HETEROTROPHIC NUTRITION

This is the type of nutrition in which organisms take in readymade organic food substances made by autotrophs (producers).

TYPES OF HETEROTROPHIC NUTRITION

1. **Holozoic nutrition:** involving feeding on solid organic materials obtained from the bodies of other organisms. This occurs in all animals, some protists and some specialised plants
2. **Saprotrophic nutrition (Saprophytic nutrition):** involves feeding on soluble organic compounds obtained from dead animals and plants. This occurs in many protists, fungi and bacteria and in some animals.
3. **Symbiosis:** the living together in close association of two or more organisms of different species involving nutrition. There are common types of symbiotic relationships i.e. ❖ Parasitism
   - ❖ Mutualism
   - ❖ Commensalism

NUTRIENTS, FOOD AND DIET

Organisms have two basic nutritional requirements i.e. energy and building materials which are supplied in the form of chemicals known as **nutrients**. Such nutrients are categorized into ❖ Organic nutrients: these include carbohydrates, lipids, proteins and vitamins ❖ Inorganic nutrients: these include mineral salts.

Such nutrients are found in the food we eat.

DIET

Diet is the quantity and nature of the food we eat i.e. which nutrients and how much of each.

Balanced diet

Is one which contains the correct proportions and quantity of the various nutrients, water and dietary fibre required to maintain health.

The essential nutrients for the balanced diet provide of a mammal consists of the following components.

- ❖ Carbohydrates and fats in relatively large quantities as sources of energy
- ❖ Proteins in large quantities for growth and repair processes
- ❖ Vitamins and minerals in smaller quantities for protection of good health and prevention of deficiency diseases.

NUTRIENT	FOOD SOURCE COMPOSITION	FUNCTIONS	DEFICIENCY DISEASE, SIGNS AND SYMPTOMS
Carbohydrates	Starch e.g. tubers, grains and pulses Sugars from corns, honey, root vegetables, milk, dairy products, fruits and canes Dietary fiber or roughage from	Starch and sugars provide energy to cells in the body once metabolized and oxidised. Starch and sugars such as glycogen stores energy in the body Presence of sugars is essential for sparing proteins in tissues and lipids in the body.	May contribute to **marasmus.** Nausea, dizziness, constipation, lethargy, dehydration, bad breath, loss of appetite Body becomes weak and thin

	cereals, fruits, vegetables, wheat , barley, legumes	sugars are building blocks for more complex molecules such as nucleic acids, nucleotides (e.g. ATP and NAD) formation of structure e.g. cellulose in plant cell wall and glycol proteins in cell membranes and chitin in exoskeleton of arthropods dietary fibers increase the bulk of stool and softens it to make bowel movements easier	
Lipids	Margarine, milk, cheese, eggs, butter, G.nuts, sim sim, fish, avocado	Source of energy upon their oxidation. Store excess energy from food in fatty tissue (adipose tissue) Glycolipids are essential for formation of cell membranes Form fatty membranes of the myelin sheath around certain nerves for faster nerve impulse propagation Heat insulators keeping the body worm Offer protection to vital organs in bodies of animals For absorption and transport of micronutrients such as fat-soluble nutrients.	Dry and scaly skin Dry eyes Feeling constantly cold Dry hair or hair loss Hormonal problems Inability to feel full Mental fatigue Constant fatigue Deficiencies in fatsoluble vitamins
Proteins	Animal products such as meat, eggs, milk, chicken, fish yoghurt and cheese Plant products e.g. soya bean, beans and nuts	Source of energy if the diet is deficient in carbohydrates and fat e.g. during starvation and fasting. Source of amino acids for synthesis of new proteins for growth and repair. For formation of structures e.g. cell membranes, hair, muscles and nails Constituent of protoplasm of cells They are regulators of body processes when they form enzymes and hormones	**Kwashiorkor** in children **Symptoms** General body weakness Pot belly Brown hair Loss of appetite Stunted growth Cracked skin around the ears and mouth Swollen legs, hands and feet

VITAMINS

These are essential non-protein organic compounds which are needed in small amounts for normal growth and metabolism. If the diet lacks a particular vitamin, a disorder called deficiency disease results. Vitamins are normally classified into two basing on their solubility: -

(a) Water soluble vitamins: these are soluble in water e.g. vitamins B and C, these are readily excreted in urine and must therefore be consumed regularly.

VITAMIN	MAIN FOOD SOURCES	FUNCTIONS IN BODY	SYMPTOMS OF DEFICIENCY

Vitamin B_1 (Thiamin)	Liver, lean meat, eggs, unpolished rice, yeast extract	Helps release energy form carbohydrates	**Beri beri** **Symptoms** • Decreased appetite • Gastrointestinal disturbance • Nerve and muscle disorder
Vitamin B_2 (Riboflavin)	Whole grain cereals, meat, liver, yeast extract	Component of FAD a coenzyme in respiratory metabolism Maintenance of healthy skin and mucosa	**Ariboflavinosis** **Symptoms** • Skin lesions such as cracks in the corners of the mouth • Blurred vision • Abnormal utilization of oxygen
Vitamin B_3 (niacin or nicotinic acid)	Meat, fish, liver, whole grain products, unpolished rice, nuts, yeast extract	Component of coenzymes NAD and NADP important in respiration and photosynthesis respectively	**Pellagra** **Symptoms** • Skin and gut lesions • Muscle weakness • Loss of appetite • Pigmentation of exposed areas of the chest
Vitamin B_5 (pantothenic acid)	Most foods but especially liver, egg and legumes	Component of vitamin A Carbohydrate and fat metabolism	▪ Fatigue ▪ Numbness ▪ Tingling in the hands and feet (burning feet syndrome)
Vitamin B_6 (pyridoxine)	Meats, vegetables, wholegrain cereals, yeast extracts	Forms coenzymes in amino acid metabolism	▪ Convulsions ▪ Kidney stones ▪ Sores in eyes and mouth ▪ Poor motor coordination
Vitamin B_{12} (cobalamin)	Liver, kidney, milk, eggs, cheese and meat	Form coenzymes in DNA metabolism Needed for maturation of red blood cells	**Pernicious anaemia** Malfunction of nerves due to the degeneration of axons of spinal cord Weight loss defective formation of red blood cells Muscle twitching
Biotin	Liver, yeast, vegetables, liver, kidney Synthesized by intestinal bacteria	Coenzyme in carboxylation reactions Coenzyme in fat, protein and carbohydrate metabolism	▪ Dermatitis ▪ Loss of appetite ▪ Nerve and muscle disorders
Folic acid	Green vegetables, nuts, yeast, liver, pulses, fish, legumes	Coenzyme in DNA synthesis and amino acid metabolism	Anaemia Gastrointestinal problems

Vitamin C (ascorbic acid)	Citrus fruits, dark green vegetables, potatoes	Stimulates synthesis of collagen fibres e.g. bones, cartilage and gums Antioxidant Improves iron absorption An electron carrier in respiration	Scurvy ▪ Bleeding gums ▪ Loosening of teeth ▪ Anaemia ▪ Red spots in the skin ▪ Degeneration of muscles and cartilage ▪ Joint pains ▪ Poor wound healing ▪ Increased susceptibility to infection

(b) Fat soluble vitamins: these are ones that are soluble in lipids e.g. vitamins A, D, E and K. fatsoluble vitamins tend to accumulate in fatty tissues of the body, and may even build up to lethal concentrations if taken in excess.

VITAMIN	MAJOR FOOD SOURCES	FUNCTIONS IN BODY	SYMPTOMS OF DEFICIENCY
Vitamin A (retinol)	Oranges, paw paw, green vegetables, carrots, liver, dairy food	Maintenance of normal epithelial structure Needed for formation of visual pigments	Night blindness Increased risk of infections especially of the mucous membranes Dry skin **Xerophthalmia** (drying and degeneration of cornea)
Vitamin D (calciferol)	Liver, fish oils, dairy products, action of sunlight on lipids in the skin	Absorption and metabolism of calcium and phoshorous Formation of bones	**Rickets** in children Weak bones Deformed bones **Osteomalacia** in adults Softening of bones
Vitamin E (tocopherols)	Liver, green vegetables, wheat germ oil, sunflower oil, peanuts	Antioxidant (prevents damage to phospholipids in cell membranes) Involved in formation of DNA, RNA and red blood cells Promotes fertility in rats Prevents haemolysis of RBC	Haemolytic anaemia Sterility in rats
Vitamin K (phylloquinone)	Green vegetables, synthesized by intestinal bacteria	Blood clotting	Failure of blood to clot

AN EXPERIMENT TO ILLUSTRATE THE IMPORTANCE OF VITAMINS IN DIET OF MAMMALS

In his investigations exploring the relationship between diet and growth in rats, **Frederick Gowland Hopkins** found that a diet consisting of protein, salts, fats, and carbohydrates **could not alone** support growth.

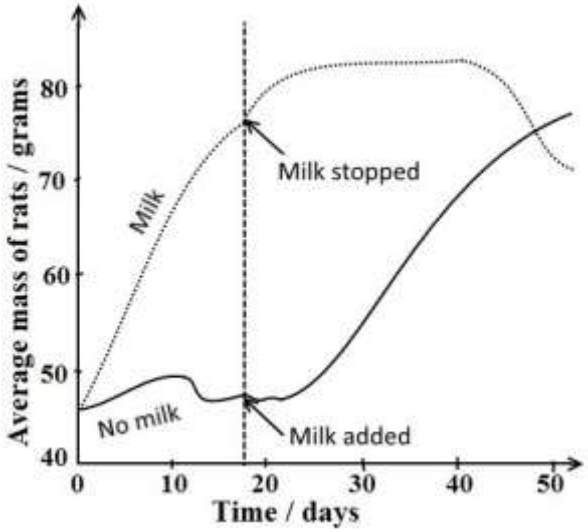
EXPERIMENT

Two groups of young rats were used.

Group A were fed on a diet of purified casein, starch, glucose, lard, minerals and water only for the first 18 days.

Group B were fed on a diet of purified casein, starch, glucose, lard, minerals and water **plus** an extra of $3cm^3$ of milk daily for the first 18 days.

After 18 days milk was given to group A rats and removed from group B's diet.



OBSERVATIONS

Group A rats increased in mass gradually from 0 day to 10 days, mass decreased gradually until about 12 days, mass remained relatively constant up to 22 days, then mass increased rapidly from about 22 days to 50 days

Group B rats increased rapidly in mass from 0 day to 18 days, then gradually increased in mass from 18 days to about 23 days, stopped growing from about 23 days to 40 days and gradually decreased in mass/lost weight thereafter.

CONCLUSION: Hopkins's experiments revealed that, to grow, animals needed small amounts of other substances he called **"accessory food factors"**- now known as **vitamins**.

EXPLANATION

Group A rats resumed growth and increased in weight after 18 days while **group B** rats stopped growing and lost weight after 18 days. While the $3cm^3$ of milk had an insignificant food value in terms of carbohydrate, fat, protein and minerals, the milk contains an extra nutrient which the rats needed to be able to grow and develop.

Related questions

1. **Why was it necessary to transfer milk from group B to group A half way through the experiment?** To ensure that all groups of rats are subjected to identical conditions e.g. feeding them on identical food so as to establish the effect of milk on growth while eliminating the possibility of other factors being responsible the observed differences in results e.g. choice of rats in one group (group A) may have been more sickly than those in group B etc.
2. **Why feeding rats on one type of protein (casein), not a variety is ruled out as a possible cause of growth stoppage and weight loss?**
   Although proteins are essential for growth and there are different types, proteins are hydrolysed in the body into different amino acids, and the body is able to make some amino acids for itself. Therefore, even though the rats were only getting casein this was enough to not have an effect on growth.
3. **Why while a diet of milk alone is sufficient for young animals, it is inadequate for adults?** Much as milk contains all the nutritional requirements like protein, carbohydrates (lactose), lipids, mineral salts, vitamins and water, some amounts may be nutritionally insufficient to meet the metabolic demands of adults.

   Some people who are lactose intolerant can't digest the main sugar (lactose) in milk. In normal humans, production of lactase enzyme that digests lactose stops between ages of two and five years, which would result in insufficient ATP production.

MINERAL IONS

Minerals are inorganic nutrients which are involved in a wide variety of body functions. Some minerals called **macronutrients** are needed in relatively large quantities others called **trace elements (micronutrients)** are needed in small quantities.

