Chapter 8 – The Respiratory System

- The respiratory system and the circulatory system work together to ensure all the cells in the body receive oxygen for respiration and that carbon dioxide is removed.

The Lungs

- A membrane called the pleura covers the surface of the lungs and inside of chest. Between the 2 layers is a thin layer of a fluid called pleural fluid.
- This fluid holds the lungs against the inside of the chest wall and allows lungs to slide along the wall when breathing.
- In lungs the bronchi branch into smaller air passages called bronchioles. The smallest bronchioles open to clusters of sir sacks called alveoli.
- The alveoli provides a surface for gas exchange. They are surrounded by blood capillaries.

Respiratory Surfaces and The Exchange of Gases

- The lungs are well suited to their gas exchange function for these reasons:
  - Alveoli provides lung with a large surface area for gas exchange so in short time amount of time large amount of gas is exchanged. Have a surface area of 50-80m².
  - Each alveolus is supplied with blood vessels, so that as much blood as possible is close to the air in the alveolus. The continuous flow of blood helps to maintain a difference in concentration of oxygen and carbon dioxide in blood and lung air.
  - The membrane forming alveolus wall is thin (1micrometer) so gas molecules travel easily from blood to lungs.
  - The membrane of the alveolus are covered by thin layer of moisture since gas can only diffuse through in and out of blood when dissoled in fluid.
  - The lung volumn can be changed by movements in respiratory muscles, so that air is made to flow into and out of the lungs. Constant changing of the air in the alveoli helps to ensure that there is always a difference in the concentrations of oxygen and carbon dioxide in the air and blood.
The Mechanisms of Breathing

Inspiration

It is the process of taking air into the lungs. In order for air to flow into the lungs the atmospheric pressure must be higher than air pressure within lungs. This is achieved by increasing the lung volume. When lung volume is increased the diaphragm and the external intercostal muscle contracts. Diaphragm flatten and the muscle moves upwards and outwards. Increasing lung volume means the air pressure is slightly lower than the air pressure outside. Air flows through nose and trachea until pressure equalises.

Expiration

The air moves out of the lungs and the diaphragm and the external intercostal muscle relaxes so the diaphragm bulges to chest and rib cage moves downwards. This causes reduction is lung volume. This means the air pressure in lungs are greater than air pressure outside the body.

Gas Exchange

- The blood in capillaries surrounding the alveoli is brought to lungs by pulmonary artery.
- This blood has been through the body capillaries where oxygen had been taken by the cells. This blood has low oxygen concentration.
- This oxygen then dissolves in the moisture on the inside of the alveolus and diffuses through the membrane through walls of capillaries and blood.
- The blood that arrived in the capillaries has higher concentration of carbon dioxide. It came from the body cells that took up the oxygen and produced CO\(_2\).
- There must be a concentration gradient for the diffusion of gases. This difference is between the gas concentration between the air in alveoli and blood capillaries.
- The concentration of O\(_2\) and CO\(_2\) is maintained by:
  - The constant flow of blood through capillaries – as blood flowing through the capillaries around each alveolus picks up oxygen and loses CO\(_2\) it is replaced with more blood pumped into the capillaries. The new blood is low in oxygen and high in CO\(_2\) so concentration gradient is maintained.
  - The movement of air in and out of alveoli. The air that picked CO\(_2\) from and lost oxygen to, the blood is replaced by new air with each breath. The new air is low in CO\(_2\) and high in oxygen.
Lung Diseases

**Emphysema** – caused by long-term exposure to irritating particles in the air taken into the lungs. They lose their elasticity and are often replaced with fibrous tissue and may break down which can reduce the internal surface area of the lungs. The loss of elasticity makes lungs inflated and voluntary effort is required for breathing. People with emphysema have 2 problems: inadequacy of surface area for gas exchange and difficulty in ventilating lungs.

**Lung Cancer** – it involves the development of a tumour, a mass of cells that divides uncontrollably. Lung cancer is linked with those who smoke and exposed to asbestos fibres. Most common lung cancer occurs in the walls of bronchi. The smoke particles irritate the mucus lining the bronchi which causes excessive mucus production. Cells at the base of the membrane divide rapidly and the accumulating mucus cannot be removed. The trapped mucus causes rapture in the alveoli.

