NUTRITION

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SYLLABUS EXTRACT

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• Examine, draw and label the major parts of the animals' digestive systems. • Observe state structural adaptations of the parts of the digestive system. • Identify food substances in the different parts of the gut. • Identify and draw the different parts that make up the mouth of insects, mammals and toad. State the functions of mouth parts of insects, mammals and toad. • Compare dentition in animals	• Structure of mouth part of insects, mammals and toads. • Functions of mouth parts of insects, mammals and toad. • Dentition in animals.
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• Identify and draw sections of parts of kidney • Dissect, display, draw and label the urinary system.	• Histology of the kidney: cortex, medulla, different regions of the nephron. • Urinary system of a toad, rat/ rabbit

INTRODUCTION

Nutrition is the process by which an organism takes in and makes use of food substances.

Nutrition is broadly divided into autotrophic nutrition and heterotrophic nutrition.

HETEROTROPHIC NUTRITION

This is the type of nutrition in which organisms consume readymade organic food of autotrophs (producers). This is because heterotrophs cannot make their own food and therefore depend on food made by autotrophs. All heterotrophs possess a method of reducing large complex food molecules into simpler soluble food molecules (digestion) and secondly they possess a means of absorbing the soluble molecules from the region of digestion into their tissues. All heterotrophs must feed on a Balanced diet, this is one which contains the correct proportions and quantity of the chemicals of life as required by a given organism. There are five types of heterotrophic nutrition namely;

1) Holozoic nutrition
2) Saprotrophic nutrition
3) Parasitism
4) Mutualism
5) commensalism

HOLOZOIC NUTRITION

This is the type of nutrition which involves feeding on complex readymade organic source of carbon obtained from the bodies of other organisms.

In holozoic nutrition, complex food is broken down inside an organism into simple soluble molecules which are then absorbed and assimilated. Most animals feed in this way, utilising a specialised digestive system. Therefore holozoic organisms obtain their energy from the digestion of complex organic food within their bodies. Holozoic nutrition involves the following processes ingestion, digestion, absorption and assimilation.

a. **Ingestion** is the intake of food into the gut or body of an organism.
b. **Digestion** is the mechanical and chemical breakdown of complex organic food substances into simple and soluble forms.
c. **Absorption** is the intake of well digested soluble substances from the digestive region across the membrane into the body tissue.
d. **Assimilation** is the utilization of the absorbed soluble food substances to form energy or materials which are incorporated into the body tissues.
e. **Egestion** is the elimination of the undigested food materials from the body i.e. defecatin

FEEDING MECHANISMS OF ORGANISMS

FILTER FEEDING

These are organisms which feed on tiny food/organic particles suspended in water. These animals use body appendages (cilia/gills) to draw water in the mouth from which they are passed on to the oesophagus. Filter feeding may also be called **suspension feeding or microphagus feeding.**

Examples of organisms which feed in this way include; most aquatic animals e.g. whales, oysters, mussels, clams, etc.

MACROPHAGUS FEEDING

Most animals, animals including humans, are macrophagus feeders, and ingest relatively large pieces of food. Their adaptations to take in such pieces of food include pincers (part of the mandibles of some artrhropods), claws of lobsters/crabs, poisonous fangs, jaws, teeth and mandibles. It may involve killing the prey or tearing off pieces of meat or vegetation. Macrophagus feeding may also be referred to as **bulk feeding.** They include tentacular feeders e.g. hydra, scraping and boring e.g. snail, biting and chewing e.g. in grasshoppers and seizing and swallowing e.g. dogfish

SUBSTRATE FEEDING

This is a method of feeding in which organisms live in or on their food source. They eat through the soft tissue of their host (food source) and create a way through to the food/organic material. Substrate feeding can also be referred to as **deposit feeding.**
Most substrate feeders are **parasites.**
Examples include insect larvae such as maggots, earthworms, caterpillar e.t.c.

FLUID FEEDING

Fluid feeders suck nutrient-rich fluid from a living host using modified mouth parts. The already digested food is then absorbed across the integument.
Examples of fluid feeders include insects such as aphids which feed on the phloem sap, mosquitoes which feed on blood, and bees which feed on nectar. Gut parasites which feed on the gut's digested food, as well as humming birds which feed on nectar. They include sucking as seen in the sucking e.g. housefly and piercing and sucking e.g. female mosquito

DIGESTION OF FOOD IN HUMANS

It occurs in two forms i.e. chemical digestion and mechanical digestion.

Mechanical digestion

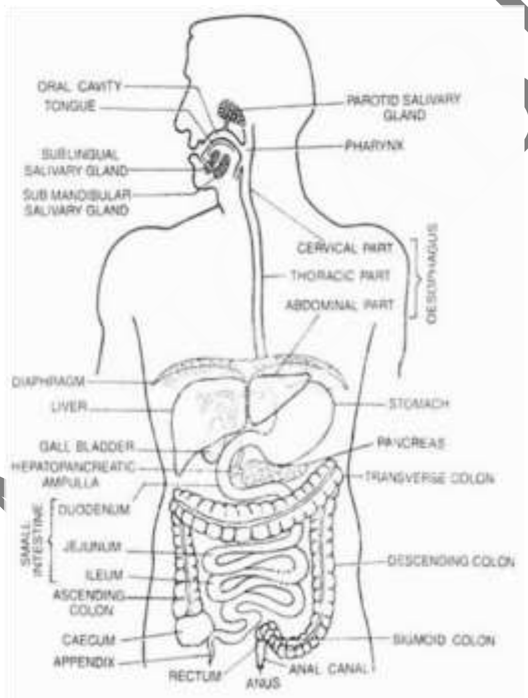
This is the ***physical break down*** of complex organic food substances by the ***chewing action (mastication***) of the teeth followed by the peristaltic movement of food in the gut.

Chemical digestion

Is the breakdown of complex organic food substances by the hydrolytic action of enzymes into simpler soluble forms

A drawing of the digestive system of man

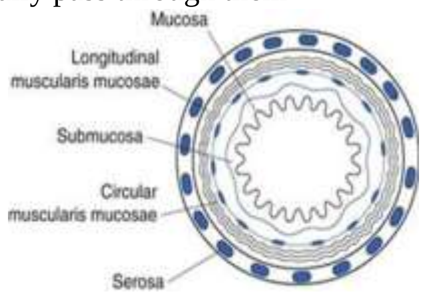
(Monger fig 11.14 B page 184, Clegg fig 13.6 page 277)



Note

The human digestive system consists of:

a) **Alimentary canal:** Mouth, throat, oesophagus, stomach, small intestine (duodenum, jejunum and ileum), large intestine (colon, caecum and appendix), rectum and anus.
b) **Accessory structures:** Teeth, tongue, salivary glands, liver, gall balder and pancreas. These are organs, glands, and tissues that enable digestive processes, e.g. by secreting fluids /chemicals, but the food does not actually pass through them



The many differentiated regions of the gut all possess the same general structure. This consist of;

a) **Mucosa**: glandular inner layer of the gut secreting mucus and a variety of enzymes. Mucus facilitates easy food movement and prevents self-digestion by the enzymes.
b) **Sub mucosa**: connective tissue containing nerves, blood and lymph vessels
c) **Muscularis externa**; inner circular and outer longitudinal smooth muscle responsible for peristalsis. Circular muscle is specialised into sphincters at various points in the gut. Auerbach's nerve plexus, located between the circular muscle and sub-mucosa, controls glandular secretion
d) **Serosa**: outer loose fibrous tissue covered by peritoneum. Peritoneum also forms mesenteries which hold and suspend the gut from the dorsal body wall.

DIGESTION IN THE MOUTH

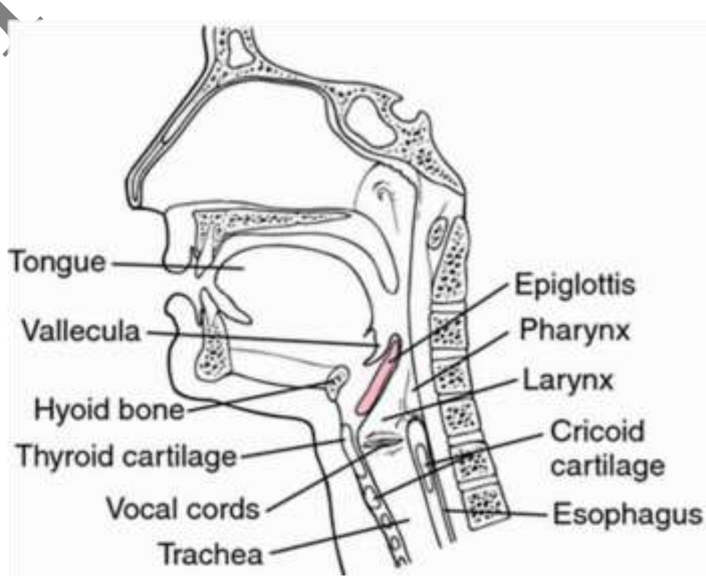
When a piece of food is put into the mouth, it is mechanically digested by the chewing action of the teeth into smaller particles. This ensures mixing of food particles with saliva to soften them for easy swallowing and also increases the surface area of food to maximise its digestion by the enzyme.

Mixing of food with saliva lubricates the food for its easy movement without friction and it also binds the chewed food particles together to enable the particles to stick together into a ball known as a bolus for easy swallowing. The saliva is secreted by the salivary glands via ducts to the mouth. The secretion of this juice is controlled by the nervous system and occurs in response to sight, taste, smell and thought of food. Saliva is a watery fluid which contains mucus, water, mineral salts e.g. chloride ions activate salivary amylase (ptyalin) which hydrolyses starch into maltose. Saliva also contains lysozymes which kill bacteria in the buccal cavity. It also keeps the surface of the throat lubricated for speech.

NOTE: Intracellular digestion refers to the condition whereby solid food particles are taken up into the cells by phagocytosis and then digested in food vacuoles within the cells.

SWALLOWING

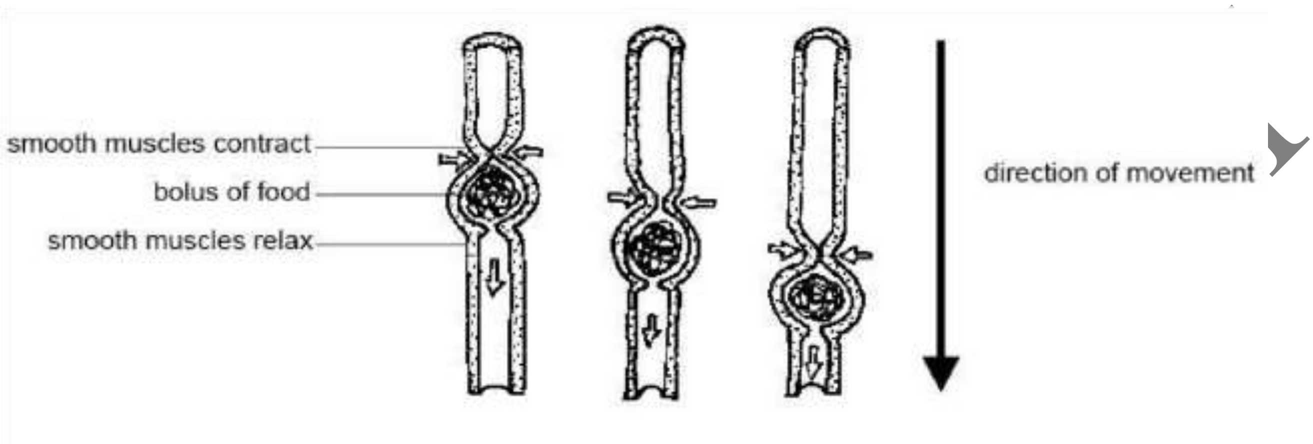
This is a reflex action which occurs when the tongue contracts and presses against the soft palate thereby pushing the bolus into the **pharynx.** From the pharynx (top most part of the trachea which is covered by the epiglottis), th e bolus enters into the oesophagus.



During food swallowing, pharynx moves upwards as a reflex action and pushes the \\ **epiglottis** to bend against the trachea entrance called the **larynx.** This reflex action prevents any food particles from entering and blocking the trachea. When the epiglottis bends over the glottis, breathing is briefly and momentarily suspended due to the closure of the glottis. In case any food particles enter into the respiratory system, coughing occurs as a reflex action to expel the food particles out of the respiratory system.

