

CHAPTER 5 : NUTRITION IN HUMANS

Learning Outcomes:

Candidates should be able to:

- (a) describe the functions of the various parts of the digestive system: mouth, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, anus, in relation to ingestion, digestion, absorption, assimilation and egestion of food, as appropriate
- (b) describe the functions of enzymes (e.g. amylase, maltase, protease, lipase) in digestion, listing the substrate and end-products
- (c) state the function of the hepatic portal vein as the transport of blood rich in absorbed nutrients from the small intestine to the liver
- (d) state the role of the liver in:
 - conversion of glucose to glycogen and vice versa
 - fat digestion
 - metabolism of amino acids and formation of urea
 - breakdown of alcohol
 - breakdown of hormones
- (e) define a *hormone* as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs
- (f) outline how blood glucose concentration is regulated by insulin and glucagon
- (g) describe type 2 *diabetes mellitus* in terms of a persistently higher than normal blood glucose concentration due to the body's resistance to insulin or insufficient production of insulin
- (h) identify the risk factors of (e.g. unhealthy diet and sedentary lifestyle) and ways to manage type 2 *diabetes mellitus*

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- (a) **Describe the functions of main regions of the alimentary canal and the associated organs: mouth, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, anus, in relation to ingestion, digestion, absorption, assimilation and egestion of food, as appropriate**

Recap:

i. **What is nutrition?**

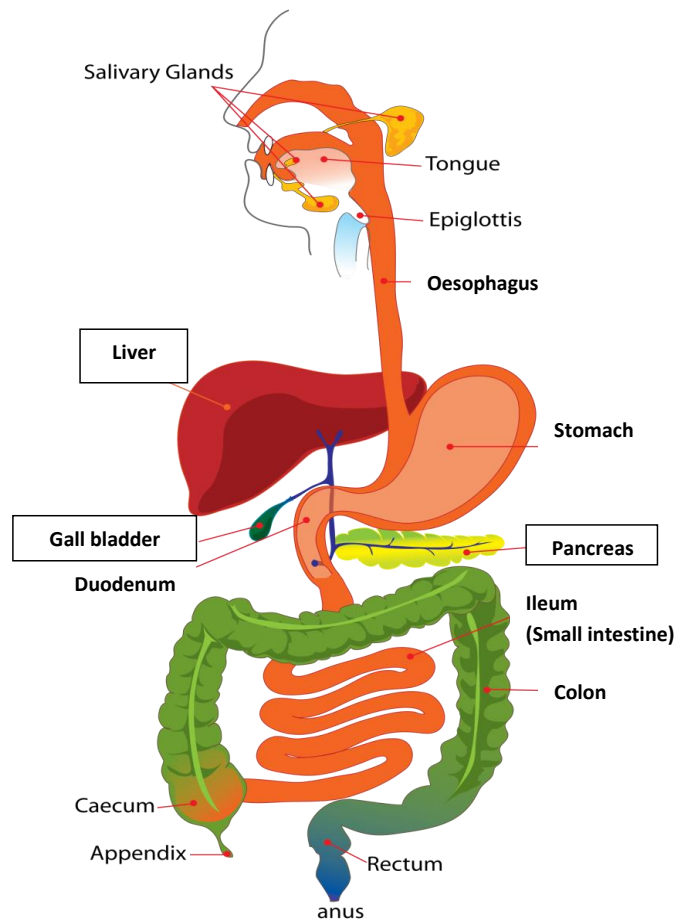
Nutrition is the process by which organisms obtain food and energy for growth, repair and maintenance of the body.

In humans, nutrition consists of the following processes:

- **Ingestion** (Food is taken into the body)
- **Digestion** (Large food molecules are broken down into smaller, soluble molecules that can be absorbed into the body cells)
- **Absorption** (Digested food substances are absorbed into the body cells)
- **Assimilation** (Some of the absorbed food substances are converted into new protoplasm or used to provide energy)

ii. **The human digestive system**

- It consists of the alimentary canal and the organs (liver, gall bladder and pancreas) associated with it.



