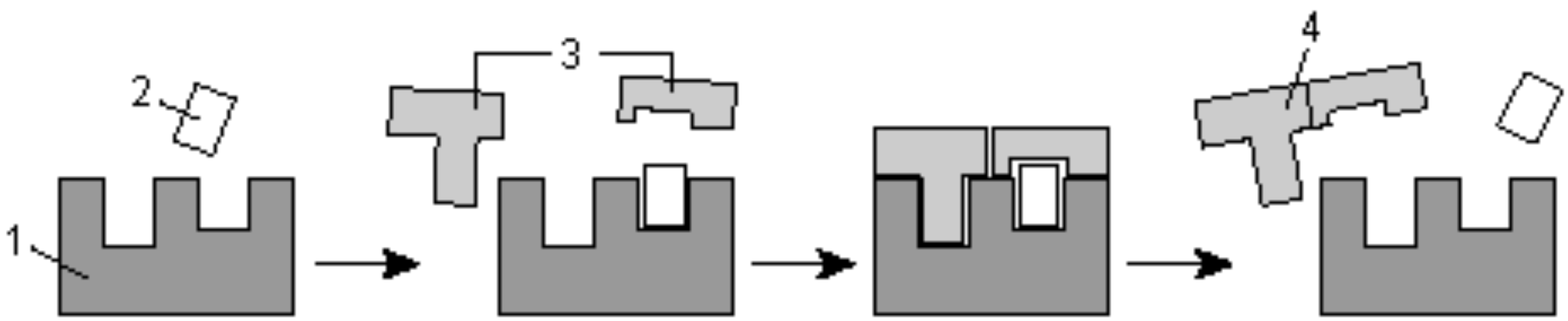
1. Named after the substrate on which the enzyme works on

   1. Ex. RNA polymerase - constructs RNA
   2. Ex. Lactase - breaks down lactose
   3. Ex. Trypsin – breaks down proteins
   4. Ex. Pepsin – breaks down proteins

F. **Substrate** is the **reactant** in an enzyme's reaction

G. The equation for an enzyme-catalyzed reaction is always:

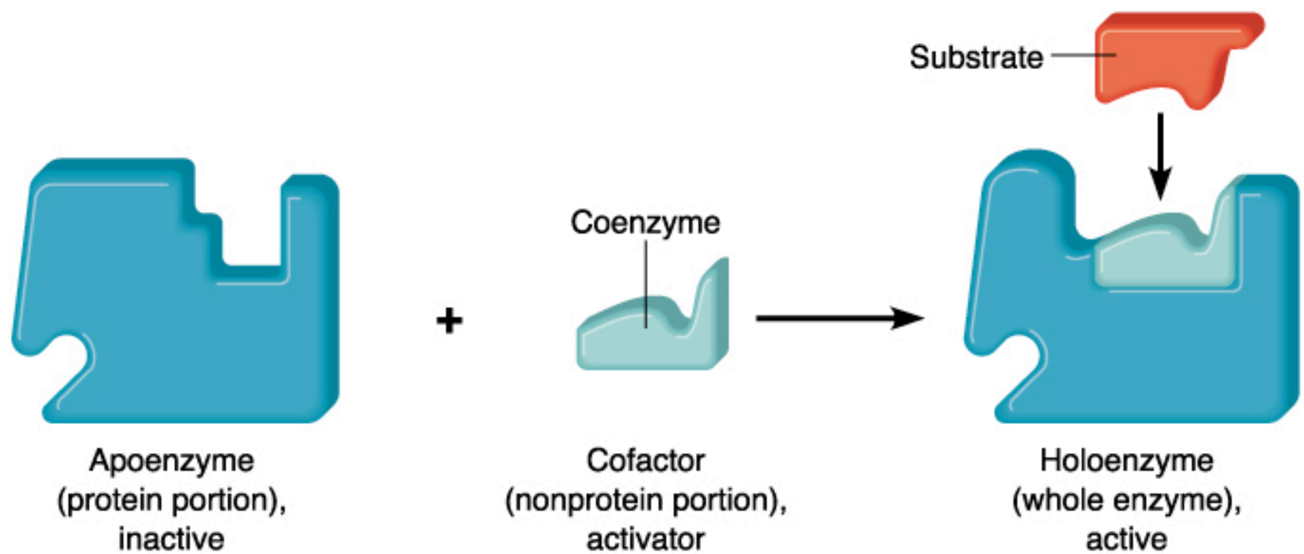
Enzyme + Substrate → Enzyme Substrate Complex →Enzyme + Product



III. What are Enzymes Made of?

A. A protein part called an APOENZYME that gives it its specificity

B. A cofactor which is a non-protein molecule or ion needed for proper enzyme function ("helpers

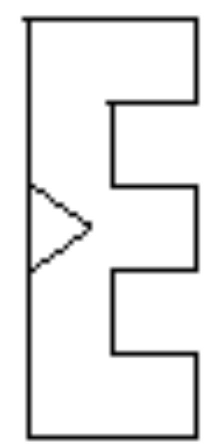


C. Coenzymes are organic cofactors

1. **Bind** to the enzyme and usually participate **directly** in the reaction

2. Are essential because they are part of a **coenzyme's structure**

Coenzyme - Enzyme Cannot Catalyze



Enzyme with Coenzyme (now active)

3. **Serve as carriers for groups of electrons**

a. **May participate in reaction by accepting or giving atoms to the reaction**

b. **Ex. NAD (nicotinamide adenine dinucleotide) is a coenzyme of many oxidation-reduction reactions**

