Chapter 1

NATURE AND SCOPE OF PHYSIOLOGY

Introduction

The animals which man has domesticated over the years to meet his own needs for food, clothing, power or companionship include cattle, buffalo, sheep, goats, horses, pigs, cats, dogs and poultry. Domestic animals like most other animal forms existing on earth including human beings, are the result of a long evolution and therefore each other and indeed to all living beings. Much has been learned or better understood about the physiology of these animals through comparative study on the other animal forms, though many a time these animals have served as experimental models for studies designed to gain knowledge about human physiology. Dog and goat for a long time yielded to such experimentation. The domestic animals have been used for obtaining information on their physiology per se only recently and most experiments have been designed to understand better the mechanisms related to production potential of these animals in terms of meat, milk and wool. Knowledge is also gained by the study of sick and abnormal individuals or through surgery. Animal ethology (study of behaviour) is a comparatively recent discipline which has contributed abundantly to our understanding of the behaviour of animals in relation to their productivity.

The place of domestic animals in nature is objectively described by placing them along with other living organisms in the accepted scheme of classification as formulated by the biologists. The domestic animals belong to the Animal Kingdom, which like the plant kingdom, is divided into a number of major categories, the Phyla. The animal Phyla range from the relatively simple protozoa mostly single celled forms, to the chordata which encompasses backboned animals, including domestic animals and human beings. This scheme of classification is based on the concept of evolution of life and the animals are classified on the basis of closeness or the distance of their relationship. The life cycle of the animal (Ontogeny) is said to repeat the evolutionary development of the animal (Phylogeny).

The domestic animals belong to the phylum Chordata, sub phylum Vertebrata, characterised by the presence of a back bone or vertebral column. They are further classified to belong to class Mammalia and sub class Eutheria. The cow, buffaloes, goat, sheep etc. belong to order Ungulata in sub class Eutheria. The horse and asses belong to order Perissodactyla. The cats and dogs belong to order Carnivora. The poultry belong to the order Galliformes in Class Aves.

Nature and Scope of Physiology

The word physiology was originally used by Jean Fernel as early as 1542 when its meaning was 'natural knowledge'. By the end of the nineteenth century it came into general use to cover that branch of biology which deals with the function of living organisms.

Physiology as briefly defined is the study of mechanisms of body functions. Thus, physiology not only seeks to define the functions of living organisms like feeding, digestion, respiration, transport of gases in the blood, circulation and functions of the heart, excretion and kidney functions, muscle and movement, reproduction etc but also seeks to answer to 'why' and 'how' all these functions are regulated. Physiology is also to know about how the living organisms adjust to the adversities of the environment, obtain enough water to live or avoid too much water, escape freezing to death or dying from excessive heat, move about to find suitable surroundings, food and mates and how they obtain information about the environment through their senses.

Veterinary and agriculture scientists are more interested about the body functions of domestic animals which are useful to mankind in one way or other so that judicious manipulation of these functions

can yield more of meat, milk and fibre. They are interested to know about the mechanism of milk formation and secretion, physiology of muscle growth, hair and fibre growth as well as skin. Most of the domestic animals falls within the general category of ruminants which distinguish them from other classes of animals in having a compound stomach and in their ability to utilize the complex carbohydrate cellulose with the help of microbes inhabiting the rumen, a property quite unique in the animal kingdom. In this way, they provide an important part of man's day to day life by converting the useless cellulose to easily consumable and highly nutritious feed stuffs like meat and milk. Thus, physiology tries to explain the phenomenon of life in terms of physical and chemical laws. This concept is distinct from the vitalism concept which prevailed earlier. But vitalism can still not be declared obsolete as we still lack in hypotheses to explain such phenomenon as thought and consciousness in physico-chemical terms. However, in this book we have taken the mechanistic view that most of the phenomenon in the animal body can be explained in terms of various physical and chemical laws.

Physiology cannot be explained separately than the mechanism of cell physiology since individual cells are the basic units of both the structure and the function of living things. However, we do not wish to say that there are no differences in cell function in a liver cell and nerve cell. On the other hand these differences in cell function generally represent specialization of one of more of the fundamental common properties. Thus the excitability of nerve cells represents a specialization of electrical phenomenon common to the membranes of virtually all cells. The secretion of protein hormones by certain gland cells of the body is a specialized form of the genetically controlled protein synthesis found in all cells. These specialization have all occurred as a part of evolution and have resulted in the adaptation of certain cells for specific roles.

