Cambridge IGCSE · Biology 0610 · Notes

Chemical digestion and absorption

Read online at **pastopic.com/cambridge/biology-0610/notes/chemical-digestion-and-absorption**

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Read first: **Diet, the digestive system and physical digestion**, **Enzymes**

What you need to know

This topic is on every paper: one-mark multiple-choice questions about enzymes, where they work and where food is absorbed, and parts of structured questions built around a diagram of the gut, a villus or an enzyme experiment. Outcomes 8 to 12 are **Extended only** (Papers 2 and 4). By the end of this topic you should be able to:

1. **Describe chemical digestion**: large insoluble molecules broken down into small soluble molecules.
2. **State why it matters**: only small soluble molecules can be absorbed.
3. **Describe what three enzymes do**: amylase breaks down starch to simple reducing sugars; proteases break down protein to amino acids; lipase breaks down fats and oils to fatty acids and glycerol.
4. **State where amylase, protease and lipase are secreted, and where they act.**
5. **Describe the two functions of hydrochloric acid in gastric juice**: killing harmful microorganisms in food, and giving an acidic pH for the best enzyme activity.
6. **State that the small intestine is where nutrients are absorbed.**
7. **State that most water is absorbed in the small intestine, and some in the colon.**
8. **Extended only:** describe how starch is digested: amylase breaks starch down to maltose, then maltase breaks maltose down to glucose on the membranes of the epithelium lining the small intestine.
9. **Extended only:** describe how protein is digested: pepsin in the acidic stomach, trypsin in the alkaline small intestine.
10. **Extended only:** explain that bile is alkaline and neutralises the acidic mixture coming from the stomach into the duodenum, giving a suitable pH for the enzymes there.
11. **Extended only:** explain how villi and microvilli increase the internal surface area of the small intestine.
12. **Extended only:** describe the structure of a villus, and the roles of its capillaries and lacteal.

The organs, teeth, physical digestion and how bile emulsifies fat are in the previous topic, Diet, the digestive system and physical digestion. How enzymes work (active site, optimum, denaturing) is in Enzymes.

Understand it

Why food must be digested chemically

Most of the food you eat is made of **large molecules**: starch, proteins and fats. They are **insoluble** and far too big to pass through the wall of the gut into the blood. **Chemical digestion** uses **enzymes** to break them into **small, soluble molecules**, which can then be **absorbed**: they pass through the lining of the small intestine into the blood (or the lymph) and are carried to the cells that need them.

Physical digestion (chewing, churning) only makes smaller **pieces** of the same molecules. Chemical digestion changes the **molecules** themselves.

Three enzymes, three jobs

Each digestive enzyme acts on one kind of food molecule (its **substrate**) and makes particular **products**:

Enzyme	Substrate	Products
Amylase	starch	simple reducing sugars (maltose)
Protease	protein	amino acids
Lipase	fats and oils	fatty acids **and** glycerol

"Protease" is the name for any enzyme that digests protein; pepsin and trypsin (below) are two proteases. Enzymes are not used up, and they are never a product.

Where the enzymes are made and where they work

Enzymes are **secreted** (made and released) by glands, and they **act** in the space inside the gut, where the food is.

Enzyme	Secreted by	Acts in
Amylase	salivary glands	mouth
	pancreas	small intestine (duodenum)
Protease	stomach	stomach
	pancreas	small intestine (duodenum)
Lipase	pancreas	small intestine (duodenum)

So the **pancreas** makes all three (in pancreatic juice, which flows into the duodenum), the **salivary glands** make only amylase, and the **stomach** makes protease (and hydrochloric acid) but no amylase or lipase. **Protein digestion starts in the stomach**; starch digestion starts in the mouth; fat digestion only happens in the small intestine. The pancreas also makes the hormones insulin and glucagon, but they go into the blood, not the gut.

Here is the whole gut in one table, with what each part does:

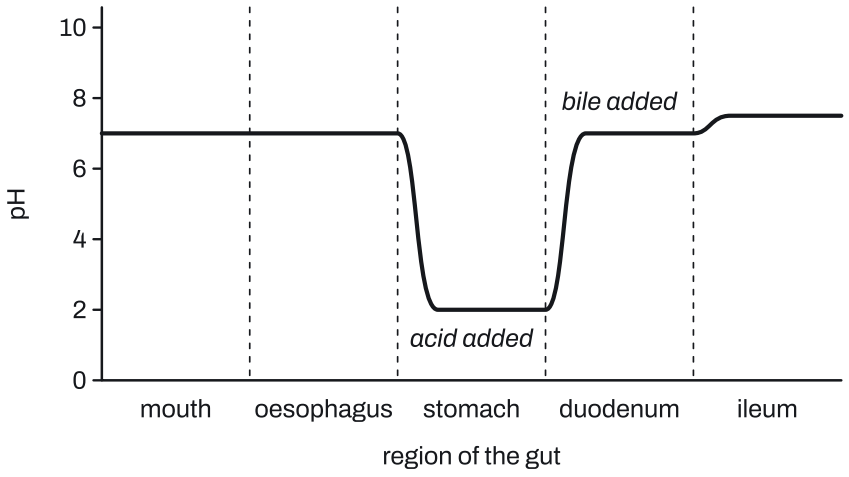
Part	What happens there
Mouth	ingestion; chewing; salivary amylase starts digesting starch
Oesophagus	carries food to the stomach; no digestion, no absorption
Stomach	churning; makes hydrochloric acid and protease; protein digestion starts
Liver	makes bile
Gall bladder	stores bile and releases it into the duodenum
Pancreas	secretes amylase, protease and lipase into the duodenum
Duodenum	receives pancreatic juice and bile; most chemical digestion
Ileum	digestion finished; **absorption** of nutrients and most water
Colon	absorbs some more water
Rectum and anus	store faeces; egestion

Hydrochloric acid in the stomach

The stomach wall makes **gastric juice**, which contains protease and **hydrochloric acid**. The acid has exactly two jobs to learn:

1. It **kills harmful microorganisms** (bacteria, pathogens) in food.
2. It gives an **acidic pH**, the **optimum pH** for the stomach's protease.

Hydrochloric acid is not an enzyme, and it does not digest food itself.



Extended: the digestion of starch

Starch is digested in two steps, by two enzymes:

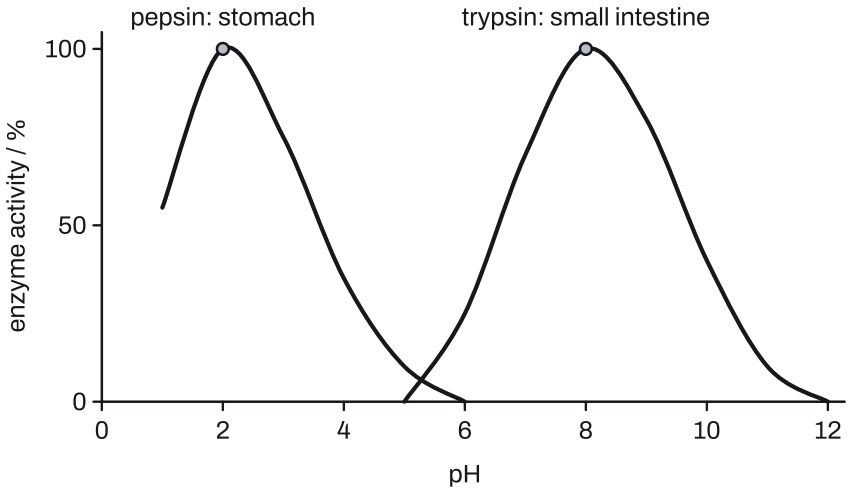
1. **Amylase** breaks **starch** down to **maltose** (a sugar made of two glucose units). It works in the mouth (from the salivary glands) and in the duodenum (from the pancreas).
2. **Maltase** breaks **maltose** down to **glucose**. Maltase is not poured into the gut by a gland: it sits **on the membranes of the epithelium lining the small intestine**, on the microvilli. So the last step of starch digestion happens right at the surface where glucose is absorbed.

Glucose is small and soluble, so it is absorbed.

Extended: the digestion of protein

Two proteases digest protein to amino acids, each in a different pH:

- **Pepsin** is made in the **stomach** and works in its **acidic** conditions (optimum about pH 2).
- **Trypsin** is made in the **pancreas** and works in the **alkaline** conditions of the **small intestine** (optimum about pH 8).



Each enzyme works in the part of the gut whose pH matches its optimum. Away from its optimum, the enzyme's **active site changes shape** (it is **denatured**), so the substrate no longer fits (the shapes are no longer **complementary**) and no **enzyme–substrate complexes** form.

Extended: bile neutralises the acid

The food leaving the stomach is very acidic. In the duodenum it meets **bile**, which is an **alkaline** mixture. Bile **neutralises** the acid, giving a **suitable pH for the enzymes** of the small intestine (amylase, trypsin, lipase and maltase), which work best in neutral or slightly alkaline conditions. (Pancreatic juice is also alkaline and helps.) Bile's other job, emulsifying fats, was in the previous topic.