The principle minerals required in the human diet, and their sources are as shown in the table below

(a) Macronutrients

Mineral	**Major food source**	**Function(s)**
Calcium (Ca^{2+})	Dairy foods, eggs, green vegetables	Constituent of bone and teeth; Needed in blood clotting; Needed in muscle contraction; Are enzyme activators
Chloride (Cl^-)	Table salt	Maintenance of anion/cation balance; formation of hydrochloric acid in the stomach; maintenance of water balance.
Magnesium (Mg^{2+})	Meat, green vegetables	Component of bones and teeth; Enzyme activator.
Phosphate (PO_{43-})	Dairy foods, eggs, meat, vegetables	Constituent of nucleic acids, ATP, phospholipids (in cell membranes), bones and teeth.
Potassium (K^+)	Meat, fruits and vegetables	Needed for nerve and muscle action and in protein synthesis
Sodium (Na^+)	Table salt, dairy foods, meat, eggs, vegetables	Needed for nerve and muscle action; maintain anion/cation balance.
Sulphate (SO_{42-})	Meat, eggs, dairy foods	Components of proteins and enzymes

(b) Micronutrients

Mineral	**Major food source**	**Function(s)**
Cobalt (Co^{2+})	Meat	Component of vitamin B_{12} which is needed for the formation of red blood cells *Deficiency in diet leads to pernicious anaemia*
Copper (Cu^{2+})	Liver, meat, fish	Constituent of many enzymes; needed for bone and haemoglobin formation
Fluoride (F^-)	Many water supplies	Improves resistance to tooth decay
Iodide (I^-)	Fish, shellfish, iodised salt	Component of growth hormone, thyroxin *Deficiency in diet leads to Goitre; cretinism in children*
Iron (Fe^{3+} or Fe^{2+})	Liver, meat, green vegetables	Constituent of many enzymes, electron carriers, haemoglobin and myoglobin. *Deficiency leads to anaemia*
Manganese (Mn^{2+})	Liver, kidney, tea and coffee	Enzyme activator and growth factor in bone development *Deficiency leads to poor bone development*
Molybdenum (Mo^{4+})	Liver, kidney, green vegetables	Essential for metabolism of enzymes involved in DNA metabolism.
Zinc (Zn^{2+})	Liver, fish, shellfish	Enzyme activator, involved in the physiology of insulin

WATER

This makes up about 70% of the total body weight of mammals and serves a wide variety of important functions which were discussed in CHEMICALS OF LIFE **Note:**

- Failure to replace water results in dehydration which can adversely affect physiological performance.

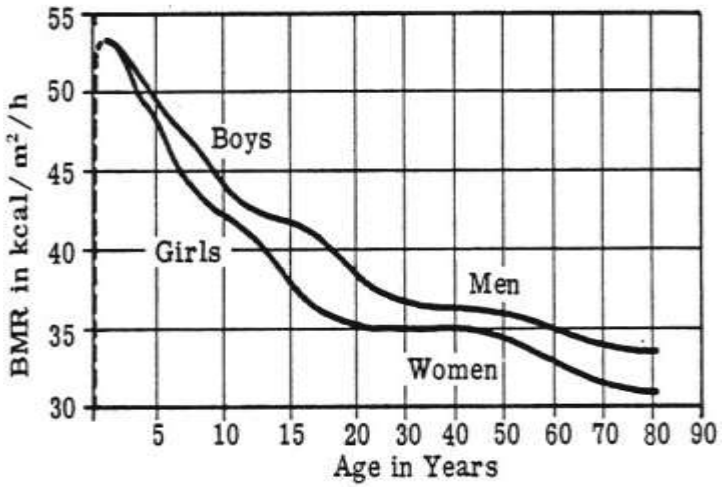
- Drinking too much water in a short time can lead to water intoxication, as water dilutes the tissue fluid and inflates cells. This can lead to metabolic disorders e.g. nausea, vomiting, muscle cramps and in extreme cases, death.

ENERGY-FOOD INTAKE AND CONSUMPTION

The body needs energy for **three main** reasons:

- Maintain the **basal metabolic rate** (**BMR**) – minimum energy a body requires at rest to perform vital functions like beating of the heart, breathing, peristalsis, impulse transmission, synthesis of biological molecules like proteins, etc.
- Sustain body activities like muscle contraction during movement, locomotion, etc.
- Generation of heat to maintain body temperature at about 37^0C

The graph below shows the variation in BMR of males and female with time



(a) state the

(i) Factors shown in the graph, which affect BMR: Age and sex

(ii) Other factors not shown in the graph, which affect BMR:

Muscle mass, Body size, level of physical activity, and Pregnancy and lactation, Diet, Drugs, Environmental factors e.g. temperature, Hormonal factors e.g. during pregnancy and lactation, Genetics

Explanation of variation in BMR with the factors in (a) (i) above.

Variation in BMR with sex

- At about 2.5 years and below, BMR in males is equivalent to BMR in females **because** infants have basically identical composition of carbohydrates, fats and protein.
- From about 2.5 years throughout life, BMR is slightly higher in males than in females **because** males usually have more body muscle than females while females usually have more fat than males per unit body mass and surface area. The more muscle tissue in the body, the more energy the body needs just to function e.g. to conduct impulses and biosynthesis compared to fat cells that largely store fat, with little biosynthesis.

Variation in BMR with age

- Infants and children have relatively high BMR than old-aged adults **because** at infancy and childhood much of the energy consumed is used in biosynthesis of cellular components required for growth. At adulthood, biosynthesis is greatly reduced since growth has stopped.
- From the age BMR was **first** determined to about 20 years of age, BMR decreases rapidly, then remains constant up to about 50 years of age and thereafter decreases slowly.
- From infancy to maturity at 20 years of age, biosynthesis of cellular components required for growth decreases rapidly, then remains constant by middle age until 50 years of age and thereafter decreases slowly, partly because of loss of muscle tissue, and also because of hormonal and neurological changes. Only repair and replacement of worn out cells occurs at slow rate by adulthood.

Explanation of variation in BMR with the factors in (a) (ii) above.

- **Muscle mass** (amount of muscle tissue in the body). Muscle requires more energy to function than fat. The more muscle tissue in the body, the more energy the body needs just to exist.

- **Body size:** Larger bodies tend to have a higher BMR because they usually have larger internal organs and fluid volume to maintain. Taller people have a larger skin surface, therefore have higher metabolism to maintain a constant temperature.
- **Genetics:** Genotypes and genetic disorders determine the rate of BMR.
- **Physical activity:** Regular exercise increases muscle mass and causes the body to burn kilojoules at a faster rate, even when at rest.
- **Hormonal factors (e.g. during pregnancy and lactation):** Hormonal imbalances caused by certain conditions, including hypo- and hyperthyroidism, can affect the metabolism. Expectant and lactating mothers require more energy to support foetal and baby growth respectively.
- **Environmental factors (e.g. temperature):** Weather can also have an effect on body metabolism; if it is very cold or very hot, the body works harder to maintain its normal temperature and that increases the metabolic rate.
- **Drug content in the body:** Caffeine and nicotine can increase your metabolic rate, while medications including some antidepressants and anabolic steroids can contribute to weight gain regardless of what you eat.
- **Diet:** Certain aspects of one's diet can also affect metabolism e.g. inadequate intake of iodine for optimal thyroid function can slow down body metabolism.

EFFECTS OF UNDERFEEDING AND OVERFEEDING

- If energy output exceeds energy input, carbohydrate reserves (glycogen) and fat reserves (adipose tissue) are respired and the person's body mass decreases. When carbohydrate and fat reserves exhaust, tissue protein is respired and the body wastes away.
- If energy intake exceeds energy usage over a period of time, carbohydrate is turned into fat and the person's body mass increases leading to **obesity** (overweight).

Disadvantages of obesity:

- the extra mass causes a person to get tired quickly
- increases chances of stroke/heart attack.

How an obese person can lose weight:

- Eating less energy food
- Taking more exercises to increase energy output

STARVATION AND GENERAL UNDEREATING

Starvation results from the inadequate intake of nutrients or the inability to metabolize or absorb nutrients this can be due to:

- Prolonged fasting
- Anorexia
- Deprivation of food
- Disease

SYMPTOMS OF STARVATION

Weight loss, dehydration, apathy, listlessness, withdrawal, increased susceptibility to infectious disease, discoloured hair color, flaky skin, and massive edema in abdomen and lower limbs causing the abdomen to appear bloated.

ADVERSE EFFECTS OF STARVATION

(i) Marasmus: occurs on account of extreme energy deficiency, typically from inadequate amounts of protein and calories.

Task: ***Describe the signs and symptoms of a child suffering from marasmus.***

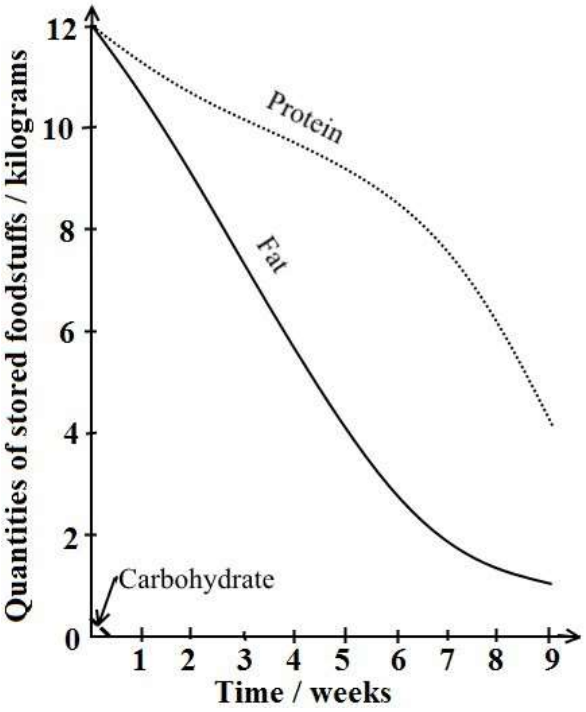
(ii) Kwashiorkor: is related to marasmus, affects children who are protein-energy deficient, and can result in edema (fluidic inflammation) and an enlarged fatty liver, resulting in the counterintuitive distending of bellies.

Task: ***Describe the signs and symptoms of a child suffering from Kwashiorkor.***

INTERVENTIONS AGAINST STARVATION

- Rehydration and feeding the starving person low-bulk food with much proteins, much energy and fortified with vitamins and minerals.
- Avoid foods high in bulk but low in protein content

The graph below shows changes in body energy reserves during starvation



Explanation of changes in energy reserves ▪ Glycogen, proteins, and fats are all metabolized during starvation.

▪ Exhaustion of blood glucose stimulates **glucagon** secretion and **insulin** secretion is inhibited. ▪ Within the first 24 hours, the very low glycogen amount stored in the liver and muscles decreases rapidly to depletion **because** glycogen is broken down into glucose for oxidation to release energy, while the amounts of fats and protein remain high. Anaerobic breakdown of glycogen in skeletal muscle is also stimulated.

▪ Within week 1, a few hours after depletion of carbohydrate/glycogen, the amount of fats decreases rapidly while the amount of protein decreases gradually until about 6 weeks of starvation. ✓ This is because fats are hydrolysed rapidly into fatty acids and glycerol while oxidation of amino acids releases energy.

- ✓ The liver metabolizes fatty acids into **ketone bodies** that are degraded to release energy. Accumulation of ketones causes **ketosis,** by condition characterised by blood becoming **acidic**
- ✓ Fatty acids in skeletal muscles are broken down to release energy, thus decreasing the use of glucose by tissues other than the brain.
- ✓ Glycerol is converted into small amount of glucose, but most of the glucose is formed from the amino acids of proteins.
- ✓ The brain begins to use ketone bodies, as wells as glucose, for energy.
- ✓ Dependency on fats for energy release decreases the demand for glucose, protein breakdown reduces but does not stop.
- ✓ The liver degrades **non-essential proteins** into glucose for the brain in a process called **gluconeogenesis,** which involves converting carbon skeletons into pyruvate or Krebs' cycle intermediates and excreting amino groups from the body as urea.

▪ From 6 weeks to 8 weeks, amount of fat decreases slowly to very low levels, while amount of protein decreases rapidly.

- ✓ This is because as fat reserves / stores are getting depleted, metabolism of fats to release energy occurs gradually and the body begins to rapidly break down **essential proteins**, leading to loss of liver and heart function as these organs are broken down for fuel metabolizing proteins as the major energy source.
- ✓ Muscles, the largest source of protein in the body are rapidly depleted.

