4.1 Structure and action of enzymes

Objectives:

- Define the term catalyst as a substance that increases the rate of a chemical reaction and is not changed by the reaction
- Define enzymes as proteins that function as biological catalysts
- Describe why enzymes are important in all living organisms in terms of reaction speed necessary to sustain life
- Describe enzyme action with reference to the complementary shape of an enzyme and its substrate and the formation of a product

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A **catalyst** speed up a chemical reaction and remains unchanged at the end of the reaction. Enzymes are proteins, produced by organism, that speed up chemical reactions. They are known as **biological catalysts**.

How enzymes work

Many chemical reactions take place in organisms. These reactions happen too slowly to keep organisms alive unless they are speeded up by enzymes. there are many different types of enzymes as each one catalyses a different reaction. Most enzymes work inside cells, but many of those that we will discuss here work outside cells, for example in the gut.

1 Breaking large molecules into small ones

This is important in nutrition when large food molecules are broken down into small ones so that they can be absorbed and then used. Bacteria and fungi release enzyme to break down their food and we release enzymes into the gut for the same reason.

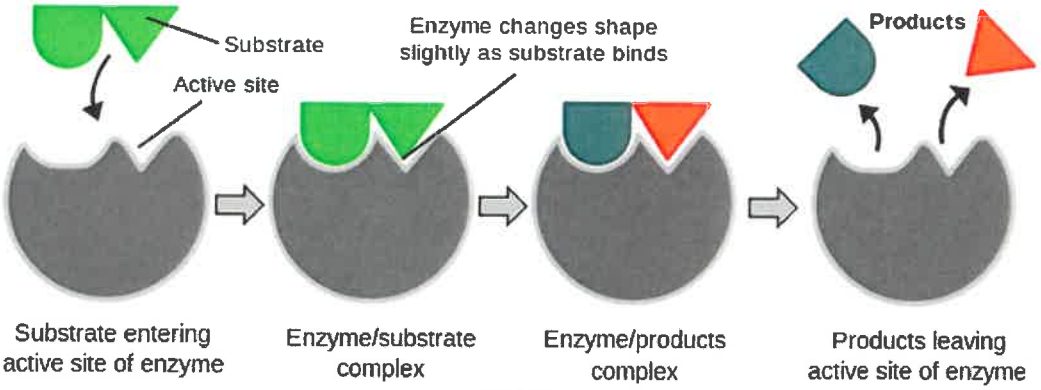
2 Building up large molecules from small ones

Small molecules, such as glucose, are joined together to make large molecules. These enzymes work inside cells to speed up the formation of storage molecules, such as starch, and structural molecules such as cellulose for cell walls of plants.

3 Converting one small molecule into another

Many of the chemical reactions that occur inside cells involve small changes to molecules, such as adding or removing atoms or groups of atoms. For example, there are enzymes that remove hydrogen from compounds during respiration.

Figure 4.1.1 (right) shows the way in which an an enzyme catalyses the breakdown of a molecule.



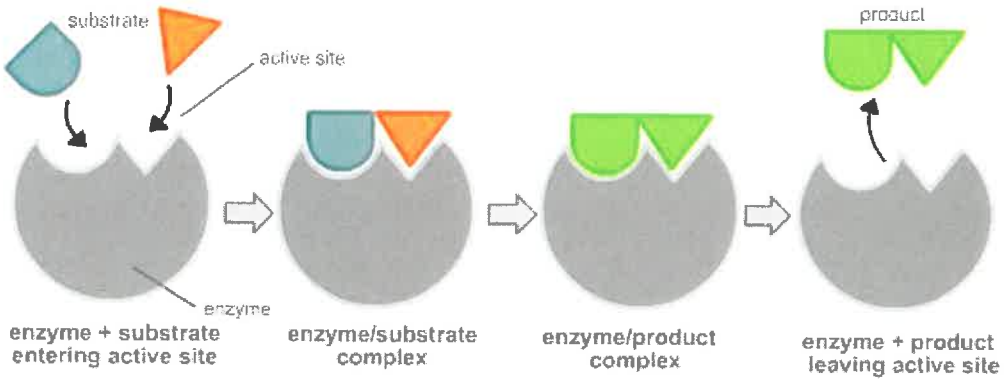


Figure 4.1.2 (left) shows how an enzyme is involved in building a molecule from two smaller molecules

Enzymes are made of protein

All enzymes have five important properties.

1. they are all proteins
2. Each enzyme catalyses one reaction
3. They can be used again and again
4. They are influenced by temperature
5. They are influenced by pH

Directions: write 5 things that you thought were most important from the reading 4.1 Structure and action of enzymes

1.