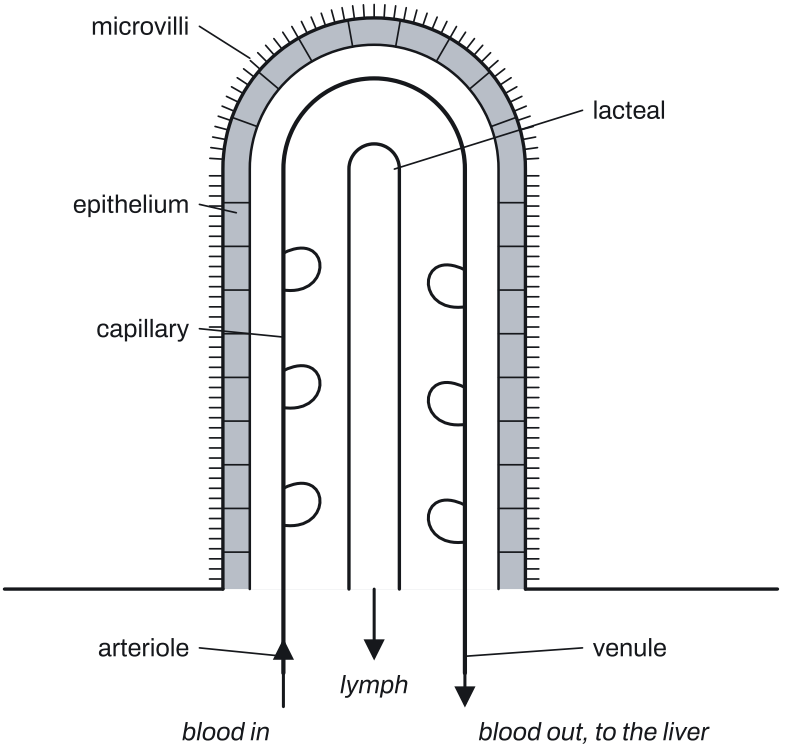
This is why starch digestion **stops in the stomach and restarts in the duodenum**: the acid in the stomach denatures salivary amylase; in the duodenum bile has neutralised the acid, so pancreatic amylase can work.

Absorption

Absorption is the movement of the small digested molecules (and water, mineral ions and vitamins) from the gut into the blood. **The small intestine is where nutrients are absorbed**, mostly in the ileum. Water is absorbed in two places: **most in the small intestine**, and **some in the colon**. The stomach, oesophagus and rectum absorb almost nothing.

Extended: villi and microvilli

The lining of the small intestine is covered in millions of tiny finger-like **villi** (one is a villus). Each epithelial cell on a villus has its own tiny folds of cell membrane, the **microvilli**. Villi, and the microvilli on them, give the inside of the small intestine a **very large surface area**, so digested food is absorbed much faster than it would be through a smooth tube.



A villus has:

- an **epithelium only one cell thick**, so molecules have a short distance to travel;
- **microvilli** on the epithelial cells, increasing the surface area further (and carrying maltase);
- a dense **network of blood capillaries** just under the epithelium;
- a **lacteal** up the middle, a small vessel of the lymphatic system.

The two kinds of vessel absorb different things:

- **Capillaries** absorb **glucose and amino acids** (and water and mineral ions). The blood flows away and is carried to the **liver** (by the hepatic portal vein). Because the blood keeps flowing, the concentration of glucose in the blood stays lower than in the gut, so absorption continues.
- The **lacteal** absorbs **fatty acids and glycerol**, the products of fat digestion. They leave in the lymph.

Key facts and formulas

There is no formula list in the IGCSE Biology exam. Everything below must be learnt.