Systems of Body and Their Physiological Functions

The body of domestic animals is like the body of human beings and other animal forms, in that it consists of many organs, each organ having its own particular function to perform. Each organ is made up predominantly of a particular type of tissue. The cell is the unit of the tissue. The cells are adopted to perform the special functions of the organ. The organs are organised into several systems according to the functions they perform. Some of them are outlined below.

Blood and lymph are fluid tissues. Blood is the main transport system. It carries oxygen (O_2) and nutritive substances and antibodies to the tissues and removes carbon dioxide (CO_2) and waste products from the tissues. The physical properties of water in the blood helps to maintain body temperature. Blood carries metals like iron and hormones like thyroxine.

Circulatory System : Heart is the chief organ of circulation of the blood. The blood is pumped by the heart along the arteries to the capillaries and is returned by venules and veins.

Respiratory System : Respiratory system consists of passages and organs concerned with breathing. Oxygen (O_2) from the air is taken into the lungs and from there it diffuses into the blood which carries it to the tissues. The CO_2 which is produced by the tissues is carried by the blood from the body tissues to the lungs and breathed out in the expired air.

Digestive System : It consists of alimentary canal and the glands associated with it. It deals with the digestion and absorption of food. The digestive system of ruminants differ from that of non-ruminants. The food supplies energy to the body and supplies nutrients for its growth and maintenance.

Urinary System : Consists of kidneys, ureters and urinary bladder. The kidney helps to keep the composition of the blood constant by excretion of waste products. Kidney also helps in maintenance of blood pressure .

Skin : Skin protects the body and it is concerned with general sensation and it plays an important role in the regulation of body temperature.

Endocrine Glands or Ductless Glands : These glands produce special chemical substances known as hormones which pass directly into the blood stream. These hormones control the various body functions.

Reproductive System : This system is concerned with the preservation of species. The function of male reproductive organ is to produce sperms and male sex hormones. The function of female reproductive system is to produce ova and female sex hormones.

Special Sense Organs : include tongue (taste), nose (smell), eye (sight) and ear (hearing). Through these organs, the animal remains aware of external environment.

Nervous System : It consists of brain, spinal cord and the nerves arising from them. They are concerned with the quick control of bodily functions and coordination.

Locomotor System : This include the parts concerned with the movement of the body. This comprises bones, joints and muscles.

Osmosis

If pure water is placed on one side of an semipermeable membrane (eg bladder wall) and an aqueous solution is placed on the other side, the water passes through the membrane into the solution. This phenomenon is termed osmosis (from Greek for 'push'). The tendency to move through the semipermeable membrane is called osmotic pressure. The osmotic pressure is proportional to the concentration of the solute and also to the absolute temperature, (degree Kelvin, K°). Semipermeable membrane is one which allows the movement of the solvent but not of the solute.

Thus a solution of sugar separated from pure water by a semipermeable membrane will permit only the movement of water into the sugar solution but it will not permit the movement of sugar out of it. Thus there will be a net movement of water into the sugar solution (osmotic flow) through the membrane from the solution of lower solute concentration to the solution of higher solute concentration. Osmotic flow provides the basis for net water movement across many biological membranes and epithelia.

The sum of the concentrations of solutes in a solution is sometimes obtained by measuring the colligative properties of the solution (eg by measuring the depression of freezing point). The osmolarity so measured is expressed as osmoles or milliosmoles. These units are, in theory, equivalent to the molarity of a solution of an ideal non dissociating solute exhibiting the same colligative properties.

Osmotic pressure is a consequence of the total number of particles, dissolved in a solution. A 1 molar (1M) solution of glucose has the same number of particles as does a 0.5M solution of sodium chloride, or, more correctly, of sodium and chloride ions. Every molecule of sodium chloride dissociates into one Na^+ ion and one Cl^- ion, whereas the glucose does not dissociates. The logic can be extended further. Magnesium chloride ($MgCl_2$) dissociates to one Mg^{2+}ion and two Cl^- ions, for a total of three. Thus a 0.33M solution of $MgCl_2$, a 0.5M

solution of NaCl, and 1 M solution of glucose are all said to be isoosmotic. The three solutions each contain the same number of particles.

