**11. The Digestive system**

The alimentary canal (gastrointestinal tract) is composed of the mouth, oesophagus, stomach, small and large intestine.

**The Digestive system**

Without food, water and oxygen, human beings could not survive. The digestive system is the set of organs which transform whatever we eat into substances that can be used in the body for energy, growth and repair. Once the food has been broken down by various chemical processes, and the nutrients removed, the rest is excreted as waste. The whole process involves many different organs and sometimes takes several hours.

**TOPIC 1: DIGESTION**

**WHAT IS DIGESTION?**

The breakdown and transformation of solid and liquid food into microscopic substances. These substances are then transported by the blood into different areas of the body. There are four stages of digestion:

**Mouth:** ingestion (the taking in of food or liquid into the body), chewing and swallowing; start of starch digestion

**Stomach:** mixing and protein digestion

**Small intestine:** carbohydrate and fat digestion; absorption

**Large intestine:** waste and excretion.

**WHERE DOES DIGESTION START?**

In the mouth where the action of teeth and saliva combine in the first stage of breakdown, chewing and partially digesting the food so that it will pass more easily along the oesophagus. The ball of food that leaves the mouth is known as a bolus.

**WHAT IS SALIVA?**

Saliva is a liquid secreted by three pairs of salivary glands: the parotid gland (situated below the ear), the submandibular gland and the sublingual gland (both situated below the tongue). It contains water, mucus and the enzyme salivary amylase.

Saliva has three functions:

* To lubricate the food with mucus, making it easier to swallow
* **To start digestion:** it contains the enzyme salivary amylase, which acts on cooked starch turning it into shorter polysaccharides
* To keep the mouth and teeth clean.

**WHAT IS AN ENZYME?**

If you think about the food you eat, and the difference in size between it and the microscopic cells and tissues that it will feed and support in your body, it is easy to understand why a digestive system that breaks food down into different units is needed. Enzymes are an important part of the process. If the digestive system is a conveyor belt, enzymes are the machines and workers which slowly change whatever is on the belt to make it smaller and smaller so that, eventually, it can be carried around the body in blood. They are made of protein and act as catalysts i.e. they make chemical changes happen in other substances, whilst themselves remaining unchanged. They act on food, changing it into smaller particles.

**WHAT IS THE TONGUE?**

**Structure:** the tongue is a muscular organ, covered with a membrane. It is held in place by attachments to the mandible (lower jaw) and the hyoid bone. Tiny projections known as papillae cover the top, increasing its surface area and producing a rough texture. Sensory nerve endings in the papillae form what we commonly know as taste buds.

**Functions:** the tongue has three digestive functions - taste, chewing and swallowing:

* **Taste:** the tongue is covered with thousands of taste buds which are sensitive to salt, sweet, sour and bitter chemicals in food and drink. They help us enjoy what we eat and drink and act as the first line of defence, warning us when food, drink or foreign matter are off or inedible.
* **Chewing:** the tongue aids chewing by moving food around the mouth, pushing it between the teeth and covering it with saliva, which contains enzymes that start the digestive process. The food is turned into a partially digested mass known as a bolus.
* **Swallowing:** when the food is ready to travel to the stomach, the tongue pushes it to the back of the mouth.

**HOW DOES FOOD GET FROM THE MOUTH TO THE STOMACH?**

Via the action of swallowing and through the portion of the gastrointestinal tract known as the oesophagus. The tongue pushes the bolus to the back of the mouth, towards the pharynx, a muscular tube behind the mouth. The food passes into the pharynx and down to the oesophagus. The epiglottis, a small flap of cartilage which forms part of the larynx (the windpipe) moves upwards and forwards, blocking the entrance to the larynx. This stops the food from 'going down the wrong way' and prevents choking.

**WHAT IS THE OESOPHAGUS?**

**Structure:** the oesophagus is a muscular tube which leads from the pharynx, at the back of the mouth, to the stomach, the first main organ of digestion.