**Lung Infections** – Pneumonia is an infection caused by bacteria, viruses and fungi or other organisms. The inflammation resulting from infection causes secretion of fluid and mucus into the alveoli reducing amount of air that they can contain and surface area. Tuberculosis is a lung infection caused by bacterium Mycobacterium tuberculosis.

**Asthma** – is an allergic response to foreign particles entering the body. During an asthma attack the muscles surrounding the bronchioles go into spasm – suddenly involuntary contractions and this cause narrowing of air passage and difficulty in breathing. This irritation secretes excessive mucus and reduce air volume entering the lung.
**Figure 8.2** The structure and functions of the parts of the respiratory system
Chapter 9 – The Digestive System

The Alimentary Canal

- It is the continuous tube that runs from the mouth to the anus. Other associated organs make up the canal and the lining of the alimentary canal is the surface through which nutrients are absorbed.
- The process in which carbohydrate, protein and fat molecules are broken down to products small enough to be absorbed into the blood and into cells is called digestion.
- The digestive system is arranged in a way that it carry out 6 functions: ingestion of food and water, mechanical digestion of food, chemical digestion of food, movement of food along the alimentary canal, absorption of digested food and water into blood and lymph, and elimination of material that is not absorbed.

**The Mouth** - Ingestion occurs in mouth. The food is broken down mechanically. The food is mixed with saliva secreted by the salivary glands.
- The saliva contains mucus and digestive enzymes, salivary amylase which begins chemical digestion of starch beaking down large starch molecules into smaller molecules.
- The boulus is pushed down the back of the mouth by the tongue, the pharynx. The pharynx leads into the oesophagus connecting to the stomach.

**The Oesophagus** – made up of double layer of circular muscle and longitudinal muscle with fibres arranged along the length of the canal.
- As food enters the oesophagus the circular muscles contract to form constriction.
- By contraction successive bands of the circular muscle the constriction moves in a wave down the oesophagus pushing food in front. This constriction is peristalsis.

**The Stomach** – As the food passes down the oesophagus and diaphragm it enters the stomach. The oblique muscle layers in the stomach allows it to contract to churn food. The lining of the stomach mucosa, is specialised for secretion of gastric juice responsible for chemical digestion in stomach.
- Gastric juice is secreted by gastric glands which are located in gastric glands. The gastric juice contains HCl, mucus, and digestive enzymes. Each of the following is secreted by specialised cells in the gastric pit.
- Chemical digestion is done by the digestive enzymes in the gastric juice. The stomach has a thick layer of mucus which is why food isn’t absorbed. The enzyme pepsin is
T. Ishra

responsible for the chemical breakdown of food. The constriction in the stomach – pyloric sphincter is sufficient to prevent the contents from moving.

The Small Intestine

The first part of the stomach is the duodenum. Digestion continues under the influence of intestinal juice secreted by glands in the lining, pancreatic juice secreted by pancreas and bile by liver which is stored in gall bladder.

The pancreatic juice enters the duodenum and helps to neutralise the acid that has come with the material from stomach.

Many enzymes involved in the digestion of food are contained in the pancreatic juice. For example: Pacreatic amylase – breaks down starch, trypsin – splits proteins into smaller units, ribonuclease and deoxyribonuclease – enzymes digesting DNA and RNA, and pancreatic lipases – enzymes breaking down fats to fatty acids & glycerol.

Bile does not have enzymes but have bile salts which are important in digestion of fats. They emulsify fats breaking into tiny droplets – mechanical digestion which increases surface area on which lipases can act to chemically break fat. In completion of digestion carbohydrates – simple sugars, proteins – amino acids and fats – fatty acids and glycerol.

