Enzymes

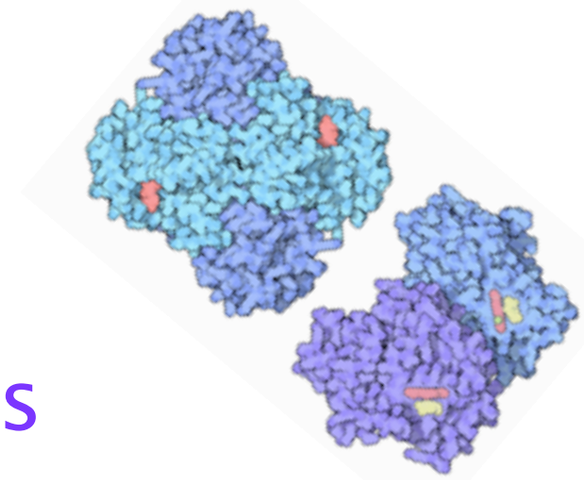
Topic 3.6 & 7.6

SPEED UP CHEMICAL REACTIONS!!!!!!!

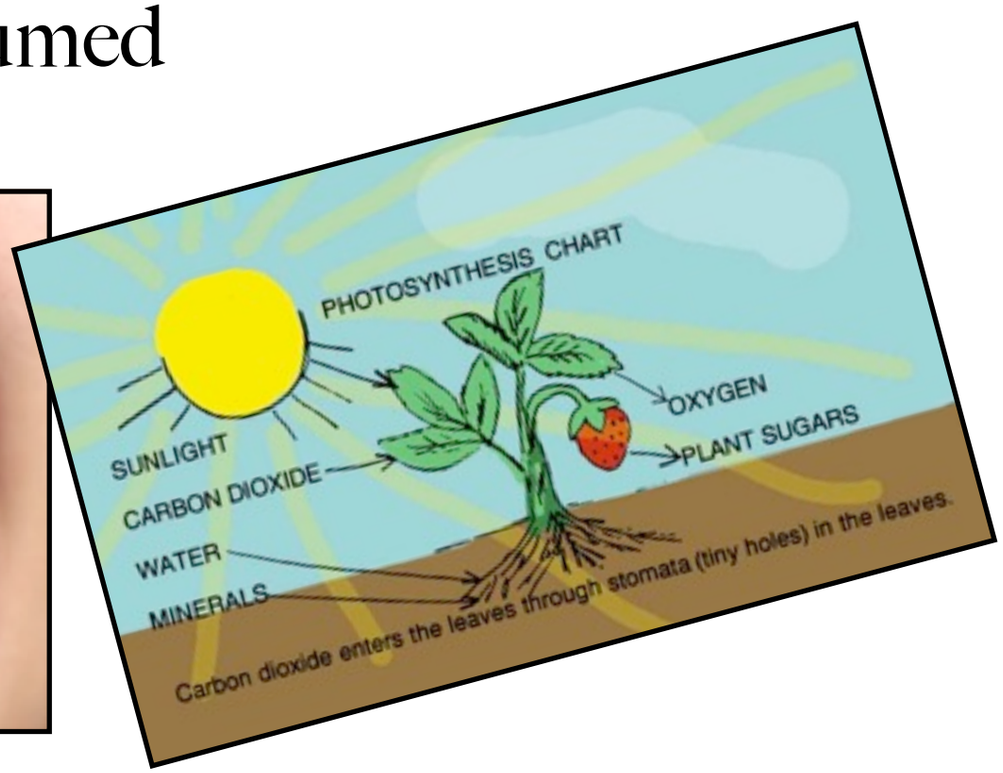
Key Words

- Enzyme
- Substrate
- Product
- Active Site
- Catalyst
- Allosteric site
- Activation Energy
- Denature
- Enzyme-Substrate Complex
- Lock & Key model
- Induced fit model

ENZYMES!



- Enzymes are protein molecules and catalysts
  - They speed chemical reactions that occur in living organisms without being consumed



- Without enzymes, many of the reactions that occur within our bodies would not be able to happen fast enough to sustain life.

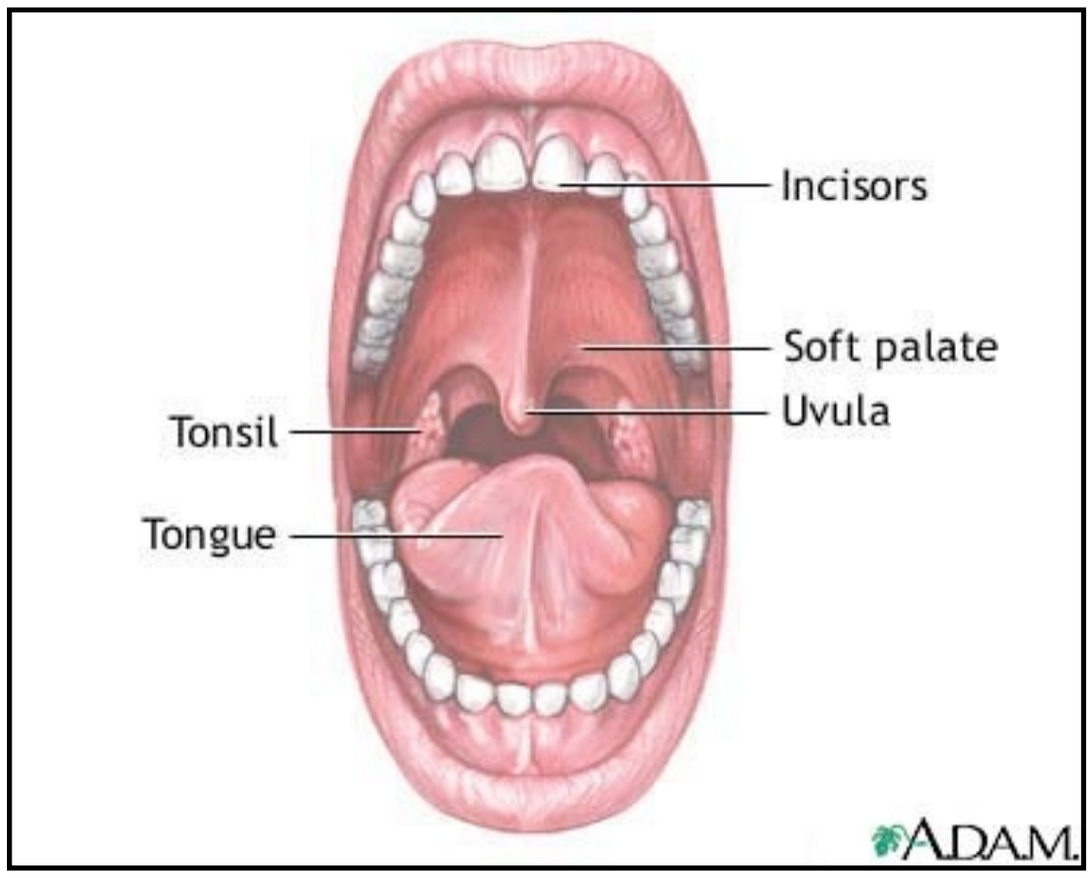
Characteristics of Enzymes

- In enzymatic reactions, the molecules at the beginning of the process that interact with the enzyme are called substrates. The enzyme converts them into different molecules, called the products
- Enzymes are very specific due to their 3D tertiary and quaternary structure
- ie) Catalase breaks up hydrogen peroxide into hydrogen and oxygen

What's in a name?

- The names of enzymes usually end in "-ase"

» the enzyme in our **saliva** is called **AMYLASE**



AMYLASE in our saliva breaks starch into maltose in order to simplify digestion.

Enzyme Specificity

- Enzymes are specific for one particular reaction or group of related reactions.

ose = sugar

Lactose
(milk sugar)

Lactase

Triglycerides
(lipid)

Lipase

Amylose
(starch)

