Proteins / Enzymes

Objectives :

- Describe and explain the properties of enzymes

- Explain how enzymes work with reference to the lock and key model and the Induced fit model

- Describe and explain the factors that affect the rate of an enzyme catalyzed reaction including the effects of temperature, pH, enzyme concentration and substrate concentration, competitive and noncompetitive inhibitors (Human biology book p 38-39)

**** Students should be able to sketch graphs to show the expected effects of temperature, pH and substrate concentration on the activity of enzymes. They should be able to explain the patterns or trends apparent in these graphs***

- Practical skill: Investigate the effect of pH, temperature, enzyme and substrate concentration on the activity of enzymes

- Explain the use of immobilized enzymes in the production of lactose free milk (refer to human biology page 43 -45)

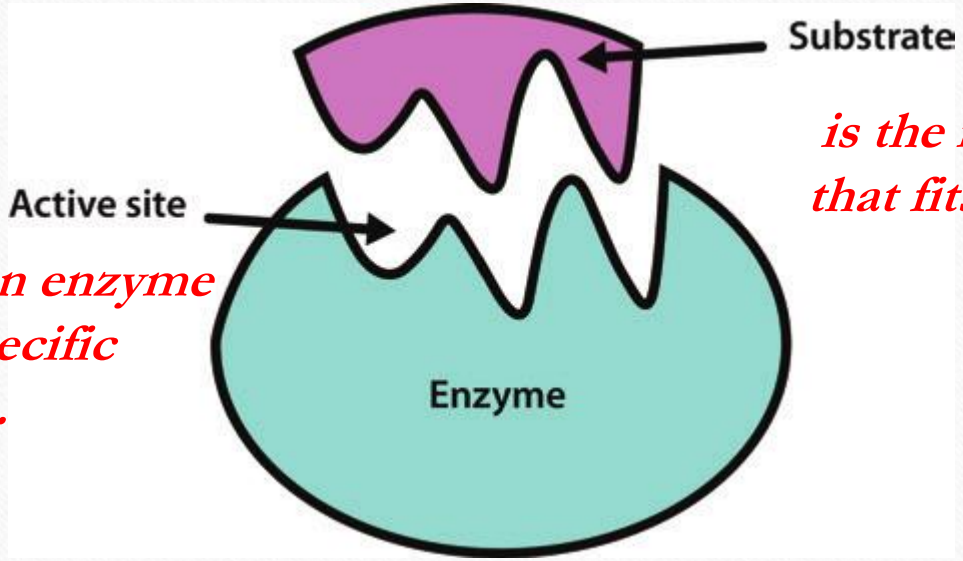
Resources :

Book pages 36,37,38

Enzymes are biological catalysts that speed up chemical reactions within cells. They are essential for life as they are needed for important functions in the body such as digestion. **Some enzymes may help break down large molecules into smaller ones, while others help join small molecules to make larger ones.**

The **molecule that binds to the enzyme** is called the **substrate.**

All enzymes have an active site to which a specific substrate binds.
https://www.youtube.com/watch?v=wNG2uPao8BI



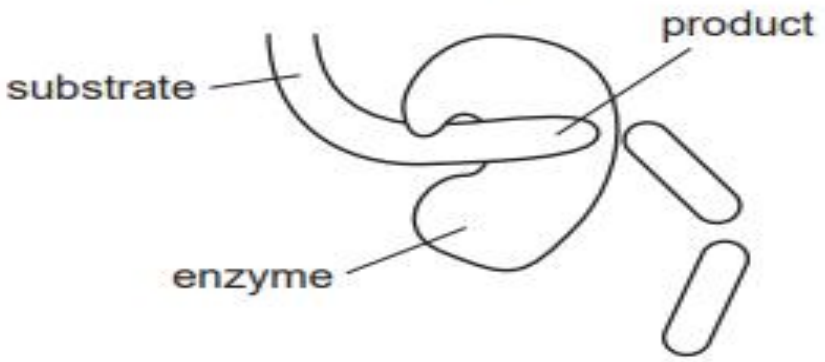
is the molecule that fits the active site.

Is the area on an enzyme to which the specific substrate binds.

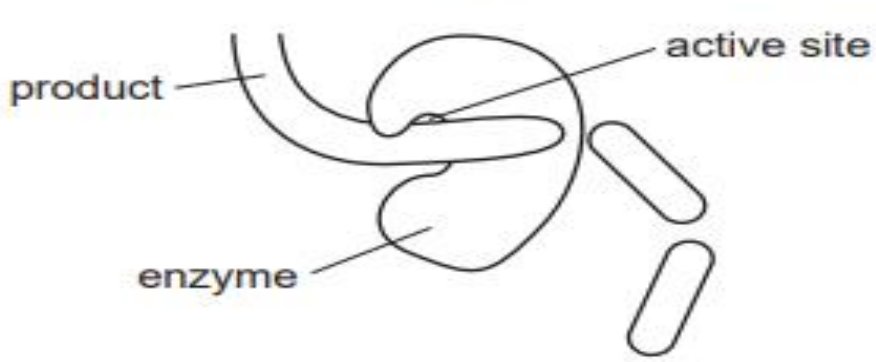
The diagrams show a protease enzyme catalysing the breaking of part of a protein molecule into smaller pieces.

Which diagram has three correct labels?