**Function:** to carry chewed food from the pharynx to the stomach. Food moves along it by a muscular contraction known as peristalsis. The muscle fibres contract and relax which acts like a wave on the tube, pushing the bolus forwards. The lining of the oesophagus secretes mucus to ease and lubricate the passage of food.

**Section 2: the stomach**

**WHAT IS THE STOMACH?**

**Structure:** the stomach is a J-shaped, elastic organ which expands and contracts depending on what is in it. Food enters it from the oesophagus via the cardiac sphincter, a valve that stops back flow of the stomach's contents, and leaves it through the pyloric sphincter into the duodenum, the first part of the small intestine. The wall of the stomach is a combination of layers of muscle fibre with an inner mucous membrane. The latter has lots of folds, called rugae. When the stomach is full they stretch out, enabling expansion, then they contract when it empties.

**WHAT DOES IT DO?**

**Functions:**

* Digests proteins through the action of enzymes
* Churns food with gastric juices
* Helps to lubricate the food by producing mucus (from the mucous membrane)
* Absorbs alcohol
* Kills bacteria by producing hydrochloric acid.
* Storage of food prior to it passing to the small intestine

**GASTRIC JUICES CONTAIN:**

* **hydrochloric acid:** neutralises bacteria and activates pepsin
* **rennin:** enzyme that curdles milk protein (only in infants)
* **pepsin:** enzyme that acts on proteins turning them into polypeptides.

At this stage proteins have been partially digested and, along with the carbohydrates such as starch which were partially digested in the mouth, they have to wait until the small intestine to complete digestion.

**DID YOU KNOW?**

Food may stay in your stomach for as little as 30 minutes or as long as four hours, depending on what it is. Carbohydrate meals are the quickest to leave the stomach because they are not digested until the small intestine.

**THE CHEMISTRY OF DIGESTION**

The whole digestive process is a combination of different chemical reactions that act on the food we eat, reducing it to the building blocks of nutrients for absorption and use by the body. Every piece of food we eat is composed of fats, carbohydrates and proteins. These must be broken down into their relative chemical compounds in order for the body to use them i.e. by the time the bread you eat reaches your muscles as energy it has been chewed, churned, liquefied and the starch changed to useable glucose. The following shows the main chemical reactions and breakdowns at different stages of digestion.

**WHAT ARE PROTEINS?**

Proteins foods include dairy products, meat, fish and beans. They are made up of interlinked polypeptide chains and are the building material for the body. In order to be used by the body they must be broken down into their smaller components - amino acids. There are approximately 20 amino acids classified by whether they are essential (those the body cannot make, that must therefore be supplied in the diet) and non-essential (those the body can make).

Proteins are broken down in the body by the following processes:

* In the stomach, the enzyme pepsin begins the digestion of proteins in the stomach by breaking them down into large polypeptides.
* In the small intestine, enzymes from the pancreas, including trypsin and chymotrypsin, break the large polypeptides into smaller chains.
* Finally, still in the small intestine, enzymes from the intestine, including aminopeptidase, breaks up the small polypeptides into individual amino acids ready for absorption.

**WHAT ARE FATS?**

Fats are classified into saturated, monounsaturated or polyunsaturated categories. Saturated fats can be found in dairy products and meat. Monounsaturated fats can be found in olive oil and avocados. Polyunsaturated fats can be found in sunflower oil and oily fish. Some polyunsaturated fats cannot be made by the body and are therefore also classified as essential fats and must be consumed in the diet. In order to be used by the body, fats must be broken down to fatty acids and glycerol.