4. **Interact with the substrate molecule**

a. **Ex. Weaken bonds in the substrate**

5. **Many water-soluble vitamins help make up parts of coenzymes**

   a. **Ex. Niacin (nicotinic acid) makes up part of coenzyme NAD^+**

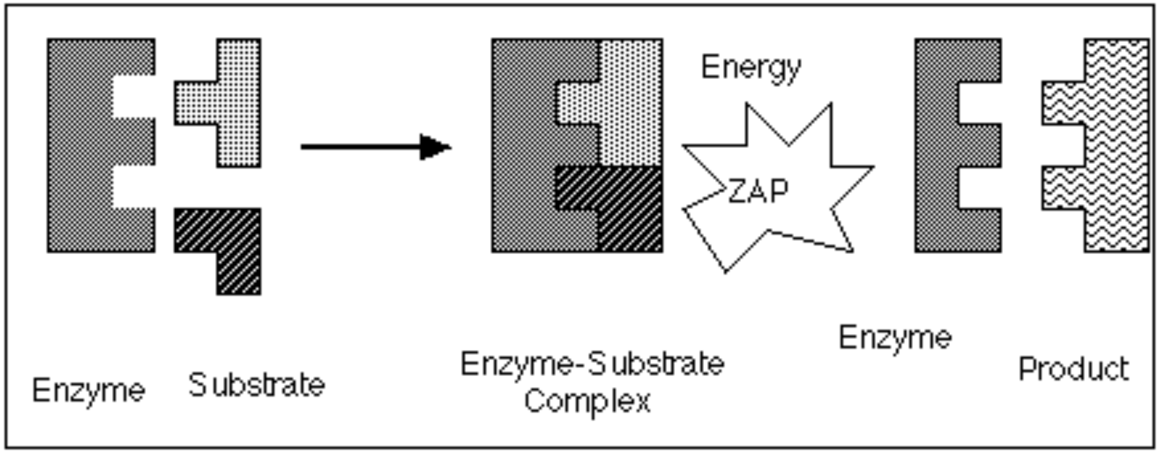
   b. **Ex. Riboflavin (vitamin B2) makes up part of coenzyme FAD**

Models: Enzyme Function

I. Lock and Key Model ANIMATION

A. The enzymes and substrate fit perfectly Together

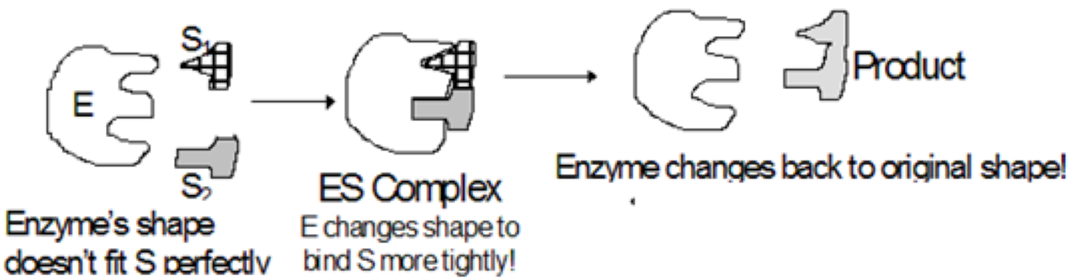
B. Only specific substrate(s) will fit into the active site, and enzymes will only act on their substrate



II. The Induced-Fit Model

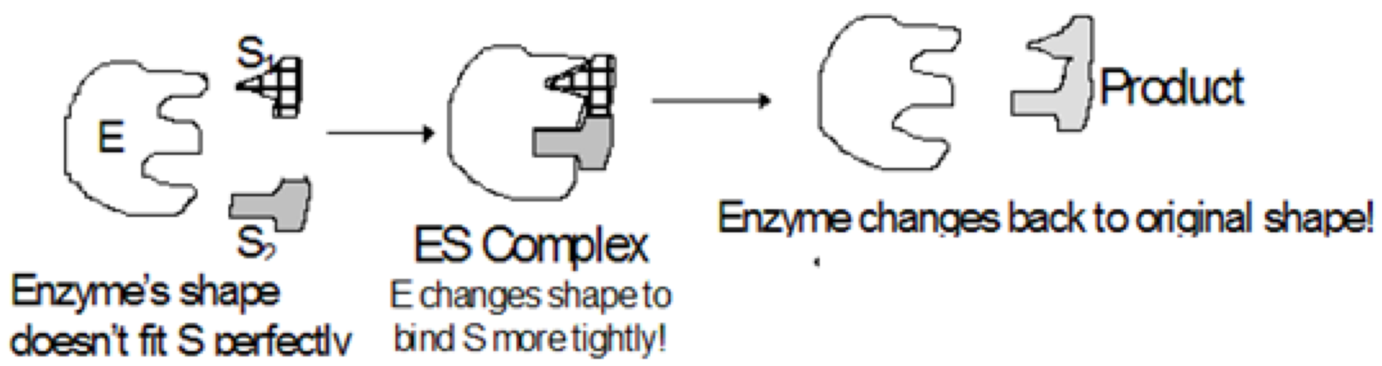
A. **Induced Fit** Model is a **refinement** of the **Lock and Key** model

B. The act of binding the substrate(s) **induces slight** changes in shape that accommodates the substrate **more** perfectly and facilitates the chemical reaction about to take place



