5 Nutrition in Humans

Study Station ▸▸

A Nutrition

Learning Outcome

- Understand that nutrition involves these processes — ingestion, digestion, absorption, assimilation and egestion.

1. The process by which organisms obtain food and energy for growth, repair and maintenance of the body is called **nutrition**. It consists of the following processes:

Feeding/Ingestion
Food is taken into the body usually through the mouth.

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Digestion
Food molecules are broken down into simple molecules that can be absorbed by the alimentary canal.

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Absorption
Digested food is absorbed by the small intestine.

↓

Assimilation
Absorbed nutrients are converted into new cell components or used by the cell to provide energy.

↓

Egestion
Undigested food is removed as faeces.

Link Discover Biology (3rd Edition) Textbook — Section 5.1

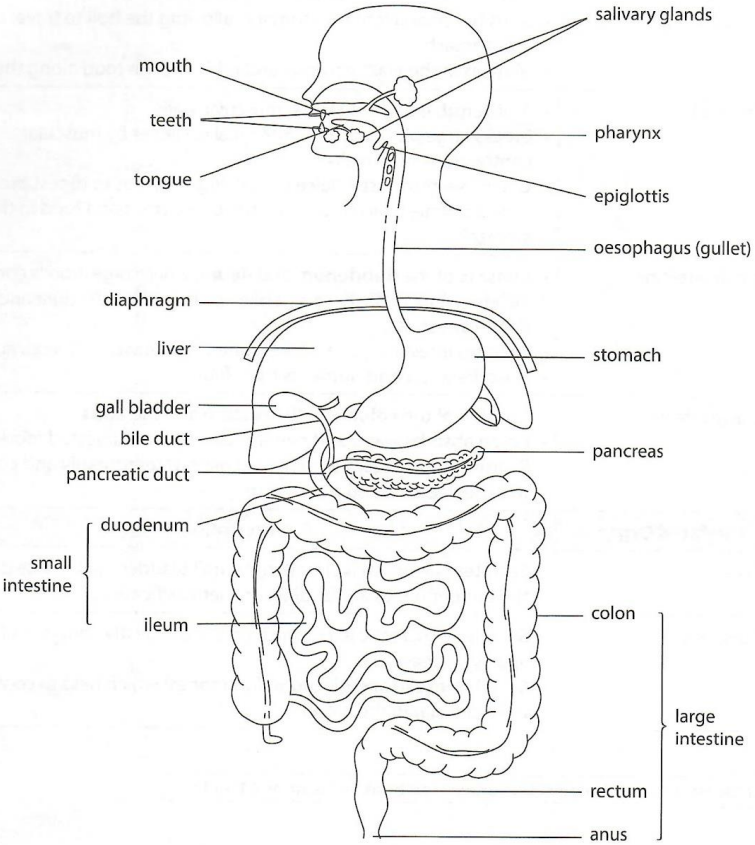
B Digestive System and the Related Organs

Learning Outcome

- Describe the functions of the main parts of the human alimentary canal and the related organs with respect to ingestion, digestion, absorption, assimilation and egestion of food.

1. **Digestion** is the process by which big, complex food molecules are broken down into smaller, simpler soluble molecules that the body can absorb.

2. The digestive system carries out two types of digestion — **physical digestion** and **chemical digestion**.
3. **Physical digestion** is the mechanical breakdown of food into smaller pieces.
   - The smaller pieces of food provide more exposed surface area for enzymes to work, increasing the efficiency of chemical digestion.
   - Examples: teeth chewing food in the mouth, churning action of the stomach walls which breaks food into chyme, emulsification of fats into tiny droplets in the small intestine
4. **Chemical digestion** is the breakdown of food into simpler, soluble molecules which are small enough to be absorbed by the body. It is carried out by the action of digestive enzymes.
5. The diagram below shows the human digestive system.



6. The human digestive canal consists of the **alimentary canal** (gut) and the related organs — **liver, gall bladder** and **pancreas**. The liver is the largest gland in the body, located below the diaphragm.

