

Biological molecules and enzymes

Revision notes · The elements and building blocks of carbohydrates, proteins and lipids, food tests, and how temperature and pH affect enzymes.

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. **Biology only** is not in the Double Award and is only examined on Paper 2.

Biological molecules and enzymes Spec 2.7-2.14B

Carbohydrates, proteins and lipids Spec 2.7, 2.8

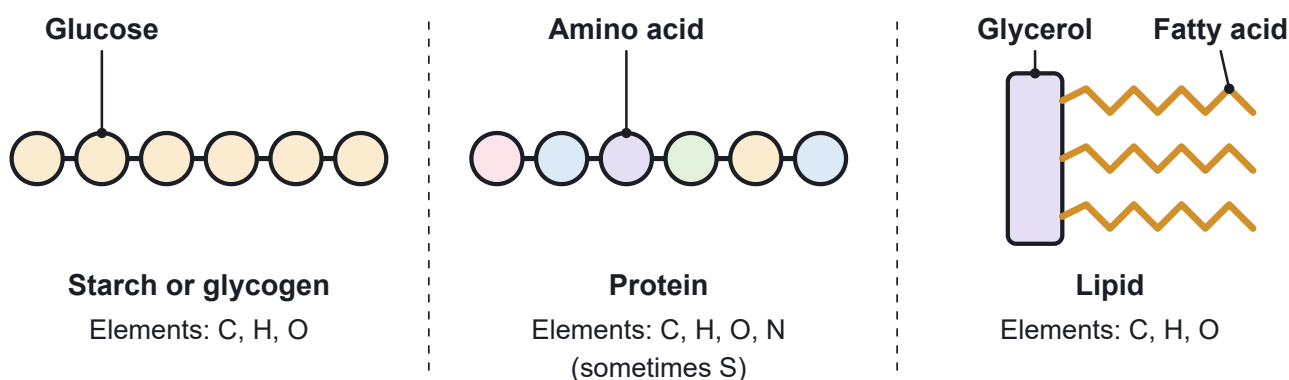
Carbohydrates, proteins and lipids (fats and oils) are the three main groups of **biological molecules**. They are all made from a small number of chemical elements.

Elements in biological molecules	
Biological molecule	Elements present
Carbohydrates	Carbon, hydrogen and oxygen (C, H, O)
Proteins	Carbon, hydrogen, oxygen and nitrogen (C, H, O, N), and sometimes sulfur (S)
Lipids (fats and oils)	Carbon, hydrogen and oxygen (C, H, O)

Carbohydrates, proteins and lipids are **large molecules** made up from smaller basic units. Many small units are joined together to make one large molecule.

Large molecules and their basic units	
Large molecule	Made from
Starch	Many simple sugars (glucose) joined together
Glycogen	Many simple sugars (glucose) joined together
Protein	Amino acids
Lipid	Fatty acids and glycerol (one glycerol and three fatty acids)

Starch is the storage carbohydrate in plants. Glycogen is the storage carbohydrate in animals. Both are made from glucose, which is a simple sugar.



Large molecules are built from smaller units: **glucose** → starch or glycogen, **amino acids** → protein, **glycerol + three fatty acids** → lipid.

Exam tip: A lipid is made from one glycerol and three fatty acids. Learn the numbers 1 and 3, and remember that, of the three groups, only proteins contain nitrogen.

Practical: food tests Spec 2.9

You can use chemical reagents to identify the main biological molecules in a food. If the food is a solid, crush it with a little water and use the liquid. For the fat test, shake the food with ethanol instead. Always wear eye protection.

Practical: A negative result means the reagent keeps its original colour. Learn the start colour as well as the positive result.

Food tests			
Food	Reagent	Method	Positive result
Glucose (a reducing sugar)	Benedict's solution	Add Benedict's solution and heat in a hot water bath for a few minutes	Blue to green, yellow, orange or brick-red , depending on the amount of sugar
Starch	Iodine solution	Add a few drops of iodine solution to the sample	Orange-brown to blue-black
Protein	Biuret reagent	Add biuret reagent to the sample and mix	Blue to purple (lilac)
Fat	Ethanol	Shake the sample with ethanol, then pour the mixture into water	A cloudy white emulsion forms

In a negative result, iodine stays orange-brown, Benedict's solution and biuret reagent stay blue, and the ethanol test stays clear. Ethanol is flammable, so keep it away from naked flames. Benedict's solution is heated in a water bath, not directly over a flame.

