The human digestive system

4.2.2.1 · Organisation · revision notes

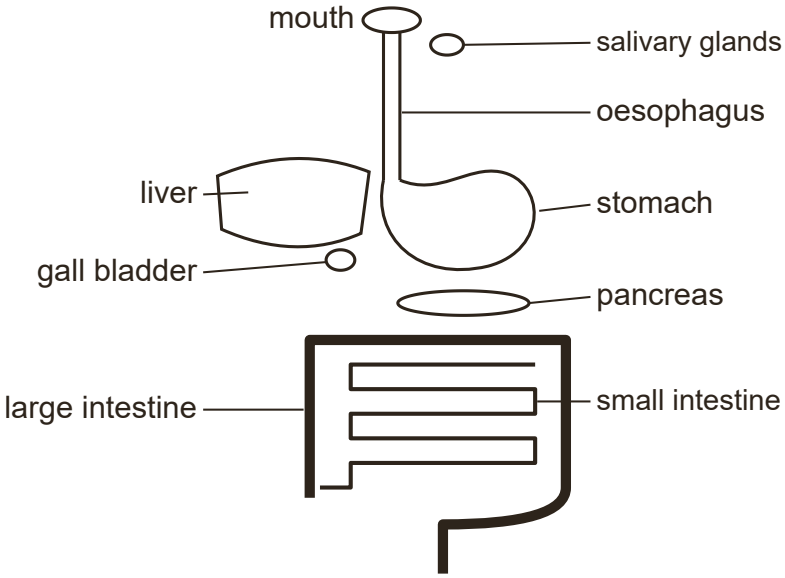
How the organs of the digestive system work together to digest and absorb food, how enzymes work, and what bile does. Expect recall of enzymes and their products, 'explain' questions on the lock and key model and denaturing, and questions on two required practicals: food tests and the effect of pH on amylase.

Key facts

- Amylase: starch → sugars (salivary glands, pancreas, small intestine)
- Lipase: lipids → fatty acids + glycerol (pancreas, small intestine)
- Benedict's (heated): blue → brick red = sugar
- Biuret: blue → purple = protein
- Denatured = active site has changed shape, so the substrate no longer fits
- Protease: proteins → amino acids (stomach, pancreas, small intestine)
- Bile: made in liver, stored in gall bladder; alkaline and emulsifies fat
- Iodine: orange-brown → blue-black = starch
- Sudan III: red-stained layer on top = lipid
- Amylase practical: rate = 1 ÷ time, or the equation given, e.g. 1000 ÷ time (shorter time = faster rate)

Digestion and digestive enzymes

- The digestive system is an organ system: several organs work together to **digest** food (break large, insoluble molecules into small, soluble ones) and **absorb** the products into the bloodstream.

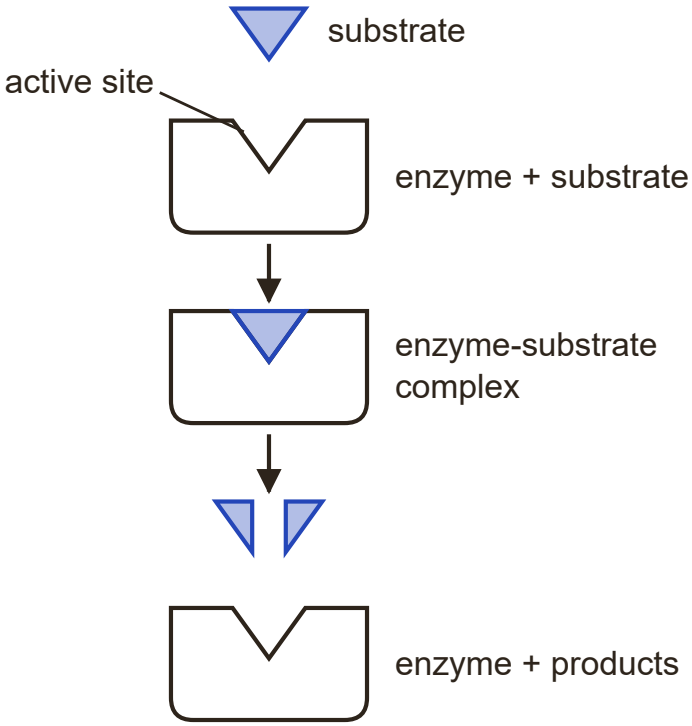


The digestive system (a simplified front view)

- **Carbohydrases** break carbohydrates down into simple sugars. **Amylase** is a carbohydrase: starch → sugars. It is made in the salivary glands, pancreas and small intestine.
- **Proteases**: proteins → amino acids. Made in the stomach, pancreas and small intestine.
- **Lipases**: lipids (fats) → fatty acids + glycerol. Made in the pancreas and small intestine.
- The products of digestion are used to build new carbohydrates, lipids and proteins. Some glucose is used in respiration.