7. The table describes the main parts of the digestive system and the related organs.

Part	Description
Mouth	• Ingests food • Salivary glands secrete saliva • Teeth break up large pieces of food into smaller pieces by chewing • Tongue mixes the food with saliva and rolls the food into **boli** (small masses of food, singular: bolus)
Pharynx	• Joins the mouth to the oesophagus, larynx (voice box) and trachea (windpipe) • Prevents food or drink from entering the trachea during swallowing by a flap-like tissue called the epiglottis
Oesophagus	• Joins the pharynx to the stomach, allowing the boli to travel down to the stomach • Muscles in the walls contract and relax to push food along the tube
Stomach	• A distensible bag with thick, muscular walls • Breaks large pieces of food into smaller pieces by muscular contractions of its walls • Glands secrete gastric juice containing enzymes to digest proteins • Forms chyme, which is the mixture of enzymes and food in the stomach
Small intestine	• Consists of the **duodenum** and **ileum**, where digestion is completed • Receives pancreatic juice and bile via the pancreatic duct and bile duct respectively • Secretes intestinal juice, which contains maltase, proteases and lipase • Absorbs water and nutrients from food
Large intestine	• Consists of the **colon** and the **rectum** and the **anus** • Colon absorbs water and mineral salts from undigested food • Rectum stores faeces (undigested matter) temporarily and contracts to expel faeces through the anus
Related Organ	**Description**
Liver	• Secretes bile which is stored in the gall bladder, via the bile duct into the duodenum to aid fat digestion (emulsification)
Pancreas	• Secretes pancreatic juice which contains digestive enzymes (amylase, lipase, protease) • Secretes insulin and glucagon (hormones) which help to control the level of sugar in the blood

Link Discover Biology (3rd Edition) Textbook — Sections 5.1 and 5.2

C Chemical Digestion

Learning Outcomes

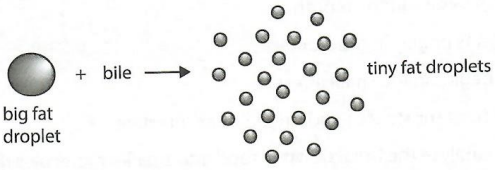
- Describe the functions of enzymes (amylase, maltase, protease and lipase) in digestion.
- List the substrates and end products of digestion.

1. The digestion of the different types of food begins in different parts of the alimentary canal:
   - Digestion of starch begins in the mouth.
   - Digestion of proteins begins in the stomach.
   - Digestion of fats begins in the small intestine.
2. The digestion of all food substances ends in the small intestine.
3. Digestive enzymes catalyse the breakdown of food into smaller molecules that can be absorbed by the body. The table below shows the final products of digestion.

Large Molecules	Final Products of Digestion
Carbohydrates	Glucose
Proteins	Amino acids
Fats	Fatty acids and glycerol

4. The following processes occur in the mouth:
   - Food stimulates the salivary glands to produce saliva which contains salivary **amylase**.
   - Salivary amylase has an optimum pH of 7. It digests starch to maltose.
   - The teeth break food up into smaller pieces, increasing the surface area-to-volume ratio for amylase to act on.
   - The tongue rolls the food into a bolus which is swallowed and passed down the oesophagus to the stomach.
5. The following processes occur in the stomach:
   - The gastric glands produce gastric juice which contains hydrochloric acid, pepsin (a protease) and mucus.
     - Functions of hydrochloric acid: provides the optimum acidic pH (about pH 2) for pepsin to work, denatures the salivary amylase present in food, kills harmful microorganisms in food
   - Pepsin digests proteins to polypeptides.
   - Mucus protects the stomach wall from being digested and moistens the food.
   - Food stays in the stomach for 3 to 4 hours.
   - Muscular walls of the stomach churn the food, breaking it into partially digested food called **chyme**.
   - Chyme passes into the duodenum in small amounts.

