ZOOLOGY

UNIT II

BLOOD, HUMAN HEART & RENAL PHYSIOLOGY

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DR. WKB'S ZOOLOGY STUDY MATERIAL

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BLOOD

Blood is red, vascular connective tissue. It is opaque, somewhat sticky and viscous fluid flowing in the blood vessels and is commonly known as river of life. It forms about 7-8% of the body weight and there is about 6.8 litres of blood in the normal adult person. It is slightly alkaline in nature with pH 7.4. Human blood is formed of two components namely Blood Plasma and Blood Corpuscles or Formed elements.

- **Blood Plasma**: It is pale straw coloured non-living fluid matrix of blood. It forms about 55-60% of blood and is formed of 90-92% water, 1-2% inorganic salts, 7-8% proteins and other organic compounds like glucose, amino acids, vitamins, urea, uric acid, hormones, antibodies etc.
- **Blood Corpuscles**: There are three types of cells which freely float in plasma namely:
  - **Erythrocytes:** Also called as Red Blood Corpuscles (RBCs). These are circular, biconcave and enucleated. These are more in number than the WBCs and are about 5-5.5 million per cubic mm of blood in adult males and 4.5-5 million per cubic mm of blood in females (called RBC count). Each RBC is about 7.5μm in diameter, bounded by elastic and semipermeable membrane, while cytoplasm lack most of cell organelles but contain large amount of red coloured iron containing respiratory pigment called haemoglobin, which has affinity for oxygen and gives red colour to the blood. The life span of human RBCs is of 115-120 days, after which they are destroyed called haemolysis in liver and spleen at the rate of 2.5 million per day. New RBCs are formed at the same rate in bone marrow of long bones by process called erythropoiesis. When RBC count decreases then it is called *anemia*, while RBC count increases much more than normal level in *polycythemia*.
  - **Leucocytes:** Also called as white blood cells (WBCs). These are rounded or amoeboid shaped, nucleated and non-pigmented cells. These are less in number than RBCs and are 5000 to 10,000 per cubic mm of blood (called WBC count). Their size ranges in 8-15 μm so are larger than RBCs. The rise of WBC count is called *leucocytosis* while the fall of WBC count below 4000 is called *leucopenia*. The formation of leucocytes occurs in bone marrow, Payer's patches, lymph nodes, thymus, etc. and is called *leucopoiesis*. Leucocytes are further divided into two categories namely:
    - **Granulocytes:** These have granular cytoplasm and lobed nucleus, so also called polmorphonuclear leucocytes. These are produced in the red bone marrow from the precursor cells called myeloblasts (myeloid tissue). These form about 65% of total leucocytes (6.5×10^9 per litre). These are of three types on the basis of the shapes of their nuclei and the staining reactions of their granules namely:
      - **Neutrophils**: These comprise about 60-65% of the total number of white cells so most abundant sub-type. Their count is 4900 per mm^3 of blood. These vary in size from 10-12 μm. The cytoplasm is with fine granules which stain both acidic and basic dyes so appear violet in colour. The nucleus is 3-5 lobed. The life span is of 10-12 hours. These are chief phagocytic cells of the body and engulf the

microbes by phagocytosis so neutrophils are called soldiers of the body.

- **Basophils**: These comprise about 0.5-1% of the TLC so are least in number. These vary in size from 8-10 μm. The cytoplasmic granules are coarse which takes up basic stains like methylene blue, so appear blue in colour. The nucleus is 2 or 3 lobed or S-shaped. Their life span is 8-12 hours. Basophils secrete heparin and histamine and thus have important role in local anticoagulation and formation of ground substance.
- **Acidophils**: These constitute about 2-3% of the TLC. These are slightly larger in size than the neutrophils and size range is 10-15 μm. The cytoplasmic granules are coarse and take acidic stains like eosin, so also called eosinophils. The nucleus is bilobed. The life span is of 14 hours. These increase in allergic diseases, such as asthma or hay fever and in parasitic infections e.g., Ascariasis. These also help in healing of wounds as destroy the microbes by releasing cytotoxins on them.

