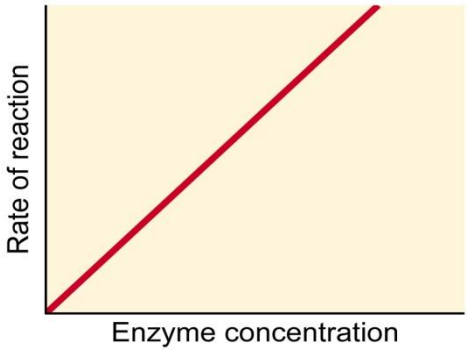
S.2 BIOLOGY HOLIDAY NOTES

Factors Affecting The Rate Of Enzyme Reaction

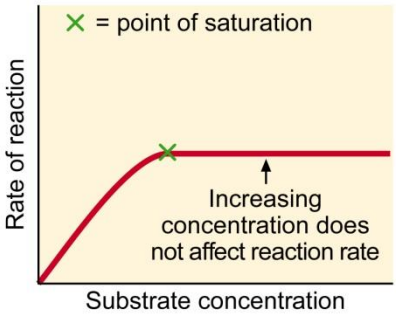
i. Enzyme concentration

Provided that the substrate concentration is high and other condition kept constant, the rate of enzyme reaction is proportional to the enzyme concentration i.e. an increase in enzyme concentration increases the rate of enzyme controlled reaction.



ii. Substrate concentration

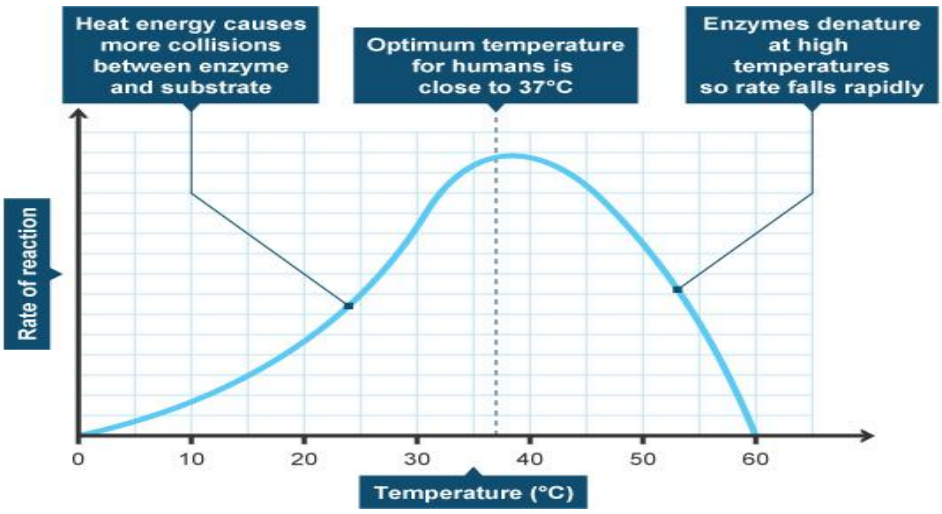
For a given concentration, the rate of enzyme reaction increases with increase in the substrate concentration up to a point where increase in the substrate concentration produces no increase in the rate of reaction. At this point the active sites of enzymes are all saturated with substrate.



iii. Temperature

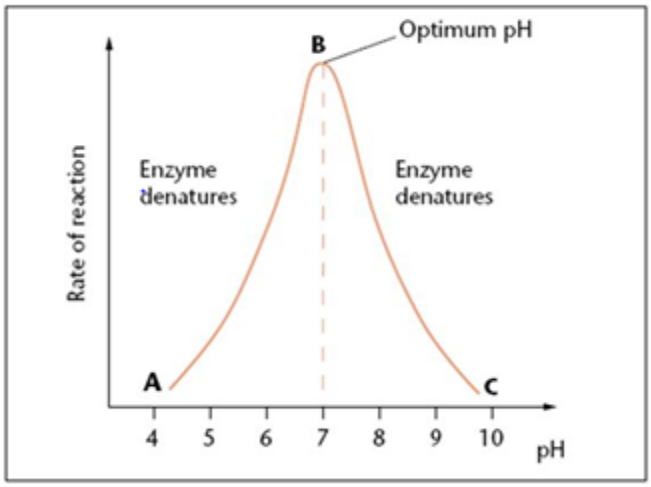
Enzyme work best at optimum temperature. Beyond the optimum temperature the rate of enzyme action decreases. This is because the enzymes are denatured. Extremely low temperature inactivates enzymes but can regain their catalytic influence when optimum temperature is restored.

Optimum temperature is that temperature which promotes maximum activity/reaction.



iv. pH of the medium

Under conditions of constant temperature, every enzyme functions most efficiently over a narrow range of pH (optimum pH) when the pH is altered above or below this value the rate of enzyme activity decreases. This is due to disruption of ionic bond that helps to maintain the specific shape of the active site.



