IGCSE BIOLOGY 0610 · CHAPTER 4 NOTES · ~11 MIN READ

Biological molecules & enzymes

Carbohydrates, fats, proteins and DNA, the five food tests with the exact colour changes — and enzymes: the lock-and-key model, temperature, pH, denaturation and how to investigate them.

Carbohydrates, fats, proteins | Food tests | DNA | Enzymes | Temperature & pH

AS by Aiza Ma'am
mentorriyaz.in

No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- **Carbohydrates** and **fats** contain C, H, O. **Proteins** also contain **N**. Large molecules are built from small **building blocks**: glucose, amino acids, fatty acids + glycerol.
- Food tests: **iodine** (starch, blue-black), **Benedict's** (reducing sugar, brick red), **biuret** (protein, purple), **ethanol emulsion** (fat, cloudy white), **DCPIP** (vitamin C, blue → colourless).
- **Enzymes** are **proteins** that act as **biological catalysts**. Each has an **active site** that fits only one substrate. High temperature or the wrong pH **denatures** them.

BY THE END YOU CAN

- Name the elements in carbohydrates, fats and proteins, and their building blocks.
- Describe the tests for starch, reducing sugars, protein, fat and vitamin C.
- Describe the structure of DNA and complementary base pairing. EXT
- Define catalyst and enzyme, and describe the lock-and-key idea (active site and substrate).
- Describe and explain how temperature and pH affect enzyme activity.
- Plan and interpret an enzyme investigation.

1 Biological molecules

Which elements?

CARBOHYDRATES	FATS (LIPIDS)	PROTEINS
C H O	C H O	C H O N
carbon hydrogen oxygen	carbon hydrogen oxygen	+ nitrogen (sometimes S)
e.g. glucose, starch	e.g. oils, butter	e.g. enzymes, muscle

carbon · hydrogen · oxygen in all three; only proteins also contain nitrogen

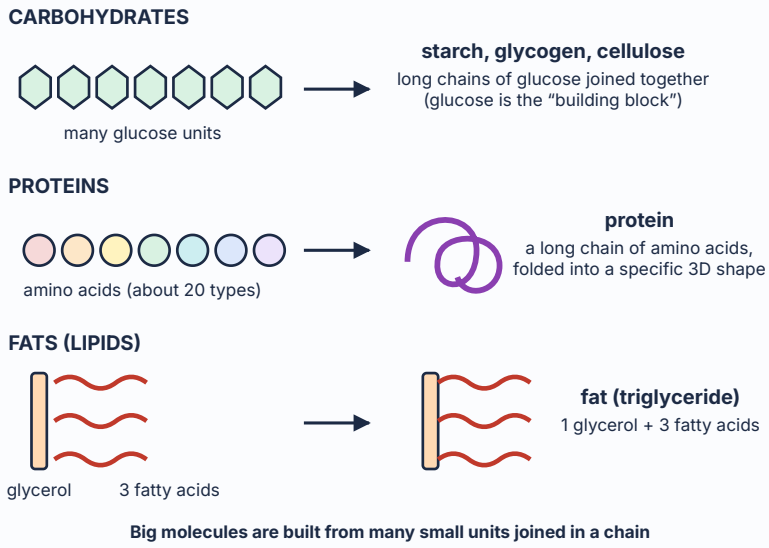
Carbohydrates and fats contain carbon, hydrogen and oxygen. Proteins contain these plus nitrogen.

- **Carbohydrates:** carbon, hydrogen, oxygen. The ratio of H to O is usually 2 : 1 (for example glucose $C_6H_{12}O_6$).
- **Fats and oils (lipids):** carbon, hydrogen, oxygen — but much less oxygen than a carbohydrate.
- **Proteins:** carbon, hydrogen, oxygen, **nitrogen**, and sometimes **sulfur**.

MEMORY TRICK

C-H-O for sugars and fat, C-H-O-N for protein. If a question asks "which element is in protein but **not** in carbohydrate?", the answer is **nitrogen**.