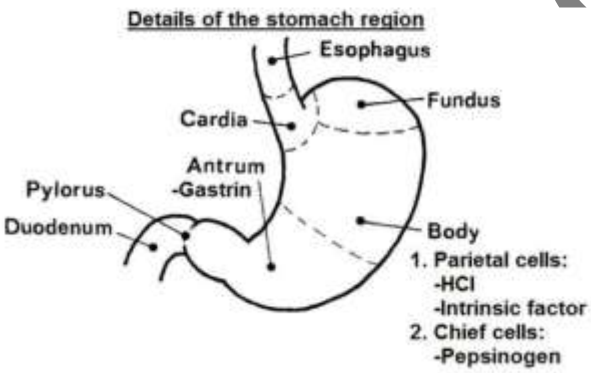
When food enters the oesophagus, it moves in a wave like fashion, due to the contraction of the circular muscles behind the bolus and contraction of the longitudinal muscles in front of the bolus. Such movement is called **peristalsis.**

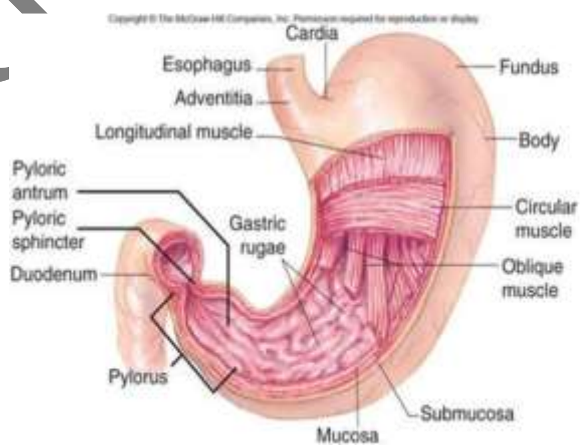
At the end of the oesophagus is the cardiac sphincter muscle which relaxes and allows food to enter into the stomach.



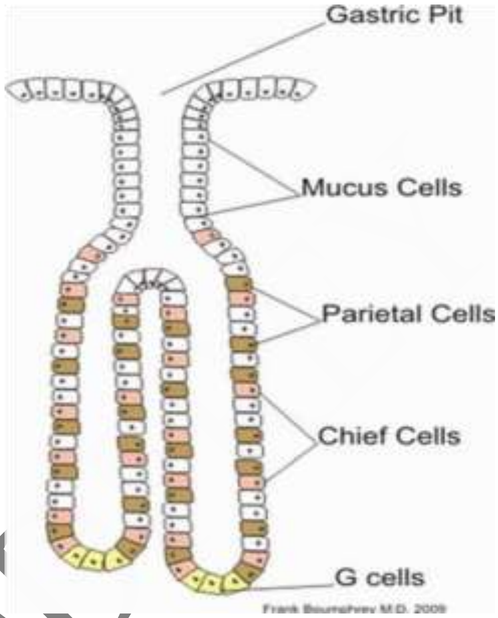
DIGESTION IN THE STOMACH

The stomach is a J-shaped structure on the left side situated below the diaphragm. (Roberts Fig 9.1A page 125, Kent fig 3 page 163, R.Soper fig 8.12 page 238)





The stomach is a large distensible organ with many secretory cells. It is a muscular sac with a folded inner layer called the **gastric mucosa**. Embedded in this is a series of gastric pits which are lined with secretory cells. When food reaches the stomach, its presence stimulates the stomach walls to secrete **gastrin hormone** into the blood stream which stimulates the gastric gland to secrete gastric juice. The cells of the gastric gland include the **oxyntic or parietal cells** which secrete hydrochloric acid. Hydrochloric acid plays the following roles



i. It activates pepsinogen and prorennin into pepsin and rennin respectively
ii. It provides an optimum acidic pH for pepsin enzyme to catalyse the hydrolysis of proteins into polypeptides.
Note ; hydrochloric acid secreted is at a concentration of 0.15M and pH=1.
iii. It renders calcium and iron salts soluble for absorption in the intestines
iv. It loosens the fibrous and cellular components of tissues.
v. It kills microbes such as bacteria which may come along with the food.
vi. It begins the chemical digestion of sucrose but lacks a suitable temperature; therefore it cannot complete its digestion.
vii. It denatures the tertiary structure of proteins which unfolds for easy digestion by enzymes.
viii. It begins the hydrolysis of nucleo proteins into proteins and nucleic acids
ix. It stops amylase enzyme action

The gastric glands also contain the chief/zymogen/peptic cells which secrete pepsinogen and prorennin, the inactive forms of pepsin and rennin enzymes so as to avoid the self-digestion of the cells surrounding them. Rennin enzyme coagulates the soluble milk protein called **caseinogen** into the insoluble protein called **casein** which later becomes hydrolysed into polypeptides by pepsin.

Note: prorennin can also be activated into rennin by pepsin enzyme.

The gastric gland also has the goblet cells which secret mucus. The mucus is used to lubricate the gut for the movement of food without any friction. In addition, mucus also protects the stomach wall from being digested and destroyed by the proteases (protein digesting enzymes such as pepsin), thereby forming a barrier between the enzymes and the stomach.

Due to the churning movement of the stomach walls, the food is thoroughly up mixed the gastric juice and pounded into a semi solid called **chyme** which now flows through the duodenum via the **pyloric sphincter.**

(Roberts fig 9.4B page 129, Kent fig 1 page 186, R.Soper fig 8.20 page 243)

SECRETIONS FROM CELLS LOCATED IN THE GASTRIC WALL

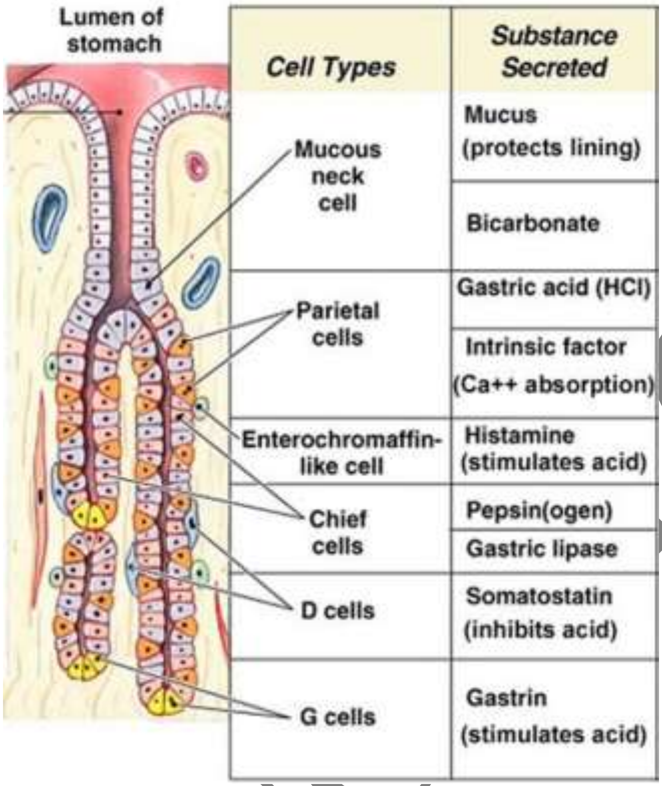
The secretions of the mucous cells, chief cells, and parietal cells are known collectively as ***gastric juice***, whose components include: ***mucus, pepsinogen, hydrochloric acid*** and ***intrinsic factor***

Type of Cell	Secretion	Stimulus for secretion	Function
Mucous Cells (i) Mucous surface cells (ii) Mucous neck cells	Mucus	Tonic secretion, with irritation of mucosa	Physical barrier between lumen and stomach lining.
	Bicarbonate	Secreted with mucus	Buffers gastric acid to prevent damage to epithelium
Chief / Peptic / zymogenic cells	Pepsinogen	Acetylcholine, acid secretion.	Pepsin digests protein, including **collagen**
	Gastric lipase		Digests lipids
	Prochymosin (Prorennin)		Rennin curdles soluble Caseinogen (milk protein) into insoluble casein whose slow flow enables digestion
Parietal / **oxyntic cells**	Hydrochloric acid	Acetylcholine, gastrin, histamine	(i) Activates pepsinogen to pepsin, Prorennin to rennin (ii) Kills bacteria. Only ***Helicobacter pylori***, that cause ***gastritis*** and **gastric ulcers** survive in the stomach
	Intrinsic factor		● Complexes with vitamin B $_{12}$ to enable absorption of Vitamin B_{12} necessary for red blood cell formation ● Vitamin B12 is a cofactor of enzymes which synthesise tetrahydrofolic acid, which, in turn, is needed for the synthesis of DNA components ● Little ***intrinsic factor*** causes **pernicious anemia**
Enteroendocrine cell s (APUD-cells: a mine precursor uptake and decarboxy lation cells)			
(a) G cells (Gastrin-producing cells)	Gastrin hormone	Acetylcholine, peptides, and amino acids	Stimulates secretion of gastric juice Increases contractions of gastro-intestinal tract (iii) Relaxes the pyloric sphincter.
(b) D cells (Somatostatinproducing cells)	Somatostatin hormone	Acid in stomach	(i) **Inhibits** stomach secretion of **gastrin** and **HCl** (ii) **Inhibits** duodenal secretion of **secretin** and **cholecystokinin** (iii) **Inhibits** pancreas secretion of **glucagon**
(c)VIP-producing cells (vasoactive intestinal peptide)	Vasoactive intestinal peptide	Distension of the stomach wall	(i) Induces smooth muscle relaxation (ii) Inhibits gastric acid secretion (iii) Stimulates pepsinogen secretion by chief cells

(d) Enterochromaffin cells (Serotonincontaining cells)	Histamine	Acetylcholine, gastrin	Stimulates gastric acid secretion

The hydrochloric acid in the oxyntic/parietal cells of the stomach walls is formed in away similar to the transport of carbon dioxide in the red blood cell. Inside the oxyntic cell, an enzyme **carbonic anhydrase** catalyses the formation of carbonic acid from carbon dioxide and water. The carbonic acid dissociates into hydrogen ions and hydrogen carbonate ions

The hydrogen ions then combine with chloride ions derived from the dissociation of sodium chloride in the plasma of the surrounding blood capillaries to form hydrochloric acid which is secreted by the oxyntic cells. The hydrogen carbonate ions massively move out of the oxyntic cells due to the membrane being permeable to negatively charged ions and impermeable to positive ions. As a result, chloride ions move into the oxyntic cells as the hydrogen carbonate ions move out of the oxyntic cells by diffusion. Hydrogen ions of the hydrochloric acid are actively pumped into the duct of gastric gland and the negatively charged chloride ions diffuse with the positively charged hydrogen ions. Potassium ions are counter pumped into the parietal cell in exchange for hydrogen ions. The net result is production of hydrochloric acid in the parietal cells and its secretion into the duct of gastric gland.



DIGESTION IN THE DUODENUM

Most of the digestion occurs in a shorter first part of the small intestines called the duodenum into which the pancreatic and bile ducts open. Due to alternate contractions and relaxations the stomach wall muscles (churning), cells responsible for the production of a hormone called **vasoactive intestinal peptide or polypeptide** which stimulates many activities along the gut, whose effects work together to increase motility. After a maximum of four hours in the stomach, the acid chyme leaves the stomach and enters into the duodenum due to the relaxation of the pyloric sphincter muscle. Caused by the actions of VIP.

Secretin hormone

The presence of acidic chyme in the duodenum stimulates the endocrine cell of the duodenal walls to secrete the hormone secretin. It stimulates the liver to secrete bile into the gall bladder. It stimulates the pancreas to secrete non enzymatic substances mainly hydrogen carbonate ion used to neutralise the acid from the stomach in order to provide an alkaline pH for the optimum enzyme activity of the pancreatic enzymes. It also inhibits the secretion of hydrochloric acid by the oxyntic cells after the chyme has left the stomach.

Enterogastrone hormone

Presence of fatty acids in food. This hormone inhibits the oxyntic cells from secreting hydrochloric acid in order to provide an optimum pH for the optimum activity of the pancreatic enzymes. It also slows down the peristaltic movements of the gut to give enough time for the digestion of fats.

Cholecystokinin hormone (CCK)/pancreozymin

Presence fatty food in the duodenum is the stimulus for the secretion of this hormone. The hormone stimulates the pancreas to secrete pancreatic enzymes. It also leads to the contraction of the gall bladder to release bile.