- **Agranulocytes:** These are non-granular white blood cells that contain non-lobulated nuclei. These form about 35% of the total leucocytes (3.5 x 10^9 per litre). These are divided in two sub-types

  Namely:

  - **Monocytes**: These are the largest sized leucocytes ranging from 12-15 μm in diameter but may be upto 20 μm. These form about 6-8% of all the leucocytes. The number of monocytes varies from 1100-400 per cubic mm of blood. The nucleus is oval, kidney or horse-shoe shaped and is usually excentric. These are usually formed in lymph nodes and the spleen from the precursor cells called monoblasts. These are highly motile and phagocytic in action and engulf bacteria so these form the second line of defense. These also differentiate into macrophages or scavenger cells which remove the damaged and dead cells to clean the body.
  - **Lymphocytes**: These constitute about 20-255 of TLC. Their number varies from 1,500-2,700 per cubic mm of blood. Their size ranges from 8-12 μm. The nucleus is large and rounded so that cytoplasm forms a thin peripheral layer. Depending upon the size there are two types of lymphocytes namely small about 7 μm and large lymphocytes about 20 μm. These are formed in the thymus and lymphoid tissues like lymph nodes, spleen, tonsils etc. from the precursor cells called lymphoblasts. These are non-motile and non-phagocytic. Primary function of the lymphocytes is to produce antibodies and opsonins.
  - **Blood Platelets**: These are smallest sized blood corpuscles about 2-3 μm

in diameter. These are oval shaped, colorless and discoidal non-nucleated cytoplasmic fragments. These occur only in the blood of mammals. These are formed from the giant cells called megakaryocytes of bone marrow. Each has a mass of basophilic granules at the centre, giving appearance of nucleus. Their number varies from 1.5 – 3.5 x 105 per cubic mm of blood. A marked decrease in number of platelets in the blood is called *thrombocytopenia* (e.g., 100,000 µl) characterized by clotting disorders which leads to excessive bleeding. Increase in number of blood platelets is called *thrombocytosis*. Their life span is of about one week (average 10 days) after which they are phagocytosed by leucocytes. These play major role in the process of blood clotting. At injury, the platelets release a number of platelet factors and an enzyme thromboplastin which cause the coagulation of blood and clot formation to prevent excessive bleeding.

Thrombocytes also called spindle cells are spindle shaped cells and nucleated cells found in blood of vertebrates other than mammals. Nucleus is oval shaped. These help in blood clotting in other vertebrates.

Functions of Blood

Blood is commonly called as river of life because it performs a number of functions essential for the survival of an organism.

A. Functions of Plasma

- Transportation of nutrients (e.g., glucose, amino acids, vitamins etc.), respiratory gases (e.g., about 3% O_2 and 7% CO_2), wastes (e.g., urea, uric acid etc.) and hormones of endocrine glands.
- It helps in temperature regulation called homeothermy by transporting heat from muscles to other organs of body.
- Bicarbonates and proteins of blood plasma act as acid-base buffers.
- Prothrombin and fibrinogen plasma proteins help in blood clotting at injuries.
- Globulins of blood plasma act as antibodies and provide immunity (disease resistance).
- Blood proteins also help in transportation of minerals like iron, copper etc.

B. Functions of RBCs

- Haemoglobin transports about 97-99% of oxygen from the lungs to body tissues as oxyhaemoglobin.
- Haemoglobin also transports about 23% of carbon dioxide from the body tissues to the lungs as carbaminohaemoglobin.

C. Functions of WBCs

- Neutrophils act as soldiers guarding the body. They eat up invading microbes by phagocytosis.
- Basophils secrete heparin which prevents coagulation of blood in the blood vessels.
- Acidophils help in healing of wounds.
- Monocytes act as scavengers and eat up damaged and dead cells to keep the body clean.
- Lymphocytes produce antibodies which provide immunity from disease causing pathogens.

D. Functions of Blood Platelets

At injury, these release an enzyme thromboplastin, which causes coagulation of blood (clot formation) to prevent excessive bleeding.

BLOOD GROUPS

Human blood contains certain specific substances called antigens and antibodies. These chemicals differ from one person to other. Based on this human blood is

classified into many blood groups. The important blood groups are ABO groups, Rh groups and MN groups.

ABO BLOOD GROUPS

The ABO system of blood grouping was discovered by Landsteiner in 1900. Landsteiner found two types of antigens in the RBC namely antigen A and antigen B. Similarly, there are two types of antibodies in the plasma called antibody a and antibody b.

Based on the presence or absence of antigens and antibodies human beings are classified into four groups called A, B, AB and O.

1. 'A' group persons contain antigen 'A' and antibody 'b'.
2. 'B' group persons contain antigen 'B' and antibody 'a'.
3. 'AB' group persons contain both antigen 'A' and 'B', but no antibody.
4. 'O' group persons contain no antigen but both antibodies 'a' and 'b' are present.