Exercise 1

1. A group of rats were encouraged to over eat by feeding them with unlimited supplies of processed foods such as chocolate and cakes over a three-week period. These rats were called cafetarian rats. Over the same period, another group of control rats fed on unlimited supplies of their natural food.

	Average over 21 days	
	Cafetarian rats	Control rats
Energy content of food eaten(kj)	11670	6480
Gain in the body mass (g)	131	103
Gain in body fat (g)	66	40
Energy used (kj)	9440	4690

(i) What was the effect of feeding the rats on food other than their natural food? (1½ marks)

(ii)Determine the average gain in mass of the cafetarian rats over the control rats during the 21 days (03 marks)

(iii)State three features of the two groups of rats which should be kept the same (1½ marks)

(iv) Which chemical of life in the rats would have been responsible for most of the gain in mass? (½ mark)

(b)Explain the observation that some people eat enormous amounts of foods without putting on weight where as others become over-weight on quite small food intake:

(c)Using evidence from the data, explain why cafetarian rats were able to gain more weight than control rats. (2 marks)

(d)Why were control rats necessary in this experiment? (1 mark)

1. HOLOZOIC NUTRITION

This involves the consumption of complex organic food which is broken down inside the organisms into simple soluble molecules which are then absorbed and assimilated. It is mainly used by animals which have a specialized digestive tract, the alimentary canal.

BASIC PROCESSES INVOLVED IN HOLOZOIC NUTRITION

(i) Ingestion-is the taking in of food into the body. Organisms use a variety of feeding mechanisms which depend on the size and nature of food.

(ii) Digestion-is the breakdown of large organic molecules into smaller, simpler soluble molecules. This can be categorized basing on

(a) Mechanism of breakdown of food

- **Mechanical (physical) digestion**: This involves mechanical breakage of food by a variety of structures including teeth, radula, gizzard and rhythmic contraction of the muscles of the gut wall.
- **Chemical digestion**: This involves breakdown of food by a chemical process catalysed by enzymes. The type of chemical process which these enzymes catalyse during digestion is hydrolysis.

(b) Where digestion is taking place

- **Extracellular digestion**: where chemical digestion of food is completed outside the cells for example in mammals, food is digested in the alimenatry canal before it is taken up by the cells lining the gut.
- **Intracellular digestion**: where solid food particles are taken up by phagocytosis and then digested in the food vacuole with in the cell e.g. protists such as amoeba, paramecia and sponges. Intracellular digestion is more premitive since it is associated with simpler organisms.

(iii) Absorption: is the uptake of the useful soluble molecules from the digestive region, across a membrane into the body tissue proper.

(iv) Assimilation: is the utilization of the absorbed food molecules to provide either energy or materials to be incorporated into the body.

(v) Egestion: is the elimination/removal of undigested waste food materials from the body.

Holozoic organisms can be classified according to the type of food ingested: ❖

Herbivores: feed on plants.

❖ **Carnivores**: Feed on animals.

❖ **Omnivores**: Feed on a mixed diet of animals and plant materials.

Holozoic organisms can also be classified according to the form of food they ingest:

❖ **Microphagus feeders**: these are animals that take in food in the form of relatively small particles for example earthworms and filter feeders like mussels

❖ **Fluid feeders**: these ingest food in fluid form for example aphids, butterflies and mosquitoes.

❖ **Macrophagous feeders**: these take in food in the form of relatively large pieces, for example Hydra and sea anemones, which use tentacles to catch their prey, and large carnivores such as sharks.

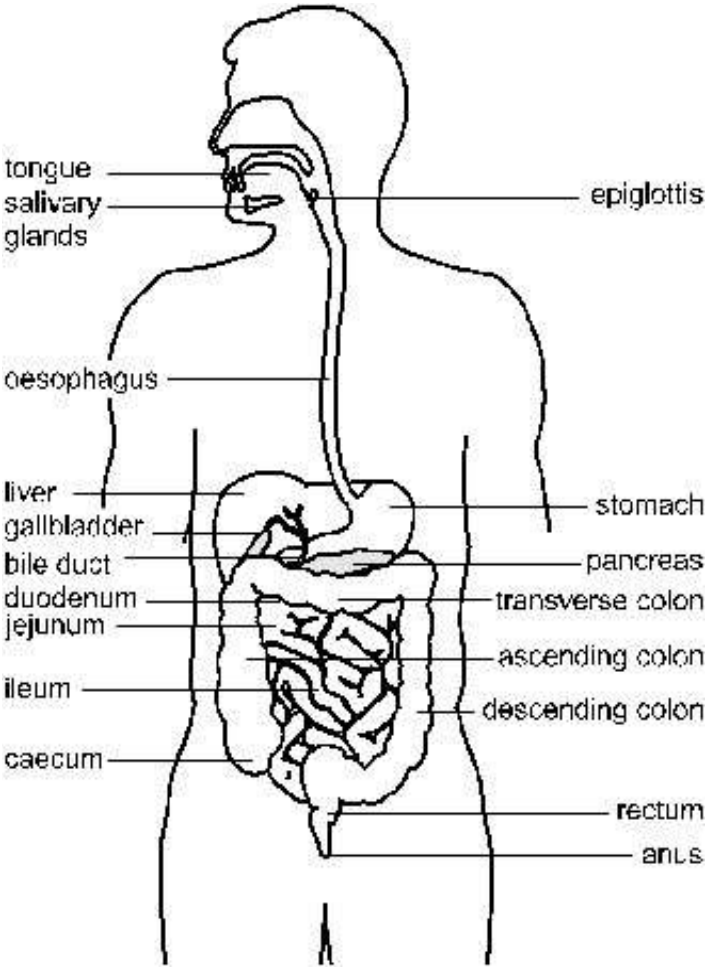
FEEDING MECHANISMS OF ANIMALS

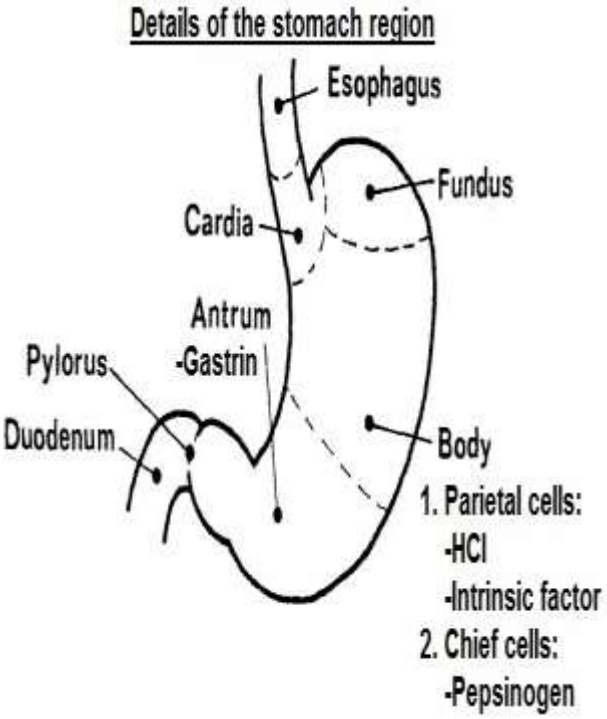
N ature of Food	***Mechanism***	***Organisms***	***Description***
Small particles	filter feeding / microphagous feeding;	Whales, sharks, flamingo, herring;	Body appendages (gills/beaks/keratinous plates) filter planktons/blue green algae suspended in water into body cavity /mouth then digestion occurs.
	Pseudopodial feeding	Amoeba	Pseudopodia enclose the food particle to form **food vacuoles** which on associating with **primary lysosomes** form **secondary lysosomes,** and after digestion, soluble products simply/facilitatively diffuse /actively move into the cytoplasm while undigested wastes are egested by **exocytosis**.
	Flagellate feeding	Euglena, sponges	Flagellar beating directs microscopic food particles to the region of ingestion, then intracellular digestion occurs.
	Ciliary feeding	Paramecium, *Amphioxus*	Cilia beating directs microscopic food particles to the region of ingestion, then intracellular digestion occurs.
	Tentacular Feeding	Sea cucumber	Mucus on tentacles traps food particles
	Setous feeding	Water flea (*Daphnia)*, culex mosquito larvae	Setae on appendages trap and direct small food particles into the digestive system.
	Mucoid feeding	Some molluscs	Mucus layer traps food particles, later swallowed and new layer formed.
Fluids or soft tissues	Fluid feeding;	Aphids, leeches, fleas, lice, mosquitoes, housefly, vampire bats/ Tapeworm, *Trypanosoma*;	Nutrient-rich fluid from the living host; is sucked by modified mouth parts; Already digested food is absorbed across the integument;
Large particles	Substrate feeding / deposit feeding;	Insect larvae / earthworms;	Non-selective swallowing of mud, silt, sand, etc after burrowing their way through the food / organic material;
	Bulk feeding / macrophagous feeding;	Land snail, caterpillar, termites, snakes, birds, seals, squids, many mammals, spiders, blowfly larvae, crabs, dragonfly, etc.	May involve scraping and boring (termites, snails) / Capturing and swallowing (snakes, birds, dogfish, seals) / Capturing, chewing and swallowing (squid, mammals) / Capturing, digesting externally and ingesting (spider, starfish, blowfly); using appendages like tentacles/pincers, claws/ poisonous fangs and jaws/ mandibles;

THE HUMAN DIGESTIVE SYSTEM

The human digestive system consists of:

1. **Alimentary canal:** Mouth, throat, oesophagus, stomach, small intestine (duodenum, jejunum and ileum), large intestine (colon, caecum and appendix), rectum and anus.
2. **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.





HISTOLOGY OF THE DIGESTIVE TRACT REGIONS

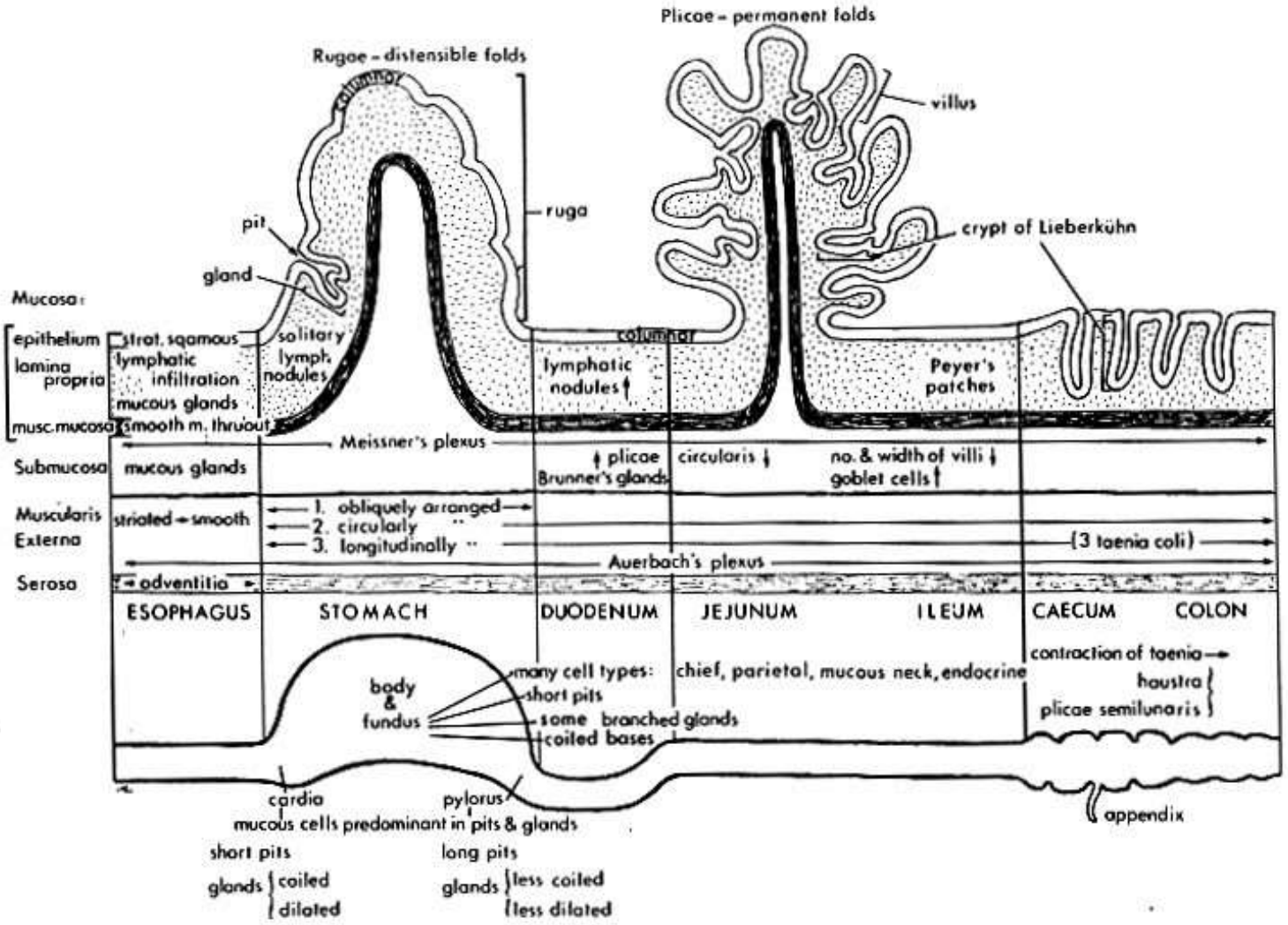
Although each different region of the gut possesses its own special characteristics, all have a basic common structure consisting of **four** distinct layers, the mucosa, submucosa, muscularis externa and serosa.