When bile reaches the duodenum, its bile salts, **sodium glycochlolate** and **sodium tourocholate** carry out emulsification of fats which they physically breakdown into very small droplets by reducing their surface tension which increases the surface area for the action of lipase enzyme to maximally hydrolyse them into fatty acids and vi **Chymotrypsin** catalyses the hydrolysis of polypeptides into peptides. Chymotrypsin is also secreted in an inactive form called chymotrypsinogen to prevent it from digesting and destroying the duodenal walls which are protein in nature.

Within the duodenum, the food becomes more fluid and eventually enters the ileum. This more fluid food is called **chyle.**

Brunner's glands, found in the wall of the duodenum, secrete an alkaline mucus which neutralises the acid from the stomach and protects the duodenal lining from auto-digestion. These glands do not produce any enzymes.

DIGESTION IN THE ILEUM

When food leaves the duodenum it goes to the ileum. In humans, a zone intermediate between the duodenum and the ileum, the jejunum is identified. The presence of food in the ileum stimulates the endocrine cells of the intestinal wall to secrete hormones such as enterogastrone which stimulates the various glands in the intestinal wall to secret a digestive juice called intestinal juice (saccus entericus) which contains the following enzymes.

1. **Peptidases** which catalyse the hydrolysis of peptides into amino acids, thereby completing the digestion of proteins.

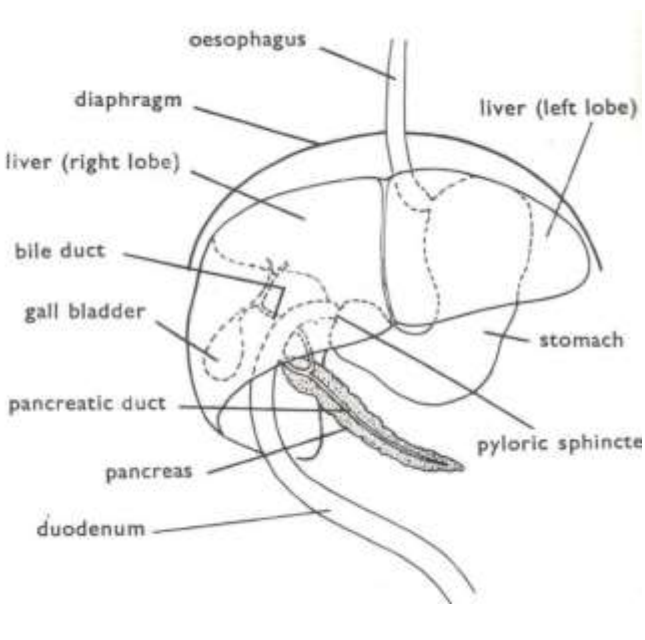
glycerol.

In the duodenum, the different pancreatic enzymes, in the pancreatic juice, carryout different roles which include the following;

- i **Pancreatic amylase** Which catalyses the hydrolysis of starch into maltose
- ii **Lipase** catalyses the hydrolysis of fats to fatty acids and glycerol
- iii **Nuclease** catalyses the hydrolysis of nucleic acids to nucleotides
- iv **Carboxypeptidase** catalyses the hydrolysis of peptides to amino acids
- v **Trypsin.** This enzyme is produced in an inactive form called **trypsinogen** which is activated by the non- digesting enzyme called **enterokinase** Trypsin catalyses the hydrolysis of polypeptides to peptides

Drawing showing the relationship between the duodenum, gall bladder and the pancreas

(Clegg fig 13.14 page 283)



2. **Enterokinase**
3. **Nucleotidase** which catalyse the hydrolysis of nucleotides into their components namely; phosphoric acid, nitrogenous bases and pentose sugars.
4. **Erepsin** which catalyses the hydrolysis of peptides and dipeptides into amino acids
5. **Maltase** which catalyses the hydrolysis of maltose into glucose molecules, thereby completing starch digestion.
6. **Sucrase** which catalyses the hydrolysis of sucrose into glucose and fructose molecules.
7. **Lactase** which catalyses the hydrolysis of lactose into glucose and lactose molecules.
8. **Intestinal lipase** which catalyses the hydrolysis of lipids into fatty acids and glycerol.
9. **Intestinal amylase** which catalyses the hydrolysis of starch into maltose.

After digestion of food is completed, the simplest soluble food substances are absorbed across the walls of the ileum into the blood stream by the **villi** of the intestines

Adaptations of the ileum to absorption of food

i. It is long, wide and folded to provide a large surface area for maximum absorption of the soluble food substances into the blood stream and also decreases the speed of food movement to allow diffusion, osmosis and active transport of the digested food into the blood stream.

ii. It has numerous finger-like projections called villi which offer a large surface area for maximum absorption of soluble food substances into the blood stream.

iii. Its epithelium has tiny projections on the cells called microvilli which further increase the surface area for efficient food absorption.

iv. It has a thin epithelium which reduces the diffusion distance for the soluble food substances into the blood stream in order to allow a high rate of diffusion.

v. It has a permeable epithelium which allows movement of soluble food substances across it into the blood stream with minimum resistance.

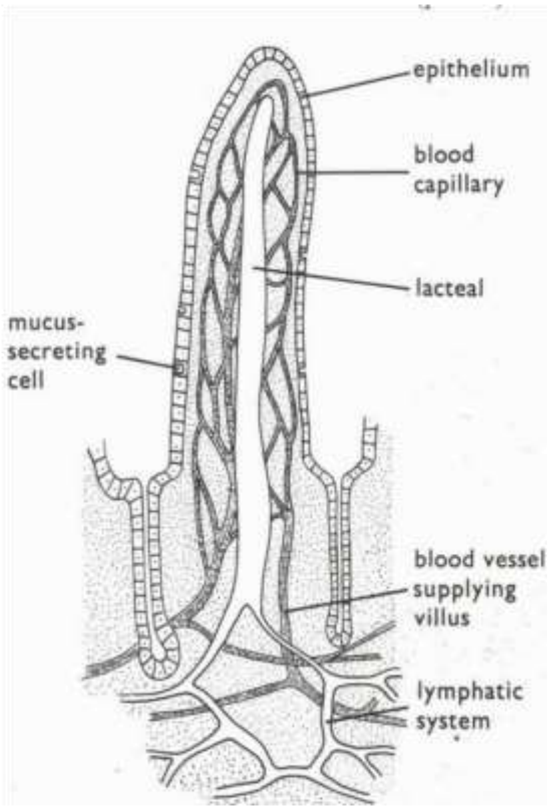
vi. Each villus has a dense network of blood capillaries which offer a large surface for the absorption of food materials and also allows the absorbed food materials to be rapidly carried away from the absorption area which maintains a steep diffusion gradient for more materials to be absorbed.

vii. Each villus contains a permeable lacteal, a branch of the lymphatic system in which fatty acids diffuse as well as glycerol, and become transported away from the gut.

viii. Its cells have numerous mitochondria to produce sufficient energy for transport of food from the ileum to the blood.

ix. It is line with a lot of mucus to prevent self-digestion.

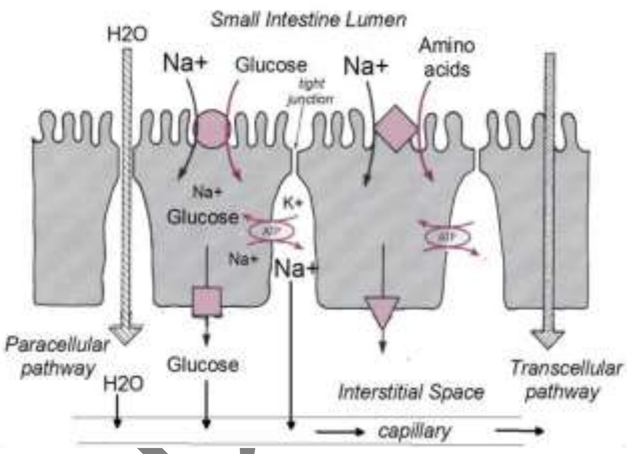
(Clegg fig 13.15 page 283 or 13.17 page 285, Kent fig 1 page 168, Glen and Suzan Toole fig 15.4 page 303, R.Soper fig 8.21 e page 244)



Describe the three main kinds of movement of the small intestines

1. Localized constriction, the small intestine walls contract and relax in order to mix up the food.
2. Pencular constrictions, responsible for mixing up food
3. Peristaltic movement, circular muscles contract such that food is moved along the gut

MECHANISM OF FOOD ABSORPTION



Glucose, amino acids, fructose, galactose and salts are actively absorbed using energy in form of ATP into the dense network of blood capillaries via the thin and permeable epithelium of the villi. They are also partly absorbed by diffusion if their concentration gradient in the blood stream is lowe r than that in the gut. Vitamins and some salts are usually absorbed into the blood capillaries by diffusion while water is absorbed by osmosis. The absorbed food substances are transported from the epithelium by capillaries and veins which converge into t he hepatic portal vein, a blood vessel that leads directly to the liver.
The fatty acids and glycerol diffuse into the columnar epithelia of the villi from where they recombine to form lipids.

The lipids combine with proteins to form **lipoproteins** which are in form of water soluble droplets called **cylomicrons.** Cylomicrons are too large to pass through the pores of the membrane of the capillaries hence they leave the epithelial cells by exocytosis and enter into the lacteals which are part of the vertebrate lymphatic system, which is a network of vessels that are filled with a clear fluid called lymph. Lymph containing cylomicrons passes into larger vessels of the lymphatic system and eventually into the larger veins that return blood to the heart. The lymph also transports all fat soluble substances.

Diagram showing the movement of absorbed food

(Clegg fig 13.19 page 287)

LARGE INTETSINES

This mainly carries out absorption of water into the blood capillaries by osmosis. It also absorbs vitamins e.g. Vitamin K which is synthesized by bacteria called *Escherichia coli* that live in the large intestine, along with mineral salts.
The walls of the large intestines have goblet cells which secret a lot of mucus to lubricate the movement of undigested food through the large intestine.

APPENDIX AND CAECUM

There's digestion of cellulose in these two organs by cellulase enzyme, into simple sugars.

The enzyme cellulase is secreted by mutualistic bacteria that live in both caecum and appendix of non-ruminant herbivorous animals e.g. rabbits. These two parts are non-functional in man.

RECTUM

In the rectum, food is stored temporarily and more water is osmotically absorbed from it into blood capillaries

THE CONTROL OF DIGESTION

Because the secretion of digestive juice is an energy consuming activity, there is need to control their secretion in order to prevent wastage of energy and other materials and increase the efficiency of food digestion. It also prevents the break down and damage of the gut walls by the enzymes and hydrochloric acid.

CONTROL OF SALIVA SECRETION

This is by both simple unconditioned reflexes and conditioned reflexes e.g. sight of food leading to salivation, smell, taste and expectation may also lead to salivation.

Simple unconditioned reflexes occur when food is within the buccal cavity and in contact with the taste buds of the tongue. The chemo receptors become stimulated and fire impulses along the sensory neurons to the brain which in turn also sends impulses to the salivary glands via the motor neurons. The salivary glands are then stimulated to secrete saliva containing salivary amylase for starch digestion into maltose.

The conditioned reflexes are seeing food, smelling food and thinking about food. These also stimulate the receptors and send impulses to the brain.

CONTROL OF GASTRIC JUICE SECRETION

This control occurs under three phases;

i. Nervous/cephalic phase
ii. Gastric phase
iii. . Intestinal phase

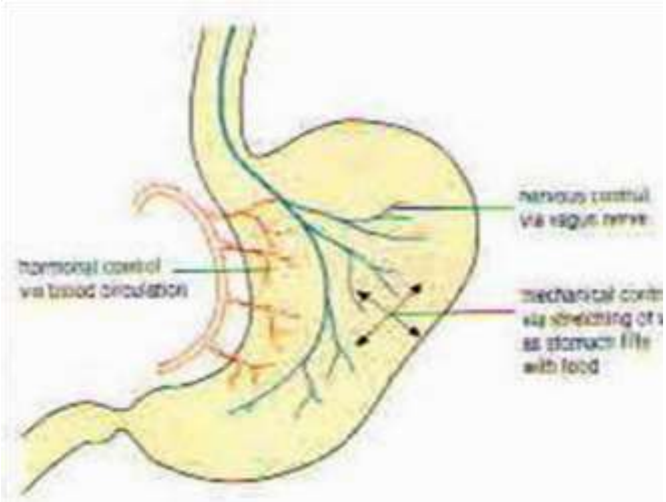
Nervous/cephalic phase

Presence of food in the buccal cavity, tasting, smelling, thinking, seeing or swallowing of food stimulates the brain to send impulses via the **vagus nerve** to the gastric glands of the stomach which become stimulated to secrete the acidic gastric juice (under the influence of gastrin hormone) so as to prepare the stomach to receive food from the mouth by having a correct acidic pH. The impulses also cause an increase in peristaltic movement of the gut as well as relaxation of the pyloric sphincter.The brain also sends impulse via the vagus nerve to the liver and pancreas to stimulate them to secrete bile stored in the gall bladder and pancreatic enzymes respectively.