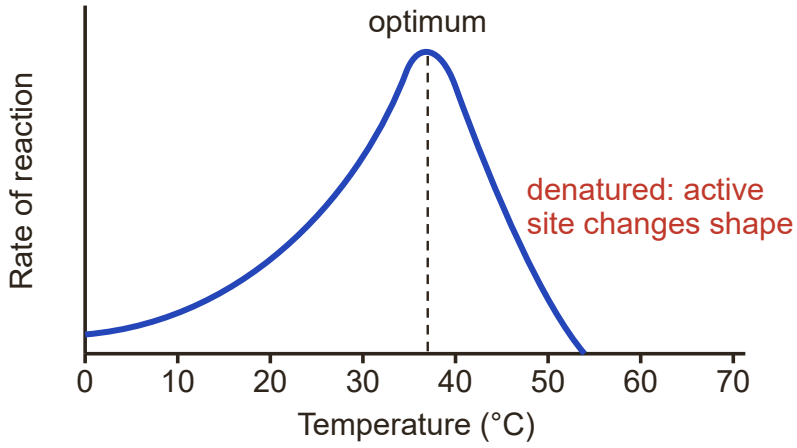
How enzymes work

- Enzymes are biological catalysts: large proteins (chains of amino acids folded into a specific shape) that speed up reactions without being used up.
- Each enzyme has an **active site** with a specific shape. Only a substrate with the matching (complementary) shape fits, so each enzyme catalyses one specific reaction. This is the **lock and key** model.



Lock and key: only a substrate with the complementary shape fits the active site.

- As temperature rises, the rate increases up to the **optimum** (about 37 °C for most human enzymes), because the molecules move faster and collide more often.
- Above the optimum temperature, or at a pH far from the optimum pH, the shape of the active site changes. The substrate no longer fits, so the reaction slows or stops. The enzyme is **denatured**.



Enzyme activity and temperature. Above the optimum the enzyme is denatured.

- Each enzyme has its own optimum pH: the stomach protease works best in the hydrochloric acid the stomach makes; amylase works best at around neutral pH.

Bile

- Bile is made in the **liver**, stored in the **gall bladder** and released into the small intestine.
- It is **alkaline**, so it neutralises the hydrochloric acid from the stomach.
- It **emulsifies** fat: it breaks large drops into small droplets, which have a much larger surface area.
- The alkaline conditions and the larger surface area both increase the rate at which lipase breaks down fat.

Required practicals

- Food tests: grind the food with distilled water and filter it to get a solution.
- Sugars: add Benedict's reagent and heat in a hot water bath. Blue → green, yellow or brick red if sugar is present.
- Starch: add iodine solution. Orange-brown → blue-black. Protein: add Biuret reagent. Blue → purple. Lipids: add Sudan III stain; a red-stained layer floats on top.
- Safety: wear eye protection and heat Benedict's in a water bath, not over a flame.
- pH and amylase: warm starch solution, amylase and a pH buffer separately in a water bath, then mix them and start a stop clock.
- Every 30 seconds, put a drop of the mixture into iodine on a spotting tile. Record the time when the iodine stays orange-brown (no starch left).
- Repeat at other pH values, keeping the temperature and the volumes and concentrations of starch and amylase the same.
- The shorter the time, the faster the rate. The pH with the shortest time is closest to the optimum.

How to answer each type of question

Recall enzymes, where they are made and their products 1 to 4 marks **Grade 4**

1. Learn each enzyme with its substrate, its products and where it is made.
2. Give the specific product: 'amino acids', not 'smaller molecules'.
3. For lipase, give both products: fatty acids and glycerol.

Example. (a) Name the type of food molecule that proteases break down.
(b) Name the **two** products when lipase breaks down lipids.
(c) Name **one** organ that makes amylase.

Model answer.

(a) proteins	(1)
(b) fatty acids (1) glycerol	(1)
(c) salivary glands / pancreas / small intestine	(1)

Describe a food test

2 to 3 marks | Grade 4

1. Name the correct reagent.
2. Give any extra step, e.g. heat in a water bath for Benedict's.
3. Give the positive result as a colour change 'from ... to ...'.

Example. Describe how a student could test a sample of food for sugar.
Give the result if sugar is present.

Model answer. Add Benedict's reagent (1) and heat in a hot water bath (1). It changes from blue to brick red (or green / yellow) if sugar is present (1).

Explain the effect of temperature or pH on an enzyme

2 to 4 marks | Grade 5

1. If a graph is given, describe the trend first and quote the optimum.
2. Below the optimum temperature: molecules move more slowly, so there are fewer collisions between enzyme and substrate.
3. Above the optimum, or at the wrong pH: the active site changes shape.
4. Finish the chain: the substrate no longer fits the active site, so the enzyme is denatured.