6. The following processes occur in the small intestine:
   - The pancreas secretes pancreatic juice containing pancreatic amylase, protease and pancreatic lipase through the **pancreatic duct**.
   - The gall bladder releases bile.
     - Bile emulsifies fats by breaking large fat molecules into tiny fat droplets. This increases the surface area to speed up fat digestion by lipases. Emulsification is a physical break-up process and not a form of chemical digestion.



   - The intestinal epithelial cells release maltase, protease and lipase.
   - These alkaline fluids neutralise acidic chyme and provide a suitable alkaline pH (pH 8) for the pancreatic and intestinal enzymes to work.

7. The table below summarises the digestion of different food substances.

Food Substance	Digested In	Enzyme	Enzymatic Action
Carbohydrates	Mouth	Salivary amylase	starch → maltose
	Small intestine	Pancreatic amylase	starch → maltose
		Maltase	maltose → glucose
Proteins	Stomach	Protease	protein → polypeptides
	Small intestine	Protease	protein → polypeptides polypeptides → amino acids
Fats	Small intestine	Lipase	emulsified fats → fatty acids + glycerol

Common Error

✗ Emulsification is part of chemical digestion.

✓ Emulsification is a physical process.

Explanation
Emulsification is the physical breakdown of large fat molecules into smaller ones. It is a non-enzymatic process.

Worked Example 5.1

After eating a banana, the contents from two different digestive organs in a person, **A** and **B**, were tested. The results are shown in the table below.

Test Reagent	Organ A	Organ B
Iodine solution	Solution remained brown	Solution changed to blue-black colour
Benedict's solution	Solution remained blue	Solution remained blue

Which of the following **correctly** identifies organs **A** and **B**?

	Organ A	Organ B
A	Mouth	Small intestine
B	Small intestine	Large intestine
C	Stomach	Mouth
D	Large intestine	Stomach

Solution

Option **C** is the correct answer.

Explanation

- Starch has been digested in organ **A** but not in organ **B** and starch digestion begins in the mouth.
- Reducing sugars are absent in both organs. Digestion of double sugars and complex sugars to reducing sugars takes place in the small intestine.

Tip

It is important to take note of the start and end organs for the digestion of carbohydrates, proteins and fats.

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Checkpoint 5.1

1. What is the main function of the colon?
   - **A** To absorb digested materials
   - **B** To absorb water
   - **C** To get rid of undigested food material from the body
   - **D** To produce enzymes to digest food
2. Bile is stored in the _____.
   - **A** lungs
   - **B** pancreas
   - **C** gall bladder
   - **D** liver

3. Intestinal juice is composed of _____.

   A mucus
   B maltase, protease and lipase
   C hydrochloric acid
   D all of the above

4. Pepsin is a protease found in the stomach that digests proteins to polypeptides. It works well in acidic pH.
   (a) State how the stomach provides the optimum pH for the protease to work.
   (b) The partly digested food in the stomach forms chyme. Describe the activity of the protease as chyme enters the alkaline small intestine.

Tip

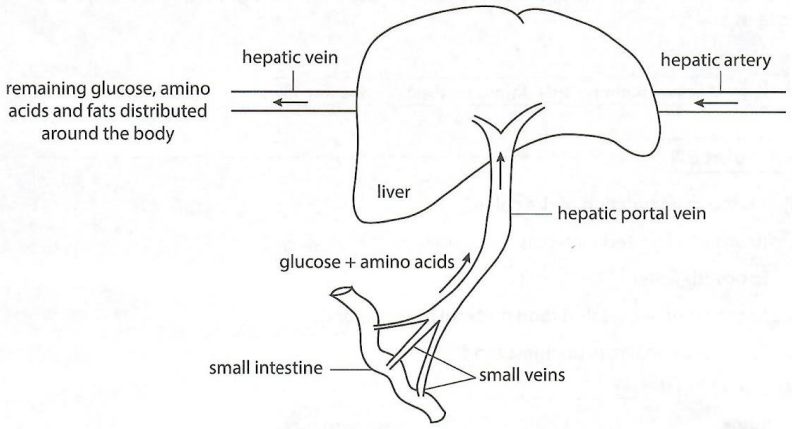
Questions on protease have been asked in examinations. One example can be found in Q GCE 'O' Level Science (Biology) Oct/Nov 2021 Paper 1 Q25.