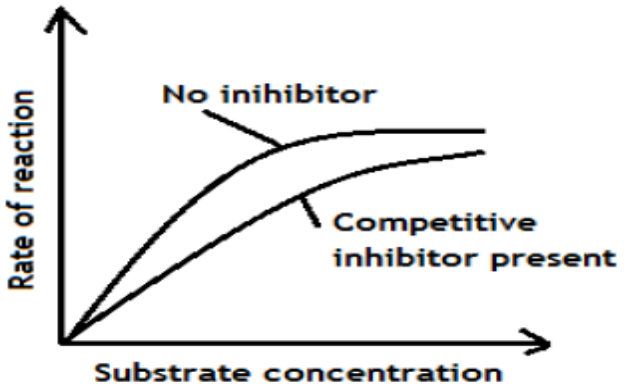
The graph shows the effect of pH on the rate of an enzyme-controlled reaction.

i. Presence of activators and co-enzymes. Some enzymes work only when these are present.

ii. Surface area; the rate of enzyme activity increases with increase in surface area; surface can be increased by cutting material into smaller pieces.

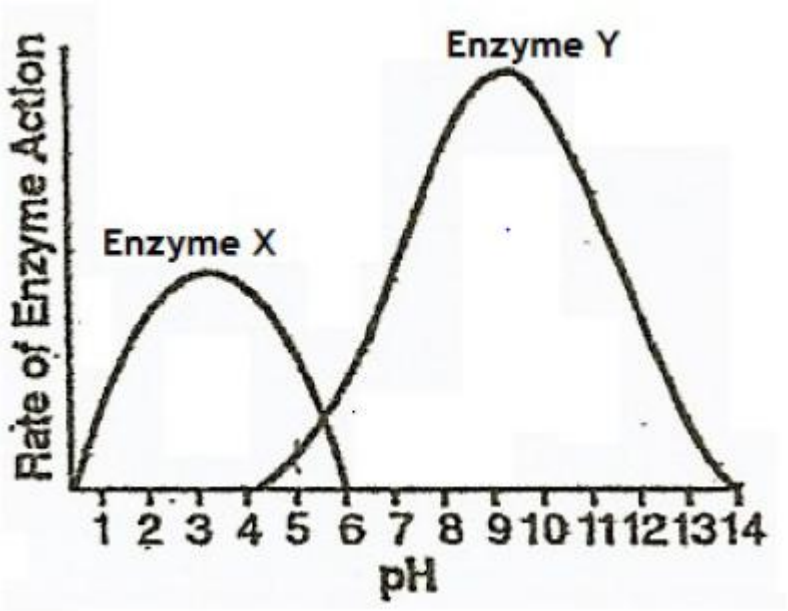
iii. Presence of inhibitors e.g. cyanide, malonic acid, silver, mercury and silver compounds. These reduce enzyme activity.

Enzyme inhibitors: are substances which alter the catalytic action of the enzyme and consequently slow down, or in some cases, stop catalysis.



Exercise

At constant temperature, each enzyme works most effectively over a narrow range of pH. Some enzymes require an alkaline medium e.g. ptyalin and lipase while others require acidic media e.g. pepsin and rennin.



QUESTIONS

(a) State the optimum pH for:

(i) Enzyme X

(ii) Enzyme Y

(b) Using the table below, identify enzymes

(i) X

(ii) Y

EXPERIMENTS ON ENZYMES

1. AN EXPERIMENT TO SHOW THAT ENZYME ACTIVITY IS AFFECTED BY TEMPERATURE

Materials used:

- ✓ 3test tubes

- ✓ salivary amylase
- ✓ iodine solution
- ✓ water bath
- ✓ thermometer
- ✓ source of heat
- ✓ stop clock
- ✓ Starch solution.

Procedure

i. $4cm^3$ of starch solution and $2cm^3$ of salivary amylase is poured in each of the three test tubes labelled 1, 2 and 3.

ii. Test tube 1 is placed in a beaker of cold water.

iii. Test tube 2 is placed in a beaker of warm water and temperature maintained between 35°C-40°C.

iv. Test tube 3 is place in hot water at a temperature above 40°C.

v. The test tubes are left to stand for forty minutes. The contents of the test tubes are then tested for starch using iodine solution.

Experimental set up

Observations

Mixture in test tube 1 turns blue-black

Mixture in test tube 2 turns brown

Mixture in test tube 3 turns blue or black

Conclusion; enzyme activity is affected by temperature

Explanation

Temperatures between 35°C-40°C were optimum for enzyme activity thus starch was broken down to glucose while that above 40°C denatured enzymes. Temperature below the optimum temperature inactivated enzymes.

2. THE EFFECT OF PH ON THE ENZYME ACTIVITY

Aim; an experiment to show that enzyme activity is affected by pH

Materials used; test tubes, enzyme pepsin, dilute hydrochloric acid, dilute sodium hydroxide solution, water bath, heat source, stop clock and an egg.