In blood transfusion, the ABO grouping should be tested. When a donor receives a wrong blood group, agglutination of blood occurs in the body of the donor and this lead to death.

In blood transfusion, one must consider the antibodies of the recipient; the antibodies of the donor has no effect because it is diluted before transfusion.

'A' group person can receive blood from another 'A' group and 'O' group person. He cannot receive blood from 'A'B group because 'A' group person contains antibody 'b' which reacts with the antigen 'B' of 'AB' group person.

Similarly, 'B' group person can receive blood from another 'B' group and 'O' group. But not from 'AB' group.

'AB' group person can receive blood from all the four groups. 'O' group person can receive blood only from 'O' group and not from any other group.

The 'AB' group person is called an universal recipient because he can receive blood from all groups.

The 'O' group person is called universal donor because he can donate his blood to any group.

RH FACTOR

Landsteiner and Wiener (1940) discovered the existence of a special type of antigen in the RBC of Rhesus monkey. Since this factor was first discovered in Rhesus monkey, it was named Rhesus factor of Rh factor. The Rh factor is also present in the RBC of some human beings and it is absent from others. Based on the presence or absence of Rh factor, the human beings are classified into two groups. They are Rh positive (Rh^+) and Rh negative (Rh^-). The Rh^+ person has Rh antigen in the RBC whereas the Rh^- has no Rh antigen.

In the European countries, 85% of the human beings are Rh^+ and the remaining 15% are Rh^-. In India 93% are Rh^+ and 7% are Rh^-. In china, 99.5% are RH^+ and only 0.5% are Rh^-.

The Rh antigen has no natural antibody. However, Rh antibody can be produced artificially. An Rh- person develop Rh antibody when he receive blood from a Rh^+ person. Even a small amount of Rh^+ blood (as small as 0.05 ml) can evoke the production of Rh antibody in the Rh^- person. The antibody once formed remains throughout the life.

Genetics of Rh Factor

There are several varieties of Rh antigen and antibody. The commonest Rh antigen is called antigen D and its antibody is called anti-d. The production of antigen is controlled by multiple alleles. The antigen D is produced by a dominant gene represented by Rh. When this gene is recessive it cannot produce the antigen.

Hence Rh^+ persons may be homozygous dominant (RhRh) or heterozygous (Rhrh). The Rh^- persons are always homozygous recessive rhrh. The Rh factor follows the Mendelian principle of inheritance. The blood type of the children can be easily visualized by knowing the blood types of parents.

The foetus of a Rh^- mother rhrh (genotype) and Rh^+ homozygous father RhRh will be Rh^+. The Rh^+ foetus develops in the uterus of mother. Sometimes foetal RBCs containing Rh antigen enter the maternal blood. The mother's responds to the Rh antigen and it produces Rh antibody in the mother's blood. The antibody returns to the foetal blood. The antibody reacts with the Rh antigen present in the foetal blood, thereby causing agglutination and destruction of red cells. This may cause the abortion of foetus or the death of new born child. This kind of disease is called *erthroblastosis foetalis*.

MN BLOOD GROUP

The MN blood group in humans is under the control of a pair of co-dominant alleles, L^M and L^N. The MN blood group system is under the control of an autosomal locus found on chromosome 4, with two alleles designated L^M and L^N. The blood type is due to a glycoprotein present on the surface of a red blood cell (RBC), which behaves as a native antigen. Phenotypic expression at this locus is codominant because an individual may exhibit either one or both antigenic substances. Frequencies of the two alleles vary widely among human populations.

M^+ and N^+ RBCs are common (75% of population) and M^+N^+ cells are the most common genotype (50% of population). These antigens were an early discovery and are some of the oldest blood antigens known after the ABO system. They were first described by Karl Landsteiner and Philip Levine in 1927. Anti-M and anti-N antibodies are usually IgM and are rarely associated with transfusion reactions.

Anti-N is sometimes seen in dialysis patients due to cross-reactions with the residual formaldehyde from sterilizing the equipment. This is usually irrelevant for transfusion since this variant of the antibody does not react at body temperature.

HUMAN HEART

In human beings, the heart is a muscular organ. It is located inside the chest cavity or thoracic cavity. The heart is covered by fibrous sac called pericardium. It is divided into four chambers namely right auricle, right ventricle, left auricle, and left ventricle. The walls of these chambers are made up of a special muscle called myocardium, which contracts continuously and rhythmically to distribute blood to all the body cells.