D Transport of Absorbed Nutrients

Learning Outcome

- State the function of the hepatic portal vein in transporting blood rich in absorbed nutrients from the small intestine to the liver.

1. All digested food substances, such as sugars, amino acids, fatty acids and glycerol, are absorbed in ileum of the small intestine.
2. Glucose and amino acids are absorbed into blood capillaries which then unite to form the **hepatic portal vein**.
3. The hepatic portal vein is a dedicated vessel from the small intestine to the liver which helps to transport nutrients to the liver. The hepatic vein then transports nutrients to other parts of the body.



4. The absorbed nutrients are first brought to the **liver** for storage and metabolism.
   - Insulin stimulates the liver to convert excess glucose to glycogen which is stored in the liver.
   - Excess amino acids are deaminated to urea.
5. Fats are absorbed into the bloodstream and carried to all parts of the body, including the liver.

6. **Assimilation** refers to the process in which absorbed nutrients are converted into new cytoplasm or used to provide energy. The table below summarises how glucose, amino acids and fats are utilised in the body.

Glucose	Amino Acids	Fats
• Taken into cells and used in cellular respiration to release energy • Excess glucose returns to the liver and is stored as glycogen (glycogen is converted back into glucose when energy is needed)	• Enter cells and are converted into new cytoplasm that is used for growth and repair of worn-out body parts • Used to form enzymes and hormones • Excess amino acids are deaminated in the liver	• Used to build protoplasm (e.g., cell membranes) when there is sufficient glucose • Broken down to provide energy when glucose is insufficient • Excess fats are stored in **adipose tissues** under the skin or around the heart and kidneys

Common Error

✗ Nutrients absorbed from the small intestines are directly transported to the rest of the body.

✓ Nutrients absorbed are first transported to the liver.

Explanation
Nutrients absorbed are first metabolised and converted into their storage forms in the liver before the remainder is carried to the rest of the body for utilisation.

Link — Discover Biology (3rd Edition) Textbook — Section 5.3

E Roles of the Liver

Learning Outcomes

- State the role of the liver in carbohydrate metabolism, fat digestion, metabolism of amino acids and the formation of urea, and the breakdown of alcohol and hormones.
- Define a hormone.
- Explain how blood glucose concentration is regulated by insulin and glucagon.

1. The liver has roles in regulating blood glucose levels, fat digestion, deamination of amino acids, breaking down of hormones and detoxification.
2. A **hormone** is a chemical substance produced in very small quantities by an endocrine gland. It is secreted directly into the bloodstream and transported to target organ(s) where it exerts its effects.
   - After hormones have served their purpose, they are broken down in the liver to ensure that their effects are not prolonged.
   - Insulin and glucagon are hormones that are produced and secreted by the pancreas. They act on liver and muscle cells to regulate blood glucose concentration.

3. The table below summarises the action of insulin and glucagon in the regulation of blood glucose concentration.

Stimulus	Hormone	Effects
Increased blood glucose concentration (e.g. after a meal)	Insulin	• Makes cell membranes more permeable to glucose, allowing more glucose to diffuse into liver and muscle cells • Stimulates liver and muscle cells to convert excess glucose to glycogen for storage • Increases the use of glucose for respiration • Blood glucose concentration decreases to normal level
Decreased blood glucose concentration (e.g. during fasting)	Glucagon	• Stimulates liver cells to convert glycogen to glucose • Blood glucose level rises to normal level

4. The liver produces and secretes bile, a greenish-yellow liquid. Bile is stored in the gall bladder and is released into the small intestine to help with fat digestion.
5. The liver removes excess amino acids.
   - The amino group (NH_2) in an amino acid is removed and converted to urea which is removed from the body in the urine. This process is called **deamination**.
   - The remaining deaminated amino acid is converted first to glucose and subsequently to glycogen for storage.
6. The liver cells carry out **detoxification**, where harmful substances are converted to harmless ones.
   - Alcohol may cause damage to the digestive system and slow down brain functions.
   - The liver cells have an enzyme which breaks alcohol down into substances that can be used for respiration.