Gastric phase

When food reaches the stomach, the stomach walls expand or stretch. This stimulates their stretch receptors to fire impulses to the Meissner’s plexus in the stomach wall. The plexus then fires impulses to the gastric glands which then become stimulated to secrete gastric juice via the gastric ducts, rich in HCl

Diagram showing the control of digestive juices around the stomach



Some impulses from the stretched receptors are also sent to the endocrine cells of the mucosa (stomach wall layer) which becomes stimulated and secret gastrin hormone into the blood stream which carries these hormones to the gastric glands. The gastric glands are stimulated by this hormone to secrete acidic gastric juice for about four hours, however this secretion is gradual as compared to the cephalic phase, to allow digestion of food in the stomach.

If food in the stomach contains fats, whose digestion requires a longer period of time and requires less acidic conditions, it initiates the secretion of enterogastrone hormone from the stomach wall, which reduces the churning movements of the stomach and reduces the flow of acidic gastric juice

Intestinal phase

When the acidic chyme comes into contact with the wall of the duodenum, the duodenal walls are stimulated to secrete three hormones. Namely;

i. Secretin hormone
ii. Cholecystokinin hormone (pancreozymin hormone) CCK
iii. Enterogastrone hormone
iv. Enterocrinin

Secretin hormone

When secreted into the blood stream, this hormone carries out the following roles.

a. It inhibits further secretion of gastric juice and more particularly hydrochloric acid.
b. It stimulates the pancreas to secrete bicarbonate ions (HCO_3^-) so as to neutralise hydrochloric acid in the chyme, in order to provide a suitable pH for the duodenal enzymes
c. It stimulates the liver to secrete bile which contains hydrogen carbonate ions that can neutralise hydrochloric acid

<u>Cholecystokinin (CCK)</u>

When secreted into the blood stream, this hormone carries out three major roles;

- It prevents emptying of the stomach with food.
- It stimulates the gall bladder to contract so as to release bile into the duodenum.
- It stimulates the pancreas to secrete pancreatic enzymes into the pancreatic juice <u>Enterocrinin hormone</u>

This stimulates the intestinal glands to secrete the digestive juices saccus entericus.

<u>Enterogastrone hormone</u>

When secreted into the blood stream, this hormone inhibits the secretion of hydrochloric acid by the oxyntic cells into the gastric juice and also reduces the churning movement of the stomach.

Presence of fats in the stomach also stimulates the secretion of enterogastrone

NOTE: secretin is produced in response to the amount of hydrochloric acid in the chyme while cholecystokinin is produced in response to the fatty food in the duodenum.

ASSIMILATION OF FOOD

After absorption of food, it is put to use by the body cells in the various ways which include the following;

Assimilation of carbohydrates

Carbohydrates are used for the following;

i. ATP synthesis in respiration
ii. Used in recognition mechanisms as glycoproteins
iii. Used in the production of mucus
iv. Excess carbohydrates are stored in the form of glycogen in the liver and muscles.

Excess carbohydrates may be converted into fats for storage.

Assimilation of proteins (amino acids)

1. Proteins are used for the formation of protoplasm of cells.
2. They are used for growth
3. Used for the production of enzymes and antibodies
4. Used for the formation of body structures such as hairs, nails, hooves, cell membranes e.t.c.
5. Used in the maintenance of a constant optimum pH by acting as buffers. This is because variations in pH would be fatal to the organism as they would lead to enzyme denaturation.
6. They can be used as a source of energy during severe starvation i.e. they can be used for ATP synthesis in respiration when most of the stored food has been exhausted.
7. Formation of hormones e.g. insulin
8. They are used in recognition mechanisms during which materials are recognized by cells using glycoproteins.
9. They are used as carriers of materials across the cell membrane

When in excess, the amino acids from proteins are deaminated by the liver cells into **ammonia** which is then converted into a less toxic chemical called **urea** by the liver cells and then excreted by the kidney and sweat glands of the skin. **Deamination** is the removal of the nitrogen containing amino group to form ammonia which is then excreted as urea in urine. The remaining molecule after deamination forms a carbohydrate which is oxidized in respiration to form ATP.

Assimilation of lipids (fatty acids and glycerol)

a) Formation of sebum and synovial fluid
b) Formation of bone marrow.
c) Transportation for fat soluble vitamins e.g. A, D, E and K.
d) For production of ATP during tissue respiration
e) Formation of the plasma membrane
f) Insulate the body against excessive heat loss.
g) It protects and cushions the delicate organs against mechanical shock and any other damage.
h) Some of it can be converted into glucose to support respiration

DIGESTION OF FOOD IN OTHER

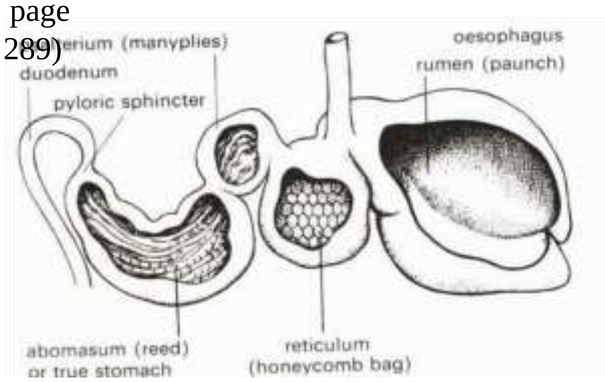
Herbivores are animals which mainly eat plants and algae. Herbivorous mammals have the following adaptations to their nutrition.

a. Their molars and premolars have cusps and ridges for maximum grinding of the hard cellulose materials into smaller particles.
b. They have large and well developed molars and premolars for maximum grinding of the hard cellulose materials into smaller particles.
c. The joints between the upper and the lower jaw are loose to allow their movement sideways, upwards and downwards. These movements of the jaws enable the maximum grinding of cellulose materials into smaller particles.
d. They have well developed masseter muscles to provide enough power for grinding and crushing the tough cellulose materials into smaller particles.
e. Some mammals have a four chambered stomach which enables them to chew their cud for maximum grinding and crushing of the tough cellulose material.
f. The surface of the upper molars and premolars are highly folded into a W-shape to allow for maximum crushing of the food as it fits very well into the shape.
g. Tongue is highly muscular for manipulating food during chewing
h. They contain mutualistic cellulose bacteria for the chemical digestion of cellulose into simple sugars.
i. The upper jaw lacks incisors to provide a hard pad against which the lower incisors press and cut the grass.
j. Between the front and cheek teeth, there's a gap called diastema used by the tongue to manipulate and separate food
   i.e. the firmly crushed grass is separated from the one being chewed for the first time.

FOOD DIGESTION IN RUMINANT MAMMALS

Ruminant mammals digest cellulose using a four chambered stomach. Such mammals include cattle, goats, sheep
e.t.c. by using their lower incisors, grass is pressed against the upper horny part and crushed or cut into very small pieces. It is then grinded and crushed using the large and well developed premolars and molars at the back of the jaw. The tongue is used to mix it with saliva and roll it into a bolus for easy swallowing. In the rumen/paunch, food undergoes fermentation (anaerobic respiration) and the cellulose is digested by enzymes from the cellulose digesting bacteria called cellulase. The enzyme breaks down cellulose to ***glucose*** which undergoes fermentation to form ***organic acids***. Ethanoic acid, butanoic acid, propanoic acid as well as carbon dioxide and ethane are produced plus heat which keep the animal warm. These acids are absorbed into the blood stream by the ruminant animal through the

Diagram to show the four chambers of the ruminant digestive system (Clegg fig 13.22 page 289)



walls of the rumen. Carbon dioxide and ethane are breathed out as gases. The organic acids that are absorbed are used as the major source of energy by the animal in respiration.

Note: the bacteria benefit from this mutualistic association by obtaining food and shelter as well as protection from damage or any other danger.

From the rumen, food enters the reticulum/honey comb bag where further fermentation occurs. From the reticulum, food is regurgitated through the oesophagus to the mouth for more grinding and crushing into simpler forms to provide a large surface area for its maximum digestion by cellulose. Thereafter, the food is reswallowed back to the stomach and directly to the omasum/psalterium where water is osmotically absorbed into the blood stream as well as straining and concentrating the food.

From the omasum, food moves too another chamber called the abomasums which is the true stomach of the ruminant where the walls secrete digestive enzymes for chemical digestion of food into simpler forms

Note: other examples of mutualistic associations include the following.

1. **Cellulose digestion in termites**

   The wood eating termites contain in their intestines, a flagellate organism called *Trichonympha* which absorbs food by phagocytosis and then secretes cellulase into the food vacuole to digest the food (cellulose). Some of the products of digestion escape into the gut of the termite which uses them for respiration. The flagellate therefore benefits from the association by getting the food nutrients from the termite as it digests the food taken by the termite and also gets shelter from the termite. The termite gets already digested food from the flagellate for its metabolic activities.

2. **Cellulose digestion in rabbits (Non ruminants)**

   Non ruminants have an enlarged caecum and appendix which contain a large population of cellulose digesting bacteria that secrete cellulose enzyme which digests the cellulose into simple materials. In this mutualistic association, the herbivore provides the bacteria population with shelter, protection and readily available supply of food in form of cellulose. The bacteria carry out the process of cellulose digestion thereby supplying the herbivore with end product of cellulose digestion.

Coprophagy

Coprophagia or coprophagy is the consumption of feces. Many animal species eat feces as a normal behavior; other species may not normally consume feces but do so under unusual conditions. Coprophagy refers to many kinds of feces eating including eating feces of other species (heterospecifics), of other individuals (allocoprophagy), or its own (autocoprophagy), those once deposited or taken directly from the anus.

Coprophagous insects consume and redigest the feces of large animals. These feces contain substantial amounts of semi-digested food (herbivores' digestive systems are especially inefficient). A notable feces-eating insect is the dungbeetle and the most common is the fly. Termites eat one another's feces as a means of obtaining their hindgut protists. Termites and protists have a symbiotic relationship (e.g. with the protozoan *Mixotricha paradoxa*) that allows the termites to digest the cellulose in their diet via the protists. It has also been proposed that hormones are passed to offspring in this way.

Pigs sometimes eat the feces of herbivores e.g. chicks that leave a significant amount of semi-digested matter, including their own. However, allowing domestic pigs to consume feces contributes to the risk of parasite infection. *Cattle* in the United States are often fed with chicken litter due to the high amount of protein and low cost of the feed compared to other sources of protein. *Capybara*, *rabbits*, *hamsters* and some other related species are hindgut fermenters which digest cellulose by microbial fermentation. In addition, they extract further nutrition from grass by ingesting their feces meaning their food passes through the gut a second time. *Soft fecal pellets* of partially digested food are excreted and generally consumed immediately. Consuming these cecotropes (or *night feces* produced in the cecum), is important for obtaining vitamin B12, which intestinal bacteria produce from Cobalt salts. The rabbit instinctively eats these grape-like pellets, without chewing, in exchange keeping the mucous coating intact. This coating protects the vitamin- and nutrient-rich bacteria from stomach acid, until it reaches the small intestine, where the nutrients from them can be absorbed. They also produce normal droppings, which are not eaten. Vitamin B12 must then be re-introduced to the digestive system since only the stomach (and not the intestines) is capable of absorbing vitamin B12. The young of *elephants* and *hippos* eat the feces of their mothers or other animals in the herd to obtain the bacteria required to properly digest vegetation found on their ecosystems. When they are born, their intestines do not contain these bacteria (they are sterile). Without them, they would be unable to obtain any nutritional value from plants. *Gorillas* eat their own feces and the feces of other gorillas. Similar behavior has also been observed among *chimpanzees.* Such behavior may serve to improve absorption of vitamins or of nutritive elements made available from the reingestion of seeds. *Hamsters*, *guinea pigs* and *chinchillas* eat their own droppings, which are thought to be a source of vitamins B and K, produced by bacteria in the gut. Apes have been observed eating horse feces for the salt content. Monkeys have been observed eating elephant feces. Coprophagia has also been observed in the rat. Mother *cats* are known to eat the feces of their newborn kittens during the earliest phase after birth, presumably to eliminate cues to potential predators and to keep the den clean.