2.

3.

4.

5.

4.2 Factors affecting enzyme action

Objectives:

- Investigate and describe the effect of changes in temperature and pH on enzyme activity

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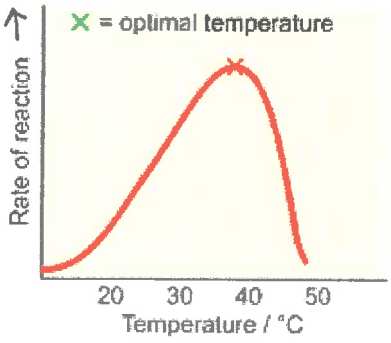
The activity of an enzyme is determined by measuring the rat of the reaction that the enzyme catalyses. This may be done either by measuring how much product is formed or by measuring how much substrate is used over a period of time. The rate is like the speed of the reaction measured in quantity of product or substrate per unit of time, example: per minute.

Effect of temperature of enzymes

The activity of enzymes is influenced by temperature. This graph shows the effect of increasing temperature on the rate of an enzyme-catalysed reaction.

Look at the graph and observe that the rate of reaction:

- is slow at low temperatures, ex: at 10°C
- increased as the temperature increases to 40°C
- reaches a maximum temperature at about 40°C
- decreases at temperatures greater than 40°C
- is approaching zero closer to 50°C



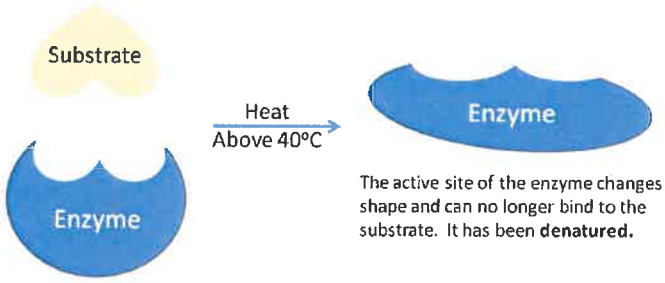
The temperature at which the maximum rate of reaction occurs is called the **optimum temperature**. This is the best temperature for the enzyme. Here are some examples of optimum temperatures:

- fungal and plant enzymes: approximately 20°C
- human enzymes: 37°C (body temperature)
- some of the enzymes produced by bacteria for use in industry: 90°C

In diagram 4.1.1 and 4.1.2 (both on page 1), the shape of an enzyme's active site remains unchanged before and after it is used. Only certain substrates (molecules) will fit into the active site. That is why there are several different enzymes with different active site shapes to fit different substrates.

As temperature increases, enzymes and substrate molecules will have a greater **kinetic energy** (energy of motion). They both move around more quickly and there are more chances of them colliding into each other. Therefore, it is more likely that the substrate will fit into the active site and reaction will take place.

At higher temperatures, the heat can cause the active site to change shape, which prevents the substrate from fitting into it. A reaction will not happen. We say that the enzyme has been **denatured** and it can no longer catalyse the reaction.



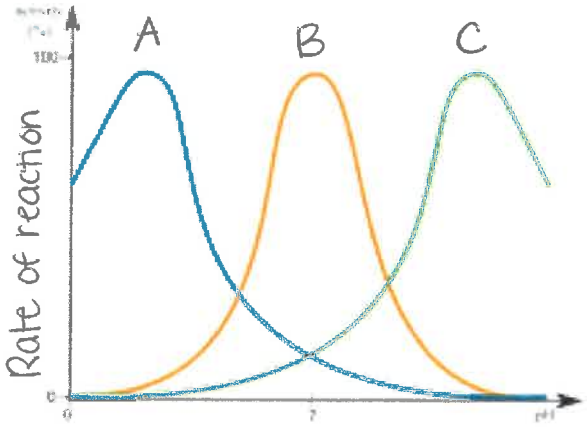
Enzymes and pH

Enzymes are influenced by the pH of their surroundings.

Many enzymes work best in neutral conditions, but some prefer acidic and some prefer alkaline conditions.

Look at the graph (right) showing the action of enzymes A, B, and C.

- Enzyme A works best at pH 2 - that is its optimum pH
- The optimum pH for enzyme B is 7
- The optimum pH for enzyme C is 13
- Up to pH 2, the rate of reaction increased for enzyme A and then between pH 2 and pH 10 it decreases. There is no reaction above pH 10.
- Between pH 4.5 and pH 8.0 the rate of reaction increases for enzyme B and then between pH 8 and pH 10 it decreases. There is no reaction below pH 4.5 or above pH 10.
- Between pH 3 and pH 13 the rate of reaction increases for enzyme C and then between pH 13 and pH 14 is decreases. There is no reaction below pH 3.