A

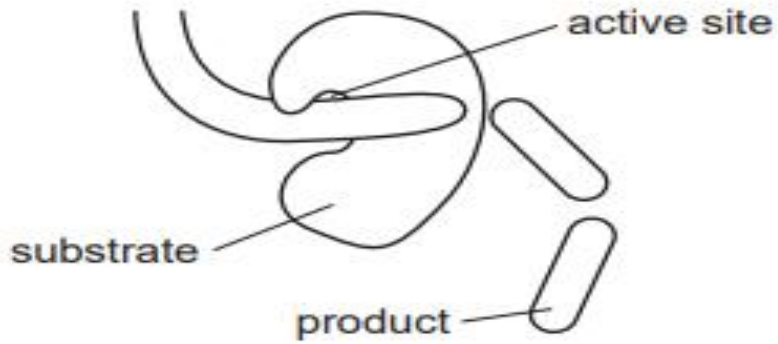


B



C

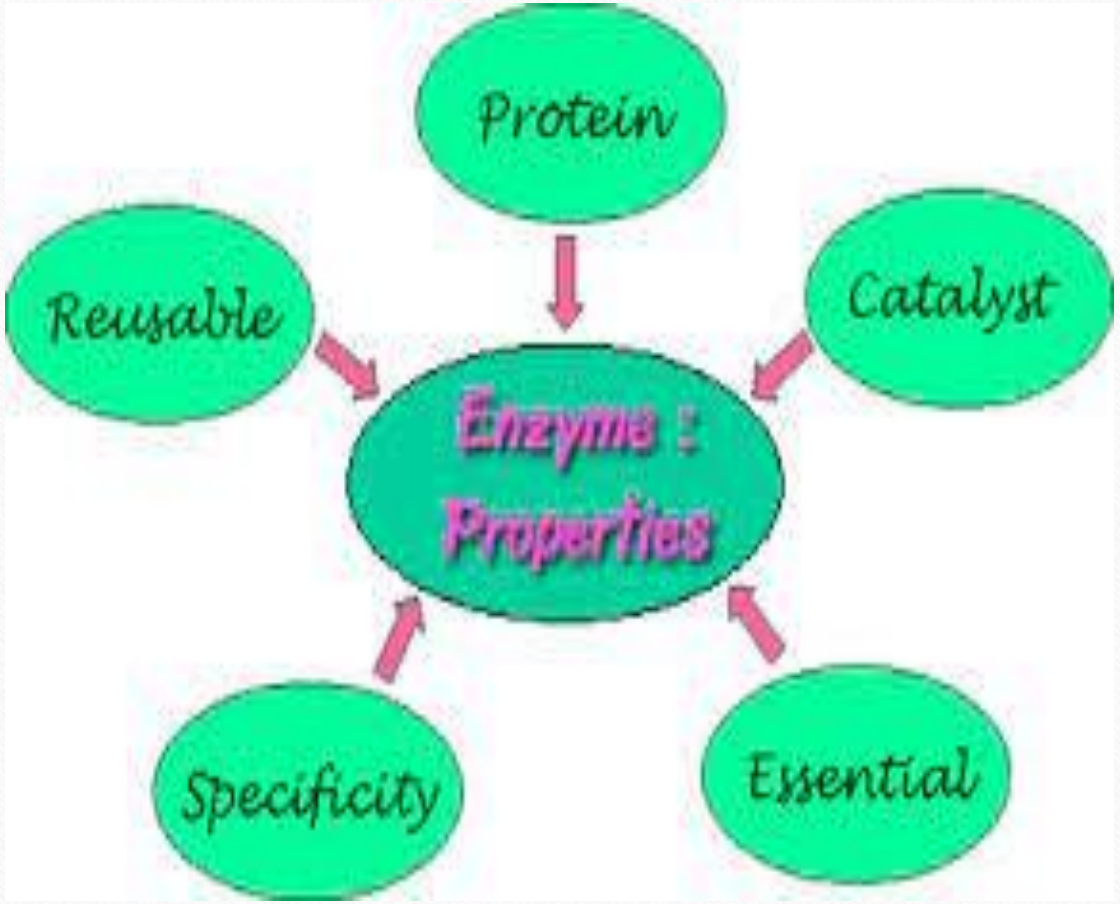
D



Properties of enzymes

All enzymes share the following properties:

- ✓ They are all proteins folded into complex shapes.
- ✓ They are specific, which means that each enzyme can only catalyse one reaction because only a substrate molecule with a specific shape can bind to the active site.
- ✓ Like all proteins, they are affected by pH and temperature.
- ✓ They are not used up in reactions and therefore can be reused.



How do enzymes work ? https://www.youtube.com/watch?v=UVeoXYJlBtI

One of the theories that explains the interaction between the enzyme and substrate is **the lock and key theory,** where the enzyme is the lock and the substrate is the key . This is because the shape of the active site is complementary to the shape of the substrate.
Once a specific substrate fits the active site of the enzyme, an enzyme-substrate complex forms. The bonds within the substrate are weakened which results in the formation of a new product.