FOOD DIGESTION IN CARNIVOROUS ANIMALS

Carnivores are animals that mainly eat other animals. The diet of carnivorous animals consists of mainly blood and animal tissue (proteins) these animals act as predators i.e. a predator is an animal which hunts, captures and kills another animal called prey for food. Carnivorous animals have got the following adaptations which enable them to capture their prey;

a. Most predators have a sharp sense of smell to easily locate their prey.
b. Most predators have well developed sharp pointed canines for tearing the fresh of the prey.
c. Some have carnassial teeth present for shearing flesh.
d. They are usually able to run very fast as compared to their prey in order to capture the prey.
e. Most predators are physically stronger than their prey so as to easily capture the prey.
f. Some predators swallow the whole prey by having highly elastic mouth parts i.e. the jaw bones are not tightly fixed together e.g. in the python
g. Some have a long and sticky tongue for reaching distant prey e.g. toads.
h. Most predators have very sharp claws that are used to hold the prey and kill it.
i. Most predators have a keen eye sight to easily see their prey from a distance.

j. Most predators carry out stealth movement which enables them not to alert their prey so that they can easily be captured.
k. Some of them carry out group hunting so as to successfully capture their prey e.g. lions

DIFFERENCES BETWEEN CARNIVORES AND HERBIVORES RELATED TO NUTRITION

Carnivores	Herbivores
• Closed pulp cavity in teeth • Upper jaw incisors present • Canines present and well developed • Carnassial teeth present • Cheek teeth pointed • Articulation of lower jaw prevents lateral movement • Relatively short alimentary canal • No cellulose digestion	• Open pulp cavity in teeth • Upper jaw incisors absent in most herbivores • Canines small or absent to create a diastema • Carnassial teeth absent • Cheek teeth flattened with enamel ridges and dentine grooves • Articulation of lower jaw permits lateral movement • Relatively long alimentary canal • Cellulose digestion occurs in caecum

SAPROTROPHISM (SAPROTROPHIC NUTRITION)

The process of obtaining soluble organic substances from extracellular digestion of dead or decayed organic matter.
Saprotroph: An organism that absorbs soluble nutrients from extracellular digestion of dead/decaying organic matter.

EXAMPLES OF SAPROTROPHS

(i) *Saprobes*: fungi like mushrooms, yeasts and moulds

(ii) *Saprophytes*: saprotrophic plants e.g. sugar stick, gnome plant, Indian-pipe and putrefying bacteria which convert complex organic substances into simpler compounds e.g. Zygomonas bacterium ferments glucose producing alcohol, lactic acid and carbon dioxide, Clostridium aceto butylicum forms butyl alcohol from carbohydrates, Lactobacillus converts sugars into lactic acid.

(iii) *Saprophages*: Animal scavengers, such as dung beetles and vultures

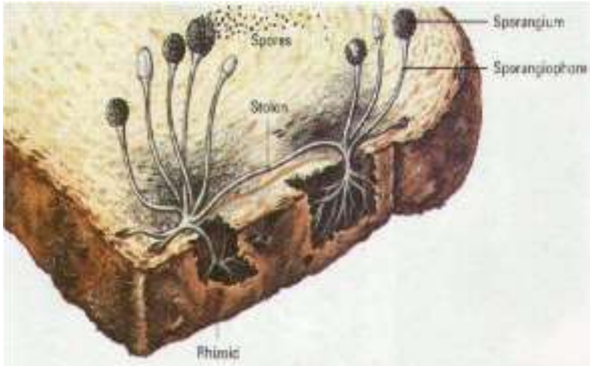
IMPORTANCE OF SAPROPHYTES

- Recycling of materials e.g. carbon, nitrogen, phosphorus
- Brewing and baking e.g. yeast (S*accharomyces*)
- Making antibiotics e.g. Penicillin
- Decomposition of wastes e.g. sewage
- Production of yoghurt and cheese
- Food source e.g. mushrooms
- Industrial applications e.g. leather tanning, production of vitamins, etc.

DESCRIPTION OF SAPROTROPHISM IN FUNGAL MOULD LIKE MUCOR/RHIZOPUS

Digestion in fungi is extracellular since it takes place outside the body of the fungus. Under suitable conditions (moisture / water, oxygen, neutral / mildly acidic pH, temperature of about 25 °C) hyphae secretes different enzymes into the dead animal/plant body through the cell wall (proteases, lipases, carbohydrases e.g. amylase) which break down insoluble complex organic substances into simple soluble substances as follows:
-Proteases break down proteins into amino acids
-Lipases break down lipids into fatty acids and glycerol

- Carbohydrases e.g. Amylases break down starch into maltose/simple disaccharides The end products of extra-cellular digestion such as fatty acids and glycerol, glucose, amino acids plus other nutrients like vitamins e.g. thiamine and ions e.g. potassium, phosphorus, and magnesium are re-absorbed into the hypha through the cell wall by endocytosis / simple diffusion / facilitated diffusion / active transport and passed on throughout the mycelium complex to enable growth and repair. As they feed, the hyphae branch and grow through the decaying food material. The thin hyphae and large number of branches ensure that the mould has a large surface area to volume ratio. Thus it is well adapted for secreting enzymes over a large area and absorbing the products of digestion.



COMPARISON OF SAPROPHYTES WITH PARASITES

Differences		*Similarities*
Parasites	**Saprophytes**	Both:
Energy derived from living organisms	Energy derived from dead organisms	**(1)** are heterotrophs **(2)** absorb soluble food **(3)** have simple digestive systems **(4)** have sexual and asexual phases in their reproduction **(5)** produce large numbers of offspring.
Most are aerobic	Anaerobic and aerobic	
Most plant and animal groups have representatives	Almost totally fungi and bacteria	
Nutritionally highly adapted	Simple methods of nutrition	
Very specific to their host	Use a variety of food sources	
Many stages in lifecycle	Usually a single adult stage, with spores inclusive	

PARASITIC MODE OF FEEDING

Parasitism is a close relationship between organisms of different species in which one organism called parasite obtains nutrients from and harms a larger living organism called host. There are two types of hosts;

a) **Primary host (final host/definitive host):** a host in which a parasite attains sexual maturity.
b) **Secondary host (Intermediate host)**: a host in which a parasite passes one or more of its asexual stages; usually designated first and second, if there is more than one.

Parasites are faced with the following problems which have made them develop various adaptations.

1. They face the danger of failing to penetrate the host
2. They face the danger of failing to obtain nutritive molecules from the host.
3. They may fail to attach themselves safely on the host so that they cannot easily be dislodged.
4. They face the danger of failing to find the right host which should disperse them to their final host in succeeding generations
5. They can be destroyed by the digestive enzymes and immune responses of the hosts.
6. They face the danger of being eliminated completely or becoming extinct.
7. They face a danger of failing to survive in areas of low oxygen tensions, excess heat, and darkness

Due to the above problems, parasites have developed structural, physiological and reproductive adaptations to increase their chances of survival.

Physiological adaptations

1. Production of enzymes by parasitic plants and animals which digest the tissues of the host external to the parasite so as to allow penetration into the host e.g. fungi and plasmodium
2. Production of anticoagulants by blood feeding parasitic animals such as mosquitoes and ticks so as to avoid blood clotting in the mouth during feeding
3. They are highly chemo sensitive in order to reach the optimum location in the host's body e.g. plasmodium
4. Most of them respire anaerobically so as to stay in areas of low oxygen tensions e.g. most endo parasites
5. They have developed an ability to tolerate high temperatures, darkness and pH changes in places where they live e.g. most endo parasites
6. They have very rapid means of escape which increases their chances of survival e.g. fleas and mosquitoes
7. Production of a lot of mucus by some parasitic animals especially the intestinal worms for self-protection against damage by the digestive enzymes of the host
8. Some endo parasites produce chemicals to protect themselves against the immune response of the host.

Structural adaptations	Reproductive adaptations
1. Development of penetrative devices for entry into the host e.g. penetrative houstoria in fungi, sharp proboscis in ecto-parasite, cutting teeth in hook worms (*Necatar Americana* and *Ancrylostema duodenata*) 2. Suckers in leeches and tight spirals in Cuscuta 3. Development of a thick resistant outer covering in some parasites so as to resist the action of digestive juices and enzymes e.g. in endo-parasites such as Ascaris and Taenia e.t.c 4. Development of body colours which enable them to camouflage and increase their chances of survival e.g. the brown ticks resemble the brown colour of the brown cattle 5. Development of much specialised mouth parts in some ecto-parasites so as to penetrate the host and suck the nutrients e.g. the sharp stylets in fluid feeders like mosquitoes, aphids and tsetse flies. 6. Development of highly specialised haustorial structures by some parasitic plants such the Cuscuta (Dodder plants) which are equipped with penetrative enzymes such as cellulose that enables the parasite to penetrate and obtain nutrients from the host 7. They lack feeding organs, locomotory organs, sense organs and the alimentary canal so as to reduce their size and fit in the intestines or bodies of the host and for reducing energy expenditure on such organs for example *Fasciola hepatica* (liver fluke), tape worm, hook worm e.t.c. 8. Failure to develop photosynthetic pigments such as chlorophyll in some parasitic plants such as Cuscuta	1. Most of them are hermaphrodites with the ability to carry out self fertilisation to increase the rate of reproduction e.g. Fasciola, Taenia and Fungi. 2. Most of them have an asexual phase in their lifecycles to have a high rate of reproduction and avoid extinction. 3. Most of them carryout permanent union of the sexes to allow permanent coitus (mating) which increases the rate of reproduction e.g. *Fasciola*, and *Schistosoma* (blood fluke) 4. Release of sexually mature forms of the parasites as free living organisms e.g. in some parasitic animals such as the horse hair worms 5. Production of large number of infective agents such as eggs, cysts, and spores which increases their chances of survival to avoid extinction e.g. a single tape worm may produce over 10 million fertile eggs per year. 6. Development of reproductive bodies that are highly resistant when out of the host so as to survive adverse or unfavourable conditions e.g. development of cysts in protozoan such as amoeba, Cyst circus (blood worms), spores in fungi e.t.c. Development in the above structures is suspended until when they reach the proper host. 7. Use of an intermediate host (vector) for their transfer to the primary host e.g. malaria parasite, plasmodium is carried by the female anopheles mosquito to man. The pore is a vector for *Schistosoma mansoni*. 8. Some parasites localise the strategic points where the opposite sex can easily get them for easy transmission from one organism to another e.g. *Meisseria gonorrhea* which causes gonorrhea, *Trepanema pallidum* which causes syphilis, HIV which causes AIDS are localised in the sex organs for easy transmission. 9. Some parasites use hereditary transmission which carries them to other hosts to increase the chances of spreading. Hereditary transmission is whereby some parasites infect the ovary of the primary host such that the eggs laid or the young ones born are also infected with parasites.

Control of parasites

a) Avoid eating infected under cooked meat
b) Through proper disposal of sewage which prevents these worms from spreading

c) Through cooking meat thoroughly for example prolonged heating destroys the tapeworm bladders
d) Give an infected person doses of medicine which flushes the worm out of the wall of the intestines in faeces, for example $CuSO_4$ and 40% ricotine.
e) Through regular meat inspection before it is consumed by man.
f) By prohibition of the discharge of raw sewage into inland waters and seas.

PARASITIC FLATWORMS

Phylum Platyhelminthes

Class	Parasite	Host		Harm caused to host
		Primary	Secondary	
Trematoda	*Fasciola hepatica* (liver Fluke)	Sheep Cow	Pond snails	Liver rots
	Schistosoma mansoni (blood fluke)	Human beings	Pigs	Schistosomiasis **(**Bilharzia**)**
Cestoda	*Taenia solium* (Pork tape worm)	Human beings	Pigs	Aneamia - Diarrhea Weight loss Abdominal (intestinal) pain
	Taenia saginata (Cattle tapeworm)	Human beings	Cattle	

Phylum Nematoda

This phylum contains a parasite called *Ascaris lumbricoides.* The parasite is transmitted through faecal pollution of soil which may be swallowed during feeding by humans. This parasite develops in the small intestines when its eggs are ingested.