The products of digestion such as vitamins, minerals, nutrients are absorbed through the walls of the small intestine into the blood. Large surface area is required for nutrient absorption which can be done in a number of ways: the inner lining known as mucosa has folds that extend into the interior has villi that extend from the folded surfaces. The cells covering outside of the villi have tiny microscopic projections from external surfaces – microvilli.
The primary function of villi is for nutrient absorption. Inside villi there are lymph capillaries called lacteal surrounded by blood capillaries. The muscular movement of the intestinal walls enhance the absorption of nutrient as the villi moves. This movement brings villi into contact with other parts of intestinal content. Absorption occurs through diffusion and active transport. From the walls of the villi sugars amino acids, water, water soluble vitamins are absorbed into the blood capillaries. The substances are absorbed in blood capillaries and carried to liver by heptic portal vein.

In here they are processed or remain in blood to be carried to other body cells. Substances in lacteals are transported in the lymph system which is later emptied in the blood through veins in the upper chest.

Large Intestine

In large intestine most of the remaining water is absorbed so content is more solid. Bacteria of the large intestine break down much of the remaining organic compounds. Some bacteria produce vitamins which are absorbed through the wall.

The solid component made of water, undigested food material, bacteria, bile pigments and the remains of the cells are called feaces.
**Diet Affects in the Alimentary Canal**

**Constipation** – occurs when the movements of the large intestine are reduced and the contents remain there for a long period of time. As water is absorbed, the faeces become drier and harder than usual. Can be caused by roughage – cellulose which humans can't digest.

**Diarrhoea** – defecation of watery faeces. Caused by the irritation of the small and large intestines, which increases peristalsis so that the contents move through before adequate absorption of water. This may be result of viral or bacterial infection.

**Bowel Cancer** - is an uncontrolled growth of cells in the walls of the large intestine. Overweight, meant and low fibre foods are risk factors for bowel cancer.

**The importance of Soluble Fibre In Diet** – Fats in the intestines are trapped by soluble fibres which lowers cholesterol, heart disease and cancer.

**Coeliac Disease** - people with such disease cannot tolerate gluten. If eaten then the immune system responds by destroying the villi in the small intestine. Without villi nutrients are not absorbed which can make the person malnourished. Symptoms: muscle cramps, joint pain, tingling in legs.

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<table>
<thead>
<tr>
<th>Organ</th>
<th>Mechanical digestion</th>
<th>Chemical digestion</th>
<th>Other functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>Breaks food into smaller particles by chewing</td>
<td><em>Saliva, which contains salivary amylase,</em> begins starch digestion.</td>
<td>Food is dissolved in saliva so that it can be tasted</td>
</tr>
<tr>
<td>Oesophagus</td>
<td></td>
<td><em>Gastric juice,</em> which contains <em>pepsin,</em> breaks down proteins to polypeptides.</td>
<td>Carries food from the mouth to the stomach</td>
</tr>
<tr>
<td>Stomach</td>
<td>Waves of contraction churn food</td>
<td><em>Pancreatic juice</em> contains <em>pancreatic amylase,</em> which breaks starch into disaccharides; <em>pancreatic protease,</em> which breaks proteins and polypeptides into peptides; <em>pancreatic lipases,</em> which break lipids into fatty acids and glycerol; and <em>nucleases,</em> which digest DNA and RNA.</td>
<td>Stores large quantities of food as it is eaten; absorbs certain drugs, including some alcohol.</td>
</tr>
<tr>
<td>Small intestine</td>
<td>Muscular contractions churn food; bile salts emulsify lipids</td>
<td><em>Intestinal juice</em> contains <em>amylases</em> to break down disaccharides to simple sugars; <em>peptidases</em> to break down peptides to amino acids; and <em>lipases</em> to break down lipids to fatty acids and glycerol.</td>
<td>Absorbs simple sugars, amino acids, fatty acids, glycerol, vitamins, mineral nutrients and water</td>
</tr>
<tr>
<td>Large intestine</td>
<td></td>
<td></td>
<td>Absorbs water and vitamins; stores faeces; defecation</td>
</tr>
</tbody>
</table>

**Fluids That Help in Digestion**

Stomach produces and secretes substances that are important for digestion. The main product secreted is the gastric juice which is made up of hydrochloric acid, mucus, and digestive enzymes. The gastric juice gets mixed with the food for digestion to begin.