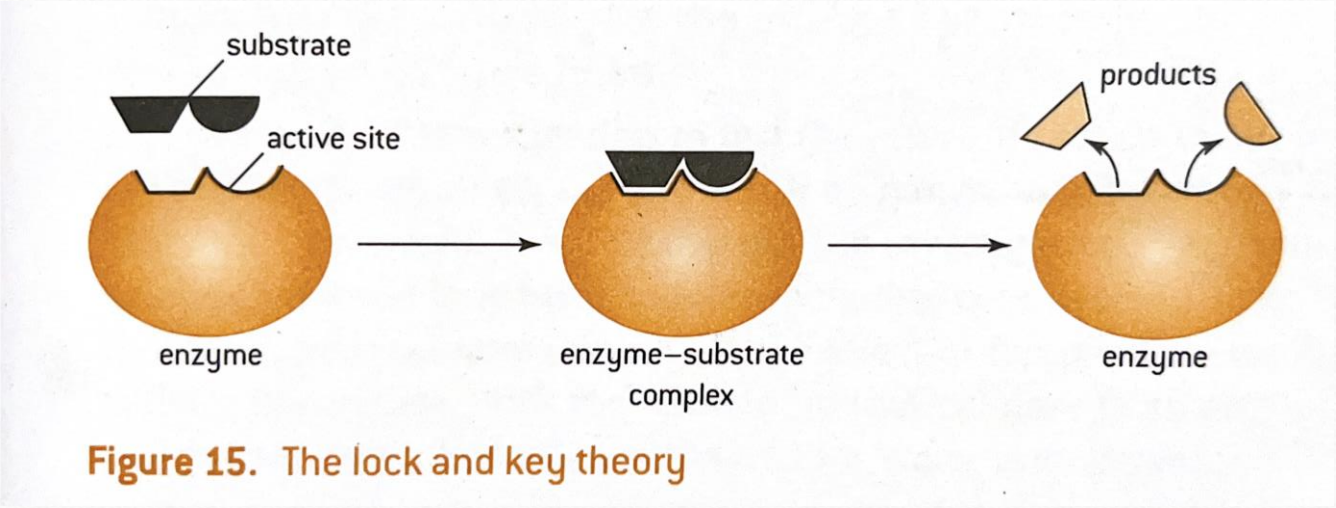
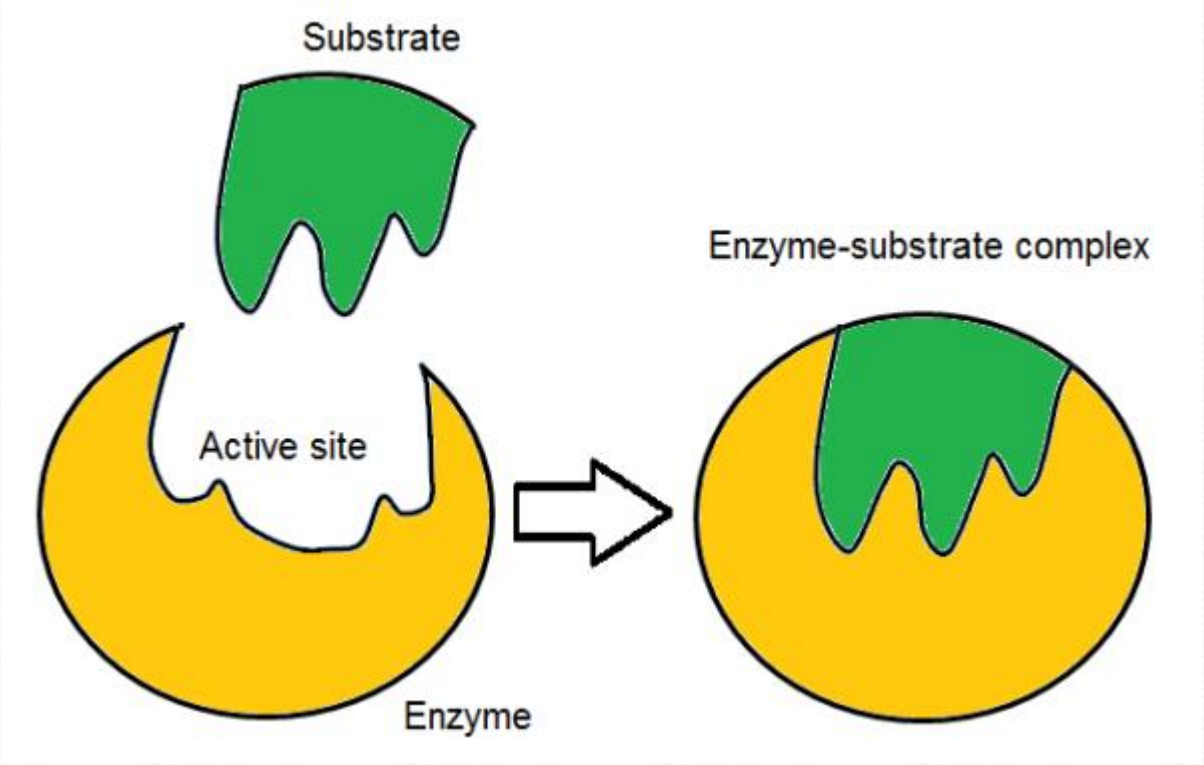
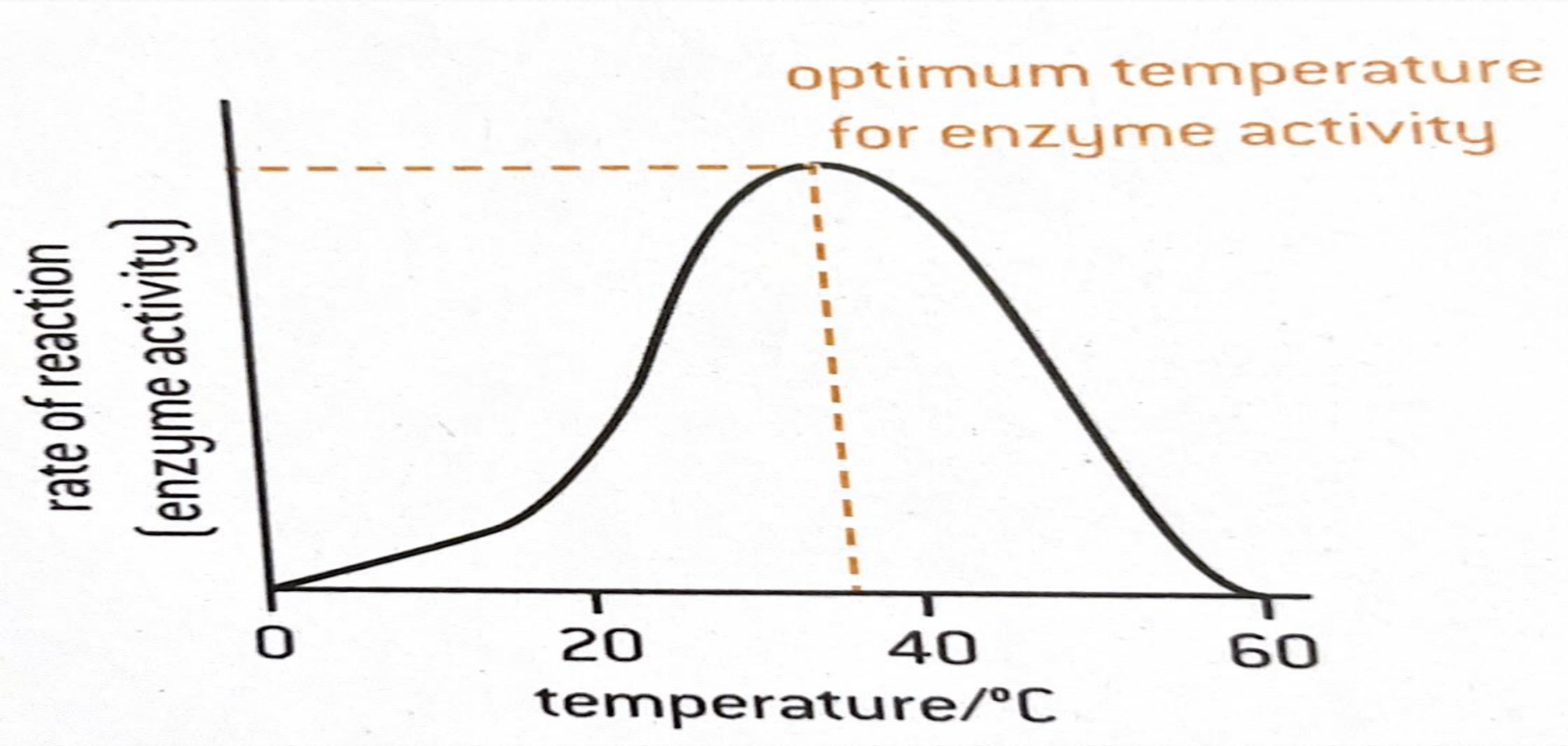