LIFECYCLE OF TAENIA

Taenia is an endoparasite. They are of two types i.e. beef tapeworm and

Adaptations

the pork tapeworm. The beef tapeworm lives in the intestines of a cow
whereas pork tape worm lives in the intestinal walls of humans. The i. It has hooks and suckers that allow it to
lifecycle of taenia involves two vertebrate hosts. With the beef hold on tightly to the wall of the
tapeworm, the cow is the intermediate host whereas with pork tapeworm, intestine man is the
primary host and the pigs are intermediate hosts. ii. Its flat body gives it a large surface
area for absorbing its hosts digested food The adult tapeworm is a ribbon-like platyhelminthes up to
3-10 metres iii. Suckers are for attachment and a body long. The tapeworm consists of a
'scolex' or a 'head' followed by a covering which protects them from the linear series of segments
called proglotidds. Proglotidds are more than host's immune digestive system.
1 mm thick. iv. They have no gut which enables them to
absorb predigested food.

The anterior part of the head is a small muscular knob bearing suckers v. It lays many eggs to ensure survival and a double row of curved hooks at the top. Behind the scolex, the vi.
Hooks for boring through the gut of the narrow neck region gives to proglotidds by a continuous process of host

budding. As individual segments grow and mature, they are pushed back vii. Eggs have a thick shell which are not
from the scolex. Each mature proglotidds, contains a hermaphroditic set easily destroyed
of reproductive organs and following self-fertilisation.

Eggs develop shells and yolk before passing to the uterus which fills and they accumulate. The egg shell dissolves and the tiny embryo emerges. At intervals these segments known as gravid proglotidds, break off the chain and one expelled with the host's faeces. Six-hooked embryos are each surrounded by a hard case until this is dissolved by the digestive juices of the secondary host.

Embryos bore the gut wall and get into the muscles carried by blood where they develop into bladder worms. The bladder worm is ingested by man when under cooked infected meat. Finally larva makes entry into the human gut through the scolex which turns inside and out, and attaches onto the gut wall.

NOTE: further development only takes place when the eggs are consumed by the intermediate host.

LIFECYCLE OF LUMBRICOIDES

Ascaris lumbricoides, is a round worm (nematode) that inhibits the human small intestines. Ascaris can reach a length of 30cm, and a hundred of this size are enough to block the intestine and kill the host.

Usually males are smaller than females. During its life cycle, eggs are passed out of the female into the host's intestines and are deposited in the faeces. After a developmental period, when they are swallowed by the proper host for example man. Usually, in food they hatch into larvae which burrow into veins or lymph vessels to the intestinal walls. They move to the heart and pulmonary arteries where they are carried to the lungs while growing in size.

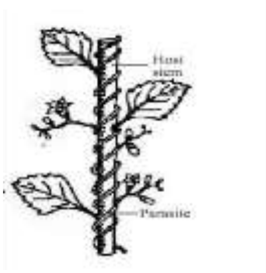
Once in the lungs, they climb the air passages (bronchii and trachea) and through the trachea reach the oesophagus then to the stomach and to the intestines where they block the intestinal lumen when they become too many in it and so when they block the air passage they lose their way into them as they migrate from the lungs. This parasite does not have an intermediate host.

Adaptations of Ascaris to a parasitic mode of life

a) Possession of a muscular pharynx with which food is sucked in from the intestines
b) Possession of a resistant cuticle which has the ability to resist destruction by the host's digestive enzymes and juices.
c) Ability to position itself in a habitat where it gains maximum benefits of protection, warmth and above all nourishment.
d) Lay eggs which are protected by a resistant shell which is their main ineffective and resistant stage
e) Ability to respire anaerobically in such an oxygen deficient environment
f) Ability to copulate within the intestines followed by the laying of copius quantities of eggs by the females.

PARASITIC PLANTS AND FUNGI

Cuscuta on a host plant



The dodder plant (Cuscuta).

Division/phylum: Tracheophyta

Subdivision: Spermatophyta (bears seeds)

Class: Angiospermatophyta (produces seeds)

Order: Convolvales (twinning/crippling plants)

Family: Convolvalaceae (fixes other plants for nutrients)

LIFECYCLE OF CUSCUTA

It is at times called dodder, which is a stem parasite. Cuscuta is a flowering plant belonging to the family convolvulaceae. Most members of this family have twinning stems and include morning glory and sweet potatoes. The dodder is a very long twinning plant and sometimes reaches up to 720m long. Cuscuta does not have chlorophyll and therefore has yellow stems, leaves and flowers.

Members of this genus are all obligate parasites mostly of higher plants. The parasite has the capacity to spread rapidly on its host. It does not only draw heavily on the host for food substances but also results in a dense and shady barrier (canopy) over the host which drastically reduces the growth and vigor of the host plants mainly by shading off light. It is non-specific and this facilitates its rapid spread to neighbouring plants.
The dodder reproduces by means of small seeds but also vegetatively by de-touched stem pieces and this makes it difficult to eradicate. When its seeds reach the ground, they germinate with the radicles poorly penetrating the ground. The remaining part of the embryo digests its enveloping endosperm and passes most of its nutrients to the radicle which broadens out after which the middle part of the young shoot loops, straightens out and rotate in search of a host.

As soon as the shoot gets into contact with the host, the radicle dies out so that there is no more contact within soil. It then starts getting all nutrients from the host using sucking houstoria. After germination the parasite can live without a host for only about nine days after which it dies but it finds one it is capable of flowering and fruiting within 38 days.

Adaptations of dodder to a parasitic mode of life

a) It's a non-specificity makes it able to survive on a wide range of hosts
b) Loss of unwanted organs like roots since it absorbs its food directly from the host and lack of chlorophyll together with a reduced leaf area since the plant hardly needs to photosynthesise.
c) Possession of sucking roots known as haustorial which are equipped with the necessary enzymes which dissolve the host's walls of conducting tissues where they absorb water, organic nutrients and mineral salts.
d) Ability to reproduce faster, both sexually by producing a large number of viable seeds and asexually by fragmentation. This facilitates its dispersal.

LIFE CYCLE OF *PHYTOPHTHORA INFESTANS*

Phytophthora is one of the parasitic fungi

- *Phytophthora* produce two kinds of spore i.e. diploid oospores, formed sexually from fusion of haploid antheridia and oogonia, and
- chlamydospores formed asexually. Both types of spore have thick cell walls for surviving harsh conditions.
- Under cool wet conditions, *Phytophthora* spores (oospores or chlamydospores) germinate to form
- hyphae or directly produce sporangia. Sporangia release free swimming biflagellated zoospores, which travel in moisture at the surface of leaves, and in soil. On reaching plant root or leaf surface a zoospore forms a cyst.
- The encysted zoospore then germinates to form hyphae on the host surface, which penetrates plant
- leaf or root tissues to absorb nutrients. After *Phytophthora* infects the
- plant, it produces sporangia and zoospores which further infect
- other tissues of the same plant or nearby plants. Sexual reproduction occurs when positive and negative mating types are present. Haploid nuclei of antheridium and oogonium fuse together when the antheridium enters the oogonium to form a diploid oospore, which develops into a sporangium and the cycle will continue as is would asexually.

Comparison between cyclic and non-cyclic photophosphorylation		
Differences		**Similarities,**
Non-cyclic photophosphorylation	**Cyclic photophosphorylation**	**in both**
Electrons flow unidirectionally	Electrons flow cyclically	• ATP is formed • photosystem I is involved • electron movement is located in the thylakoid membrane • protons are moved out of the thylakoids • protons are actively pumped from the stroma into the thylakoid space • there is photo excitation of electrons in photosystems • there is flow of electrons through several electron carriers • there are pigment systems which accept and loose electrons
First electron donor is water (source of electrons)	Fast electron donor is photosystem I	
Last electron acceptor is NADP	Last electron acceptor is photosystem I	
The products are ATP, $NADPH_2$ and oxygen	The product is ATP	
It involves both photosystems I and II	It involves only photosystem I	
Photolysis of water occurs	There is no photolysis of water	

(Glen and Suzan Toole, fig 14.7 page 278

SAMPLE QUESTIONS

1. The table below shows how the rate of photosynthesis of C4 and C3 plants vary with the temperature at different light intensities. The rate is in arbitrary unit.

Temperature/^{0}C		0	5	10	20	30	35	40
Rate of photosynthesis	C_4 plants at high light intensity	0	5	12	25	28	32	38
	C_3 plants at high light intensity	0	10	12	15	18	20	10
	C_3 plants at low light intensity (Arbitrary units)	0	2	5	8	10	10	6

a) Represent the above results graphically on the same axes. (8mks)

b) Explain how differently temperature affects the rate of photosynthesis in C_3 plants from C_4 plants at high light intensity.

c) Explain the changes in rate of photosynthesis for C_3 plants under low light intensity. (8mks

d) Explain the effect of light intensity on the following. (6mks)

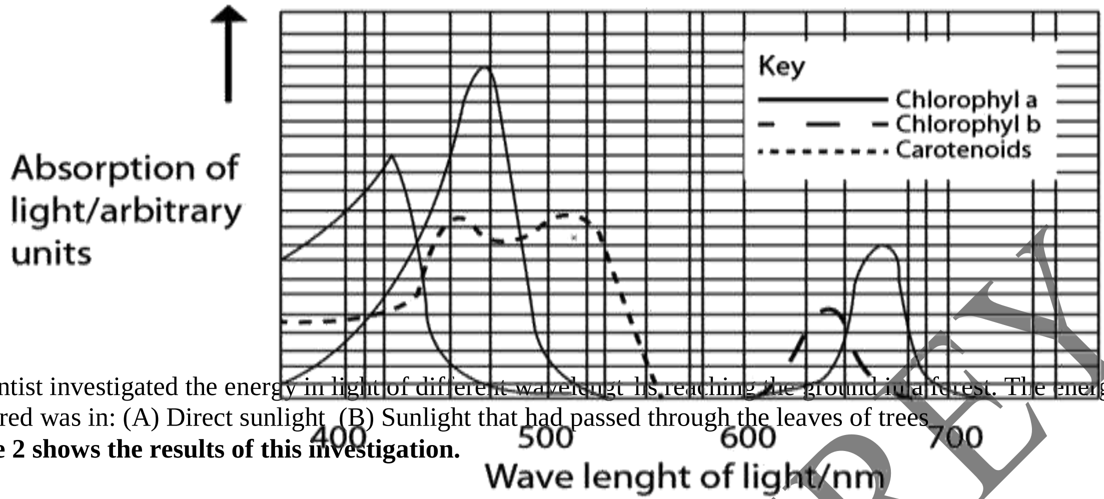
i) Leaf colour ii) Leaf size iii) Internode length

e) Name three other factors that may limit the rate of photosynthesis. (3mks)

f) Differentiate between the concept of limiting factors and competitive exclusion principle. (6mks)

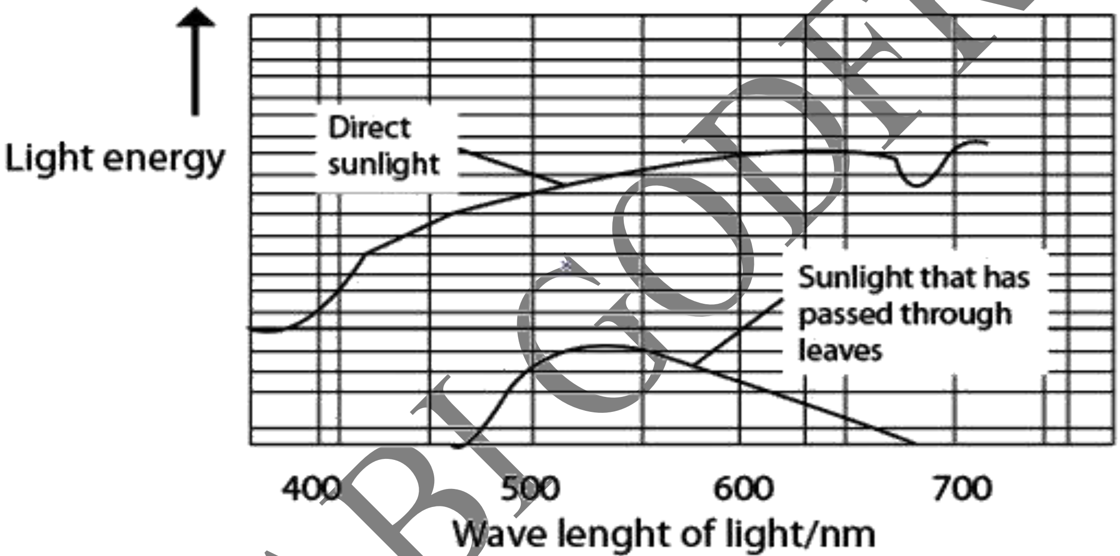
2. Chlorophylls and carotenoids are plant pigments that absorb light for photosynthesis. Different species of plant contain different amounts of these pigments. The pigments that each plant species has are adaptations to where and how they live, their ecological niche

Figure 1 shows the absorption of light of different wavelengths by chlorophyll a, chlorophyll b and carotenoids.