The right and left auricles are separated by fibrous portion called *inter-atrial septum*. Similarly, two ventricles are separated by an *inter-ventricular septum*. The auricles are separated from the ventricles by an *auriculo-ventricular septum*. The right auricle opens into the right ventricle by a right *auriculo-ventricular aperture*. Similarly, the left auricle opens into the left ventricle by left *auriculo-ventricular aperture*.

Between the right atria and the right ventricle is present a valve called Tricuspid valve. Bicuspid (mitral) valve is present between the left atria and the left ventricle. Semilunar valve guards the openings of the right and the left ventricles into the pulmonary artery and the aorta respectively.

Special cardiac musculature called nodal tissue is distributed throughout the heart. Present at the upper right corner of the right atrium is *Sino-atrial node (SAN*), which is the Pacemaker of the heart. Present at the lower left corner of the right atrium is another structure called as *Atrio-ventricular node (AVN*).

AV bundle (a bundle of nodal fibres) continues from the AVN and passes through the atrio-ventricular septa to reach the inter-

ventricular septum. There, it divides immediately into right and left bundles. From these branches, minute fibres arise throughout the ventricular musculature. These fibres are called *purkinje fibres*. The Right, left bundles and Purkinje fibres forms the Bundle of His. Significance of nodal musculature is that it is auto-excitable and generates and maintains action potential to sustain the rhythmic contraction activity of the heart.

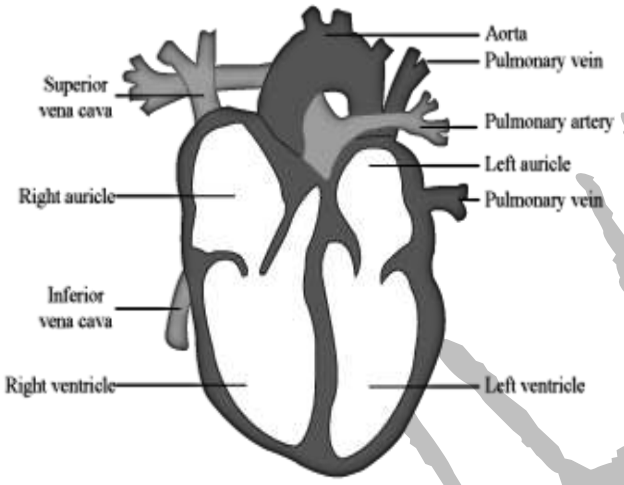

Fig: Human Heart

Flow of Blood in Human Heart

The heart has superior and inferior vena cava. They carry deoxygenated blood from the upper and lower regions of the body respectively and supply the deoxygenated blood to the right auricle of the heart.

The right auricle contracts and passes the deoxygenated blood to the right ventricle, through an auriculo-ventricular aperture (tricuspid valve).

The right ventricle contracts and passes the deoxygenated blood into the two pulmonary arteries, which pumps it to the lungs where the blood is oxygenated. From the lungs, the pulmonary veins transport the oxygenated blood to the left atrium of the heart.

The left atrium contracts and through the auriculo-ventricular aperture (bicuspid valve), the oxygenated blood enters the left ventricle.

The blood passes to aorta from the left ventricle. The aorta gives rise to many arteries that distribute the oxygenated blood to all the regions of the body.

Since the blood goes twice through the heart, to supply once to the body, it is known as *double circulation.*

CARDIAC CYCLE

Cardiac cycle is the sequence of events which occur from the beginning of one heart beat to the beginning of the next heartbeat.

In the beginning, all the 4 chambers of the heart are in a state of joint diastole (relaxation).

Tricuspid and bicuspid valves open and blood from the veins and the vena cava flow into the atria, and then into the ventricles because of the opening of the valves.

SAN generates an action potential, and both atria undergo contraction (Atrial systole).

The flow of blood into the ventricles increases by 30%.

The action potential is conducted towards the ventricles through the AVN and the AV bundles, from where the bundle of His transmits this action potential over the entire cardiac musculature.

The ventricles contract (ventricular systole) and the atria relax (atrial diastole) as a result of the conduction of action potential.

Ventricular pressure increases. Hence, bicuspid and tricuspid valves close, to prevent the back-flow of blood into the atria. Further increase in pressure in the ventricles leads to the opening of the semilunar valves.

Blood from the ventricles flow into the pulmonary artery and the aorta, and subsequently into the circulatory pathways.

Consequently, the ventricles relax (ventricular diastole), ventricular pressure falls, and the semilunar valves close to prevent the back-flow of blood into the ventricles.

Ventricular pressure further falls. As a result, the bicuspid and tricuspid valves open. This is because pressure is exerted on the atria by the blood entering them through the veins.

