Chapter 6 – Nutrition in Humans

Subject content

Content

- Human alimentary canal
- Chemical digestion
- Absorption and assimilation

Learning outcomes

(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

(b) describe **peristalsis** in terms of rhythmic wave-like contractions of the muscles to mix and propel the contents of the alimentary canal

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

(d) describe the **structure of a villus** and its role, including the role of capillaries and lacteals in absorption

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

(f) state the role of the **liver** in
- carbohydrate metabolism
- fat digestion
- breakdown of red blood cells
- metabolism of amino acids and the formation of urea
- breakdown of alcohol

(g) describe the effects of excessive consumption of **alcohol**: reduced self-control, depressant, effect on reaction times, damage to liver and social implications

Use the knowledge gained in this section in new situations or to solve related problems.

Definition

Phrase	Definition
Nutrition	Organisms obtain food and energy for growth, repair and maintenance of body
Peristalsis	Rhythmic, wave-like muscular contractions in walls of alimentary canal
Digestion	Food substances physically & chemically broken down → smaller, soluble and simple molecules that can be absorbed into body cells
Absorption	Digested food substances are absorbed into the body cells
Assimilation	Some absorbed food substances are 1. converted into new protoplasm 2. used to provide energy

6.1 Nutrition and the Human Digestive System

Nutrition

Nutrition

Obtain food and energy for growth, repair and maintenance of body

Processes of nutrition

Process	Explanation
1. **Ingestion**	Food is taken into the body
2. **Digestion**	• Large complex insoluble food molecules → small simple soluble molecules • Absorbed into body cells
3. **Absorption**	Digested food substances absorbed into body cells
4. **Assimilation**	Some of absorbed food substances 1) converted → new protoplasm 2) used to provide energy
5. **Egestion**	Remove undigested matter from body

Digestion

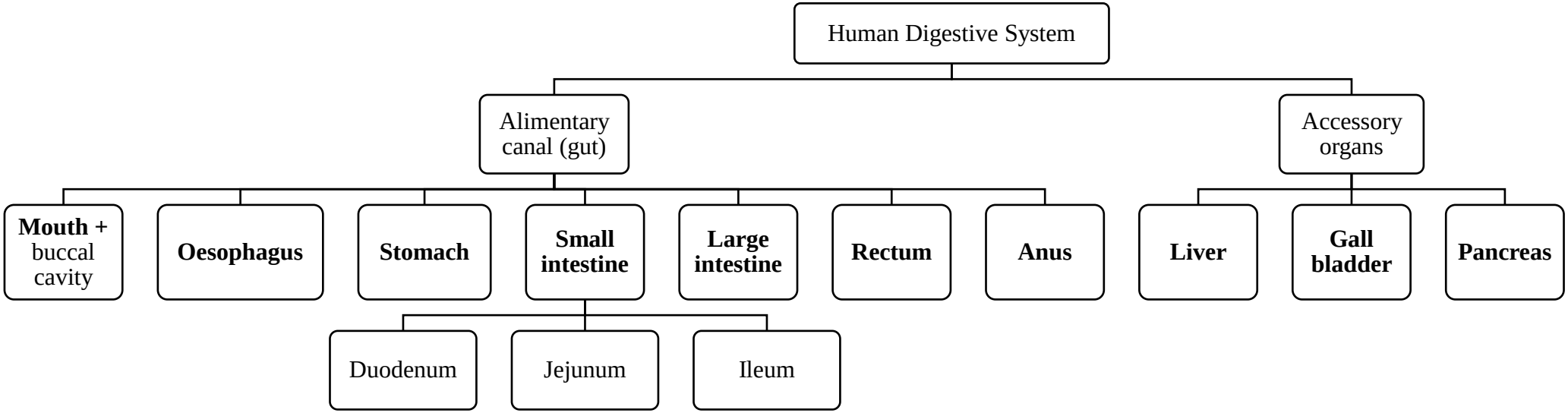
Digestion

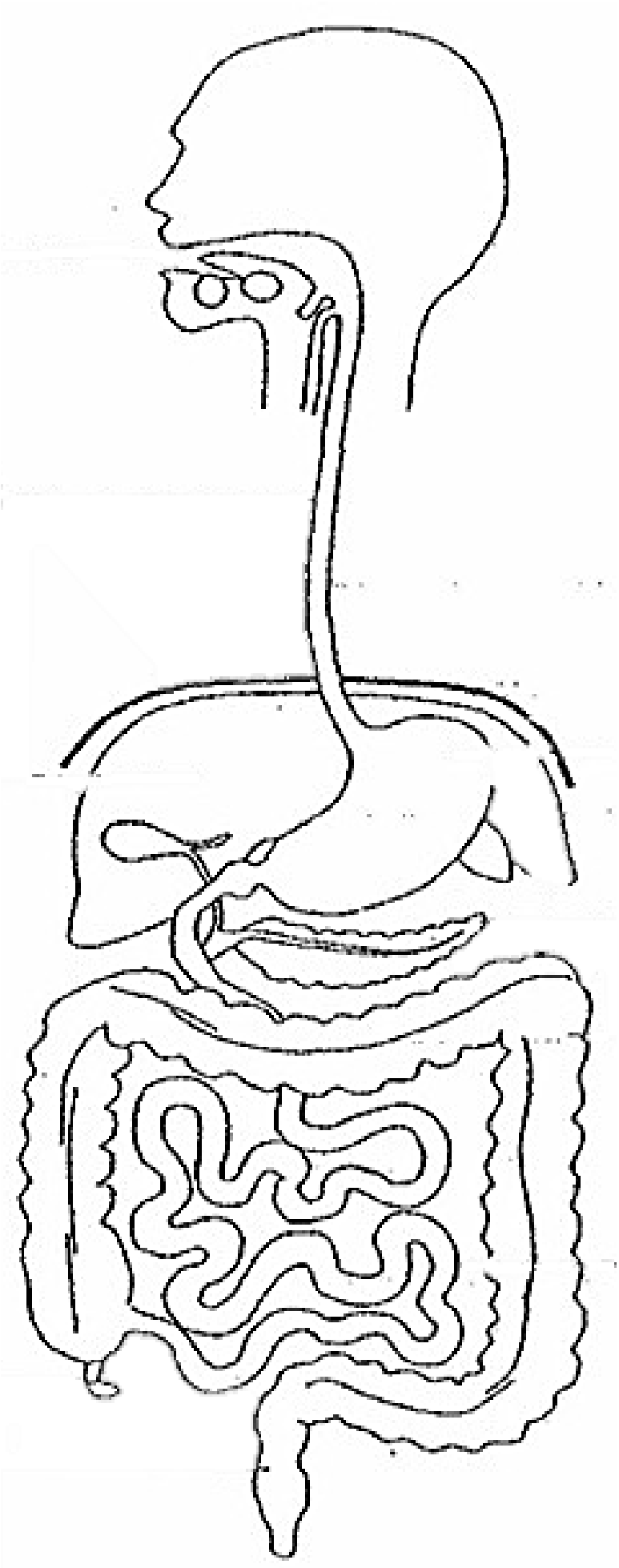
Large, insoluble and complex food molecules are physically & chemically broken down into smaller, soluble and simple molecules (absorbed into body cells)