Fats are broken down in the body by the following processes:

* In the small intestine, fat are emulsified by bile salts from the liver (i.e. turned into liquid form and carried in another liquid - bile)
* In the small intestine, lipase from the pancreas breaks down emulsified fats into fatty acids and glycerol ready for absorption

**WHAT ARE CARBOHYDRATES?**

Carbohydrates are classified as monosaccharides, disaccharides or polysaccharides. Monosaccharides include fructose in fruit. Disaccharides include lactose in milk. Polysaccharides include starch and fibre in cereals, potatoes and other plant sources, and glycogen in meat. All carbohydrates are broken down to monosaccharides for absorption and all eventually become glucose to supply the body with energy.

Carbohydrates are broken down in the body by the following processes:

* In the mouth, salivary amylase begins the breakdown of polysaccharides
* In the small intestine, intestinal amylase breaks down polysaccharides to disaccharides
* In the small intestine, maltase, lactase and sucrase convert disaccharides to monosaccharides ready for absorption.

**Section 3: The small intestine**

**WHAT IS THE SMALL INTESTINE?**

The small intestine, ironically, is not that small. It is seven metres long and divided into three different parts: the duodenum, the jejunum and the ileum. The walls have several layers, including a muscular layer, a layer containing blood vessels, lymph vessels and nerves and an inner mucous membrane. The inner wall is covered with villi, tiny finger-like projections which increase the surface area for absorption and contain a network of blood and lymph vessels.

**WHAT DOES THE SMALL INTESTINE DO?**

Completion of the chemical digestion of food and the subsequent absorption of nutrients takes place in the small intestine.

Nutrients are absorbed through the villi into the blood and lymph vessels. Hardly any food is absorbed elsewhere in the digestive system.

**HOW DOES DIGESTION AND ABSORPTION TAKE PLACE IN THE SMALL INTESTINE?**

**1.** Peristaltic movements mix food with intestinal and pancreatic juices as well as bile. The movements push the food against the villi. Intestinal juices are composed of enzymes:

* maltase, sucrase and lactase which split disaccharides into monosaccharides
* enterokinase which activates trypsin in pancreatic juice
* peptidases which split polypeptides into amino acids

**2.** A number of hormones in the small intestine help digestion by stimulating the production of pancreatic or intestinal juices and regulating acidity levels, for example cholecystokinin (CCK)

**3. Absorption:** digested food is absorbed by either active transport or diffusion

* Most nutrients, including amino acids and sugars, are absorbed by active transport through the walls of the villi where they enter the bloodstream and are carried to the liver in the hepatic portal vein.
* Fats, fatty acids and glycerol diffuse into the lacteals (lymphatic capillaries). They are called lacteals because the fat passes into them in suspension, causing the lymph to look milky.

**OTHER FUNCTIONS OF THE SMALL INTESTINE**

To protect the digestive system from infection. It is the only section of the digestive system with a direct link to the protective lymphatic system.

**DID YOU KNOW?**

90% of absorption takes place in the small intestine whereas only 10% takes place in the stomach and large intestine.

**ORGAN: Mouth**

**Salivary glands**

**SECRETION:** Salivary amylase

**ACTION:** Converts starch into shorter chain polysaccharides

**ORGAN: Stomach**

**SECRETION:** Rennin

**ACTION:** Coagulates milk into curds (in infants)

**SECRETION:** Hydrochloric acid

**ACTION:** Neutralises bacteria

**SECRETION:** Pepsin

**ACTION:** Coagulates proteins into peptones (any of various water-soluble protein derivatives obtained by partial hydrolysis of a protein by an acid or enzyme during digestion)

**ORGAN: Duodenum**

**SECRETION:** Pancreatic juice trypsin

**ACTION:** Converts peptones into shorter chain polypeptides

**SECRETION:** Pancreatic juice lipase

**ACTION:** Converts fats into fatty acids and glycerol

**SECRETION:** Pancreatic juice amylase

**ACTION:** Converts polysaccharides into disaccharides

**SECRETION:** Bile

**ACTION:** Emulsifies fats

**ORGAN: Small intestine (from the villi)**

**SECRETION:** Intestinal juice

* Maltase
* Sucrase
* Lactase

**ACTION:** Convert disaccharides into monosaccharides

**SECRETION:** Enterokinase

**ACTION:** Activates trypsin in pancreatic juice

**SECRETION:** Peptidases

**ACTION:** Convert polypeptides into amino acids

**Section 4: the large intestine and waste**

**WHAT IS THE LARGE INTESTINE?**

The large intestine deals with waste. It is about 1.5m long and sits draped around the small intestine, in an arch shape. It consists of the caecum, appendix, colon, rectum, anal canal and anus.