The shape of the active site can be altered by changes in pH. When the rate of reaction is zero, the shape of the active site has changed and the substrate molecules no longer fit. At these values of pH enzymes are denatured.

Directions: write 5 things that you thought were most important from the reading 4.2 Factors affecting enzyme action

1.

2.

3.

4.

5.

SUMMARY QUESTIONS

1 Write definitions of the following terms:
- **(a)** catalyst
- **(b)** enzyme
- **(c)** substrate
- **(d)** product
- **(e)** optimum temperature.

2 Explain the following statements.
- **(a)** Only small quantities of enzymes are required inside cells.
- **(b)** Amylase digests starch, but trypsin does not.
- **(c)** When investigating the effect of pH on enzymes, the reaction mixtures must always be kept at the same temperature.

3 Describe the three types of reaction that are catalysed by enzymes.

4 The table shows the effect of temperature on the relative activity of an enzyme kept at pH 7.

temperature (°C)	relative activity
5	4
15	8
25	16
35	32
45	30
55	7

- **(a)** Draw a graph of the results in the table.
- **(b)** Describe the results as shown in the graph.

5 The table shows the relative activity of an enzyme in solutions of different pH kept at 35 °C.

pH	relative activity
3	5
5	14
7	32
9	10
11	4

- **(a)** Draw a graph of the results in the table.
- **(b)** Describe the results as shown in the graph.

EXAM-STYLE QUESTIONS

1 Which of the following gives the features of enzymes?
- **A** Enzymes are made of carbohydrates and are catalysts.
- **B** Enzymes are made of carbohydrates and are chemical messengers.
- **C** Enzymes are made of proteins and are biological catalysts.
- **D** Enzymes are made of proteins and are chemical messengers.

(Paper 1) *[1]*

2 Starch and human salivary amylase were mixed together at different temperatures. Which temperature will give the fastest rate of starch digestion?
- **A** 20 °C
- **B** 60 °C
- **C** 37 °C
- **D** 10 °C

(Paper 1) *[1]*

3 The pH of enzyme-controlled reactions may be changed from pH 7 to pH 8. How does this affect the rate of the reactions?
- **A** always increases the rate
- **B** always decreases the rate
- **C** has no effect on the rate
- **D** may change the rate or have no effect on the rate.

(Paper 1) *[1]*

Extension

4 A student investigated the effect of temperature on amylase.

An amylase solution was divided equally between six test-tubes, **A** to **F**.

Starch solution was put into six test-tubes, **1** to **6**.

The test-tubes were put into water baths at the temperatures given in the table.

After 10 minutes the solutions were mixed: **A** added to **1**, **B** to **2**, etc.

The contents of the test-tubes were stirred and then they were put back into the water baths.

After 5 minutes the contents of the test-tubes were tested for the presence of starch.

The results are in the table.

test-tubes	temperature (°C)	presence (✓) or absence (✗) of starch
A + 1	5	✓
B + 2	15	✓
C + 3	25	✗
D + 4	35	✗
E + 5	45	✗
F + 6	55	✓

(b) Explain why the test-tubes were left for:

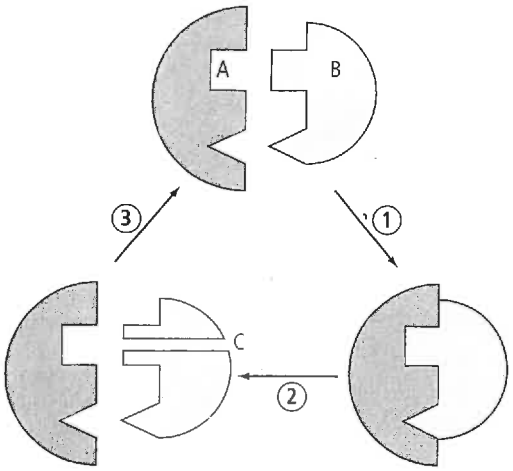
(i) 10 minutes before mixing amylase with starch

(ii) 5 minutes before testing for starch. *[4]*

(c) State in which test-tubes amylase was active. *[1]*

(Paper 2)

5 The diagram shows an enzyme-catalysed reaction.



(a) State the names of **A**, **B** and **C**. *[3]*

(b) Use the diagram to describe what happens when an enzyme catalyses a reaction. *[4]*

(d) Use the model to explain what happens when the enzyme molecule changes shape in high temperatures or extremes of pH. *[4]*

(Paper 3)