Types of digestion

Types	Function	Site	Action
1. **Physical digestion**	• Mechanical break-up of food → smaller pieces • SA:V of food mass ↑	1) Mouth 2) Stomach 3) Small intestine	Chewing, churning Peristalsis
2. **Chemical digestion**	• Chemical break down of complex food molecules → simpler soluble molecules • Chemical bonds broken (covalent bonds)		Hydrolytic reactions: catalysed by digestive enzymes

Human digestive system



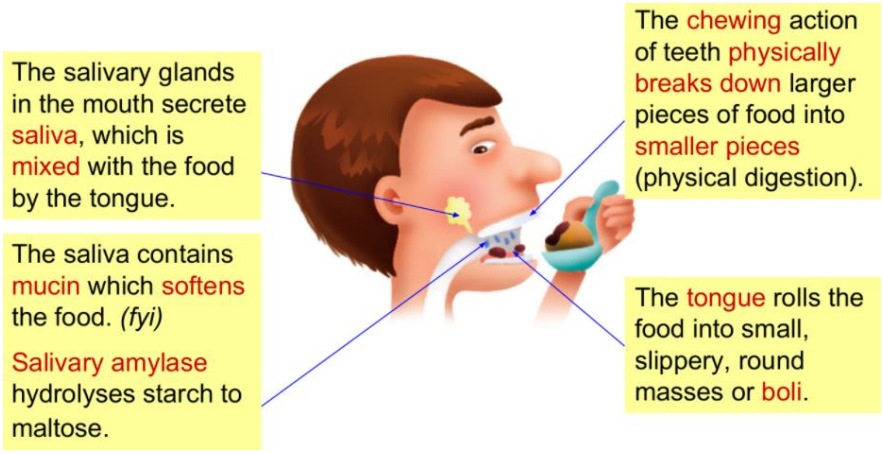


6.2 Digestion

Mouth & buccal cavity

Digestion begins in the mouth – ingest food

Parts	Function
1. **Teeth** (physical)	**Chewing action**: break down large pieces of food into smaller pieces • increase surface area of food particles • enzymes act on it more efficiently
2. **Salivary glands** (chemical)	• Secrete saliva into mouth • Saliva flows **salivary ducts** → buccal cavity 1) Moisten & soften food 2) Contain salivary amylase
3. **Tongue**	• Mix the food with saliva • **Taste buds**: identify and select suitable foods • Roll food → **boli** (small, slippery, round masses)



Pharynx

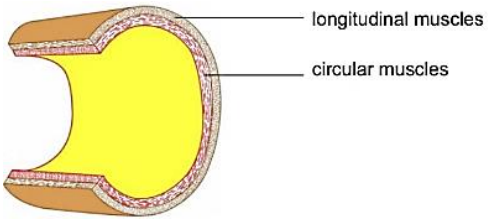
- Connects buccal cavity → oesophagus & larynx (voice-box)
- Leads to the trachea (leads to lungs)
- Has glottis (slit-like opening)
- Food and air pass through
  1. Air → trachea
  2. Food → oesophagus

Movement of epiglottis:

Process	**Larynx**	**Epiglottis**	Result
Swallowing	Move upwards	Move downwards	• Trachea covered by epiglottis • Prevent food from entering trachea
Breathing	Move downwards	Move upwards	• Trachea is open • Allow air to enter the lungs

Oesophagus (gullet)

Pass through thorax & diaphragm (sheet of muscle which separates thorax from abdomen) to join stomach

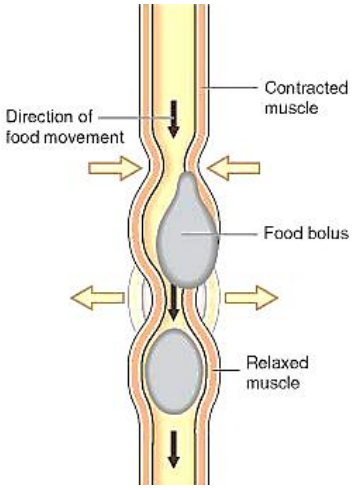


Peristalsis (occurs throughout alimentary canal)

Rhythmic, wave-like muscular contractions in walls of alimentary canal

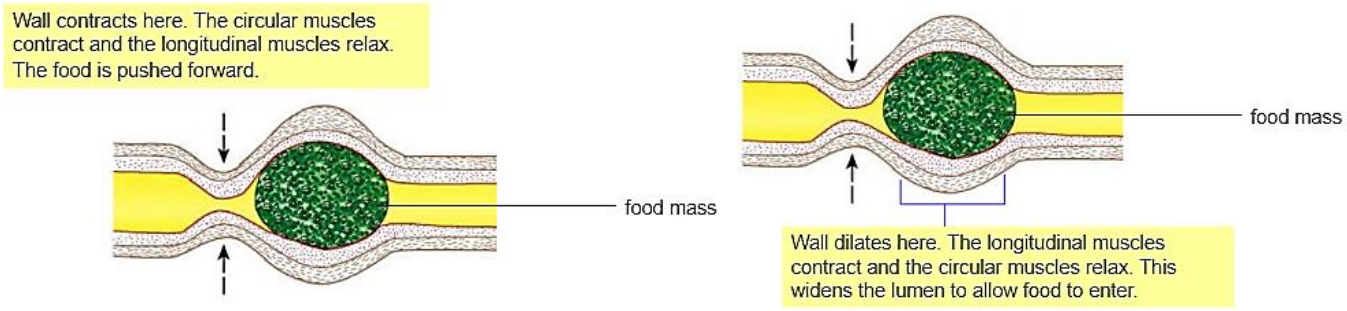
Muscles (antagonistic)