Procedure

i. $2cm^3$ of egg albumen and $2cm^3$ pepsin are placed into each of the three test tubes labelled 1, 2 and 3.

ii. $1cm^3$ of 2M dilute hydrochloric acid, sodium hydroxide and distilled water are added to test tubes 1, 2 and 3 respectively.

iii. The test tubes are placed in the water bath at 35°C-40°C for 30 minutes.

Experimental set up

Observation

Mixture in test tube 1 becomes clear

Mixture in test tube 2 remains cloudy

Mixture in test tube 3 remains cloudy/turbid.

Conclusion

Enzyme activity is affected by pH

Explanation

Pepsin work best in acidic medium therefore it hydrolyses the egg albumen in the test tube 1 while it did not hydrolyse the egg albumen in test tubes 2 and 3 because the pH was not favourable.

3. EFFECT OF SUBSTRATE CONCENTRATION ON ENZYME CATALYSED REACTION.

Aim; an experiment to show that enzyme activity is affected by substrate concentration

Materials used; solution of hydrogen peroxide, enzyme catalase, measuring cylinder, stop clock

Procedure

Four test tubes are prepared as follows:-

i. Test tube 1; $5cm^3$ of hydrogen peroxide

ii. Test tube 2; $2.5cm^3$ of hydrogen peroxide + $2.5cm^3$ of distilled water

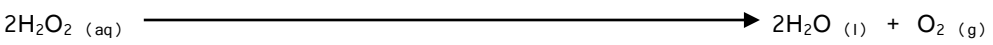
iii. Test tube 3; $1cm^3$ of hydrogen peroxide + $4cm^3$ of distilled water

iv. Test tube 4; $0.5cm^3$ of hydrogen peroxide + $4.5cm^3$ of distilled water

Experimental set up

Start the reaction by injecting $2cm^3$ of catalase solution in each test tube and shake well to mix.
Observation; more bubbles were produced in test tube 1, followed by 2, 3 and 4 respectively.
Conclusion; enzyme activity is affected by substrate concentration.

Note; hydrogen peroxide is produced by active cells of the body and it is toxic. Therefore it is eliminated immediately by converting it to harmless substances (water and oxygen). This reaction is catalysed by the enzyme catalase.



$$2H_2O_{2\,(aq)} \longrightarrow 2H_2O_{(l)} + O_{2\,(g)}$$

Therefore more bubbles produced means hydrogen peroxide is being decomposed.
Therefore test tube 1 had the highest concentration of hydrogen peroxide (substrate) and the reaction proceeded fastest. Test tube 4 contained the lowest amount of the substrate and the reaction proceeded slowest.

MAMMALIAN TEETH

Teeth, *(singular: **tooth**)* are hard structures found in the jaws of many of the higher animals.

General functions of teeth

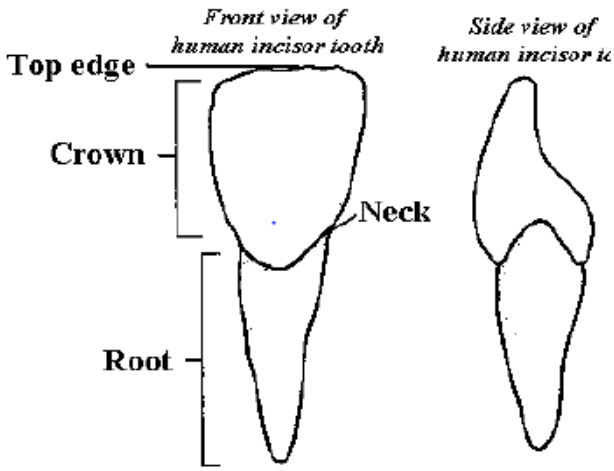
(1) tearing food
(2) chewing food
(3) For defense in carnivores.

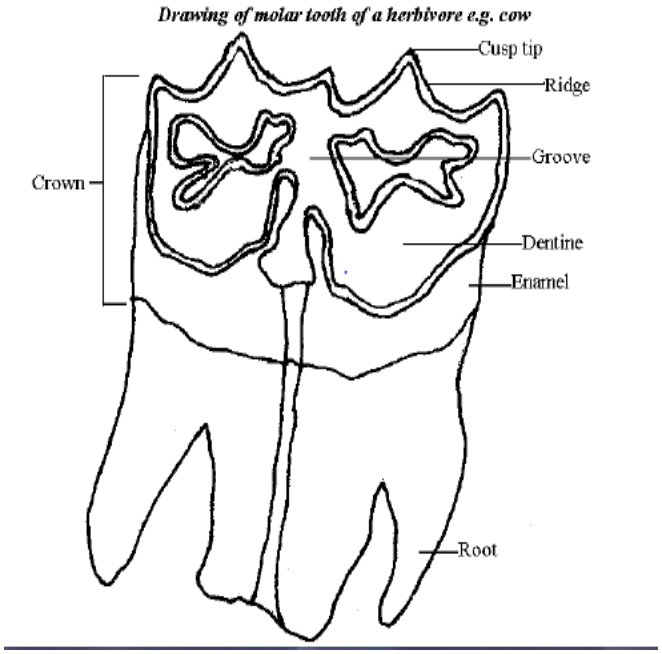
Types of teeth, characteristics and functions