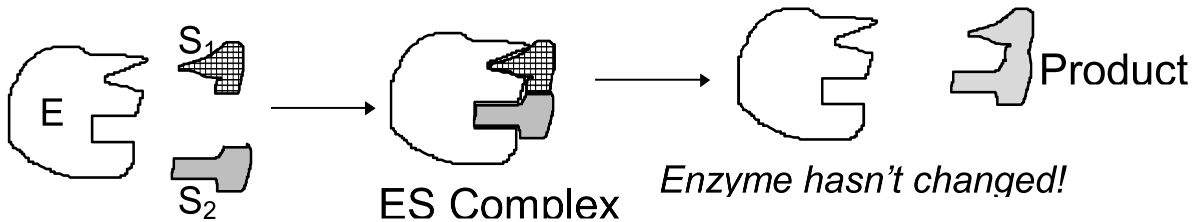
C. Upon binding, the enzyme undergoes a slight conformational change to more perfectly bind the substrates.

D. Then the reaction takes place, the enzyme-substrate complex separates, and the enzyme reassumes its original shape



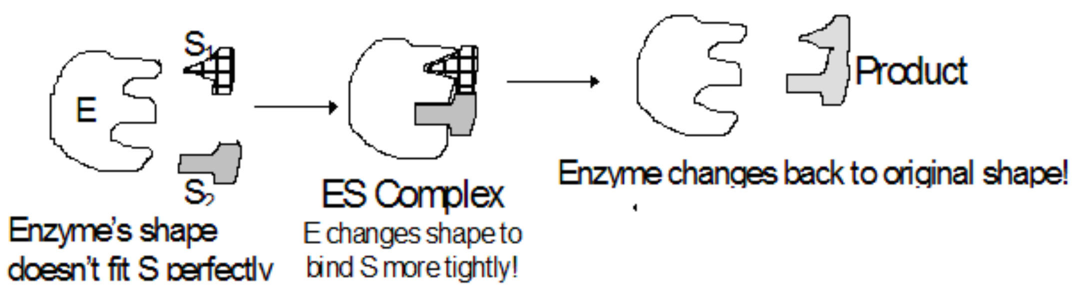
E. Lock and Key model vs. Induced Fit model

a.



ex. Lock and Key

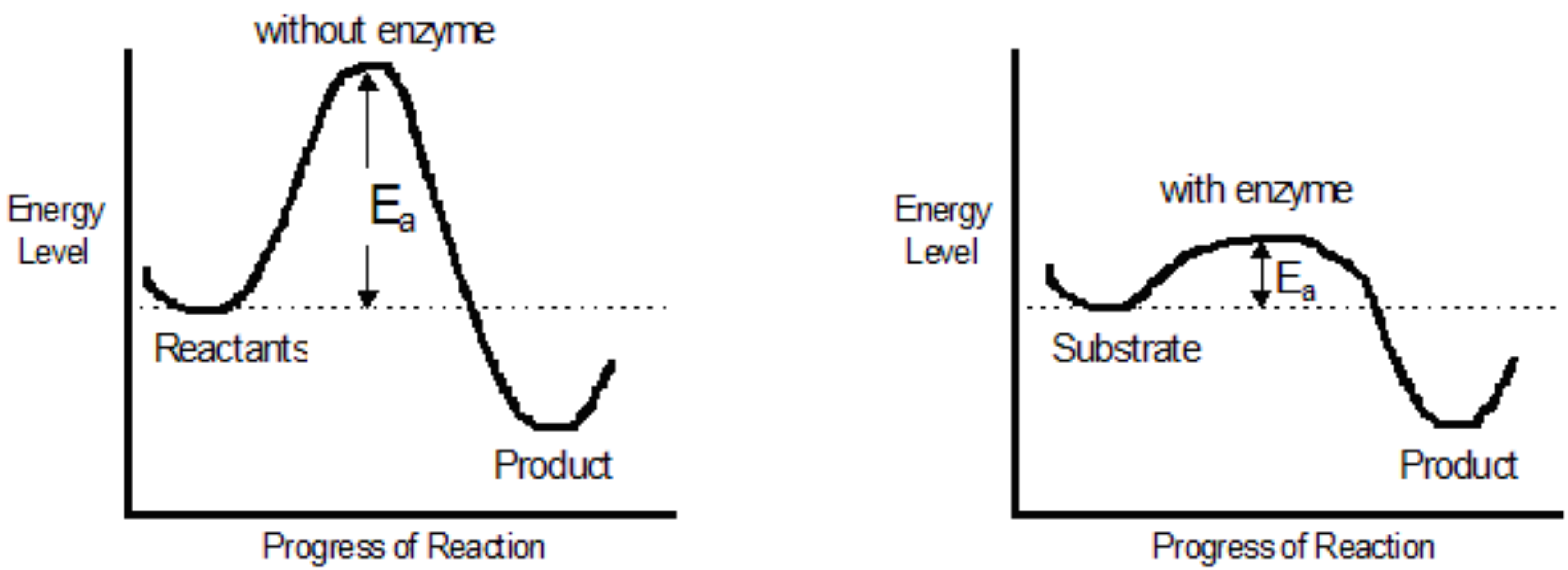
b.