Formula	Status
Chemical digestion: large insoluble molecules → small soluble molecules, so they can be absorbed	Learn it
Amylase: starch → simple reducing sugars (maltose)	Learn it
Protease: protein → amino acids	Learn it
Lipase: fats and oils → fatty acids + glycerol	Learn it
Amylase from the salivary glands (acts in the mouth) and pancreas (small intestine)	Learn it
Protease from the stomach (acts there) and pancreas (small intestine); lipase from the pancreas (small intestine)	Learn it
Hydrochloric acid: kills microorganisms; gives the acidic optimum pH for stomach enzymes	Learn it
Nutrients absorbed in the small intestine; water mostly in the small intestine, some in the colon	Learn it
Extended: maltase: maltose → glucose, on the epithelium membranes of the small intestine	Learn it
Extended: pepsin in the acidic stomach; trypsin (from the pancreas) in the alkaline small intestine	Learn it
Extended: bile is alkaline and neutralises stomach acid in the duodenum	Learn it
Extended: capillaries → glucose and amino acids, to the liver; lacteal → fatty acids and glycerol	Learn it
Rate $= \frac{1}{\text{time}}$; percentage change $= \frac{\text{change}}{\text{original}} \times 100$	Learn it

How to do it

We tagged 150 questions for this topic (2021–2025, Papers 1–4; 125 different, since some multiple-choice questions appear on more than one paper). 31 of them mix types, so the counts add up to 204.

Question type	Questions
State where an enzyme, acid or bile is made or acts	45
Name an enzyme's substrate and products	44
State where nutrients and water are absorbed	30
Explain pH in the gut: acid, bile, and why amylase stops in the stomach	21
Identify the parts of a villus and explain how villi are adapted	20
Define chemical digestion and say why it is needed	16
Read an enzyme activity graph and link it to a part of the gut	9
Explain the role of bile in fat digestion	8
Interpret a digestion experiment	6
Describe the whole route of a food, from digestion to absorption	5

Most are one-mark multiple choice on Papers 1 and 2. On Papers 3 and 4 they are parts of a longer question, usually starting from a diagram of the gut, a villus or an experiment.

1. State where an enzyme, acid or bile is made or acts (45 questions)

1. **Decide: made, or acts?** "Secreted by", "produced by" and "made in" ask for the gland; "acts in", "site of action" and "where does it digest" ask for the part of the gut the food is in.
2. **Use the table** in "Understand it": amylase from the salivary glands and pancreas; protease from the stomach and pancreas; lipase from the pancreas; acid from the stomach; bile made in the liver, stored in the gall bladder.
3. **On a diagram**, find the organ first (the previous topic shows how), then give its letter.

Variations you will meet:

- **"Where does amylase act?"** The mouth and the small intestine, never the stomach. Examiners say many students choose the stomach or the pancreas.
- **"Where does protein digestion begin?"** The stomach.
- **"Where is lipase made?"** The pancreas only.
- **A row of enzyme, substrate and site**: check all three. "Stomach, protease, protein" is right; "mouth, amylase, protein" is wrong.
- **"Circle the organ that secretes protease"** from a list without the stomach: the pancreas. Circle exactly one.
- **"Secretes protease and amylase"**: the pancreas. **"Secretes insulin"**: also the pancreas.

- **"Stores bile"**: the gall bladder (it doesn't make bile).
- **Extended: "Describe where maltose is digested in the small intestine"**: on the membranes of the epithelium (the epithelial cells lining the villi). "In the small intestine" alone gets nothing, as it is in the question.
- **Extended: "Where is trypsin made, and where does it act?"** Made in the pancreas, acts in the duodenum (small intestine). Pepsin is made in the stomach, not the pancreas.

2. Name an enzyme's substrate and products (44 questions)

1. **Match the enzyme to its substrate**: amylase → starch; protease → protein; lipase → fats and oils; **Extended:** maltase → maltose.
2. **Give the products**: simple reducing sugars (or maltose); amino acids; fatty acids **and** glycerol; **Extended:** glucose.

Variations you will meet:

- **"Substrate of amylase"**: write **starch**, not "carbohydrate" (examiners don't accept it).
- **Fat digestion has two products**: fatty acids **and** glycerol. Giving only one loses a mark; "glucose" for glycerol is a common slip.
- **"Products of protein digestion in the stomach"**: amino acids. Not "proteases" (enzymes are never products).
- **Diagrams of molecules**: a long chain of identical units breaking into single units is starch → sugars (or protein → amino acids if the units differ); an enzyme drawn unchanged at the end is correct.
- **A bread taste test**: bread tastes sweet after chewing because salivary **amylase** has turned starch into maltose.
- **Extended: "Name the two enzymes that turn starch into glucose"**: amylase (starch → maltose), then maltase (maltose → glucose).
- **Extended: an enzyme you haven't learnt**, such as lactase: use the name. Lactase digests lactose (a sugar in milk) to smaller sugars.

3. State where nutrients and water are absorbed (30 questions)

1. **Nutrients**: the small intestine (the ileum).
2. **Water**: both the small intestine (most) and the colon (some).