Types of teeth	Characteristics/ Adaptations	Function of tooth
1. Incisors:	• They have a **chisel**-shaped edge for cutting food. • one root for supporting the tooth in the jaw	For cutting, biting and holding food
2. Canines:	• These have long, curved and pointed edge for piercing and tearing food. • The canine tooth also has a single root for supporting them in jaw.	For tearing and piercing food e.g. flesh
3. Premolars:	• These lie behind the canine. • Have many **cusps and ridges** for chewing. • Has two roots for supporting	To grind / crush/ chewing food into smaller particles

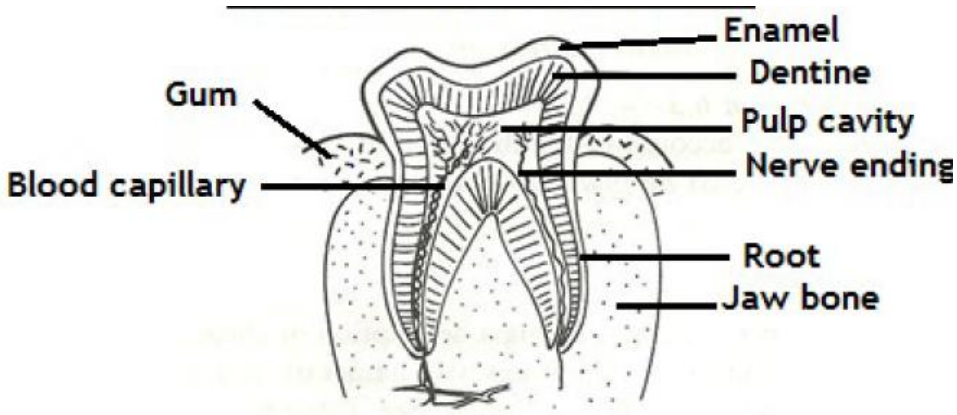
	the tooth in the jaws.	
4. Molars:	• These are larger than premolar. • Have many **cusps and ridges** that form a large working area • Three roots for supporting the tooth in the jaw.	To grind / crush food into fine particles

EXTERNAL STRUCTURE OF TEETH





Internal structure of a molar tooth



FUNCTIONS OF PARTS OF A TOOTH

(a) **Enamel:** Hardest part of a tooth which protects inner parts. Enamel is dead.

(b) **Dentine:** It is also like bone but not as hard as the enamel; Dentine is living and growth occurs here.
(c) **Pulp cavity:** Contains blood capillaries and nerve endings
(d) **Blood capillaries:** Supply digested food and oxygen to and take away wastes from tooth
(e) **Nerves:** Enable the tooth to sense changes.
(f) **Roots:** They fix the tooth firmly in the jaw bone
(g) ***Cement***: makes the tooth firm in the jaw.
(h) ***Gum***: makes the tooth firm in the jaw. It is also called gingiva.

DENTITION

It refers to the type, number, and arrangement of a set of teeth in the jaws.

DENTAL FORMULA

A formula which shows the number and type of teeth in each half jaw both upper and lower), of mammals.

The number of teeth in the upper jaw is written above that of the lower jaw and the order followed is incisors (I), canine (C), premolars (PM), molars (M).

Dental formulae in selected animals

Animals	**Dental formula**
Man **(omnivore)**	$I=^{2}/_{2}$ $C=^{1}/_{1}$ $PM=^{2}/_{2}$ $M=^{3}/_{3}$
Cow **(herbivore)**	$I=^{0}/_{3}$ $C=^{0}/_{1}$ $PM=^{3}/_{3}$ $M=^{3}/_{3}$
Dog **(carnivore)**	$I=^{3}/_{3}$ $C=^{1}/_{1}$ $PM=^{4}/_{4}$ $M^{2}/_{3}$
Rat (gnawer)	$I^{1}/_{1}$ $C^{0}/_{0}$ $PM^{0}/_{0}$ $M^{3}/_{3}$

DISEASES WHICH AFFECT TEETH

Disease	**Causes**
Dental caries	Caused by too much sugary foods and low calcium in the diet.
Periodontal diseases	Caused by lack of vitamins A and C in the diet. It Is characterised by gum bleeding.

HOW TO KEEP TEETH HEALTHY

(i) Brush teeth regularly (after every meal) and vertically (up-down direction)
(ii) Brush teeth using toothpaste which contains fluoride.
(iii) Avoid eating too much sugary foodstuffs like sweets.
(iv) Eat fibrous substances like sugarcane regularly to improve blood circulation into teeth.
(v) Eat food rich in calcium and phosphates plus vitamins to enable proper tooth growth.
(vi) Avoid biting hard substances and opening bottles using teeth.
(vii) Avoid extremely hot and cold drinks or foods.
(viii) Visit the dentist regularly for dental check-ups.