Big molecules from small units



Large biological molecules are chains of smaller units.

Large molecule	Made from	Examples and uses
starch, glycogen, cellulose	many **glucose** units	starch = plant energy store; **glycogen** = animal energy store (liver, muscle); **cellulose** = plant cell walls
proteins	many **amino acids**	enzymes, haemoglobin, antibodies, muscle, hormones
fats and oils	1 **glycerol** + 3 **fatty acids**	energy store, insulation, protects organs

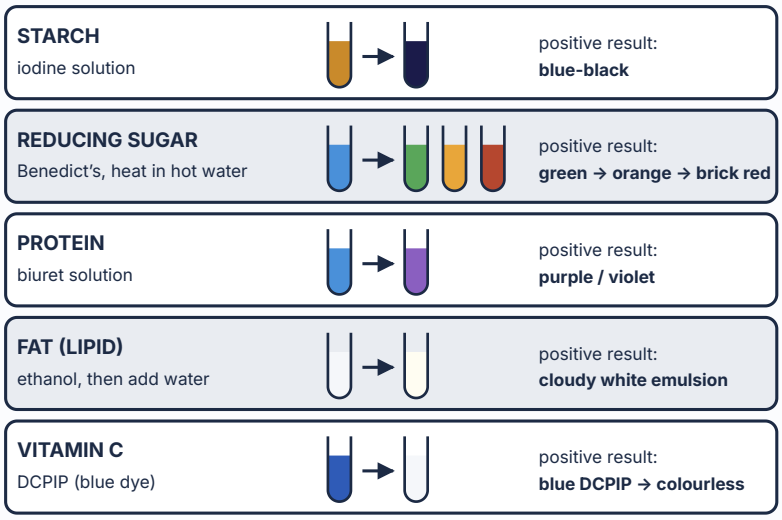
- The **order of amino acids** in a protein decides how it folds into its 3D shape — and the shape decides what the protein does.
- **Starch, glycogen and cellulose** are all made of glucose but joined differently. That is why cellulose is strong (cell walls) while starch is a store.

COMMON MISTAKE

"Fats and oils are made of amino acids." Fats are **fatty acids and glycerol**; **proteins** are amino acids.

2 Food tests

The five tests



Always give the colour BEFORE and AFTER: e.g. "orange-brown to blue-black"

Colour changes for each food test. Always write the colour before and after.

Test for	Reagent and method	Positive result
starch	add **iodine solution**	orange-brown → **blue-black**
reducing sugar (e.g. glucose)	add **Benedict's solution** and **heat in a hot water bath** (about 80 °C)	blue → green → yellow → orange → **brick red**
protein	add **biuret solution** (or sodium hydroxide, then a few drops of copper sulfate)	blue → **purple / violet**
fat (lipid)	mix with **ethanol**, shake, then pour into **water**	clear → **cloudy white emulsion**
vitamin C	add the food (juice) **drop by drop** to blue **DCPIP**	blue → **colourless**

- **Benedict's** colour tells you roughly **how much** reducing sugar there is: green = a little, brick red = a lot.
- For **solid foods**, crush them with water first, then filter or use the liquid.
- Keep **safety** in mind: wear eye protection and take care with the hot water bath. Ethanol is flammable — no naked flames.

EXAM TIP

Say the colour before and after: "Benedict's: blue to brick red". "It goes red" alone loses marks.

COMMON MISTAKE

Saying Benedict's test is for "sugar". It detects **reducing sugars** only (glucose, maltose…). Table sugar (sucrose) is **not** a reducing sugar.