Figure 15. The lock and key theory

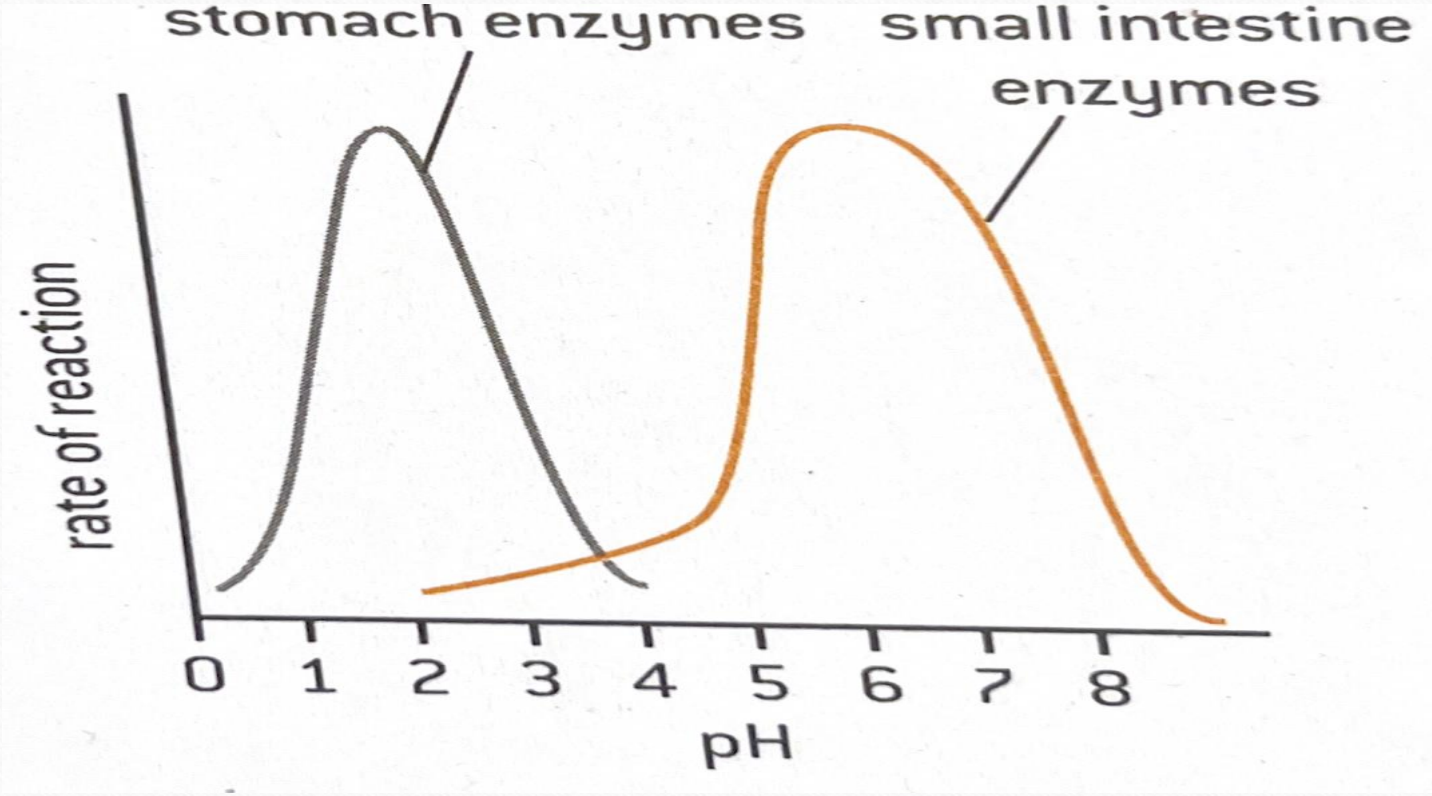
Induced fit model : https://www.youtube.com/watch?v=pVoytz_3H_s

The induced-fit model states **a substrate binds to an active site and both change shape slightly, creating an ideal fit for catalysis.**





Describe the effect of temperature on the enzyme activity



How do you think changing the PH affects the enzyme activity ?

