CHAPTER

9 Transport

Animation 9.1: Mineral uptake
Source & Credit: Plant transport system

We know that life of organisms is the product of complex metabolic processes occurring in them. In order to run their metabolism, cells need some materials from environment and also need to dispose some materials into environment. For this purpose, materials are transported to and from cells.

One method for the movement of molecules is diffusion but it alone cannot fulfill the needs. It takes much time for materials in solution to diffuse even a few inches. For the molecules of materials, diffusion can work only in unicellular and simple multicellular organisms, because every corner of their body is in close and direct contact with environment. In complex multicellular bodies, cells are far apart from environment and such bodies need a comprehensive system for the transport of materials.

9.1 TRANSPORT IN PLANTS

Water is vital to plant life. It is necessary not just for photosynthesis and turgor, but much of the cellular activities occur in the presence of water molecules. Internal temperature of plant body is also regulated by water. Land plants get water and minerals from soil. After absorption by roots, water and minerals have to be transported to the aerial parts of body. Similarly food is manufactured in leaves (by photosynthesis). This food is transported to other parts of body for utilization and storage.

Recalling:

Cells are the primary sites for metabolic processes. That is why they are regarded as the units of life.

Animation 9.2: Transport in plant
Source & Credit: ontrack-media

All land plants (except mosses and liverworts), have developed complex vascular tissues (xylem and phloem) that move water and food throughout plant body.

Recalling

Xylem tissue is responsible for the transport of water and dissolved substances from roots to aerial parts. It consists of vessel elements and tracheids. Phloem tissue is responsible for the conduction of dissolved organic matter (food) between different parts of plant body. It consists of sieve tube cells and companion cells.

Water always moves from an area of higher water potential to an area of lower water potential. The relationship between the concentration of solute and water potential is inverse. When there is a lot of solute (i.e. hypertonic solution), the water potential is low and vice versa.

9.1.1 WATER AND ION UPTAKE

In addition to anchor the plant, roots perform two other vital functions. First; they absorb water and salts from soil. Second; they provide conducting tissues for distributing these substances to the tissues of stem.

The **conducting tissues** (xylem and phloem) of root are grouped in the centre to form a rod-shaped core. This rod extends throughout the length of root. Outside the conducting tissues, there is a narrow layer of thin-walled cells, the **pericycle**.

A single layer of cells i.e. **endodermis** surrounds this pericycle. External to this, there is a broad zone of **cortex**. It consists of large and thin-walled cells.Cortex is bounded on outside by a single layer of **epidermal cells.** Roots also have clusters of tiny **root hairs**, which are actually the extensions of epidermal cells.
Root hairs provide large surface area for absorption. They grow out into the spaces between soil particles where they are in direct contact with water. The cytoplasm of root hairs has higher concentration of salts than soil water, so water moves by osmosis into root hairs. Salts also enter

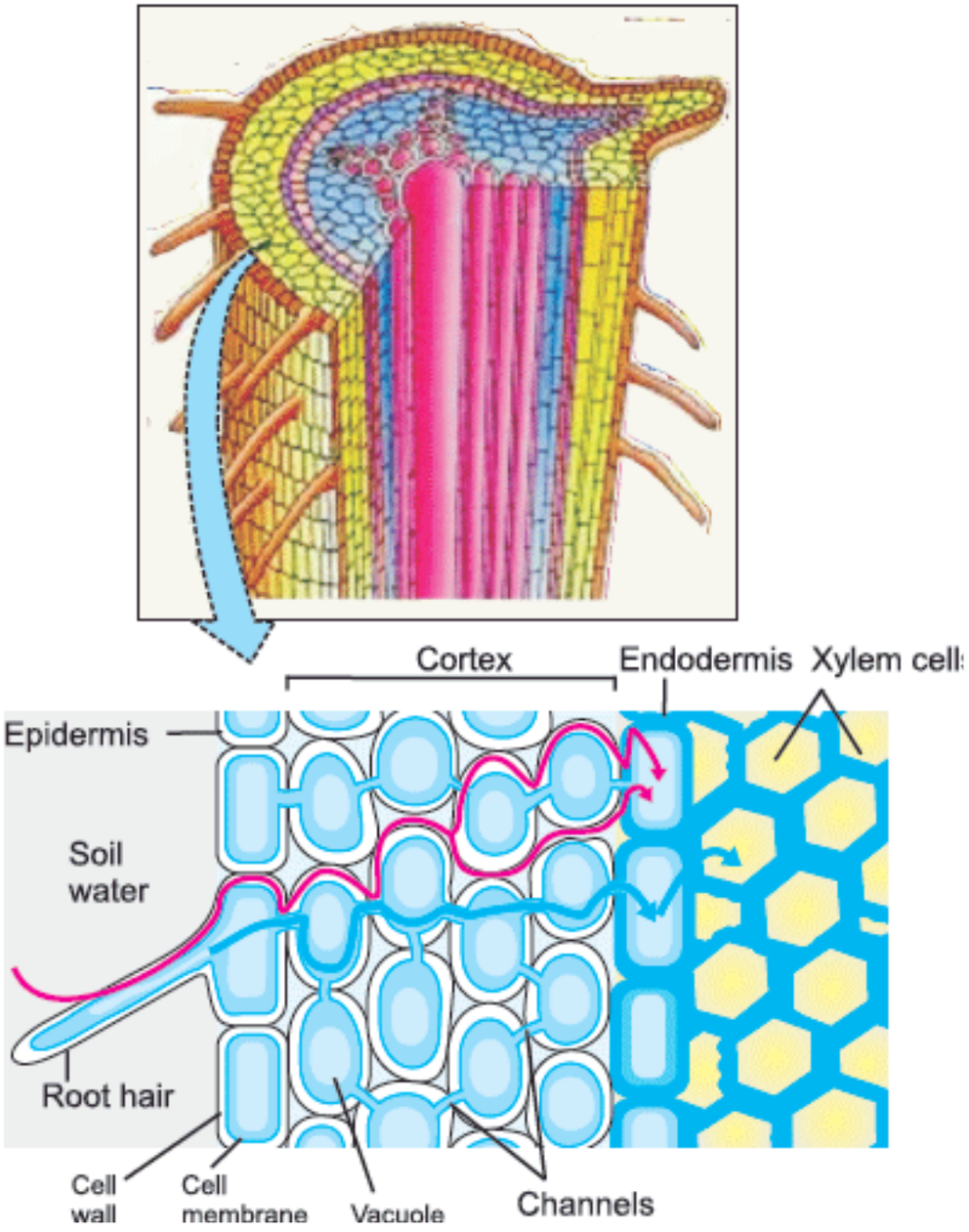


Figure 9.1: Uptake of water and ions by root

root hairs by diffusion or active transport. After their entry into root hairs, water and salts travel through intercellular spaces or through cells (via channels, called plasmodesmata) and reach xylem tissue. Once in xylem, water and salts are carried to all the aerial parts of plant.

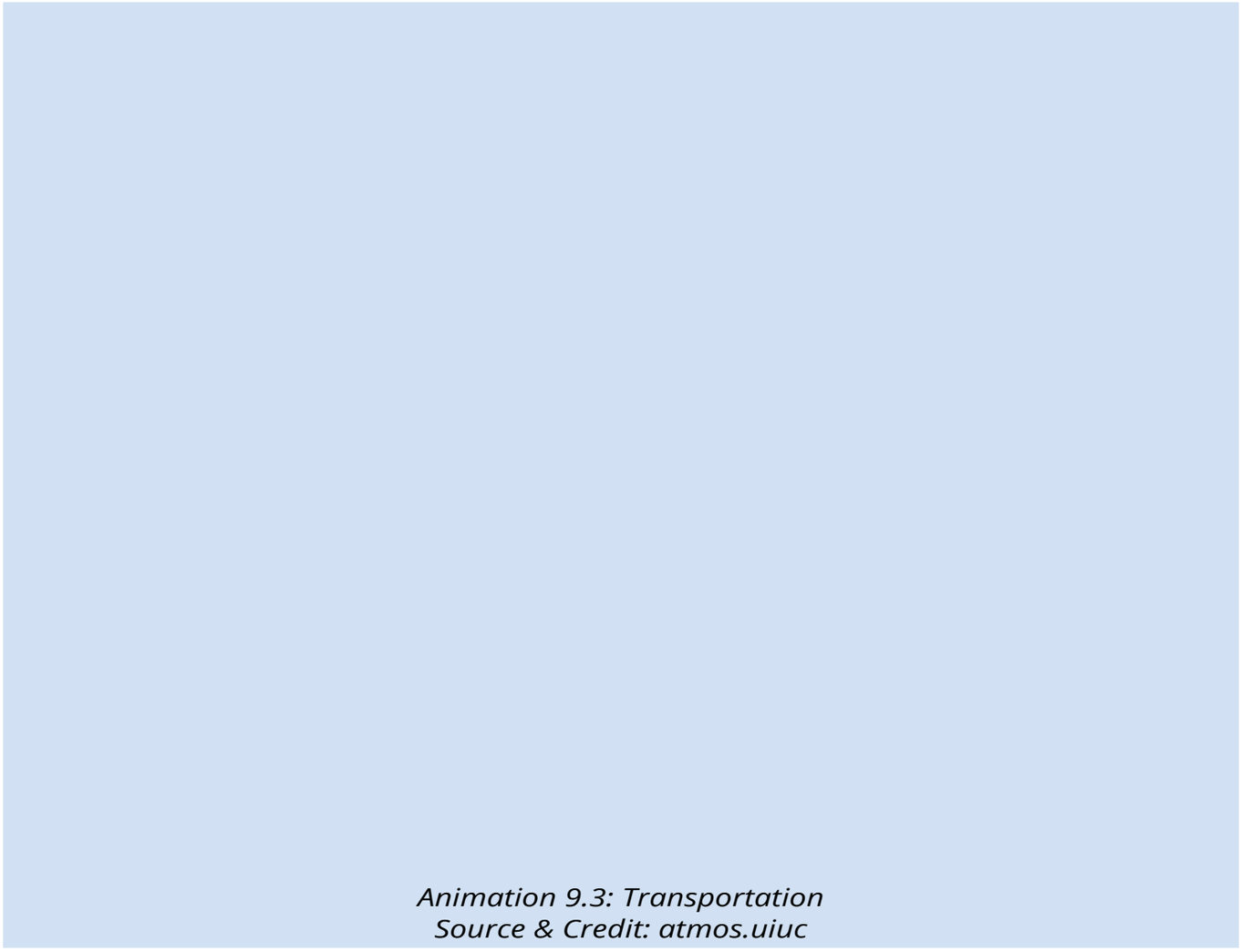
Plants also form beneficial relationships with soil bacteria and fungi in order to increase absorption of minerals.

Analyzing and Interpreting:
Identify root hairs on the growing roots of onion, carrot, radish etc.

9.1.2 TRANSPIRATION

Transpiration is the loss of water from plant surface through evaporation. This loss may occur through stomata in leaves, through the cuticle present on leaf epidermis, and through special openings called **lenticels** present in the stems of some plants.

Most of the transpiration occurs through stomata and is called **stomatal transpiration**. The mesophyll cells of leaf provide large surface area for the evaporation of water. Water is drawn from xylem into mesophyll cells, from where it comes out and makes a water-film on the cell walls of mesophyll. From here, water evaporates into the air spaces of the leaf. Water vapours then diffuse from air spaces towards stomata and then pass to outside air (Figure 9.2).



Animation 9.3: Transportation
Source & Credit: atmos.uiuc

Animation 9.4: Absorptive Root
Source & Credit: cas.miamioh

Roughly 90% of the water that enters a plant is lost via transpiration.

Video 9.5: Transpiration pull
Source & Credit: gifsoup

Opening and closing of stomata

Most plants keep their stomata open during the day and close them at night. It is the responsibility of stomata to regulate transpiration via the actions of guard cells. The two guard cells of a stoma are attached to each other at their ends. The inner concave sides of guard cells that enclose a stoma are thicker than the outer convex sides. When guard cells get water and become turgid, their shapes are like two beans and the stoma between them opens. When guard cells loose water and become flaccid, their inner sides touch each other and stoma closes.

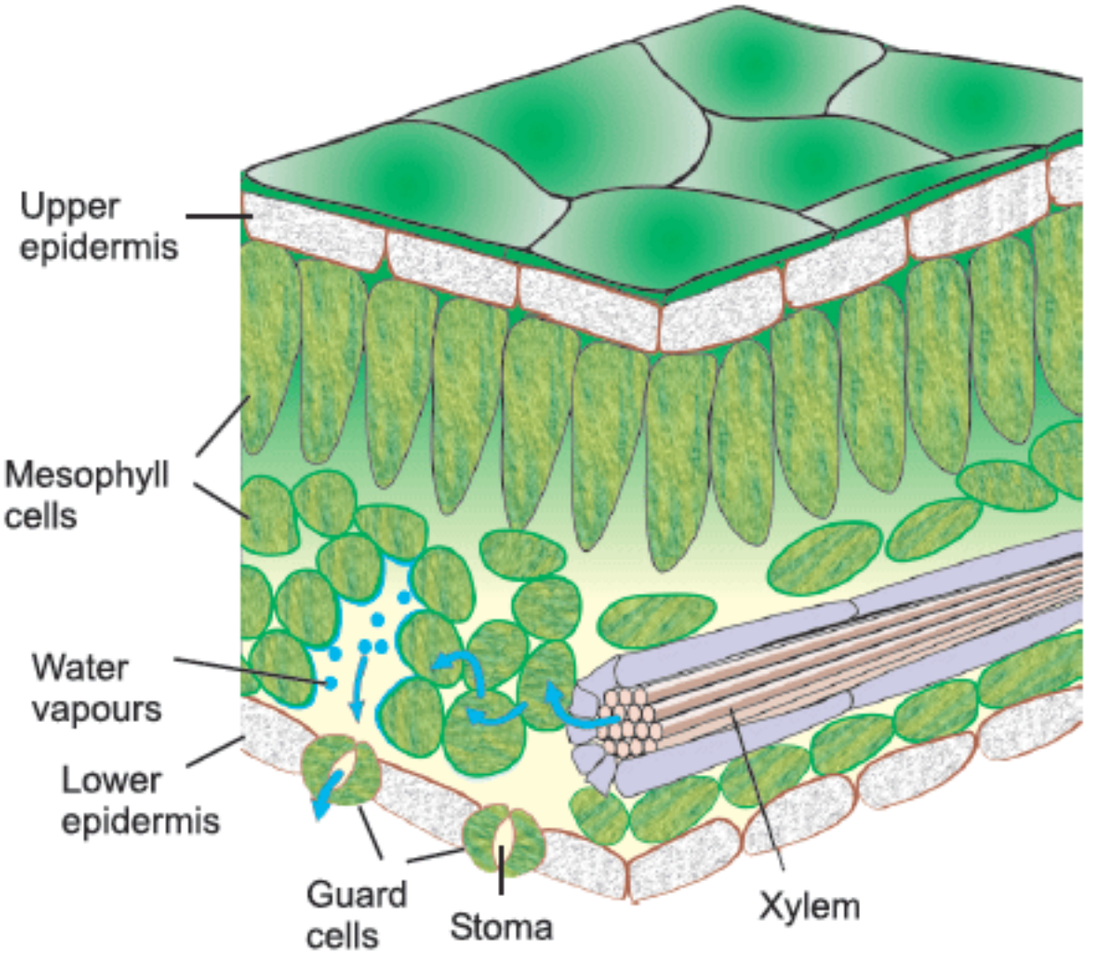


Figure 9.2: Events of transpiration shown in the section of a leaf

Some plants open their stomata during night when overall water stress is low.

In chapter 4 we have studied that the concentration of solutes (glucose) in guard cells is responsible for the opening and closing of stomata. Recent studies have revealed that light causes the movement of potassium ions from epidermal cells into guard cells. Water follows these ions and enters guard cells. Thus their turgidity increases and stoma opens. As the day progresses, guard cells make glucose i.e. become hypertonic. So water stays in them. At the end of the day, potassium ions flow back from guard cells to epidermal cells and the concentration of glucose also falls. Due to it, water moves to epidermal cells and guard cells loose turgor. It causes the closure of stoma.