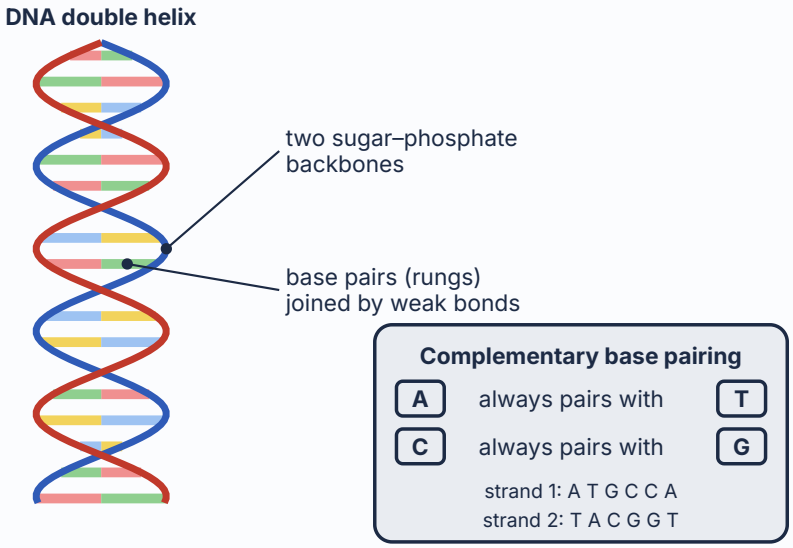
WORKED EXAMPLE

Orange juice A decolourises 1 cm³ of DCPIP after 10 drops. Orange juice B takes 25 drops. Which has more vitamin C?

1. DCPIP is decolourised by vitamin C
2. fewer drops were needed for A
3. **so A contains more vitamin C (more vitamin C in each drop)**

DNA

EXTENDED



DNA is a double helix: two strands joined by pairs of bases. A always pairs with T, and C always pairs with G.

DNA — a **long molecule** with the shape of a **double helix**: two strands wound around each other. It carries the **genetic code**.

- Each strand has a backbone and a row of **bases**: **A**denine, **T**hymine, **C**ytosine, **G**uanine.
- The two strands are held together by **base pairs**: **A–T** and **C–G**. This is **complementary base pairing**.
- The **order of the bases** is the code for making proteins (see Inheritance, variation & selection).

MEMORY TRICK

Apples **T**ree, **C**ar **G**arage — **A–T** and **C–G**.

WORKED EXAMPLE

EXT **One strand of DNA reads A T G C C A. Write the base sequence of the complementary strand.**

1. A pairs with T, T with A, G with C, C with G
2. A→T, T→A, G→C, C→G, C→G, A→T
3. **T A C G G T**

WORKED EXAMPLE

EXT **In a sample of DNA, 20% of the bases are adenine (A). Calculate the percentage of guanine (G).**

1. A pairs with T, so T is also 20%
2. A + T = 40%, leaving 60% for C and G
3. **C and G pair, so they are equal: 60 ÷ 2 = 30% guanine**

3 Enzymes

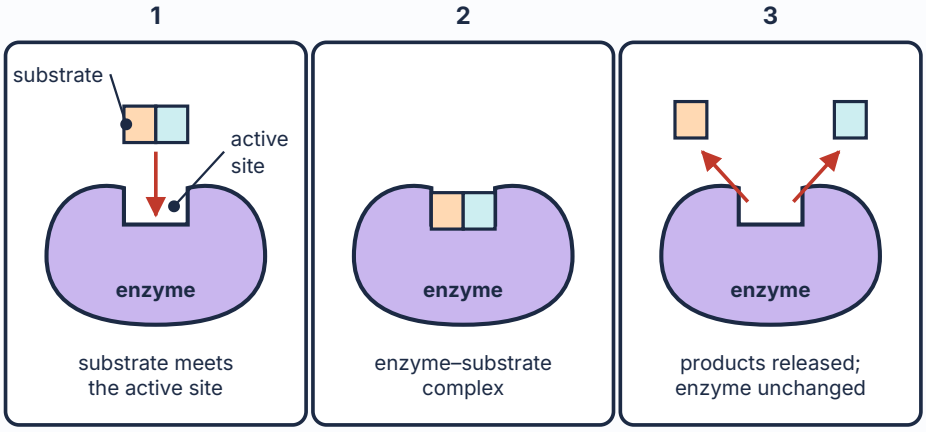
What enzymes do

Catalyst — a substance that **increases the rate** of a chemical reaction and is **not changed** by the reaction.