Enzymes as biological catalysts Spec 2.10

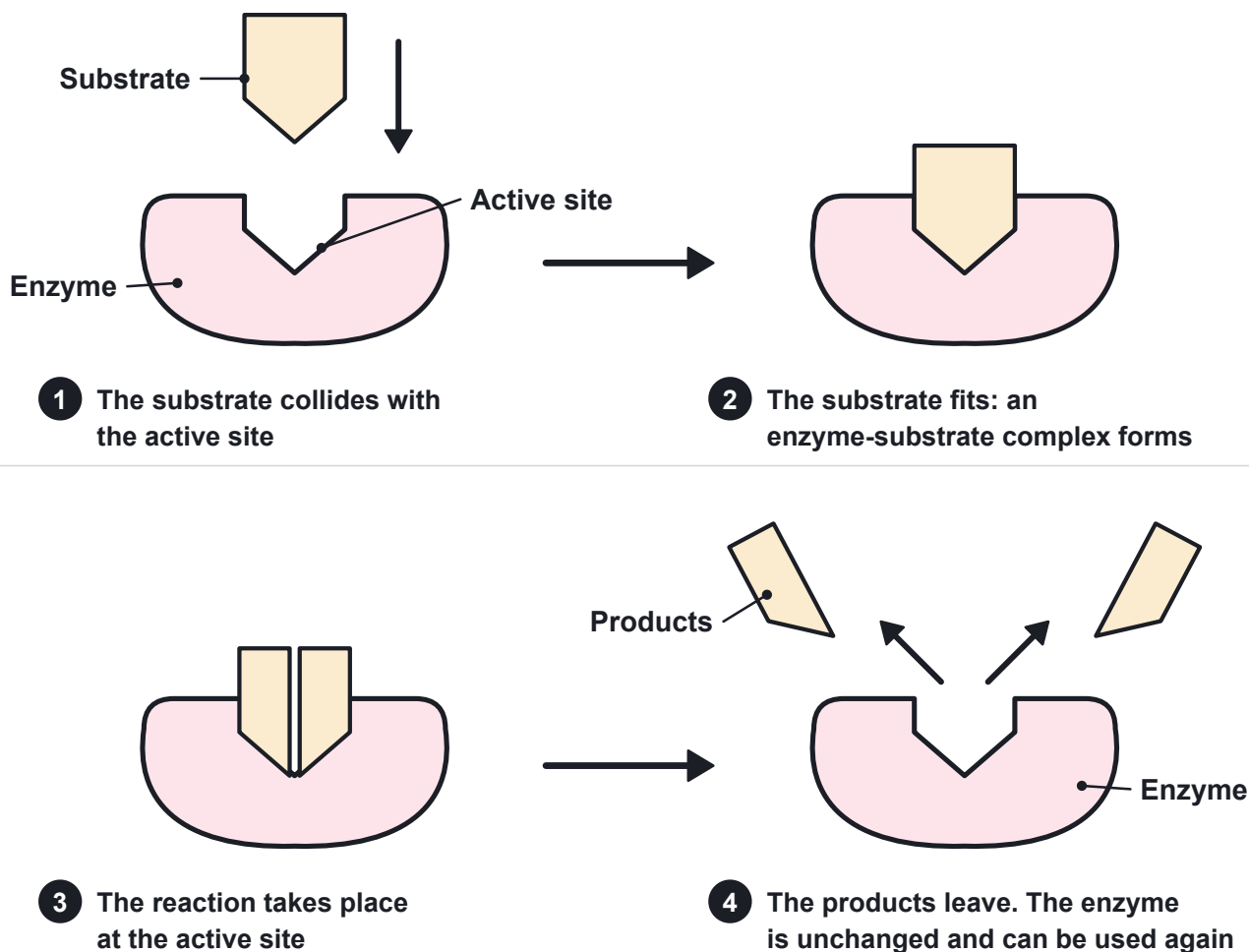
Metabolic reactions are the chemical reactions that happen in living cells. They are controlled by **enzymes**. Enzymes are proteins that act as **biological catalysts**. A catalyst speeds up a reaction without being used up. Each enzyme has a region called the **active site**, which has a particular shape.

The molecule an enzyme acts on is called the **substrate**. The substrate has a shape that is **complementary** to the active site, so it fits in, like a key in a lock. This is called the lock and key model.

