The Digestive System

A Level

The digestive system is composed of the gastrointestinal tract (GI) and the accessory organs of digestion.

The gastrointestinal tract (GI), also referred to as the "gut", is the passageway from the mouth to the anus. It is composed of all of the major organs that food moves through as it is digested.

The accessory organs are the organs that aid in digestion, but which food does not travel through.

Part A The gastrointestinal tract

Drag the items (left) into the correct order (right) to show the passage of food through the gastrointestinal tract (top to bottom) in humans.

Note that not all of the items below are regions that food moves through, and so you should not use all of the items below.

Available items

- larynx
- anus
- pharynx
- large intestine
- liver
- bladder
- kidneys
- mouth
- pancreas
- oesophagus
- stomach
- small intestine

Part B Parts & functions

Match the part of the digestive system to the function(s) in the table below.

Part	Function(s)
	main site of digestion and absorption of nutrients
	produces acidic solution that kills microorganisms, denatures proteins, and enables digestive enzymes with a low optimal pH (e.g. pepsin) to function
	produces alkaline solution that contains digestive enzymes
	absorbs water and ions, and ferments indigestible material
	produces bile which helps break down lipids
	moves food into the stomach

Items:

stomach **pancreas** **small intestine** **oesophagus** **liver** **large intestine**

Part C Digestive enzymes

Fill in the table below to show how large macromolecules are broken down into smaller molecules in the digestive system.

Enzyme	Site(s) of origin	Reactant(s)	Product(s)
amylase	salivary glands, pancreas		
pepsin	stomach		
lipase	stomach, pancreas		
maltase	small intestine	maltose	
lactase	small intestine	lactose	
sucrase	small intestine	sucrose	

Items:

glucose & galactose **glycerol & fatty acids** **glucose only** **proteins** **small peptides/amino acids**

glucose & fructose **trisaccharides & disaccharides** **starch** **triglycerides**

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The Small Intestine

A Level

The small intestine is the main site of digestion and absorption of nutrients.

Part A Structure and function

There are three sections of the small intestine:

- the duodenum (main site of digestion)
- the jejunum (main site of absorption of nutrients e.g. amino acids, monosaccharides, fatty acids, etc.)
- the [ ] (site of absorption of vitamin B12 and bile salts)

All three sections of the small intestine contain internal projections called [ ]. Each [ ] is approximately $1\ \mathrm{mm}$ long in humans and is composed of multiple tissue layers (including blood capillaries). The tissue layer that forms the lining is called the intestinal epithelium. Each intestinal epithelial cell contains hundreds to thousands of membrane projections called [ ]. These are sometimes collectively referred to as the "brush border" because they look like the bristles on a brush. Each [ ] is approximately $1\ \mu\mathrm{m}$ long in humans.

The villi and microvilli help increase the [ ] ratio of the wall of the small intestine, which improves the efficiency of both digestion and absorption.

Items:

villus | microvilli | microvillus | ileum | volume-to-surface-area | caecum | surface-area-to-volume | villi

Part B Digestion

The brush border contains many membrane-bound digestive enzymes, including maltase, lactase, sucrase, lipases, and peptidases. As carbohydrates, lipids, and proteins pass through the small intestine, they are broken down as they come into contact with these enzymes.

The brush border also contains a particular type of peptidase, called enteropeptidase, which is needed to convert some inactive peptidases into active peptidases (e.g. inactive trypsinogen to active trypsin).

What is the name of the organ that secretes these inactive peptidases into the small intestine?

Part C Absorption

In addition to membrane-bound enzymes, the brush border contains membrane transport proteins that allow nutrients to be absorbed into the bloodstream. Nutrients are transported out of the intestinal lumen and into the intestinal epithelial cells. From here they are transported to the blood capillaries.

Amino acids and glucose are both transported by a process in which sodium ions move into the intestinal epithelial cell **down** their concentration gradient (from high to low), providing the energy needed to move amino acids/glucose into the intestinal epithelial cell **up** their concentration gradients (from low to high).