Table 1 : Osmolarity of different fluids

Fluid	Osmolarity (milliosmoles)
Saliva	30-80
Seminal Plasma	230-330
Blood Serum	155
Tears	157
Urine	30-700
Cerebrospinal fluid	154
1%KCI	135
1%NaCl	172

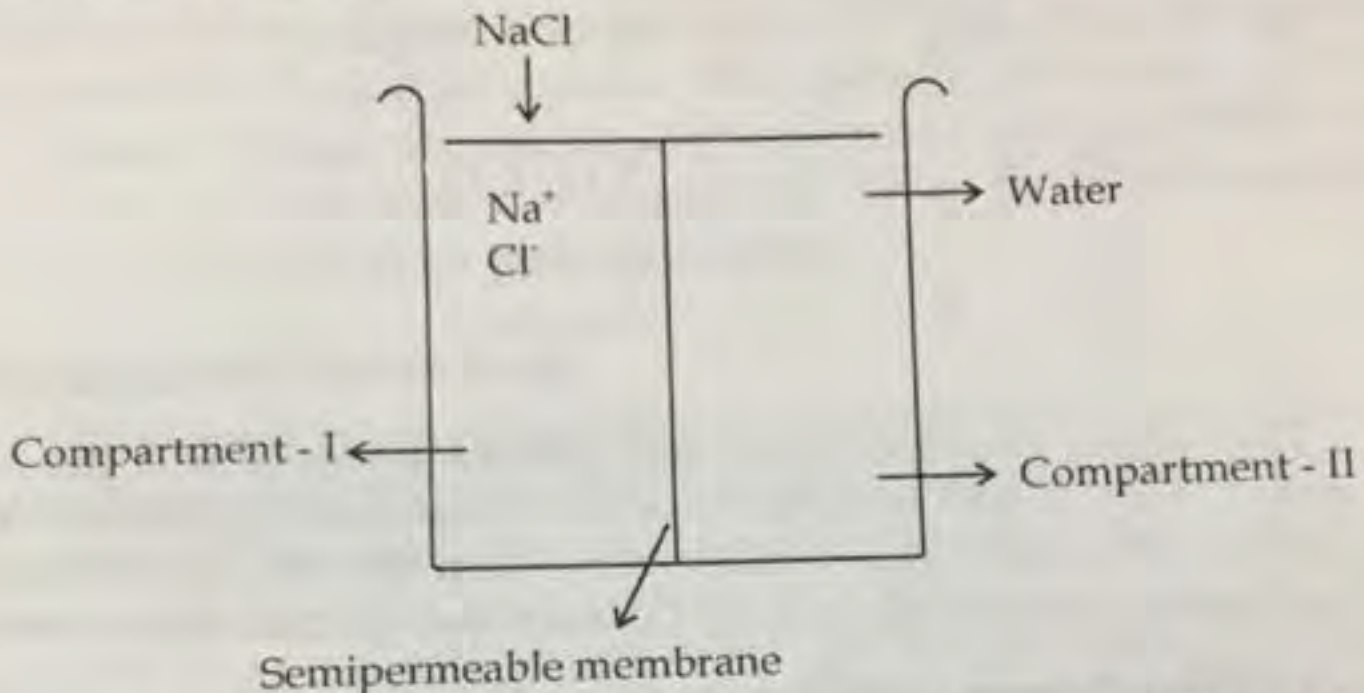
Diffusion

Diffusion is the process by virtue of which molecules move from higher concentration to lower concentration. The ratio of diffusion of gases through porous bodies are inversely proportional to the square root of their densities. For example, the lower the density higher will be the rate of diffusion. A membrane does not stop the process of diffusion, if it is permeable to the particles of the dissolved substances. The process of diffusion is caused by the kinetic motion of the molecules. Blood when passes through the capillaries, continual exchange occurs between the plasma portion of the blood and the interstitial fluid in spaces surrounding the capillaries. Since the capillaries are porous, large amount of fluid can diffuse back and forth between the blood and tissue spaces.

Donnan Equilibrium

Donnan equilibrium concerns the distribution of diffusible solutes separated by a membrane that is freely permeable to water and electrolytes but totally impermeable to one species of ion confined to one of the two compartments. In this situation, the diffusible solutes become unequally distributed among the two compartments. Donnan's equilibrium is fundamental to many situations in physiology such as kidney tubules and red blood cells.

Suppose NaCl is dissolved in pure water in a compartment which is separated from water in a second compartment through a semipermeable membrane.



After a short while the Na^+ and Cl^- ions will diffuses from compartment I to compartment II until the concentration of Na^+ and Cl^- becomes equal on both sides of the membrane.