Amylase

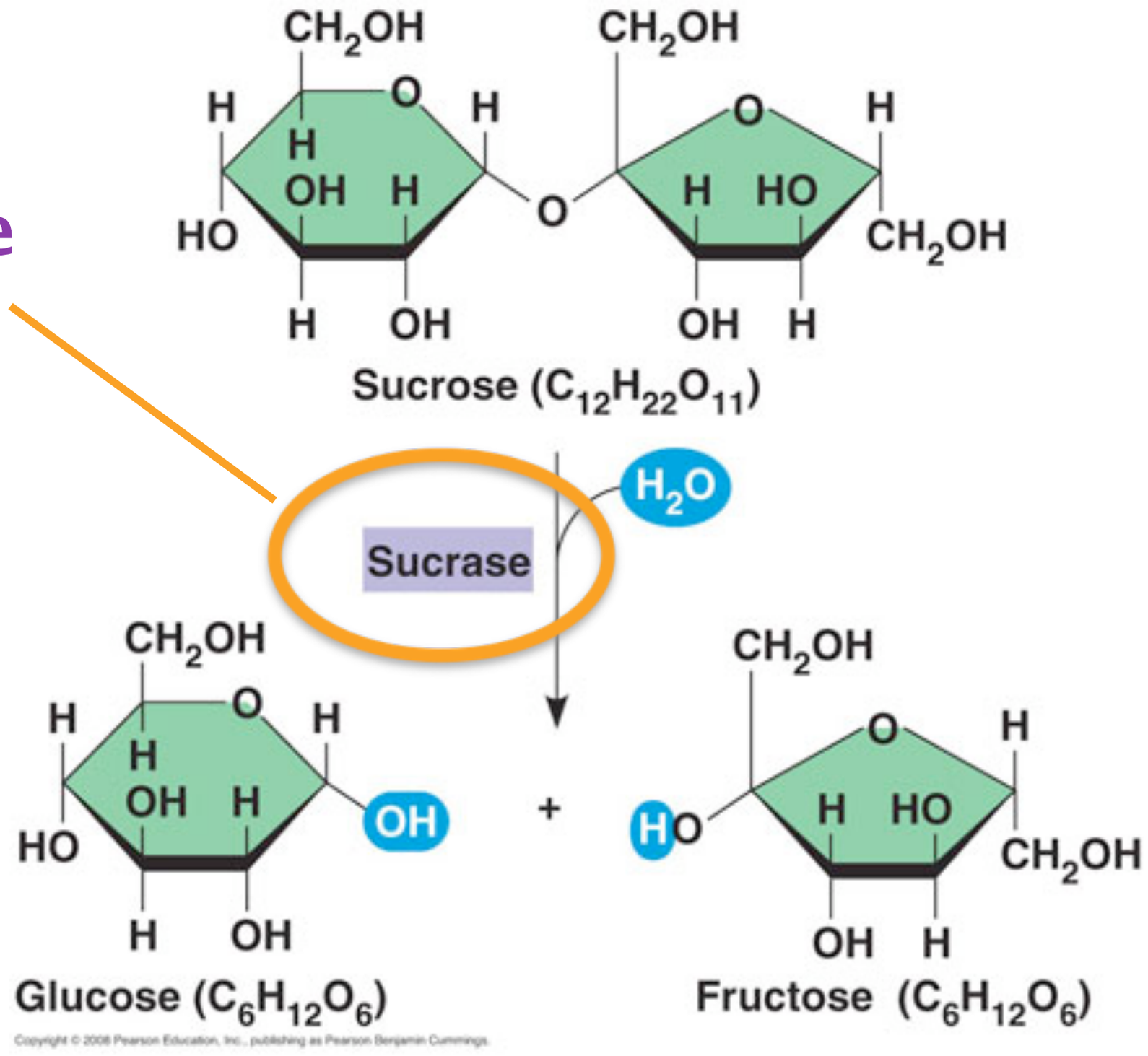
ase = enzyme

Protein

Protease

Enzyme Action & Sucrase

Enzyme **sucrase** breaks down a molecule of sucrose into glucose and fructose



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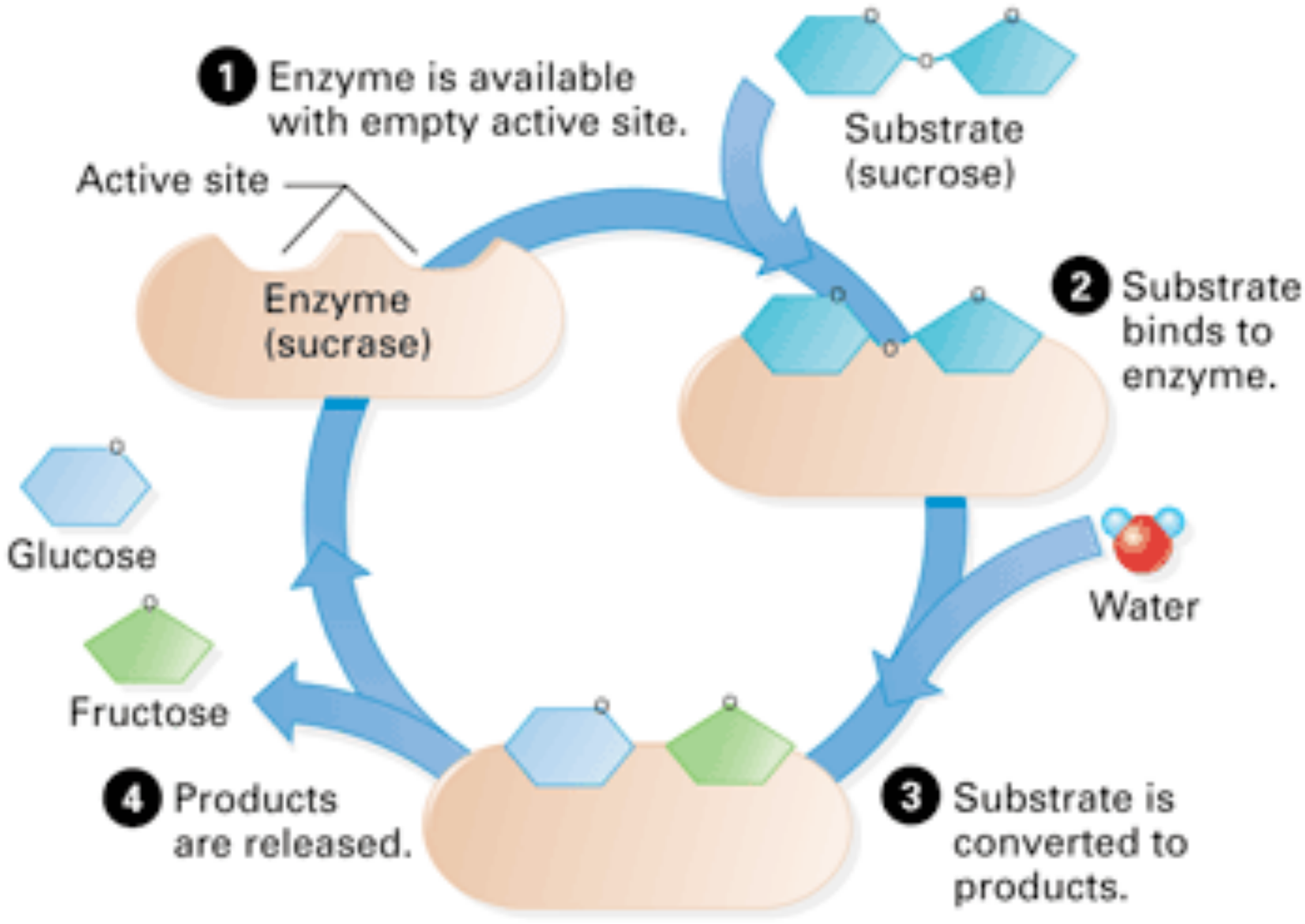
How do Enzymes work?



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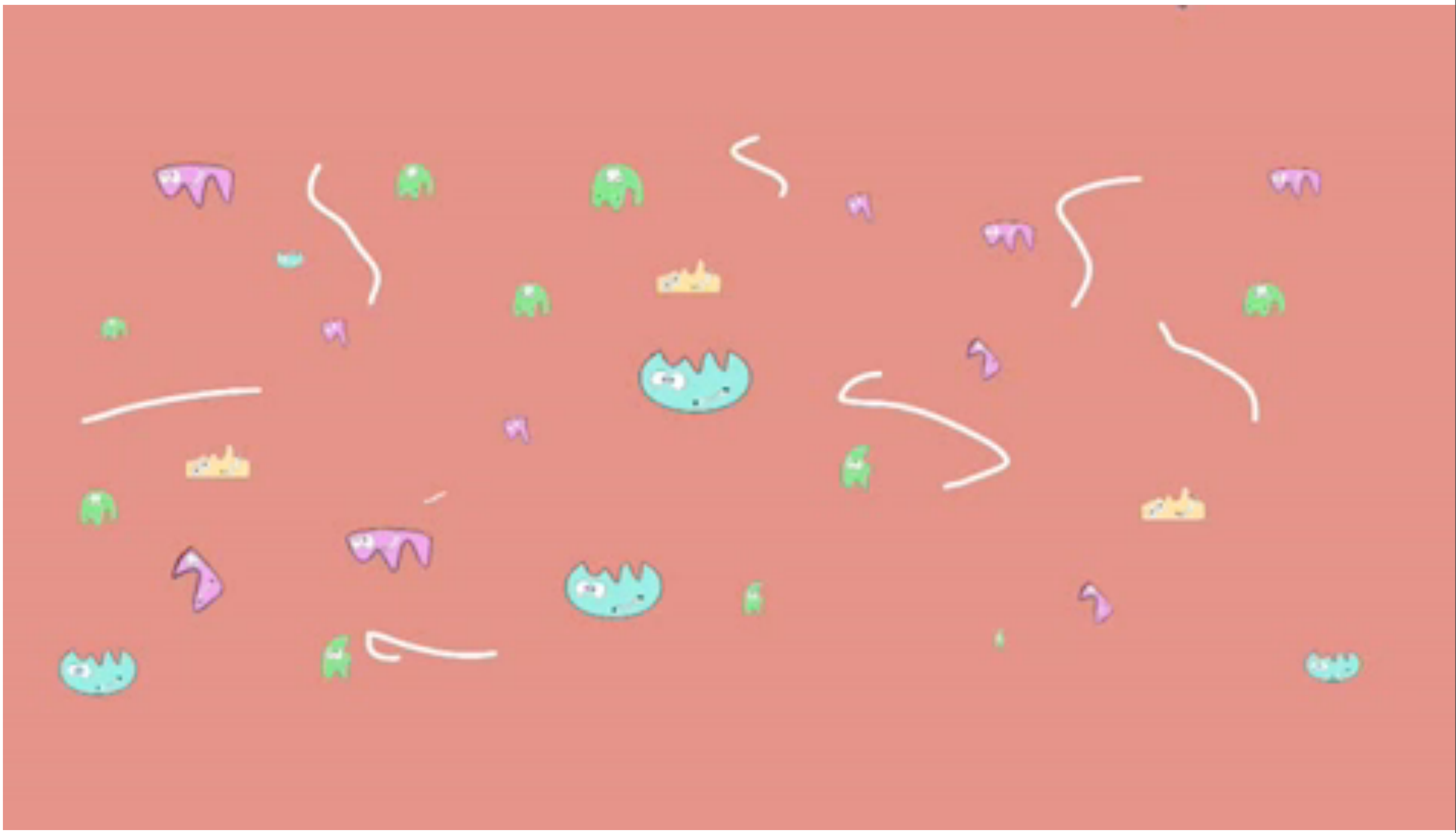
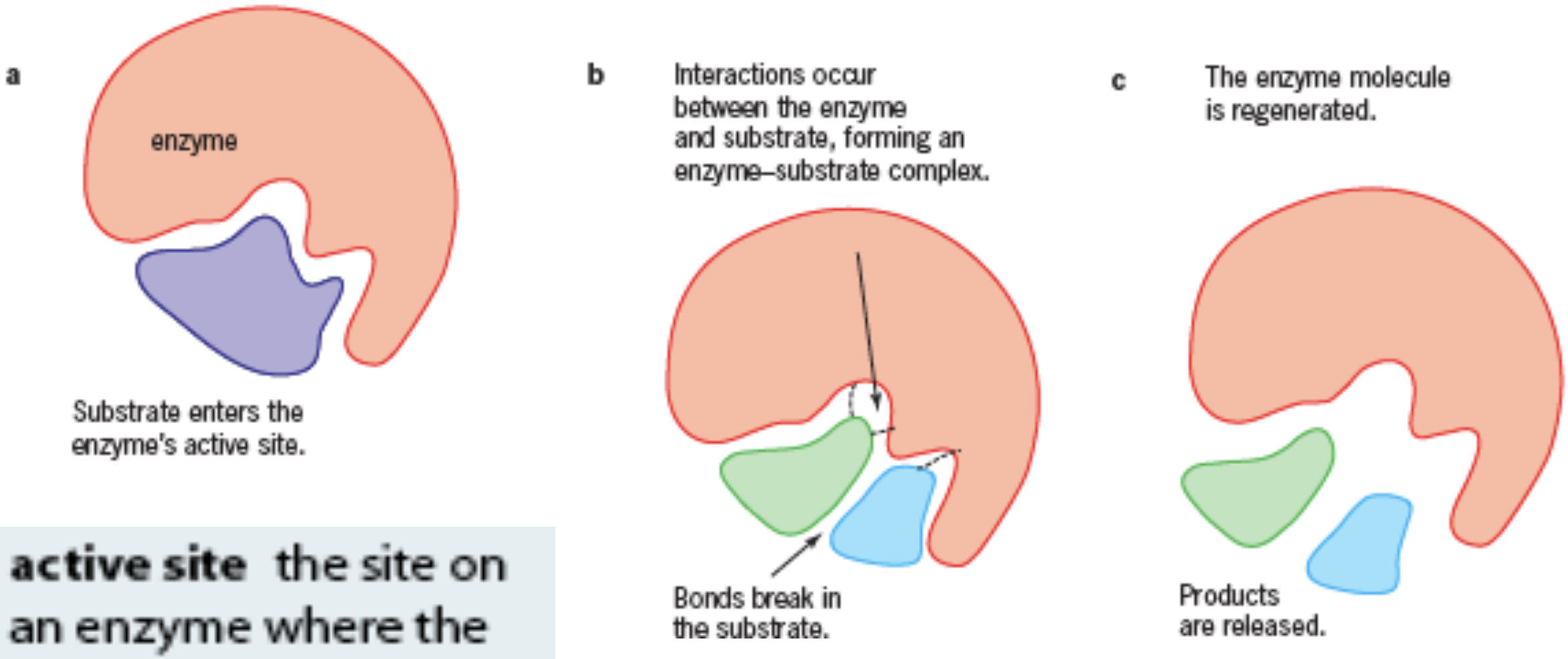


Lock & Key Model



active site the site on an enzyme where the substrate binds; where the chemical reaction that is catalyzed by the enzyme takes place

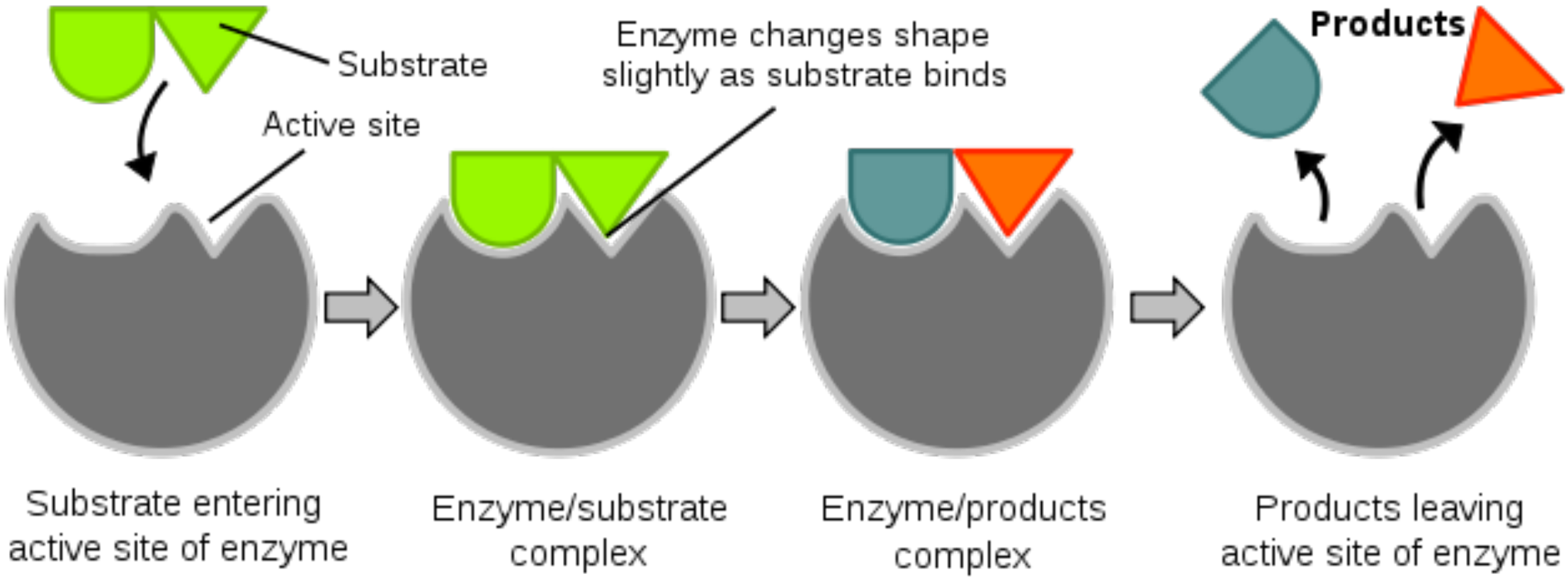
A perfect match between the shape of the active site of an enzyme and the shape of its substrate like a perfect match between a lock and a key

So what's the problem?