Video 9.6: Opening and Closing Stomata
Source & Credit: blood.gq

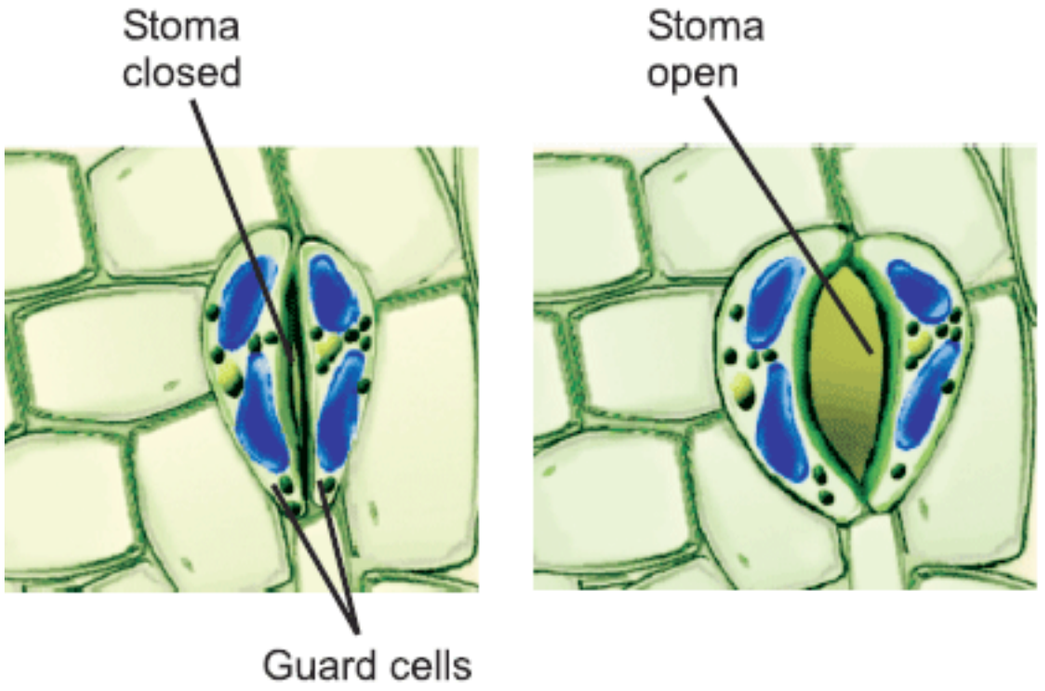


Figure 9.3: Opening and closing of stoma

FACTORS AFFECTING THE RATE OF TRANSPIRATION

The rate of transpiration is directly controlled by the opening and closing of stomata and it is under the influence of light. In strong light, the rate of transpiration is very high as compared to dim light or no light. Other factors which affect the rate of transpiration are given below.

Temperature

Higher temperature reduces the humidity of surrounding air and also increases the kinetic energy of water molecules. In this way it increases the rate of transpiration. The rate of transpiration doubles with every rise of 10 ^{o}C in temperature. But, very high temperatures i.e. 40-45 ^{o}C cause closure of stomata, so transpiration stops and plant does not loose the much needed water.

Air humidity

When air is dry, water vapours diffuse more quickly from the surface of mesophyll cells into leaf air spaces and then from air spaces to outside. This increases the rate of transpiration. In humid air, the rate of the diffusion of water vapours is reduced and the rate of transpiration is low.

Air movement

Wind (air in motion) carries away the evaporated water from leaves and it causes an increase in the rate of evaporation from the surfaces of mesophyll. When air is still, the rate of transpiration is reduced.

Leaf surface area

The rate of transpiration also depends upon the surface area of leaf. More surface area provides more stomata and there is more transpiration .

There is strong evidence that even mild water stress results in reduced growth rate in plants.

SIGNIFICANCE OF TRANSPIRATION

Transpiration is called a necessary evil. It means that transpiration is a potentially harmful process but is unavoidable too. Transpiration may be a harmful process in the sense that during the conditions of drought, loss of water from plant results in serious desiccation, wilting and often death.

On the other hand, transpiration is necessary too. It creates a pulling force called **transpirational pull** which is principally responsible for the conduction of water and salts from roots to the aerial parts of plant body. When water transpires from the surfaces of plant, it leaves a cooling effect on plant. This is especially important in warmer environments. Moreover, the wet surfaces of leaf cells allow gaseous exchange.

Practical Work:

To describe the structure and number of stomata present on the epidermal peel of a leaf

Stomata are the microscopic pores in the epidermis of leaves. They are the passageways for gases and water vapours.

Problem:

Observe the stomata on the epidermal peel of a leaf and describe their structure and number.

Apparatus required:

Petri dish, water, glass slides and cover slips, methylene blue, light microscope

Background information:

- A stoma is an opening through which leaves exchange gases and loose water (transpire).
- Each stoma is surrounded by two bean-shaped guard cells.
- The epidermis of leaves has stomata among its epidermal cells.

Procedure:

1. Take a thick leaf and peel off a thin layer (epidermis) from its surface.
2. Place the thin layer in water in a Petri dish.
3. Cut a piece of the peeled off epidermis and place it in a drop of water on a glass slide.
4. Pour a drop of methylene blue and place a cover slip on the material.
5. Observe under the low and high powers of the microscope.

Observation:

Observe the epidermis and point out the stomata present in it. Count the total stomata and count how many of these are open. Draw observation on notebook.

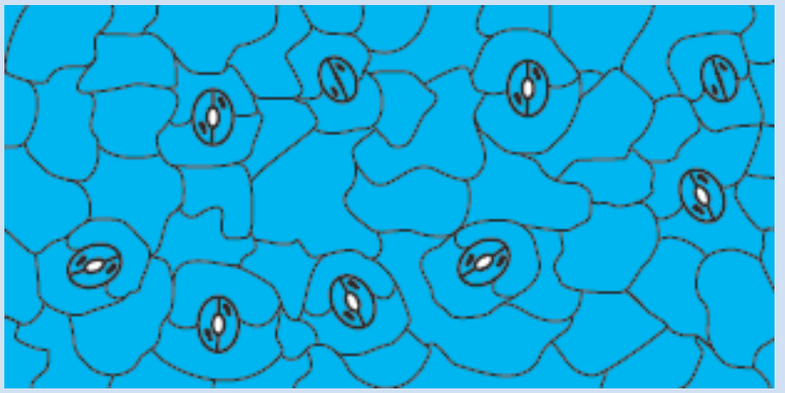


Figure 9.4: Microscopic view of the epidermis of a leaf

Evaluation:

i. How many stomata did you observe?

ii. What is the structure of guard cells and how does it help in the opening and closing of stomata?

Analyzing and Interpreting:

Wilting in a potted plant:

Due to non-availability or extra loss of water, the cells of herbaceous plants loose their turgidity and wilt. Wilting is defined as the loss of rigidity of non-woody parts of plants. This phenomenon can be observed by keeping a herbaceous plant without watering for a few days.

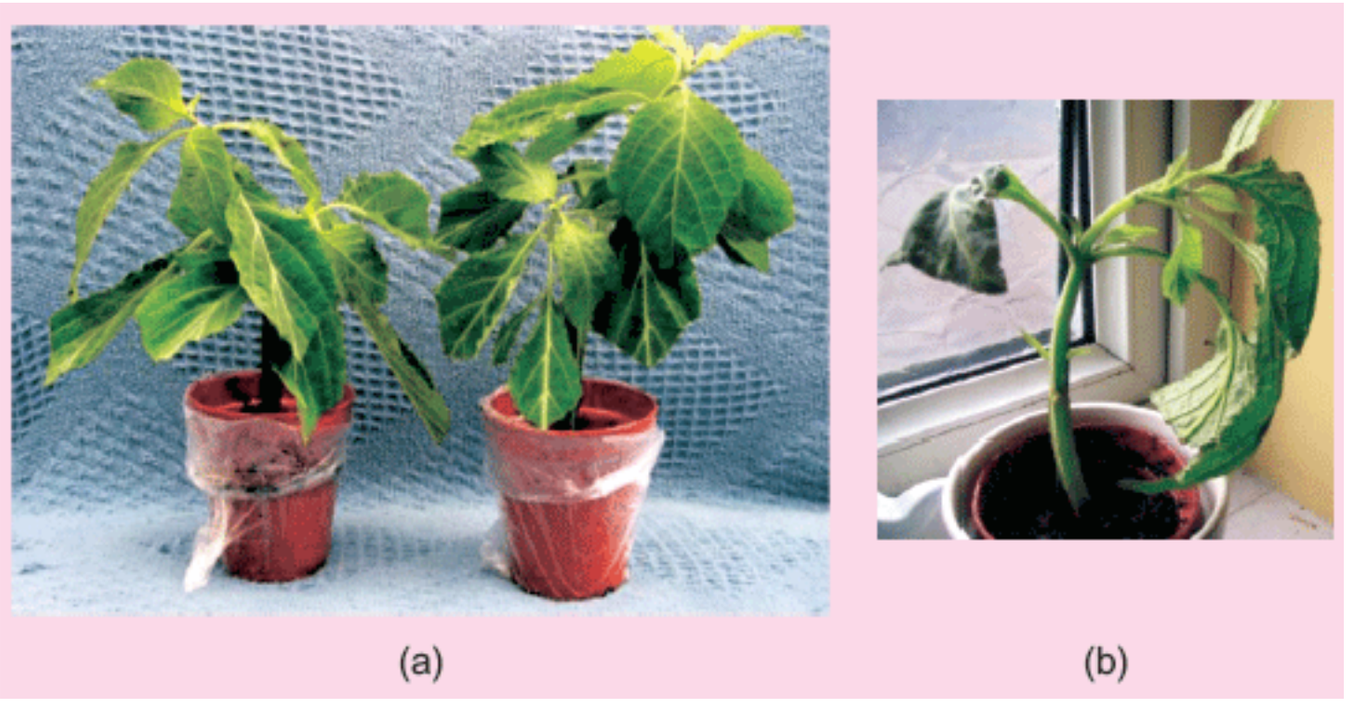


Figure 9.5: (a) Normal plant, (b) same plant in wilting stage

Practical work:

Investigation of the transpiration in a potted plant

Problem:

Explore the occurrence of transpiration.

Apparatus required:

A potted plant, 2 bell-jars, polythene bag, copper sulphate

Background information:

- Transpiration is the loss of water from plant surface.
- Polythene bag stops the escape of water vapours.

Hypothesis:

Transpiration occurs in plants which are given adequate supply of water and are placed in light.

Deduction:

A plant placed in light would transpire and water vapours can be observed.

Procedure:

1. Take a potted plant and cover the pot and base of stem with polythene bag.
2. Place the potted plant on a glass plate and invert a dry bell-jar over the pot and plant.
3. Leave the apparatus in sunlight.
4. Set up a control experiment with no plant.

Observation:

After an hour, drops of colourless liquid are seen inside the bell-jar with the plant. To show that these drops are water, touch them with anhydrous copper sulphate (white) and its colour changes to blue. No drops of water are found in the control experiment where there was no plant (Figure 9.6).

Results:

The water droplets on the inside of the jar containing the plant came from the leaves because the rest of the plant body and the soil were covered with polythene bag. Thus the potted plant present in the bell-jar showed the phenomenon of transpiration.

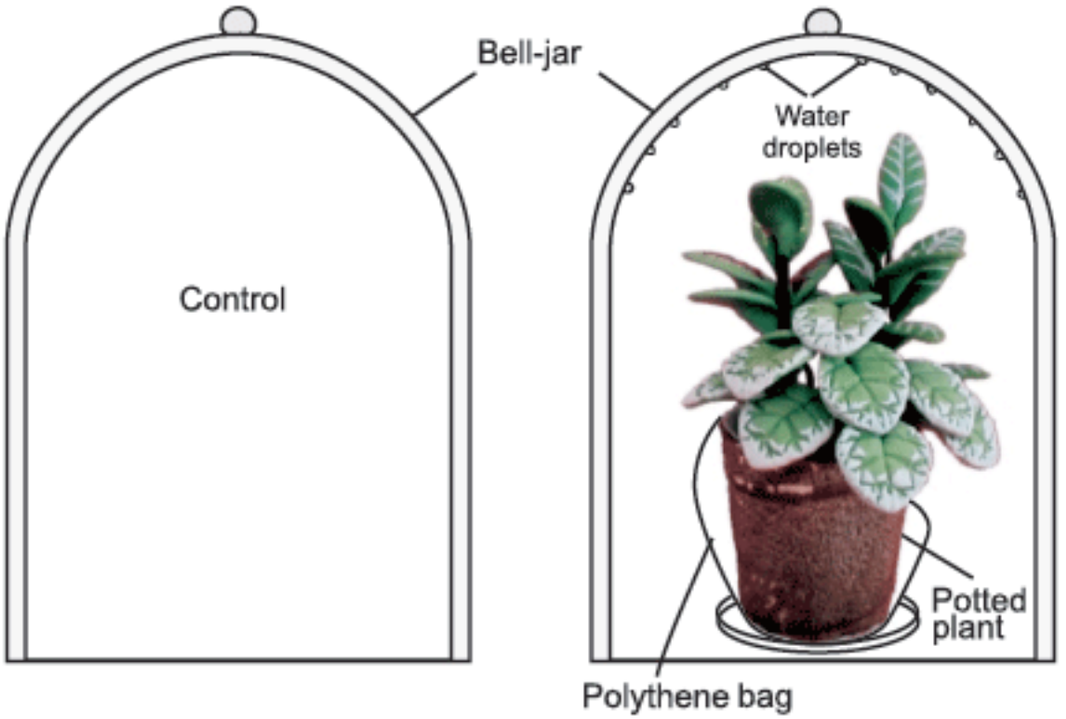


Figure 9.6: Experiment set up for transpiration in potted plant

Analyzing and Interpreting:

Identification of xylem and phloem in the prepared slides. See the photomicrographs and identify the xylem and phloem tissues by observing the prepared slides available in the school laboratory.

Practical work:

Investigation of the pathway of water in a cut stem

Transport of water and salts from roots to the aerial parts of plant body is termed as ascent of sap.

Problem:

Explore the pathway adopted by water during its transport in stem.

Background information:

- Xylem tissue consists of vessel elements and tracheids. Vessel elements form long tubes while tracheids are long cells with overlapping ends.
- Transpirational pull is the major force responsible for ascent of sap.

Hypothesis:

Water moves through the xylem tissue of stem.

Deduction:

If a plant is given water with some stain added, the transverse section of stem will show the same colour in the xylem region.

Procedure:

1. Fill a beaker with dilute eosin solution.
2. Place the shoot of a herbaceous plant (e.g. white coloured Petunia) inside the beaker as shown in the Figure 9.7. The lower end of the shoot must be completely submerged in the solution.
3. Keep the apparatus for a night.
4. Cut the longitudinal sections of stem. Examine and observe it under microscope.

Observation:

The white stem of the plant will show red lines. When examined under the light microscope, the longitudinal section of stem will also show that the xylem portions have become red.

Results:

The water along with the red eosin stain was absorbed by the stem and was transported through xylem tissues.

Practical work:

Investigation of the rate of water loss (transpiration) at two surfaces of a leaf

Leaves have different rates of water loss (transpiration) from the upper and lower surfaces.

Problem:

Explore the difference in the rate of transpiration at two surfaces of a leaf.