- Specialised cells of the **mucosa** known as mucus cells secrete mucus into the lumen of the stomach and into gastric pits. It spreads across mucosa to coat the lining of the stomach with a thick, acid and enzyme resistant barrier.
- **Parietal cells** in the gastric pits produce HCl. The HCl protects the body by killing pathogenic bacteria naturally found in food. HCl also helps to digest proteins by
denaturing them into an unfolded shape that is easier for enzymes to digest. The protein digesting enzyme **pepsin** is activated by the exposure of HCl inside the stomach.

- **Chief cells**, also found within the gastric pits of the stomach, produce two digestive enzymes: pepsinogen and gastric lipase. **Pepsinogen** is the precursor molecule of the very potent protein-digesting enzyme pepsin. Because pepsin would destroy the chief cells that produce it, it is secreted in its inactive pepsinogen form.
- When pepsinogen reaches the acidic pH found in the stomach - hydrochloric acid, it changes shape and becomes the active enzyme pepsin. Pepsin then breaks dietary proteins into their amino acid building blocks.
- **Gastric lipase** is an enzyme that digests fats by removing a fatty acid from a triglyceride molecule.
- The mixing action in the stomach is mechanical. The smooth muscles of the stomach produces contractions that produce mixing waves that mixes food with gastric juice.
- When the food is being churned the enzymes present will chemically digest large molecules into smaller units. Pepsin breaks proteins into smaller amino acids.

Gastric juices are made of 3 main components.

- A mucous that protects the stomach lining from the acid and digestive enzymes in the stomach.
- Pepsinogen, which is converted to pepsin, which digests proteins. Pepsinogen production is stimulated by the presence of gastrin in the blood.
- Hydrochloric acid (HCl) converts pepsinogen to pepsin which breaks down proteins to peptides. HCl maintains a pH in the stomach of approximately 2.0. It also dissolves food and kills microorganisms.

**The simple definition is pepsinogen is a zymogen that is converted into pepsin by the hydrochloric acid in the stomach and the pepsin is a digestive enzyme that chemically digests or breaks down, proteins into shorter chains of amino acids.**

- Enzymes are macromolecular biological catalysts. Enzymes accelerate, or catalyze, chemical reactions.
- Proteins – Are basically chains of amino acids.
Chapter 10 – Removal Of Waste (Urinary System)

Removal of metabolic wastes from the body is called excretion. Several organs process these wastes: **Sweat glands**: they secrete water, for cooling. There by products in water like salts, urea and lactic acid. **Lungs**: they remove carbon dioxide from the body. **Liver**: They covert amino acids. **The kidneys**- are responsible for maintaining the constant concentration of materials in the body fluids.

The Liver

**Proteins**: they are body builders that is they make up the structural materials of cells. As long as body has a sufficient supply of carbohydrates and fats or has stored fat then small amount of protein is used for energy release. Excess protein cannot be stored in cells so they need to be removed. Worn out red blood cells are source of proteins. Proteins are broken into amino acids which can be later used to produce new proteins and small amount of this amino acid is excreted by the body. The proteins build up from amino acids become primary constituents of cell structures, enzymes, antibodies, and glandular secretions. If energy sources are used up the body metabolises proteins for more energy. **Deamination**: In order to make use of proteins the amino group must be removed (NH\(_2\)) and it happens in the liver with the help of enzymes. When the amino group is removed it is converted to ammonia by liver cells and then to urea and is eliminated from the body through urine.

- The remaining amino acid made of carbon and hydrogen gets converted to carbohydrate. This carbohydrate can be broken down to release energy.

\[
\text{amino acid + oxygen} \xrightarrow{\text{enzymes}} \text{carbohydrate + ammonia}
\]

- Since the ammonia is highly soluble in water and harmful to cells it is quickly converted to urea by the liver. A moderate amount of urea is not as harmful which is then excreted through the urine.

\[
\text{energy + carbon dioxide + ammonia} \rightarrow \text{urea + water}
\]

The Kidney - Structure

It is the main organ that excretes metabolic wastes from the body. There are 2 pairs of kidneys each about 11 cm long. There are renal arteries and renal veins that carry and take blood back to the body from the kidney once it is filtered. There is a ureter that carries the urine once it has been filtered. A bladder that holds the urine and urethra that carries the urine to the exterior.
The kidney contains a cortex that is the outer part. If the kidney is halved there are pyramid structures within them called the medulla. There is a renal artery that carries blood and then divides into small arterioles. There is the renal vein that carries the blood from the kidney once it has been filtered.