The lock-and key hypothesis cannot account for the binding and simultaneous change that is seen in many enzyme reactions, nor the fact that some enzymes can bind to more than one similarly shaped substrate.

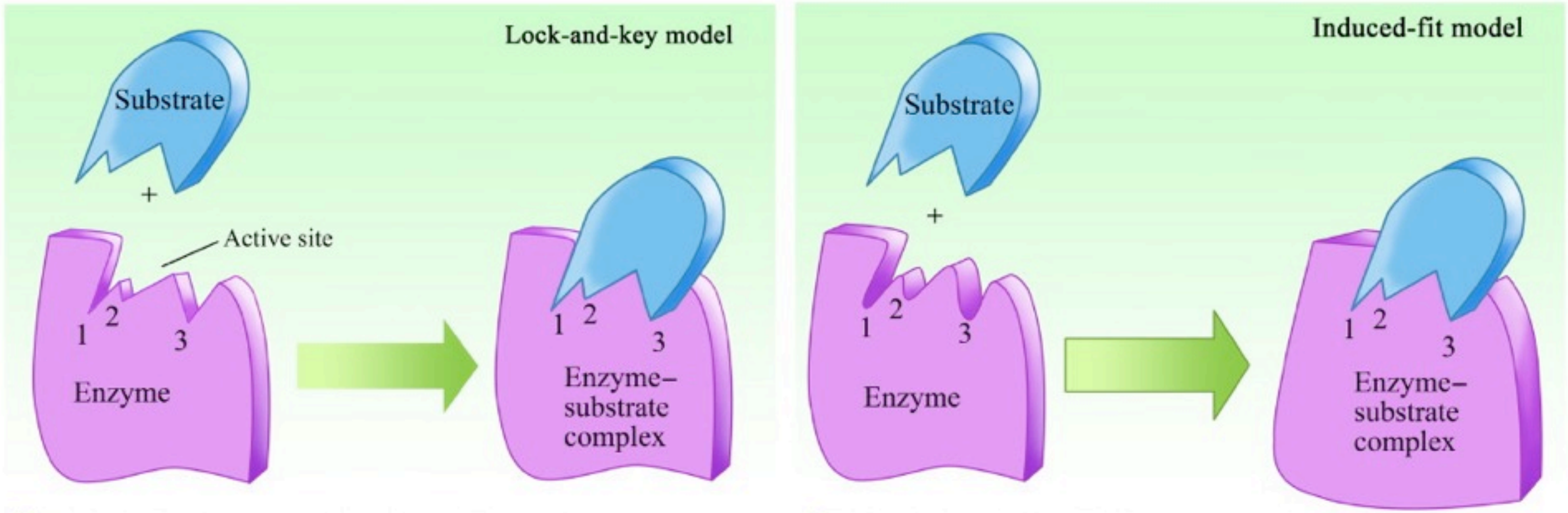
So……alter the model….

Induced Fit Model



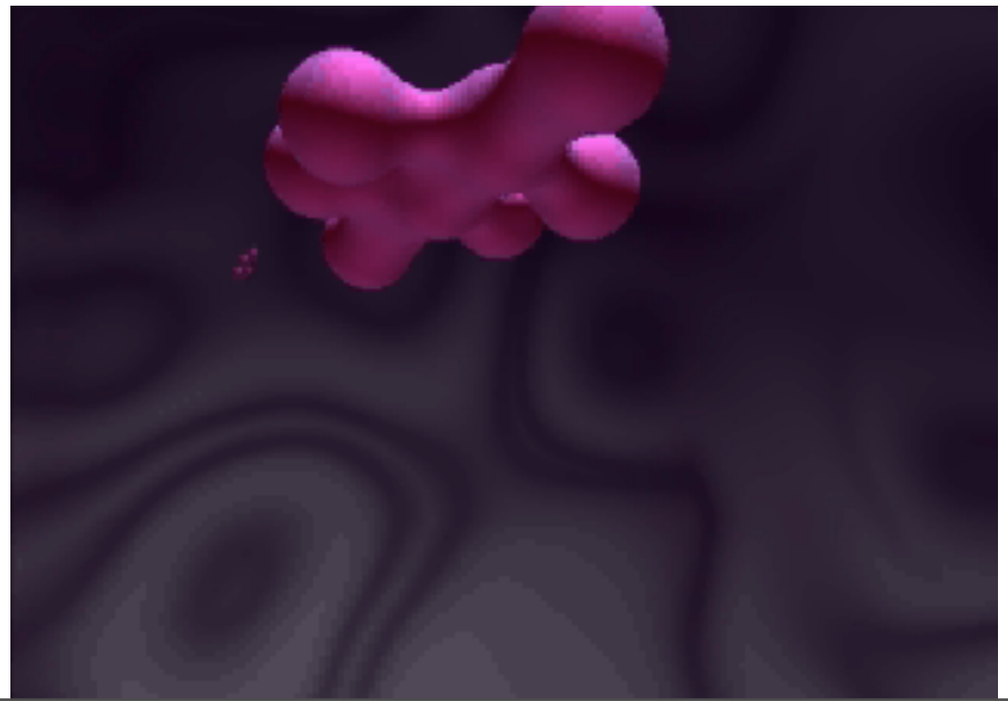
The substrate causes or induces a slight change in the shape of the active site so it can fit perfectly. As the enzyme changes shape, the substrate molecule is activated so that it can react and the resulting product or products are released.

What is the difference?



A In the lock-and key model, the shape of the substrate and the confirmation of the active site are complementary to one another.

B In the linduced-fit model, the enzyme undergoes a confirmational change upon binding to substrate. The shape of the active site becomes complementary to the shape of the substrate only after the substrate binds to the enzyme.



How does an enzyme affect activation energy?

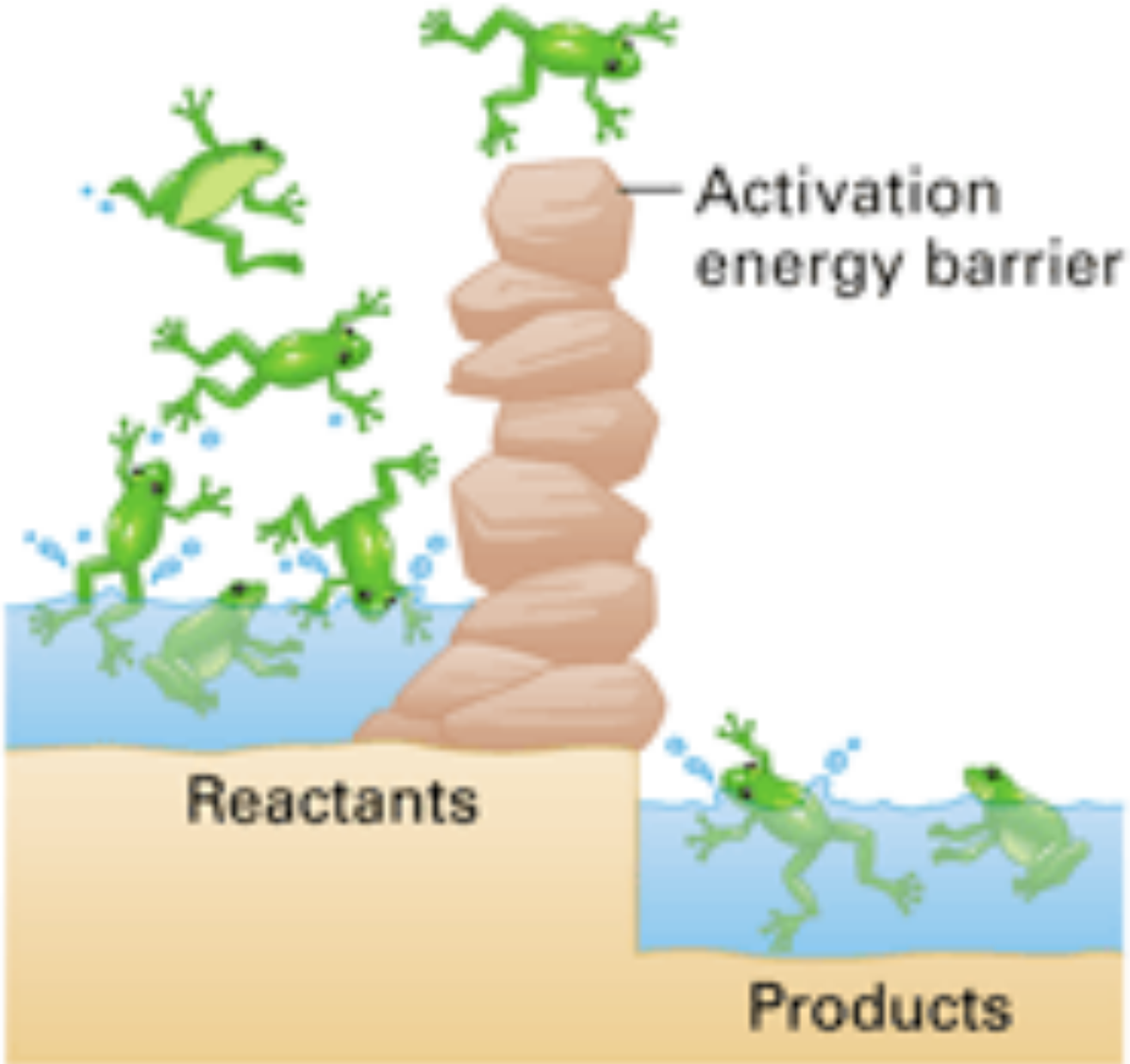
Activation energy → the amount of energy needed to trigger the reaction

Metabolic reactions that occur in living organisms have to occur at the body temperature of the organism, which is never high enough to bring substrates to their transition state.

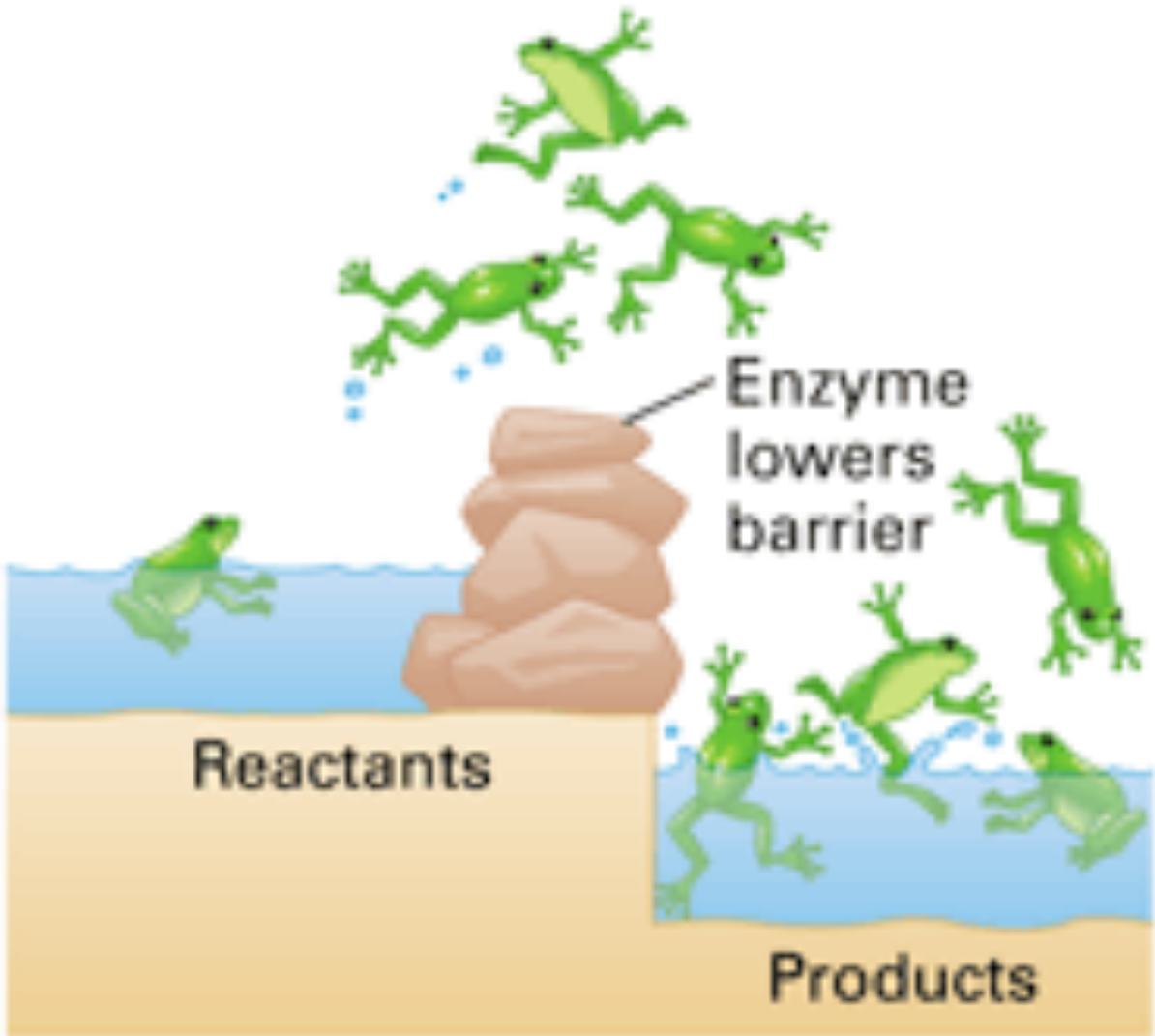
Enzymes catalyze this process by **providing a reaction pathway which is lower in the amount of energy** required to activate the reaction. They reduce the activation energy required.