(i) **Serosa (Adventitia): this is the outer most layer made up of a**reolar connective tissue, same composition as mesenteries. It is called **serosa** when the outermost layer lies adjacent to the peritoneal cavity. it is called **adventitia** when the outermost layer is attached to surrounding tissue.

(ii) **Muscularis externa:** this consists of three muscle layers:

- inner oblique layer
- middle circular layer
- outer longitudinal layer

VERTICAL SECTION THROUGH THE ALIMENTARY CANAL



(iii) **Auerbach's plexus (Myenteric plexus):** these form a network of **unmyelinated** nerve fibers and ganglia between Muscularis externa longitudinal and circular muscles

Functions

- Brings about **peristalsis** when stimulated by pressure of food in the gut.
- Receives impulses from the **vagus nerve**
- Control of nerve impulses is **involuntary**
- Promotes secretion of intestinal juices
- Causes sphincter muscles to open, thus permitting food to pass from one part of the digestive system to another

(iv) **Submucosa:** this consists of loose connective tissue, collagen, large arteries and veins, lymph vessels, nerves and glands such as Brunner's glands present in the duodenum and Goblet cells present in the duodenum and ileum. Brunner's glands secrete alkaline mucus to neutralize acidic chyme from the stomach

(v) **Meissner's plexus (Submucosal plexus):** these form the nerve network of unmyelinated nerve fibres and associated ganglia located with the submucosa. it is believed to work against the myenteric plexus to control the muscular contractions more finely. In intestines, it works with Auerbach's plexus in producing peristaltic waves and increasing digestive secretions.

(vi) Mucosa: this is the inner most layer of the wall, it is divided into three layers i.e.

1. ***Muscularis mucosa: a t***hin layer of smooth muscle at the boundary between mucosa and submucosa, it contains both circular and longitudinal muscles

2. ***Lamina propria:*** this is formed by a very cell-rich loose connective tissue (fibroblasts, lymphocytes, plasma cells, macrophages, eosinophilic leucocytes and mast cells), it contains numerous cells with **immune function** to provide an effective **secondary line of defense** e.g. **Peyer's patches** which are lymphoid structures located in the ileum. Lamina propria of **villi** includes **lacteals** (**lymphatic capillaries**) while that of **intestinal villi** may include smooth muscle fibers. In **oral cavity** and **oesophagus**, lamina propria is located immediately beneath a stratified squamous epithelium
3. ***Surface epithelium***:Mucosal epithelium is highly differentiated along the several regions of the digestive tract. At the upper and lower ends of the tract, the epithelium is protective, **stratified squamous**, along the lining of the stomach, small intestine, and colon, the epithelium is **simple columnar** while in the stomach, surface epithelium contains mucous cells that secrete protective, alkaline mucus

   This is highly modified along the alimentary canal to form

   - **Gastric pits:** the shallow indentations in surface epithelium of stomach mucosa into which gastric glands open.
   - **Intestinal crypts** (**crypts of Lieberkühn**): these contain secretory **Paneth cells** at the deep end, which secrete lysosomal enzymes that contribute to protecting cells in the crypt lining.
   - **Villi:** these are very small, typically densely-packed, invaginations of a mucosa that increase the surface area for absorption. These occur in the duodenum and ileum.
   - **Rugae** are distensible folds in the **gastric** mucosa in the stomach

PRINCIPLES OF DIGESTION

Food obtained by organisms must be processed into small soluble molecules for absorption into the body tissue.

With the aid of structures such teeth, tentacles, claws, pincers, food is taken into the gut or alimentary canal or gastro-intestinal tract by the act of ingestion.

The food is then subjected to digestion which converts solid food into soluble compounds capable of being absorbed.

Digestion in humans is extracellular, this starts with physical digestion and then followed by chemical digestion. The digestive enzymes are secreted by the glands which are either outside the gut e.g. salivary gland and pancreas or located within the gut wall itself.

Physical and chemical processes of digestion go hand in hand i.e. Mechanical digestion chop up the solid lump of food into smaller pieces providing a larger surface area which aid chemical digestion Variable quantities of acids or alkali are also secreted to provide the correct PH for optimum functioning of enzymes.

DIGESTIVE ENZYMES

Digestive enzymes are broadly divided into three groups, though their details vary in different animals. They include:

(i) **Carbohydrases** which catalyses the breakdown carbohydrates

(ii) **Lipases** which catalyse the breakdown lipids (fats and oils). (iii)

Proteases which catalyze the break down proteins

HOW DIGESTIVE ENZYMES WORK

Enzymes are specific in the reactions they catalyse and therefore many enzymes are required to completely break down a large macromolecule. One enzyme breaks up a molecule into smaller sections and then others reduce these parts to their basic components.

For example:

Proteins are first attached by enzymes which break the peptide bonds/links in the interior of the molecule. Such enzymes called **endopeptidase** spilt the proteins and larger polypeptides into smaller pepetides. Examples of endopeptidases in human gut include pepsin and trypsin.

The smaller peptides are then attached by enzymes which break off their terminal amino acids. These enzymes are called **exopeptidase** and are of two types: the **aminopeptidases** which break off amino acids at the end of the polypeptide chain which has the amino($-NH_2$) group and the **carboxypeptidase** which attach the end of the polypeptide chain with free carboxyl (-COOH) group. The same principle applies to the carbohydrases.

Certain enzymes break the glycosidic bonds in the interior of the polypeptin chain forming shorter polypeptides and other enzymes then attach the end of these polypeptide chains liberating free monosaccharides.

Fats, being smaller molecules, are broken down into fatty acids and glyceraol by single enzyme lipase. (check illustrations; BS pg 246)

THE PROCESS OF DIGESTION Digestion in buccal cavity

In the buccal cavity the food is subjected to the chewing action of the teeth (mastication). During chewing the muscular tongue moves food around the mouth and mixes and moistens it with saliva secreted by the salivary glands.

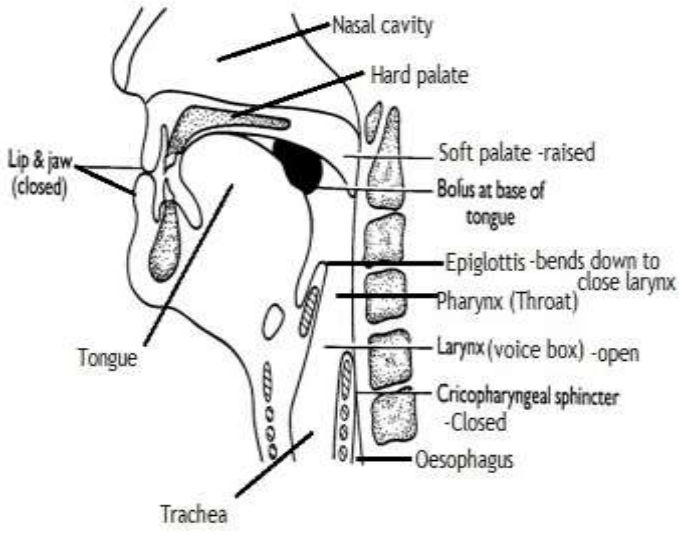
The secretion of saliva is initiated by sight, smell, taste or thought of food. The receptors on the taste buds on the tongue, the eyes and the olfactory (smell) receptors in the nose trigger the reflexes that bring about salivation. Saliva is a watery secretion which contains:

- **Enzymes salivary amylase (ptyalin):** This starts the chemical digestion of starch. It catalyses the hydrolysis of starch to disaccharide maltose ➢ **Lysozyme**: kills bacteria in the buccal cavity.
- **Mucous**: moistens and lubricates food in preparations for its passage down the oesophagus.
- Various **mineral salts:** including **sodium hydrogen carbonate** which maintains PH at around 6.5-7.5, the optimum pH for salivary amylase and **chloride ions** which speed up the activity of salivary amylase.

Towards the back of the buccal cavity the semi-solid, partially digested food particles are stuck together and moulded into a **bolus.**

Swallowing

By the action of the tongue the bolus is pushed towards the pharynx. From here as result of reflex action it is swallowed into the oesophagus through the pharynx.



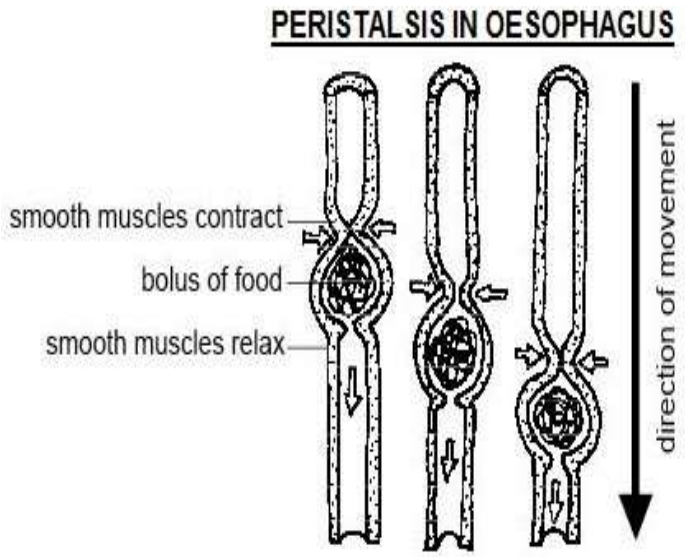
Note:

❖ Triggered by tactile stimulation of the soft palate and wall of the pharynx, swallowing is a reflex in which contraction of the tongue forces the bolus against the soft palate thereby closing the nasal cavity. The opening into the larynx, the glottis, is closed by the valve-like epiglottis, so the bolus enters the oesophagus. While all this is happening respiration is momentarily inhibited.

❖ The nerve centre responsible for controlling this swallowing reflex is located in the hind brain.

The bolus is propelled down the oesophagus to the stomach by **peristalsis.** The passage of food to the stomach is controlled by a narrow sphincter made up of smooth muscles called the **cardiac sphincter.**

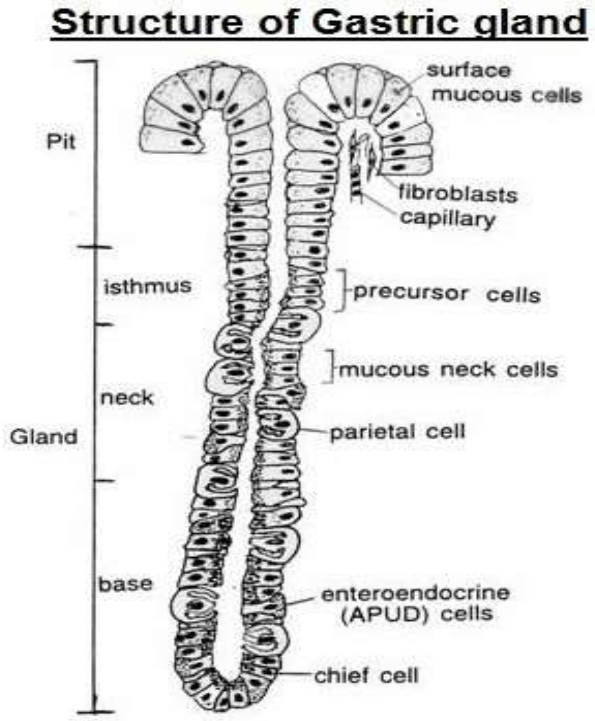
During peristalsis, food is pushed through the gut by two layers of smooth muscles, the outer longitudinal and inner circular layer of muscle in the gut wall. The circular muscle contracts behind the bolus, narrowing the oesophagus and pushing the bolus down while the longitudinal muscles contract in front of the bolus, shortening this section and pulling it past the advancing bolus.