1. **Circular muscles** (inner wall) – control diameter of lumen
2. **Longitudinal muscles** (outer wall)



Process:

Muscles		Alimentary canal		Movement of food substances
C	L	Lumen	Length	
contract	relax	narrower	longer	Pushed along gut
relax	contract	wider	shorter	Allowed to enter region



Stomach

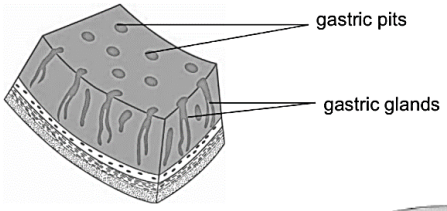
Stomach: elastic, muscular bag

Physical digestion	Chemical digestion
Churning	**Hydrochloric acid** + **pepsin**
Peristalsis → **mix** food + gastric juices	Gastric glands secrete **gastric juice**: 1. Hydrochloric acid + 2. Pepsinogen (inactive pepsin)
Chyme: food liquified after partial digestion	Partial **hydrolysis**: proteins $\xrightarrow{\text{pepsin}}$ polypeptides

Function of HC*l*:

1. Kill harmful microorganisms in food
2. Provide optimum pH → activity of enzymes
3. Denature salivary amylase
4. Convert inactive form of enzymes → active

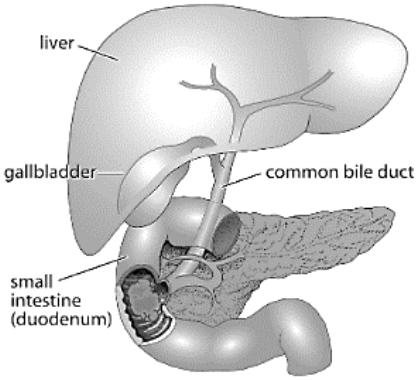
pepsinogen (inactive) $\xrightarrow{HCl}$ pepsin (active)



Liver and gall bladder

Liver: produce + secrete bile $\xrightarrow{\text{bile duct}}$ duodenum

Gall bladder: store bile



Bile (greenish-yellow liquid)

- Alkaline in nature
- Not an enzyme, does not contain digestive enzymes
  → not affected by changes in pH / temperature
- Contains bile salts and bile pigments

Function of bile:

1. Reduce acidity of chyme from stomach
2. Creates optimal alkaline environment → action of other digestive enzymes
3. **Emulsify** fats: physically break down fats → tiny fat droplets
   - increase SA:V of fats
   - faster rate of hydrolysis: fats $\xrightarrow{\text{lipase}}$ fatty acids + glycerol

Pancreas

Pancreas

- Secrete **pancreatic juice** $\xrightarrow{\text{pancreatic duct}}$ duodenum
- Digestive enzymes

Enzyme	Hydrolysis
1. **Pancreatic amylase**	starch → maltose
2. **Pancreatic protease**	proteins → polypeptides
3. **Pancreatic lipase**	fat globules → fatty acids + glycerol

Small intestine

3 segments

1. **Duodenum**
2. **Jejunum**
3. **Ileum**

Chyme enter duodenum → stimulates secretion of:

1. Pancreatic juice (by pancreas)
2. Bile (by gall bladder)
3. Intestinal juice (by glands in intestinal walls)

Digestive enzymes in intestinal juice – require **alkaline** medium to function optimally

Enzyme	Hydrolysis
1. **Intestinal maltase**	maltose → glucose + glucose
2. **Intestinal lactase**	lactose → glucose + galactose
3. **Intestinal sucrase**	sucrose → glucose + fructose
4. **Intestinal peptidases**	polypeptides → amino acids
5. **Intestinal lipase**	lipids → fatty acids + glycerol

Note:

High concentration	Walls of	Process
epithelial cells	duodenum	Digestion (need intestinal juice)
villi	jejunum	Absorption
	ileum	

Large intestine

Large intestine

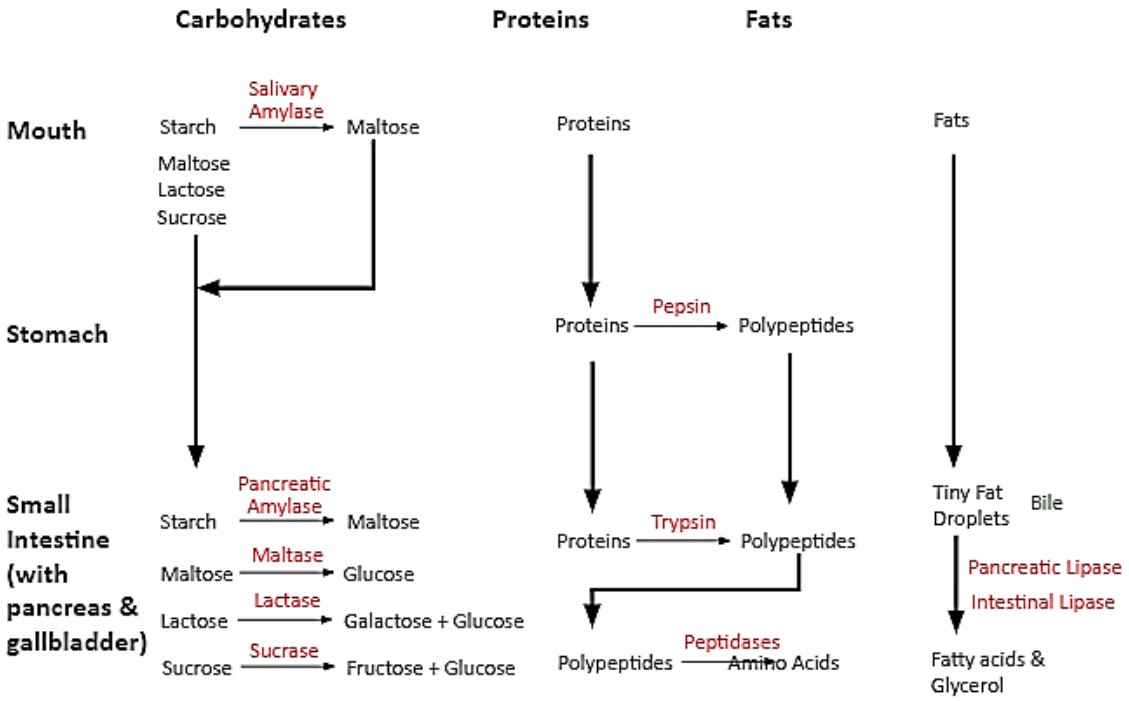
- **Remaining matter** enters: mixture of
  (a) water
  (b) bile pigments
  (c) dead cells from intestinal lining
  (d) bacteria
  (e) cellulose
- Reabsorption of **remaining water + mineral salts** → bloodstream