Enzymes do not change the amount of products made, but only change the rate at which they are produced.

Activation Energy



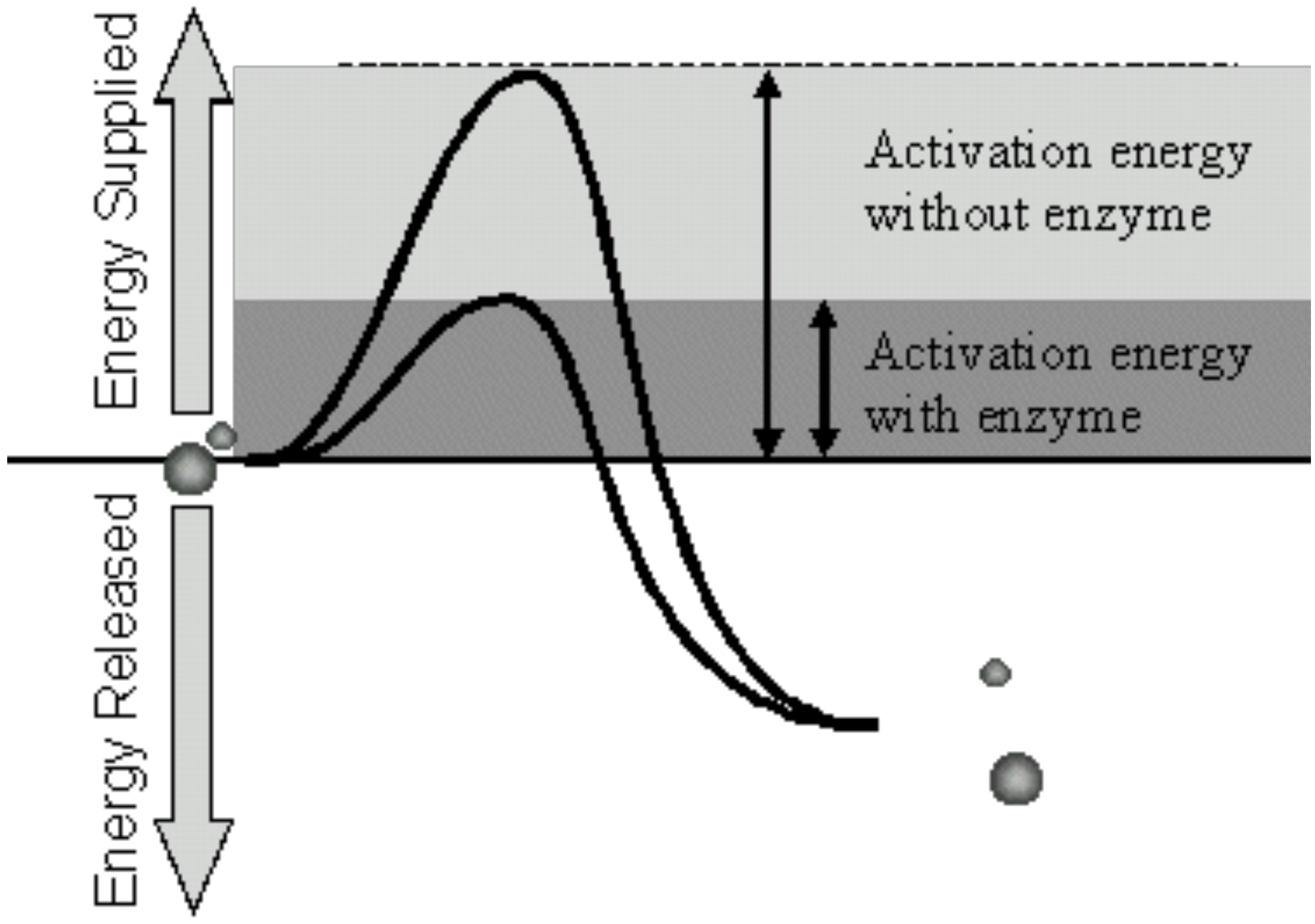
Without enzyme



With enzyme

Activation Energy

The amount of activation energy that is required is considerably less when enzyme is present

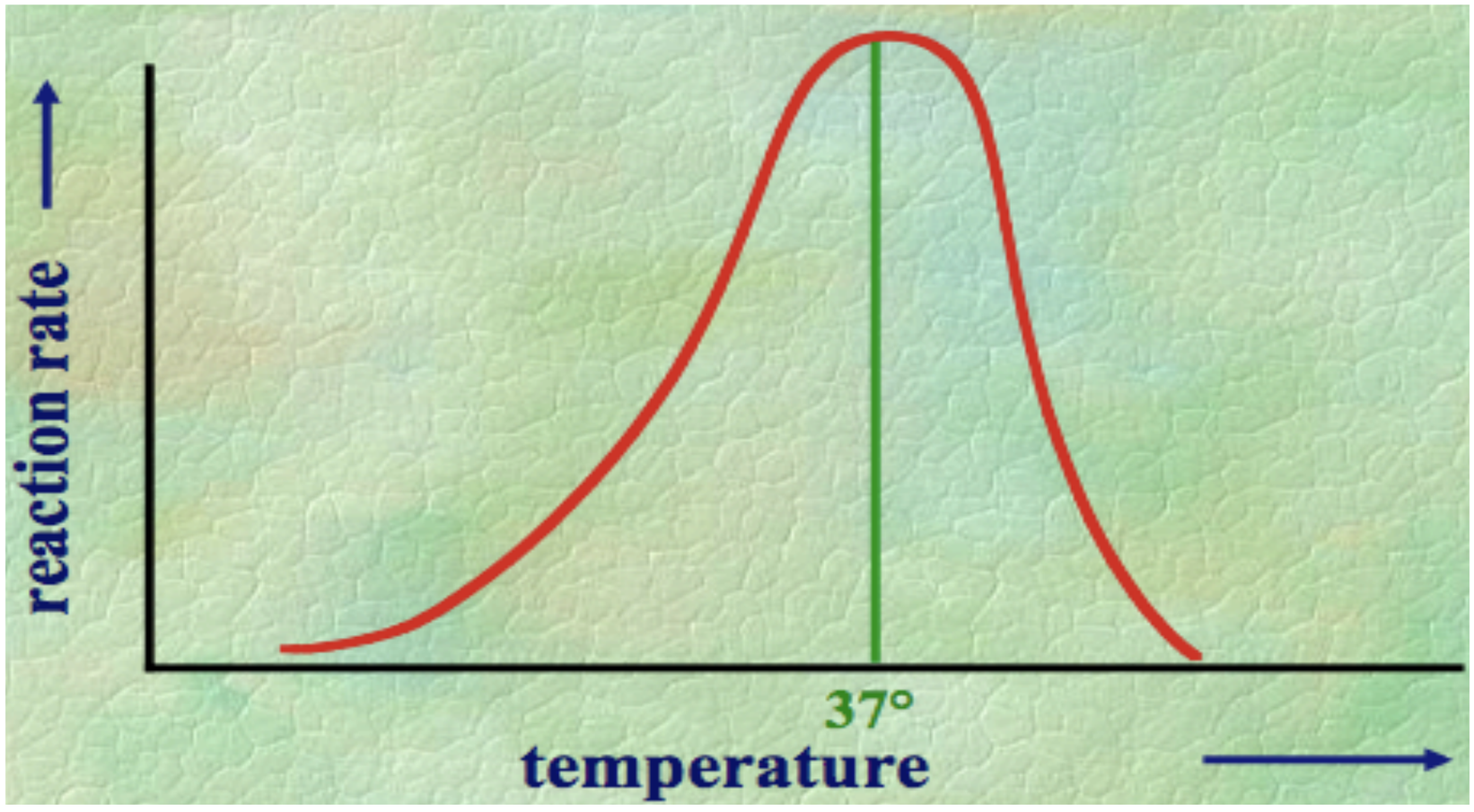


Factors Affecting Enzymes

- ✓ Temperature
- ✓ Substrate concentration
- ✓ pH
- ✓ Enzyme concentration
- ✓ Heavy Metal Ions

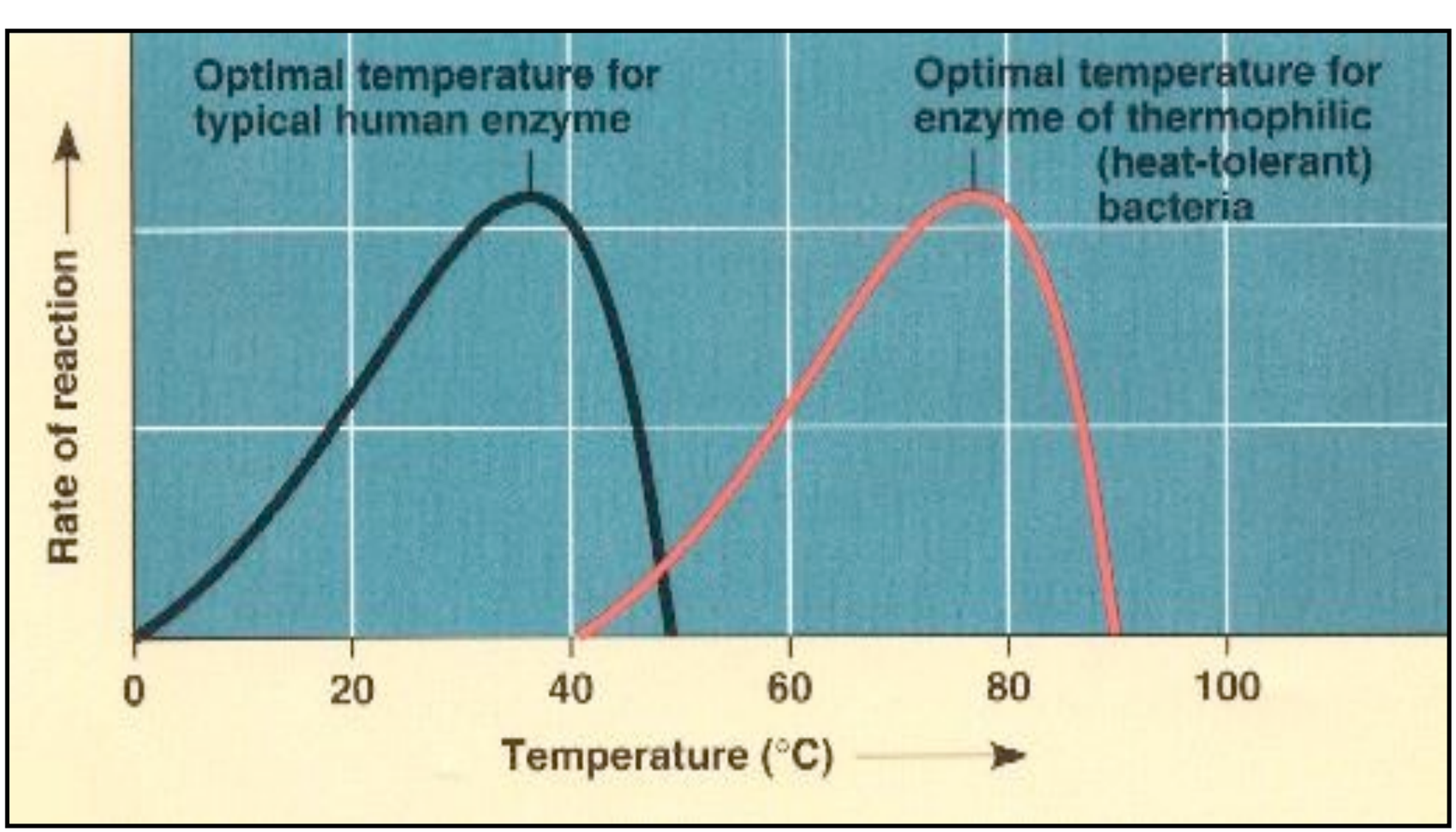
Temperature

- Enzymes and their substrates meet as a result of random collisions
- As temperature increases, molecules move faster and there are more molecular collisions, causing more enzyme-substrate complexes to form.