**The Nephron**

Below is a picture of nephron are they are microscopic. They are the filtering units in the kidney. There is a black box in between the medulla and the cortex that is where the nephrons exist.

**Microscopic Structure of Kidney**

- The nephrons are the place where the urine formation occurs. Below is a detailed picture of what a nephron looks like.

**How Does A Nephron Work?**

- Each nephron contains a renal corpuscle and renal tubule. It begins with an expanded end called glomerular capsule. It is an enclosed knot made of arterial capillaries called glomerulus.
- Leading from the glomerular capsule a tube called the proximal convulated tubule and beyond this point there is straight portion and then it forms a loop called the loop of Henle.
- The loop of Henle later becomes convoluted and it is now called the distal convoluted tube. The distal convoluted tubules of several nephrons join into a collecting duct that opens into a chamber in the kidney called renal pelvis.
- The renal pelvis is like a funnel and it channels fluid from collecting duct into the ureter.
The kidney is responsible for removing waste from the body so it is supplied blood vessels which enters through renal arteries. 1.2L of blood passes through kidney per minute. After blood enters through the renal arteries it divides into arterioles. Each renal corpuscle is supplied by an arteriole, the afferent arteriole which then forms glomerulus. The capillaries eventually unite to form another arteriole called efferent arteriole which passes out of the renal corpuscle. Shortly after leaving the renal corpuscle it breaks into secondary capillary network that surrounds the convoluted tubules and loop of henle called the peritubular capillaries. Venous blood drains from the network of capillaries and leaves through renal vein.

**Glomerular Filtration**

- This is the first process where the fluid is forced out of the blood into the glomerular capsule. The forcing of fluid is enhanced by the high pressure of blood.
- The efferent is narrow and has lower diameter than the afferent which causes resistance and higher pressure of blood flow.
- The walls are one cell thick so when blood enters the glomerulus, high pressure forces water and dissolved blood components through the differentially permeable cell membrane into the capsule. This fluid is a filtrate.
- The filtrate is made of water, salts, amino acids, fatty acids, glucose, urea, uric acid, creatinine, hormones, toxins and various ions.
- In this process 20% of blood plasma is filtered by the glomerular capsule.

**Reabsorption**

- The components that have been filtered from the capillaries of the glomerular capsule are useful to the body. Some selective reabsorption takes place.
- This is carried out by the renal tubule. Water, amino acids, glucose, ions such as sodium, potassium, calcium and bicarbonate are reabsorbed.

![Diagram](image)

*Figure 10.6* The process of filtration, reabsorption and secretion. a As blood flows through the kidneys, some of the plasma is filtered out of the glomerular capillaries and into the glomerular capsules. b Some materials within the blood that are not filtered into the renal tubules at the glomerular capsules can be secreted into other portions of the tubules. c As fluid flows along the renal tubules, water, ions, glucose and other substances required by the body are reabsorbed from the tubules and returned to the blood.

- Large surface area helps with reabsorption which is achieved by the convoluted tubules and the loop of Henle. And by the huge number of nephrons.
- Water reabsorption can be regulated depending on body’s requirements. This is a active process done under hormonal control called facultative reabsorption.

**Tubular Secretion**

- In this process selective reabsorption removes substances from the filtrate into the blood, tubular secretion adds materials to filtrate from blood such as hydrogen ions, potassium, creatinine and drugs.
- It removes certain unwanted materials from the body and by doing so the blood pH is maintained.
- The body has to maintain a pH of 7.4-7.5 and acidic food lowers this. In order to raise pH hydrogen ions and ammonium ions are put back into the filtrate.
- Water and other substances not reabsorbed drain from collecting duct to the renal pelvis to the ureter to the urinary bladder and excreted by urethra.