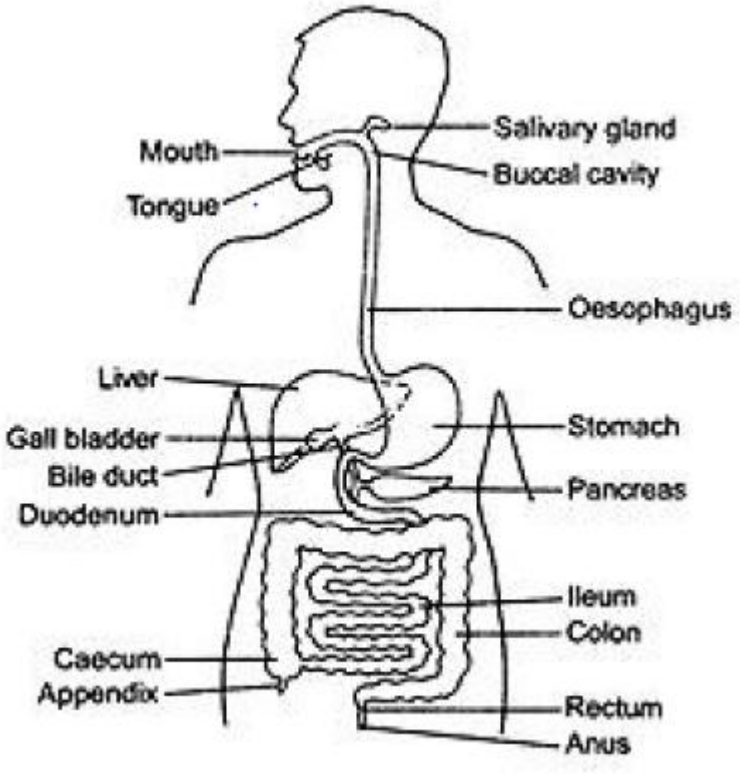
THE HUMAN DIGESTIVE SYSTEM

Digestion in man takes place in the special tube known as the alimentary canal which begins from the mouth and ends at the anus.

Major parts of the alimentary canal includes:- mouth, oesophagus (gullet), stomach, duodenum, ileum, colon, rectum and anus.

Accessory organs are the Organs, glands, and tissues that assist the digestive process, e.g. by supplying fluids /chemicals, but the food does not actually pass through them. They include: teeth, tongue, salivary glands, liver, gallbladder and pancreas.

Drawing of human alimentary canal and associated organs



THE LIVER

The liver is the most diversified organ in the body of mammals i.e. the liver performs very many functions compared to other organs.

FUNCTIONS OF THE LIVER

1. The Liver regulates blood glucose:

(i) If in excess (above 90mg/100cm3), glucose is converted into glycogen for storage.

(ii) If little (below 90mg/100cm3), glycogen is converted into glucose for use.

2. The liver regulates amino acids in the body:

Excess amino acids are not stored in the body, but undergo deamination process. i.e. the amino group (-NH2) from the amino acid is removed to form ammonia, which later forms urea. Urea is carried in blood stream to the kidney for excretion.

3. The liver regulates lipids (fats) in the body:

It forms and degrades phospholipids and cholesterol.

4. The liver forms red blood cells in foetus and breaks down worn out red blood cells in adults.

5. The liver forms plasma proteins from amino acids:

6. The liver produces bile, which is important in fat digestion

7. The liver stores fat soluble vitamins A, D, E, K and water soluble vitamins B12 and C

8. The liver stores minerals like Iron, potassium, copper, zinc and trace elements.

9. The liver stores a lot of blood in its large network of blood vessels, hence acting as a blood reservoir during emergency cases.

10. The liver destroys all hormones after doing their effects in the body.

11. The liver detoxifies poisonous substances i.e. toxic substances are turned harmless by the liver cells.

THE BASIC STAGES OF THE DIGESTIVE PROCESS IN HUMANS (holozoic nutrition)

1. ***Ingestion***: the intake of food into the body.
2. ***Digestion***: the breakdown of large molecules into smaller ones
3. ***Absorption***: the uptake of nutrient molecules from the digestive tract into the bloodstream.
4. Assimilation: utilizing the absorbed food in the body; e.g. to provide energy.
5. ***Defecation (Egestion)***: removal of undigested residue from the body.

DIGESTION IN MAN

Digestion is the process by which large food molecules are broken down into soluble molecules which can be absorbed and assimilated into the tissues of the body.

Types of Digestion.

1. **The mechanical processes:** which include
   a. chewing and grinding of food by the teeth
   b. churning and mixing of the contents of the stomach to expose more surface area to the enzymes that finish the digestive process.
   c. Action of bile salts which breakdown fats into small fat droplets a process called emulsification.
2. **Chemical processes:** this includes hydrolysis action of food using digestive enzymes.