Temperature

- Every enzyme has an **optimal temperature** at which it works best!

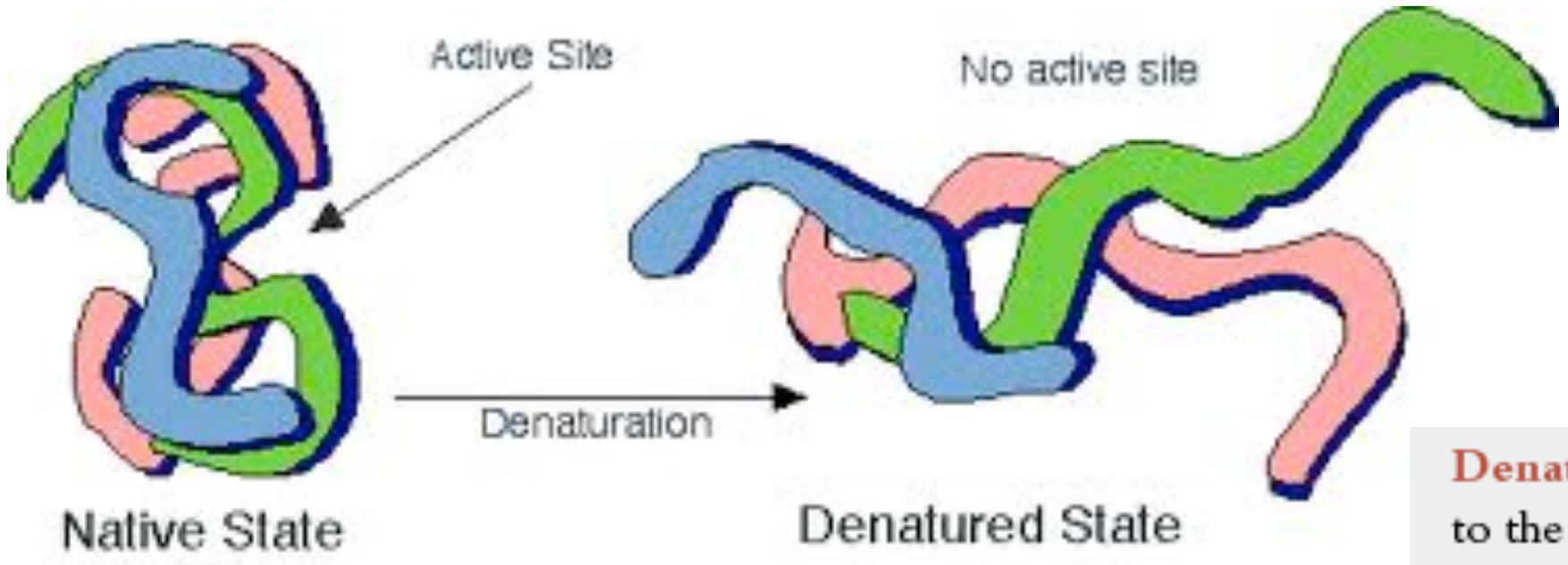


A **typical human enzyme** works best at approximately 37°C.

A **heat-tolerant organism** enzyme works best at approximately 76°C.

Temperature

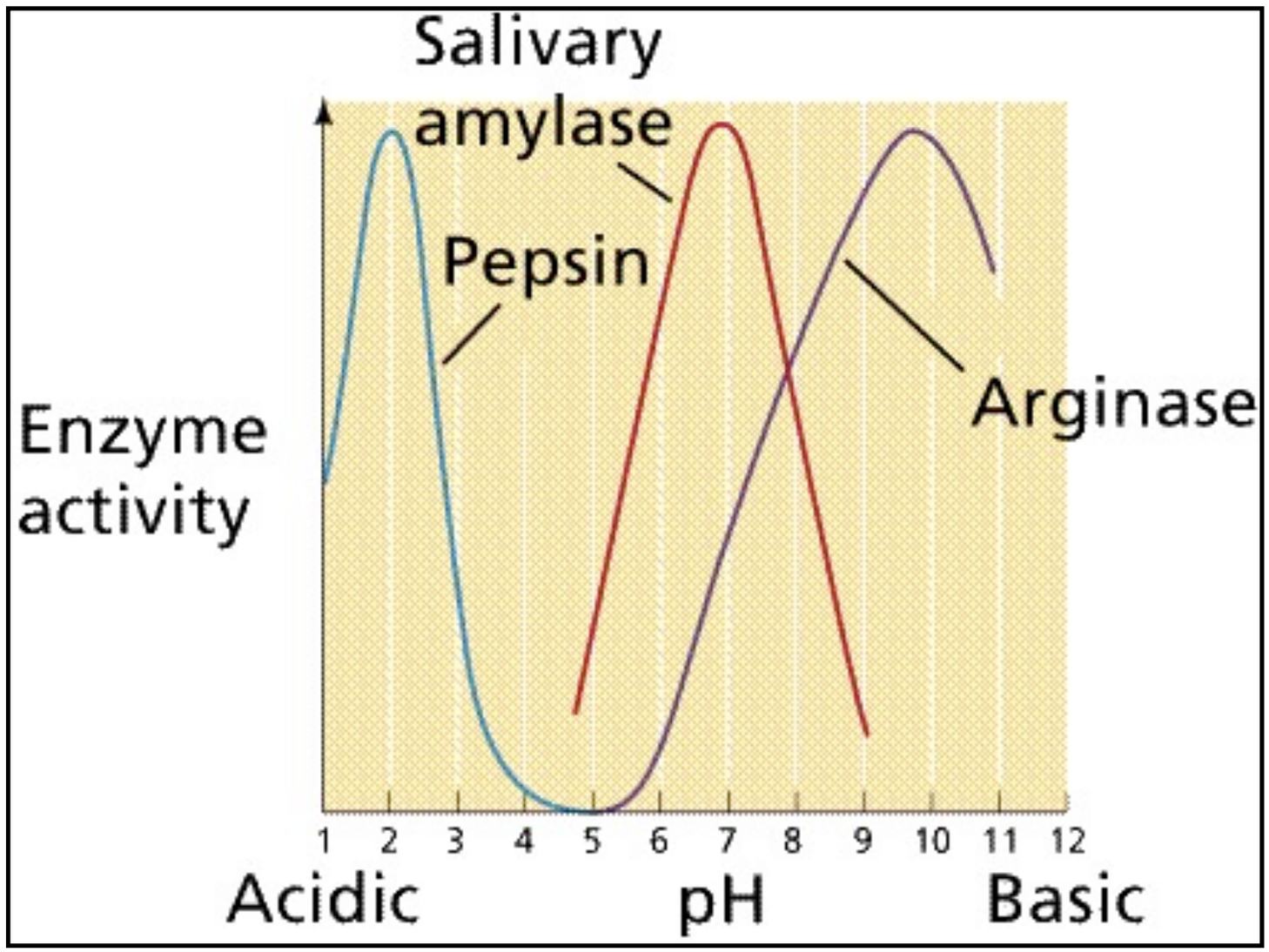
- At low temperatures, molecules move slower and the likelihood of collisions is reduced.
- At high temperatures, the bonds holding the protein together are disrupted and the enzyme **denatures**.
- This changes the shape of the active site and the substrate can no longer bind.



Denaturation irreversible changes to the structure of an enzyme or other protein so that it can no longer function

pH

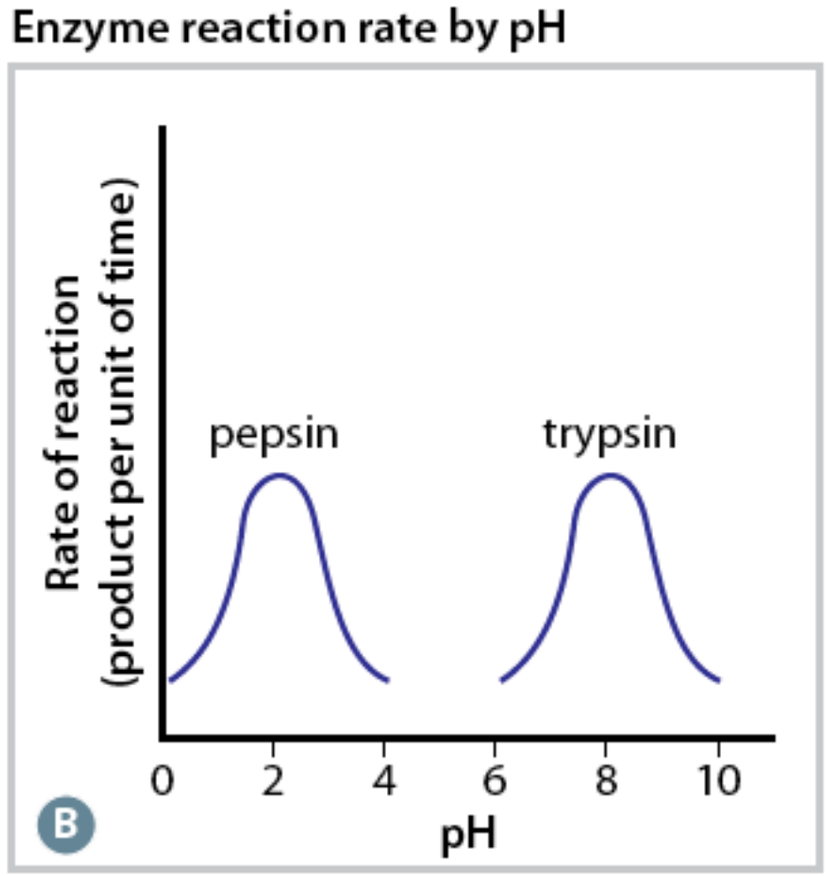
- Enzymes also have an **optimal pH** at which they work best.