Digestion in the stomach

The stomach is highly elastic and muscular organ which can expand easily to hold large amount of food. The stomach wall is thick, highly folded and is dotted with numerous pits, the gastric pits leading to tubular **gastric glands**. The gastric glands secrete the **gastric juice.**

Arrival of food in the stomach stimulates secretion of **gastrin hormone** into the blood stream, which stimulates the **gastric glands** to secrete **gastric juice**, whose components include: ***mucus, pepsinogen, hydrochloric acid*** **and** ***intrinsic factor.*** The components of gastric juice are secreted by different cells and perform different roles as illustrated in the table below



Type of Cell	Secretion	Function
Mucous cells (i) Mucous surface cells (ii) Mucous neck cells	Mucus	Forms a barrier at the stomach lining, to prevent tissue digestion.
	Bicarbonate salts	Buffers gastric acid to prevent damage to epithelium
Chief / Peptic / zymogen Cells	Pepsinogen	Pepsinogen on activation to pepsin catalyses hydrolysis of protein to polypeptides
	Prorennin	Rennin coagulates soluble milk protein **Caseinogen** into insoluble **casein** in babies, whose slowed flow enables digestion by **pepsin**.

Parietal / oxyntic cells	Hydrochloric acid	❖ Activate pepsinogen to pepsin and prorennin to rennin. ❖ Provides the optimum PH for the action of the gastric enzymes. ❖ Kills bacteria thus acting as a defense mechanism. ❖ Denatures many proteins, their tertiary structure is altered making them easier to digest. ❖ Begins the hydrolysis of sucrose to glucose and fructose. ❖ Stops the working of salivary amylase enzyme
	Intrinsic factor	❖ Forms a complex which enables absorption of vitamin B_{12} that is necessary in red blood cell formation ❖ Little *intrinsic factor* causes **pernicious anemia**

Note:

- ❖ Pepsinogen is also activated by pepsin itself this is also termed as autocatalysis.
- ❖ These enzymes are secreted in an inactive form because they are proteolytic enzymes and might otherwise attack the tissues themselves before being released.
- ❖ Once secreted, the active forms of the enzymes are prevented from attacking the tissues by the mucus lining the stomach wall. The mucus is secreted by the **mucous-secreting cells** situated towards the neck of the gastric glands.

While the enzymes are working, mechanical digestion of the food by the churning action of the thick muscular wall of the stomach pound the food into a semi-fluid state called **chyme.**

The cardiac and pyloric sphincter prevents the uncontrolled exit of food from the stomach. Both act as valves and retain food in the stomach for periods of up to four hours. Relaxation of the pyloric sphincter releases small quantities of the food into the duodenum at regular intervals.

Assignment:

1. Give the functions of the stomach in the process of digestion.
2. How is the structure of the stomach related to its functions?
3. What are the functions of gastric juice?
4. Read and write notes about how HCl produced by oxyntic cells is formed. Ref. FA pg 128)

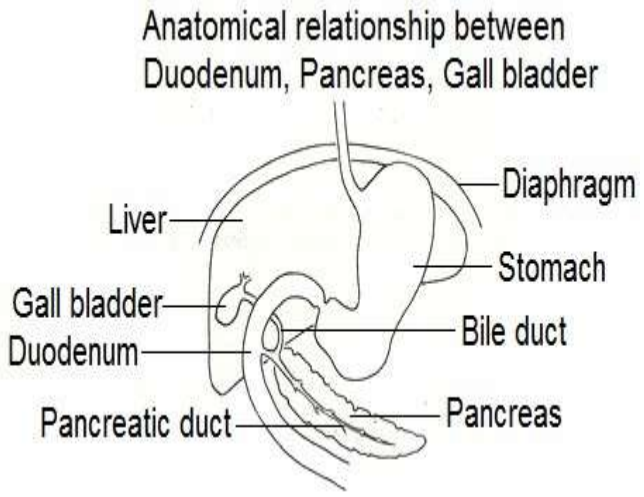
Digestion in the small intestine

The first part of the small intestine is the **duodenum**. It short, about 25cm long and the pancreatic and bile duct opens in it. The duodenum leads to the **ileum** which is long (3m long). The submucosa and mucosa together are folded.

(a) The duodenum

Peristaltic contraction of the stomach keeps the chyme moving toward the duodenum. The passage of food into the duodenum is controlled by a ring of muscle, the **pyloric sphincter**, situated immediately between the far end of the stomach and the duodenum. The duodenum is the main seat of chemical digestion in the gut. The agents of digestion are from three sources: **the liver**, **pancreas** and **wall of the small intestine**.

The liver produces **bile** which is stored in the gall bladder. From the gall bladder the bile flows through the bile duct into the duodenum.



Bile is a mixture of substances, not all of which are involved in digestion. The digestive components are:

- The **bile salts**, sodium taurocholate and glycocholate. These emulsify fats by lowering their surface tension, causing them to break up into numerous tiny droplets. This increases the total surface area of the fat, thereby facilitating the digestive action of the enzyme lipase.
- **Sodium bicarbonate**, which neutralizes the acid from the stomach. This makes the pH of small intestine distinctly alkaline which favours the action of the various enzymes.

Note: Bile salts are not enzymes: they are not proteins and have no chemical effect on fats, only physical effect of emulsifying them.

The **pancreas** secretes pancreatic juice containing digestive enzymes into the duodenum via the pancreatic duct. These enzymes are produced by groups of cells within pancreas. They include:

- **Pancreatic amylase**- complete the hydrolysis of starch to maltose which began in the mouth
- **Pancreatic Lipase**-breaks down lipids (fats and oils) to fatty acids and glycerol
- **Trypsinogen**-which when converted to trypsin by **enterokinase** secreted from microvilli, digests proteins into smaller polypeptides and activates more trypsinogen into trypsin
- C**hymotrypsinogen**-which is converted to chymotrypsin that digests proteins to amino acids.
- **Carboxypeptidases**-that converts peptides to amino acids
- **Nucleases**-break down nucleic acids to nucleotides

Note: The pancreatic juice has a variety of peptidases which release free amino acids from polypeptide chains. However, protein digestion is completed mainly by enzymes produced in the wall of the small intestine.

Pancreatic juice also contains **mineral salts** (e.g. sodium hydrogen carbonate) which neutralizes acid chyme from the stomach and so provide a more neutral pH in which the intestinal enzymes can operate.

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. 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.

The presence of acidic chyme in the duodenum stimulates the endocrine cell of the duodenal walls to secrete the hormones which include;

a) Secretin hormone

It stimulates the liver to secret bile. 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.

b) Enterogasterone hormone

This inhibits the oxyntic cells from secreting hydrochloric acid in order to provide an optimum pH for the optimum activity of the pancreatic enzymes.

c) Cholecytokinin hormone (CCK)

The hormone stimulates the pancreas to secrete pancreatic enzymes.

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. **Trypsin.** This enzyme is produced in an inactive form called **trypsinogen** which is activated by the non-digesting enzyme called **enterokinase**
Trypsin catalysesthe hydrolysis of polypeptides to peptides
iii. **Chymotrypsin.** This also 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.**

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 glycerol.

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.

(b) The ileum

The secretory cells in the wall of the small intestine produce mucus and a variety of enzymes (intestinal juice/succus entericus) whose collective function is to complete the digestion of the various compounds already started by the other secretions. These enzymes include:

- **Maltase** which hydrolyses maltose to glucose, thus completing the digestion of starch.
- **peptidases** which break down polypeptides to free amino acids thereby completing the digestion of proteins.
- **Sucrase** which hydrolyses sucrose (cane sugar) to glucose and fructose;
- **Lactase** which hydrolyses lactose (milk sugar) to glucose and galactose, and nucleotidases which split nucleotides into their constituent subunits.
- **Enterokinase**-which activates trypsinogen.

Note:

1. Alkaline fluid (due to sodium hydrogen carbonate) and mucus of the intestinal juice are secreted by coiled **Brunner's glands** whereas the enzymes are produced by cells at the bottom of the narrow tubes called **crypts of Lieberkühn.**

2. **Crypts of Lieberkühn** are formed when the epithelium folds at the base of the villi. It is here that new epithelial cells are made to replace those which are constantly being shed from the villi (the average life of these cells is about five days). The cells secrete most of their enzymes as they move up the sides of the villus.
3. All the enzymes involved in digestion in the small intestine, apart from those made by pancreas are bound to the cell surface membranes of the microvilli of the epithelium or located within the epithelial cells. Therefore it is at these sites that final breakdown of carbohydrate (disaccharides to monosacharides), and protein (dipeptides and some tripeptides to amino acids) occurs. (*Check illustration: BS pg 247; fig 8.23*)
4. The **Paneth** cells at the base of the crypts secrete lysozyme, the antibacterial enzyme.
5. Throughout the small intestine, are special epithelial cells called **goblet cells** which secrete mucus.

How is the flow of the secretions into the small intestine controlled? (See control of digestive secretions)

Assignment 1:

1. Describe how each of the following parts of the human digestive system their structure is related to their function(s)

(i) **Mouth (ii) Stomach (iii) Intestine (iv) Liver (v) pancreas**

FOOD ABSORPTION

Absorption of the soluble end-products of digestion occurs through the **villi** of the ileum.

A large surface area is required for efficient absorption to occur. The wall of the ileum achieves this in the following ways: ❖ *It is very long*

- ❖ *Its walls are folded (folds of Kerkring) to provide a large internal projection,*
- ❖ *The folds themselves have numerous finger-like projection called villi*
- ❖ *The epithelial cells lining the villi bear numerous microvilli which further increase the surface area for absorption*. (check illustration: BS pg 245 fig. 8.2)

The villi contain smooth muscles which enable them to contract and expand, this bringing them into contact with newly-digested food.

The walls of the villi are richly supplied with blood capillaries to carry away the absorbed food.

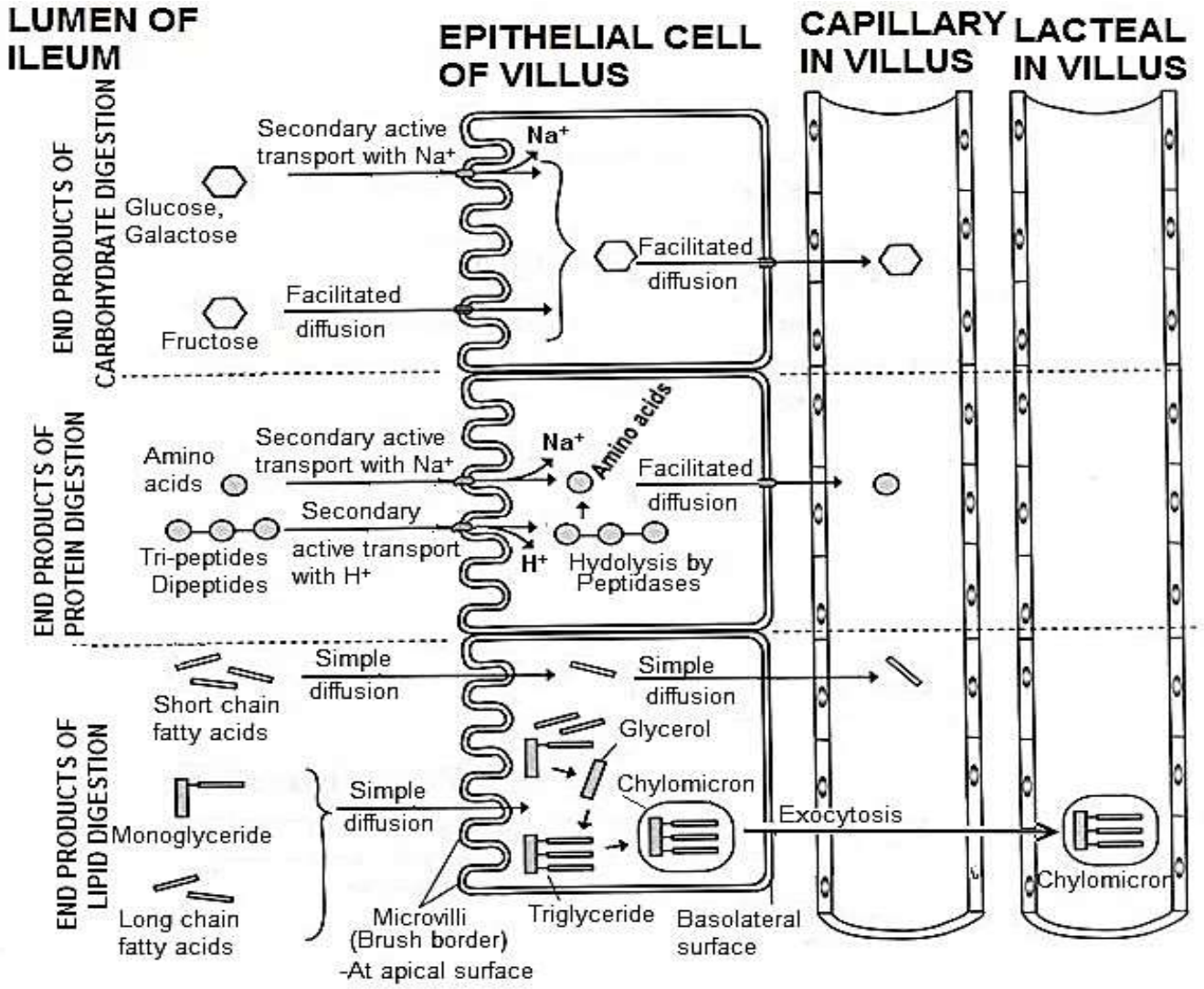
Structure of the villus *(Draw and label the structure of villus; use any advanced biology text book)*