What is the name of this type of process?

Part D Surface area

How does the high surface area of the intestinal wall (which is achieved by the presence of villi and microvilli) improve the efficiency of digestion and absorption? Select all that apply.

- [ ] it increases the volume of the intestinal lumen
- [ ] it provides more space for insulin and glucagon to be secreted from
- [ ] it decreases the volume of the intestinal lumen
- [ ] it provides more space for membrane transport proteins
- [ ] it provides more space for bile to be secreted from
- [ ] it provides more space for membrane-bound enzymes

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The Liver

A Level

The liver is one of the "accessory organs" of digestion i.e. food does not pass through the liver, but the liver plays an important role in the digestion of food as it passes through the digestive system. It also carries out many other functions including energy storage & release, detoxification of toxins, and breakdown of excess amino acids.

Part A Accessory organ

As an accessory organ of digestion, the main role that the liver plays is to help digest lipids. It does this by producing [ ]. This is secreted into the gallbladder for storage, and from there is secreted into the [ ] where it helps dissolve fats in a process called [ ].

Once fats have been dissolved (i.e. broken up into smaller particles), lipase enzymes (secreted by the [ ]) can hydrolyse triglycerides into fatty acids and [ ].

After being absorbed by the intestinal cells, these can then reform into triglycerides to be stored in adipose tissue, or be used as respiratory substrates to provide energy for cells.

Items:

pancreas | esterification | bile | large intestine | stomach | gastric acid | small intestine | emulsification | glycerol | glycogen

Part B Energy storage & release

Which of the following molecules are stored in the liver and can be broken down to release energy? Select all that apply.

- [ ] amylose
- [ ] ATP
- [ ] glycogen
- [ ] amylopectin
- [ ] glucose
- [ ] triglycerides
- [ ] cellulose

Part C Breakdown of amino acids

In the digestive system, proteins are broken down into amino acids, which are released into the bloodstream. These amino acids can be taken up by cells and used to build new proteins. Excess amino acids are used in respiration. However, they must be "deaminated" first. The liver carries out this process of deamination, removing the amino group (NH_2) and converting it into ammonia (NH_3). The deaminated amino acid can be used in respiration, while the ammonia is converted into a less toxic waste product to be excreted by the kidneys.

What is the name of this waste product in mammals?

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The Pancreas

A Level

The pancreas is an organ that is part of both the digestive system and the endocrine system. It is one of the "accessory organs" of digestion i.e. food does not pass through the pancreas, but the pancreas plays an important role in the digestion of food as it passes through the digestive system.

Part A Structure and functions

The pancreas as both an [ ] gland (a gland that secretes substances via ducts on to an epithelial surface - in this case, the intestinal epithelium) and as an [ ] gland (a gland that secretes substances directly into the bloodstream).

Endocrine functions: regions of pancreatic tissue called [ ] secrete [ ] which [ ].

Exocrine functions: regions of pancreatic tissue called [ ] secrete [ ] which [ ].

Items:

pancreatic acini | **digest carbohydrates, lipids, and proteins** | **an alkali solution containing enzymes** | **hormones** | **exocrine** | **islets of Langerhans (pancreatic islets)** | **regulate blood glucose levels** | **endocrine**

Part B High glucose levels

What is the name of the hormone, produced by the pancreas, that is secreted in response to high blood glucose levels?

Which regions and cell types secrete this hormone? Select all that apply.

- [ ] regions: pancreatic acini
- [ ] regions: pancreatic islets (islets of Langerhans)
- [ ] cell type: α cells (alpha cells)
- [ ] cell type: β cells (beta cells)
- [ ] cell type: δ cells (delta cells)

Part C Low glucose levels

What is the name of the hormone, produced by the pancreas, that is secreted in response to low blood glucose levels?

Which regions and cell types secrete this hormone? Select all that apply.