ex. Induced Fit

III. How does an Enzyme Work?

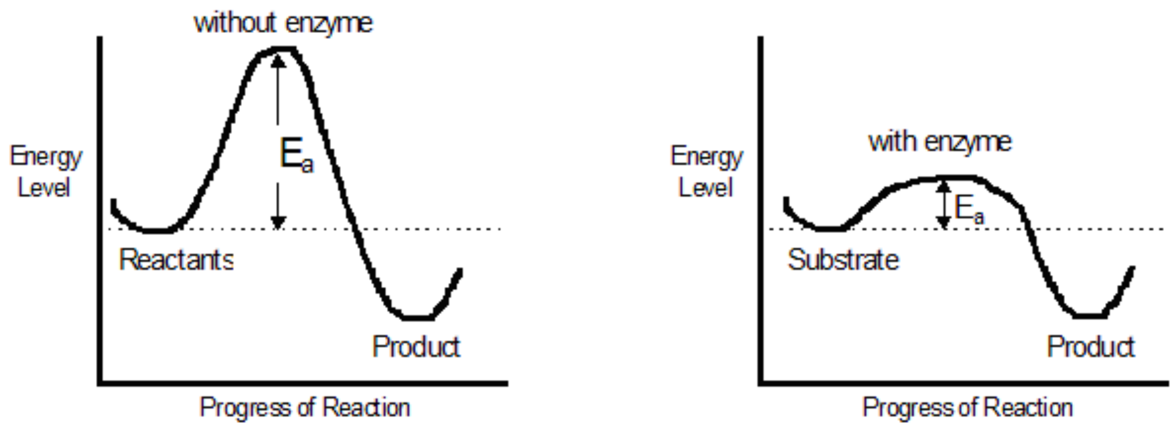
A. **Enzymes lowers the ACTIVATION ENERGY required for the reaction to proceed Ted-ed**



B. Activation Energy is defined as the energy that must be supplied to cause molecules to react with one another

C. Enzymes do this by bringing the substrate molecules together and holding them long enough for the reaction to take place

D. E.g. Reactions that occur at 100°C can occur at 37°C with the use of an enzyme



Factors Affecting Enzyme Activity

I. Enzymes are Proteins

A. Enzyme are affected by the same things that effect proteins

B. Since the shape of enzymes determines the shape of the active site, which determines their function, anything that changes the shape of an enzyme will effect the enzymatic yield.

C. **Some factors are:**

1. **pH**

2. **Temperature**

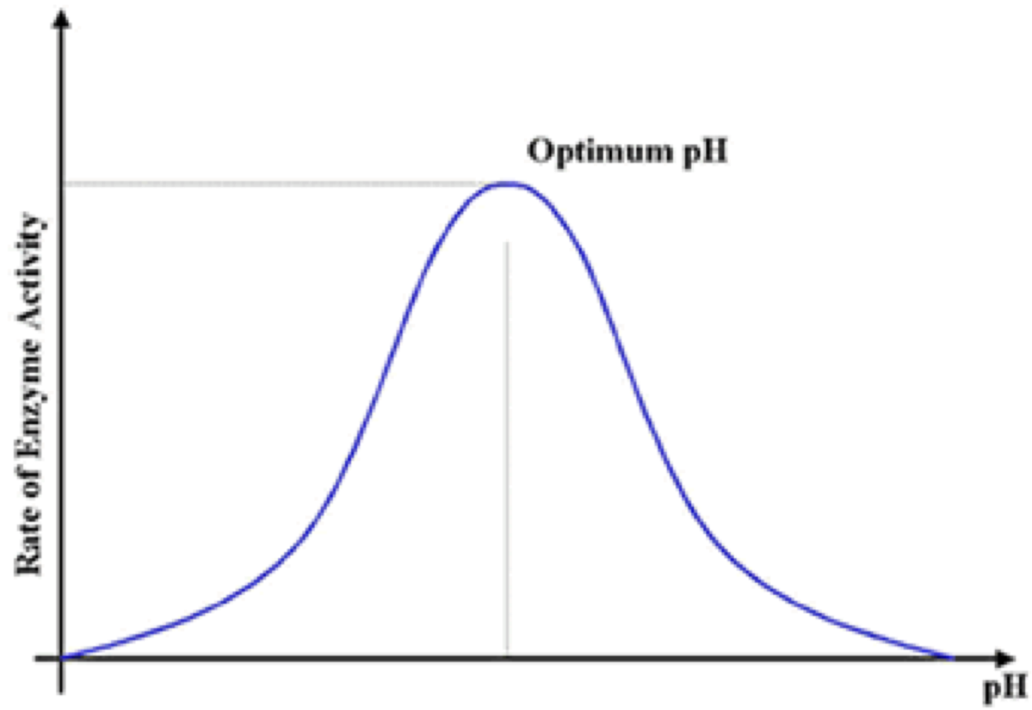
3. **Concentrations of substrates**

4. **Concentration of enzyme**

5. **Presence of inhibitors**

II. pH

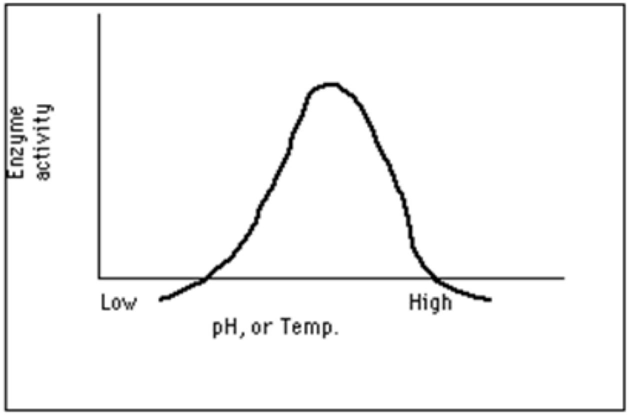
A. Enzyme **shape** is dependent upon **pH-sensitive** interactions between **R-groups**