Monosaccharide and amino acids are absorbed are absorbed either by diffusion or active transport across the epithelial lining of the villi into the blood capillaries beneath. The blood capillaries join to form the hepatic portal vein which delivers the absorbed food the liver.

Fatty acids and glycerol are absorbed into the columnar epithelial cells lining the villi where they are reconverted into lipids. Proteins present in the epithelial cells coat the lipid molecules to form lipoprotein droplets called chylomicrons. These pass out of the epithelium cells by exocytosis into the lymphatic vessels in the villi as white emulsion of minute globules. This gives the lymph vessels a milky appearance, for which reason they are known as lacteals.

The lipoprotein droplets are carried by the lymph in the lymphatic system to veins near the heart where they eventually enter into blood plasma. An enzyme in the blood plasma then hydrolyses the lipids back to fatty acids and glycerol in which form they are taken up by the cells.

A SUMMARY OF THE PROCESS OF ABSORPTION OF END PRODUCTS OF DIGESTION



In organic salts, vitamins and water are also absorbed in the small intestine.

Water is extensively absorbed in the **colon** whose wall is much folded for this purpose. Some metabolites and inorganic substances such as calcium and iron in excess in the body are exerted in the large intestine as salts. The colon also has symbiotic bacteria which synthesis amino acids and some vitamin, especially vitamin K, which are absorbed into bloodstream.

Thus, by the time it reaches the rectum, indigestible food is a semi-solid ready to be egested through the anus as **faeces**. This process is called **defaecation** and it is facilitated by the lubricative effect of large amounts of mucus which are secreted by the lining of the rectum.

Adaptations of the ileum to absorption of food

- long and highly folded for increased surface area in absorption of soluble food substances.
- has numerous finger-like projections called villi which increase the surface area for absorption of soluble food.
- Ileum epithelial cells have microvilli which further increase the surface area for efficient food absorption.
- epithelium is thin to reduce diffusion distance for soluble food substances to allow fast rate of diffusion.
- epithelium is permeable to allow movement of soluble food substances across with minimum resistance.

- ❖ Ileum villi have dense network of blood capillaries to rapidly carry away digested food from the absorption area which maintains a steep diffusion gradient.
- ❖ Ileum villi have permeable lacteal, a branch of the lymphatic system for carrying away fats
- ❖ Ileum epithelial cells have numerous mitochondria to generate ATP energy for active transport of some ions.
- ❖ Ileum inner surface is lined with a lot of mucus to prevent autolysis (self-digestion) by proteolytic enzymes.

Exercise 2

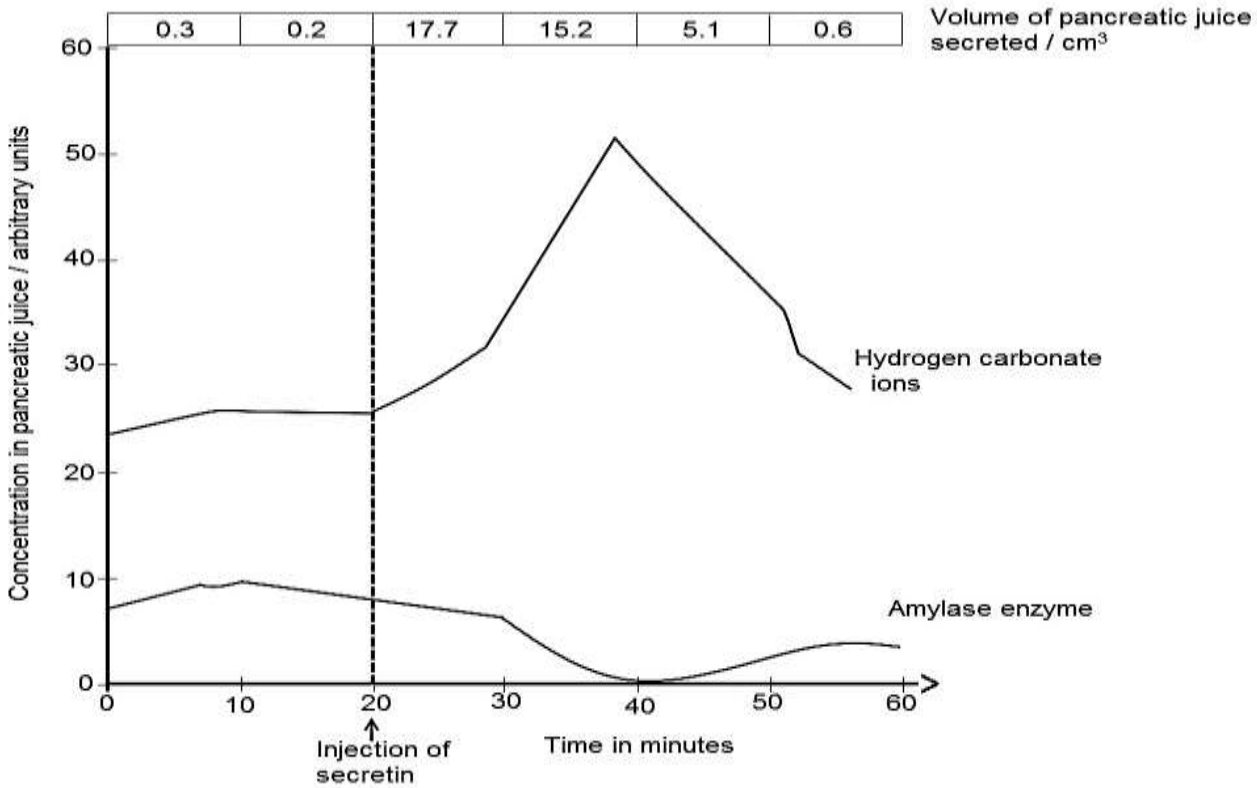
1. (a) Explain how the structure of villi in the small intestine is related to absorption of digested food.

(b) The table below shows experimental results of the rate of absorption of hexose sugars (Glucose, galactose and fructose), and pentose sugars (xylose and arabinose) by pieces of living intestine and by pieces of intestine poisoned with cyanide. The results are shown as relative to the rate for glucose.

	Rate of absorption	
	By living	By poisoned
Glucose	1.00	0.33
Galactose	1.10	0.53
Fructose	0.43	0.37
Xylose	0.31	0.31
Arabinose	0.29	0.29

Explain the observed rates of sugar absorption shown by the two tissues.

2. The graph below shows how an injection of secretin affects the secretion of pancreatic juice by the pancreas.



(a) Use the graph to explain the effect of secretin on pancreatic secretion. (b) (i) From the graph, comment on the composition of pancreatic juice. (ii) State any other digestive secretion stimulated by secretin.

(c) Certain types of ulcers are thought of to be made worse by the production of too much acid from the stomach. Medical doctors have used several methods to treat such ulcers. Suggest how each of the following treatments might reduce the amount of acid secreted by the stomach:
(i) Cutting the gastric vagus nerve.
(ii)Blocking the action of acetylcholine by giving the patient atropine.

3. (a) Why are pepsin and trypsin secreted in an inactive form. (3 marks)
(b)Why are endopeptidases secreted earlier in the digestive system than exopeptidases?

CONTROL OF DIGESTION IN HUMANS

A combination of hormonal and nervous stimulations and inhibitions of the gut that regulate the secretion of digestive juices in the gut.

IMPORTANCE OF CONTROL OF DIGESTION

- ❖ Secretion of digestive juices depends on respiratory energy therefore unnecessary secretion must be prevented to avoid wastage of respiratory substrates.
- ❖ Secretion of **proteolytic enzymes** in inactive form prevents **autolysis** (self-digestion of tissues).

Nervous and hormonal control of digestive secretions

The production of digestive secretions must be timed to coincide with the presence of food in appropriate region of the gut. In mammals, the production of digestive secretions is under both nervous and hormonal control.

Saliva

Secretion of saliva into the buccal cavity from the salivary glands is controlled by two types of reflexe action: a **simple unconditional (inborn) reflex** and **conditioned reflex**.

- A simple unconditioned reflex occurs when food is present in the buccal cavity. Contact of food with the taste bads of the tongue stimulates receptors sensitive to sweet, salty and bitter tastes. Sensory neurons carry nerve impulses from these receptors to the brain. Nerve impulses travel along motor neurons from the brain to the salivary glands, which are stimulated to secrete saliva.
- Conditioned reflexes of seeing/sight, smelling or thinking of food also operated in the same way as simple unconditioned reflex described. The eye, the ear and the olfactory (smell) receptors in the nose are the important receptors.

Gastric juice

Secretion of gastric juice occurs in three phases: nervous phase, gastric phase and intestinal phase.

1. **Nervous phase**: the presence of food in the buccal cavity and its swallowing trigger reflex nerve impulses which pass along the vagus nerve from the brain to the stomach. The sight, smell, taste and even the thought of food can trigger the same reflex. The gastric glands of the stomach are stimulated to secrete gastric juice. This takes place before the food has reached the stomach and therefore prepares it to receive food. This phase lasts for approximately one hour.
2. **Gastric phase**: takes place in the stomach and it involves both nervous and hormonal control.
    - Stretching of the stomach by the food it contains stimulate the stretch receptors in the wall of the stomach. These send nerve impulses to Meissner's plexus in the submucosa, which in turn sends impulses to the gastric glands, stimulating the flow of gastric juice.
    - Stretching of the stomach by the presence of food also stimulates special endocrine cells in the mucous to secrete the hormone **gastrin**. The gastrin travels via bloodstream to the gastric glands and stimulates them to produce gastric juice rich in hydrochloric acid.

- Presence of fats in the stomach initiates the production of **enterogasterone** hormone from the stomach wall which reduces the churning motion of the stomach and reduces the flow of acid gastric juice.

3. **Intestinal phase:** When acidified chyme enters and makes contact with the walls of the duodenum, it triggers both nervous and hormonal response.
   - Receptors in the small are stimulated by the presence of food, the reflexes, which pass through the brain inhibit secretion of gastric juice and slow the release of chyme from the stomach. This prevents too much food being released into the small intestine at once.
   - In addition, the mucosa of the duodenum produces two hormones, **cholecystokinin** (CCK) also known as pancreozymin) and **secretin.** The two hormones are taken in bloodstream to the stomach, pancreas and the liver. In the stomach, secretin inhibits secretion of gastric juice and CCK inhibits stomach emptying.