A scientist investigated the energy in light of different wavelengt hs reaching the ground in a forest. The energy measured was in: (A) Direct sunlight (B) Sunlight that had passed through the leaves of trees

Figure 2 shows the results of this investigation.



Sun leaves and shade leaves are two different kinds of leaves on beech trees. Sun leaves grow on branches exposed to direct sunlight, shade leaves grow on branches exposed to light that has passed through leaves. An ecologist collected sun leaves and shade leaves from beech trees and determined the mean mass of each photosynthetic pigment in both types of leaf. The results are as shown in figure 3

Photosynthetic pigment	**Mean mass of each pigment per m^2 of leaf area/µg**	
	Sum leaves	**Shade leaves**
Chlorophyll a	299.3	288.9
Chlorophyll b	90.7	111.1
Carotenoids	0.10	0.07

(a) Plot a suitable graph to represent the data in figure 3

(b) Describe the absorption of light of different wavelength by chlorophyll

(c) Comment on light absorption of different wavelengths by chlorophylls and carotenoids (d) Explain

(i) The penetration of light through the forest

(ii) Why few species of plant can survive under shady habitats

(e) Explain

(i) The advantage of producing more chlorophyll b in shade leaves to beech trees

(ii) Why in leaves at the top of trees in a forest, carbon dioxide is often the limiting factor for photosynthesis

(f) Each type of pigment is produced by a specific enzyme-controlled pathway. Suggest how the same plant can produce more pigment in some leaf cells than others

(g) Suggest the morphological adaptations of plants for shady environment

(h) With evidence explain the role of carotenoids to leaves of plants

3. (a) Compare photosynthesis and aerobic respiration. (9mks)

(b) Explain the effects of low oxygen on

(i) C_3 plants (ii)
C_4 plants

(c) Explain why C4 plants are more efficient in photosynthesis than C3 plants.

4. The table below shows the results obtained in an experiment to study the effects of carbondioxide on the rate of photosynthesis of two plant species, one growing in an area of high light intensity and the other growing in an area of high light intensity. The photosynthetic rate was measured in arbitrary units.

Carbondioxide concentration by volume		0.02	0.04	0.06	0.10	0.12	0.14	0.16
Photosynthetic rate (arbitrary units)	High light intensity plant	33	55	68	87	89	90	90
	Low light intensity plant	10	20	40	42	44	45	45

a) Represent the above results graphically (9mks)

b) Compare the shapes of the curves obtained for high and low light intensity plants. (8mks)

c) Explain your comparisons in (b) above (6mks)

d) Describe the shape of the graph obtained under low light intensity. (5mks

e) What is the effect of the following on the rate of photosynthesis?

(i) Carbondioxide concentration. (2mks)

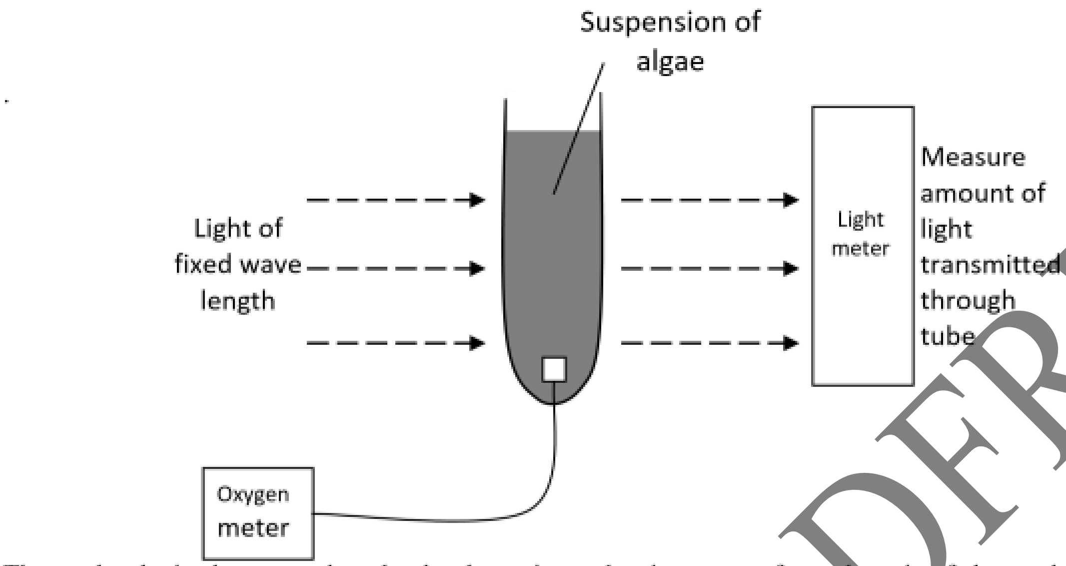
(ii) Light intensity (2mks)

f) (i) State the normal atmospheric carbondioxide concentration. (1mk)

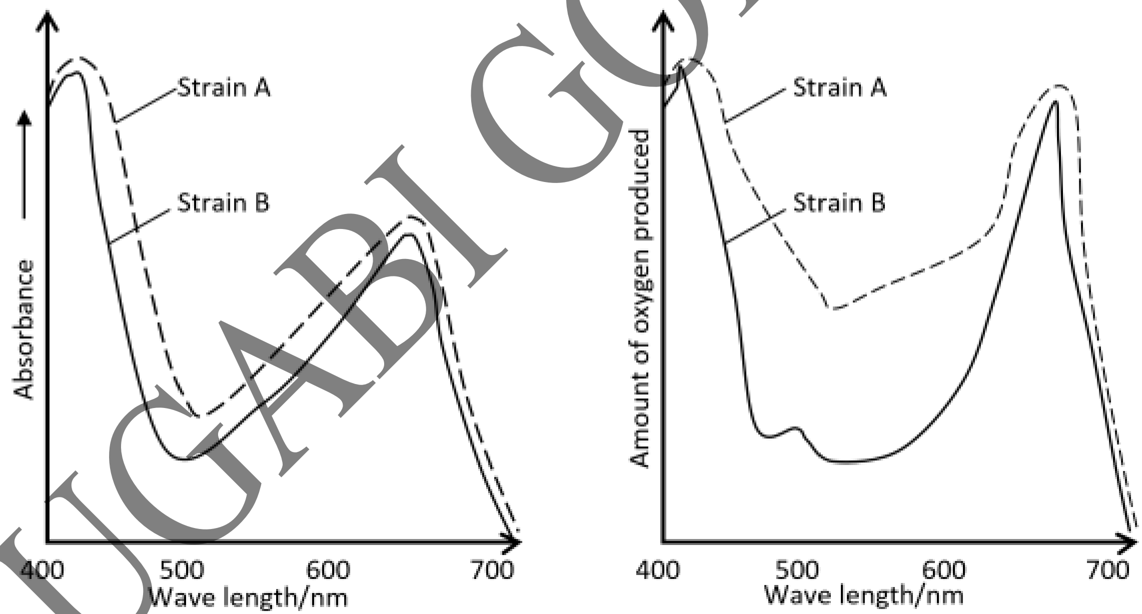
(ii) What is the rate of photosynthesis at the normal atmospheric carbondioxide for each plant? (2mks)

g) State the adaptations of the leaf for photosynthesis (5mks)

5. Investigations were carried out using two strains of the same species of unicellular alga, one of which was a mutant that could not survive long periods of intense illumination. Light of known wavelength was passed through a tube containing the alga and measurements were taken both of oxygen produced and of the light transmitted. The experimental setup was staged as shown below



The results obtained were used to plot the absorption and action spectra for each strain of alga as shown below.



a) State how the absorption and action spectra of the two strains are comparable

b) Using the information provided, with a reason state which of the two strains why algae is a mutant.

c) Explain the changes in amount of oxygen produced by strains A and B of algae

d) Suggest the precautions that can be undertaken to obtain accurate results from the experiment above. Give reasons for your answer

e) (i) other than measurement of amount of oxygen produced which other methods can be used to obtain the results of the action spectrum above

(iii) Explain why the method used to obtain results of action spectrum is not considered to be accurate

(iv) How are the algae used in the experiment adapted for photosynthesi

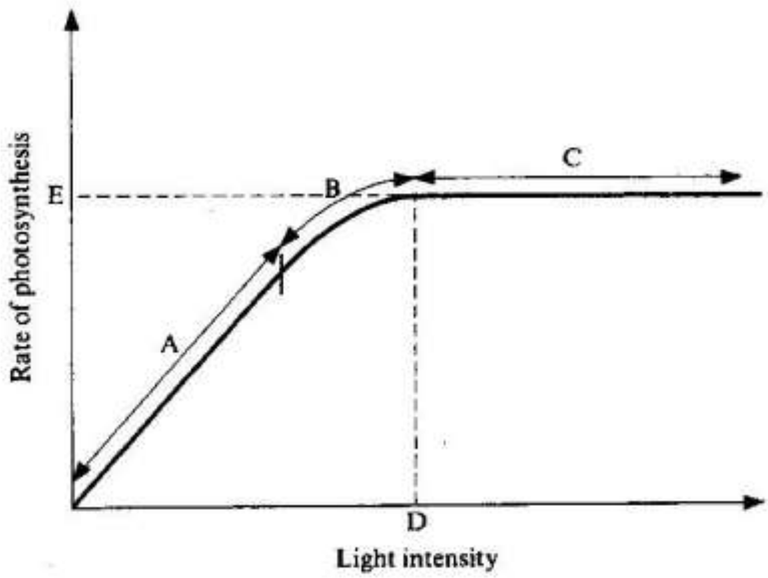
6. a) What is meant by the following in regard to photosynthesis? (2 marks)

i. Kranz anatomy

ii. C_3 plants

(b) *In spite of the higher productivity of C_4, which is almost four times greater than in C_3, majority of plants perform C3 photosynthesis. Explain this statement fully.*

(c) Give 2 **structural** differences between C_3 and C_4 plants (2 marks) (d) The figure below illustrates the concept of limiting factors.

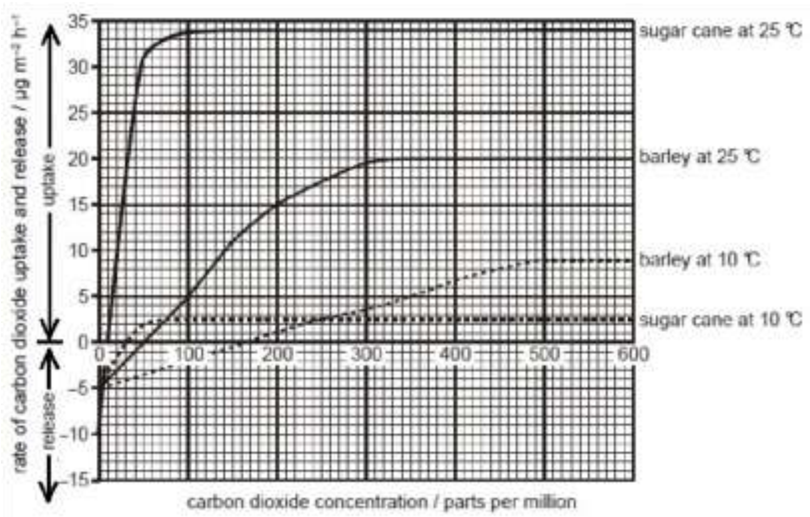


(i) State the principle of **'limiting factors'** (1 mark).