Rectum & anus

Rectum: temporarily store **faeces** (undigested & unabsorbed matter)
Egestion: once rectum is full, muscular walls contract → expel faeces through anus

*** Digestive enzymes in human digestive system:

Region	Secretion	Source	Enzyme	Hydrolysis
Mouth	Saliva	Salivary gland	salivary amylase	starch → maltose
Stomach	Gastric juice	Gastric gland	pepsin	protein → polypeptides
Small intestine	Bile	Liver	bile	(not enzyme)
	Pancreatic juice	Pancreas	pancreatic amylase	starch → maltose
			pancreatic lipase	fats → fatty acid + glycerol
			pancreatic trypsin	protein → polypeptides
	Intestinal juice	Intestinal gland	intestinal maltase	maltose → glucose + glucose
			intestinal lactase	lactose → glucose + galactose
			intestinal sucrase	sucrose → glucose + fructose
			intestinal lipase	fats → fatty acid + glycerol
			intestinal peptidases	polypeptides → amino acids



6.3 Absorption

Absorption

process whereby digested food substances are absorbed into the body cells

Substances

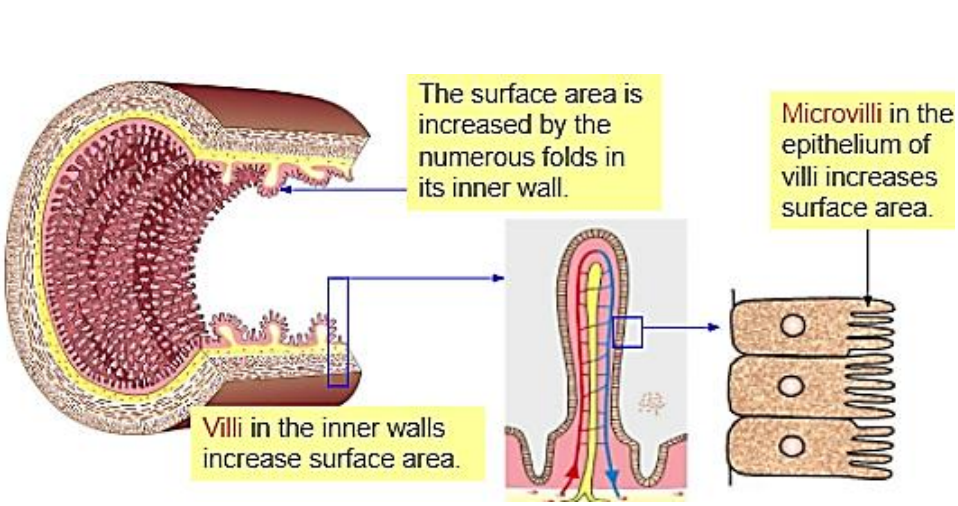
Absorb	Explanation
1. Products of digestion 1) simple sugars 2) fatty acids + glycerol 3) amino acids	• Absorbed throughout small intestine (**ileum**) • Absorbed nutrients: small intestine → bloodstream
2. Water + mineral salts	• Absorbed by **small intestine** + **colon** • Small intestine absorbs most of the water

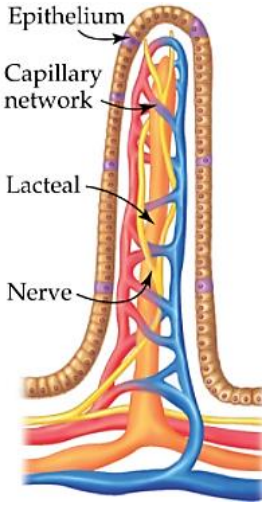
Adaptation of small intestine

1. Inner wall is highly folded
2. Numerous **villi** present on folds (finger like projections)
3. Numerous **microvilli** present on epithelial cells of villi

Adaptation of **villus**

- increase SA:V of small intestine
- faster absorption of digested food substances

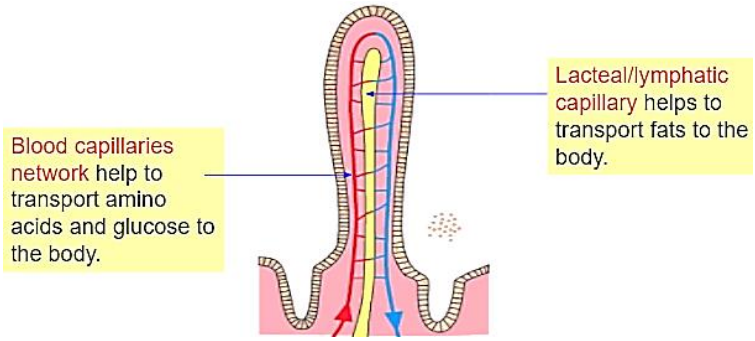




Adaptation	Explanation	Outcome
1. **Numerous microvilli** on epithelial cells	Increase surface area of small intestine	Faster rate of absorption of digested nutrients (lumen of SI → villi)
2. Epithelium: **one cell thick**	Reduce diffusion distance between lumen of SI & villus	Faster rate of absorption …
3. Dense **blood capillary network**	• Maintain steep concentration gradient of digested nutrients between lumen of SI & villus • Transport digested nutrients away quickly + continuously	Faster rate of absorption …
4. Small intestine: 6 m long		Sufficient time for absorption of digested nutrients …
5. Epithelial cells have numerous **mitochondria**	Increase respiration	Increased release of energy for active transport of digested nutrients …