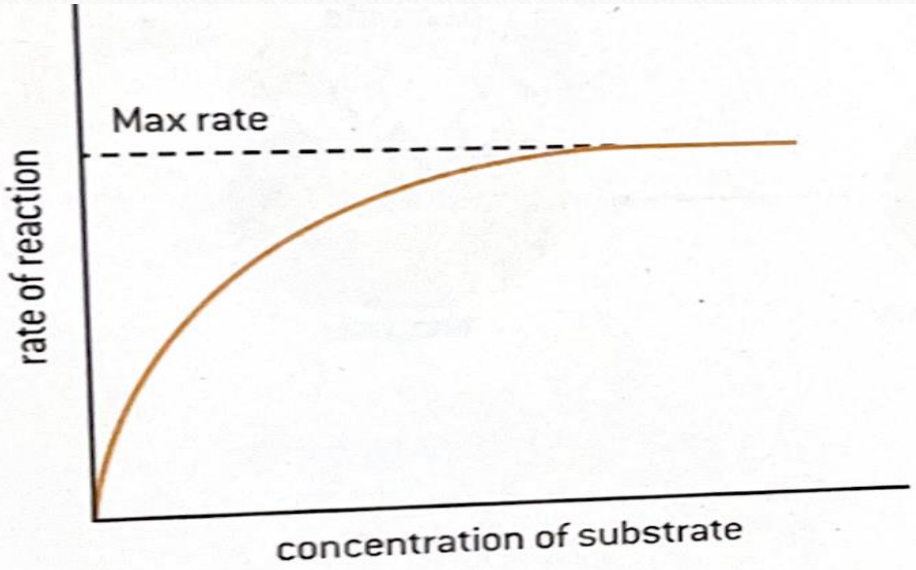


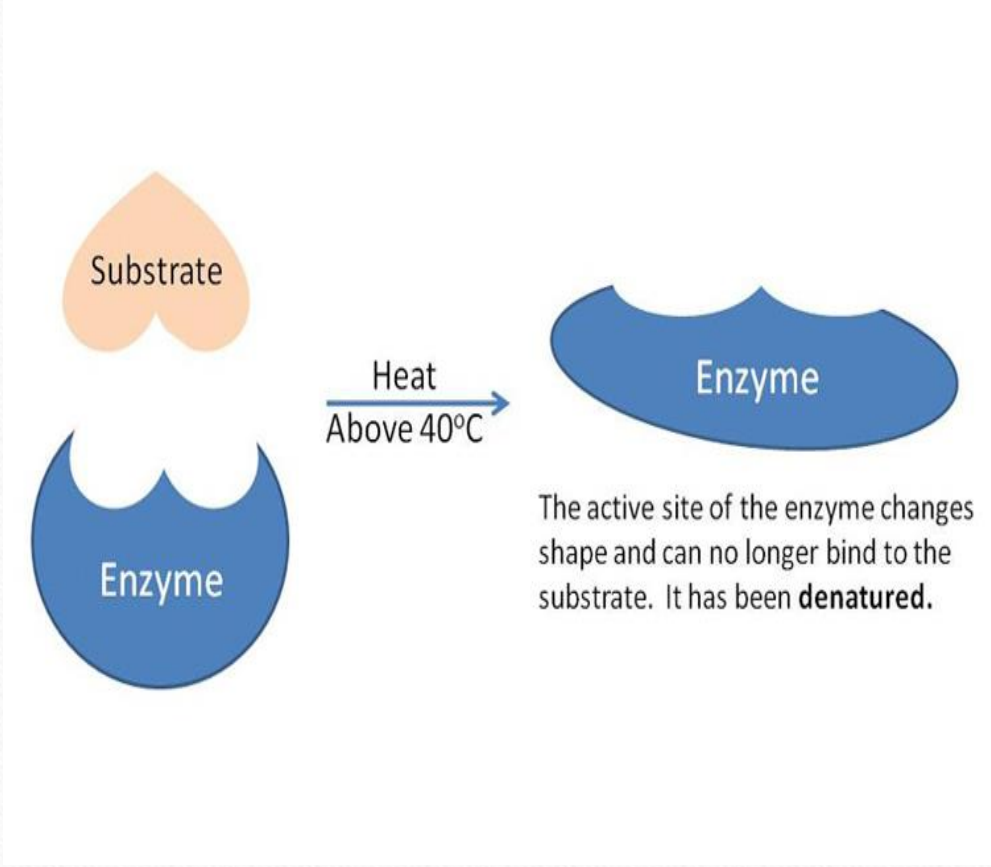
Figure 19. Effect of substrate concentration on the rate of an enzyme-catalysed reaction

Describe the effect of substrate concentration on the enzyme activity ?

Enzymes and temperature

All enzymes are affected by temperature . As the temperature increases, the enzyme activity and the rate of reaction increase. At the optimum temperature, the maximum rate of reaction is reached.

Beyond the optimum temperature, the enzyme begins to lose its shape, including the shape of the active site. Therefore, the enzyme will no longer fit the substrate. When an enzyme loses its shape and is unable to function it is said to be denatured. Denaturing can occur when the enzyme is exposed to high temperatures or extreme pH.



Enzymes and pH

There is no one optimum pH for all enzymes. The optimum pH for an enzyme depends on where it normally works. For example, enzymes that work in the stomach have a very low optimum pH of about 2, while enzymes that work in the small intestine have an approximately neutral pH of about 7.5 .

Most enzymes in the human body have an optimum pH near to 7.5. At the optimum pH, the enzyme works most efficiently, and the maximum rate of reaction is reached. Above or below the optimum pH, the rate of reaction and enzyme activity decrease. If the conditions are too acidic or too basic an enzyme will lose its shape and denature.