(ii) Explain the limiting factor at A? (3 marks)

(iii) What is represented by point E (2 marks)

7. In an investigation of photosynthesis, the rate of carbon dioxide absorption by leaves of two plants, barley and sugar cane, was measured. The leaves were provided with air, moving at a constant rate, through an apparatus shown below: Light intensity was kept constant and high, equivalent to full sunlight. Concentration of CO_2 in air entering the apparatus could be varied. The carbon dioxide taken up or given out by the leaves was determined by calculating the **difference** between the concentration in the inflowing and Leaves remained attached to the plants during the investigation. Two different temperatures, 10 °C and 25 °C, were used for each type of plant. The results of the investigation



(a) For each plant species, describe the observed carbon dioxide uptake / release at the different temperatures (11 marks)

(b) Explain the observed carbon dioxide uptake / release in the two species at the different temperatures. (08 marks)

(c) Explain why all the measurements were made at the same light intensity.

(d) Suggest why it was important that the leaves remained attached to the plants while the measurements were made.

(e) Compare the response of the two species, sugar cane and barley, to differences in carbon dioxide concentration and temperature.

8. a) State the features of a leaf that favour carbon dioxide diffusion (03 mark

b) Explain how the diffusion of carbon dioxide into the leaf is enhanced by its features(03 marks)

c) The diffusion of CO_2 into a leaf is bound to meet several resistances. State **one** area carbon dioxide diffusion

is likely to meet resistance(01 mark)

State how increased abscissic acid level regulates stomata movement (03 marks)

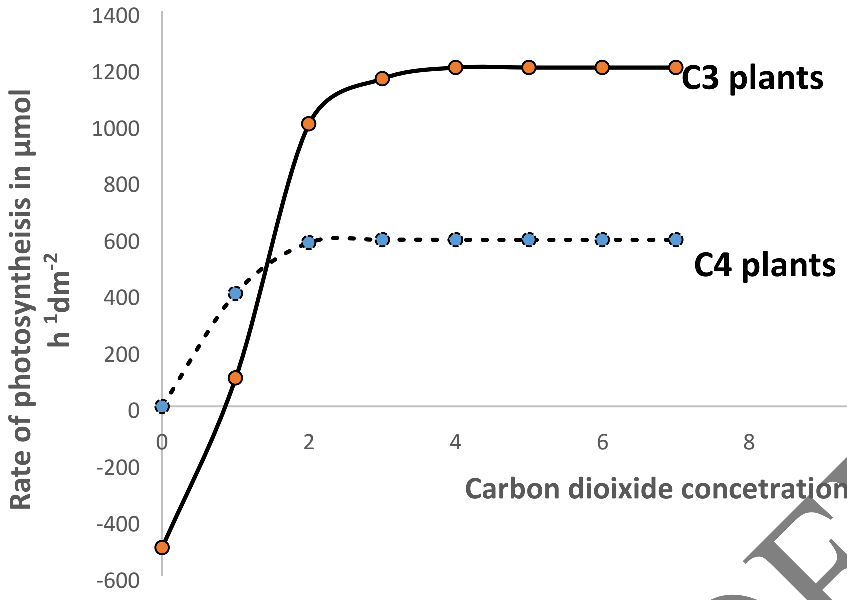
9. (a) Briefly describe the type of **plant cells** concerned with the transport of

i. Water and salts (03 marks)

ii. Sugars and amino acids (03 marks)

(b) Briefly explain how each of the cells described above are important in support of woody plants (04 marks)

10. The figure below shows the variation of rates of photosynthesis of C4-plants and C3-plants with increase in carbondioxide concentration in the leaves.



(a) State the difference(s) in the rate of photosynthesis of C4 plants and C3 plants when carbondioxide concentration increases from 0 to 4 µmol. (*03Marks*)

(b) Explain how the rate of photosynthesis in both C4 and C3 plants would vary during extremely high concentration of carbondioxide. (*03 Marks*)

(c) Suggest with reasons which of the C3, C4 and CAM plants would be severely limited to carry out photosynthesis in;

(i) Cool and wet conditions (*02 Marks*

(ii) Hot and dry conditions (02 Marks)

11. An experiment was carried out to investigate the photosynthetic rates of three vegetative crops; gynadropsis, crotalaria and amaranthus grown under the same natural illumination, water and atmospheric air regimes. The rates of photosynthesis are in carbon dioxide uptake in mg dm^{-3} of leaf per hour.

Temperature (^{0}C)	**CO_2 uptake (mg dm^{-3})**		
	Gynandropsis	Crotalaria	Amaranthas
05	00	20	0
10	22	40	10
15	50	49	27
20	60	54	42
30	80	48	55
35	85	45	54
40	80	42	50
50	66	15	40
60	02	00	11

a) (i) On the same axes plot graphs of rate of photosynthesis (CO_2 dm^{-3}) of a leaf per hour. Against temperature (^{0}C) for the three crop species. *(17 marks)*

b) Comment briefly on the relative photosynthetic rates of the three crop species. *(03marks)*

c) Describe the carbon dioxide uptke for the three plants?
(10 marks)

d) How are the photosynthetic rates of these plants affected at 60^{0}C? Give explanation. *(04 mar*

e) On the basis of the photosynthetic capacities of the three plants, what can you deduce about their ecological ranges?

f) List two other factors that affect rate of photosynthesis in plants.
(02 marks)

12. The table below shows the results obtained in an experiment to study the effects of carbondioxide on the rate of photosynthesis of two plant species, one growing in an area of high light intensity and the other growing in an area of high light intensity. The photosynthetic rate was measured in arbitrary units.

Carbondioxide concentration by volume		0.02	0.04	0.06	0.10	0.12	0.14	0.16
Photosynthetic rate	High light intensity plant	33	55	68	87	89	90	90
	Low light intensity plant	10	20	40	42	44	45	45

a) Represent the above results graphically (9mks)

b) Compare the shapes of the curves obtained for high and low light intensity plants.
(8mks)

c) Explain your comparisons in (b) above (6mks)

d) Describe the changes in the photosynthetic rate obtained under low light intensity. (5mks

e) What is the effect of the following on the rate of photosynthesis?

(iii) Carbondioxide concentration. (2mks)

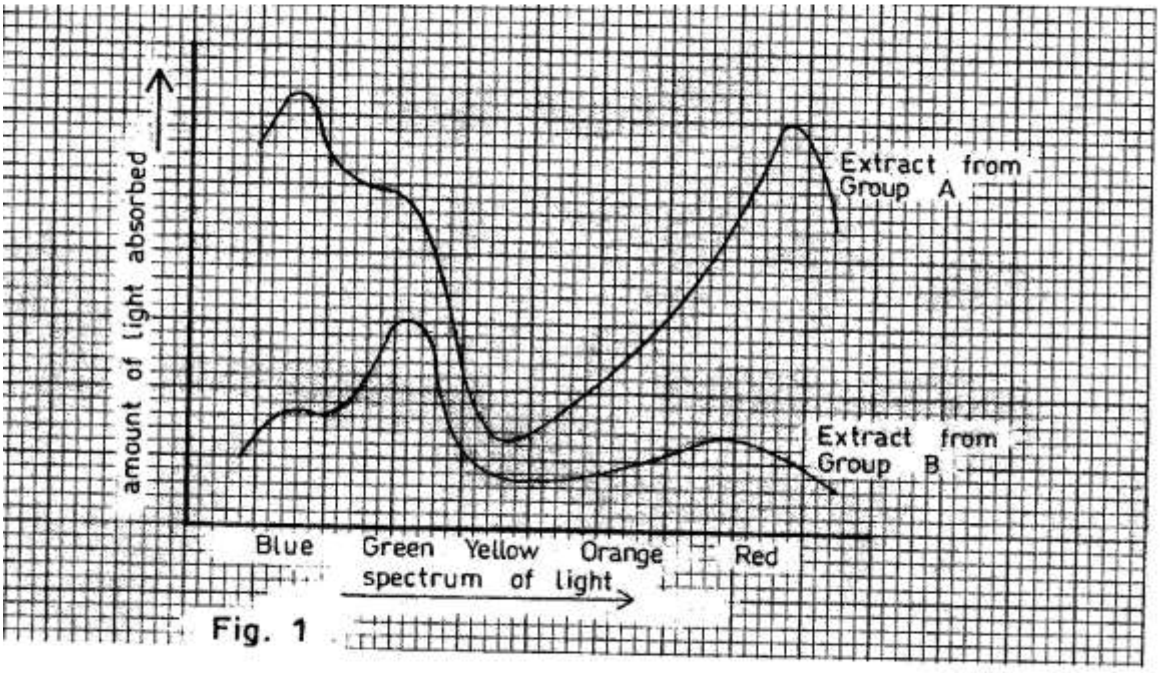
(iv) Light intensity (2mks)

f) (i) State the normal atmospheric carbondioxide concentration. (1mk)

(ii) What is the rate of photosynthesis at the normal atmospheric carbondioxide for each plant? (2mks)

g) State the adaptations of the leaf for photosynthesis (5mks)

13. Two groups of maize seeds were germinated and grown in different culture solutions. Group A were provided with a complete nutrient solution while Group B were provided with a solution lacking magnesium. An extract of photosynthetic pigments was made from leaves of each group of seedlings at the end of three weeks. Figure 1 is the absorption spectra obtained from the extracts.



In another experiment, six identical shoots of pond weed were placed in separate test tubes of pond water in which a dilute solution of sodium hydrogen carbonate had been added. Each test tube was then exposed to light which had passed through a different coloured filter. The light in all cases was from a 40 watt bulb, placed 40 cm from the test tube. The time taken for 20 bubbles to leave the cut end of each shoot was recorded three times and the average results are recorded in Table 1.

Table 1

Colour of filter	**Average time taken to release 20 bubbles in seconds**	**Number of bubbles released per minute.**
Violet	58	
Blue	40	
Blue-green	62	
Green	132	
Yellow	96	
Orange-red	70	

Use the information to answer the questions that follow:

a) Compare the light absorption by extract from Group A and that from Group B across the light spectrum.

b) Explain the light absorption across the light spectrum for each extract.

c) How does a coloured filter affect light passing through it.

d) (i)Copy and complete Table 1, by calculating the number of bubbles released by each shoot per minute.
(ii) Plot a graph to show the relationship between the colour of the filter and the rate at which bubbles are
released

e) (i) Compare your graph with that in figure 1, and state the relationship between the two;
(ii) What conclusion can you draw from the relationship?

f) State what would be observed if the distance between the bulb and the test tubes was gradually reduced. Explain your answer.

g) Explain why

(i) the type of bulb and the distance of the bulb from the test tubes were kept constant.

(ii) a dilute solution of sodium hydrogen carbonate was added to pond water in the test tubes.

(iii) There were three measurements made on each shoot rather than a single one.

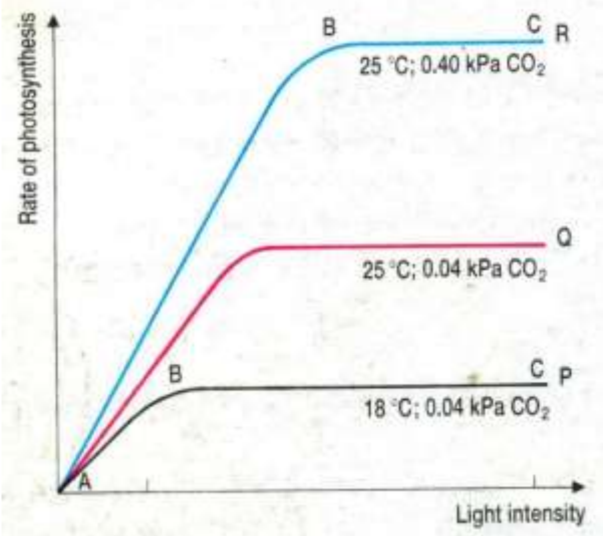
14. (a) Measuring the rate of photosynthesis by counting bubbles is not an accurate method. Outline the lightindependent reactions of photosynthesis.

(b) (i) Explain: (i) why the light-independent reactions of photosynthesis can only continue for a short time in darkness.

(ii) how the light-independent reactions of photosynthesis rely on light-dependent reactions.

15. a) State **two** pieces of evidence that photosynthesis is a two stage process (*02 marks*)

The figure below shows the results of three experiments on the effects of changing light intensity on the rate of photosynthesis under different environmental conditions.



b) Compare the rates of photosynthesis in curves **P** and **Q** (*04 marks*)

c) Suggest the factor which has been varied to produce the results in curves

i) **P** and **Q** (*1 mark*)

ii) **Q** and **R** (*1 mark*)

d) Suggest the factors responsible for the levelling off of curves

i) **R** (*1/2 mark*)

ii) **Q** (*1/2 mark*)

e) State the law that can be used to explain these results (*01 mark*)

END