Apparatus required:

A potted plant, cobalt chloride filter papers, forceps, glass slides, rubber bands, filter paper discs

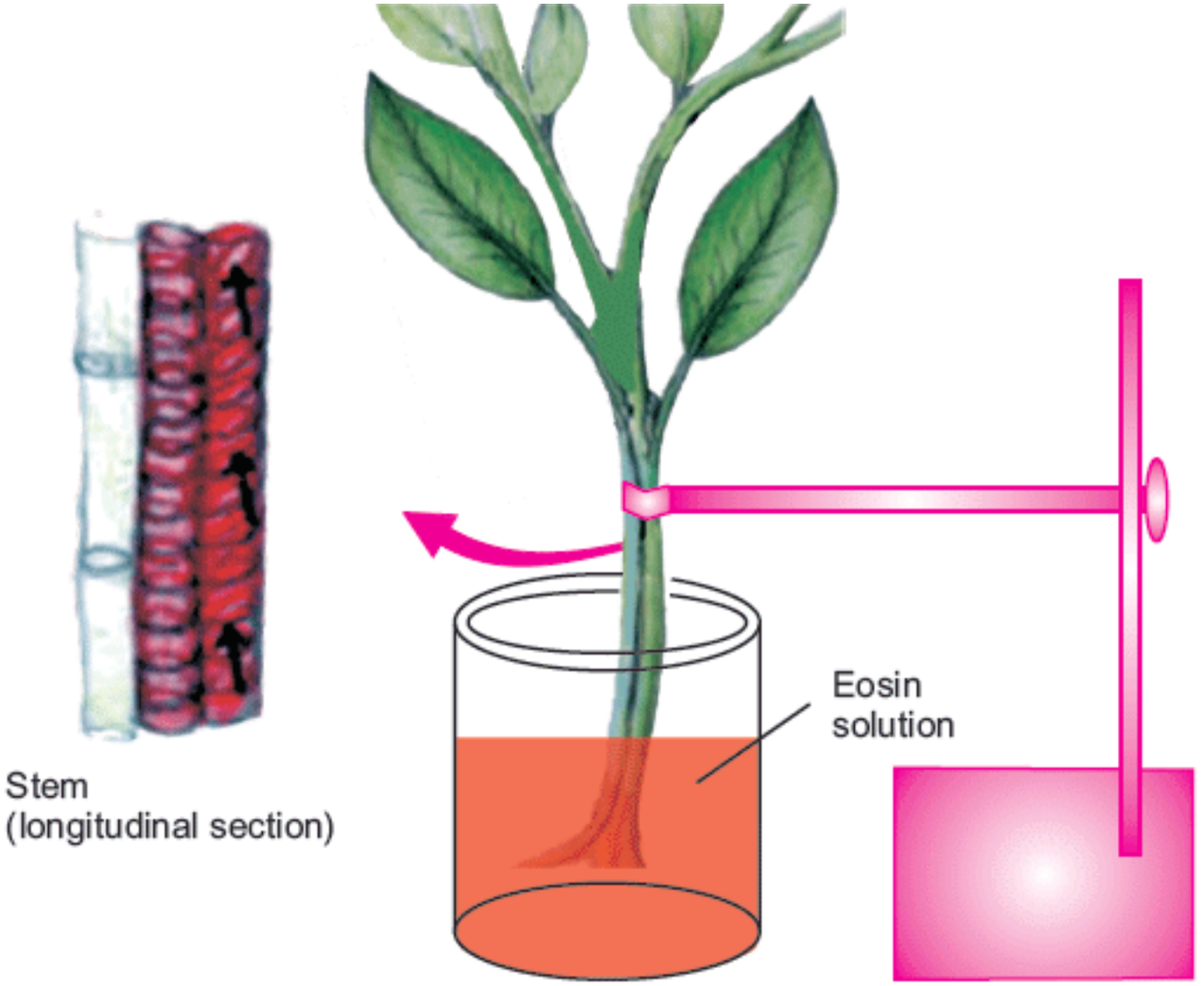


Figure 9.7: Experimental set up to explore the pathway of water

Background information:

- Cobalt chloride paper is blue when dry and it turns pink when it comes in contact with water vapours.
- Leaves of terrestrial plants have more stomata on their lower surface as compared to the upper ones.

Hypothesis:

There is more transpiration from the lower leaf surface as compared to the upper one.

Deduction:

If there is more transpiration from the lower surface, the cobalt chloride paper placed on the lower surface will show more colour change as compared to the paper placed on the upper surface.

Procedure:

1. Prepare dry cobalt chloride papers. For this, treat filter paper discs with slightly acidic cobalt chloride solution and dry the treated discs. Now, the dark blue filter paper discs will be called cobalt chloride paper.
2. Take a potted plant. Water the plant and leave it for an hour.
3. Take two equal size cobalt chloride papers and with the help of forceps place one piece of cobalt chloride paper on the upper surface and the other paper on the lower surface of a leaf.
4. Place dry glass sides on the upper and the lower cobalt chloride papers and fix them with a rubber band. (The glass slides will prevent the cobalt chloride papers to come in contact with atmospheric humidity.) Figure 9.8.

Observation:

Note changes in the colour of the two cobalt chloride papers. Both papers will start turning pink. Note that the paper placed at the lower surface of the leaf takes less time in turning pink.

Results:

Cobalt chloride paper placed on the lower surface of leaf contacted more water as compared the paper placed on the upper surface. It means that there is more water loss (transpiration) from the lower surface of leaf. The reason is that leaves have more stomata on their lower surfaces.

Evaluation:

i. What does it show when blue cobalt chloride paper starts turning pink?

ii. What is the relationship between the rate of transpiration and the number of stomata?

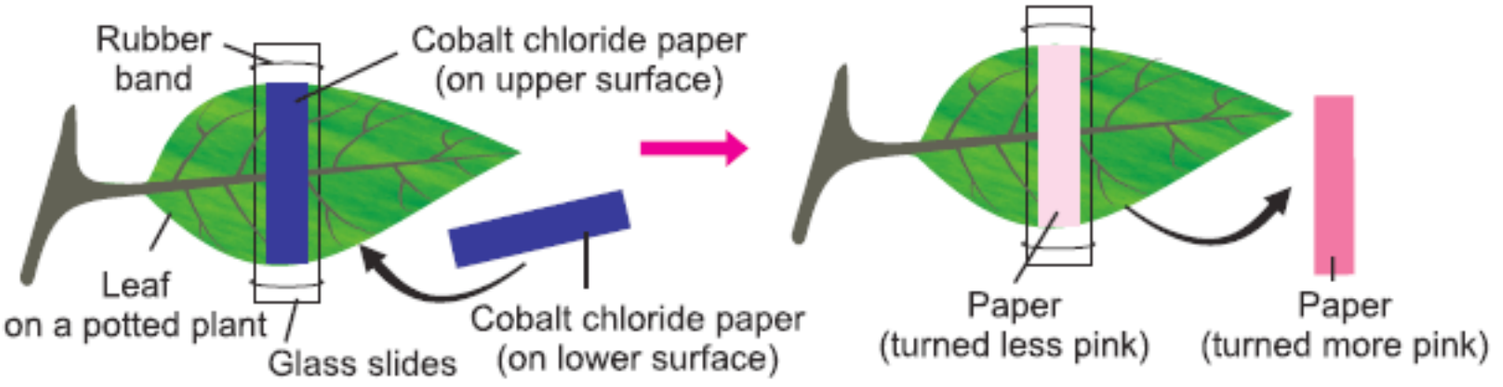


Figure 9.8: Experiment to explore the rate of transpiration on the two surfaces of a leaf

9.1.3 TRANSPORT OF WATER

The process by which water is raised to considerable heights in plants has been studied for years in botany. The result of this research is **"cohesion-tension theory"**.
According to this theory, the force which carries water (and dissolved materials) upward through the xylem is transpirational pull. Transpiration creates a pressure difference that pulls water and salts up from roots.
When a leaf transpires (loses water), the water concentration of its mesophyll cells drops. This drop causes water to move by osmosis from the xylem of leaf into mesophyll cells. When one water molecule moves up in the xylem of the leaf, it creates a pulling force that continues all the way to root.

This pulling force created by the transpiration of water is called **transpirational pull.** It also causes water to move transversely (from root epidermis to cortex and pericycle). Following are the reasons for the creation of transpirational pull.

- Water is held in a tube (xylem) that has small diameter.
- Water molecules adhere to the walls of xylem tube (adhesion).
- Water molecules cohere to each other (cohesion).

Animation 9.2 : Translocation Of Water And Nutrients
Source & Credit: Plantcellbiology

These attractions make an overall tension among water molecules. This tension forms 'columns' of water. The columns of water move from root to shoot and the water content of the soil enters in these 'columns'.

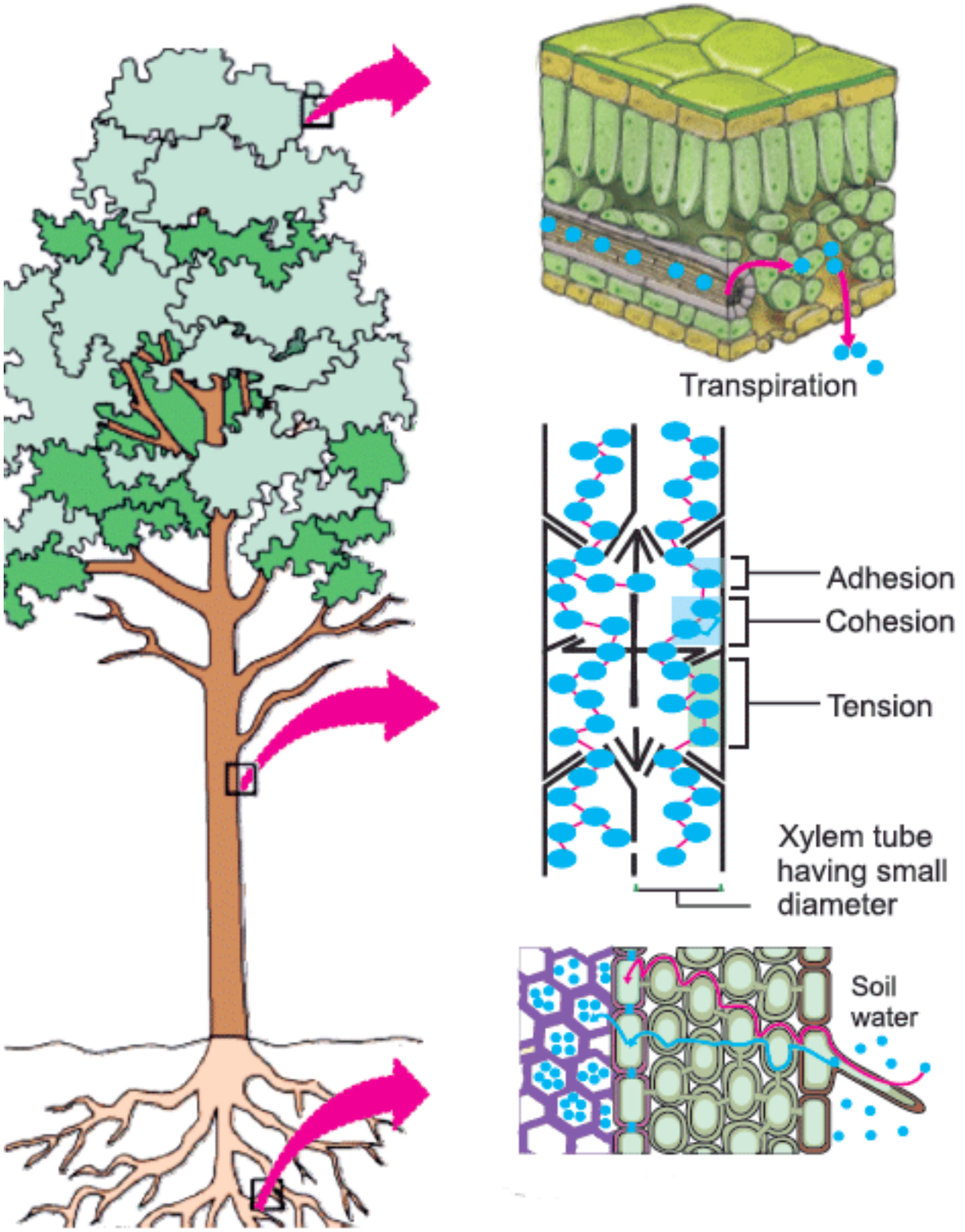


Figure 9.9: Transport of water

9.1.4 TRANSPORT OF FOOD

Phloem is responsible for transporting food substance throughout plant body. The glucose formed during photosynthesis in mesophyll cells, is used in respiration and the excess of it is converted into sucrose. In most plants, food is transported in the form of sucrose. Like the concept of "water movement in plants", movement of food in plants has been studied for years. The currently accepted hypothesis states that transport of food is through **pressure-flow mechanism**. In pressure-flow mechanism, food is moved from sources to sinks.

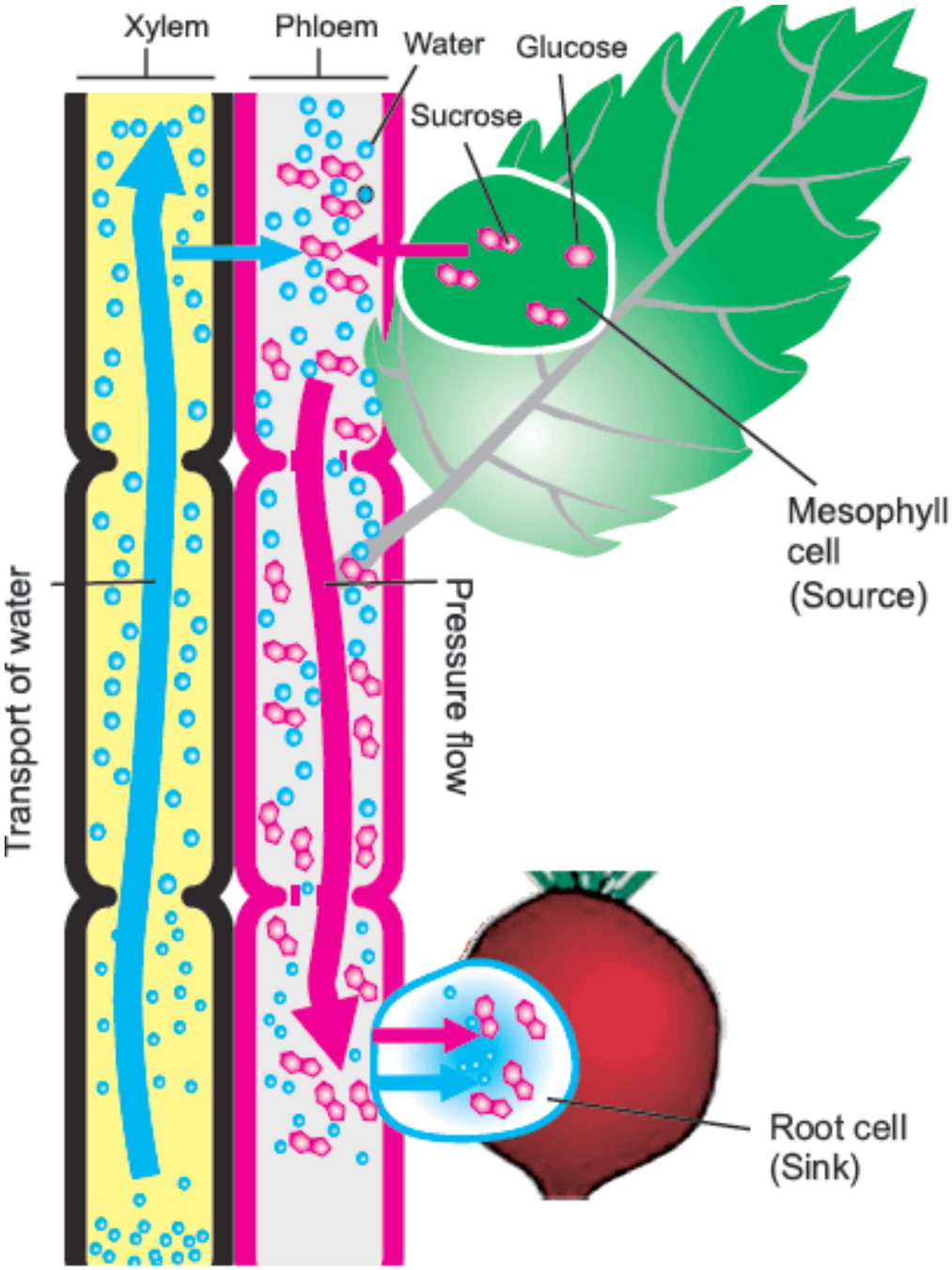


Figure 9.10: Transport of food

Sources include the exporting organs, typically a mature leaf or storage organ. **Sinks** are the areas of active metabolism or storage e.g. roots, tubers, developing fruits and leaves, and growing regions. A storage organ is capable of storing food and exporting the stored materials.

For example; root of beet is a sink in first growing season, but becomes source in next growing season, when sugars are utilized in the growth of new shoots.

At source, food (sugars) is moved by active transport into the sieve tubes of phloem. Due to the presence of sugar in sieve tubes, their solute concentration increases and water enters them from xylem (via osmosis). This results in higher pressure of water in these tubes, which drives the solution of food towards sink.