- [ ] regions: pancreatic acini
- [ ] regions: pancreatic islets (islets of Langerhans)
- [ ] cell type: α cells (alpha cells)
- [ ] cell type: β cells (beta cells)
- [ ] cell type: δ cells (delta cells)

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Blood Glucose Regulation

A Level

Glucose is the main respiratory substrate used by cells for respiration. Because of this, organisms need to tightly regulate how much glucose is available. When glucose is abundant it needs to be stored so that, when glucose is scarce, stored glucose can be released to cells. There are two main hormones responsible for this regulation: insulin and glucagon.

Part A Insulin secretion

Drag the items (left) into the correct order (right) to show the sequence of events that result in insulin secretion.

Note that not all of the items below are part of the correct sequence of events, and so you should not use all of the items below.

Available items

- a rise in glucose concentration results in more glucose diffusing (by facilitated diffusion) into the β cells of the islets of Langerhans
- Voltage-gated calcium ion channels open, which causes calcium ions to move **into** the cells
- ATP-sensitive potassium ion channels **close**, which means that potassium ions stop diffusing out of the cells, and so the cells begin to depolarise from $\approx -70\,\mathrm{mV}$ to $\approx -30\,\mathrm{mV}$
- ATP-sensitive potassium ion channels **open**, which means that potassium ions diffuse out of the cells, and so the cells begin to depolarise from $\approx -70\,\mathrm{mV}$ to $\approx -30\,\mathrm{mV}$
- the rate of respiration of glucose increases in the cells, which results in more ATP being produced
- Calcium ions cause insulin-containing secretory vesicles to release insulin by **exocytosis**
- Voltage-gated calcium ion channels open, which causes calcium ions to move **out of** the cells
- Calcium ions cause insulin-containing secretory vesicles to release insulin by **endocytosis**

Part B Insulin action

Most cells in the body have insulin receptors in their cell membranes.

Which of the following events occur as a result of insulin binding to these insulin receptors? Select all that apply.

- [ ] insulin-dependent glucose membrane transport proteins open, causing an **increase** in uptake of glucose from the bloodstream by cells
- [ ] insulin-dependent glucose membrane transport proteins open, causing a **decrease** in uptake of glucose from the bloodstream by cells
- [ ] glucose is converted into glycogen (i.e. **glycogenesis**) in liver cells and skeletal muscle cells
- [ ] glycogen is broken down into glucose (i.e. **glycogenolysis**) in liver cells
- [ ] glucose is converted into triglycerides (i.e. **lipogenesis**) in liver cells and adipose cells
- [ ] triglycerides are broken down into glycerol and fatty acids (i.e. **lipolysis**) in adipose tissue, and glycerol and amino acids are converted into glucose (i.e. **gluconeogenesis**) in liver cells

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Part C Glucagon action

Unlike insulin, only a few cell types have glucagon receptors in their cell membranes.

Which of the following events occur as a result of glucagon binding to these glucagon receptors? Select all that apply.

- [ ] insulin-dependent glucose membrane transport proteins open, causing an **increase** in uptake of glucose from the bloodstream by cells
- [ ] insulin-dependent glucose membrane transport proteins open, causing a **decrease** in uptake of glucose from the bloodstream by cells
- [ ] glucose is converted into glycogen (i.e. **glycogenesis**) in liver cells and skeletal muscle cells
- [ ] glycogen is broken down into glucose (i.e. **glycogenolysis**) in liver cells
- [ ] glucose is converted into triglycerides (i.e. **lipogenesis**) in liver cells and adipose cells
- [ ] triglycerides are broken down into glycerol and fatty acids (i.e. **lipolysis**) in adipose tissue, and glycerol and amino acids are converted into glucose (i.e. **gluconeogenesis**) in liver cells

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Part D Name the hormone

Name **another** hormone that causes glycogenolysis in liver cells and muscle cells by binding to membrane receptors of those cells.