Once again, joint diastole is experienced and the entire cycle is repeated.

HEART SOUNDS

Heart sounds are of two types which occur due to the closure of cuspid valves and semilunar valves and are respectively called 'lubb' and 'dupp'. Heart sounds give valuable information about working of valves. So any damage to these valves (either bicuspid / tricuspid or semilunar valves) effects the quality of sound. This is called heart murmur. Heart murmurs are caused by turbulent blood flow through a narrowed valve or by changes in the direction of the blood flow. Heart beat or heart sound are measured or listened by means of instruments called *stethoscope*.

Lubb

1. First Heart sound.
2. Formed due of closure of the tricuspid and bicuspid valves at the beginning of ventricular systole.
3. Low pitched of long duration (0.15 sec).
4. Frequency = 25-45 Hz.

Dubb

1. Second Heart sound.
2. Formed due of closing of semilunar valves towards the end of ventricular systole.
3. High pitched of short duration (0.12 sec).
4. Frequency = 50 Hz.

URINE FORMATION

The formation of urine takes place by three processes:

1. Ultrafiltration or Glomerular filtration
2. Selective reabsorption
3. Tubular secretion

Ultrafiltration

The straining or filtration of blood by the Malphigian corpuscle is called ultrafiltration. It is the first step in urine formation. The arterial blood flows in the glomerulus. This blood is filtered by the Bowman's capsule and it enters the capsular space. The fluid present in the capsular space is called glomerular filtrate. The glomerular filtrate exactly resembles a cell and protein free blood. In 24 hours, about 180 litres of glomerular filtrate is formed. The filtration is facilitated by two factors namely pores present in the capillaries of glomerulus and blood pressure in capillaries.

Selective Reabsorption

It is the intake of useful substances into the blood from the glomerular filtrate. Every day about 180 litres of glomerular filtrate are formed. But a normal man excretes only 1 to 2.5 litres of urine i.e., about 1% of the glomerular filtrate. This is called as urine output. The useful substances of glomerular filtrate are reabsorbed into the blood by way of the capillary network enveloping the uriniferous tubule. The following substances are reabsorbed from glomerular filtrate of the uriniferous tubule:

- Amino acids, glucose, protein and phosphate are reabsorbed in the first part of proximal tubule.
- Sodium chloride and bicarbonates are absorbed along the proximal and distal tubule.
- Potassium is reabsorbed from the distal tubules and collecting duct.
- Sodium is reabsorbed from the ascending limb.

As the renal fluid moves into the collecting duct, the renal fluid is called urine. At the end of the duct, the urine is more concentrated than the original glomerular filtrate and is also hypertonic to plasma. Thus, out of the 180 litres of glomerular filtrate about 178-179 litres are reabsorbed. Water reabsorption occurs by osmosis which is passive process. But the absorption of glucose, amino acids and vitamins is active process.

Tubular Secretion

It is the release of unwanted materials from the blood into the nephron. The concentration of certain substances in the final urine is higher than present in the glomerular filtrate. Again urine contain certain additional substances which are not present in the glomerular filtrate like aminohippuric acid, K^+, H^+, creatinine, phosphate etc. These substances are supposed to be secreted by urinary

epithelium into the lumen of urinary tubules. Thus glomerular filtrate is converted ultimately into well concentrated urine.

COMPOSITION OF URINE

The urine is a pale yellow coloured fluid. The yellow colour is due to the presence of urochrome pigment formed from the haemoglobin of dead RBC's in the liver cells. It is acidic in nature and has a pH of 6.0. It soon gets a strong smell of ammonia which forms as a result of degradation of urea. Urine has saltish taste.

Chemically it is formed of 95 - 96% water, 2% urea, 2-3 % other wastes like uric acid, hippuric acid, creatinine, phosphates and oxalates. It also contains non-nitrogenous organic compounds like vitamin C, oxalic acid and phenolic substances.

MICTURITION

The passing of urine through the opening in the urinary bladder is called micturition. Urine is stored in urinary bladder. As the bladder gets filled with urine, it gets stretched. Stretch receptors on the walls of the bladder send signals to CNS. CNS sends counter signals to initiate contraction of the smooth muscles of the bladder, and relax the urethral sphincter to cause urine to be released (micturition).

Daily urine output is 1.5 to 1.8 litres. The volume of urine output is directly proportional to the fluid intake.

Any Error in this document is silent testimony of the fact that it was a human effort"

"Dr. WKB"