Xylem is a one way street from roots to leaves for water and salts. Phloem is a two way street for food. The direction of the movement of food is decided by supply and demand in sources and sinks.

At the sink end, food is unloaded by active transport. Water also exits from the sieve tubes. The exit of water decreases pressure in sieve tubes, which causes a mass flow from the higher pressure at the source to the now lowered pressure at the sink (Figure 9.10).

Plants need a lot of water. Young Brassica plants take up an amount of water equal to their shoot weight in about 5 hours - if that applied to us, we would have to drink 3 gallons of water an hour to stay alive!

9.2 TRANSPORT IN HUMAN

Like other higher animals, the task of the transport of different material in human body is performed by two systems i.e. blood circulatory system and lymphatic system. The two systems are well-coordinated and associated with each other. Here we will go into the details of human blood circulatory system (or cardiovascular system). Like other vertebrates, humans have a closed blood circulatory system (meaning that blood never leaves the network of arteries, veins and capillaries). The main components of the human blood circulatory system are blood, heart and blood vessels.

Recalling

Some invertebrates like arthropods have open circulatory system

According to the pressure flow mechanism what is the actual force behind the movement of food in phloem?

Drop in the pressure at the sink end.

How is plasma separated from blood?

Blood is taken from an artery and an anticoagulant (chemical that inhibits blood clotting) is mixed in it. After about 5 minutes, plasma separates from blood cells, which settle down.

9.2.1 BLOOD

Blood is a specialized body fluid (a connective tissue) that is composed of a liquid called blood plasma and blood cells. The weight of blood in our body is about 1/12th of our body. The average adult body has about 5 litres of blood.
In a healthy person, plasma constitutes about 55% by volume of blood, and cells or cell-like bodies are about 45% by volume of the blood (Figure 9.11).

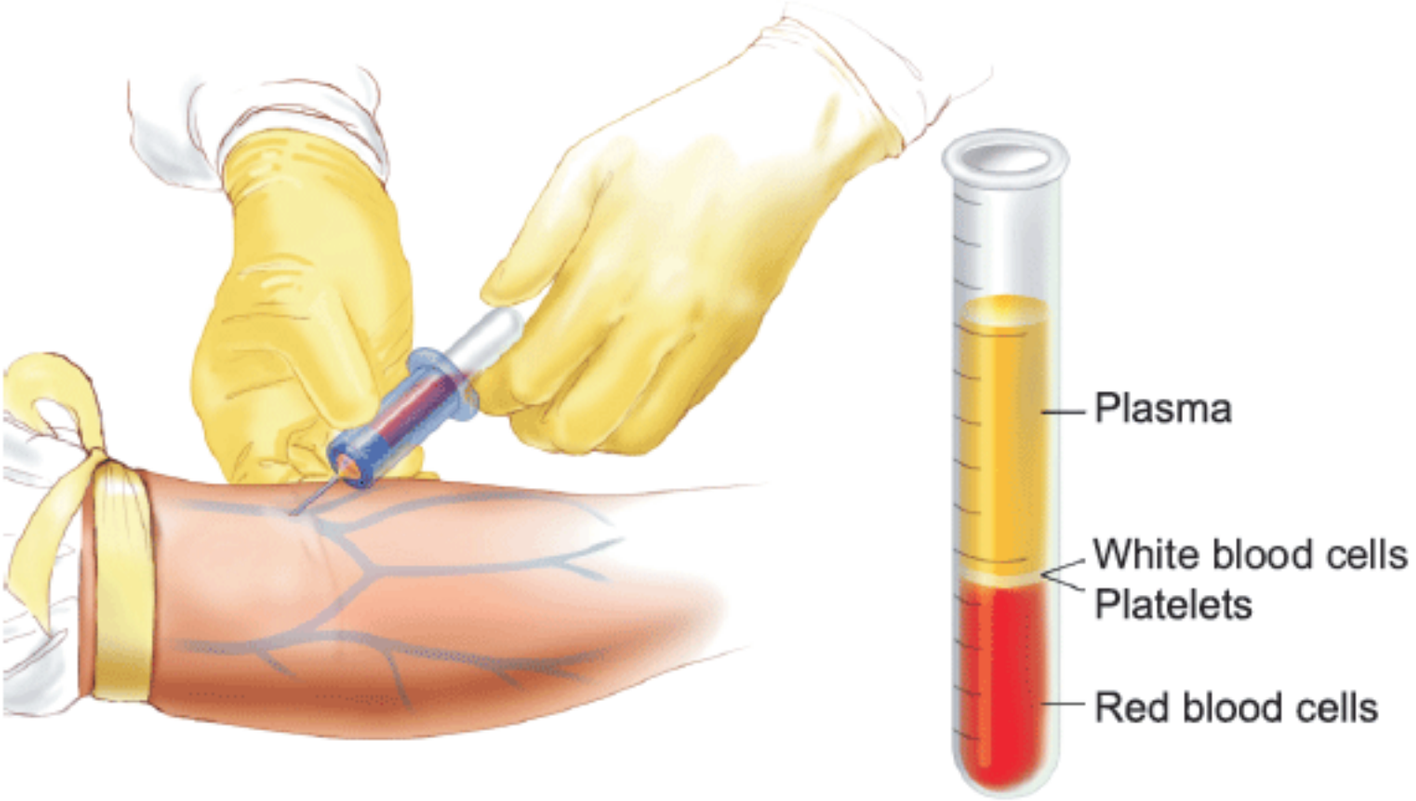


Figure 9.11: Percentage composition of human blood

BLOOD PLASMA

Plasma is primarily water in which proteins, salts, metabolites and wastes are dissolved.Water constitutes about 90-92% of plasma and 8-10% are dissolved substances.

Salts make up 0.9 % of plasma, by weight. Sodium chloride (the table salt) and salts of bicarbonate are present in considerable amounts. Ca, Mg, Cu, K and Zn are found in trace amounts. Changes in the concentration of any salt can change the pH of blood (normal is 7.4). **Proteins** make 7-9 % by weight of plasma. The important proteins present in plasma are antibodies, fibrinogen (blood clotting protein), albumin (maintains the water balance of blood) etc. Plasma also contains the digested food (absorbed from digestive system), nitrogenous wastes and hormones. Respiratory gases i.e. CO_2 and O_2 are present in the plasma.

BLOOD CELLS AND CELL-LIKE BODIES

These include red blood cells (erythrocytes), white blood cells (leukocytes) and platelets (thrombocytes).

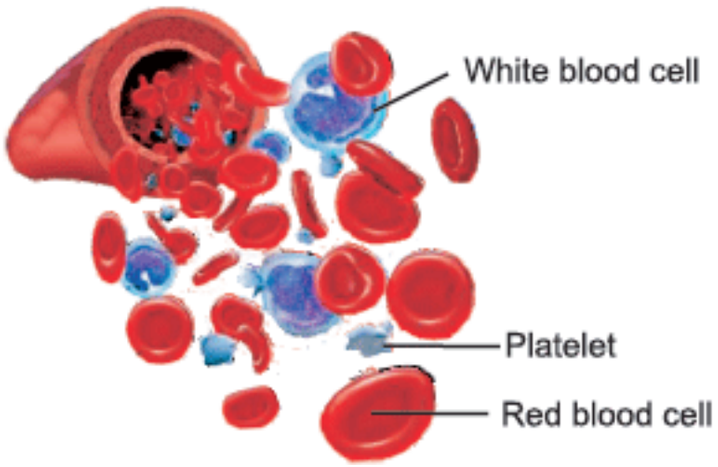
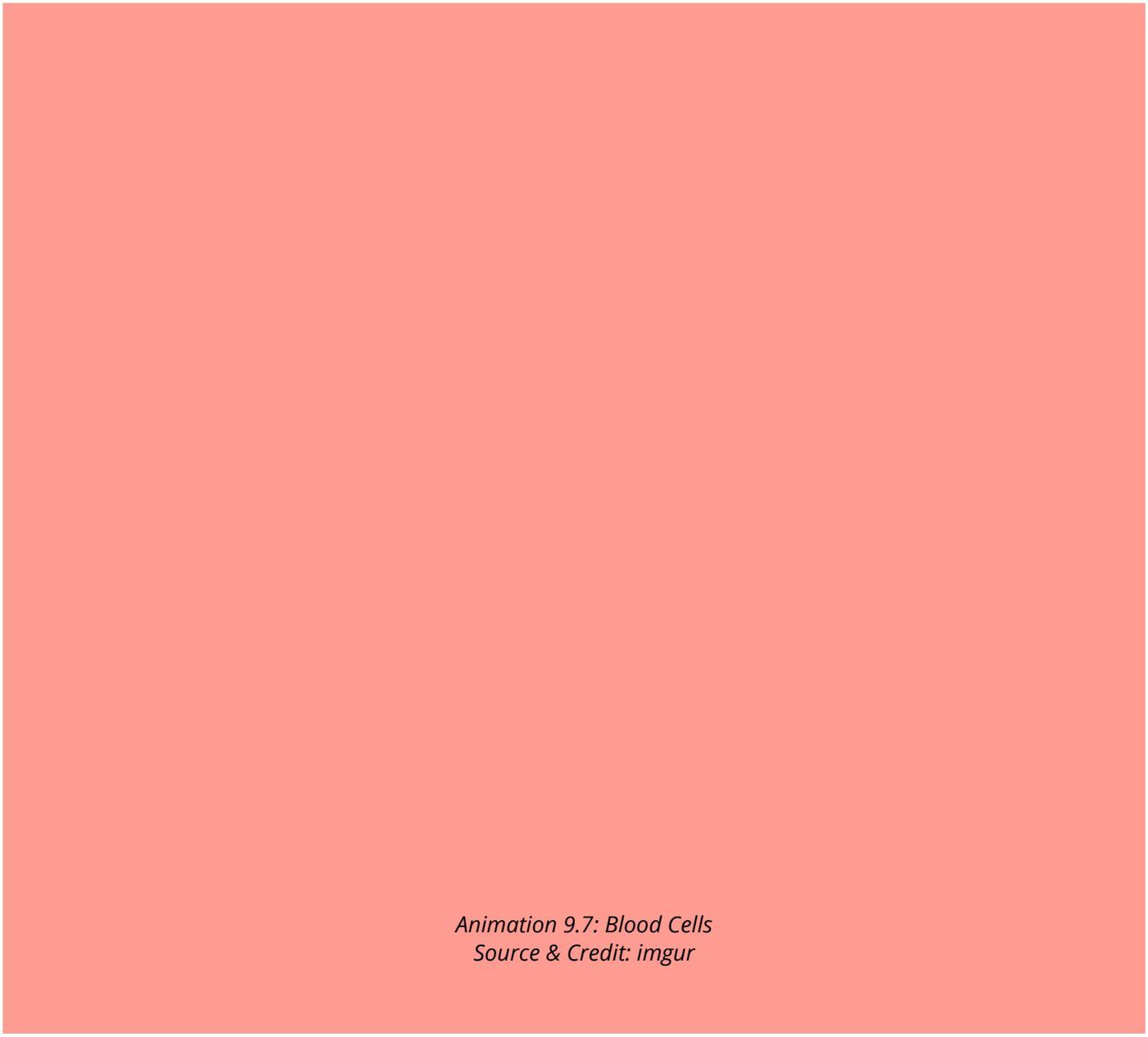


Figure 9.12: Different cells and cell-like bodies in blood plasma

Red Blood Cells (Erythrocytes)

These are the most numerous of blood cells. A cubic millimeter of blood contains 5 to 5.5 million of RBCs in males, and 4 to 4.5 million in females. When RBCs are formed, they have nucleus. In mammals, when a red blood cell matures, its nucleus is lost.



Animation 9.7: Blood Cells
Source & Credit: imgur

After the loss of nucleus, RBC enters blood. About 95% of the cytoplasm of RBCs is filled with hemoglobin, which transports O_2 and small amounts of CO_2 .The remaining 5% consists of enzymes, salts and other proteins. RBCs are biconcave and have an elastic cell membrane. In the embryonic and foetal life, they are formed in liver and spleen. In adults, they are formed in the red bone marrow of short and flat bones, such as sternum, ribs and vertebrae. Average life span of RBC is about four months (120 days) after which it breaks down in liver and spleen by phagocytosis.

In a normal person about 2-10 million red blood cells are formed and destroyed every second.

White Blood Cells (Leukocytes)

These are colourless, because they do not contain pigments. They are not confined to blood vessels and also migrate out into tissue fluid. One cubic millimeter of blood contains 7000 to 8000 WBCs. Their life span ranges from months to even years, depending on body's needs. WBCs function as the main agents in body's defence system. There are two main types of WBCs.

Granulocytes have granular cytoplasm. These include **neutrophils** (destroy small particles by phagocytosis), **eosinophils** (break inflammatory substances and kill parasites) and **basophils** (prevent blood clotting).

Agranulocytes have clear cytoplasm and include **monocytes** (produce macrophages which engulf germs) and **B and T lymphocytes** (produce antibodies and kill germs).

Platelets (Thrombocytes)

They are not cells, but are fragments of large cells of bone marrow, called **megakaryocytes**. They do not have any nucleus and any pigment. One cubic millimeter of blood contains 250,000 platelets. The average life span of a blood platelet is about 7 to 8 days. Platelets help in blood clotting. The clot serves as a temporary seal at the damaged area.

WBCs die in the process of killing the germs. These dead cells accumulate and make the white substance called pus, seen at infection sites.	In dengue fever, there is a sharp decrease in the number of platelets in blood. Because of this, patients bleed from the nose, gums and under the skin.

Table 9.2: Composition of blood

	Description	Amount in %age	Functions
Plasma	Liquid portion of blood	55% by volume	Carries blood cells and important blood proteins, hormones, salts etc.
Cell Types	**Description**	**Average Number present**	**Functions**
Red Blood Cells (Erythrocytes)	Like a biconcave disc; without nucleus; contain haemoglobin	5,000,000 per mm^3	Transport Oxygen and a small amount of CO_2
White Blood Cells (Leukocytes)	Granular and agranular; contain nucleus; Larger in size than RBCs	7500 per mm^3	Play role in body's defense by different ways like: Engulf small particles Release anticoagulants Produce antibodies
Platelets (Thrombocytes)	Fragments of bone marrow cells (megakaryocytes)	250,000 per mm^3	Involved in blood clotting

Analyzing and Interpreting:
Identify red blood cells, white blood cells and platelets in specimens of prepared slides or diagrams (Figure 9.13)

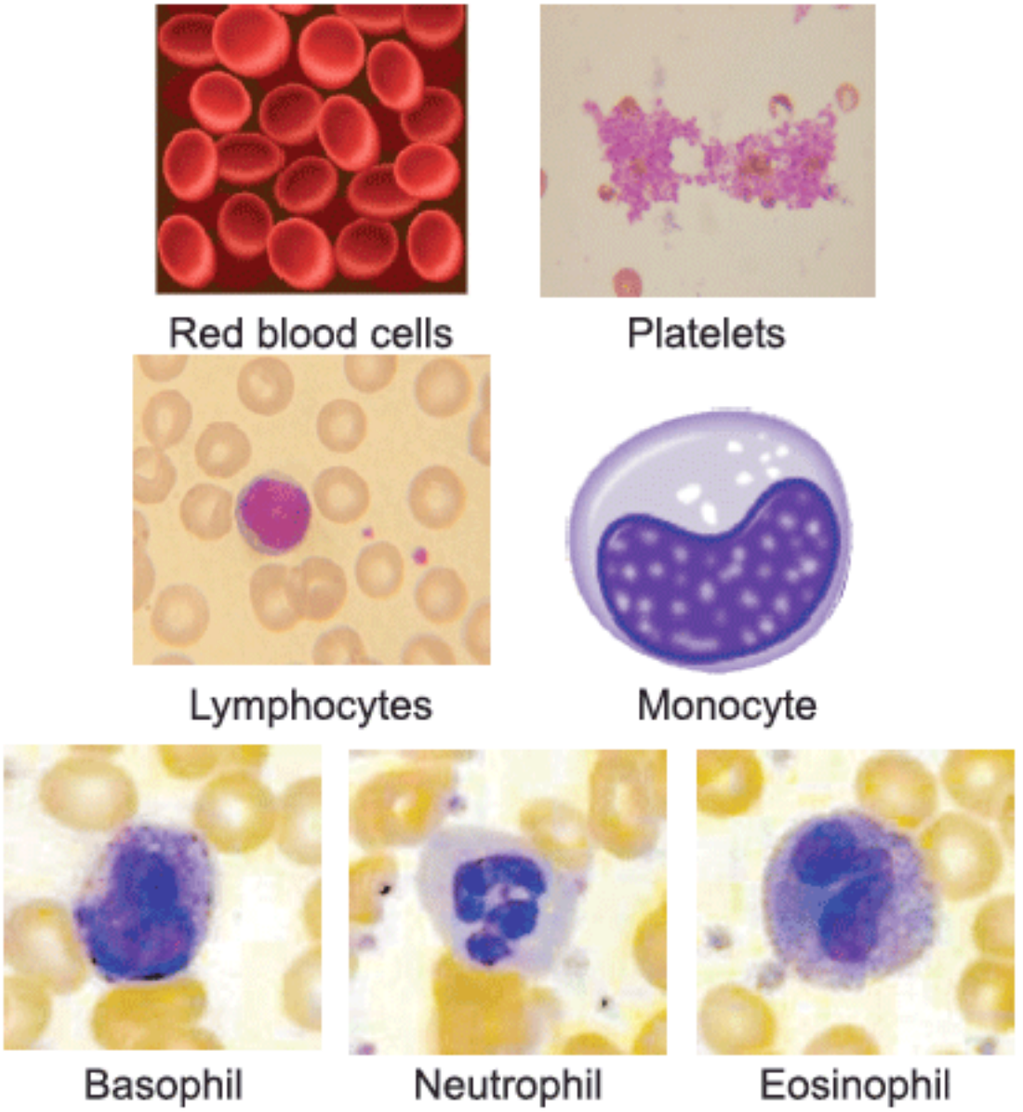


Figure 9.13: Blood cells as seen under microscope
(Courtesy: http://en.wikipedia.org/)

? Which blood cells are the most numerous in healthy human body?