STAGES OF DIGESTION

1. DIGESTION IN THE MOUTH

Digestion starts with chewing, which breaks food into pieces small enough to be swallowed and also increases the surface area of food to digestive enzymes.

During chewing, saliva mixes with food.

Saliva, which has a pH of about 6.8 to 7.0, contains many substances that perform different functions:

(i) ***Enzyme Salivary amylase*** speeds up the breakdown of starch into maltose.

(ii) Saliva ***moistens food*** and binding it together for swallowing

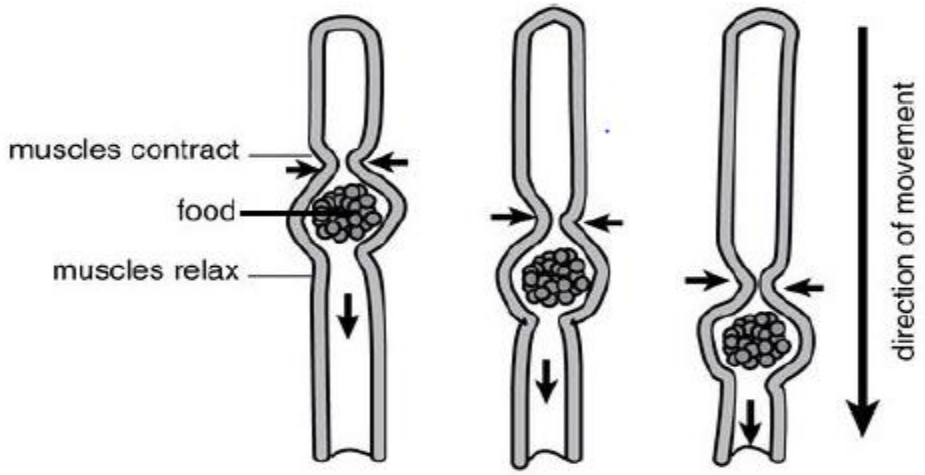
(iii) ***It contains Mucus*** which binds and lubricates the food; to enable swallowing.

Swallowing

The tongue collects, rolls food into a bolus and pushes it into oesophagus. Food is blocked from entering the trachea by a muscular tissue called the epiglottis.

Food moves in the gullet (oesophagus) by a process called ***peristalsis.***

Peristalsis ***is*** a series of overlapping wave-like contractions that squeeze food down the oesophagus. When food arrives at the bottom of the oesophagus, the cardiac sphincter relaxes and permits it to flow into the stomach



2. DIGESTION IN THE STOMACH

Arrival of food in the stomach causes secretion of **Gastric juice** from the stomach walls**,** which has several components:

1. **Pepsinogen** which is activated to **pepsin** by HCl and catalyses hydrolysis of protein into peptides/ polypeptides.
2. **Prorennin** which is activated to **rennin** by HCl. Rennin converts the soluble milk protein **caseinogen** to insoluble card **casein** which is then acted upon by pepsin enzyme.
3. The mucus protects the stomach wall from the action of HCl and pepsin enzyme.
4. Hydrochloric acid serves the following functions:-
   i. It provides an acidic medium in the stomach which is optimum for the enzyme action.
   ii. It activates pepsinogen to pepsin.
   iii. It kills the bacteria taken along with the food.
   iv. It stops further action of salivary amylase since this enzyme does not work in acidic medium.

Note; -Pepsin and prorennin are secreted in an inactive forms called pepsinogen and prorennin respectively. This prevents pepsin from destroying the cells which produce it (self digestion/ autolysis) since they are protein in nature.

-Water soluble substances with relatively small molecules e.g. water, common salt and alcohol are partly absorbed through the stomach wall.

NB: The secretion of gastric juice is a reflex stimulated by: Site, Smell, Taste, Thought or physical presence of food in the stomach.

3. DIGESTION IN THE DUODENUM

Bile, which is formed in the liver but stored in the gall bladder**,** PLUS **pancreatic juice** secreted by the pancreas are released onto food in the duodenum**.**

Bile contains **bile salts** which emulsify fats i.e. bile salts break the fat mechanically into tiny particles to increase the surface area for digestion.

Pancreatic juice is **alkaline** and contains the non- enzymatic substances and enzymes which perform different roles:

Non-enzymatic substances

(i) Sodium bicarbonate salts neutralize the **hydrochloric acid** which comes along with food from the stomach, so as to enable enzymes in the duodenum to work.

(ii) **Mucus**, which lubricates the duodenal wall to facilitate flow of food.