Absorption in intestines

Nutrient	Process	Explanation
1. Glucose 2. Amino acids	1) **diffusion** 2) **active transport**	• lumen of SI $\xrightarrow{\text{diffuse + active transport}}$ blood capillaries → hepatic portal vein → liver
3. Fatty acids + glycerol	1) **diffusion**	• lumen of SI $\xrightarrow{\text{diffuse}}$ epithelium • epithelium $\xrightarrow{\text{recombine, form minute fat droplets}}$ lacteals



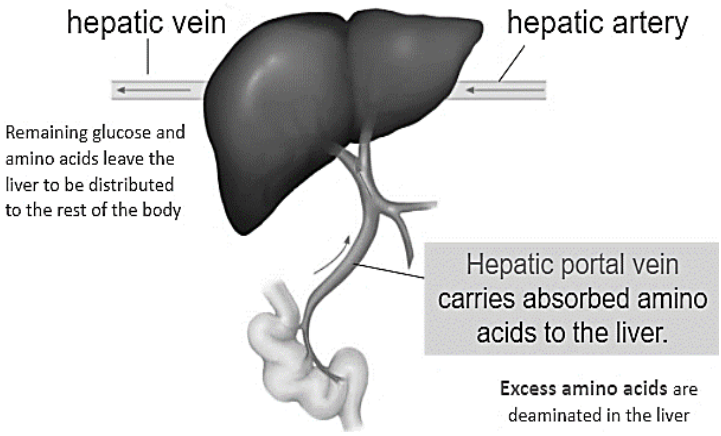
6.4 Transport and Assimilation of Absorbed Nutrients

Assimilation

Some absorbed food substances converted into new protoplasm / used to provide energy

Assimilation

1. Converting into new materials for cells
2. Used as substrate to release energy (respiration)



Nutrient	Functions	Excess
Glucose	• Cellular respiration: oxidised to release energy	• Return to liver • Converted to glycogen, stored in liver & muscles (regulation of blood glucose concentration)
Amino acids	Protein: • make new protoplasm – cellular repair & growth • synthesise enzymes + hormones	• Not stored – deaminated in liver • Amino acids enter cells, binds to other amino acid molecules to form protein
Fats	• synthesis of cell membranes • produce steroid hormones	• Stored in adipose tissues (under the skin and around organs – heart & kidneys) • Hydrolysed in liver → energy (insufficient glucose supply)

Constipation

Dietary fibre (roughage)

- Indigestible materials in diet – e.g. cellulose
- Make up most of undigested matter that is egested from the body
- Stimulates peristalsis
  - increase speed of movement of faeces
  - precent over-absorption of water

Process

- Proper peristaltic movements do not occur
- Undigested matter in large intestine cannot be moved along fast enough
- Too much water absorbed
- Faeces become dry and hard – difficult to remove through anus

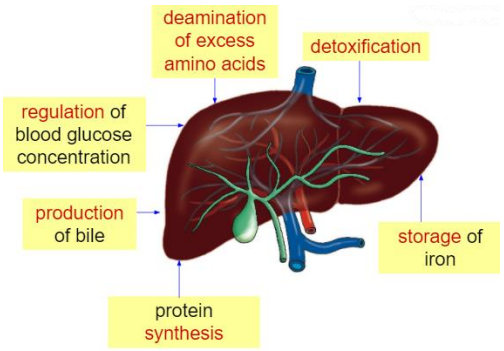
Prevent constipation

1. Take in enough dietary fibre
2. Drink sufficient water

6.5 Functions of the Liver

Functions of liver

1. **Regulate blood glucose concentration**
2. **Produce bile**
3. **Store iron**
4. **Synthesise protein**
5. **Deaminate amino acids**
6. **Detoxification**



Function	Explanation		
1. **Regulate blood glucose concentration**	[blood glucose]	higher than normal	lower than normal
	islets of Langerhans in pancreas: secrete hormone	insulin	glucagon
	stimulate liver cells to convert	excess glucose ↓ glycogen (stored in liver & muscles)	stored glycogen ↓ Glucose (diffuse into blood)
	[blood glucose]	decrease back to normal	increase back to normal
2. **Secrete bile**	Stored temporarily in gall bladder before use – fat digestion		
3. **Store iron**	• Red blood cells: worn out → destroyed in spleen • Haemoglobin brought to liver → broken down 1) release iron (stored in liver) 2) produce bile pigments		
4. **Synthesise protein**	Ribosomes in liver cells: synthesise proteins from amino acids (a) prothrombin (b) fibrinogen		
5. **Deaminate amino acids**	• **Deamination**: **amino groups** removed from amino acids & converted to urea		

<table>
<tr><td></td><td>
<table>
<tr><th>amino group</th><th>carbon residue</th></tr>
<tr><td>▪ Removed & converted into urea
▪ Deamination produces ammonia (toxic)
▪ Ammonia: converted to urea & excreted in urine</td><td>▪ Converted to glucose and oxidised to release energy
▪ Excess glucose: converted to glycogen & stored in liver</td></tr>
</table>
• Excess amino acids are transported to liver
</td></tr>
<tr><td>6. Detoxification</td><td>Detoxification: convert harmful substances → harmless products
• alcohol $\xrightarrow{\text{alcohol dehydrogenase}}$ acetaldehyde (toxic, responsible for side effects of alcohol consumption)
• acetaldehyde $\xrightarrow{\text{acetaldehyde dehydrogenase}}$ acetic acid (non-toxic)
• acetic acid broken down:
1) release energy
2) further processed to form glucose (substrate in respiration – release energy for cellular activities)</td></tr>
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Excessive consumption of alcohol