Red blood cells

BLOOD DISORDERS

There are many types of blood disorders, including: bleeding disorders, leukaemia,thalassaemia etc. Here we will discuss leukaemia and thalassaemia.

The world celebrates the International Thalassaemia Day on 8th of May. This day is dedicated to raise public awareness about thalassaemia and to highlight the importance of the care for thalassaemia patients.

Leukaemia (blood cancer)

Leukaemia is the production of great number of immature and abnormal white blood cells. This is caused by a cancerous mutation (change in gene) in bone marrow or lymph tissue cells. The mutation results in uncontrolled production of defective white blood cells (leukocytes).
It is a very serious disorder and patient needs to change blood regularly with normal blood, got from donors. It can be cured by bone marrow transplant. It is effective in most cases , but very expensive treatment.

There are about 60-80 million people in the world who carry thalassaemia. India, Pakistan and Iran are seeing a large increase of thalassaemia patients. Pakistan alone has 250,000 such patients. The patients require blood transfusions for lifetime. (Source: The Thalassaemia International Foundation)

Thalassaemia (g. thalassa = sea; haem = blood)

It is also called Cooley's anaemia on the name of Thomas B. Cooley, an American physician. It is a genetic problem due to mutations in the gene of haemoglobin. The mutation results in the production of defective haemoglobin and the patient cannot transport oxygen properly. The blood of these patients is to be replaced regularly, with normal blood. It can be cured by bone marrow transplant but it does not give 100% cure rate.

BLOOD GROUP SYSTEMS

Blood group systems are a classification of blood based on the presence or absence of antigens on the surface of red blood cells. An antigen is a molecule that can stimulate an immune response (antibody production etc.).

ABO Blood Group System

It is the most important blood group system in humans. It was discovered by the Austrian scientist **Karl Landsteiner,** who found four different blood groups (blood types) in 1900. He was awarded the Nobel Prize in Medicine for his work.

In this system, there are four different blood groups which are distinct from each other on the basis of specific antigens (antigen A and B) present on the surface of RBCs. A person having antigen A has blood group A, a person having antigen B has blood group B, a person having both antigens has blood group AB, and a person having none of the A and B antigens has blood group O.

After birth, two types of antibodies i.e. anti-A & anti-B antibodies appear in the blood serum of individuals. These antibodies are present according to the absence of corresponding antigen. In persons with blood group A, antigen A is present and antigen B is absent. So their blood will contain anti-B antibodies. In persons with blood group B,antigen B is present and antigen A is absent. So their blood will contain anti-A antibody.

A total of 29 human blood group systems are now recognized by the International Society of Blood Transfusion (ISBT).

In persons with blood group AB, antigens A & B are present i.e. neither is absent. So their blood serum will contain no antibody. In persons with blood group O, neither antigen A nor antigen B is present i.e. both are absent. So their blood serum will contain both antibodies i.e. anti-A & anti-B.

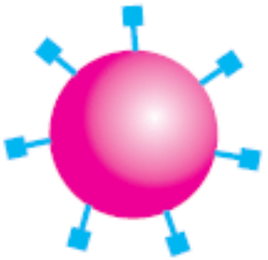
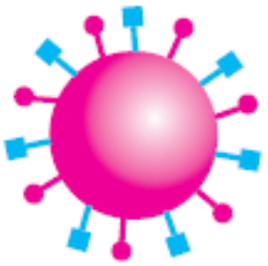
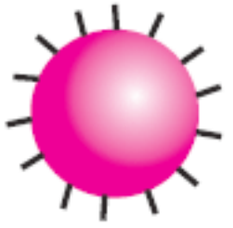
	Blood group A	Blood group B	Blood group AB	Blood group O
Red Blood Cells				
Antigens on RBCs	 antigen A	 antigen B	 Antigen A & B	None
Antibodies in serum	 Anti-B	 Anti-A	None	 Anti-A & Anti-B

Figure 9.14: Presence and absence of antigens and antibodies in ABO blood group system

Blood transfusions in ABO blood group system

Blood transfusion is the process of transferring blood or blood-based products from one person into the circulatory system of another. Blood transfusions can be life-saving in some situations, such as massive blood loss due to injury, or can be used to replace blood lost during surgery. People suffering from anaemia, haemophilia, thalassaemia or sickle-cell disease may require frequent blood transfusions.

A number of infectious diseases (such as AIDS, hepatitis B and hepatitis C etc.) can pass from the affected blood donor to recipient. Before blood transfusion, the blood of donor is checked for the presence of germs etc.

Transfusion of blood is done after confirming that no **agglutination** (clumping of cells) results in the blood of recipient. If agglutination occurs, the clumped cells can not pass through capillaries. For the confirmation of no agglutination, blood samples of donor and recipient are cross-matched for compatibility. Antibodies of recipient's blood may destroy the corresponding antigen-containing RBCs of donor or antibodies of donor's blood may destroy antigen-containing RBCs of recipient.

O blood group individuals are called **universal donors**, because they can donate blood to the recipients of every other blood group. **AB blood group** individuals are called **universal recipients**, because they can receive transfusions from the donors of every other blood group.

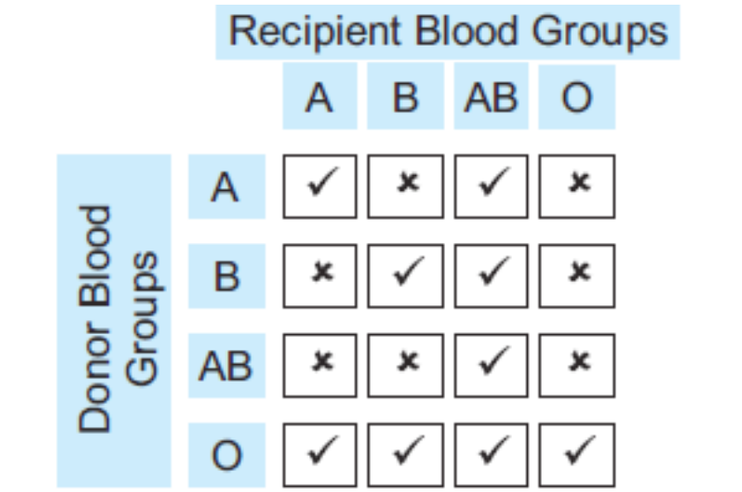
Rh Blood Group System (+ ve & - ve blood group system)

In 1930's, Karl Landsteiner discovered the Rh-blood group system. In this system, there are two blood groups i.e. Rh-positive and Rh-negative. These blood groups are distinct from each other on the basis of antigens called **Rh factors** (first discovered in Rhesus monkey), present on the surface of RBCs. A person having Rh factors has blood group.

Rh-positive while a person not having Rh factors has blood group Rh-negative. Unlike the naturally occurring anti-A & anti-B antibodies of the ABO-system, an Rh-negative
person does not produce anti-Rh antibodies unless Rh-factor enters in his / her blood.

Blood transfusions in Rh blood group system

Rh-positive blood group can be transfused to Rh-positive recipient because recipient's blood already has Rh-antigens and it will not produce anti-Rh antibody. Rh-negative blood group can be transfused to Rh-negative because donor's blood does not have Rh-antigen and so recipient's blood will not produce anti-Rh antibody. If an Rh-negative person receives Rh-positive blood, he / she will produce anti-Rh antibodies against Rh-factors. Rh-negative blood can be transfused to Rh-positive recipient, only if donor's blood (Rh-negative) has never been exposed to Rh-antigens and does not contain any anti-Rh antibody.



? Persons with blood group O are called universal donors. What is the actual universal donor blood group? Blood group O-positive or O-negative!

O-negative blood group

9.2.2 HUMAN HEART

Heart is a muscular organ responsible for pumping blood through blood vessels by repeated contractions. The term "cardiac" means "related to the heart". The bulk of the walls of heart chambers is made of **cardiac muscles**.

In human body, heart is situated between lungs, in the middle of chest cavity (thorax) under breastbone.

Recalling

Cardiac muscles are involuntary in action and are composed of branched striated cells,each with a single nucleus.

Heart is enclosed in a sac known as **pericardium**. There is a fluid, known as **pericardial fluid,** between pericardium and heart walls. It reduces friction between pericardium and heart, during heart contractions.

Human heart consists of four chambers, like the heart of birds and other mammals. The upper thin-walled chambers are called left and right **atria** (singular 'atrium'), and the lower thick-walled chambers are called left and right **ventricles**. Left ventricle is the largest and strongest chamber in heart.

The heart is usually felt to be on the left side because the left chamber of the heart i.e. (left ventricle) is stronger (it pumps blood to all body parts).

Human heart works as a **double pump.** It receives deoxygenated (with less oxygen) blood from body and pumps it to lungs. At the same time, it receives oxygenated (with more oxygen) blood from lungs and pumps it to all body. Inside heart chambers, the deoxygenated and oxygenated bloods are kept separated. Here is a brief description of the circulation of blood inside heart to show its double-pump mechanism.

Right atrium receives deoxygenated blood from body via the main veins i.e. superior and inferior vena cavae. When right atrium contracts it passes the deoxygenated blood to **right ventricle**. The opening between right atrium and right ventricle is guarded by a valve known as **tricuspid valve** (because it has 3 flaps). When right ventricle contracts, the blood is passed to pulmonary trunk, which carries blood to lungs. Tricuspid valve prevents the backflow of blood from right ventricle to right atrium. At the base of pulmonary trunk, **pulmonary semilunar valve** is present which prevents the backflow of blood from pulmonary trunk to right ventricle.

The walls of left ventricle are the thickest one. These are about a half-inch thick. They have enough force to push blood into the body. This gives an evidence that the structures of the parts of heart are adaptive to their functions.

The oxygenated blood from lungs is brought by pulmonary veins to **left atrium.** Left atrium contracts and pumps this blood to **left ventricle**. The opening between left atrium and left ventricle is guarded by a valve known as **bicuspid valve** (because it has two flaps). When left ventricle contracts, it pumps the oxygenated blood in aorta, which carries blood to all parts of body (except lungs). Bicuspid valve prevents the backflow of blood from left ventricle to left atrium. At the base of aorta, **aortic semilunar** valve is present which prevents the backflow of blood from aorta to left ventricle (Figure 9.15).

Animation 9.8 : Blood flow
Source & Credit: thomascsherman

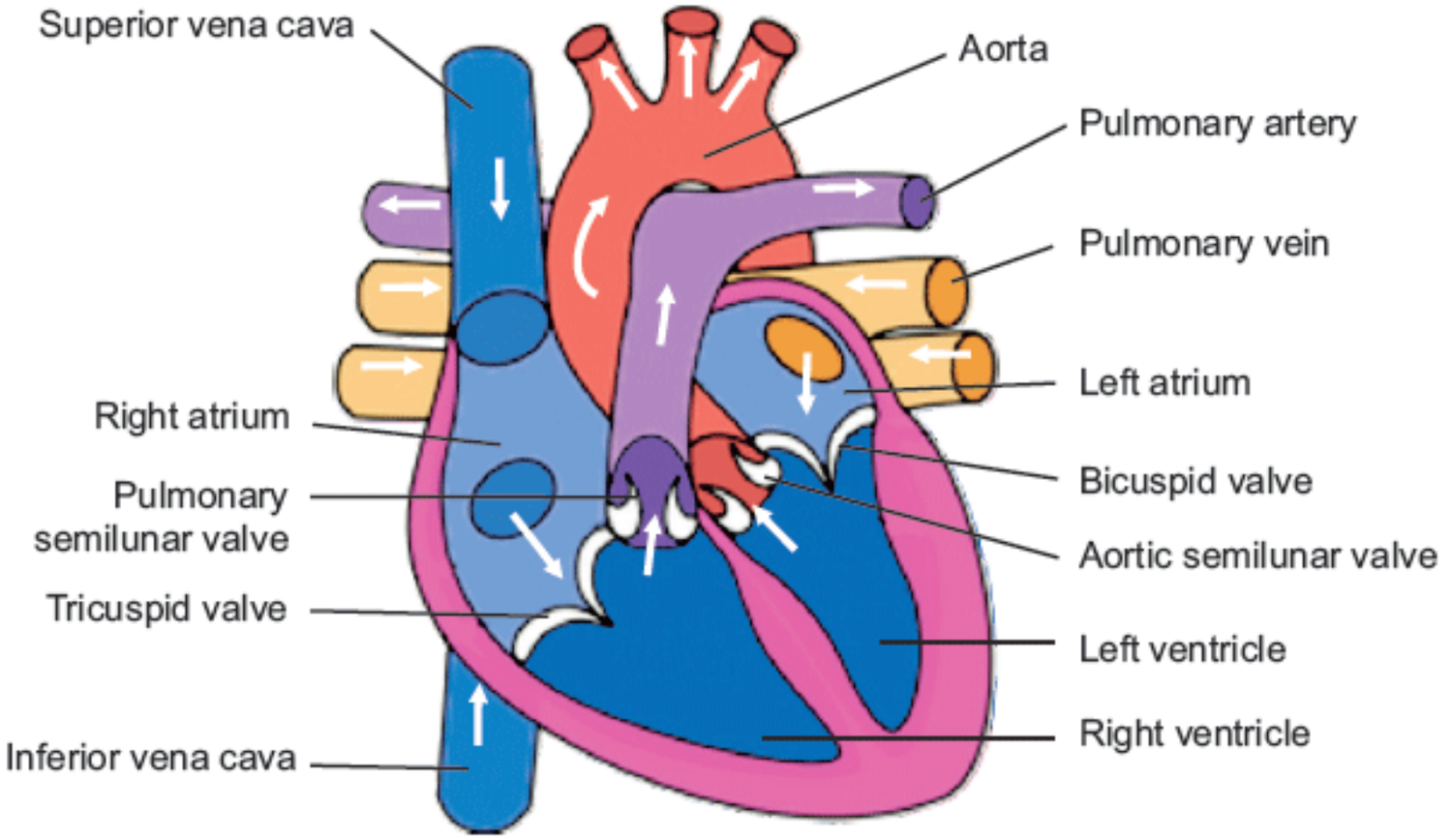


Figure 9.15: Human heart; structure and blood flow

Both atria are filled simultaneously. They contract together to pump the blood to both the ventricles. Similarly, both ventricles contract simultaneously to pump the blood out of heart

Pulmonary and systemic circulation

We see that right side of heart collects deoxygenated blood from body and distributes it to lungs while left side collects oxygenated blood from lungs and distributes it to body. The pathway on which deoxygenated blood is carried from heart to lungs and in return oxygenated blood is carried from lungs to heart is called **pulmonary circulation** or **circuit** (Figure 9.16). Similarly, the pathway on which oxygenated blood is carried from heart to body tissues and in return deoxygenated blood is carried from body tissues to heart is called **systemic circulation** or **circuit.**

The blood in pulmonary circulation is at lower pressure than the blood in systemic circulation. It gives sufficient time to blood for gaseous exchange in lungs.