1. The substrate collides with the active site of the enzyme.

2. The substrate fits into the active site, forming an enzyme-substrate complex.
3. The reaction takes place at the active site.
4. The product or products leave the active site and the enzyme is free to be used again.

Enzymes are **specific**. Only a substrate with a shape that fits the active site can bind to it, so each enzyme catalyses only one type of reaction.



The lock and key model. The substrate is complementary to the active site, and the enzyme is not used up.

*Exam tip: The mark scheme word is **complementary**. Say the shape of the substrate is complementary to the shape of the active site, not that they are 'the same'.*

Temperature, pH and enzyme activity Spec 2.11, 2.13

Temperature

As temperature increases, the particles move faster and have more kinetic energy. Enzyme and substrate collide more often, so the rate of reaction increases. The rate is highest at the **optimum temperature**, which is around 37 °C for many human enzymes.

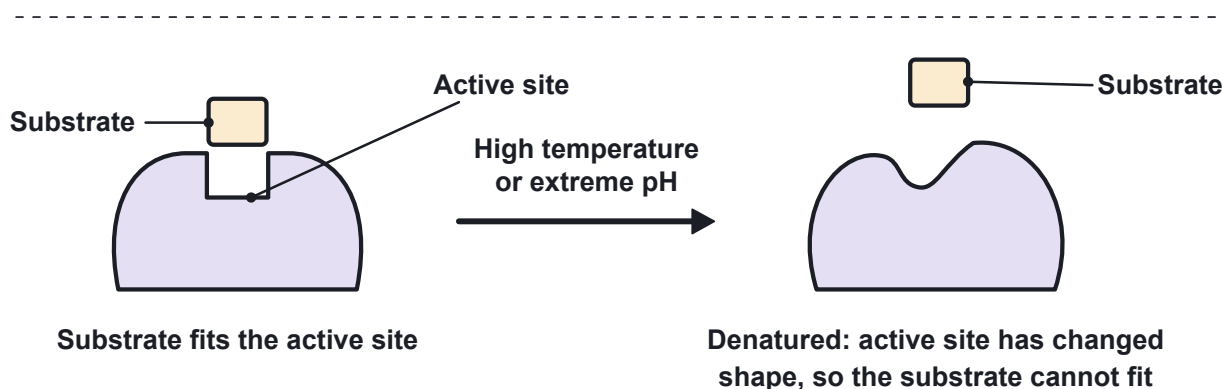
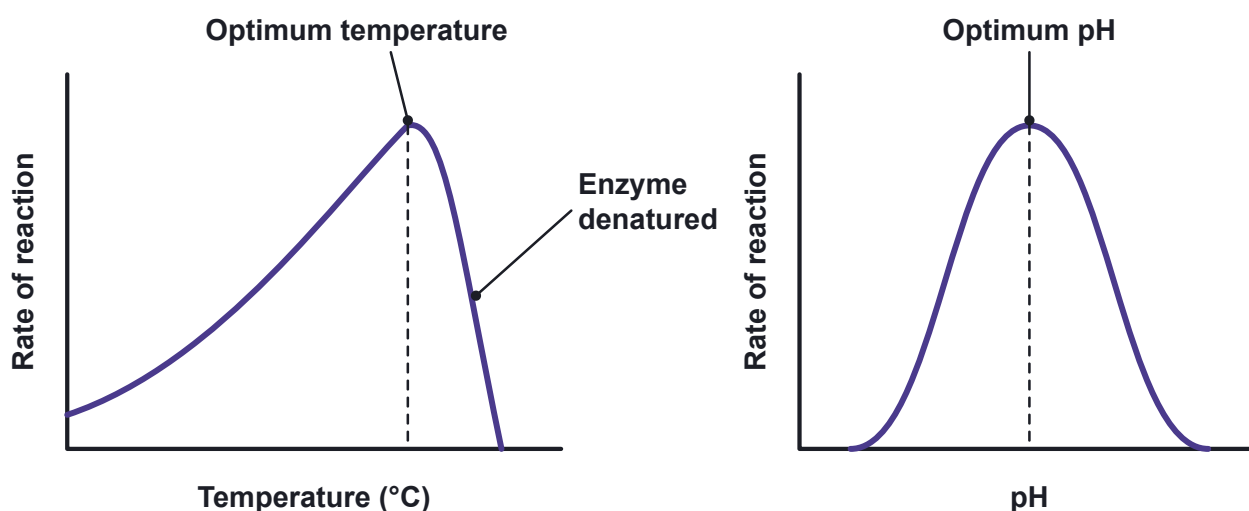
Above the optimum temperature, the enzyme's structure is damaged and the shape of the active site changes. The substrate no longer fits, so the enzyme is **denatured** and the rate falls quickly towards zero. Denaturing is permanent.

pH

Each enzyme has an **optimum pH** where it works fastest. If the pH is higher or lower than the optimum, the shape of the active site is altered, so the substrate fits less well and the rate decreases. At extreme pH the active site changes shape so much that the substrate cannot fit: the enzyme is denatured.