Aspect	Effect
Digestive system	1) Stimulate acid secretion in stomach → increase risk of **gastric ulcers** 2) **Cirrhosis** of liver • liver cells destroyed & replaced with fibrous tissue • liver less able to function
Nervous system	1) **Depressant**: slows down brain functions 2) Reduced **self-control** • personal / social liberties • regret after effects of alcohol worn off
Reaction time ↑	1) Blurred vision, poor muscular coordination 2) Clumsy, ✖ walk steadily 3) Judgement deteriorates & underestimate speed → traffic accidents

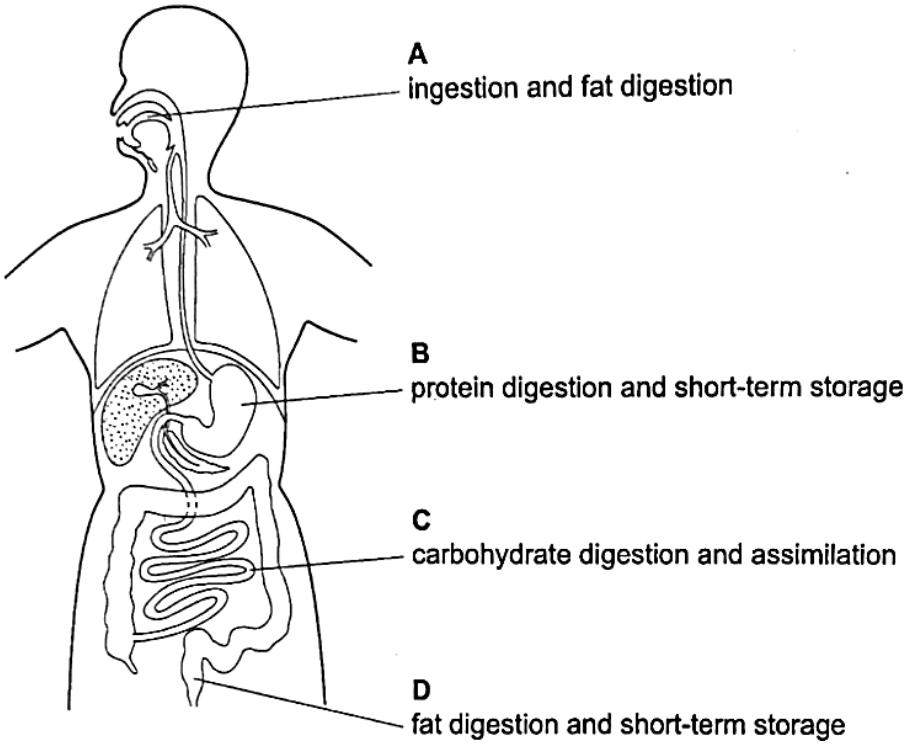
Typical questions

Multiple choice questions

1. Which row shows the conditions in the region of the alimentary canal where food is digested to produce both amino acids and fatty acids? (N2013/P1/Q7)

	pH	enzymes present
A	acid	amylase and lipase
B	acid	lipase and protease
C	alkaline	amylase and protease
D	alkaline	lipase and protease

2. The diagram shows the human alimentary canal with labels for the functions of some of its parts. Which label is correct? (N2014/P1/Q7)



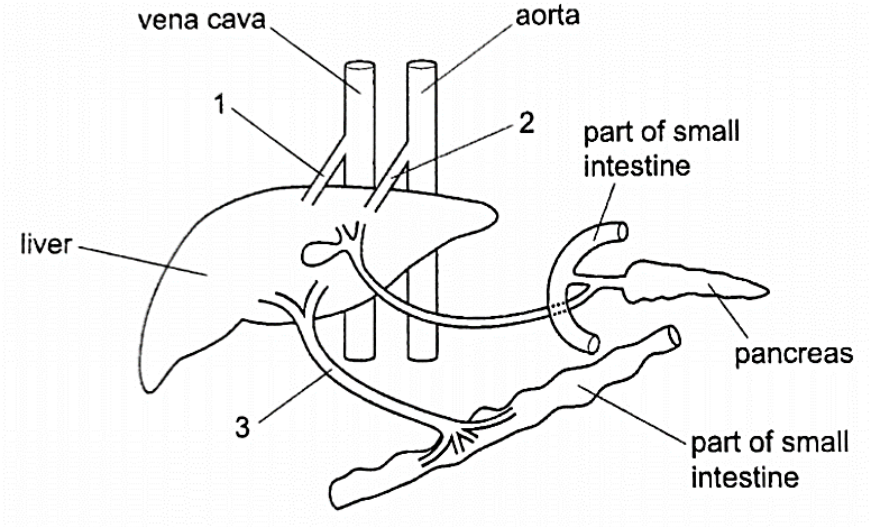
3. Some processes that occur in the body are listed. (N2014/P1/Q8)

   1 breakdown of red blood cells
   2 breakdown of starch
   3 formation of urine
   4 storage of glycogen

   Which processes occur in the liver?

   A 1 and 2
   B 1 and 4
   C 2 and 3
   D 3 and 4

4. The diagram shows the liver and some associated structures. (N2016/P1/Q7)



Which structure(s) contain liquid flowing away from the liver?

A 1 and 3
B 1 only
C 2 and 3
D 2 only

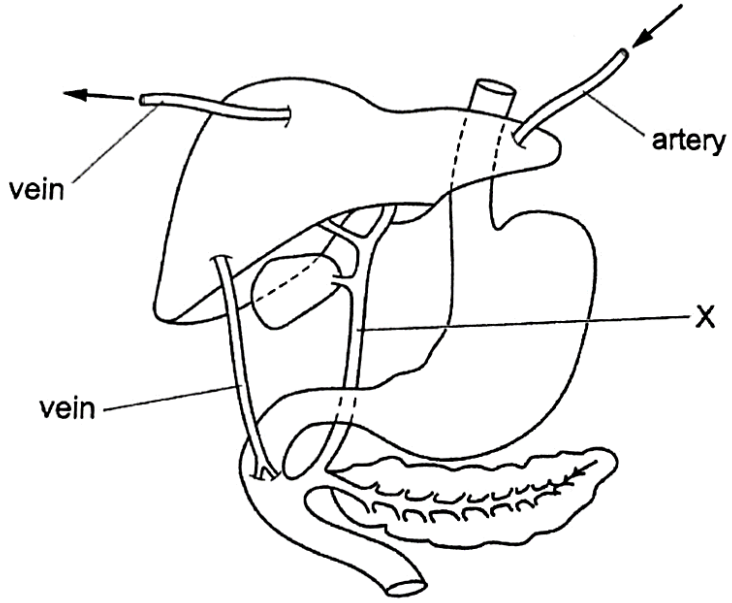
5. The list shows processes that occur when food is eaten. (N2017/P1/Q7)

1 absorption
2 assimilation
3 digestion
4 ingestion

In which order do these processes occur?