Organ	Function
Mouth	Teeth-which break down large pieces of food into smaller pieces. This increases surface area of the food so enzymes can act on it more efficiently. Salivary glands- secrete saliva. Saliva contains enzymes amylase which helps in digestion of starch. Tongue- helps to mix food with saliva and roll them into bolus for easy swallowing.

3E Science (Biology) Chapter 5 Notes

Oesophagus	It is a narrow muscular tube which connects to the stomach. The wall of the oesophagus contains two layers of muscles. Longitudinal and circular muscles which work antagonistically to push food down to the stomach. Peristalsis , the rhythmic wave-like muscular contractions in the wall of the alimentary canal occurs here.
Stomach	It is a distensible muscular bag with numerous gastric glands that secrete gastric juice. Its main function is to store food temporarily as well as for digestion of proteins .
Duodenum	It is the first part of the small intestine. The linings contain glands which secrete digestive enzymes. Most of the digestion occurs in the duodenum.
Ileum	It is the last part of the small intestine. Most digested food is absorbed in the ileum. The walls of the small intestine are specially adapted to absorb digested food and water.
Large intestine	It is about 1.5 metres long and consists of the colon and rectum. The main function of colon is to absorb water and mineral salts from the undigested food. No digestion occurs in the large intestine. Faeces are stored temporarily in the rectum.
Anus	Faeces are expelled through the anus.

Associated Organ	Function
Gall bladder	Bile is stored temporarily in the gall bladder. When the gall bladder contracts, the bile flows into the duodenum via the bile duct.
Liver	The liver cells produce and secrete bile. Bile is an alkaline greenish-yellow liquid containing bile salts and bile pigments. Bile pigments give bile its color and are removed with the faeces or undigested matter.
Pancreas	The pancreas is connected to the small intestine via the pancreatic duct. The pancreas produces pancreatic juice which contains digestive enzymes . The pancreas also secretes hormones insulin and glucagon. These hormones play an important role in regulating blood glucose level in the body.

i. **Digestion in humans**

- What is digestion?

The process whereby **large** food molecules are broken down into smaller, soluble molecules that can be absorbed into the body cells.

Digestion involves two processes:

Physical digestion and **chemical** digestion

Physical digestion involves **mechanical** break-up of food into small particles. This occurs:

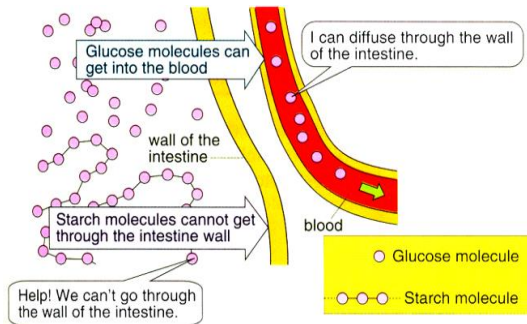
In the mouth, when you chew food by action of the teeth and tongue.

In the stomach, where continual contractions and relaxations of the muscles in the stomach wall cause a churning action. This breaks up the food particles and mixes them with digestive enzymes.

Physical digestion increases **surface area to volume ratio** of the ingested food so that digestive enzymes can act on the food more efficiently.

Chemical digestion is the breaking down of large molecules in food such as proteins, starch and fats, into smaller soluble molecules which can be absorbed. This involves hydrolytic reactions catalysed by digestive **enzymes**.

- Why does food need to be digested?
 - i. To break down **large** complex food molecules into **smaller**, simpler soluble molecules that can pass through the partially permeable cell membranes. (Refer to diagram below)



Digestive processes along the alimentary canal

Mouth

- **Salivary glands** are stimulated to produce **saliva**
- Saliva contains enzyme called **salivary amylase** which digests **starch to maltose**
- **pH** of saliva is **neutral**
- Chewing breaks down food into smaller pieces, this helps to **increase surface area to volume ratio** for **faster** digestion **by amylase**
- The tongue rolls the food into small boli that are easy to swallow