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Oral Glucose Tolerance Test

A Level

The oral glucose tolerance test (OGTT) is used to diagnose diabetes.

A result from an OGTT measuring blood glucose and insulin concentrations is shown below.

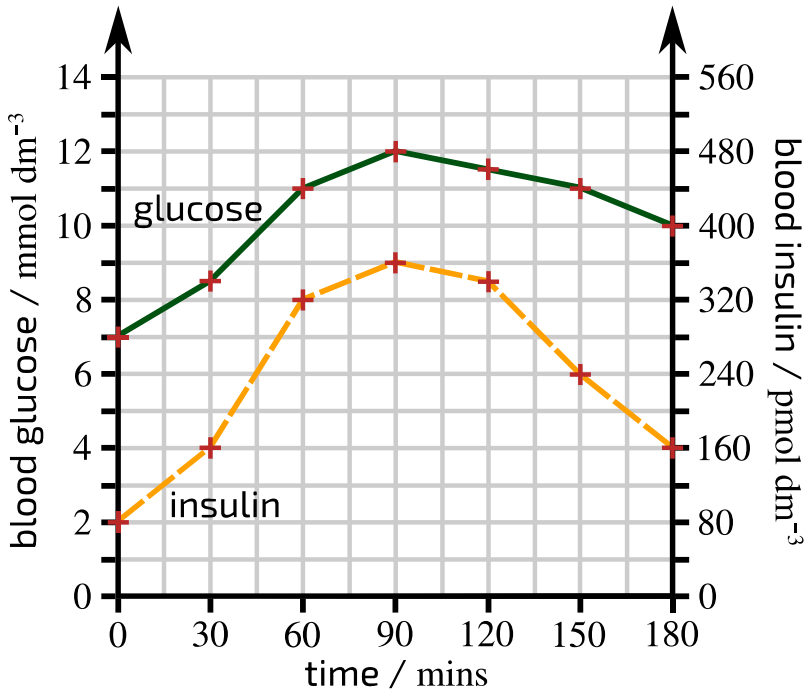

Figure 1: The results of an oral glucose tolerance test. The patient fasted for 12 hours prior to the test. At the beginning of the test (time = 0 mins), the patient was given a glucose solution to drink and a blood sample was taken. Blood samples were then taken every 30 mins over the next 3 hours. Glucose and insulin concentrations were measured from these blood samples and the results were plotted on a graph.

Part A Glucose increase & decrease

Calculate the percentage increase in blood glucose concentration from 0 minutes to 90 minutes.

Give your answer to the nearest percent.

Calculate the percentage decrease in blood glucose concentration from 90 minutes to 180 minutes.

Give your answer to the nearest percent.

Part B Glucose vs insulin concentrations

Calculate the value of $\frac{\text{blood glucose concentration}}{\text{blood insulin concentration}}$ at 90 minutes.

Give your answer to 1 significant figure.

Part C Molecules of glucose

The individual has approximately $5\,\text{litres}$ of blood in their body.

Estimate the number of molecules of glucose in their circulatory system at 90 minutes.

Give your answer to 2 significant figures.

Part D Diabetes diagnosis

The OGTT result in **Figure 1** shows evidence of diabetes.

Which type of diabetes does the patient have, and how can this be concluded? Select a type and **two** pieces of evidence below.

- [ ] type: 1
- [ ] type: 2
- [ ] evidence: the graph shows normal changes in blood glucose and insulin concentrations
- [ ] evidence: insulin is produced in response to a rise in blood glucose concentration
- [ ] evidence: not enough insulin is produced in response to a rise in blood glucose concentration
- [ ] evidence: blood insulation concentration is almost as high as blood glucose concentration
- [ ] evidence: blood glucose concentration decreases slowly in response to insulin
- [ ] evidence: blood glucose concentration continues to increase even when blood insulin concentration is increasing

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Adapted with permission from OCR A Level Biology B, June 2017, Fundamentals of Biology, Question 32