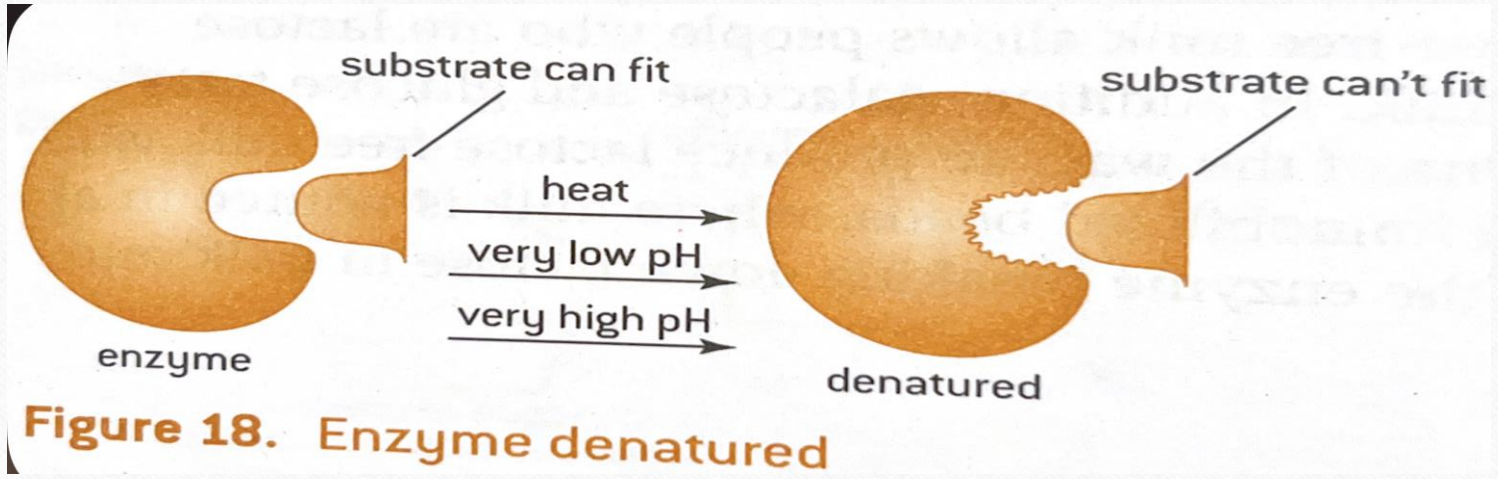
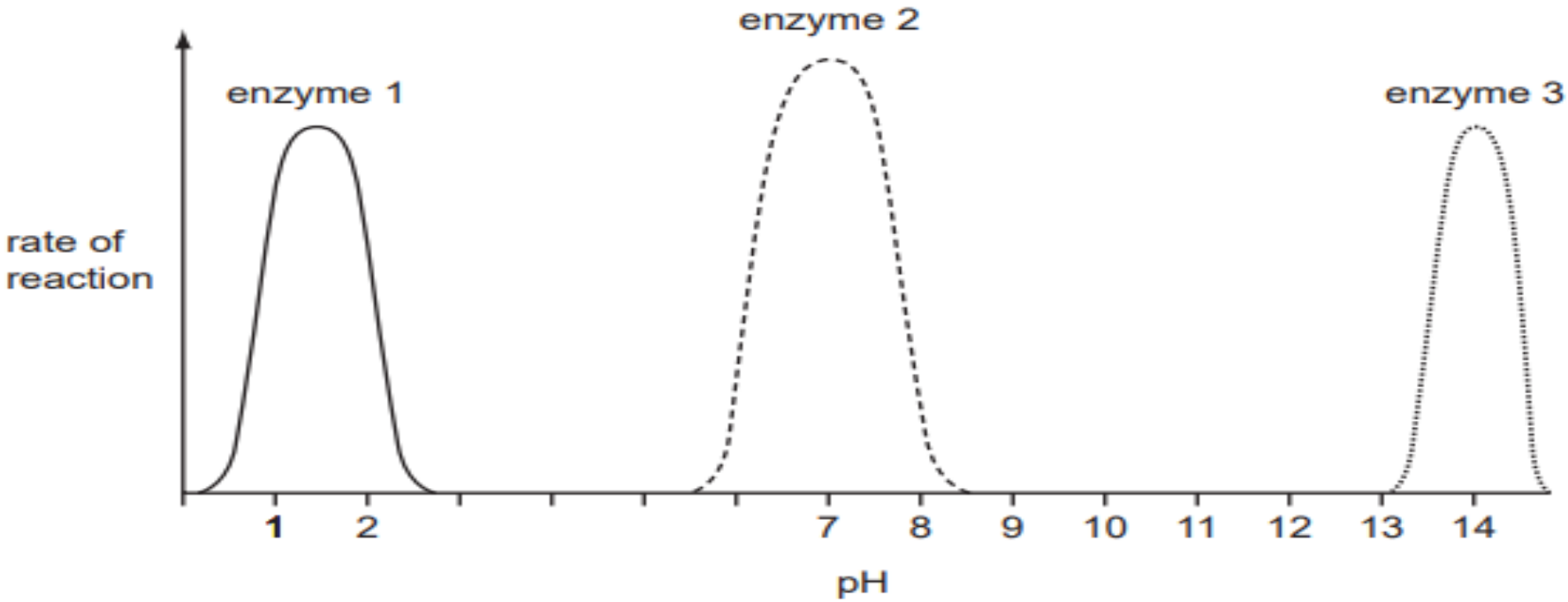


Figure 18. Enzyme denatured

The graph shows the effect of pH on the rate of reaction of three different enzymes.



What does the graph show?

A Each enzyme works best at a different pH.

B Each enzyme works best over a narrow temperature range.

C Enzymes work best in acid conditions.

D Enzymes work best in alkaline conditions.

Six test-tubes were set up at different temperatures. Each contained identical solutions containing starch and amylase mixtures. The table shows the time taken for the reactions to finish in each test-tube.

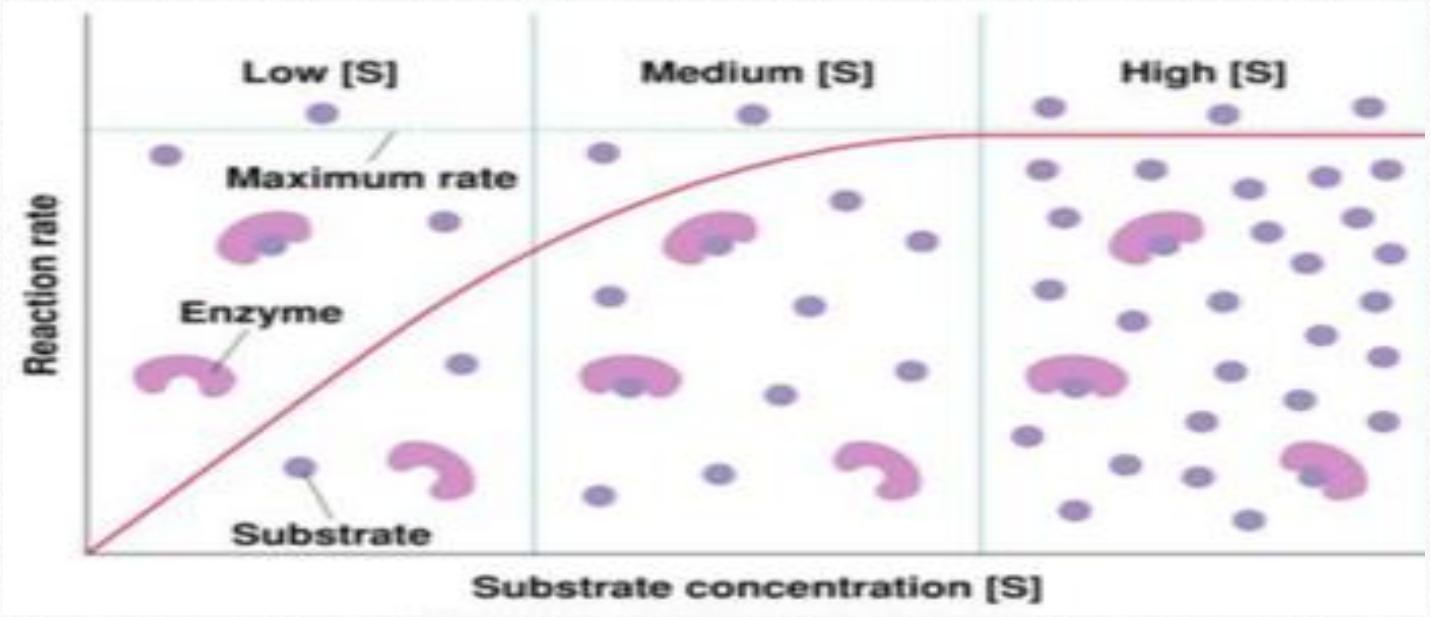
temperature / °C	15	25	35	45	55	65
time / seconds	35	22	13	5	35	66