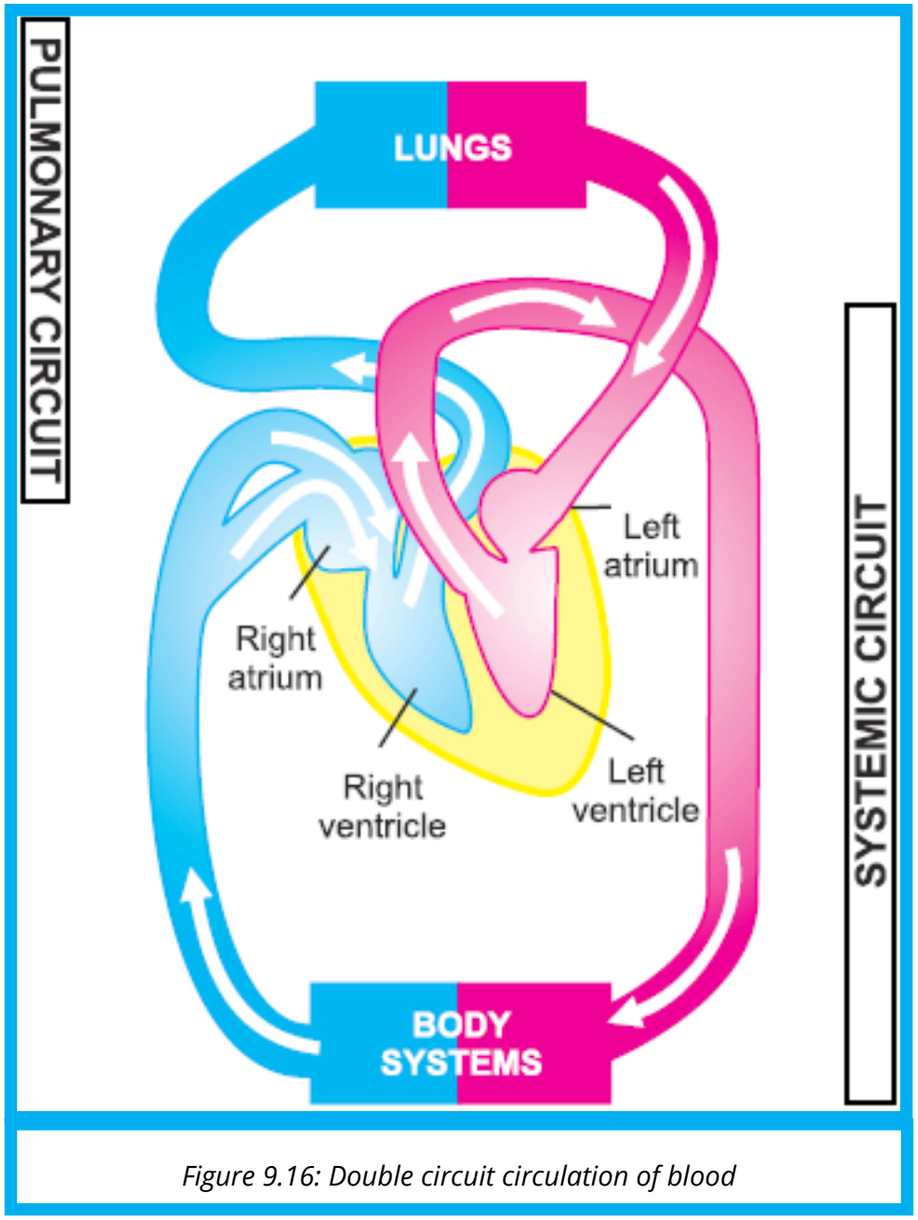


Figure 9.16: Double circuit circulation of blood

Analyzing and Interpreting:

In a given diagram of human heart, identify the components which you have studied in the current topic.

Heartbeat

The relaxation of heart chambers fills them with blood and contraction of chambers propels blood out of them. The alternating relaxations and contractions make up the cardiac cycle and one complete **cardiac cycle** makes one heartbeat. Complete cardiac cycle consists of the following steps. Atria and ventricles relax and blood is filled in atria. This period is called **cardiac diastole.** Immediately after their filling, both atria contract and pump blood towards ventricles. This period in cardiac cycle is called **atrial systole**. Now, both ventricles contract and pump blood towards body and lungs.

Animation 9.9 : How Blood Flows Through the Heart
Source & Credit : goldiesroom

Animation 9.10 : The Whole Heart
Source & Credit : Heart Point

The average human heart beats 70 times per minute. So, it would beat approximately 2.5 billion times during a lifetime of 66 years. In normal adults, the mass of heart is 250-350 g and the size is equal to a clenched fist.

The period of ventricular contraction is called **ventricular systole**. In one heartbeat, diastole lasts about 0.4 seconds, atrial systole takes about 0.1 seconds, and ventricular systole lasts about 0.3 seconds (Figure 9.17). When ventricles contract, tricuspid and bicuspid valves close and "lubb" sound is produced. Similarly when ventricles relax, the semilunar valves close and "dubb" sound is produced. "Lubb-dubb" can be heard with the help of a stethoscope.

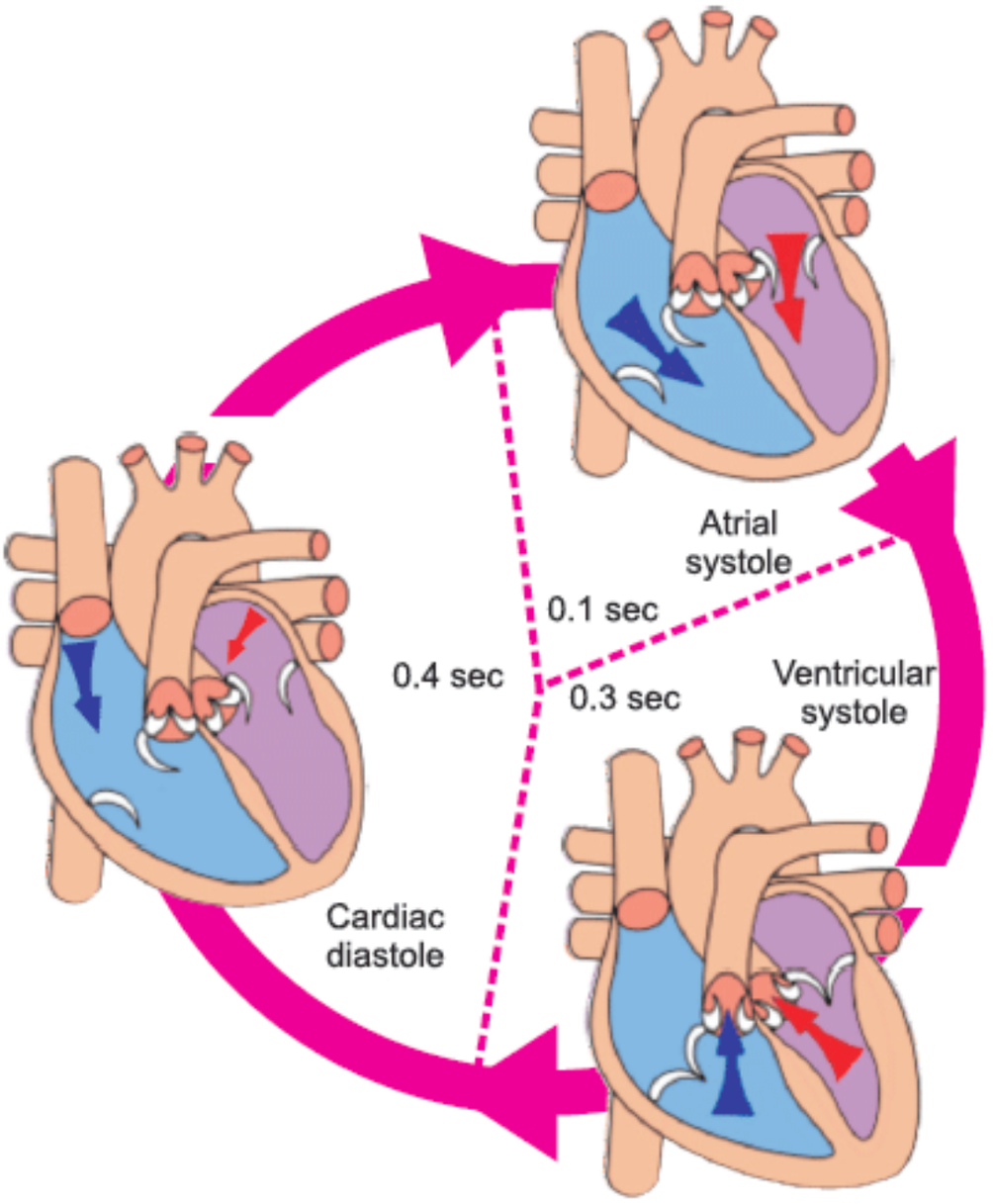


Figure 9.17: One cardiac cycle

Heart rate and Pulse rate

Heart rate is the number of times the heart beats per minute. At rest or during normal activities, the normal heart rate is 70 times per minute in men and 75 times per minute in women. The heart rate fluctuates a lot depending on factors such as activity level and stress level.

Heart rate can be measured by feeling the pulse. **Pulse** is the rhythmic expansion and contraction of an artery as blood is forced through it by the regular contractions of heart.Pulse can be felt at areas where artery is close to skin for example at wrist, neck, groin or top of foot. Most commonly, people measure their pulse in their wrist.

? When does our heart take rest? During sleep, during sitting, or never!

Never

Practical Work:

Investigation of the effect of physical activity on pulse rate

Pulse rate tells us the heart rate. As heart pumps blood through body, a pulsing can be felt in some of the blood vessels close to skin's surface. Pulse rate is measured to see how well heart is working.
Problem: How is pulse rate measured and how it is affected by various activities?

Background information:

- The pulse rate increases when involved in some physical exertion or exercise.
- Daily physical exercise increases the stamina and strength of the cardiovascular system.

Procedure:

1. Turn the palm side of your hand facing up.
2. Place your index and middle fingers of your opposite hand on your wrist, approximately 1 inch below the base of your hand (Figure 9.18).
3. Press your fingers down in the groove at this point. You should feel a throbbing -your pulse.

Animation 9.11 : Blood Pressure 2
Source & Credit : biology.clc.uc

4. Count the number of beats for 10 seconds, then multiply this number by 6. This will give you your pulse rate per minute at resting condition.
5. Do some physical exercise for example running in place, jumping jacks, or other exercise for one minute. After the exercise, measure your pulse rate by the same method (step 1 to 4).
6. Sit on a chair and take rest. After about five minutes, take your pulse again and write it down.
7. Record the differences in the table form and compare your calculations with the differences counted by your class fellows.

Observation:

Student pulse rate at rest will vary between 60 - 110 beats per minute. If pulse rate at rest is about 70 times per minute, it may increase up to 100 beats per minute during exercise.

Evaluation:

I. Are the heart rates of all students the same or different?
Ii. What is the average heart rate of all the students?

Figure 9.18: Method of taking pulse

Physical exertion and exercise should not be very strenuous that they increase your pulse rate beyond the limit.

9.2.3 BLOOD VESSELS

The third part of blood circulatory system are blood vessels, which function to transport blood throughout body. The most important vessels in blood circulatory system are arteries, veins, and capillaries. (Table 9.1)

Arteries: Arteries are the blood vessels that carry blood away from heart. In adults, all arteries with the exception of the pulmonary arteries, carry oxygenated blood.

The structure of arteries is well adapted to their function. The walls of an artery are composed of three layers. The outermost layer is made of connective tissue. The middle one is made up of smooth muscles and elastic tissue while the innermost layer is made up of endothelial cells. The hollow internal cavity in which blood flows is called lumen.

When arteries enter body organs, they divide into smaller vessels known as arterioles. Arterioles enter tissues and divide into capillaries.

Capillaries: Capillaries are the smallest blood vessels present in tissues. These are formed by the divisions of arterioles. The exchange of materials between blood and tissue fluid is carried out through capillaries.

The walls of capillaries are composed of only a single layer of cells i.e. endothelium. This layer is so thin that molecules of the digested food, oxygen and water etc. can pass through them and enter tissue fluid. Waste products such as carbon dioxide and urea can diffuse from tissue fluid into blood.

Capillaries are so small that the red blood cells need to partially fold into bullet-like shapes in order to pass through them in single file.

Veins: A vein is a blood vessel that carries blood towards heart. In adults, all veins with the exception of pulmonary veins, carry deoxygenated blood.

Veins are also well-adapted to their function. The walls of vein are composed of the same three layers as are present in artery wall, with the difference that the middle layer of vein has less smooth muscles and elastic tissue as compared to artery. So the middle layer of vein is comparatively thin. The lumen of the veins is broader than that of arteries.

In a tissue, capillaries join to form small venules, which join to form veins. Most veins have flaps called valves that prevent the backflow of blood.

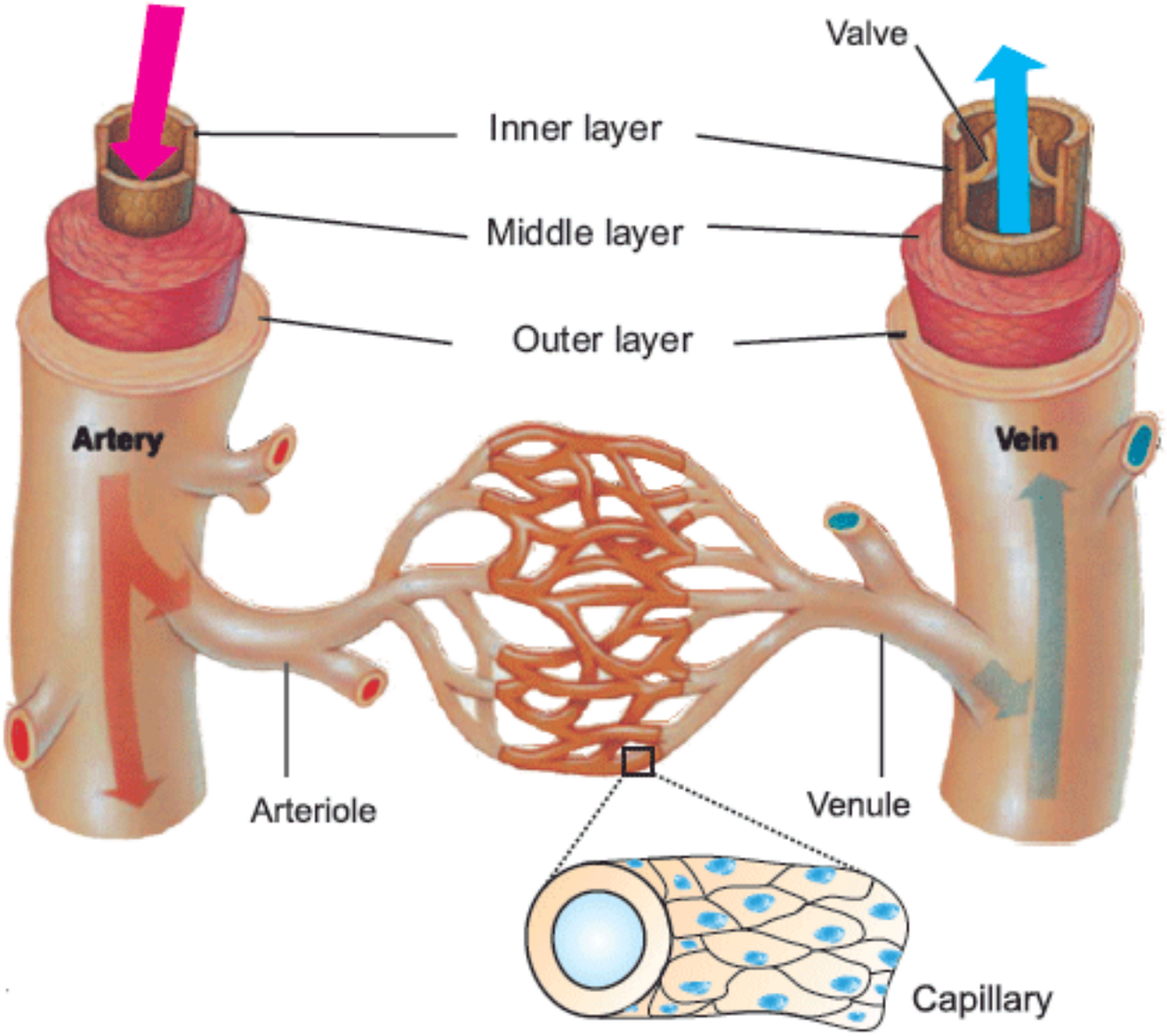


Figure 9.19: Blood vessels

Vascular surgery is a field in surgery in which diseases of arteries and veins (like thrombosis etc.) are managed by surgical methods. A vascular surgeon treats the diseases of all parts of blood circulatory system except that of heart and brain.