**Functions:** to reabsorb water and nutrients from digestive waste and to get rid of waste. Whatever remains of the food, once it has been through the processes of mixing, conversion and absorption carried out in the stomach and small intestine, is passed into the large intestine. Any remaining nutrients are removed and the result is faeces.

**FAECES**

Faeces are the unwanted leftovers from food, combined with cellulose (roughage which is indigestible, found in foods like vegetables and bran), dead blood cells, bacteria (both living and dead), fatty acids and mucus, used to help move the faeces through the large intestine. The colour comes from the dead blood cells and bilirubin, a bile pigment.

**Summary**

Of large intestine's functions

* Absorption of nutrients, vitamins, salt or water left in digestive waste.
* Secretion of mucus to help passage of faeces.
* Storage of faeces in rectum (short-term because the arrival of faeces in rectum tells brain of need to defecate).
* **Micro-organism/bacteria activity:** many bacteria live in the large intestine. Though they can cause disease they are harmless in the colon and may even be useful.
* **Defecation:** a 'mass movement' pushes waste along the transverse colon, often stimulated by food arriving in the stomach. It is a reflex but humans have control of it. If the reflex is ignored, more water will be absorbed from the faeces which may cause constipation.

**TOPIC 2: ACCESSORY ORGANS**

There are several other organs involved in the digestive process: the tongue, teeth and salivary glands, liver, pancreas and gall bladder. They are known as accessory organs because, although they do not form part of the gastrointestinal tract, they help the digestive process by breaking down foodstuffs and the toxins/ waste produced during digestion. The role of the tongue, teeth and salivary glands has been mentioned earlier in the chapter.

**THE LIVER IN HISTORY**

Like parts of the circulation, parts of the digestive system have always been seen as very important throughout history, both for what they do and what they represent. This is especially true with the liver. For example in ancient Rome, animals were sacrificed for their livers before battles. The organs were then used to predict what might happen. Forexample, a pale liver was bad news and predicted defeat whereas a healthy red liver meant the conditions were favourable for victory. The liquid secreted by the liver, bile, was thought to be one of four body fluids known as humours which determined personality. Black bile (or melancholy) meant a person was sad and choler (or yellow bile) meant they were irritable. A coward's liver was thought to be bloodless, which is why someone cowardly is lily-livered.

**WHAT IS THE LIVER?**

**Structure:** the largest gland in the body, the liver sits at the top of the abdomen, just below the diaphragm and just above and to the right of the medial line. It is vital because it performs many essential functions.

**Functions:** the liver is vital for cleansing and storage as well as production. It:

removes

* Toxins from drugs, alcohol, and harmful substances
* Nitrogen from amino acids.
* Stores
* Vitamins A, B12, D, E, K
* Glycogen (a compound that stores energy)
* Iron, from the breakdown of red blood cells and food
* Fats.
* Produces
* Heat (the liver is the body's radiator, producing more heat than any other organ as a result of its various functions)
* Vitamin A (from carotene, found in green-leafed vegetables and carrots)
* Vitamin D
* Heparin
* Plasma proteins: albumin, globulin, prothrombin, fibrinogen
* Bile
* Uric acid and urea, from breakdown of red blood cells and de-amination of amino acids.
* Converts
* Stored (saturated) fat into other fat products (like cholesterol)
* Glycogen to glucose, when energy is needed
* Glucose back to glycogen, in presence of insulin
* Metabolises protein.