A 1 → 2 → 4 → 3
B 3 → 2 → 4 → 1
C 4 → 3 → 1 → 2
D 4 → 3 → 2 → 1

6. The diagram shows the liver and the surrounding organs. (N2018/P1/Q8)



If a blockage occurs in the tube at X, what will happen immediately?

A Fat digestion will be inefficient

B Formation of urea will stop

C Glycogen will no longer be made from glucose

D The liver will not break down alcohol

7. A student has a high protein diet.
Which effect will this have on the composition of the blood in the hepatic portal vein and in the hepatic vein? (N2018/P1/Q9)

	Hepatic portal vein	Hepatic vein
A	High in amino acids	High in proteins
B	High in amino acids	High in urea
C	High in urea	High in amino acids
D	High in urea	High in proteins

8. Each villus contains a network of capillaries.
Some statements about the blood in these capillaries are listed.

1 assimilates starch

2 provides oxygen for active transport

3 receives absorbed glucose

4 removes cellulose

Which statements are true?

A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

Structured questions

1. William Beaumont, a Canadian army doctor, was able to investigate the functioning of the stomach. He treated Alexis St. Martin, a trapper who had been shot in the abdomen. Dr. Beaumont could not successfully close the wound and Alexis St. Martin survived with a hole in the wall of his stomach, with a passage called a gastric fistula leading to the outside of his body. Dr. Beaumont could investigate digestion of food in the stomach of Alexis St. Martin by pushing food through the fistula into the stomach. He also experimented with the gastric juice extracted from the stomach.

   The results of experiments carried out over several months are given in the following table:

Test	Site	Liquid	Food	Temperature (°C)	Time taken to complete digestion (hr)
1	stomach	gastric juice	cabbage	37	-
2	stomach	gastric juice	beef	37	2
3	test tube	gastric juice	beef	20	16
4	test tube	gastric juice	beef	37	10
5	test tube	gastric juice	cabbage	37	-

   (a) Describe and explain the results of the experiments above. [2]

   Comparing tests 4 and 5

   Describe : Digestion occurred in test 4 but not test 5.

   Explain : Pepsin in gastric juice only hydrolyses proteins in beef, and not carbohydrates in cabbage. Carbohydrases are absent in gastric juice.

   Comparing tests 3 and 4

   Describe : A higher rate of protein digestion occurs at 37°C.

   Explain : 37°C is closer to the optimum temperature of pepsin, where pepsin hydrolyses proteins to polypeptides at the fastest rate.

   Comparing tests 2 and 4

   Describe : Digestion occurs at a faster rate in stomach than test tube.

   Explain : Physical break down of food into smaller pieces through churning in the stomach increases the surface area to volume ratio of food for a faster rate of hydrolysis of proteins by pepsin.

   (b) Explain how the stomach protects itself from the effects of acid and enzymes in gastric juice. [2]

   - Secretion of mucus by cells lining walls of stomach acts as a barrier to enzymes and acid.
   - Enzymes are secreted in inactive forms and they are only activated in presence of hydrochloric acid in gastric juice.
   - Acid and enzymes are only released in presence of food in stomach.

2. The quantity of pure alcohol in a drink can be expressed as alcohol units.
One alcohol unit equals 10 cm^3 pure alcohol which is the amount of alcohol the average adult can break down in one hour.
This means that one hour after drinking one unit of alcohol there should be little or no alcohol left in the blood of an adult. (N2014/P2/A2)

(a) Name the organ which breaks down the alcohol. [1]
Liver

(b) The strength of an alcoholic drink can be indicated by the percentage of pure alcohol it contains.

(i) Calculate the number of units of alcohol consumed by a person who drank 3×175 cm^3 glasses of wine with a strength of 12.0%. Show your working. [2]
Volume of pure alcohol consumed
$= 3 \times 175 \times \frac{12}{100}$
$= 63$ cm^3
Number of units of alcohol consumed
$= 63 \div 10$
$= 6.3$ units

(ii) State how long it would take for the body to break down this amount of alcohol. [1]
Amount of time
$= 6.3 \div 1$
$= 6.3$ hours

(c) State two short-term and two long-term effects of excessive alcohol consumption. [4]
Short-term effects: reduced self-control, increased reaction time.
Long-term effects: liver cirrhosis, stomach ulcers.

3. Gallstones are made of cholesterol, bile salts and other substances. These stones may become large enough to block the bile duct. Suggest how gallstones may affect the digestion of fat. [3]
Bile is made in the liver and stored in the gall bladder. Bile is released through the bile duct into the duodenum to aid in fat digestion. If the gallstones become too large and block the bile duct, the gall bladder will not be able to release the bile. Bile emulsifies fats. It physically breaks fats into many, tiny fat droplets. The tiny fat droplets have a larger surface area to volume ratio, thus enabling lipase to digest them faster. Without bile, fat digestion will become slower and inefficient.

4. (N2011/P2/B10 OR)

(a) State the meaning of the terms:

(i) *digestion* [3]
Digestion is the process whereby large food substances are broken down into tiny, soluble and diffusible substances that can pass through the cell membrane of cells. For example, fat is a large molecule. It has to be broken down into glycerol and fatty acids first before the cells are able to absorb them.

(ii) *absorption* [3]

Absorption is the uptake of water, nutrients and dissolved minerals by cells through their cell membrane. For example, nutrients such as glucose, amino acids and fatty acids are absorbed by the epithelial cells in the small intestine.

(b) Describe the functions of the liver. [4]

1 The liver regulates the glucose concentration in blood. When the glucose concentration in blood is higher than normal, the pancreas will produce insulin. The insulin causes the liver to convert excess glucose to glycogen for storage. This restores the glucose concentration to the normal level. When the glucose concentration in blood is lower than normal, the pancreas will produce glucagon. The glucagon causes the liver to convert the stored glycogen to glucose. This restores the glucose concentration to the normal level.