B. Any change in pH **denatures** the enzyme by causing it to change **shape**:

1. A **denatured** protein is one that has **lost** its **normal** configuration, and therefore its ability to form an **enzyme-substrate** complex

2. Most enzymes prefer pH's of **6 – 8**
3. Some exceptions:
   a. **Pepsin** in the stomach - pH ~ **2**
   b. **Trypsin** in the small intestine - pH ~ **8**



III. Temperature

A. Temperature is a measure of the average kinetic energy in a container of molecules

B. As the temperature rises, the reaction rates increase

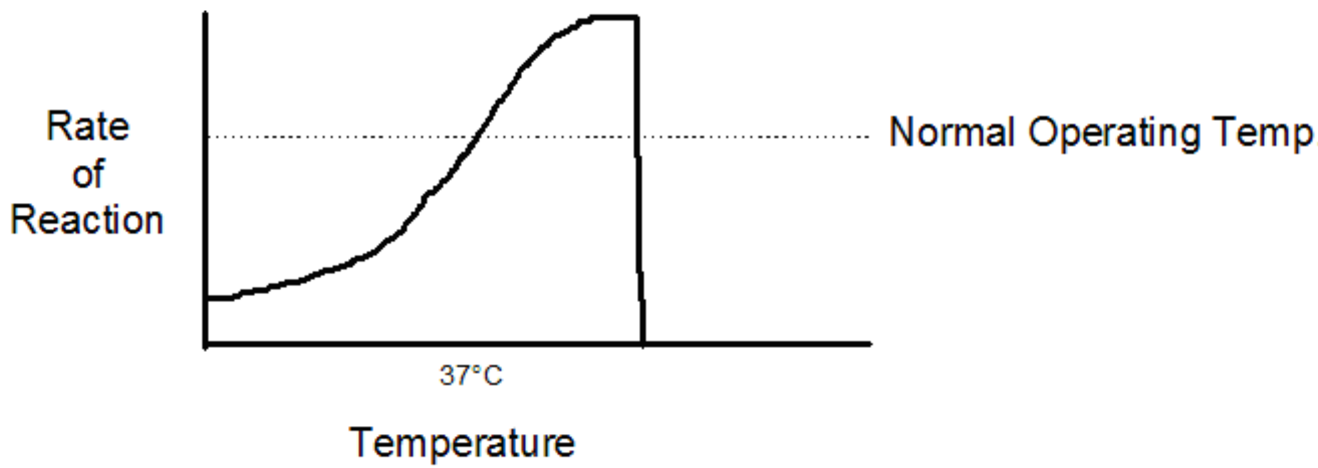
C. Increasing the temperature slightly will, at first, increase the rate of reaction and product formation because it speeds up the rate at which substrates bump into enzymes

D. 37°C is optimum for human enzymes

F. Temperature too high (above about 40 ° C) will denature the enzyme ANIMATION

1. Slight denaturation causes the enzyme reactions to slow

2. Huge denaturation causes the enzyme reactions to stop



G. As the temperature drops, the reaction rate decreases because there are fewer enzyme-substrate collisions

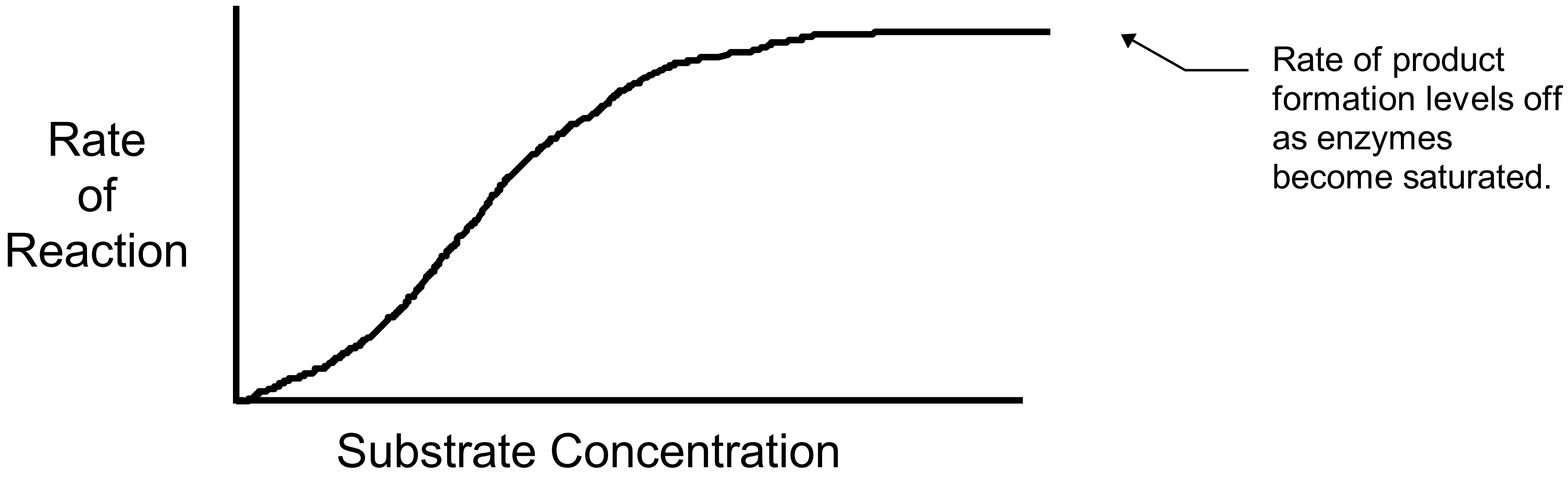
H. Very low temperatures do not normally denature the enzyme