Variations you will meet:

- **A key table** with ticks for "colon" and "small intestine": digested food only in the small intestine; water in both. So "which molecule is absorbed in both?" is water (**0610/22/O/N/25 Q9**).
- **"Where is most water absorbed?"** The small intestine, not the colon.
- **Which molecules are absorbed**: small soluble ones: glucose, amino acids, fatty acids and glycerol, water, mineral ions. Not starch, protein, maltose or fibre.
- **An arrow from the intestine into a blood vessel** shows absorption.

- **Damage to the lining of the ileum** (for example by food poisoning) means less surface area, so less food and water is absorbed.
- **Complete a table of processes by organ**: mouth: ingestion, physical and chemical digestion; stomach: physical and chemical digestion; small intestine: chemical digestion and absorption; colon: absorption of water; anus: egestion.

4. Explain pH in the gut: acid, bile, and why amylase stops in the stomach (21 questions)

1. **Functions of hydrochloric acid** (2 marks): kills microorganisms in food **(1)**; gives the optimum (acidic) pH for enzymes in the stomach **(1)**.
2. **Extended: bile's effect on pH**: bile is alkaline **(1)** and neutralises the acid from the stomach **(1)**, giving a suitable pH for enzymes in the small intestine **(1)**.
3. **Extended: why starch isn't digested in the stomach but is in the small intestine** (up to 6 marks), in this order:
   - the stomach makes hydrochloric acid, so its contents are acidic (low pH);
   - the acid denatures amylase: its active site changes shape;
   - the active site is no longer complementary to starch, so no enzyme–substrate complexes form;
   - in the duodenum, alkaline bile neutralises the acid;
   - so the pH is suitable for amylase, which digests starch again.

Variations you will meet:

- **"Which substance causes the rise in pH as food enters the small intestine?"** Bile (**0610/22/O/N/25 Q8**). Not gastric juice (it lowers the pH), and not trypsin (an enzyme).
- **"Name the acid in the stomach"**: hydrochloric acid, not "stomach acid" or "gastric acid".
- **A tablet coated in starch** survives the stomach because there is no amylase working there; it is digested in the small intestine.
- **Extended link to experiments**: a protease that works at pH 2 is from the stomach; one that works at pH 8 is from the small intestine.

5. Identify the parts of a villus and explain how villi are adapted (20 questions)

1. **Name the parts**: the lacteal is the single vessel **in the middle**; the capillaries form a network **around it**, just under the surface; the microvilli are the tiny folds **on the outer surface** of the epithelial cells.
2. **Give each part's role**: capillaries absorb glucose and amino acids; the lacteal absorbs fatty acids and glycerol; microvilli increase the surface area (and carry maltase).
3. **For "explain how villi are adapted"**, give each feature **with** its reason:
   - villi and microvilli → large surface area for absorption;
   - epithelium one cell thick → short distance for molecules to move;
   - many capillaries, with blood flowing away → keeps a concentration gradient, so absorption continues;
   - a lacteal → absorbs the products of fat digestion.

Variations you will meet:

- **"Which part absorbs fatty acids and glycerol?"** The lacteal (0610/23/O/N/25 Q12). **Glucose and amino acids?** The capillaries.
- **"Which vessel carries blood to the liver?"** The one carrying blood **away** from the villus (the venule, leading to the hepatic portal vein). After a meal it has the highest concentration of glucose and amino acids.
- **"Function of microvilli"**: increase the surface area for absorption. Don't confuse them with cilia, which move mucus in the airways.
- **A photomicrograph**: the fringe along the edge is the microvilli; the space in the middle is the lacteal.

6. Define chemical digestion and say why it is needed (16 questions)

1. **Definition** (2 marks): the breakdown of **large insoluble** molecules **(1)** into **small soluble** molecules **(1)**, by enzymes.
2. **Why** (1 more mark): small soluble molecules **can be absorbed** into the blood; large ones can't pass through the gut wall.

Variations you will meet:

- **Multiple choice that swaps the words**: only "large insoluble → small soluble" is right.
- **"Which is an example of chemical digestion?"** Starch broken down into sugars. Churning, chewing and mixing with bile are physical.
- **"Describe the role of chemical digestion"**: examiners say many answers stop at "small molecules" and forget "so they can be absorbed".
- **"Why can't starch enter an epithelial cell?"** Starch molecules are too large (and insoluble) to pass through the cell membrane.
- **Matching terms**: digestion (breaking down), absorption (into the blood), assimilation (into cells and used), egestion (removing faeces).