Pancreatic juice and bile

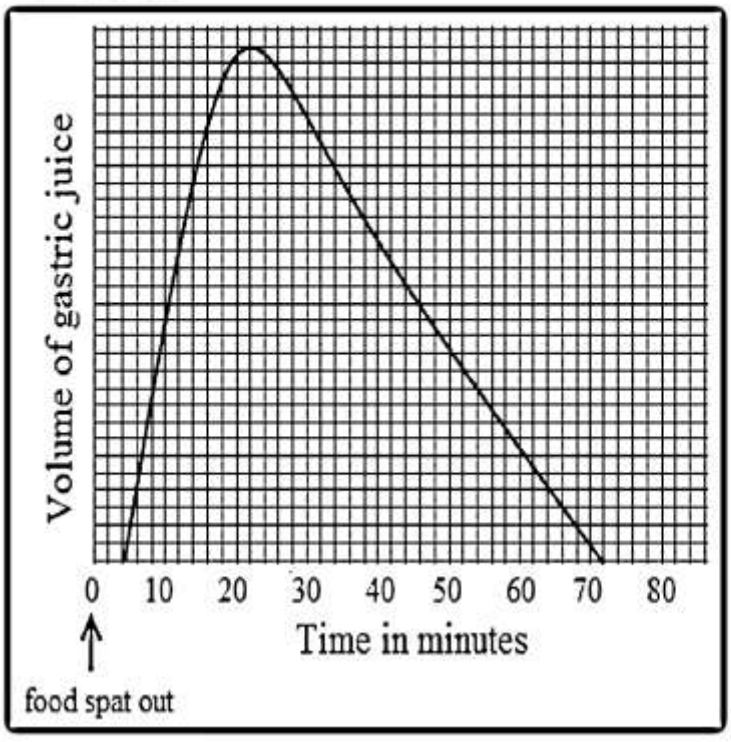
Secretin and CCK are produced in the duodenum when acidified chyme enters it from the stomach. Secretin is produced in response to the acid whereas partially digested fats and protein stimulate CCK production.

- **Secretin** is an anti-acid hormone and it stimulates the production of hydrogen carbonate ions in the pancreas and the liver making the pancreatic juice and the bile more alkaline. This helps to neutralize the acid from the stomach.
- **CCK** stimulates secretion of digestive enzymes by the pancreas and contraction of the gall bladder to release bile into the duodenum.

  The secretion of bile and the pancreatic juice is also stimulated by nervous reflexes. During the nervous and gastric phases of gastric digestion, the vagus nerve also stimulates the liver to secrete bile and the pancreas to secrete enzymes.

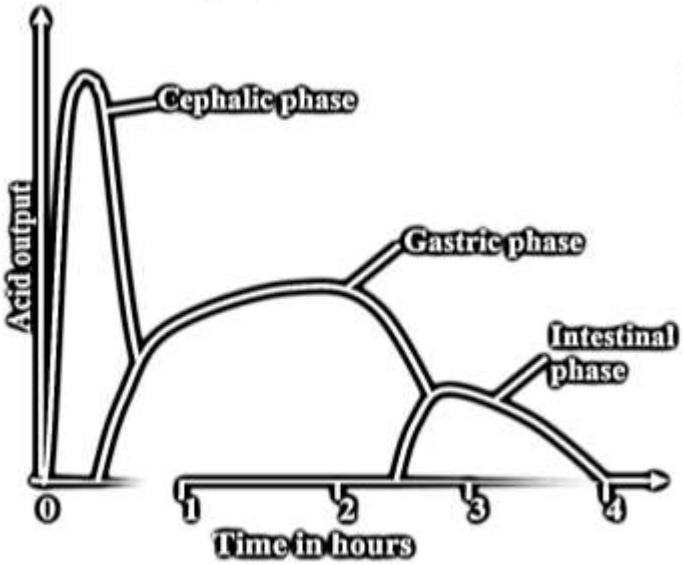
Exercise 3

1. The graph below shows the amount of gastric juice produced by the stomach of an individual who had just chewed some food. The food was spat out after being chewed, and none was swallowed.



(a) Name two constituents of gastric juice
(b) Assuming that no traces of food got down into the stomach, explain how the secretion of gastric juice was brought about.
(c) (i) How much time elapsed between the moment the food was spat out and the moment gastric juice started to be produced?
(ii) Account for the delay in (c) (i) above.
(c) If the stomach of an adult person is surgically removed through an operation, suggest with reasons, the more suitable diet for such a person after recovery from the operation.

2. The figure below shows the phases of gastric secretion related to acid output in a human during digestion.



(a) Explain the changes in acid output as shown on the graph.
Cephalic phase (04 marks)
Gastric phase (03 marks)
(iii) Intestinal phase (04 marks)

(b) Suggest why the secretions of the digestive enzymes occur only when there is digestive work to be done. (01 mark)

3. (a) Explain the benefit of the secretion of saliva being controlled by both a simple reflex action and a conditioned reflex action. (3 marks)
(b) Explain the role of cholecystokinin in the control of the secretion of pancreatic juice. (3 marks)

4.(a) In what ways is auto digestion prevented in the human gut? (2marks)
(b)Describe the functions of the pancreatic secretions (13 marks)
(c)Explain how the release of pancreatic secretions is controlled (5 marks)

ASSIMLIATION OF FOOD

Assimilation: The process by which simple soluble food substances are absorbed and used by body cells in the various ways.

The products of digestion are brought directly through the hepatic portal vein to liver, which controls the amount of nutrients released into the mainstream blood circulatory system.

Assimilation supports growth, development, body renewal, and storing up of reserves used as a source of energy.

Metabolism: Chemical processes within cells of an organism. It involves:

(i) **Catabolism:** Break down of complex molecules into simpler molecules, with release of energy**.**

(ii) **Anabolism:** Assembly / building up of complex molecules from simple molecules using energy.

FOOD	HOW ABSORBED FOOD IS USED IN THE BODY	HOW BODY DEALS WITH EXCESS
Glucose	❖ ATP synthesis in respiration ❖ Formation of glycoproteins involved in cell to cell recognition mechanisms. ❖ For production of mucus ❖ Excess carbohydrates are stored in the form of glycogen in the liver and muscles.	❖ Stored in the liver as glycogen. ❖ Excess carbohydrates may be converted into fats for storage.

Amino acids	❖ Formation of protoplasm of cells during growth ❖ Production of enzymes and antibodies ❖ Formation of body structures such as hairs, nails, hooves, cell membranes ❖ Oxidised to release ATP energy during severe starvation i.e. in the absence of glucose and fats. ❖ Formation of hormones e.g. insulin ❖ Formation of plasma membrane components e.g. glycoproteins, channel proteins	❖ Deaminated in the liver to form urea, which is expelled by kidneys. ❖ Some amino acids are **transaminated** to produce a different amino acid
Fatty acids and glycerol	❖ The long chain fatty acids are desaturated in the liver and are then broken down to carbon dioxide and water by successive oxidations. ❖ Some of it can be converted into glucose ❖ Some used to form various structures which are components of cells e.g. phospholipids	❖ Stored as fat under the skin

NUTRITION IN HERBIVORES

ADAPTATION TO DIET

(a) Adaptations of a herbivore to its diet.

Plants material is relatively tough and largely indigestible by mammals without the aid of microorganisms. The first essential of its digestion is to grind up the vegetation, so disrupting the tissues and increasing its surface area. Animals such as cattle which consume predominantly plant material are called herbivores and they posses specialized dentition which may include the following features:

- ❖ A horny pad which replaces the upper front teeth (incisors and canines) against which the chiselshaped lower incisors and canines bite when cropping grass.
- ❖ A pronounced gap, the diastema, between the incisors and premolars. This provides space in which the grass being chewed is kept separate from that which is freshly gathered.
- ❖ The cheek teeth (molars and premolars) have ridged surface which form an effective grinding surface.
- ❖ The jaws easily move from side to side to allow food to be broken down between teeth
- ❖ The teeth grow continuously throughout the herbivore's life. This essential as grinding action of the teeth wears them away.
- ❖ Large masseter muscle provides the power for grinding the vegetable matter.
- ❖ The alimentary canal is relatively long because digestion of plant material id difficult.
- ❖ The stomach of herbivorous ruminants is divided into a number of chambers, some of which produce digestive enzymes to break down food. Others including the rumen, house bacteria and protozoa which produce the enzyme cellulase essential to break down the cellulose which constitutes the bulk of the food ingested.

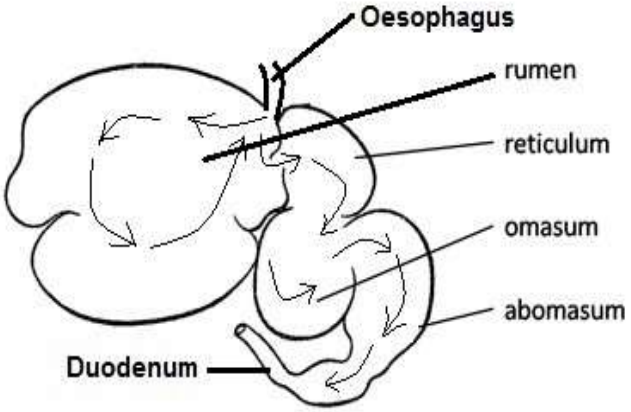
Digestion of cellulose in ruminants

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, etc.

The digestive system of a ruminant has complex stomach with four chambers i.e. **rumen**, **reticulum, omasum** and **abomasums.** The ruminant harbours millions of mutualistic (symbiotic) microorganisms in the first complex chamber, the rumen.

Four-chambered stomach showing food movement during feeding



Unchewed food is passed to the rumen by act of swallowing and later regurgitated bit by bit into the mouth for chewing.

In the rumen fluid, the cellulose-digesting bacteria digest cellulose by producing cellulase enzyme. Some of the products of digestion are absorbed by the microorganisms, the rest by the host. The bacteria are anaerobic (carry out fermentation in rumen) and the acids produced by them are neutralized by alkaline saliva, often produced in large quantities. The presence of microorganisms is essential to the ruminant since is unable to manufacture cellulase. The waste gases mainly carbon dioxide and methane produced as result of fermentation are expelled via mouth of the ruminant. Partially digested food 'cud' is passed to the second chamber, the **rectum** where it is formed into pellets. It is then regurgitated and thoroughly rechewed. This is called **rumination** or **'chewing curd'**. The food is then reswallowed and undergoes further fermentation. Then the partially digested food goes to the **omasum** which acts as a strainer-retaining large pieces requiring further breakdown and passing on the small particles to the **obomasum** (true stomach) which corresponds to the stomach in humans. From here onwards food undergoes digestion by usual mammalian digestive system.

Note:

- The relationship is mutualistic as both gain benefit. The ruminant acquires the products of cellulose breakdown which it would not obtain alone, and the microorganisms receive a constant supply of food and a warm, sheltered environment in which to live
- Because plant material is so difficult to digest, herbivorous mammals generally have much long alimentary canals than their carnivorous relatives
- In non-ruminants such as the rabbit, cellulose digestion is effected by the microorganisms in the caecum and appendix.
- In non-herbivorous mammals like humans, the caecum and appendix are functionless.

Assignment 2: ***Explain why a termite is able to digest wood.***

Adaptations of a carnivore to its diet

Carnivores such as a dog eat meat, which is mainly the muscle of another animal. This is rich in nutrients and therefore a much more concentrated source of food than plant material. Once captured and ingested, the digestion of meat presents little problem.

(b) Adaptations of carnivorous mammals to their diet

- The incisor teeth are sharp and used for nipping and biting.
- The canines are long and pointed for piercing and killing the prey and tearing flesh from the body

- ❖ The molars and premolars have a number of sharp pointed cusps. The last upper premolar and the first lower molar on each side of the mouth are particularly large and known as carnassials teeth
- ❖ The teeth of the upper jaw tend to overlap those of the lower jaw. The carnassials teeth therefore slide past one another and slice the meat into manageable pieces.
- ❖ The muscles of the jaw are well developed and powerful. This enables carnivores to grip the prey firmly during the kill and helps in crushing bone.
- ❖ There is no lateral jaw movement as in herbivore. Such movements lead to easier dislocation of the jaw, a distinct disadvantage when trying to grip struggling prey.
- ❖ Vertical movement of the jaw is less restricted, allowing wide gape for capturing and killing prey.
- ❖ The alimentary canal is short, reflecting the relative ease with which meat can be chemically digested.

2. SAPROTROPHIC NUTRITION –sometimes called saprobiontic or saprophytic.

This Involves feeding of complex organic food from the bodies of decaying organisms. Organisms which feed in this way are called **sprotrophs/saprophytes/saprobionts**. The saprotrophs either readily take up the food material which is already in soluble form or they secrete enzymes onto the solid food material, where it is digested externally into simple soluble molecules which are then absorbed and assimilated by the saprotrophs. It carried out by many fungi (e.g. mucor, Rhizopus and yeast), bacteria and protists.