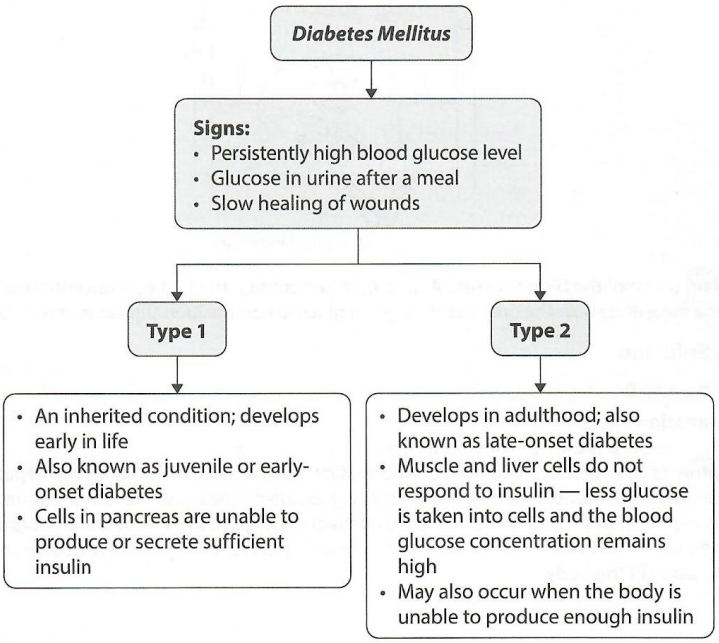
Link Discover Biology (3rd Edition) Textbook — Section 5.4

F Diabetes

Learning Outcomes

- Describe the signs of type 2 *diabetes mellitus*.
- Identify the risk factors and the management of the disorder.

1. *Diabetes mellitus* is a disorder in which the body is unable to regulate the amount of glucose in the blood.
   - It is caused either by insufficient insulin or the loss of responsiveness of cells to insulin.
   - The blood glucose concentration may become so high that the kidneys are unable to reabsorb all the glucose, resulting in large amounts of glucose being excreted in the urine.
2. There are two main types of diabetes — type 1 and type 2.



3. The table below describes the factors that increase the risk of **type 2 diabetes**.

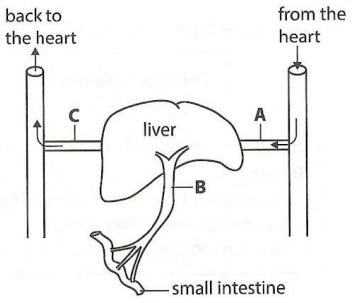
Obesity	Age	Family History	Blood Lipid Levels	Lifestyle
Obesity increases the risk of getting type 2 diabetes.	The risk increases as you age.	If you have family members with diabetes, you are at a greater risk of developing it as well.	High levels of 'bad' cholesterol and low levels of 'good' cholesterol increase the risk.	A sedentary lifestyle increases the risk. Physical activity uses up excess glucose and helps to control body weight.

4. A healthy lifestyle can reduce the risk of developing type 2 diabetes. This includes eating healthily (low calories and high fibre), engaging in regular physical activity, avoiding long periods of inactivity and maintaining healthy body weight.
5. The disorder can be managed through the regulation of carbohydrate intake and exercise. Some people may require oral medication, sometimes together with regular insulin injections.

Link Discover Biology (3rd Edition) Textbook — Section 5.5

Worked Example 5.2

The diagram shows part of the human digestive system.



Explain which of the blood vessels, **A**, **B** or **C**, would contain the highest concentration of nutrients after a meal and show the greatest changes in glucose composition throughout the day.

Solution

Blood vessel **B**.