7. Read an enzyme activity graph and link it to a part of the gut (9 questions)

1. **Describe the curve** (3 to 5 marks): activity rises, reaches a maximum at the optimum pH (quote it), then falls; say where it is zero; quote a value with its units.
2. **Link it**: an optimum around pH 2 → the stomach (pepsin); around pH 7 to 8 → the small intestine (trypsin, and amylase and lipase); around pH 7 → the mouth (salivary amylase).
3. **Extended: explain the fall**: away from the optimum the enzyme is denatured, the active site changes shape, it is no longer complementary to the substrate, and fewer enzyme–substrate complexes form.

Variations you will meet:

- **Four graphs, "which enzyme is most active in the stomach?"**: the one with the acidic optimum.
- **Two proteases on one graph**: name the acidic one pepsin (stomach) and the alkaline one trypsin (small intestine). "Protease" alone isn't enough when the question asks which one.

- **Protein jelly plates**: the area of jelly digested around a hole measures protease activity.
- **Compare two curves**: which has the higher peak, which works over the wider pH range, where both are active.

8. Explain the role of bile in fat digestion (8 questions)

Covered in the previous topic, in short: bile **emulsifies** fat into small droplets **(1)**, **increasing the surface area (1)** for **lipase** to act on, so fat is chemically digested faster **(1)**. Bile is not an enzyme.

Variations you will meet:

- **"What is a role of bile?"** It emulsifies fats, increasing their surface area. It contains no enzymes and doesn't kill bacteria.
- **Test tubes of milk**: milk + lipase + bile digests fat fastest; milk + bile alone doesn't digest it at all; boiled lipase doesn't work.
- **A fat globule** shown large in the stomach and as many droplets further on: the change happens in the small intestine (duodenum), where bile is added.

9. Interpret a digestion experiment (6 questions)

1. **Know the tests**: **iodine solution** turns **blue-black** with starch and stays **yellow-brown** (orange-brown) without it; **Benedict's solution**, heated, turns from blue to green, yellow, orange or **brick red** with reducing sugars.
2. **Say what the enzyme did**, not just the colours: "the amylase digested the starch in Y, so there was no starch left".
3. **Dialysis (Visking) tubing** is a model of the gut wall: it is partially permeable, so small molecules (maltose, glucose, amino acids) pass through and large ones (starch, protein, enzymes) don't.

Variations you will meet:

- **Starch only vs starch + amylase, tested with iodine**: blue-black (no digestion) vs yellow-brown (starch digested by amylase).
- **Starch + amylase in dialysis tubing, water outside**: after a while the water outside gives a positive Benedict's test (sugars were made and passed through the tubing) but a negative iodine test (starch stayed inside). This models digestion, then absorption.
- **Milk + lipase with a pH indicator**: fatty acids lower the pH, so the indicator changes colour; with bile the change is faster (emulsification).
- **Rate from a time**: rate $= \frac{1}{\text{time}}$; a shorter time means a faster reaction.
- **Controls**: the tube without the enzyme (or with boiled enzyme) shows that the enzyme caused the change.

10. Describe the whole route of a food, from digestion to absorption (5 questions)

Extended long answers. Follow the food, naming each enzyme, where it's made, where it acts, the product, and where that is absorbed.

- **Starch**: salivary amylase in the mouth → maltose; stops in the acidic stomach; pancreatic amylase in the duodenum → maltose; maltase on the epithelium membranes → glucose; glucose absorbed into the **capillaries** of the villi → to the liver.
- **Protein**: pepsin in the stomach, then trypsin from the pancreas in the small intestine → amino acids → absorbed into the **capillaries** → to the liver.
- **Fat**: emulsified by bile in the duodenum → lipase from the pancreas → fatty acids and glycerol → absorbed into the **lacteals**.

Variations you will meet:

- **Core version**: bread in the mouth: teeth chew it, saliva moistens it, amylase starts turning starch into maltose; the oesophagus carries it to the stomach.
- **Starting from a plant or alga eaten as food**: its starch (or protein) follows the same route.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

Core.

(a) Complete the table. **[6]**

Enzyme	Substrate	Product(s)	One organ that secretes it
amylase		simple reducing sugars	
protease	protein		stomach
lipase			

(b) State two functions of hydrochloric acid in the stomach. **[2]**

(c) State the part of the alimentary canal where most digested food is absorbed, and one other part where water is absorbed. **[2]**

(a) Amylase: starch **B1**; salivary glands (or pancreas) **B1**. Protease: amino acids **B1**. Lipase: fats (and oils) **B1**; fatty acids and glycerol **B1** (both products needed); pancreas **B1**.