The relationship between structure and function

Like all organs of the body, the structure of the kidney is directly related to its function. Some of the ways in which the structure of the kidney, particularly the nephrons, is related to its function of excretion of waste and regulation of the water content of the body are listed below:

1. The glomerular capsule surrounds the glomerulus to collect the fluid filtered out of the blood capillaries.
2. The arteriole leading out of the glomerulus has a smaller diameter than the arteriole leading in. This raises the blood pressure so that more fluid is filtered out of the blood.
3. The tubule has two sets of convolutions and a long loop so that each tubule has a large surface area for reabsorption and secretion.
4. Each kidney has over a million nephrons so the total surface area available for reabsorption and secretion is extremely large.

By carefully reading the information about kidney structure you will be able to think of other ways in which kidney structure is related to its functions. A summary of the functioning of the kidney is given in Table 10.1 on page 130.

<table>
<thead>
<tr>
<th>Region of nephron</th>
<th>Activities taking place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal corpuscle</td>
<td>Filtration of blood from capillaries of glomerulus</td>
</tr>
<tr>
<td></td>
<td>Formation of filtrate in the glomerular capsule</td>
</tr>
<tr>
<td>Proximal convoluted tubule and loop</td>
<td>Reabsorption of sodium, potassium, chloride and bicarbonate ions</td>
</tr>
<tr>
<td>of Henle</td>
<td>Reabsorption of glucose</td>
</tr>
<tr>
<td></td>
<td>Passive reabsorption of water by diffusion</td>
</tr>
<tr>
<td>Distal convoluted tubule</td>
<td>Reabsorption of sodium ions</td>
</tr>
<tr>
<td></td>
<td>Active reabsorption of water depending on the body's water needs</td>
</tr>
<tr>
<td></td>
<td>Secretion of hydrogen and potassium ions, creatinine and certain drugs like penicillin</td>
</tr>
<tr>
<td>Collecting duct</td>
<td>Active reabsorption of water, depending on the body's water needs</td>
</tr>
</tbody>
</table>
Urine Composition

- The body needs to excrete its waste products such as urea, sulfates, phosphates and in order to remove them they have to be in a solution.
- Regardless of the amount of water available in the body, or the amount taken in, about half a litre of water must be lost everyday to remove these wastes.
- When water content of the body fluid is low the urine is concentrated.
- The urine is composed of water, urea, ions, uric acid and creatinine.
- Uric acid is produced from the metabolism of substances called purines which can come from nucleic acids.
- Creatinine can come from the breakdown of creatinine phosphate found in muscles.

Kidney Disease and Kidney Failure

Kidney stones are formed from solid crystals that build inside the kidney. They usually form when the urine becomes concentrated. It could be due to insufficient fluid in diet. They can get bigger to become stones which cause intense pain.

Kidney Failure - When the kidneys lose their ability to excrete wastes and control the level of fluid in the body, it is known as kidney failure. Factors that influence it are diabetes, high blood pressure, or kidney disease that accumulates. The only way to sustain life is by dialysis or kidney transplant.

Dialysis

Dialysis is the method of removing wastes from the blood when kidney failure occurs. There are two types: 

Peritoneal Dialysis - Peritoneum is a membrane that lines the inside of the abdominal cavity. It has rich blood supply. A tube, called a catheter, is placed through the wall of abdomen, and the fluid containing glucose and other substances pass through the catheter. The fluid has no wastes, but as it passes through the catheter, containing rich blood, the wastes diffuse out from the blood and into the fluid, because there is a concentration gradient of wastes out. However, there is no concentration difference between the fluid and blood, so the useful substances stay in the blood. This fluid, containing wastes and glucose, are drained out of the catheter and into the urinary bladder, meeting with urine. Peritoneal dialysis occurs once a day.

Haemodialysis - It is the passing of the blood through artificial kidney or dialysis machine. Blood is passed from thousand of fine tubes, made of semi-permeable membranes, and immersed into a bath of fluid. The fluid has no wastes when meeting with blood. The concentration gradient for wastes is out, and so wastes diffuse from blood into the fluid. This process takes 4-5 hours, and is done 3 times a week.

![Diagrammatic view of how a dialysis machine works](image_url)