Example. A student measured how quickly a protease digested protein at different temperatures. The rate was highest at 40 °C and was zero at 65 °C.
Explain why the rate was zero at 65 °C.

Model answer. The enzyme was denatured (1). The shape of the active site changed (1), so the protein (substrate) could no longer fit into the active site (1).

Explain how bile helps the digestion of fat

3 to 4 marks | Grade 6

1. Emulsifies: large fat drops → small droplets with a larger surface area for lipase.
2. Alkaline: neutralises hydrochloric acid from the stomach, giving a pH that suits lipase.
3. End with the effect: fat is digested faster.

Example. Explain how bile increases the rate of fat digestion in the small intestine.

Model answer. Bile emulsifies fat into small droplets (1), which gives a larger surface area for lipase to act on (1). Bile is alkaline, so it neutralises the hydrochloric acid from the stomach (1). This gives a pH closer to the optimum for lipase, so fat is broken down faster (1).

Required practical: the effect of pH on amylase 2 to 6 marks **Grade 5**

1. Independent variable: pH (set with buffer solutions). Dependent variable: time for the starch to be digested.
2. Control variables: temperature (water bath), volume and concentration of starch and of amylase.
3. Method: sample every 30 seconds into iodine on a spotting tile until the iodine stays orange-brown.
4. Use the given equation to turn times into rates, then compare them.

Example. A student investigated the effect of pH on the time taken for amylase to digest starch. At pH 7 the iodine stopped turning blue-black after 150 seconds.
(a) Calculate the rate of reaction at pH 7. Use the equation: rate = 1000 ÷ time. Give your answer to 2 significant figures.
(b) Give **two** variables the student should keep the same.

Model answer.

(a) 1000 ÷ 150 (1) = 6.7 (1)

(b) Any two from: temperature / volume of amylase / concentration of amylase / volume or concentration of starch solution (1) (1)

Don’t lose marks

- Saying bile is an enzyme or that it breaks down fat. It emulsifies fat; lipase breaks it down.
- Saying bile is made in the gall bladder. It is made in the liver and stored in the gall bladder.
- Saying enzymes are 'killed' at high temperature. Enzymes are not alive: they are denatured.
- Saying enzymes are denatured at low temperature. They are just slower, because the molecules move more slowly.
- Writing 'the active site changes' but not saying that the substrate no longer fits.
- Forgetting to heat the Benedict's test, or giving a colour change the wrong way round.

More tips

Memory tricks

- The enzyme name gives away its substrate: **lip**ase → **lip**ids, **prote**ase → **prote**ins, **carbohydr**ase → **carbohydr**ates.
- Lipids → 'FAG': Fatty Acids + Glycerol.
- Food test colours: Benedict's → Brick red (and it needs heat); Biuret → purple; Iodine → Inky blue-black.
- Bile does two jobs, 'neutralise and emulsify'. Neither job breaks molecules down, so bile is not an enzyme.
- Sense check for rates: a shorter time must give a bigger rate. If it does not, you divided the wrong way round.

Exam technique

- In enzyme explanations use the key words: active site, substrate, specific (complementary) shape, denatured.
- For the pH practical, examiners often ask how temperature is controlled (water bath) and how pH is controlled (buffer solutions).
- Give colour changes as 'from ... to ...' to get the mark.
- When a graph of rate against temperature or pH is given, read the optimum from the graph and give its unit.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Name the organs of the digestive system**
Mouth and salivary glands, oesophagus, stomach, liver, gall bladder, pancreas, small intestine and large intestine.

Grade 4 — **State what each digestive enzyme produces**
Amylase turns starch into sugars, proteases turn proteins into amino acids, and lipases turn lipids into fatty acids and glycerol.

Grade 4 — **Describe the food tests and positive results**
Benedict's turns from blue to brick red when heated with sugar, iodine from orange-brown to blue-black with starch, and Biuret from blue to purple with protein.

Grade 5 — **Recall where each digestive enzyme is made**
Amylase in the salivary glands, pancreas and small intestine; proteases in the stomach, pancreas and small intestine; lipases in the pancreas and small intestine.

Grade 5 — **Explain denaturing by high temperature or pH**
The active site changes shape, so the substrate no longer fits and the rate of reaction falls.

Grade 6 — **Explain enzyme action using lock and key**
The substrate fits the specifically shaped active site, so each enzyme catalyses only one reaction.

Grade 6 — **Explain how bile speeds up fat digestion**
Bile is alkaline, so it neutralises stomach acid, and it emulsifies fat into small droplets with a larger surface area for lipase.

Grade 7 — **Calculate rates from the amylase practical**
Use the equation given, such as rate = 1000 ÷ time taken for the starch to be digested, and compare rates at each pH.

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