IV. Concentrations of Substrates

A. If the concentration of substrate increases, the amount of product increases

B. However, after a certain concentration, the rate will not increase anymore, as all the enzymes are "saturated" with substrates and cannot work any faster

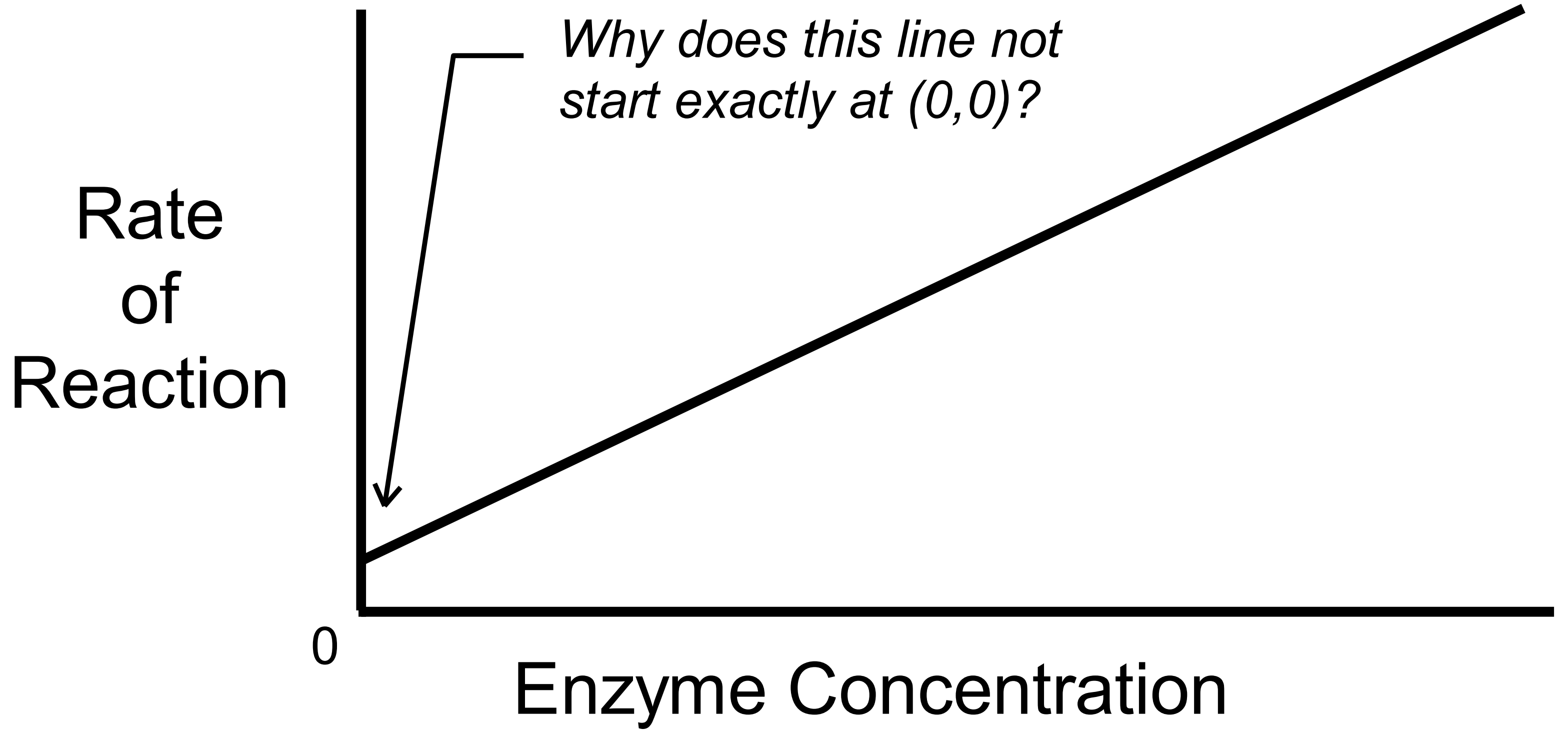
C. **If the concentration of substrate decreases, the rate of product formation will generally decrease as well**



V. <u>Concentration of Enzyme</u>

A. This is what limits the overall rate of reaction. Providing there is adequate substrate (and their is typically millions more substrate molecules than enzyme molecules), the more enzyme you add, the more product you get

B. The less enzyme you have, the less product you get. In other words, if [enzyme] increases, rate of product formation increases. If the amount of enzyme decreases, the rate of product formation decreases. The rate will only level off if you run out of substrate, which is usually not the case.