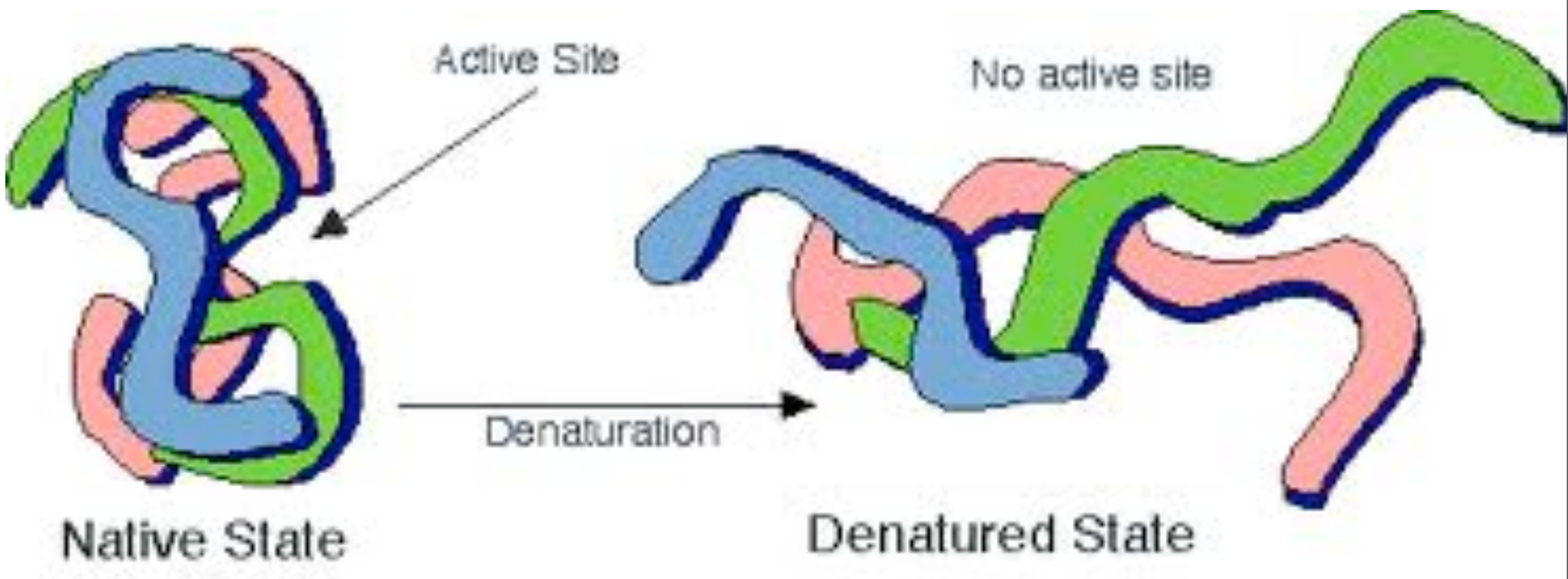
The digestive enzyme **PEPSIN** works best in the **acidic environment** of the stomach, pH 2.

pH

Changes in pH can disrupt bonds and 3D shape of the enzyme



Enzyme is said to be denatured – no longer a catalyst

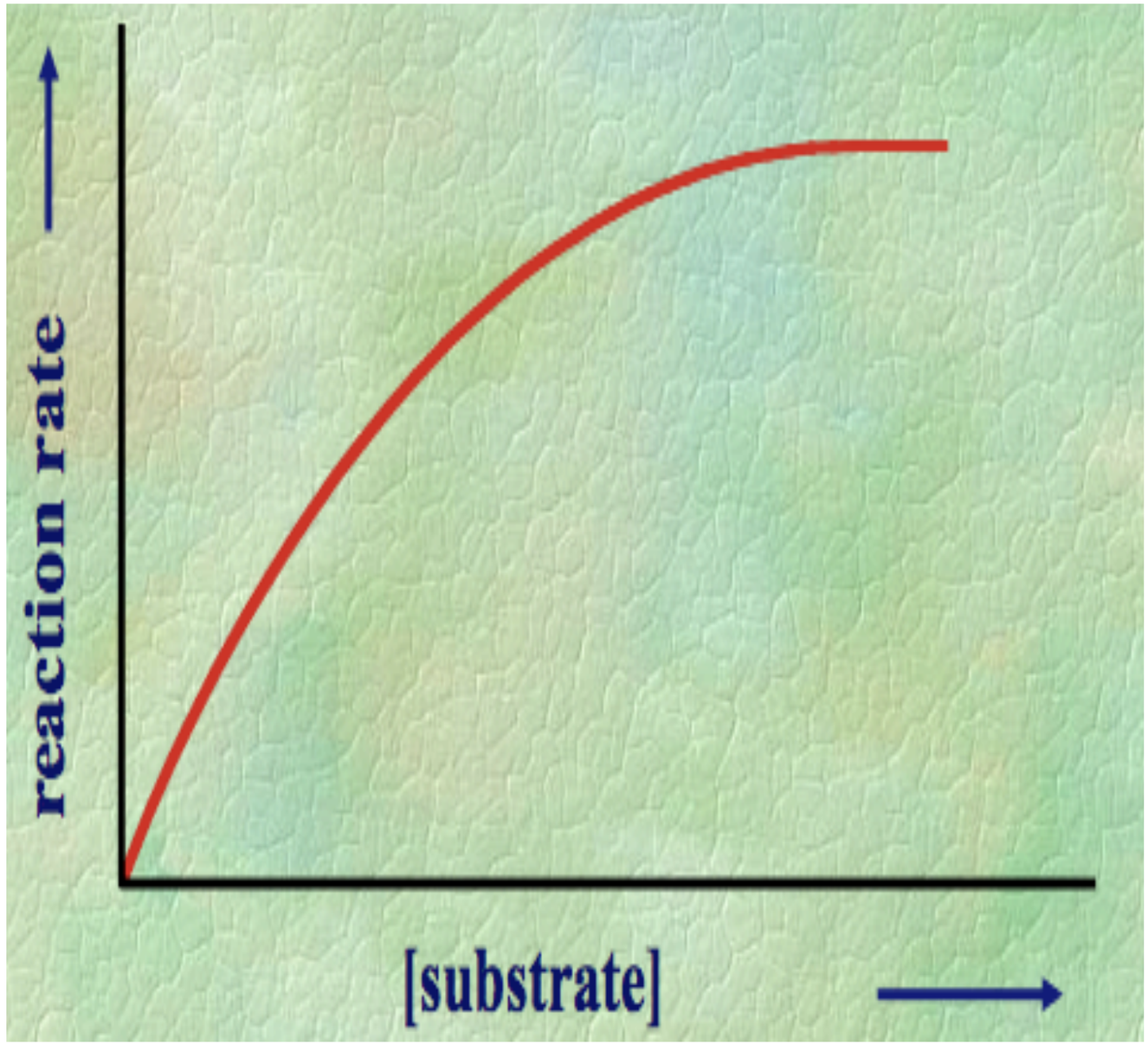


Substrate Concentration

As [substrate] increases, so does reaction rate

More substrate means more frequent collisions with enzyme

Reaction rate will plateau when all the active sites are filled with substrate

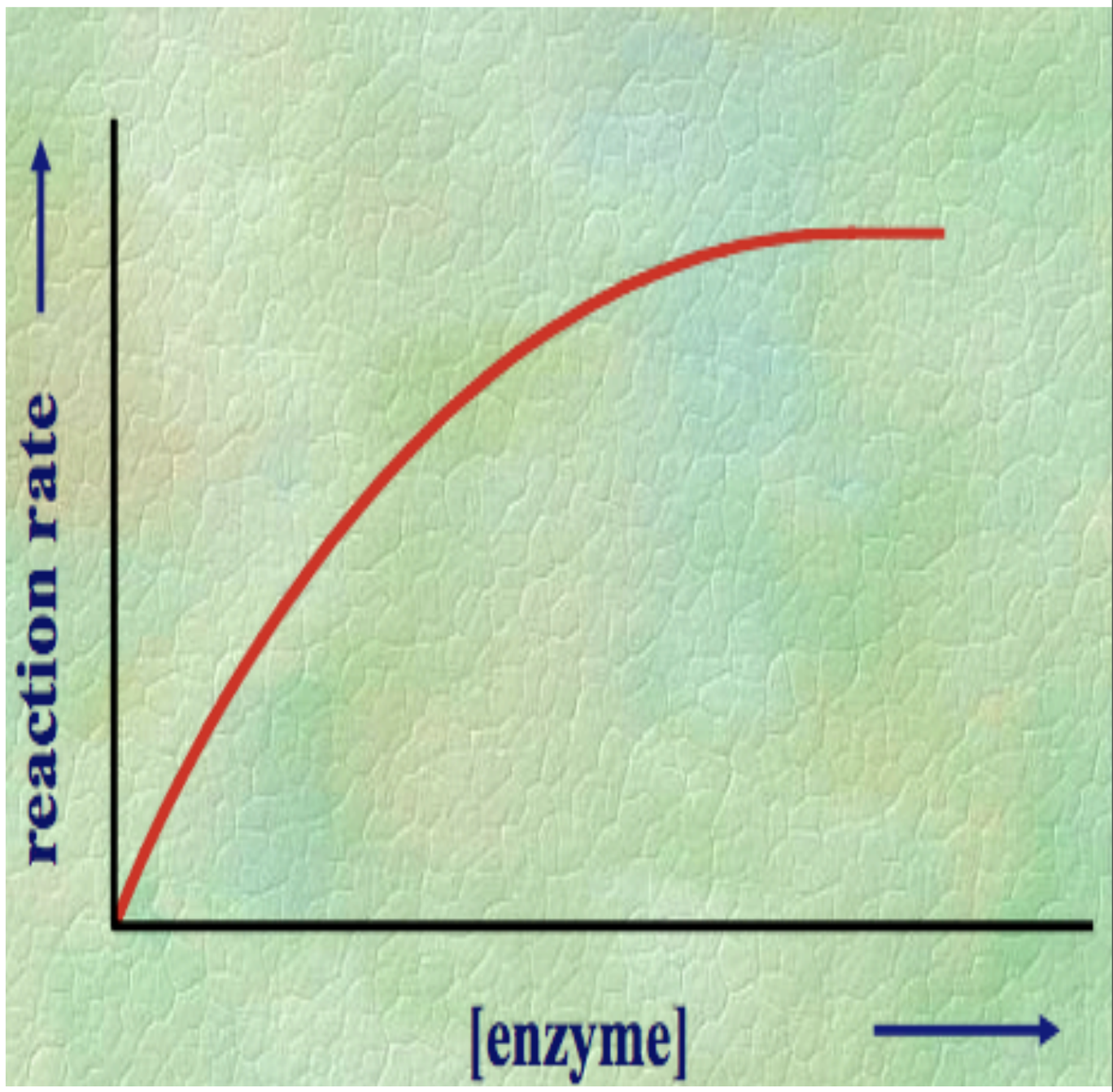


Enzyme Concentration

As [enzyme] increases, so does reaction rate

More enzymes means more frequent collisions with substrate

Reaction rate will plateau when all the active sites are filled with substrate; substrate becomes the limiting factor



Heavy Metal Ions

The presence of heavy-metal ions can permanently alter the tertiary structure of an enzyme.

Heavy metals such as Ag^{+}, Hg^{2+}, Pb^{2+} have strong affinities for –SH groups and replace the hydrogen atoms in these groups.

As the –SH group is part of the side chain of the amino acid cysteine, it is present in many enzymes, which may then be affected by heavy metals.

What happens when an enzyme fails?

TAY-SACHS DISEASE

Hexosaminidase is the enzyme necessary to break down the fats in the brain and blood

Lack of Hexosaminidase results in build up of fats in the brain

This disease is inherited genetically

FABRY DISEASE

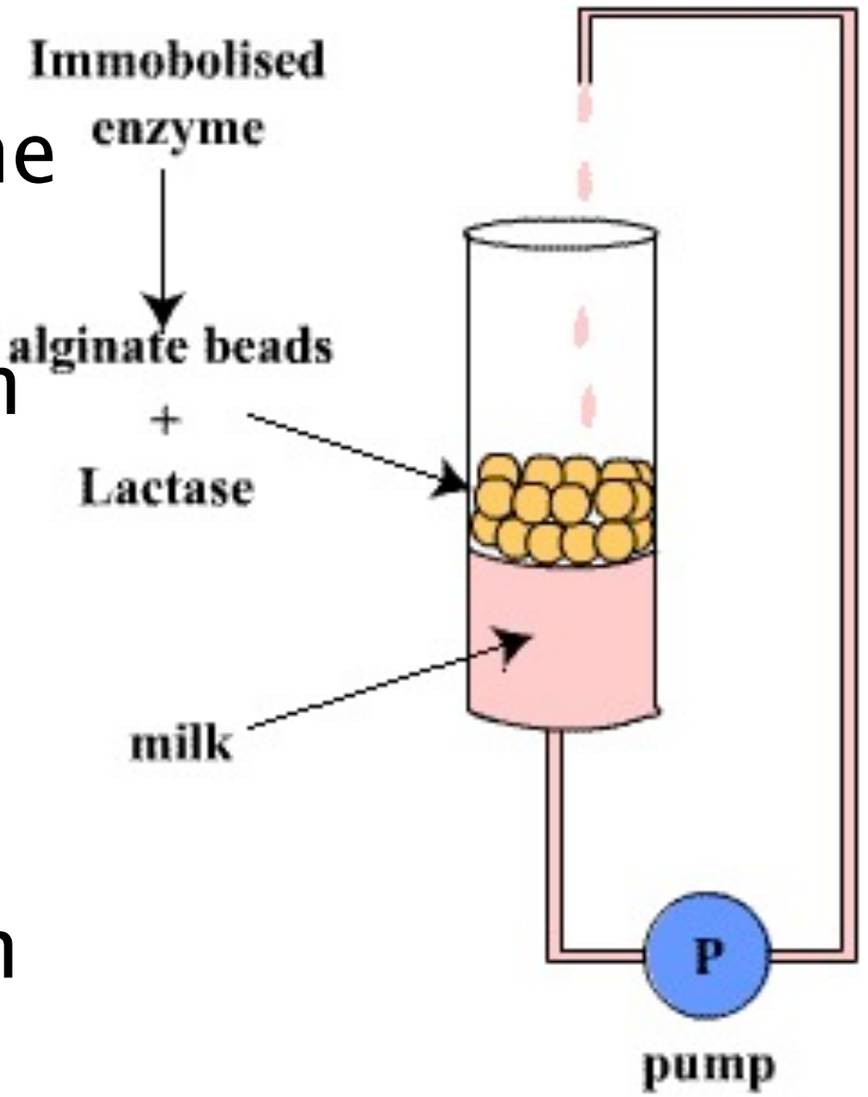
α-galactosidase is an enzyme that works in lysosomes to break down proteins, fats, nucleic acids & sugars

A defect in the gene prevents the enzyme from folding properly and it cannot carry out its usual function

The build up of Gb3 (its main substrate) causes damage to tissues and organs

Production of Lactose-Free Milk

- **Lactose** → glucose + galactose
- Around 90% of all humans show some kind of lactose intolerance.
- People who are lactose intolerant can drink milk if it is lactose free.
- Symptoms of lactose intolerance include cramping, bloating, gas and diarrhoea
- **Lactase** is an enzyme extracted form a yeast that can digest the lactose to glucose and galactose.