(b) It kills harmful microorganisms (bacteria) in the food **B1**. It gives an acidic pH, the optimum pH for the stomach's enzymes **B1**.

(c) Small intestine (ileum) **B1**; colon **B1**.

Example 2

A student set up three test-tubes at 35 °C. Each contained 5 cm^3 of milk and an indicator that is pink in alkaline conditions and turns colourless when the pH falls.

Tube	Also contains	Time to turn colourless / min
A	lipase and bile	4
B	lipase and water	10
C	bile and water	did not change in 30 min

(a) Explain why the indicator in tube B turned colourless. **[2]**

(b) Calculate the rate of reaction in tubes A and B, using rate $= \frac{1}{\text{time}}$, and state how many times faster the reaction was in A. **[3]**

(c) **Extended:** explain why the reaction in tube A was faster than in tube B. **[3]**

(d) Suggest the purpose of tube C. **[1]**

(a) Lipase broke down the fat in the milk into fatty acids and glycerol **B1**; the fatty acids lowered the pH **B1**.

(b) A: $\frac{1}{4} = 0.25$ per min; B: $\frac{1}{10} = 0.1$ per min **M1 A1**. $\frac{0.25}{0.1} = 2.5$ times faster **A1**.

(c) Bile emulsified the fat into small droplets **B1**, increasing its surface area **B1**, so lipase could digest it faster (more enzyme–substrate complexes formed) **B1**.

(d) A control, to show that bile alone doesn't digest fat (the lipase caused the change) **B1**.

Example 3

Extended. A scientist measured the activity of two proteases, X and Y, at different pH values.

pH	1	2	3	4	5	6	7	8	9	10	11
X activity / arbitrary units	40	85	60	25	5	0	0	0	0	0	0

pH	1	2	3	4	5	6	7	8	9	10	11
Y activity / arbitrary units	0	0	0	0	10	30	65	90	75	35	10

(a) Name protease X and protease Y, and state where each acts in the alimentary canal. **[4]**

(b) Describe the activity of Y. **[3]**

(c) Calculate the percentage decrease in the activity of Y between pH 8 and pH 10. **[2]**

(d) Explain why X has no activity at pH 7. **[3]**

(e) Explain how the pH in the small intestine is made suitable for Y. **[2]**

(a) X is pepsin **B1**, in the stomach **B1**. Y is trypsin **B1**, in the small intestine (duodenum) **B1**.

(b) Activity rises as pH increases, from 10 arbitrary units at pH 5 **B1**, to a maximum (optimum) of 90 arbitrary units at pH 8 **B1**, then falls to 10 arbitrary units at pH 11 **B1**.

(c) $\frac{90 - 35}{90} \times 100$ **M1** $= 61.1\%$ **A1**.

(d) At pH 7, X is denatured: its active site has changed shape **B1**, so it is no longer complementary to the protein (substrate) **B1**, and no enzyme–substrate complexes can form **B1**.

(e) Bile is alkaline **B1** and neutralises the acidic mixture entering the duodenum from the stomach **B1**.

Example 4

Extended.

(a) Describe the structure of a villus. **[3]**

(b) Describe the roles of the capillaries and the lacteal in a villus. **[3]**

(c) In a simple model, the inside of a piece of small intestine would have a surface area of 0.30 m² if it were smooth. Villi increase this area 10 times, and microvilli increase it a further 20 times. Calculate the surface area with villi and microvilli. **[2]**

(d) Explain why this large surface area is important. **[1]**

(e) Describe how the starch in a piece of bread is digested and the product absorbed. **[5]**

(a) A finger-like projection covered with an epithelium one cell thick **B1**, with microvilli on the epithelial cells **B1**; it contains a network of blood capillaries and a central lacteal **B1**.

(b) Capillaries absorb glucose and amino acids **B1** and carry them away in the blood to the liver **B1**. The lacteal absorbs fatty acids and glycerol **B1**.

(c) $0.30 \times 10 \times 20$ **M1** $= 60$ m² **A1**.

(d) More digested food can be absorbed at the same time, so absorption is faster **B1**.

(e) Amylase (from the salivary glands, then the pancreas) breaks starch down to maltose **B1** in the mouth and duodenum **B1**; maltase breaks maltose down to glucose **B1** on the membranes of the epithelium of the small intestine **B1**; glucose is absorbed into the blood capillaries of the villi **B1**.