Stomach

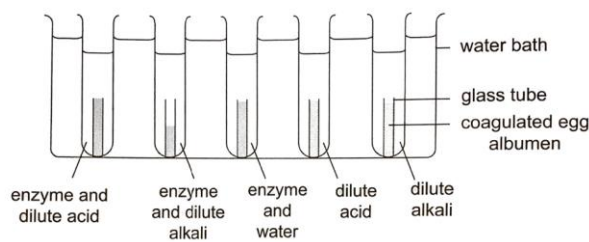
- Gastric glands are stimulated to produce **gastric juice**
- **Peristalsis** in the stomach wall **churns and breaks up food**. Peristalsis also helps to **mix the food** well with gastric juice.
- Gastric juice is a dilute solution of **hydrochloric acid** (pH 2) and enzyme **pepsin**.
The hydrochloric acid helps:
 - i. stop action of amylase by **denaturing** it
 - ii. provides **optimum pH** for enzyme **pepsin** to work
 - iii. kills harmful microorganisms in food
- Food normally remains in the stomach for about three to four hours. The partly digested food becomes liquefied, forming **chyme**.

Small intestine

1. Chyme enters the small intestine. This stimulates accessory organs (pancreas and gall bladder) to do the following:
 - a. **pancreas** produces **pancreatic juice**
 - Pancreatic juice contains enzymes **pancreatic amylase, pancreatic lipase and trypsin (a peptidase)**. These are passed through pancreatic duct **into the duodenum**.
 - b. The **gall bladder** **releases** **bile**. Bile is transported via the bile duct **into the duodenum**.
 - Bile helps to **emulsify** **fats to tiny fat droplets**. This **increases surface area to volume ratio** for **faster digestion by enzyme lipase**.
2. The epithelial cells of the small intestine produces **intestinal juice** containing **enzymes maltase, lipase** and erepsin (protease) to aid in digestion.
3. The food now comes into contact with pancreatic juice, bile and intestinal juice. All three fluids are **alkaline**. The alkalis:
 - b. Neutralise the acidic chyme
 - c. Provide optimum pH for action of pancreatic and intestinal enzymes.

Let's Try!

11. The effect of an enzyme on coagulated egg albumen (cooked egg white) is investigated. The results, after three hours, are shown in the diagram.



During digestion, where is the enzyme produced?

- A liver
- B pancreas
- C salivary glands
- D stomach wall

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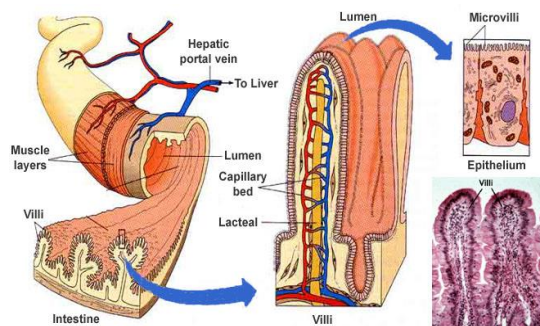
ii Absorption in humans

- What is absorption?

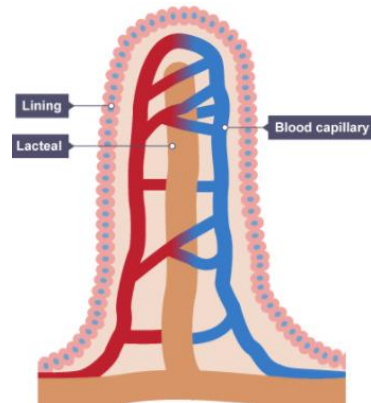
It is the process whereby digested food substances are **absorbed** into the body cells.

Products of digestion such as **simple sugars**, **amino acids**, **fatty acids** and **glycerol** are absorbed throughout the small intestine especially the ileum. The absorbed nutrients then pass from the small intestine into the bloodstream.

- How is the small intestine adapted for absorption?



- Inner surface of the small intestine is folded to form numerous finger-like projections called **villi**.
 - The epithelial cells of the villi have numerous **microvilli** to **further increase surface area to volume ratio for faster diffusion**.
 - The villi have **one cell-thick epithelium** to **shorten diffusion distance for faster diffusion** of digested food from small intestine **into bloodstream**.
 - Each villus contains **lacteal** which is **surrounded by blood capillaries**.
 - These blood capillaries continually transport digested food substances away and **maintains the concentration gradient** for the absorption of digested food substances.
- How does absorption take place in the intestine?