•Lactose-free milk can be produced by passing milk over an enzyme bound to an inert carrier. Once the lactose molecule is broken down there are no lactose ill-effects.

Other reasons to produce lactose free products:

•Milk that has been broken down takes sweeter so manufacturers need to add less sugar to products such as yogurt.

•Fermentation rates are increased in lactose-free milk, so production rates increase

•Glucose is more soluble than lactose so smoother textures are produced

The distribution of lactose intolerance around the globe shows considerable variation. Only 4% of the Scandinavian population is affected, while countries around the Mediterranean have incidences of the order of 50–75% and in Africa the figure reaches 80%. Asia is affected even more with about 90% of the population suffering from lactose intolerance.

The control of lactase production was disputed by scientists for many years. Some researchers in the 1960s argued that lactase production was stimulated in the presence of its substrate, lactose from milk. They proposed that populations that did not use milk as adults lost the ability to produce lactase, whereas groups that did consume milk continued to make the enzyme. More recent studies have cast doubt on this theory and shown that lactase production is controlled by a gene that is located on chromosome 2.

Milk and milk products are valuable sources of protein, calcium, carbohydrates and other nutrients, so the consequences of lactose intolerance in babies and young children can be serious. Other sources of the nutrients must be given: artificial milk for babies can be produced using soybeans, and adults can get protein from meat and vegetables. Yoghurt with live bacterial cultures are usually tolerated well and dark green vegetables are a good source of calcium. Lactose-free dairy products are also readily available in many countries.

Enzyme Inhibition

Inhibitors are molecules that can reduce or prevent enzyme action.

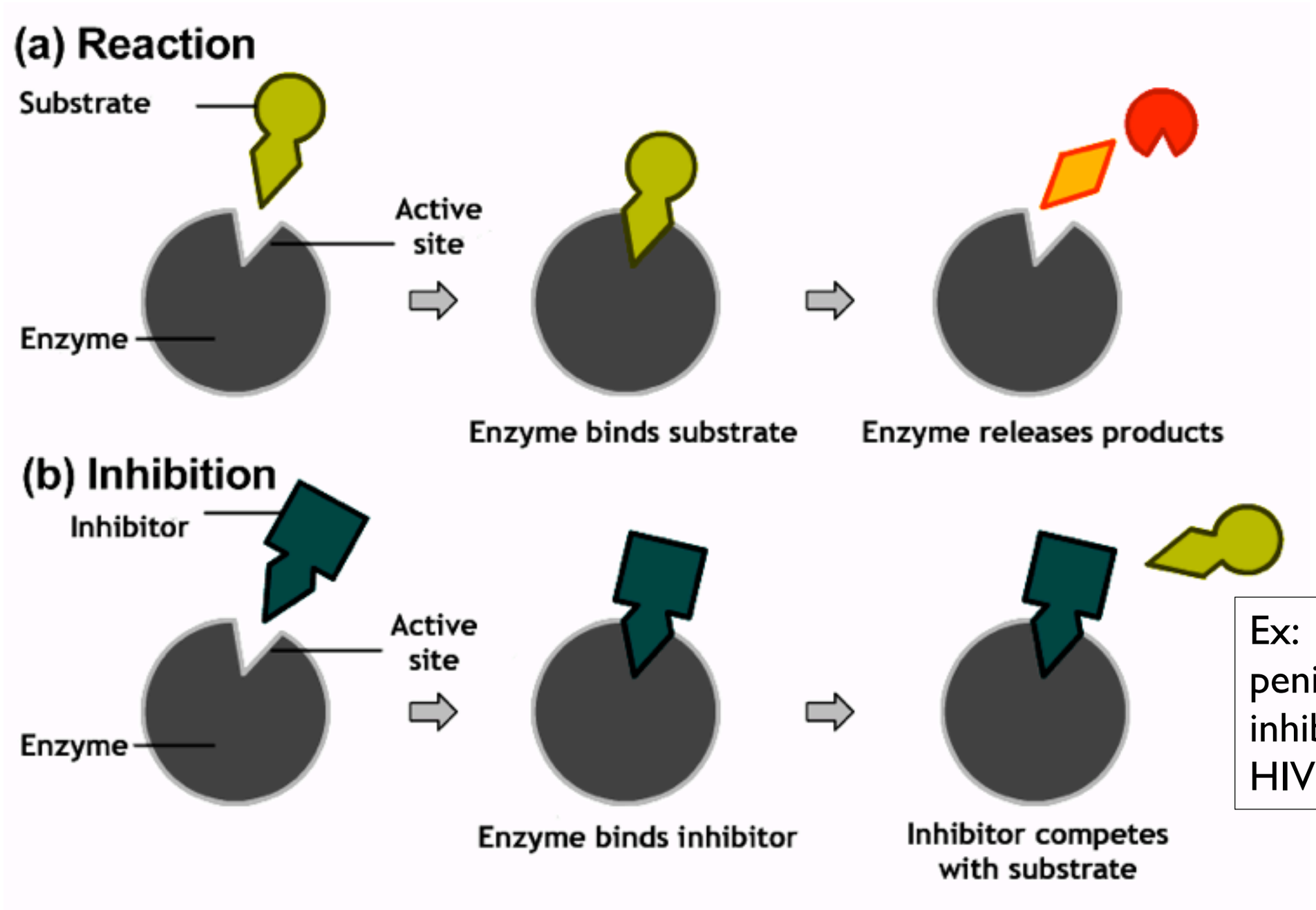
TWO TYPES:

1) Competitive

2) Non-competitive

Competitive Inhibition

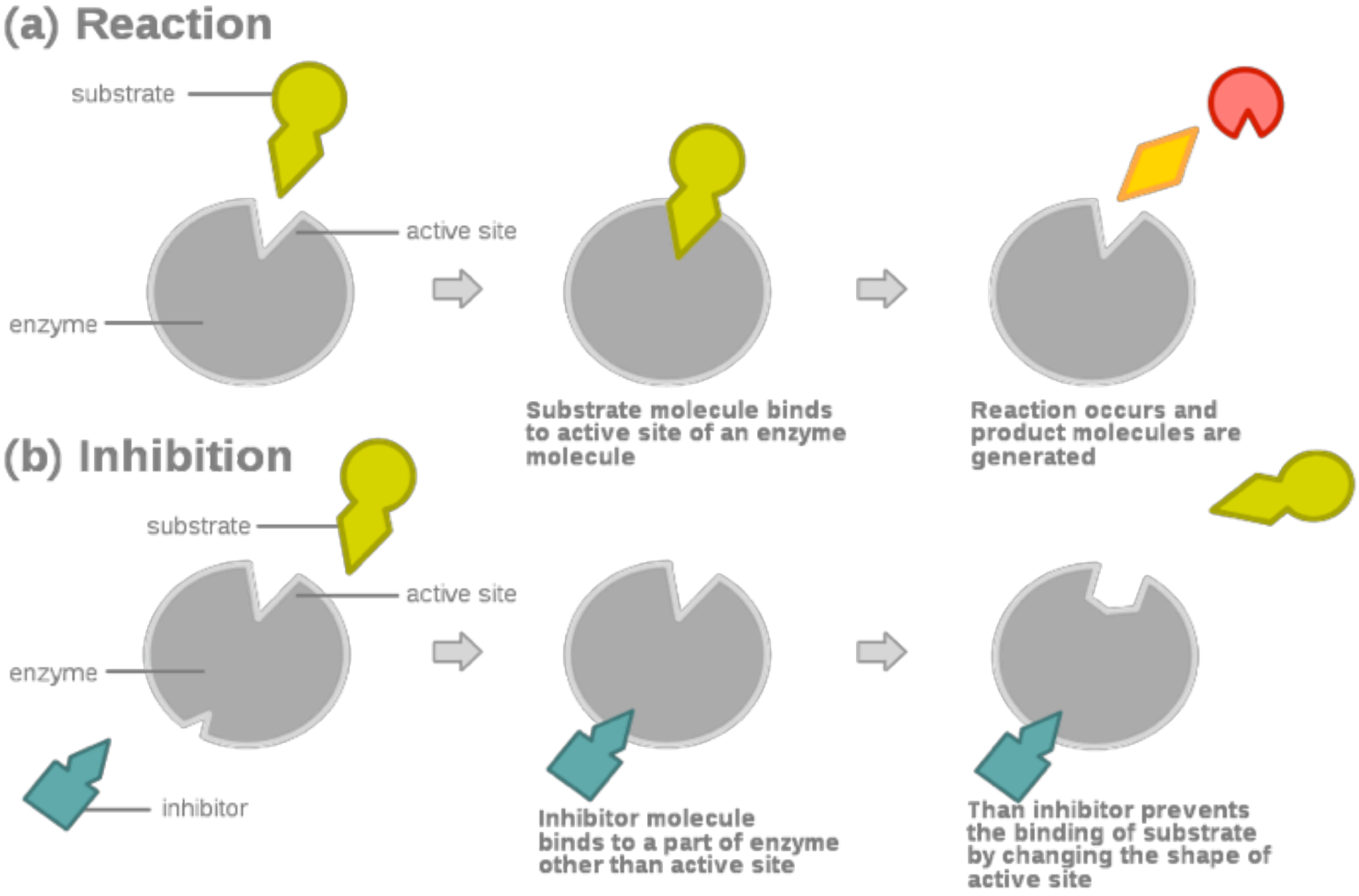
Blocks the active site by binding to it, thereby preventing the substrate from binding. This slows enzyme activity. Adding more substrate will reduce the effect of the inhibitor.



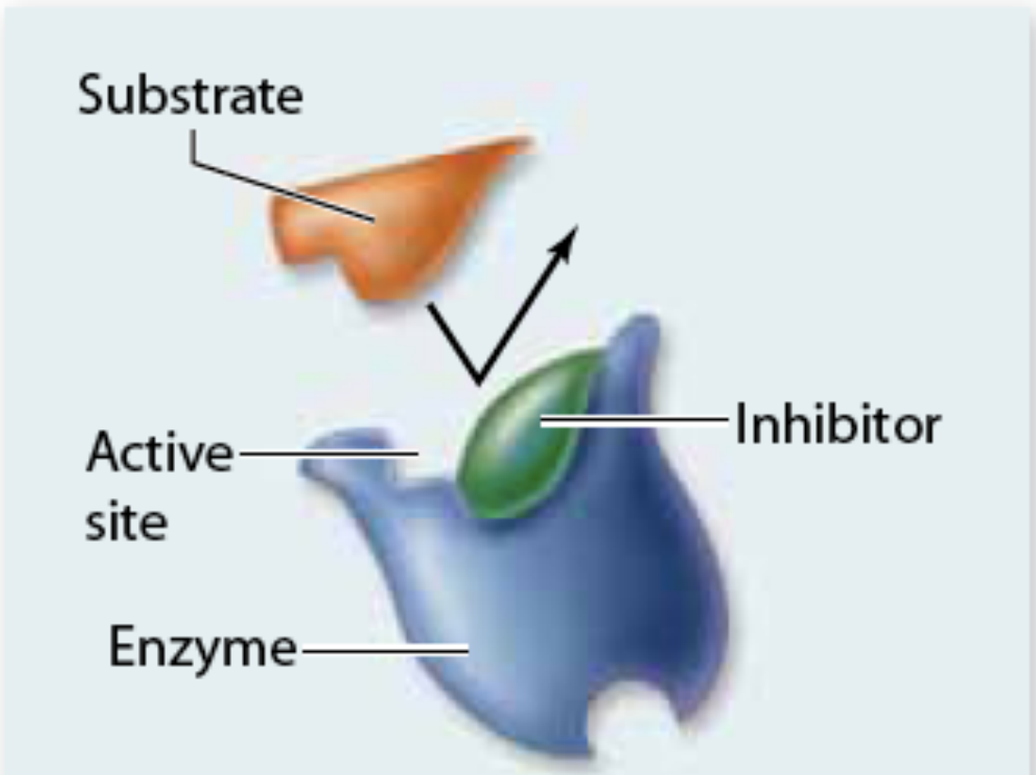
Ex: many drugs, penicillin, protease inhibitors – used in HIV treatment

Non-competitive Inhibition

The inhibitor binds to a place on the enzyme that is NOT the active site called the **allosteric site.** This changes the conformation of the enzyme (the substrate may no longer fit) and reduces its ability to catalyze the reaction (either slows it down or prevents it).