2 The liver aids in fat digestion by producing bile. Bile helps to emulsify fat, so that lipase can digest fat faster.

3 The liver synthesises plasma proteins like albumin from amino acids.

4 The liver deaminates excess amino acids to form urea. Urea is then excreted from the body in urine. The remains of the amino acids are converted first into glucose, then into glycogen.

5 The liver detoxified harmful substances like benzoic acid. Alcohol is also transported to the liver to be broken down. The alcohol is broken down by the enzyme, alcohol dehydrogenase, to form substrates that can be used in cellular respiration to release energy.

5. (N2012/P2/B10 OR)

(a) Describe the digestion of protein in the body. [3]

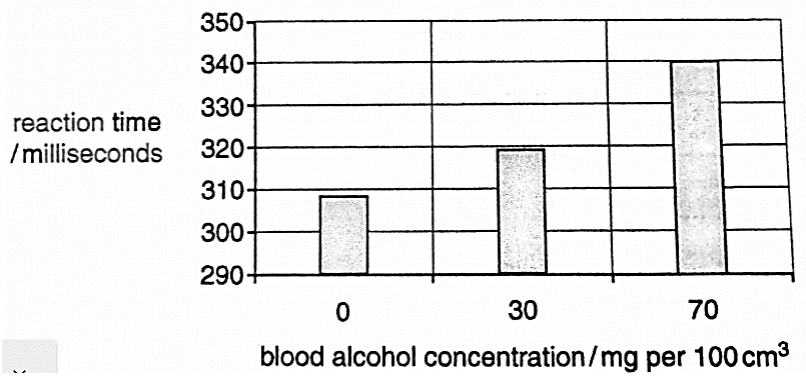
Protein digestion starts in the stomach and protein is digested by proteases in the body. The hydrochloric acid in the gastric juice produced by the stomach changes pepsinogen and prorenin to pepsin and rennin respectively. The enzyme pepsin digests proteins to polypeptides. The enzyme rennin curdles milk proteins by converting soluble caseinogen into insoluble casein. This allows casein to stay longer in the stomach to be digested by the enzyme trypsin to polypeptides. The alkaline pancreatic juice contains trypsinogen, which is converted into trypsin by intestinal enterokinase. The enzyme erepsin, in the intestinal juice then digests the polypeptides to amino acids, the end products of protein digestion.

(b) Describe the role of the liver in the metabolism of carbohydrate. [4]

The liver plays a role in the metabolism of carbohydrate by keeping the blood glucose concentration constant.

- After a meal is eaten and digested in the alimentary canal, the glucose which is obtained from the digestion of food is released into the blood stream. This causes a sharp rise in the blood glucose concentration and triggers the production of insulin by the islets of Langerhans in the pancreas. The insulin is secreted into the bloodstream and transported to the liver. The insulin stimulates the liver to convert excess glucose into glycogen for storage. This results in a drop of the blood glucose concentration to the normal level.
- When the blood glucose concentration is lower than the normal level, the production of glucagon by the islets of Langerhans in the pancreas is triggered. The glucagon stimulates the liver to convert some of the stored glycogen into glucose. The glucose is released into the bloodstream to restore the blood glucose concentration to the normal level.

6. The figure shows the effect of different alcohol concentration on a person's reaction times.



State one conclusion from the graph and suggest how this is related to drinking and driving. [4]

(N2015/P2/B9b)

As the blood alcohol concentration increases from 0 mg to 70 mg per 100 cm^3, the reaction time of the person increases from around 308 milliseconds to 340 milliseconds.

High alcohol consumption increases the reaction time and reduces the self-control of the person. The person may also have blurred vision, poor judgement and poor muscular coordination. When a drunken person is driving on the road, he is likely to cause a traffic accident. Thus, it is not advisable for a drunken person to drive.

7. Describe the roles of enzymes in human digestion. Give examples in your answer. [5]

(N2019/P2/B9 OR b)

Human digestive enzymes are involved in chemical digestion. The enzymes speed up the rate of catabolic reactions, where food substrates are broken down into smaller products that can be absorbed into the bloodstream. Most of the enzymes are hydrolase enzymes.

- Starch is broken down into maltose by salivary and pancreatic amylase. Maltose is then broken down into glucose by maltase in the small intestine. Other disaccharides are also broken down. For example, lactose is broken down into glucose and galactose by lactase in the small intestine.
- Proteins are broken down into polypeptides by pepsin in the stomach or trypsin in the small intestine. The polypeptides are then broken down into amino acids by erepsin and other proteases.
- Intestinal and pancreatic lipases break down lipids into fatty acids and glycerol.

8. Villi are found in the digestive system. Describe the structure and function of a villus. [3]

Function of villus: increase surface area to volume ratio of small intestine for faster absorption digested food substances from lumen of small intestine.

Description of structure:

1 Epithelium of villus is only one cell thick
   - reduce diffusion distance
   - faster rate of absorption of digested nutrients from lumen of SI into villus

2 Presence of numerous microvilli on the epithelial cells of the villus
   - increase SA:V
   - faster rate of absorption of digested nutrients from lumen of SI into villus

3 Villus is supplied with a dense blood capillary network
   - maintain steep concentration gradient of digested nutrients between lumen of SI and villus
   - digested nutrients are carried away quickly and continuously
   - faster rate of absorption of digested nutrients from lumen of SI into villus

4 Epithelial cells of villus have a lot of mitochondria
   - increased respiration
   - increased release of energy for active transport of digested nutrients

5 Villi are finger like projections
   - increases SA:V
   - faster rate of absorption of digested nutrients from lumen of SI into villus

9. Describe the digestion of protein in the body. [3]

* **source of enzyme + name of enzyme + action of enzyme +location + reaction**

- Pepsin produced by the gastric glands in walls of stomach **hydrolyses** protein into polypeptides.
- Pancreatic protease produced and secreted by pancreas **hydrolyses** remaining proteins into polypeptides in the small intestine.
- Proteases produced and secreted by intestinal glands **hydrolyses** polypeptides into amino acids.