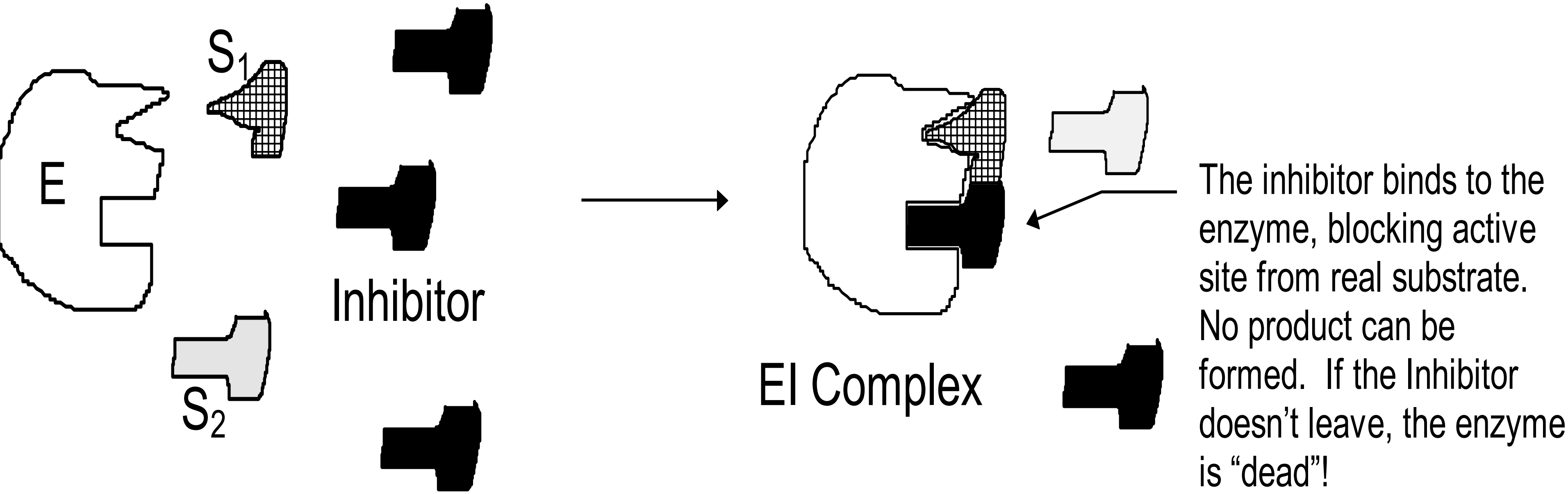
VI. Presence of Inhibitors

A. Inhibitors are molecules that bind to the enzyme in some way to prevent or reduce the rate of substrate binding to enzyme

B. There are several ways in which inhibition can work:

Competitive Inhibition:

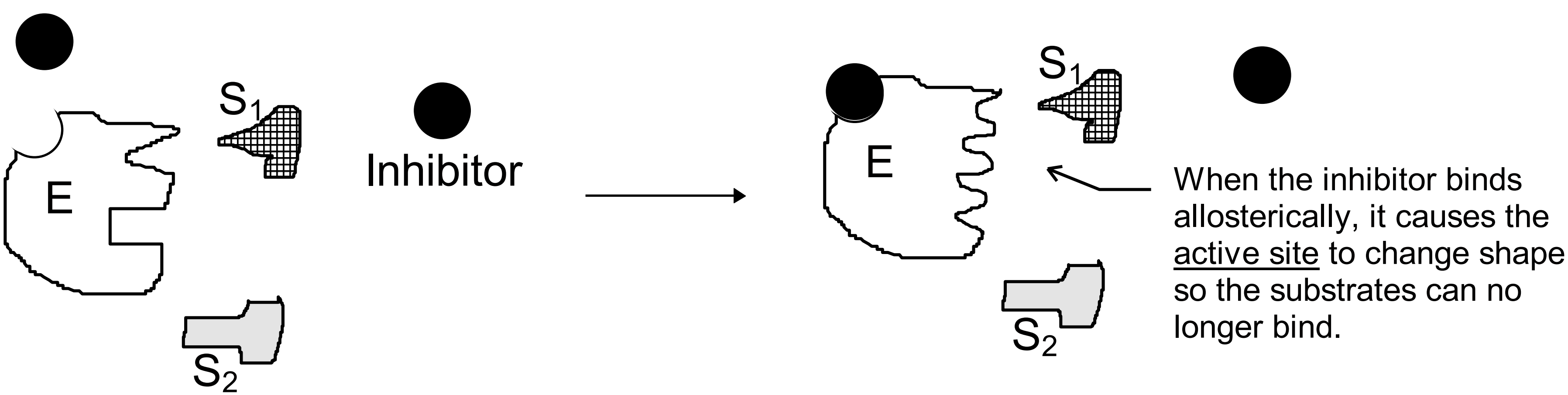
A molecule that looks like the substrate can compete for space at the active site (the place where the substrate binds to enzyme). This will slow down the reaction rate. The inhibitor binding to the Enzyme can be reversible or irreversible.