- **Glucose** and **amino acids** are absorbed by diffusion into the blood capillaries of the villi.
- Glucose and amino acids are **also absorbed by active transport**. This happens when there is a lower concentration of these digested food substances in the lumen of the small intestine than the blood capillaries.
- **Glycerol** and **fatty acids** diffuse into the epithelium. Here they recombine to form tiny fat globules which then enter the lacteals.
- What happens to undigested and unabsorbed matter?
 - Undigested and unabsorbed matter is stored temporarily, mainly in the rectum, before it is discharged as faeces through the anus. This removal of undigested matter from the body is called egestion or defecation.

(b) describe the functions of enzymes (e.g. amylase, maltase, protease, lipase) in digestion, listing the substrate and end-products

The table below summarises the enzymatic reactions occurring along the alimentary canal.

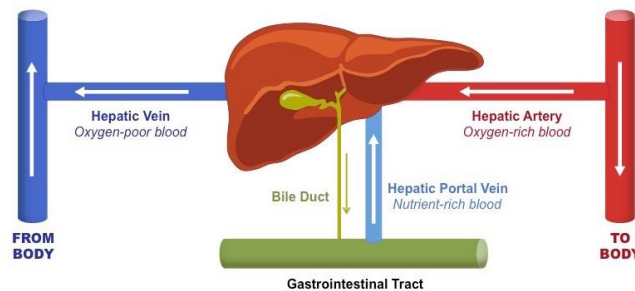
Region of digestion	Secretion	Source	Enzyme	Action
Mouth	Saliva	Salivary glands	Salivary amylase	Starch → maltose
Stomach	Gastric juice	Gastric glands	Pepsin	Proteins → polypeptides
Small intestine	Bile	Liver	-	Bile emulsify fats into tiny fat droplets
	Pancreatic juice	Pancreas	Trypsin	Proteins → polypeptides

			Amylase	Starch → maltose
			Lipase	Fats → fatty acids + glycerol
			Erepsin	Polypeptides → amino acids
			Maltase	Maltose → glucose
			Lipase	Fats → fatty acids + glycerol

(c) **state the function of the hepatic portal vein as the transport of blood rich in absorbed nutrients from the small intestine to the liver**

- i. Transport and assimilation of absorbed nutrients
 - a. How are glucose and amino acids transported and utilised?

After absorption, the blood in the villi is now rich in nutrients. The blood capillaries unite to form larger blood vessels, which in turn unite to form a large vein, the **hepatic portal vein**. The hepatic portal vein transports the nutrients to the liver.



In the liver, some glucose and amino acids are absorbed by the liver cells for the liver's own metabolism. The remaining glucose and amino acids are transported by blood out of the liver and distributed around the body.

Excess glucose not used by the rest of the body returns back to the liver to be **converted and stored as glycogen**.

Amino acids that enter the cells are converted into new protoplasm that is used for growth and repair of worn-out parts of the body.

Amino acids are also used to form enzymes and hormones.

Excess amino acids not used by the rest of the body returns back to the liver and are **deaminated** in the liver to form **urea**.

- b. How are fats transported and utilised?

Fats are absorbed into the lymphatic capillaries. The lymphatic capillaries join to form larger lymphatic vessels, which discharges fats into the bloodstream. Excess fats are stored in special tissues called adipose tissues which occur beneath the skin and around our heart and kidneys. Adipose tissues protect these organs by acting as shock absorbers.

(d) state the role of the liver in:

- **conversion of glucose to glycogen and vice versa**
- **fat digestion**
- **metabolism of amino acids and formation of urea**
- **breakdown of alcohol**
- **breakdown of hormones**

i. Function of the liver

a. Conversion of glucose to glycogen and vice versa

i. Regulate blood glucose concentration gradient

After a heavy meal:

- High blood glucose will trigger the secretion of **insulin**.
Excess glucose will be converted to **glycogen** by the liver.