At which temperature does the amylase work best?

A 15 °C **B** 35 °C **C** 45 °C **D** 65 °C

Enzymes and substrate concentration

The change in substrate concentration affects the rate of reaction. **As the substrate concentration increases, the rate of reaction increases as well**. This is due to the increase in collisions between the substrate and the enzyme. However, at a certain point when all enzyme molecules are occupied, the rate of reaction reaches its maximum and any further increase in substrate concentration will no longer affect the rate of reaction .



Competitive and Noncompetitive inhibitors

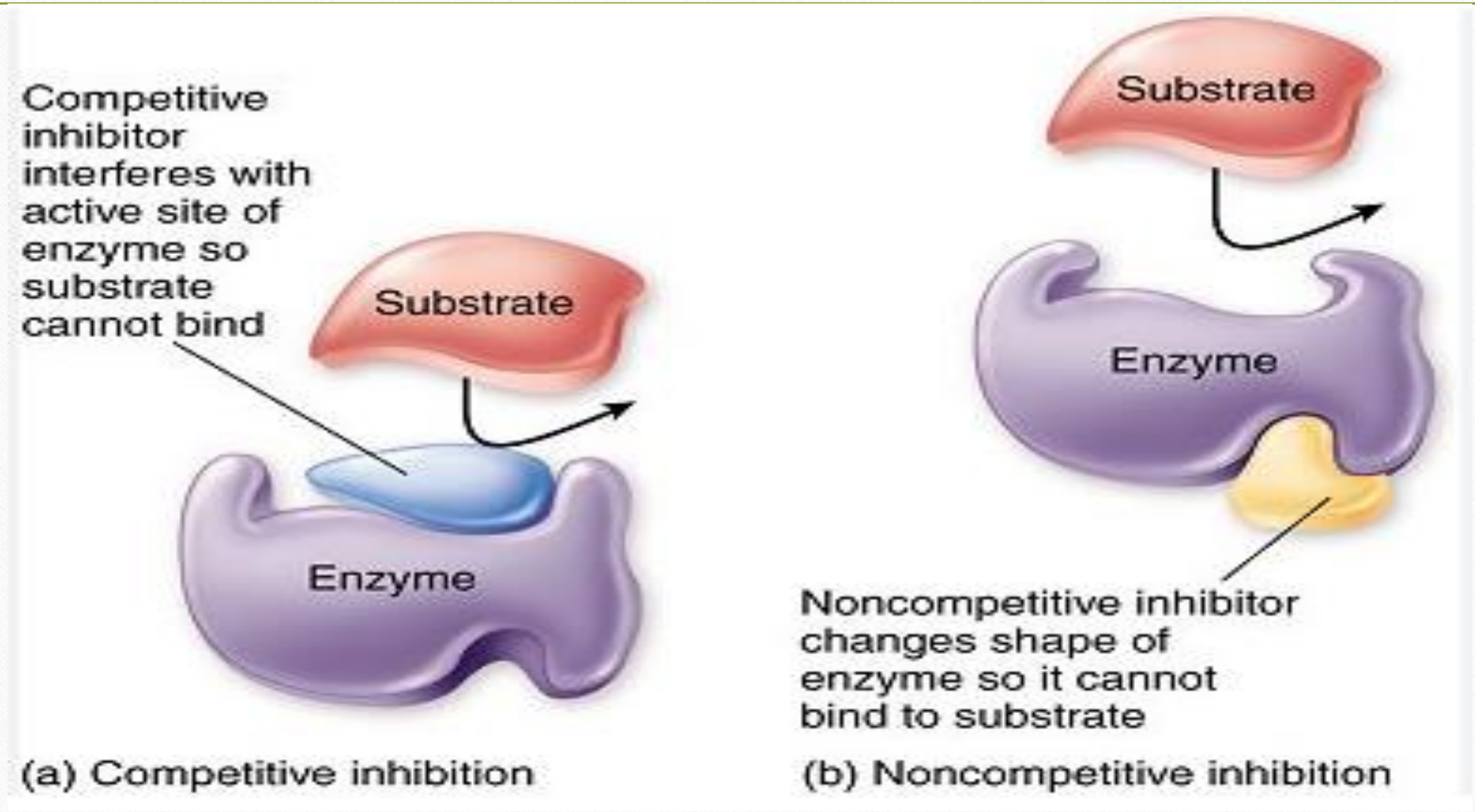
https://www.youtube.com/watch?v=d_etkljNZxk

An enzyme inhibitor is a molecule that binds to an enzyme and prevents it from catalyzing a reaction. We will look at two types of enzyme inhibition – competitive and non-competitive inhibition.

A competitive inhibitor is a molecule which has a **very similar shape** to the substrate of the enzyme that it inhibits. Because of the similar shape, the inhibitor is able to **bind to the active site** of the enzyme. When this happens, the active site is blocked and the enzyme can no longer carry out its function. **The inhibitor competes with the substrate to bind to the active site.**

A non-competitive inhibitor is a molecule which binds to the enzyme, but not in the active site. Instead, it binds to somewhere else on the enzyme causing the **active site to change shape**. The substrate is no longer complementary to the active site, and the reaction cannot be catalyzed. So this time it doesn't matter how much you increase the substrate concentration – the reaction still can't occur because the enzyme-substrate complex cannot form.