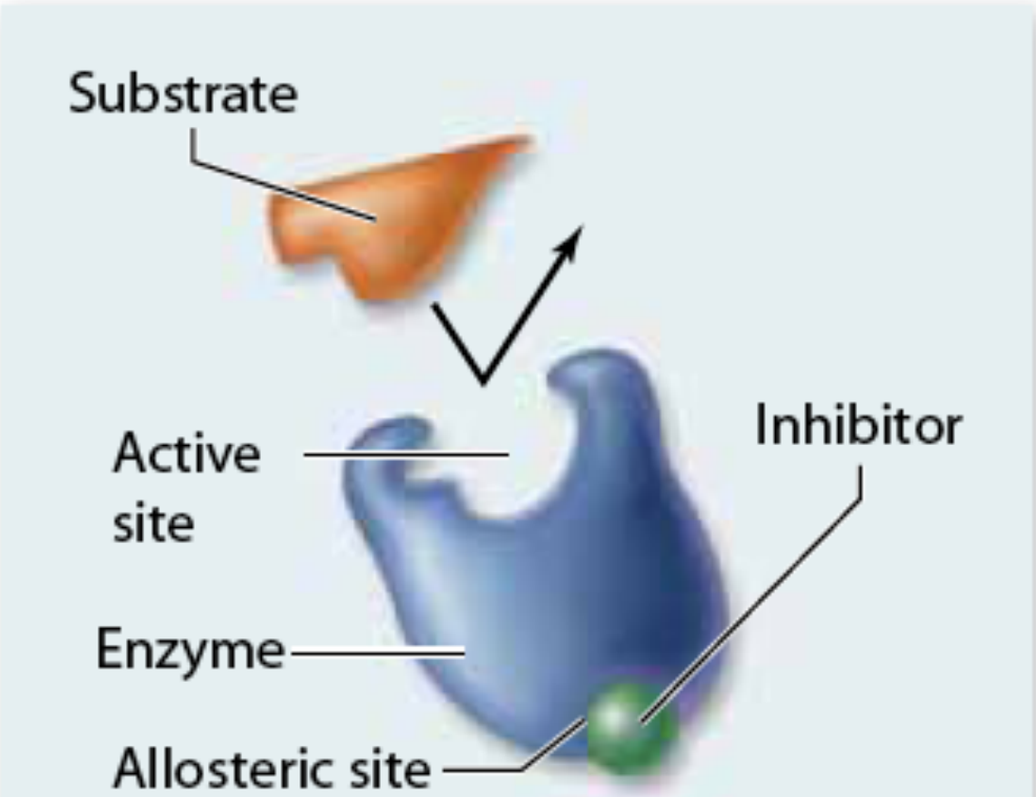


Competitive & Non-Competitive Inhibition



Competitive inhibitor interferes with active site of enzyme so substrate cannot bind

A Competitive inhibition



Allosteric inhibitor changes shape of enzyme so it cannot bind to substrate

B Noncompetitive inhibition

Metabolic Pathways & End Product Inhibition

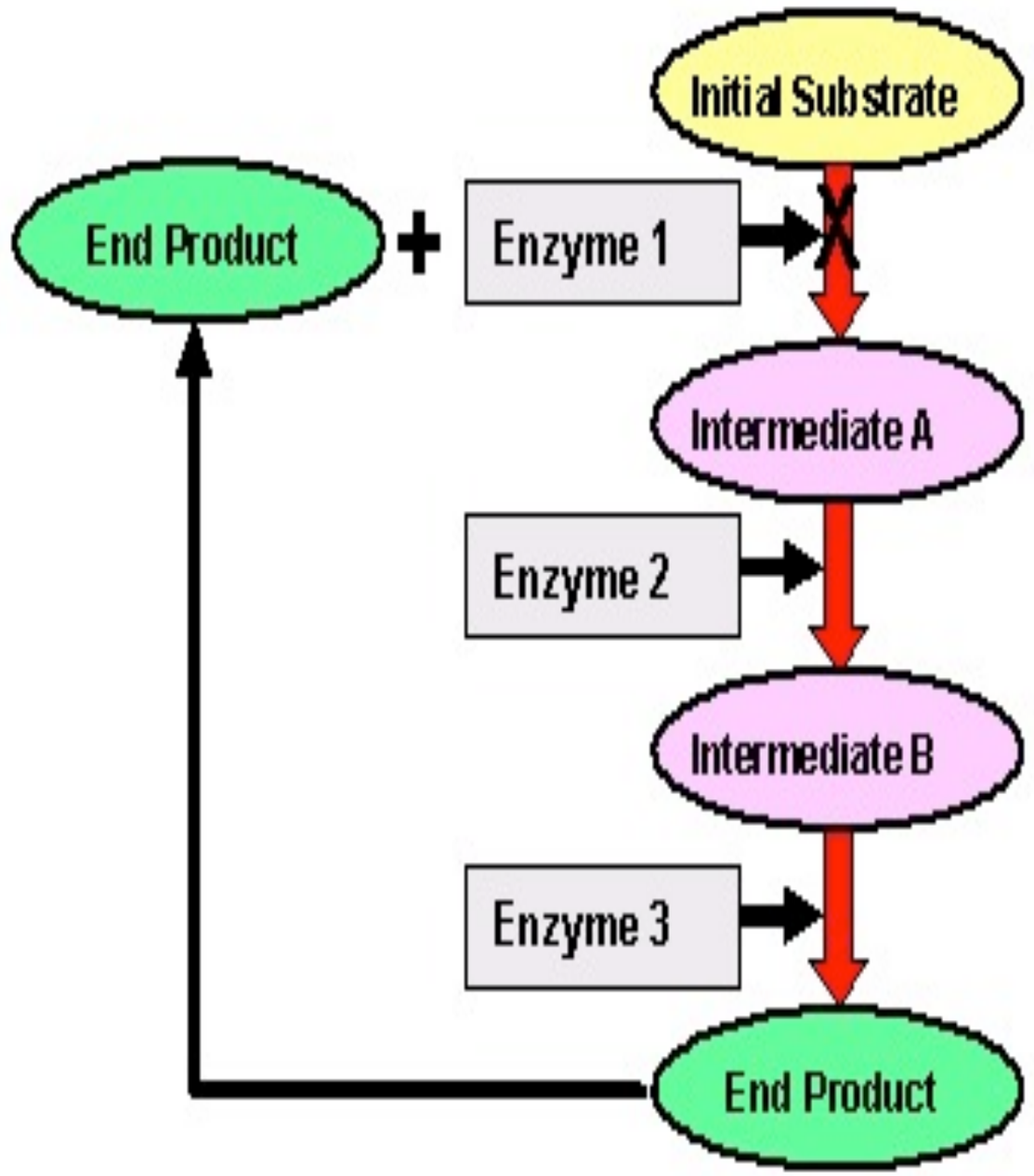
How metabolic pathways work:

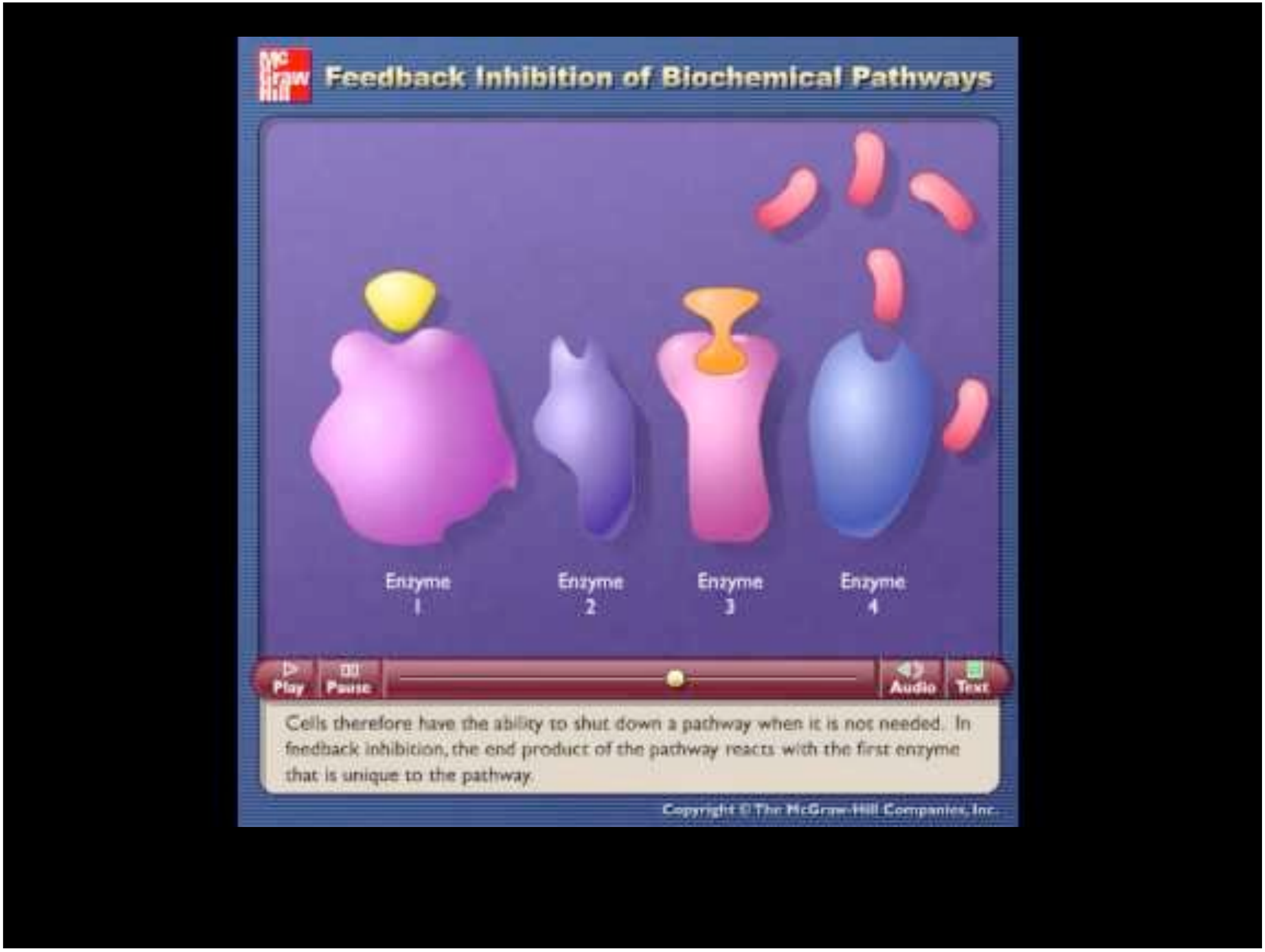
- Chemical changes in living things often occurring with a number of intermediate stages or reactions.
- The processes are too big to happen in one step, so they are a series of little steps
- Each reaction is catalyzed by its own enzyme.
- Catabolic pathways breakdown molecules
- Anabolic pathways build up molecules

End Product Inhibition

- End product inhibition is **negative feedback** used to regulate the production of a given molecule.
- The end product of the pathway "feeds back" and becomes an allosteric inhibitor of the 1st enzyme
- This stops the reaction so there will not be an excess production of the end product.

http://www.youtube.com/watch?v=c8FcZVJS1Q8




Feedback Inhibition of Biochemical Pathways
Enzyme 1
Enzyme 2
Enzyme 3
Enzyme 4
Play
Pause
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Cells therefore have the ability to shut down a pathway when it is not needed. In feedback inhibition, the end product of the pathway reacts with the first enzyme that is unique to the pathway.
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