During fasting:

- Low blood glucose will trigger the secretion of **glucagon**.
Glycogen will be converted to glucose by the liver.

b. Metabolism of amino acids

- i. Excess amino acids are deaminated to form urea. Urea is removed from the body in the urine.

c. Break down of alcohol

- i. Alcohol is broken down in the liver. Liver cells contain an enzyme called alcohol dehydrogenase. This enzyme breaks down alcohol to a compound called acetaldehyde which can be converted to compounds that can be used in respiration. In this process of detoxification, **harmful substances** are converted to **harmless** substances.

ii. Effects of excessive consumption of alcohol.

- Alcohol stimulates secretion in the stomach. Excess stomach acid increases risk of gastric ulcers.
- Cirrhosis (where liver cells are destroyed and replaced with fibrous tissues)

d. Fat digestion

- i. The liver plays an important role in fat digestion. It helps in the digestion of fats by secreting bile. Bile is stored temporarily in the gall bladder before use.

An example on how bile emulsifies fat into tiny fat droplets.



- e. Breakdown of hormones
 - i. Hormones are destroyed by the liver

Let's Try!

Explain how the action of bile helps in the complete digestion of fats.

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(e) **define a hormone as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs and is then destroyed by the liver**

What are hormones?

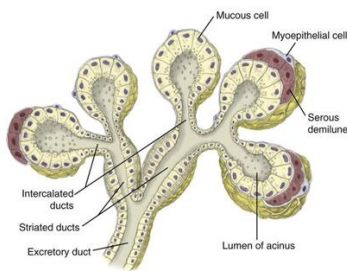
Definition

- A chemical substance
- Produced by an endocrine gland*
- In minute amounts
- Which is transported by bloodstream
- And exert its effects on one or more target organs.
- They are then destroyed by liver

What is an 'endocrine gland'*

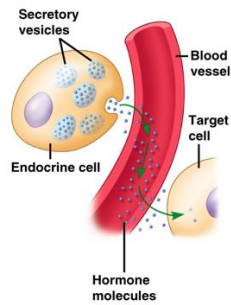
- Ductless glands which secrete hormones directly into the blood.
- The hormones insulin and glucagon, produced by islets of Langerhans in pancreas, are secreted directly into the bloodstream.
- The pancreas is both an endocrine and an exocrine gland.... Why?

EXOCRINE VS ENDOCRINE GLANDS



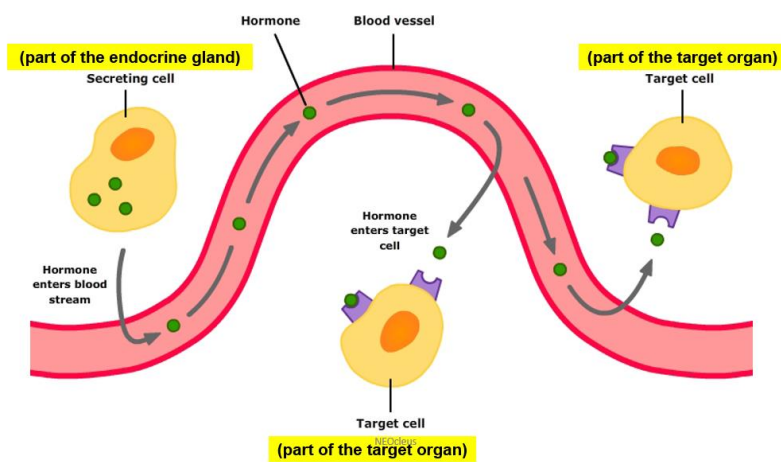
Exocrine Glands: Glands with duct(s)

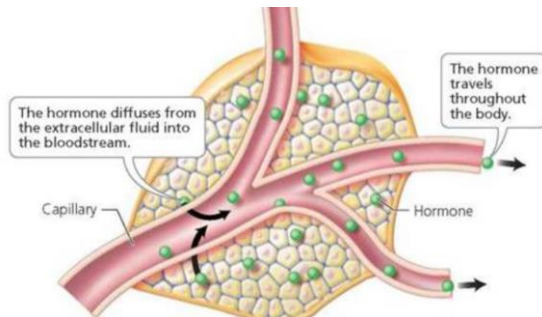
Products secreted onto an epithelial surface
e.g. skin (sweat gland, mammary gland)



Endocrine Glands: Glands without duct(s)

Products secreted directly into blood





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Cells of endocrine glands release their products, called hormones, into the extracellular fluid. The hormones then diffuse into the bloodstream to be transported throughout the body.