Table 9.1: Comparison of arteries, capillaries and veins

Characteristics	ARTERIES	CAPILLARIES	VEINS
Function	Carry blood away from heart	Allow the exchange of materials between blood and tissues	Carry blood towards heart
Thickness and Elasticity in walls	Thick and elastic	One-cell thick non-elastic walls	Thin and less elastic
Muscles in walls	Thick	No muscles	Thin
Blood pressure	High BP	Medium	Low BP
Valves	No valves	No valves	Valves present

Practical work:

Experiment to show capillary flow in the tail or fins of a fish

Capillaries are the smallest blood vessels, which are formed by the divisions of arterioles. Fishes possess a rich network of capillaries under their skin.

Procedure:

See the figure given (9.20) while setting up the experiment.

1. Place a thin wet wad of cotton on the bottom of a Petri dish towards one end.
2. Place a slide at the other end.
3. Remove a fish from the aquarium or jar of water and place it on the Petri dish such that its body lies over the wet cotton and its tail lies over the slide.
4. Place a thick wet wad of cotton over fish and place another slide over the tail. Keep both cotton wads moist by putting water drops over these.

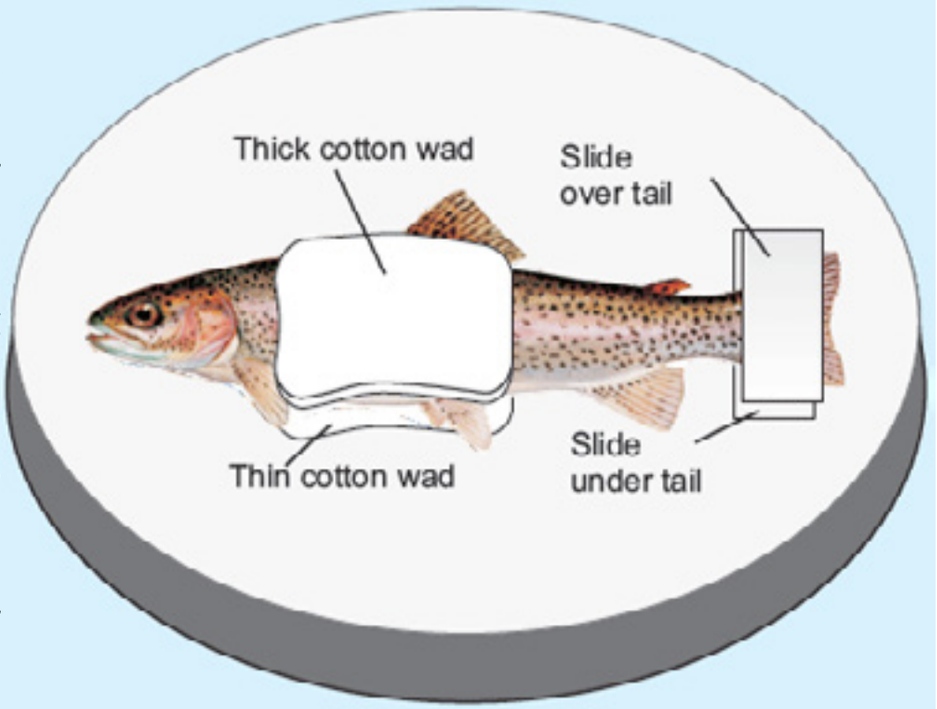


Figure 9.20: Experiment setup to show the capillary flow in fishtail

5. Remove the clips from the stage of microscope and place the Petri dish on the stage so that the tail of fish is over the opening of stage.
6. Focus the microscope on tail and adjust the part of tail where blood capillaries are seen. Draw the structure of capillary network seen in tail of fish.

?

Through which blood vessels the materials are exchanged between the blood and the surrounding tissues?

Capillaries

9.2.4 General Plan of Human Blood Circulatory System

Many scientists worked for discovering the facts about the circulation of blood in human body. Two important scientists who revealed much knowledge of blood circulatory system were **Ibn-e-Nafees** and **William Harvey**. Ibn-e-Nafees (1210-1286 AD) was a physician and he is honoured as the first scientist who described the pathway of blood circulation. William Harvey (1578-1657 AD) discovered the pumping action of heart and the pathway of blood in major arteries and veins.

Now we will see how do the major arteries and veins make arterial and venous systems respectively.

Arterial System

Large **pulmonary trunk** emerges from right ventricle and divides into right and left pulmonary arteries, which carry the deoxygenated blood to right and left lungs.

The oxygenated blood leaving the left ventricle of heart is carried in a large artery i.e. **aorta**. It ascends and forms an **aortic arch**. The arch curves left and descends inferiorly into body. From the upper surface of aortic arch, three arteries emerge, which supply blood to head, shoulders and arms. As aorta passes down through thorax, it becomes **dorsal aorta**. It gives off many branches and the important ones are listed here. Several **intercostal arteries** supply blood to ribs. **Caeliac artery** and **superior mesenteric artery** supply blood to digestive tract while hepatic artery supplies blood to liver.

Even though the heart chambers are continually bathed with blood, this does not nourish heart muscles. The blood supply to heart muscles is provided by coronary arteries, which emerge from the base of aorta. Heart muscles are drained by coronary veins, which empty into right atrium. Coronary arteries and veins are collectively called coronary circulation and it is a part of systemic circulation.

Inferior to these, there are a pair of **renal arteries** that supply blood to kidneys. **Gonadal arteries** supply blood to gonads. Just below the gonadal arteries, is **inferior mesenteric artery**, which supplies blood to a part of the large intestine and rectum.Then aorta divides into two **common iliac arteries**, each of which divides into an internal iliac artery and an external iliac artery. Each external iliac becomes **femoral artery** in upper thigh. It gives branches to thigh, knee, shank, ankle and foot.

Animation 9.12: Blood Circulatory system
Source & Credit: my-ecoach

Venous System

Veins from lungs, called **pulmonary veins** return the oxygenated blood to the left atrium of heart. Two major veins i.e. **superior vena cava** and **inferior vena cava** carry the deoxygenated blood from rest of the body and empty into right atrium.

Superior vena cava forms when different veins from head, shoulders and arms join together. From legs, the deoxygenated blood is returned to heart by many veins which empty into inferior vena cava. Veins carrying blood from calf, foot and knee join together to form **femoral vein**. It empties into **external iliac vein** which joins with the **internal iliac** and both empty into **common iliac vein**.

Right and left common iliac veins join to form inferior vena cava. Many short veins empty into inferior vena cava. Among these are **hepatic vein, renal veins,** and **gonadal veins**. All veins coming from stomach,spleen, pancreas and intestine drain into **hepatic portal vein**, which carries blood to liver. From liver, a hepatic vein carries blood and empties into inferior vena cava. Two renal veins carry blood from kidneys while two gonadal veins carry blood from gonads to inferior vena cava. In thoracic cavity, inferior vena cava also receives veins from thoracic walls and ribs.

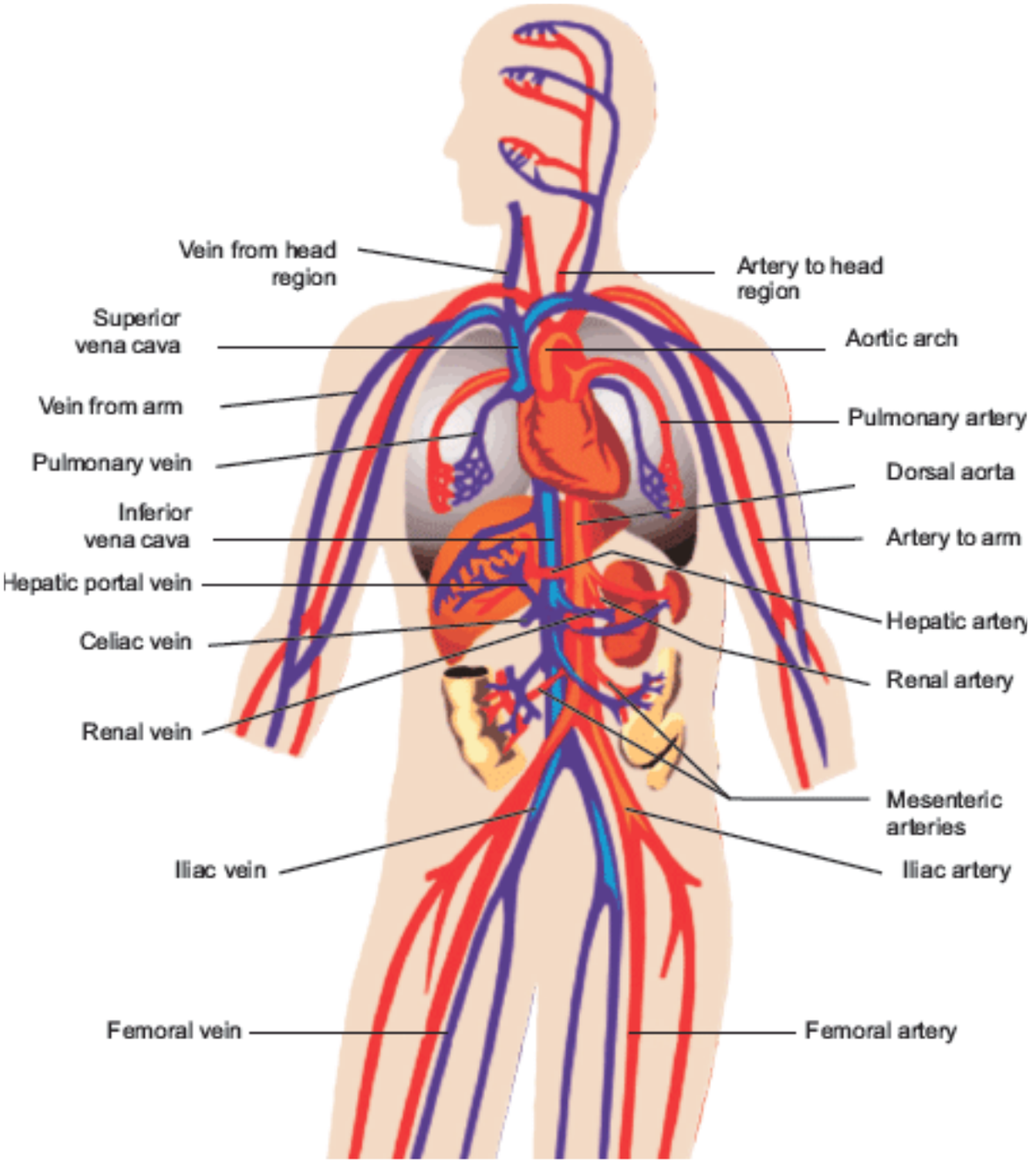


Figure 9.21: Major arteries and veins in human body

? Through which blood vessel the oxygenated blood leaves the human heart?

Aorta

9.3 CARDIOVASCULAR DISORDERS

The diseases that involve the heart or blood vessels are collectively called cardiovascular disorders. These diseases have similar causes, mechanisms, and treatments.
The risk factors that lead to cardiovascular disorders include advanced age, diabetes, high blood concentration of low density lipids (e.g. cholesterol) and triglycerides, tobacco smoking, high blood pressure (hypertension), obesity, and sedentary lifestyle.

9.3.1 ATHEROSCLEROSIS AND ARTERIOSCLEROSIS

Atherosclerosis and arteriosclerosis are the diseases of arteries. These diseases also lead to heart diseases. Atherosclerosis is commonly referred to as a “narrowing” of arteries. It is a chronic disease in which there is accumulation of fatty materials,cholesterol, or fibrin in arteries. When this condition is severe, arteries can no longer expand and contract properly, and blood moves through them with difficulty.

Accumulation of cholesterol is the prime contributor to atherosclerosis. It results in the formation of multiple deposits called **plaques** within arteries. Plaques can form blood clots called thrombus within arteries. If a **thrombus** dislodges and becomes free floating,it is called an **embolus.**

It has been estimated that cardiovascular disorders are the major cause of sudden non-accidental deaths in developed as well as developing countries.

9.3.2 MYOCARDIAL INFARCTION

The term myocardial infarction is derived from myocardium (the heart muscle) and infarction (tissue death). It is more commonly known as a heart attack. It occurs when blood supply to a part of heart is interrupted and leads the death of heart muscles. Heart attack may be caused by blood clot in

coronary arteries. It is a medical emergency, and the leading cause of death for both men and women all over the world. Severe chest pain is the most common symptom of myocardial infarction and may be in the form of sensation of tightness, pressure, or squeezing. Pain radiates most often to left arm, but may also radiate to lower jaw, neck, right arm and back. Loss of consciousness and even sudden death can occur in myocardial infarction.

Approximately one fourth of all myocardial infarctions are silent i.e. without chest pain or other symptoms. A silent heart attack is more common in the elderly, in patients with diabetes mellitus and after heart transplantation.

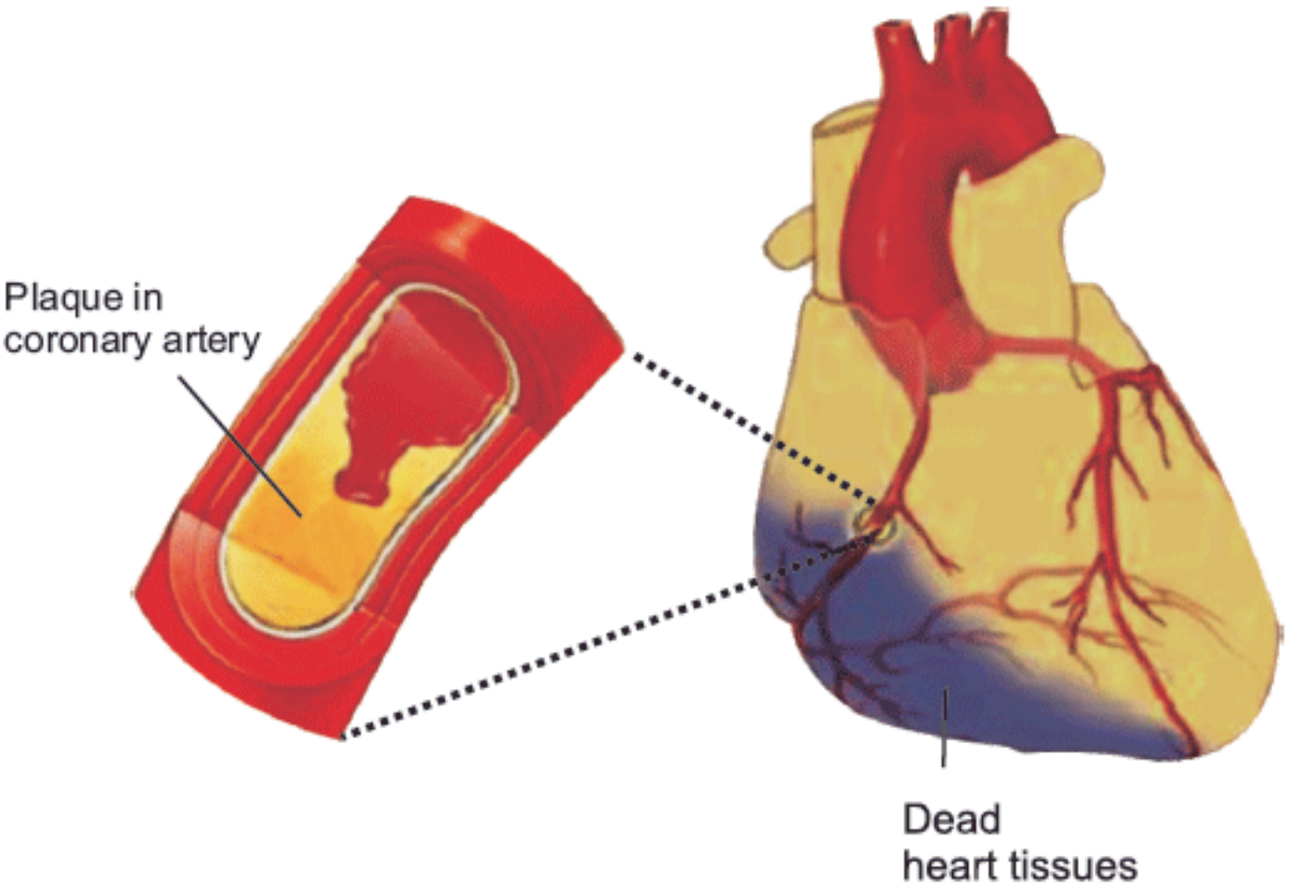
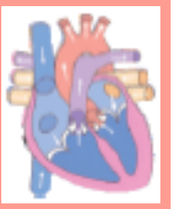


Figure 9.22: Atherosclerosis and resulting Myocardial infarction

Immediate treatment for suspected acute myocardial infarction includes oxygen supply,aspirin, and sublingual tablet of glyceryl trinitrate. Most cases of myocardial infarction are treated with **angioplasty** (mechanical widening of a narrowed or totally obstructed blood vessel) or **bypass surgery** (surgery in which arteries or veins from elsewhere in the patient's body are grafted to the coronary arteries to improve blood supply to heart muscles).