Suppose some sodium salt is added to compartment I which contains an anion to which the membrane is impermeable. In such a situation, the distribution of Na+ ions and Cl^- ions again change and a new equilibrium is set up to satisfy the requirements of physical principles. One of the conditions which must be satisfied is that there must be electroneutrality in both the compartments.

Thus compartment I will now have Na^+ and Cl^- ions as earlier and Na^+ and X^- (non diffusible ions) be added. Thus there are more Na^+ ions in compartment I.

Since only Na^+ and Cl^- can be transferred from compartment I to II not the X^-, these two diffuse from I to II in such a way that the following equation is satisfied.

$$\frac{[Na^+]_I}{[Na^+]_{II}} = \frac{[Cl^-]_{II}}{[Cl^-]_I}$$

In such a situation, the diffusible cation Na^+, becomes more concentrated in the compartment in which the non diffusible anion is added, whereas the diffusible anion becomes less concentrated in this compartment than in the other.

I			II		
Z	=	(A-)			
Y	+	Z = (Na^+)	X	=	(Na^+)
X	=	(Cl^-)	X	=	(Cl^-)

Now

$$X^2 = Y\,(Y + Z)$$

$$\frac{X}{Y} = \frac{(Y + Z)}{X}$$

Thus above equation shows that greater the conc. of Z, the ratio of conc Y + Z / X will be more. In order to maintain equilibrium X/Y should be more and this is possible only when the conc of (X) increase in that compartment and conc. of (Y) decreases in that compartment.

A Gibbs Donnan equilibrium arises in biology when a solution containing charged protein molecules and salts is separated from one containing only salts, by a membrane which allows the salts to cross easily but which is impermeable to proteins.

The consequence is that the diffusible ions take up a distribution such that (a) a potential occurs across the membrane so that (at body pH) the protein side becomes negative (b) there are more diffusible ions on the protein side of the membrane than on the other side and so the osmotic differential between the sides is due partly to the protein and partly to the excess of diffusible ions on each side of the membrane is equal. The Gibbs Donnan equilibrium is important in the red cells.

Homeostasis

All mammals including domestic animals are able to regulate the condition of their internal environment within narrow limits. Claude Bernard, the French scientist first described it as the 'Constancy of the internal milieu'. Homeostasis is a universal phenomenon in animals, allowing them to survive in stressful and varying environments. Thus the chemical milieu of the tissues, cells, body temperature, blood and intracellular ionic composition are contained within narrow limits inspite of wide fluctuations in the external environment.

Thus all the cells of the body except those on the surface are provide with a fluid environment of relatively constant temperature, hydrogen ion concentration and osmotic pressure. Because of this, many body

activities like the working of enzymes or the functioning of nerve cells etc are carried out under optimum conditions. Activities of several systems of the body are called for in the maintenance of this intricate process of homeostasis through a set of checks and balances like negative feedback mechanisms. Thus kidney, endocrine, nervous, circulatory tissue are intimately concerned with the process of homeostasis. The concept of homeostasis is key to the understanding of most body functions and mechanisms.

Muscles and Movement

Movement is one of the basic characteristic of all living things. All animals can move and one of the important attributes of the movement is contractibility which may occur in various ways. In most vertebrates, the movement of the body parts or as a whole is due to the unique property of specialized tissues called the muscle tissue. Muscles are excitable tissues or effector organs which may respond to various stimuli, such as pressure changes, heat, light etc. The functions of various systems such as digestion, reproduction, respiration, circulation, excretion and the like, are also due to movements of muscles . Muscles are therefore the tissues which accomplish the movements in an organism.

Muscles have the property of contractibility, extensibility and elasticity. In most vertebrates, muscles have two kinds of arrangements. Those muscles which move the appendages find their origins as well as insertions on the endoskeletal structures are called phasic muscles. Phasic muscles function on a lever system and always occur in antagonistic pairs. Besides this, muscles occurring in soft organs like heart, urinary bladder, digestive tract and the body wall are called tonic muscles. These muscles do not have origins and insertions comparable to phasic muscles.

Structure of Muscles

The function of the muscles is closely related to the structure, and therefore a detailed structure of the different types of muscles is necessary. In vertebrates, there are three distinct types of muscles which constitute about 60-75 percent of the total body weight.

They are : (1) Skeletal muscles (2) Smooths muscles and (3) Cardiac muscles.