Types of glands

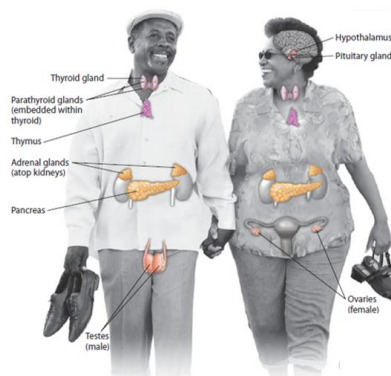
Endocrine glands

- **Ductless glands** that transport their secretions via the bloodstream
- Examples: adrenal glands, pituitary gland, and pancreas



Exocrine glands

- Ducts present to transport secretions to target organs
- Examples: sweat glands, salivary glands and pancreas



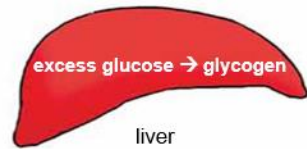
Endocrine Gland(s)	Description
Hypothalamus	Regulates secretion of some pituitary hormones
Pituitary gland	"Master gland", which secretes hormones which in turn controls the secretion of other hormones.
Ovaries	Secretes oestrogen and progesterone
Testes	Secretes testosterone
Adrenal gland (above the kidneys)	Secretes adrenaline (the fight or flight hormone)
Pancreas	Secretes insulin and glucagon

(f) Outline how blood glucose concentration is regulated by insulin and glucagon

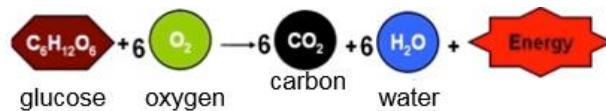
In this section, we will be exploring the effects of 2 hormones: **insulin** and **glucagon**.

Effects of insulin

- Stimulates the **liver** and **muscles** cells to convert **excess blood glucose** into **glycogen** for storage



- Insulin **increases the permeability** of the cell membrane of liver cells to **glucose**, thus glucose is absorbed **more quickly** by the liver cells.
- Increase the oxidation of glucose** during tissue **respiration**



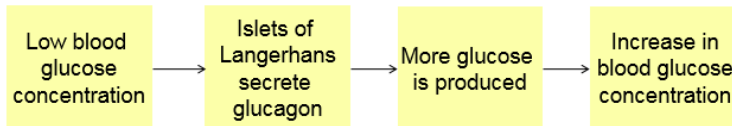
Over-secretion of insulin

- Over-secretion of insulin results in abnormally **low** blood glucose concentration.
- Symptoms includes hunger, rapid heartbeat and irritability
- In severe cases, person may lapse into a coma or even die