Enzymes in pancreatic juice

Enzyme	**Substrate (food acted on)**	**Products of digestion**
Pancreatic Amylase	Starch	maltose.
Pancreatic Lipase	Fats	fatty acids and glycerol
Trypsin (secreted as *Trypsinogen and activated by* enzyme enterokinase secreted from the wall of the duodenum**)**	Protein	Peptides/ poly peptides

From the duodenum, partially digested food called **chyle** enters into the **ileum.**

DIGESTION IN THE ILEUM

Intestinal juice called **succus entericus** is secreted to **complete the digestion of food**

Functions of intestinal juice enzymes

The enzymes catalyse breakdown of the following

Enzyme	**Substrate (food acted on)**	**Products of digestion**
Sucrase	sucrose	***glucose*** and ***fructose***
Lactase	lactose	**glucose** and ***galactose***
Maltase,	***maltose***	***glucose***
Lipase	Fats/ lipids	***fatty acids*** **and** ***glycerol***
peptidase (Erepsin)	***Peptides***	***amino acids.***

At the end of these enzyme activities, the food is a milky fluid called chyle composed of glucose, fructose, amino acids, fatty acids, glycerol, water, vitamins and mineral salts which are absorbed across the epithelial lining of the ileum.

ABSORPTION OF DIGESTED FOOD

This is the process whereby the end products of digestion enter into the Blood stream.

Water and small molecules like simple sugars, salt and alcohol are partly absorbed through the stomach wall.

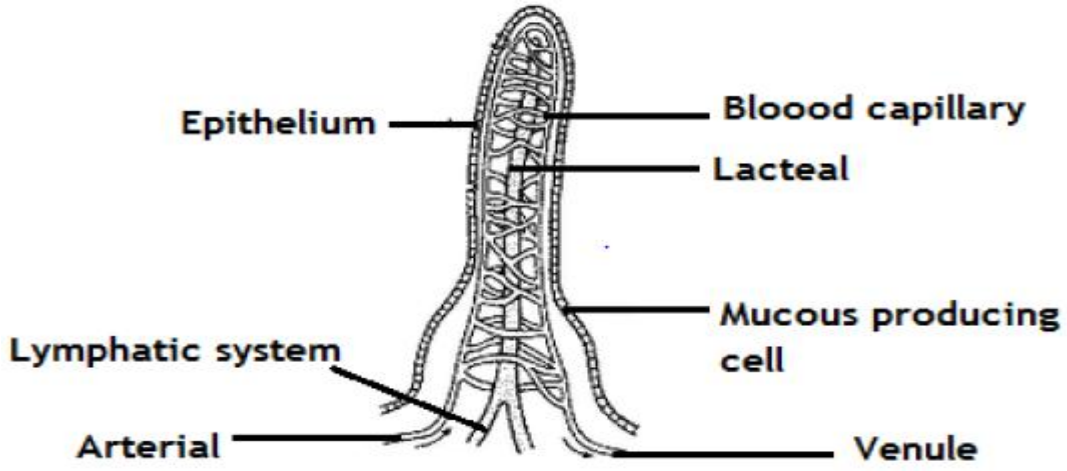
All the products of digestion are absorbed in the ileum.

At the end of these enzyme activities, the food is a milky fluid called chyle composed of glucose, fructose, amino acids, fatty acids, glycerol, water, vitamins and mineral salts which are absorbed across the epithelial lining of the ileum. The ileum is therefore the main organ of absorption

Adaptations of ileum to food absorption.

i. The ileum is very long (about 5m in adults) which provides a large surface area for absorption.
ii. Presence of finger-like projection known as villi to increase the surface area for absorption.
iii. The villi have hair-like extensions known as micro-villi to increase the surface area for absorption.
iv. The lining of the ileum is made up of a thin epithelium to reduce diffusion distance.
v. Many mitochondria which produce the energy required for active transport of nutrients.
vi. It is folded to increase surface area for absorption and increase time for absorption of food.
vii. Ileum is supplied with a rich network of blood capillaries to increase concentration gradient.

A drawing showing the structure of the villus



Adaptations of the villus to its function of absorption.

1. It is supplied with a rich network of blood capillaries to increase concentration gradient.
2. It is made up of a thin epithelium to reduce diffusion distance.
3. Many mitochondria which produce the energy required for active transport of nutrients.
4. Presence of lacteals to absorb and products of fat digestion.
5. The villus is further divided into microvilli increasing surface area for absorption.

The process of absorption

-The end products of digestion; amino acids and glucose pass by diffusion and active transport through the epithelium and capillary wall and enter the blood plasma. They are then carried in the capillary which later unite to form venules. The venules eventually join up to form the **hepatic portal vein** which carries blood from the intestines to the **liver.**

-Fatty acids and glycerol enter into the lacteal, which later unite to form the lymphatic system.

The large intestine (colon and rectum)

In humans no further digestion takes place in the large intestine. Materials passing here consist of water and vegetable fibres (roughages), mucus and dead cells from the lining of alimentary canal.

No enzyme is secreted here but absorption of water occurs in the large intestines leaving only semi-solid waste called faeces which are passed, by peristalsis, into the rectum where it is stored temporarily and later egested at the intervals via the anus.

Caecum and appendix

These are small vestigial organ in man (small structure without digestive function)

Anus

The useless undigestible material are passed out inform of faeces through the anus and the process is called egestion. If the diet does not contain enough roughage, the muscles of the rectum and colon become sluggish resulting to the inability to pass out stool easily (constipation).