Angina pectoris means "chest pain". It is not as severe as heart attack. The pain may occur in heart and often in left arm and shoulder. It is a warning sign that blood supply to heart muscles is not sufficient but shortage is not enough to cause tissue death.

World Heart Day is held on 28th September every year throughout the world. Its objective is to help people better understand their personal risks of cardiovascular disorders.



Cardiovascular disorders are the cause of 12% of adult deaths in Pakistan (Source: Federal Bureau of Statistics of Pakistan). Hypertension (blood pressure higher than normal) is the most common cause of cardiovascular disorders in Pakistan.

- There are over 12 million hypertension patients in Pakistan.
- About 10% of our population is diabetic.
- According to the World Health Organization,in Pakistan 1 in 7 urban adults is obese.

Animation 9.13 : Heart
Source & Credit: photobucket

UNDERSTANDING THE CONCEPTS

1. How would you relate the internal structure of root with the uptake of water and salts?
2. Define transpiration and relate it with cell surface and with stomatal opening and closing.
3. How do different factors affect the rate of transpiration?
4. Transpiration is a necessary evil. Give comments.
5. Explain the movement of water in terms of transpirational pull.
6. Describe the theory of pressure flow mechanism to explain the translocation of food in plants.
7. List the functions of the components of blood.
8. How do we classify blood groups in terms of the ABO and the Rh blood group systems?
9. State the signs and symptoms, causes and treatments of leukemia and thallassemia.
10 What four chambers make the human heart and how blood flows through these chambers?
11 Compare the structure and function of an artery, a vein and a capillary.
12. Draw diagrams which can illustrate the origins, locations and target areas of the main arteries in human blood circulatory system.
13. Draw diagrams which can illustrate the areas and locations of the main veins in human blood circulatory system.
14. How would you differentiate between atherosclerosis and arteriosclerosis?
15. State the causes, treatments and prevention of myocardial infarction.

SHORT QUESTIONS

1. What are lenticels and where are they found in plant body?

2. What is the role of potassium ions in the opening of stomata?
3. Define the cohesion-tension theory?
4. What do you mean by sources and sinks according to the pressure flow mechanism?
5. What are the two main types of white blood cell? How do they differ?
6. You see pus at the site of infection on your skin. How is it formed?
7. What role does the pericardial fluid play?
8. Define the terms systole and diastole.

THE TERMS TO KNOW

ABO system
Agglutination
Agranulocytes
Albumin
Angina pectoris
Anti-A antibody
Anti-B antibody
Antigen
Antigen A
Antigen B
Anti-Rh antibody
Aorta
Aortic arch
Arteriole
Arteriosclerosis
Lymphocytes
Lymphogenous cells
Megakaryocytes
Monocytes
Myocardial Infarction
Neutrophils
Pericardial fluid
Pericardium
Pericycle
Phloem
Plasma
Platelets
Pulse
Artery
Atherosclerosis
Atrial systole
Atrium
B lymphocytes
Basophils
Bicuspid valve
Bloodgroup system
Capillary
Cardiac cycle
Cardiovascular system
Cohesion-tension theory
Coronary artery
Cortex
Red Blood Cells
Rh factors
Rh-blood group system
Root hair
Semilunar valve
Stoma
Systemic circulation
T lymphocytes
Thalassaemia
Thrombocytes
Thrombus
Transpiration
Transpirational pull
Diastole
Dorsal aorta
Embolus
Endodermis
Eosinophil
Erythrocyte
Fibrin
Fibrinogen
Granulocytes
Guard cell
Haemoglobin
Heart rate
Lenticels
Leucocytes
Leukaemia
Ventricle
Ventricular systole
Venule
White Blood Cells
Wilting
Xylem
Pulmonary artery
Pulmonary circulation
Pulmonary vein
Tricuspid valve
Vein
Vena cava

ACTIVITIES

1. Observe root hairs on a growing root of onion, carrot etc.
2. Describe the structure and number of stomata after microscopic observation of an epidermal peel of a leaf.
3. Investigate the rate of water loss at the two surfaces of a leaf by a simple experiment using cobalt chloride paper.
4. Investigate transpiration in potted plant under a bell jar.
5. Identify xylem and phloem tissues in the prepared slides of stem, root and leaf.
6. Investigate the pathway of water in a cut stem, using a suitable stain.
7. Identify red and white blood cells under the light microscope on prepared slides and in diagrams and photomicrographs.
8. Investigate the effect of physical activity on pulse rate.
9. Show the capillary flow in a fishtail or fin or frog's web.

SCIENCE, TECHNOLOGY AND SOCIETY

1. State vascular surgery as one of the major fields in the careers.
2. Identify that cardiovascular disorders are the major cause of sudden non-accidental deaths.
3. Explain the social as well as personal factors that contribute to cardiovascular disorders in Pakistan.

CREDITS AND SUPPLEMENTARY READING BOOKS FOR DATA

1. William D. Schraer, Herbert J. Stilze: *Biology* - The Study of Life (Allyn and Bacon Inc., 1987)
2. P. H. Raven, Goerge B. Johnson: *Biology* (Mosby-Year Book Inc., 1992)
3. Stephan A. Miller, John P. Harley: *Zoology* Edition: 6 (The McGraw Hill Companies Inc., 2005)
4. Edward O. Wilson, Frances M. Peter: *Biodiversity* Edition: 13 (National Academies Press, 1988)
5. Susan M. Braatz, Gloria Davis: C*onserving Biological Diversity: A Strategy for Protected Areas in the Asia-Pacific Region* (World Bank Publications, 1992)
6. Bruce Alberts and Martin Raff: *Essential Cell Biology (*Garland Publishing Inc.,1998)
7. Elaine N. Marieb, Katja Hoehn: *Human Anatomy and Physiology* Edition: 8 (Benjamin-Cummings Publishing Company, 2009)

LINKS for PHOTOS

- www.nature.com
- www.tutorvista.com
- www.bio.davidson.edu
- highered.mcgraw-hill.com
- www.innerbody.com
- www.healthkey.com
- commons.wikimedia.org
- www.wildlifeofpakistan.com
- www.worthingtonbiochem.com
- www.biologycornor.com
- biology.kenyan.edu
- en.wikipedia.org

GLOSSARY

Active transport: The movement of molecules across a cell membrane from the area of lower to the area of higher concentration.
Aerobic respiration: A type of cellular respiration in which oxygen is utilized and glucose is completely oxidized into carbon dioxide and water.
Agriculture: The profession that deals with the food crops and animals which are the source of food.
Amino acids: The organic molecules which are the units of proteins.
Anaerobic respiration: A type of cellular respiration in which oxygen is not utilized and glucose is incompletely oxidized.
Anatomy: The study of the structure of internal organs.
Antibodies: Proteins produced by lymphocytes that attack antigens.
Antigens: Foreign invaders in the body that trigger an immune response.
Arteries: The thick-walled blood vessels which carry blood away from the heart.
Asexual reproduction: Reproduction which does not involve the fusing of gametes.
Assimilation: The incorporation of the products of digestion into the body, where they are used to provide energy or for growth and repair of tissues.
ATP: A high-energy chemical used in cells as an energy store.

B

Bile: A secretion produced in the liver which emulsifies fats to prepare them for digestion.
Biodiversity: Variety in and between organisms, species and ecosystems.
Bioelement: Elements that make the body of living organisms.
Biogeography: The study of the occurrence and distribution of species in different geographical regions of the world.
Biophysics: The interdisciplinary science that deals with the study of the principles of physics which are applicable to biological phenomena.
Biosphere: The earth's landmasses, oceans and atmosphere, and all the organisms living in them.
Bivalent: Having two chromosomes - one from the male gamete and one from the female gamete.

C

Capillaries: Extremely narrow tubes which carry blood around our tissues.
Carbohydrate: Food belonging to the group consisting of sugars, starch and cellulose. They are vital for energy in humans.

Carnivore: An animal which feeds only on other animals.
Cellulose: A carbohydrate which forms the cell wall in plant cells.
Chlorophyll: The green pigment inside the chloroplasts of plant cells. It enables photosynthesis to take place.
Chloroplasts: Cell organelles containing chlorophyll; found in green plant cells where photosynthesis takes place.
Chromatids: One of two daughter strands of a replicated chromosome.
Chromosomes: One of the rod shaped bodies found in the nucleus of cells that contain genetic information (DNA).
Cloning: Producing organisms which are genetically identical to one another.
Community: Populations of different organisms living together in a habitat.
Cytokinesis: The division of the cytoplasm, after nuclear division (karyokinesis).

D

Decomposer: An organism which eats dead materials and breaks them down into simple materials.
Defecation: Getting rid of undigested material from the body.
Deforestation: The process of cutting down a large number of trees in a forest and not replacing them.
Diaphragm: A large sheet of muscle that separates the lungs from the abdominal cavity.
Dietary fiber: Non-digestible carbohydrates.
Diffusion: The movement of molecules or ions from an area of higher concentration to an area of lower concentration.
Digestive system: System of organs are involved with the ingestion, digestion, absorption of food
DNA: Deoxyribonucleic Acid: The material inside the nucleus of cells which carries genetic information.
Duodenum: The first part of the small intestine where most of the digestion takes place.

E

Ecology: The study of living things within their environment.
Embryo: The developing human offspring inside the womb.
Enzyme: Proteins which speed up chemical reactions inside living organisms, by minimizing the activation energy.
Epiglottis: Small flap at the back of the tongue; it closes the glottis when we swallow so that food does not go down into trachea.
Extinct: Species of organism that is no longer living.

F

Fatty acids: Important components of lipids. Long-chain molecules made up of hydrogen and carbon atoms.

Fertilizers: Nutrients applied to crops to speed up growth.

Flaccid: Lacking turgor; lacking in stiffness.

Fossil: Remains or impression of an organism that existed in the geological past.

G

Genetics: The study of inheritance. Inheritance means the transmission of characters from one generation to the other.

Guard cells: Bean-shaped cells which control the opening and closing of stomata in a green plant's leaves.

H

Habitat: A place where plants, animals and micro-organisms live.

Haemoglobin: The red protein found in red blood cells that transports oxygen.

Herbivore: An animal which feeds only on plants.

Horticulture: The growing of garden plants;the cultivation of fruit and vegetables.

I

Ileum: The longest part of the small intestine, where food is completely digested and absorbed.

Immune system: The body's defence system against diseases and infections.

L

Limiting factors: Something which, when not sufficient, prevents or slows down a process.

Lymphocytes: A type of white blood cells which attack pathogens.

M

Meiosis: Type of cell division which forms gametes in animals and spores in higher plants, each with half the usual number of chromosomes.

Mesophyll: The inner tissue of a leaf, whose cells are green because they contain chloroplasts.

Metabolism: The sum of all chemical processes taking place in our cells, and the rate at which these proceed.

Microbiology: The division of biology that studies the life of microorganisms.

Mitochondria: Structures in the cytoplasm of all cells where respiration takes place. Singular is mitochondrion.

Mitosis: A type of cell division which produces daughter cells identical to the parent.

Morphology: The study of the structures of living organisms.

Mutation: A change in DNA which results in a change in an organism's genome.

N

Nucleus: The organelle of eukaryotic cells where genetic information is stored.

O

Omnivore: An animal which feeds on both plants and animals.

Organ: Group of tissues doing a particular job e.g. the heart.

Organ system: Group of organs doing a particular job, e.g. the circulatory system.

Organelle: Microscopic structure which does a particular job in a cell, e.g. the nucleus.

Osmosis: The movement of water molecules across a semi permeable membrane, from a solution of lower solute concentration to a solution of higher solute concentration.

Oxygenated blood: The blood containing more oxygen.

P

Palisade mesophyll: The upper layer of mesophyll where photosynthesis mostly takes place.

Pancreas: Large gland located in the abdomen near the stomach which produces Pancreatic juice for digestion and the hormone insulin.

Parasite: An organism that lives in or on another organism and causes harm to it.

Partially permeable or semi-permeable: Allowing some particles to pass through but not others.

Peristalsis: Wave-like muscular contractions in the walls of the gut which move food through the alimentary canal.

Phloem: Compound tissue through which food is transported in a plant.

Photosynthesis: The chemical change in autotrophs that uses light energy to convert carbon dioxide and water into glucose.

Physiology: The study of the functions of living organisms and their parts.

Plasma: Liquid, non-cellular part of the blood.

Platelets: White blood cell fragments which circulate in the blood and assist in clotting.

Population: Members of a single species living in a habitat.

Predator: Animal that hunts, kills and eats other animals for food.

Producer: An organism which can make its own food - i.e. a green plant.

Proteins: Organic compounds made up of amino acid molecules, one of the three main food groups.

R

Red Blood Cells: Cells which contain haemoglobin and carry oxygen.

Renal artery: Related to kidneys e.g. renal artery, renal vein.

RNA: (Ribonucleic acid) - it converts the genetic information stored in DNA into proteins.

Root hairs: Tiny hairs covering the ends of the smallest roots. They give the root a very large surface area to absorb water and mineral salts from the soil.

S

Saliva: Fluid secreted by glands in the mouth which moistens, softens and semi-digests food.
Sexual reproduction: Reproduction which involves the fusing of male and female gametes.
Spindle fibres: Fibres produced during cell division. They contract to drag chromatids to the poles of the cell.
Spongy mesophyll: The lower layer of mesophyll which contains numerous air spaces where gas exchange takes place.
Starch: A type of carbohydrate. Plants can turn the glucose into starch for storage.
Stomata (singular 'stoma'): Tiny pores in the epidermis of a leaf. They control water loss and gas exchange by opening and closing.

T

Thorax: The chest, containing the heart and lungs and encased by the ribs.
Tissue: Group of cells of the same type doing a particular job, e.g. the glandular tissue, muscular tissue, nervous tissue etc.
Trachea: The windpipe or tube from the back of the mouth to the top of the lungs.
Transpiration: The loss of water from plant surface by evaporation.
Turgor: Swelling and stiffness in plant cell due to endosmosis of water.

V

Vaccines: Substances containing disabled antigens of a particular disease; Vaccines stimulate the body to produce antibodies to provide immunity against that disease.
Valves: Structures containing a flap or flaps to ensure one-way flow of liquid.
Variegated leaf: Leaf with alternating green and white patches.
Veins: Thin-walled, valved tubes which carry blood back to the heart.
Villi: Minute hair-like projections which cover the lining of the small intestine; provide surface area for absorption.
Virus: Ultramicroscopic non-cellular organism that replicates itself inside the cells of living hosts.
Vitamins: Organic substances which are essential in small amounts to regulate the metabolism and maintain the immune system.

X

Xylem: Compound tissue which transports water and minerals up a plant.