Lack of insulin secretion

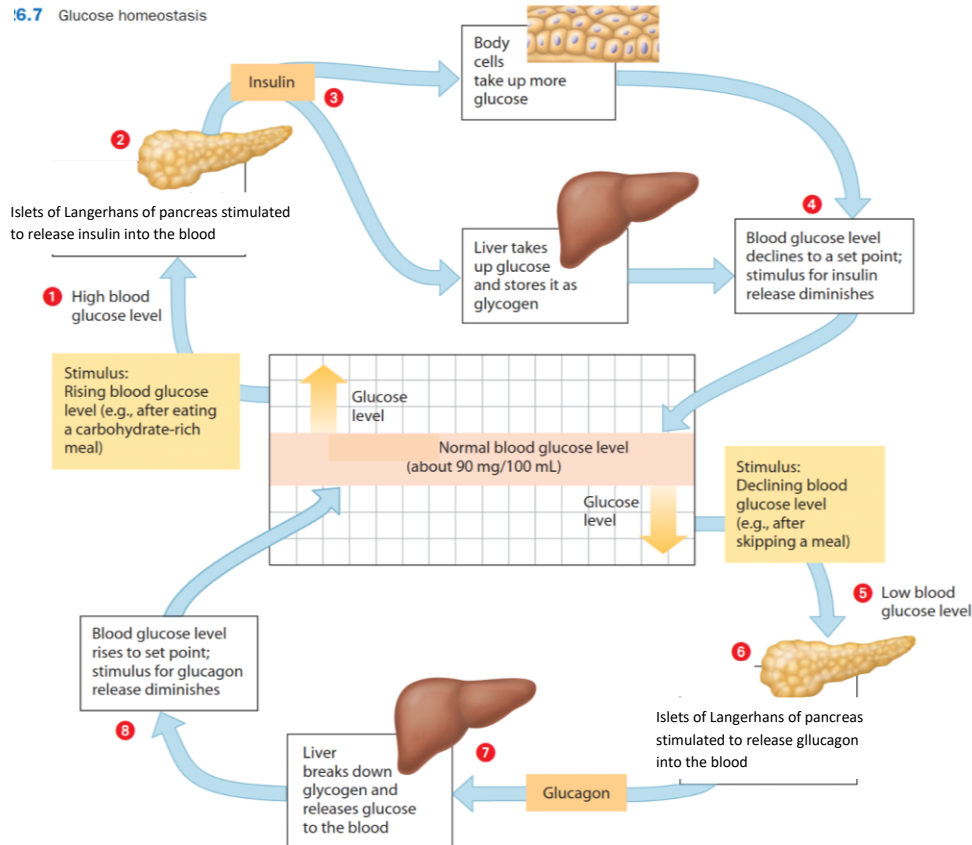
- Lack of insulin secretion results in abnormally **high** blood glucose concentration.
- Tissue cells cannot utilise or store glucose
- Symptoms includes weak body, continual weight loss and glucose present in urine
- Could lead to **diabetes mellitus** disease

Effects of glucagon



- Glucagon **increases** the blood glucose concentration.
- Main target organ of glucagon is the **liver**.
- It stimulates the following conversions:
 - Glycogen into glucose
 - Fats and amino acids into glucose
 - Lactic acid into glucose

16.7 Glucose homeostasis



(g) describe type 2 *diabetes mellitus* in terms of a persistently higher than normal blood glucose concentration due to the body's resistance to insulin or insufficient production of insulin

What is diabetes mellitus?

- **Insufficient insulin secretion** to regulate blood glucose concentration **OR** that the **body became resistant to insulin**
- Leads to **persistently higher than normal level of glucose in blood**
- Kidneys are unable to completely reabsorb glucose in body
- Causing glucose to be **excreted** in **urine**

Discussion
What would you propose as treatment for these two types of diabetic patients? Type I diabetes: Type I diabetes is also called insulin-dependent diabetes. It used to be called juvenile-onset diabetes, because it often begins in childhood. Type I diabetes is an autoimmune condition. It's caused by the body attacking its own pancreas with antibodies. In people with type I diabetes, the damaged pancreas doesn't make insulin. Type II diabetes: By far, the most common form of diabetes is type II diabetes, accounting for 95% of diabetes cases in adults. Some 26 million American adults have been diagnosed with the disease. Type II diabetes used to be called adult-onset diabetes, but with the epidemic of obese and overweight kids, more teenagers are now developing type II diabetes. Type II diabetes was also called non-insulin-dependent diabetes. With Type II diabetes, the pancreas usually produces some insulin. But either the amount produced is not enough for the body's needs, or the body's cells are resistant to it. Insulin resistance, or lack of sensitivity to insulin, happens primarily in fat, liver, and muscle cells.
Pen down your discussion here.

(h) identify the risk factors of (e.g. unhealthy diet and sedentary lifestyle) and ways to manage type 2 diabetes mellitus

Signs of diabetes mellitus

- Constantly **high** blood glucose concentration
- Presence of **glucose** in urine after a meal
- Healing of wounds is slow and difficult