ASSIMILATION

Assimilation is the process by which simple food substances after being absorbed are built up into complex constituents of the organism (utilization of absorbed food in the body).
The process of assimilation supports growth, development, the renewal of the organism, and the storing up of reserves used as a source of energy.
Metabolism refers to all the chemical processes that take place within an organism.
The body's metabolic centre is the liver.

FOOD	TRANSPORT IN THE BODY	USES TO THE BODY	HOW BODY DEALS WITH EXCESS
Glucose	Transported as blood sugar	Tissue respiration to release energy	1. Converted to glycogen which is stored in the liver and muscles. 2. Converted to fats then stored under the skin.
Amino acids	Carried in blood plasma as amino acids	- repair of damaged tissues -formation of cell membrane. -Formation of enzymes. -during starvation they are oxidized to release energy. -transamination	Deaminated in the liver to form urea.
Lipids	Carried in blood to adipose tissue.	-Oxidized to release energy (fats release twice as much energy as glucose when oxidized. -Form part of cell membranes - Some fats are stored around the heart and kidney as shock absorbers.	Stored as fat under the skin

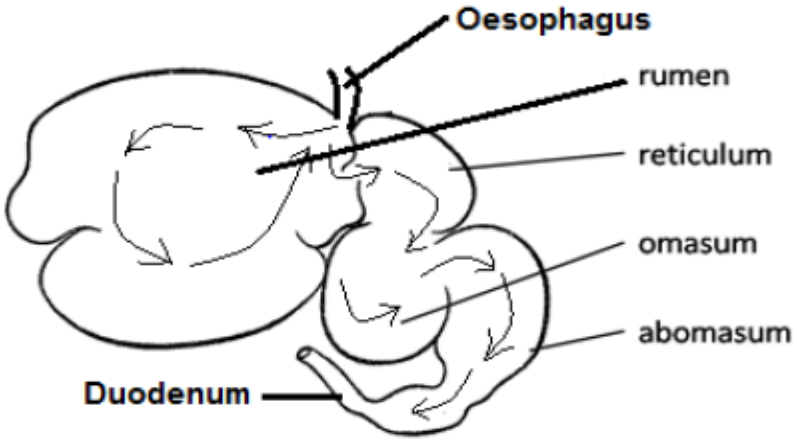
NB: **Deamination** is the removal of the amino group from the amino acid to form urea.

Digestion in herbivores

Herbivores are faced with the problem of digesting cellulose making up the plant cell walls because they cannot produce the enzyme **cellulase** which can digest cellulose. Therefore they form an association with cellulase secreting bacteria and protozoans which produce cellulase enzyme which converts cellulose to glucose.

DIGESTION IN RUMINANT MAMMALS

Ruminants: are the mammals, which have a 4-chambered stomach for the digestion of plant based food.
Rumination involves regurgitation of fermented grass known as cud, chewing and re-chewing it again to further break down plant matter and stimulate digestion.
Ruminating mammals include cattle, goats, sheep, giraffes, deer, camels, antelope.
Diagram of a 4-chambered stomach showing food movement during feeding



1. Rumen (Paunch): Bacteria and protozoa in the rumen secrete **cellulase enzyme** which breaks down cellulose into glucose which undergoes fermentation to form **organic acids**, **carbon dioxide** and **ethane**. The fermentation process produces heat that keeps ruminants warm.

2. Reticulum (Honeycomb bag): Here any foreign objects that may have been accidentally swallowed with the feed settle out in the **honeycomb** structure of the reticulum's walls. Reticulum is sometimes called **"hardware stomach".**

3. Omasum (Psalterium / Manypiles: Absorbs water from food and also absorbs more nutrients called volatile fatty acids that supply ruminants with energy.

4. Abomasum (Reed / True stomach): Here, the food particles are digested by hydrochloric acid in the same way it occurs in human stomachs.

The remaining particles are then passed on to the small intestine where most of the nutrients are absorbed by the body and made available to the ruminant.

CELLULOSE DIGESTION IN TERMITES

The wood-eating termites contain in their gut protozoa**,** which secretes **cellulase enzyme** to digest cellulose in wood. Some of the products of digestion are absorbed by the termite, which provides shelter.

CELLULOSE DIGESTION IN RABBITS (NON RUMINANTS)

The caecum and appendix of a rabbit contain bacteria that secrete cellulase enzyme for digesting cellulose into glucose.

A rabbit produces white faeces at first which they eat again to derive more nutrients; this is called **coprophagy.**

The partially digested food in white faeces is then digested as it passes through digestive system the second time finally producing brown faeces. The rabbit gains **glucose** while the bacteria get **shelter** in a mutualistic relation.

Difference between ruminants and non-ruminant animals

Ruminant animals	Non-ruminant animals
Have four chambered stomach	Have one chambered stomach
They chew cud	They do not chew cud
Most absorption and digestion is in the stomach	Most digestion and absorption is in the ileum