**WHAT IS THE GALL BLADDER?**

**Structure:** a pear-shaped sac attached by the cystic and bile ducts to the posterior of the liver. Whenever there is excess bile secreted by the liver which can't be used immediately for digestion, the bile passes first along the bile duct then along the cystic duct to the gall bladder where it will be stored until needed.

**Functions:**

* Reservoir for bile (from liver)
* Secretes mucus to add to bile
* Absorbs water from bile, making it more concentrated
* Contracts in order to empty bile into duodenum.

**WHAT IS THE PANCREAS?**

**Structure:** the pancreas is a gland situated behind the stomach, between the duodenum and the spleen. It delivers pancreatic juices to the duodenum through the pancreatic duct. The cells of the pancreas are divided into the islets of Langerhans (which produce insulin and glucagon) and a network of alveoli (small sac-like cavities). The alveoli are lined with cells that produce enzymes.

**Functions:** the pancreas works with both the digestive and the endocrine systems. It produces enzymes to break down food, the hormone insulin which regulates the blood sugar level after eating by causing the conversion of glucose to glycogen for storage in the liver and muscles, and the hormone glucagon which converts glycogen back to glucose.

**Pancreatic juices contain:**

* lipase (fat digestion)
* amylase (starch digestion)
* trypsin (protein digestion).

**WHAT IS INSULIN**

Insulin is a hormone secreted by specialised cells in the pancreas known as the islets of Langerhans. It regulates blood sugar level. When we eat, the blood sugar level rises. The sugar in the blood is in the form of glucose. Insulin helps cells absorb glucose and turns any excess glucose into glycogen, an insoluble sugar which is stored in the liver until the body needs it. Thus the blood sugar level drops. A lack of insulin causes diabetes mellitus. Type 1 diabetes is caused by auto-immune damage to the pancreas resulting in low or no insulin production. Type 2 diabetes is strongly linked to obesity and although insulin may still be produced it is unable to work properly in the body (insulin resistance). In either type, glucose cannot be properly absorbed into the body resulting in the following symptoms - a dangerously high level of blood sugar, the loss of glucose through excretion, thirstiness and excessive urine production.

**WHAT IS BILE?**

**Structure:** a thick liquid produced in the liver as a result of the breakdown of red blood cells. It contains salts, bile pigments, acids and water.

**Function:** emulsifying fats, stimulating peristalsis and creating alkaline conditions in the small intestine.

**TOPIC 3: DISEASES AND DISORDERS (PATHOLOGIES)**

**ANOREXIA**

Anorexia is a loss of appetite. Anorexia nervosa is a psychological condition which often affects teenage girls and young women. The sufferers have a fear of gaining weight or being fat and refuse to eat very much or stop eating altogether. It can be severely debilitating and sometimes fatal.

**APPENDICITIS**

Acute inflammation of the appendix, usually treated by removal of the organ.

**BULIMIA**

Bulimia is an insatiable hunger during binging episodes coupled with compensatory evacuation methods such as self-induced vomiting and excessive use of laxatives. Bulimia nervosa is a psychological condition which often affects teenage girls and young women, and increasingly young men.

**CIRRHOSIS**

Chronic damage to an organ causing hardening. Several types of cirrhosis exist but the most common is cirrhosis of the liver, which is frequently caused by excessive alcohol consumption.

**CONSTIPATION**

Infrequent or uncomfortable bowel movements, causing hard faeces to block the rectum. Caused by lack of fibre in the diet, lack of fluids and lack of exercise. Sometimes caused by stress.

**GALL STONES**

Stones formed from residues of bile pigments, cholesterol and calcium salts, found in the gall bladder.

**HEARTBURN**

Burning sensation in oesophagus or throat, caused by back flow and regurgitation of acidic stomach contents.