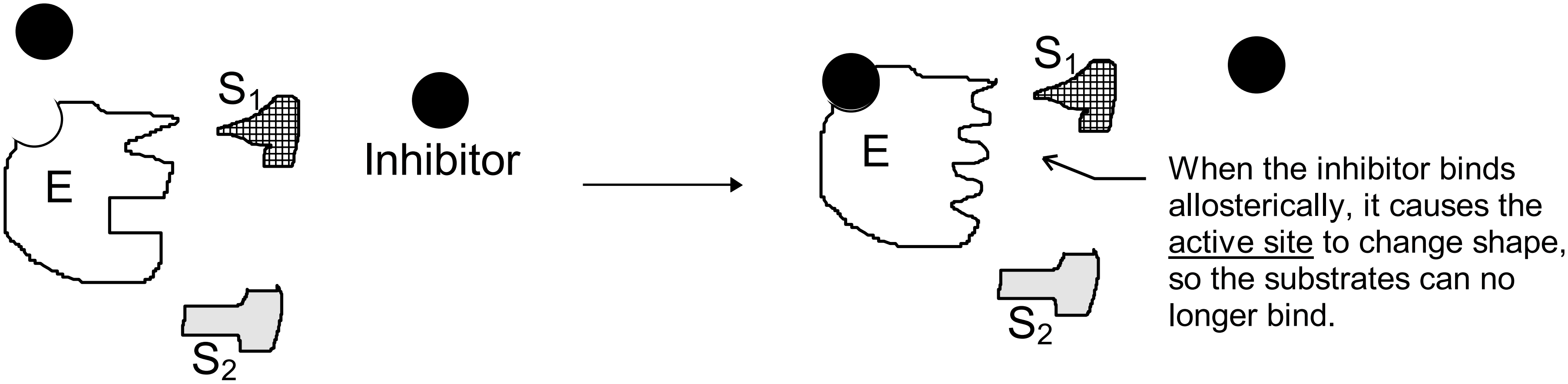


Obviously, the more inhibitors are added, the lower the rate of reaction, and the less product is going to be made.

b. Non-competitive Inhibition

In this case, the inhibitor binds to another place on enzyme (not the active site). The inhibitor may look completely different from the substrate.





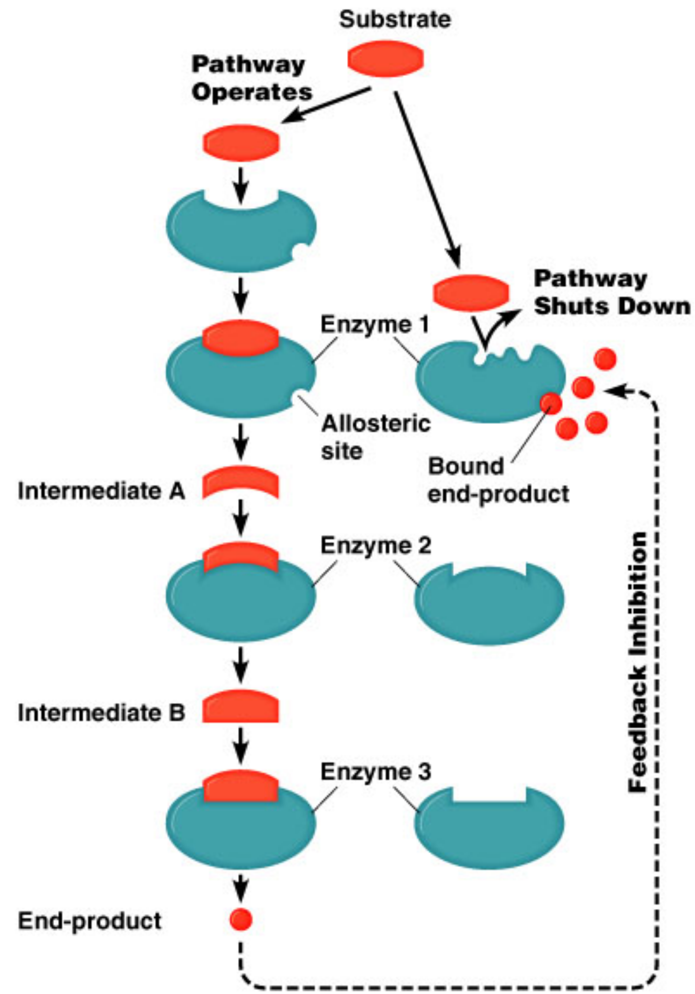
When the inhibitor binds, it causes the enzyme to change shape at the active site so substrate cannot bind. Binding may, as it is for competitive inhibition, be reversible or non-reversible. This type of inhibition is also known as "allosteric" inhibition.

C. Feedback Inhibition

When an excess of product competitively binds with enzyme active sites, getting in the way of substrate molecules and slowing enzyme activity. This is called feedback inhibition.

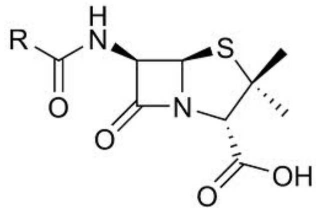
In a multi-enzyme pathway, often the end product binds at a special site on the first enzyme to shut down the whole pathway if the product builds up. This is Non-competitive inhibition or Allosteric control

ANIMATION



D. Inhibitors can also be chemicals introduced into a system from the outside, and can act as medicines or poisons.

Penicillin is a medicine that kills bacteria. It works by binding irreversibly to the enzyme that makes bacterial cell walls.



HCN (hydrogen cyanide) is a lethal irreversible inhibitor of enzyme action in humans.

Lead (Pb++) and other heavy metals (like mercury (Hg++) and cadmium) are non-competitive inhibitors that cause poisoning when they bind irreversibly to enzymes and make them denature.

I. **<u>Thyroxin: the Basics</u>**

A. A hormone produced in the thyroid gland (neck) that controls the metabolic rate (rate of the chem. reactions in the cell) in ALL the cells in your body
  Thyroid Animation

B. The more thyroxin present, the greater the metabolic rate

C. This will increase sugar and oxygen consumption and also create more body heat