Enzyme — a **protein** that acts as a **biological catalyst**.

- Living cells carry out thousands of chemical reactions (**metabolism**). At body temperature they would be **far too slow** without enzymes.
- Enzymes can **break molecules down** (digestion of starch) or **build them up** (making proteins).
- Each enzyme works on **one type** of substrate: amylase on starch, protease on protein, lipase on fat. This is **specificity**.

The lock-and-key idea



The substrate's shape fits the active site only: enzymes are SPECIFIC

The enzyme is not used up, so it can work again and again

(lock-and-key model)

The substrate fits the enzyme's active site like a key in a lock. Products leave and the enzyme is ready to be used again.

Active site — the part of the enzyme with a **shape complementary to its substrate**.

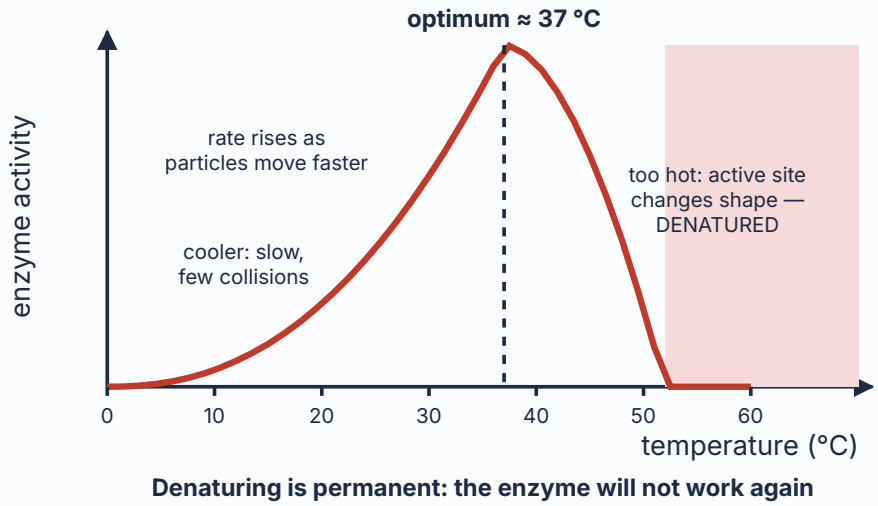
Substrate — the molecule an enzyme works on. **Product** = what it is changed into.

- The substrate binds to the active site to make an **enzyme–substrate complex** EXT. The reaction happens and the **products** leave.
- The enzyme itself is **not used up**, so a small amount of enzyme can work on a lot of substrate.
- Only a substrate with the **matching shape** fits. This is why enzymes are **specific**.

COMMON MISTAKE

"Enzymes are alive and get killed by heat." Enzymes are **proteins**, not living things. They are **denatured**, not killed.

How temperature affects enzymes



Denaturing is permanent: the enzyme will not work again

Activity rises with temperature up to the optimum, then drops sharply as the enzyme is denatured.

Optimum temperature — the temperature at which an enzyme works **fastest**. For many human enzymes it is about **37 °C**.

- **Below the optimum:** particles have less **kinetic energy**, so enzyme and substrate **collide less often** and the rate is slow. The enzyme is not damaged.
- **Above the optimum:** the enzyme's shape starts to change. The **active site** is distorted, the substrate **no longer fits**, and the rate falls. The enzyme is **denatured**.

Denaturation — a **permanent change in the shape** of the enzyme (and its active site), so it can no longer work.

EXAM TIP

In a graph description: say "rate **increases** up to about 37 °C, then **decreases** rapidly to **zero** by about 55 °C because the enzyme is denatured."