**HERNIA**

A rupture, in which an organ pushes through the surface of the structures which normally hold it in.

**JAUNDICE**

Excessive levels of bile pigments in the blood cause skin to turn yellow. Caused by malfunctioning gall bladder or obstructed flow of bile.

**IRRITABLE BOWEL SYNDROME**

No exact cause is yet known for irritable bowel syndrome (sometimes referred to as IBS), though stress and low-fibre, high fat diets are said to contribute. Symptoms include stomach and bowel pain and alternate bouts of diarrhoea and constipation.

**STRESS**

The most common effect of stress on the digestive system is ulcers. Anxiety and lack of relaxation cause overproduction of gastric juices and if they have nothing to work on they will start to attack the lining of the stomach or other structures. In short, the stomach starts digesting itself!

**ULCER**

Erosion in the walls of the digestive system, often caused by too much acid.

**COELIAC’S DISEASE**

Is a common bowel condition that is caused by intolerance to a protein called gluten.

**DIARRHOEA**

Frequent and watery bowel movements.

**FLATULENCE**

A state of excessive gas in the alimentary canal.

**GINGIVITIS**

Inflammation of the gums.

**INDIGESTION (DYSPEPSIA)**

A disorder of digestive function characterized by discomfort, heartburn or nausea.

**NAUSEA**

Is the sensation of unease and discomfort in the stomach with an urge to vomit.

**OBESITY**

Is a medical condition in which excess body fat has accumulated to the extent that it may have an adverse effect on health, leading to reduced life expectancy.

**CANDIDA**

A fungus, called Candida albicans, which causes yeast infections like thrush in the mouth, throat, intestines and other parts of the body.

**COLITIS**

An inflammation of the large intestine (the colon).

**COLITIS/ULCERATIVE COLITIS**

Is a form of inflammatory bowel disease (IBD). It is a form of colitis, a disease of the intestine, specifically the large intestine or colon, which includes characteristic ulcers, or open sores in the colon.

**CROHN'S DISEASE**

A disease of the small intestine that often spreads to the colon. Crohn's disease is characterized by diarrhoea, cramping and loss of appetite and weight, with local abscesses and scarring.

**DIVERTICULOSIS**

A condition of the large intestines characterized by the development of weakness in the intestinal wall that permits herniation or outpouching of the intestinal lining. Diverticulosis usually develops as a result of inadequate dietary fibre.

**DIVERTICULITIS**

An inflammation of a diverticulum in the digestive tract (especially the colon); characterized by painful abdominal cramping, fever and constipation.

**ENTERITIS**

An inflammation of the intestine (especially the small intestine) usually characterized by diarrhoea.

**GASTRITIS**

An inflammation of the lining of the stomach which is characterized by nausea, loss of appetite and discomfort after eating.

**INFLAMED GALL BLADDER**

An inflammation of the gall bladder.

**PERNICIOUS ANAEMIA**

A chronic progressive anaemia of older adults, thought to be caused by impaired absorption of vitamin B-12 due to the absence of intrinsic factor.

**ULCER**

Oesophageal - An ulceration of the oesophagus.

**INTERRELATIONSHIPS**

Digestive system links to:

**All systems:** provides nutrition to the whole body.

**Circulatory:** the circulatory system transports nutrients from the digestive system to every system of the body.

**Endocrine:** the endocrine system secretes certain hormones, which help metabolism**.**

**Lymphatic:** lymphatic vessels are found in the lacteals of the villi in the small intestine and help with the absorption of fats.

**Muscular:** the digestive system supplies glucose for energy to the muscular system: sphincter muscles contract along the alimentary canal to push food along - known as peristalsis.

**Nervous:** all the organs of the digestive system are stimulated by nerve impulses.

**Summary**

The digestive system

* Transforms food and drink into nutrients and waste
* Consists of every process from eating (ingestion) to excretion
* Relies on chemicals (enzymes) to carry out the break down of food.