Common mistakes

- **Saying amylase acts in the stomach.** It acts in the mouth and the small intestine; stomach acid denatures it.
- **"Carbohydrate" as amylase's substrate.** Examiners want **starch**.
- **Only one product of fat digestion.** Lipase makes fatty acids **and** glycerol; examiners say glycerol is often left out. Glycerol is not glucose.
- **Mixing up pepsin and trypsin**, or misspelling them into something in between. Pepsin: stomach, acidic. Trypsin: pancreas, alkaline small intestine.
- **Writing "protease" when the question asks which protease.** Name pepsin or trypsin.
- **Saying the liver makes trypsin**, or that the pancreas makes maltase. Trypsin comes from the pancreas; maltase is on the epithelium membranes.
- **"In the small intestine" for where maltose is digested.** The question already says that; give "on the membranes of the epithelial cells".
- **Calling hydrochloric acid an enzyme**, or naming it "stomach acid", "gastric acid" or "lactic acid".
- **Forgetting "so they can be absorbed"** when describing the role of chemical digestion.
- **Saying "acidic pH" but not what causes it**: in the 6-mark question, name hydrochloric acid (gastric juice) as the cause, and say bile is **alkaline**.
- **Leaving out "active site"** when explaining denaturing. Write that the shape of the **active site** changes.
- **Thinking most water is absorbed in the colon.** Most is absorbed in the small intestine.
- **Confusing microvilli with cilia.** Microvilli increase surface area for absorption; cilia move mucus.
- **Describing only the colours in an experiment.** Say what happened: "amylase digested the starch".

How to get the marks

- **"State"**: one word or short phrase: "pancreas", "lacteal". Circle, tick or draw lines exactly as many times as asked; extras cancel marks.
- **Use the exact terms**: starch, maltose, glucose, amino acids, fatty acids and glycerol, hydrochloric acid, duodenum, ileum, epithelium, lacteal, capillary, denatured, active site, complementary, enzyme–substrate complex.
- **"Describe the role/importance of" an enzyme** (3 marks): it's an enzyme **(1)**, what it breaks down and into what **(1)**, and that the products are small and soluble so they can be absorbed **(1)**.
- **"Explain"** needs the reason chain, one link per mark: cause → effect on the enzyme → result. Use the mark total as a guide to how many points to make.

- **Graphs**: describe the trend, give the optimum, and quote at least one value **with its units** (such as "90 arbitrary units at pH 8").
- **Villus answers**: pair each feature with why it helps (surface area, short distance, concentration gradient).
- **Calculations**: show the working, give units and round only at the end.
- **"Suggest"**: apply what you know to a new situation (an unfamiliar enzyme, an experiment); more than one answer may be accepted.

Quick check

1. Complete: amylase breaks down _____ to _____; lipase breaks down _____ to _____ and _____; protease breaks down protein to _____.
2. Name the organ that secretes all three of amylase, protease and lipase, and the only organ that secretes hydrochloric acid.
3. A starch–amylase mixture stopped giving a blue-black colour with iodine after 3 minutes at pH 7, and after 12 minutes at pH 5. Calculate the rate ($\frac{1}{\text{time}}$) at each pH, to 2 significant figures, and how many times faster the reaction was at pH 7.
4. Where in the alimentary canal is most water absorbed, and where is the rest absorbed?
5. **Extended:** (a) Explain why the pH rises when food passes from the stomach into the duodenum. (b) State which part of a villus absorbs glycerol, and which absorbs amino acids.

Answers

1. Starch to simple reducing sugars (maltose); fats and oils to fatty acids and glycerol; protein to amino acids.
2. The pancreas; the stomach.
3. pH 7: $\frac{1}{3} = 0.33$ per min. pH 5: $\frac{1}{12} = 0.083$ per min. $\frac{12}{3} = 4$ times faster at pH 7.
4. Most in the small intestine; the rest in the colon.
5. (a) Bile, which is alkaline, is added in the duodenum and neutralises the hydrochloric acid from the stomach. (b) Glycerol: the lacteal. Amino acids: the blood capillaries.

Past questions to try

- **0610/33/O/N/25 Q1**: protease substrate and products, where it is made and acts, and hydrochloric acid (Core).
- **0610/42/O/N/25 Q1**: bile's role, and the microvilli and lacteal in a photomicrograph of a villus (Extended).
- **0610/42/M/J/25 Q6**: two proteases on a pH graph; name the one that works in the stomach (Extended).
- **0610/42/F/M/23 Q2**: a starch and amylase experiment with dialysis tubing, and villi (Extended).