COMMON MISTAKE

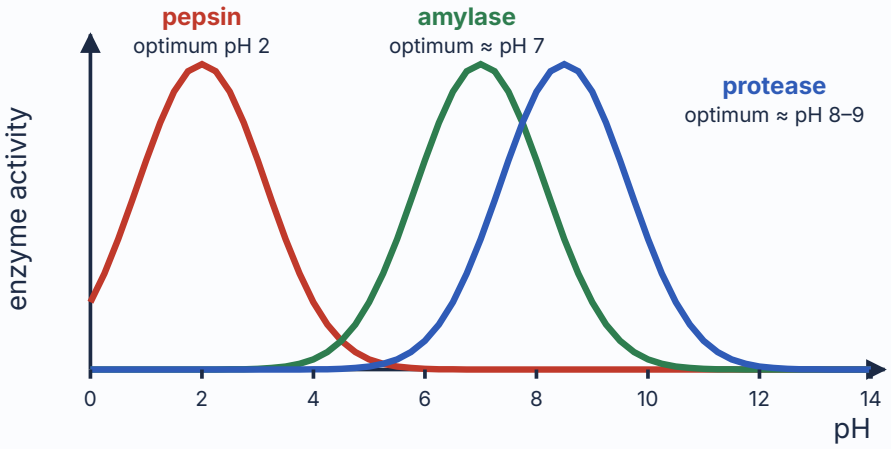
"The enzyme is dead / killed at high temperature." Say **denatured** and mention the **active site changes shape**.

COMMON MISTAKE

"At low temperature the enzyme is denatured." It is only **slowed down**. It can work again when warmed.

Aiza Ma'am

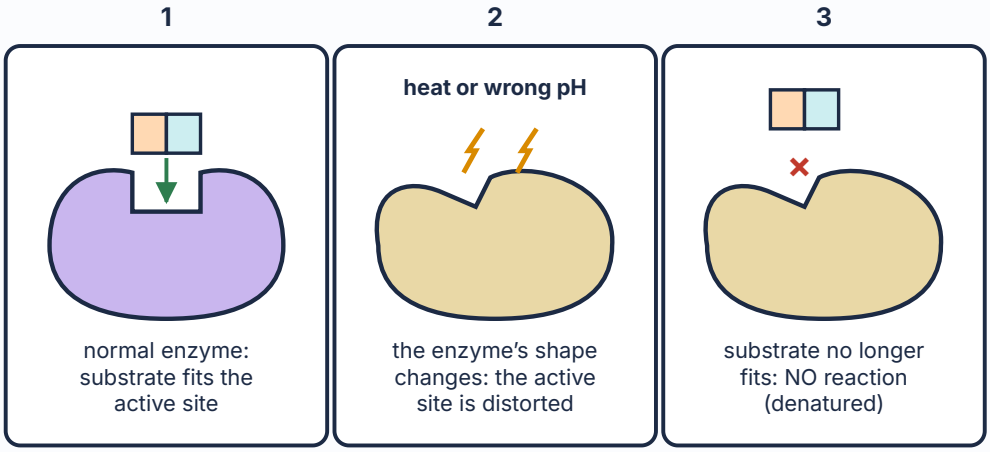
How pH affects enzymes



Each enzyme has its own optimum pH; extremes of pH denature it

Each enzyme has its own optimum pH. Strong acid or alkali denatures it.