Different enzymes have different optimum pH values. For example, amylase in the mouth works best at about pH 7 (neutral), while pepsin, a protease in the acidic stomach, works best at about pH 2.

Summary of the effects on enzyme activity			
Factor	Below the optimum	At the optimum	Above the optimum
Temperature	Rate increases as particles collide more often	Highest rate	Active site changes shape, enzyme denatured, rate falls
pH	Rate decreases as pH moves away from the optimum; denatured at extreme pH	Highest rate	Rate decreases as pH moves away from the optimum; denatured at extreme pH



Rate rises to the optimum then falls. Above the optimum temperature, or at extreme pH, the active site changes shape and the enzyme is denatured.

Exam tip: When a graph falls after a peak, always give the reason: the active site has changed shape and the enzyme has been denatured. Do not say the enzyme has been 'killed'. Enzymes are not alive.

Practical: temperature, pH and enzyme activity Spec 2.12, 2.14B

A common version of these investigations uses amylase, an enzyme that breaks down starch, and iodine solution to show when the starch has gone. Iodine stays orange-brown when there is no starch left.

Effect of temperature on enzyme activity

Practical: Independent variable: temperature; dependent variable: time for the starch to be broken down. Keep pH, volumes and concentrations the same each time.

1. Put drops of iodine solution into the wells of a spotting tile.
2. Set up water baths at different temperatures, for example 10, 20, 30, 40 and 50 °C.
3. Put starch solution and a buffer solution of one fixed pH in a test tube, and amylase solution in a second tube. Leave both in the water bath for a few minutes to reach the temperature.
4. Add the amylase to the starch and buffer, mix and start the stopwatch.
5. Every 30 seconds, use a dropping pipette to add a drop of the mixture to a well of iodine solution.
6. Record the time when the iodine stays orange-brown. This shows all the starch has been broken down.
7. Repeat at each temperature and calculate a mean time.

Typical results: the shortest time is at the optimum temperature. The time is longer at low temperatures because there are fewer collisions, and at high temperatures the enzyme is denatured so the starch may never be broken down. Calculate the rate as $1 \div \text{time}$ and plot it against temperature. Take care with hot water, and wear eye protection because iodine solution is an irritant.

Controlling variables

Variable	How it is controlled
pH	Add the same buffer solution to every tube
Volume and concentration of enzyme	Use the same amount of the same solution each time
Volume and concentration of starch	Use the same amount of the same solution each time

Biology only

Effect of pH on enzyme activity

Biology only

Practical: Independent variable: pH, using buffer solutions; dependent variable: time for the starch to be broken down. Keep temperature, volumes and concentrations the same each time.

Biology only

Use the same method, but keep the temperature fixed by putting all the tubes in one water bath (for example at 35 °C), and use buffer solutions of different pH values, such as pH 3, 5, 7, 9 and 11. Repeat each pH and calculate a mean.

Biology only

Typical results for the pH practical: the shortest time is at the optimum pH, where the enzyme works fastest. Times get longer at pH values further from the optimum. Plot the rate ($1 \div \text{time}$) against pH and draw a smooth curve through the points.

Quick check

- 1 . Which elements are present in proteins but not in carbohydrates or lipids?
- 2 . What are the smaller units that make up a protein?
- 3 . What colour does Benedict's solution turn with glucose when heated?
- 4 . What is meant by a biological catalyst?
- 5 . Why does a very high temperature stop an enzyme working?

Quick check answers

Biological molecules and enzymes

1. Nitrogen (and sometimes sulfur).
2. Amino acids.
3. From blue to green, yellow, orange or brick-red.
4. An enzyme that speeds up a reaction in a living thing without being used up.
5. The shape of the active site changes, so the substrate no longer fits and the enzyme is denatured.