Saprophytes do not have digestive system.

In nature saprotrophs are decomposers carrying out the decay of the corpses of animals and dead plants thereby degrading them into the component nutrients they contain which can be recycled

Assignment 3:

1. Describe the importance of decomposers in

(i) an ecosystem

(ii) carbon and nitrogen cycles

2. State the characteristics of saprophytism

Importance of saprophytes

- ❖ Saprotrophs contribute to the removal of dead organic remains of plants and animals by decomposing them.
- ❖ Saprotrophs provide important links in nutrient cycles. This is because the activities of saprotrophs bring about the decay of dead bodies and release from them elements that can be used by plants and various microorganisms to synthesise new organic substances. In this way they return the vital chemical elements from the dead bodies of organisms to living ones.
- ❖ Saprophytes have other importance including brewing e.g. yeast cells, food processing e.g. cheese and yoghurt, used as food e.g. mushroom, industrial processing e.g. leather tanning, sewage treatment and food spoilage.

3. SYMBIOSIS

Symbiosis is the living together in close association of two or more organisms of different species. Many associations involve three or more partners. Nutrition is commonly involved in symbiosis. The three common types of symbiotic relationships are:

(a) Mutualism

Mutualism is a close association between two living organisms of different species which is beneficial to both partners. Examples include

(i) Bacteria and plants

Nitrogen fixing bacteria of genus *Rhizobium* form mutualistic association with roots of leguminous plants. In this association the bacteria gains sugars from the plants which they use to synthesise ATP needed in the conversion of ammonia to nitrates in the process of nitrogen fixation and also protection in the nodules, the legumes gain by absorbing nitrates produced by nitrogen fixation reactions of the bacteria

(ii) Mycorrhizas:

This is a relationship between fungi and the roots of plants. In this association, the fungus gains sugar from that being translocated to the roots of the plant, the plant gains

- Protection from bacteria and other parasites attacking by antibodies produced by the fungus
- Increased mineral absorption from the soil by utilizing some of the minerals absorbed by the fungus.

(iii)Algae and coelenterates

This is a symbiotic association between the common green hydra chlorohydra viridissima and a green alga known as Zoochlorella which lives inside its epidermal cells

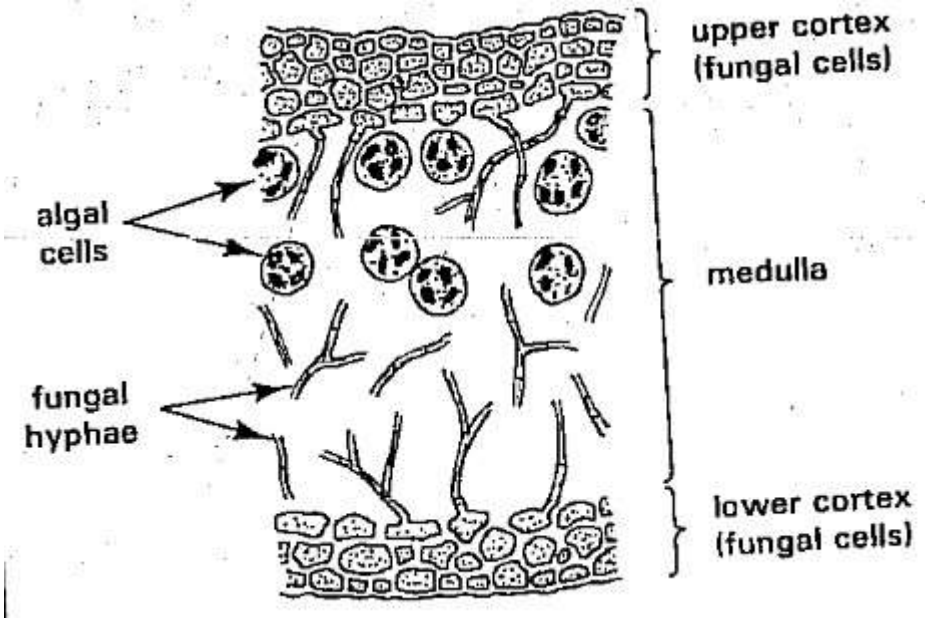
In this relationship the alga gains protection offered by the hydra in addition to the availability of carbon dioxide, nitrates and phosphates formed as excretory products by the hydra but which are useful raw materials for its photosynthesis while the hydra gains oxygen and other metabolites from the photosynthesis of the alga.

Note: this is an example of a loose mutualistic association where both organisms though benefiting can live independent lives.

(iv) Lichens

This is an association between a green alga and a fungus.the relationship is intimate that both organisms are often mistaken to be one.

A section through a lichen showing the fungal hyphae among the algal cells



In this association the fungus benefits from the products of the photosynthetic activity of the alga i.e. carbohydrates and oxygen which it uses for its own metabolism while the algae benefits from the structural support provided by the fungus and from the use of water and mineral salts absorbed by the fungus. These serve as its nutrients and in addition the water prevents it from drying out.

(v) Ruminants and bacteria and or protozoa (flagellates)

The flagellates secrete cellulase enzyme which digests cellulose of which the end products are absorbed by the ruminants for their metabolism also the bacteria synthesise vitamins B_1 and B_2 which

are used by the ruminants while the bacteria gain protection, warmth and constant supply of food from the association.

(vi) Wood eating termites and flagellates (protozoans)

1. Protozoans like *Trichonympha* in intestines of wood eating termite species produce the enzyme cellulase which they use to digest the cellulose in the wood they eat. In this association the flagellates gain protection and food from the termites while the termites gain from the use of the end products of cellulose digestion.

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.

(vii) Non ruminants and bacteria

Horses and rabbits form a mutualistic association with bacteria which live in their caecum and appendix. The benefits for both organisms are similar to those of the ruminants and organisms in their rumen

(viii) Hermit crab *Pagurus* and the sea anemone *Adamsia palliata*

In this association; the crab gains shelter and protection from the anemone because it covers it and also has stinging cells in its tentacles with which it can sting enemies of both partners while the sea anemone obtains food from the crab and also free transport to wherever the crabs going which gives it the extra benefit of finding better food.

Significance of mutualistic associations in nature

- ❖ Increases efficiency of cellulose digestion in herbivores
- ❖ Brings about fixation of nitrogen into soil through symbiotic associations of bacteria and leguminous plants
- ❖ Enables colonization during terrestrial primary succession where the lichens constitute the pioneer species.

(iii)Commensalism

Commensalism is a close association between two living organisms of different species which is beneficial to one (the commensal) and the other is neither harmed nor benefits (the host).

For example, the colonial hydrozoan Hydractinia attaches itself to whelk shells inhabited by hermit crabs. It obtains nourishment from the scraps of food left by the crab after it has eaten. In this particular case the crab is totally unaffected by the association. Another example is an orchid or lichen (the commensal) growing on a tree (the host).

(iv) Parasitism (refer to ecology notes)

PARASITIC MODE OF FEEDING

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

i. They face the danger of failing to penetrate the host
ii. They face the danger of failing to obtain nutritive molecules from the host.
iii. They may fail to attach themselves safely on the host so that they cannot easily be dislodged.
iv. They face the danger of failing to find the right host which should disperse them to their final host in succeeding generations
v. They can be destroyed by the digestive enzymes and immune responses of the hosts.

vi. They face the danger of being eliminated completely or becoming extinct.
vii. 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.

Structural adaptations

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*)

Suckers in leeches and tight spirals in Cuscuta

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

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

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.

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

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.

Failure to develop photosynthetic pigments such as chlorophyll in some parasitic plants such as Cuscuta

Physiological adaptations

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

Production of anticoagulants by blood feeding parasitic animals such as mosquitoes and ticks so as to avoid blood clotting in the mouth during feeding

They are highly chemo sensitive in order to reach the optimum location in the host's body e.g. plasmodium

Most of them respire anaerobically so as to stay in areas of low oxygen tensions e.g. most endo parasites

They have developed an ability to tolerate high temperatures, darkness and pH changes in places where they live e.g. most endo parasites

They have very rapid means of escape which increases their chances of survival e.g. fleas and mosquitoes

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

Some endo parasites produce chemicals to protect themselves against the immune response of the host.

Reproductive adaptations

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.

Most of them have an asexual phase in their lifecycles to have a high rate of reproduction and avoid extinction.

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)

Release of sexually mature forms of the parasites as free living organisms e.g. in some parasitic animals such as the horse hair worms

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.

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.

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.*

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.

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.

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.

PARASITIC PLANTS AND FUNGI

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)

ASSIGNMENT

1. (a) Briefly describe the lifecycle of Taenia

   (b) State the adaptations of this parasite to its parasitic mode of life

   © State ways in which parasites can be controlled

2. (a) Describe, with the aid of a flow diagram, the lifecycle of *Ascaris lumbricoides.*

   (b) State the adaptations of Ascaris to the parasitic mode of life.

   © State any five effects of round worms to the host

   (d) How can round worms be controlled?

3. (a) Describe the life cycle of cuscuta

   (b) State any two effects of cuscuta on the host

   © Describe the life cycle of *Phytophora infestans*

LIFECYCLE OF TAENIA

Taenia is an endoparasite. They are of two types i.e. beef tapeworm and 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 lifecycle of taenia involves two vertebrate hosts. With the beef tapeworm, the cow is the intermediate host whereas with pork tapeworm, man is the primary host and the pigs are intermediate hosts.

The adult tapeworm is a ribbon-like platyhelminthes up to 3-10 metres long. The tapeworm consists of a ‘scolex’ or a ‘head’ followed by a linear series of segments called proglotidds. Proglotidds are more than 1mm thick.

The anterior part of the head is a small muscular knob bearing suckers and a double row of curved hooks at the top. Behind the scolex, the narrow neck region gives to proglotidds by a continuous process of budding. As individual segments grow and mature, they are pushed back from the scolex. Each mature proglotidds, contains a hermaphroditic set 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.

Adaptations

i. It has hooks and suckers that allow it to hold on tightly to the wall of the intestine
ii. Its flat body gives it a large surface area for absorbing its hosts digested food
iii. Suckers are for attachment and a body covering which protects them from the host's immune digestive system.
iv. They have no gut which enables them to absorb predigested food.
v. It lays many eggs to ensure survival
vi. Hooks for boring through the gut of the host
vii. Eggs have a thick shell which are not easily destroyed.

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.

LIFECYCLE OF LUMBRICOIDES

Ascaris lumbricoides, 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.

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.

A**daptations 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. 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.
c. Ability to reproduce faster, both sexually by producing a large number of viable seeds and asexually by fragmentation. This facilitates its dispersal.
d. 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.

Exercise 4

1. (a) Compare mutualism and parasitism. (04 marks)

(b)Describe how

(i) Gut bacteria contribute to the well-being of herbivores (04 marks)

(ii)Nitrogen-fixing bacteria contribute to the well-being of herbivores (06 marks)

(c)Explain the mutualistic relationship between mammals and the micro-organisms in their alimentary tract. (08 marks)

2. (a) Distinguish between intracellular digestion and extracellular digestion (02 marks)

(b)Describe the role of digestive juices in the process of digestion in mammals (12 marks)

(c)Explain how chemical components in algae may end up into the cytoplasm of an amoeba (06 marks)

Coprophagy

Coprophagia or coprophagy is the consumption of feces. Many animalspecies 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 dung-beetle and the most common is the fly. Termites eat one another's feces as a means of obtaining their hindgutprotists. Termites and protists have a symbiotic relationship (e.g. with the protozoan *Mixotrichaparadoxa*) 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 the 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 re-ingestion of seeds. *Hamsters*, *guinea pigs* and *chinchillas* eat their own droppings, which are thought to be a source of vitaminsB 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.

Some carnivorous plants, such as pitcher plants of the genus *Nepenthes*, obtain nourishment from the feces of *commensal animals*.

FOOD DIGESTION IN CARNIVOROUS 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. They are usually able to run very fast as compared to their prey in order to capture the prey.
d. Most predators are physically stronger than their prey so as to easily capture the prey.
e. 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
f. Most predators have very sharp claws that are used to hold the prey and kill it.
g. Most predators have a keen eye sight to easily see their prey from a distance.
h. Most predators carry out stealth movement which enables them not to alert their prey so that they can easily be captured.
i. Some of them carry out group hunting so as to successfully capture their prey e.g. lions

END