Explanation

- Blood vessel **B** is the hepatic portal vein.
- Nutrients absorbed by the small intestine are first transported to the liver via the hepatic portal vein. Hence, the level of glucose will be the highest after a meal and the lowest before a meal. Thus, the hepatic portal vein shows the largest fluctuations in glucose composition throughout the day.
- The other blood vessels have a relatively constant glucose level due to the actions of insulin and glucagon in the body.

Checkpoint 5.2

1. The breakdown of excess amino acids is called _____.
   - **A** assimilation
   - **B** emulsification
   - **C** metabolism
   - **D** deamination
2. Which of the following is **not** a function of the liver?
   - **A** Formation of glycogen
   - **B** Secretion of digestive enzymes
   - **C** Formation of urea through deamination of amino acids
   - **D** Production of bile

Tip

The functions of the liver have been asked in examination questions. One example can be found in GCE 'O' Level Science (Biology) Oct/Nov 2021 Paper 4 Q4.

3. Which of the following does **not** increase the risk of type 2 diabetes?
   - **A** An active lifestyle
   - **B** A diet rich in sugar and fat
   - **C** High levels of bad cholesterol
   - **D** Having close relatives who suffer from diabetes
4. The liver plays a key role in carbohydrate metabolism. Describe the role of liver in the regulation of blood glucose levels in the following scenarios:
   (a) After eating a plate of mashed potatoes
   (b) When a person is on a diet that limits food intake

Tip

The regulation of blood sugar levels has been asked in examination questions. One example can be found in GCE 'O' Level Science (Biology) Oct/Nov 2018 Paper 1 Q34.

Test Station ▸▸

1. Mr Lee has part of his liver surgically removed because of liver cirrhosis. Which of the following describes the consequences of this surgery?

   1 Decreased rate of fat digestion

   2 Increased glycogen storage in the body

   3 Excessive breakdown of amino acids

   4 Decreased tolerance of alcohol consumption

   A 1 and 2 only **B** 1 and 4 only

   C 2 and 3 only **D** 3 and 4 only

2. Mrs Vida is having a meal. Figure 5.1 shows how her blood glucose concentration changes over time.

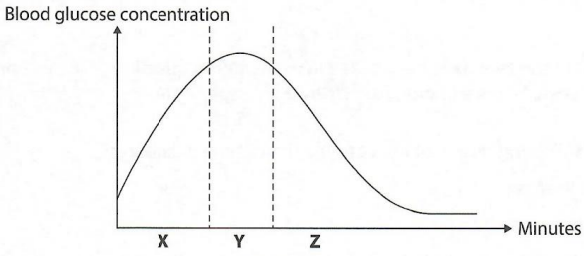


Figure 5.1

Based on Figure 5.1, which of the following is **correct**?

A At interval **Z**, the insulin level is increasing.

B At interval **Y**, the insulin level is at its minimum.

C At interval **X**, the carbohydrate level is decreasing.

D At interval **Y**, the insulin and carbohydrate levels are at their maximum.

3. From Figure 5.2, what are the possible identities of the enzyme and the organ producing it?

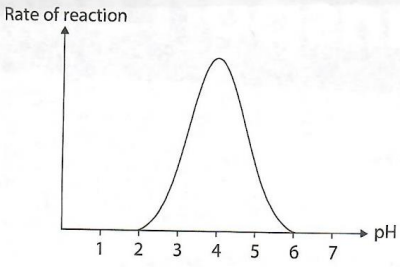


Figure 5.2

	Enzyme	Organ
A	Amylase	Salivary gland
B	Protease	Stomach
C	Lipase	Pancreas
D	Maltase	Large intestine

4. The digestion of starch begins in the mouth.

   (a) Explain how the consumption of a carbonated drink that contains carbonic acid affects the chemical digestion of starchy food in the mouth. [4]

   (b) Explain what happens to the starch in (a). [4]

5. Fat digestion takes place in the small intestine.

   (a) State the organ that produces bile. [1]

   (b) A patient had his gall bladder removed due to an illness. Explain why the doctor subsequently recommended him a diet that is low in fat. [3]