- ✓ **An example of a use for a non-competitive inhibitor is in the use of cyanide as a poison (prevents aerobic respiration)**


Competitive inhibitor interferes with active site of enzyme so substrate cannot bind
Substrate
Enzyme
(a) Competitive inhibition
Substrate
Enzyme
Noncompetitive inhibitor changes shape of enzyme so it cannot bind to substrate
(b) Noncompetitive inhibition

Competitive and non-competitive inhibitors - effect on reaction rate

Red line (no inhibitor)

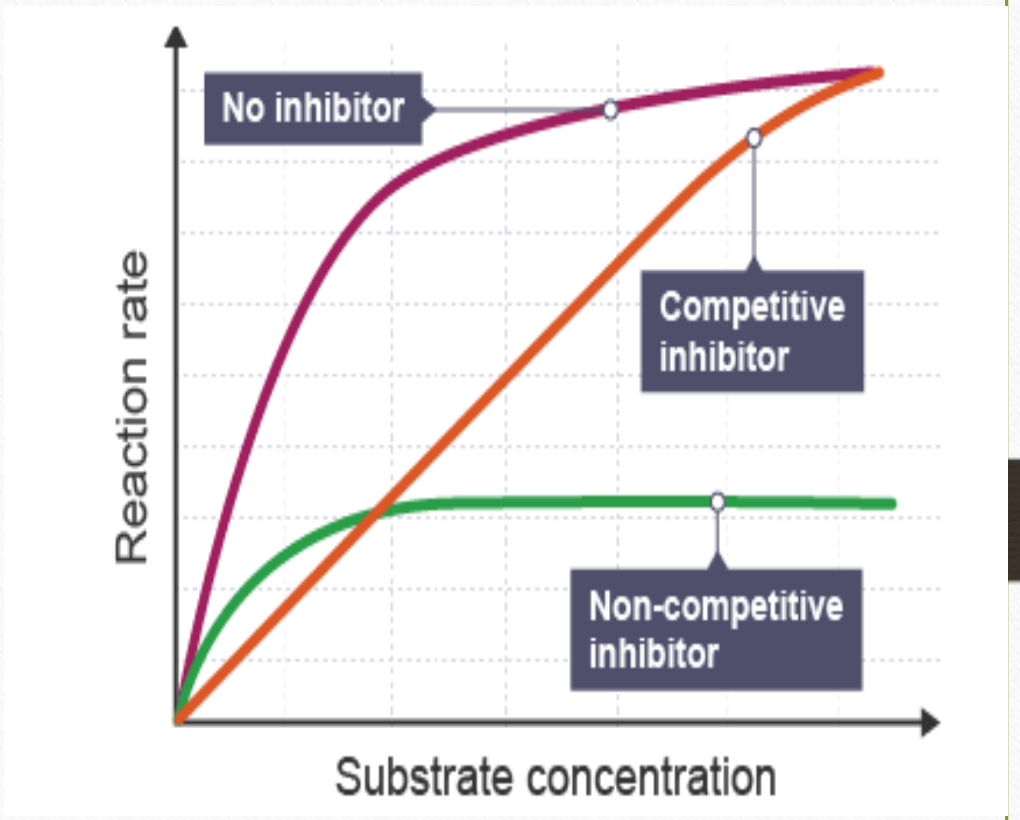
The graph levels off because all of the active sites are occupied with the substrate.

Orange line (competitive inhibitor)

There is a gradual increase in reaction rate because competitive inhibitors are occupying only some of the enzyme active sites. As substrate concentration increases, the substrate molecules outnumber the inhibitor so the reaction rate reaches the maximum.

Green line (non-competitive inhibitor)

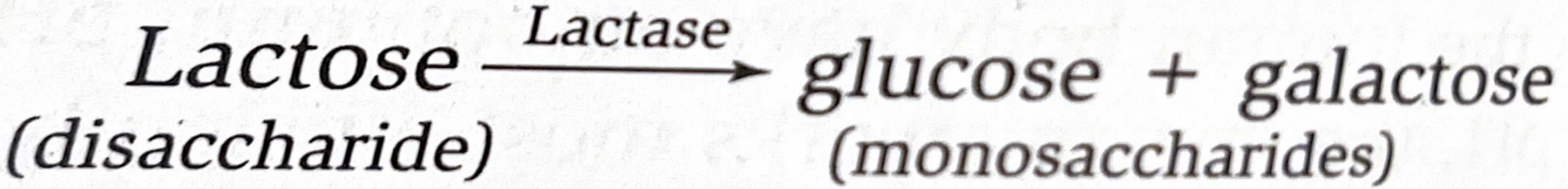
Most enzyme molecules have become inactive but some are unaffected by the inhibitors so reaction rate remains low. An increase in substrate concentration does not increase reaction rate.



Enzymes and industry

Being able to manipulate and control the temperature, pH and substrate concentration can affect the activity of the enzyme and consequently the rate of reaction. This makes it possible for us to control enzyme-catalysed reactions in industry to reach the maximum rate of reaction and increase the amount of products produced.

Lactase is an enzyme that can be obtained from fungi and is used in industry to produce lactose-free milk. Lactose is the sugar of milk, and it cannot be absorbed by the small intestine because it is a disaccharide. Lactase is an enzyme that breaks down lactose into glucose and galactose which are easily absorbed by the small intestine.



People with lactose intolerance lack the enzyme lactase and so cannot break down lactose. If milk or milk-based products enter the digestive system, they are not digested. Instead, bacteria in the large intestine feed directly on lactose resulting in abdominal pain, diarrhea, cramps and excessive gas.

The production of lactose-free milk **allows people who are lactose intolerant to consume milk. In addition, galactose and glucose taste sweeter than lactose**. One of the ways to produce lactose-free milk is to fix the enzyme to small immobilized beads, where milk is poured in at the top. This results in the enzyme breaking down lactose in milk into glucose and galactose .

https://www.youtube.com/watch?v=P7e9Mj9ATpQ