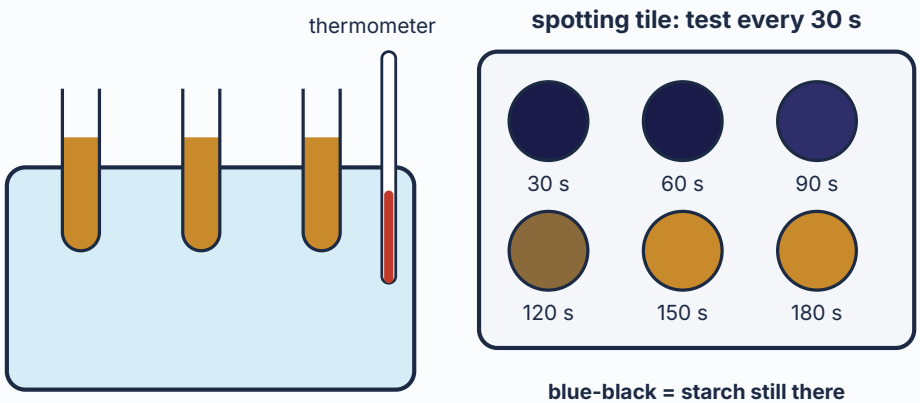
- Every enzyme has an **optimum pH**. **Pepsin** in the stomach works best at **pH 2** (acid). **Amylase** in the mouth works best at about **pH 7**.
- Moving away from the optimum changes the **charges** on the enzyme and bends the **active site**, so the substrate no longer fits. At an extreme pH the enzyme is **denatured**.



Denaturation is permanent — cooling the enzyme does not restore its shape
(low temperatures only slow enzymes down; they do not denature them)

Denaturation changes the shape of the active site. It is permanent.

Investigating enzymes



water bath at a set temperature
(try 10, 20, 30, 40, 60 °C)

blue-black = starch still there
orange-brown = starch all digested

time taken = measure of enzyme rate
(shorter time = faster enzyme)

Mix starch and amylase at a fixed temperature. Every 30 seconds, test a drop with iodine. The time it takes for the colour to stay orange-brown measures the rate.

- **Independent variable:** temperature (water baths at 10, 20, 30, 40, 60 °C) or pH (buffer solutions).
- **Dependent variable:** the **time taken** for all the starch to be digested.
- **Controlled variables:** volume and concentration of starch and amylase, the same pH (or temperature).
- Warm each solution to the water bath temperature **before** mixing.

$$\text{rate} = 1 \div \text{time}$$

a shorter time means a faster enzyme

WORKED EXAMPLE

Starch is digested in 120 s at 20 °C and in 60 s at 30 °C. Compare the rates.

1. rate = 1 ÷ time
2. at 20 °C: 1 ÷ 120 = 0.0083 per second
3. at 30 °C: 1 ÷ 60 = 0.0167 per second
4. **the rate at 30 °C is twice as fast as at 20 °C**

- **Catalase** (in liver, potato) breaks down hydrogen peroxide into water and **oxygen** — count the **bubbles** or measure the height of **foam** to follow the rate.

Aiza Ma'am

4 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. Which element is in proteins but not in carbohydrates?
2. Name the building blocks of a protein.
3. What are fats made of?
4. What colour change shows starch with iodine solution?
5. What does Benedict's solution turn with glucose when heated?
6. Which test uses a blue dye that goes colourless?
7. What is a catalyst?
8. Why can an enzyme only work on one substrate?
9. EXT Which base pairs with cytosine in DNA?

EXAM-STYLE

10. Describe how you would test a food for protein. [3]
11. Explain why an enzyme's activity falls at high temperatures. [3]
12. A student investigates the effect of pH on amylase. State two variables that should be kept the same. [2]
13. EXT Explain why the enzyme pepsin works in the stomach but not in the small intestine. [3]

Show answers

1. nitrogen
2. amino acids
3. glycerol and fatty acids
4. orange-brown to blue-black
5. blue to brick red (via green, yellow, orange)
6. DCPIP for vitamin C
7. a substance that speeds up a reaction and is not changed
8. its active site has a shape complementary to only that substrate
9. guanine
10. crush the food and mix with water
    add biuret solution
    blue changes to purple/violet if protein is present
11. the enzyme is denatured
    the shape of the active site changes
    the substrate no longer fits
12. temperature
    volume and concentration of starch / amylase
13. pepsin has an optimum pH of about 2 (acid)
    the small intestine is alkaline
    so pepsin is denatured / its active site changes shape

Stuck on a question?

Send it to us on WhatsApp. We read every message.

Want regular help? Send this to your parent →

Share with a friend

Ask on WhatsApp

Aiza Ma'am