Chapter **2**

BODY FLUIDS : WATER, ELECTROLYTE AND ACID BASE BALANCE

Water : Importance of Water in Physiological Functions of the Body

A large proportion of the body of mammals including domestic animals, is made up of water. This water is an essential attributes for the life of the animals. Animals deprived of food but provided water will survive much longer than the animals provided with food but deprived of water. Water is the basis of the liquid environment of the cells, which Claude Bernard called the milieur interieur, and Cannon the fluid matrix. Its most important biophysical qualities are its solvent properties, its ionization and its heat of vaporization. Water is essential for metabolic processes, as most of these reactions must occur in aquatic environment. Water provides the medium for the transport of nutrients from their sites of absorption to the site of metabolism. Water also provides the medium for the transport of waste products from their sites of production to their sites of final excretion. Together with the main electrolytes, water forms an excellent buffering medium. Moreover, water is an essential substrate or end product of many biological reactions. Water due to its high latent heat of evaporation or fusion is an excellent insulator for the loss of body heat and is essentially required for the loss of heat to maintain body temperature, through the evaporation of water from the skin and the respiratory tract. Water also acts as a vehicle for the transportation of nutrients, hormones, waste products and gases etc.

Body water is derived from several sources which include the water drunk, intake of water through food and metabolic body water. Water is lost from the body through several routes which include loss of water through the feces and urine, evaporation of water from the skin and respiratory tract.

The concentration of water in the body varies from one tissue to another, being least in the dentine of teeth and greatest in the grey matter of the brain. The amount of water in the body also varies considerably with the age of the animal. The younger animals contain considerably more water than the older animals. This effect is mostly due to increase in the fatty tissues in the body, which contains relatively much less water, as the relative composition of tissues of the body other than fat remains relatively constant. The proportion of water in ruminants is higher as compared to nonruminants.

The water content is particularly low in adipose tissue. The consequence of this is that, for a given body weight, the body fluids represent a smaller percentage of the body weight in fat than in thin (lean) animals. Since the proportion of bone and other none fatty tissues is fairly constant, the water content of an animal is a good indirect estimate of its fat content. Because this determination is of major interest for animal husbandry purposes, linear regressions relating total body water content to fat content have been derived for various methods and species. Body water can be estimated by dilution techniques using urea, antipyrine etc and by using radioisotopic dilution technique using tritiated water. Thus water is indispensable for all biochemical and physiological processes.

Table 1 : Water content in a pig from intrauterine life to 2 years of age

Stage of Development	% of water
Intrauterine	97
At Birth	89
6 month of age	65
2 years of age	40

Water Intake and Outgo

Water is available to the animal from three sources.

1. Water drunk by the animal.
2. Water contained in the food stuffs.
3. Metabolic body water i.e. water produced *de novo* by oxidative metabolism in the body.

Water derived from these sources is balanced by loss of water in urine and faeces, in expired air from the respiratory tract and by evaporation from the skin.

Control of Water Intake

The control of water intake is mainly a function of the medial lateral hypothalamus, but the participation of others regions of the brain is necessary for the integration of the system. The natural signals are blood plasma osmotic pressure (which acts on the hypothalamus), blood pressure (stretch receptors in the right atrium) and increased body temperature (hypothalamus). The response to these signals is the induction of thirst and the secretion of antidiuretic hormone (ADH) from the neurohypophysis.

Thirst

Thirst is regarded as a general sensation arising from lack of water in the body. True thirst arising from lack of water in the tissues persists until need is satisfied and must be distinguished from the false thirst of dryness of the mouth or throat. Dryness of the mouth and throat will always be present in general dehydration of the tissues, but moistening this region without restoring tissue water will at best afford temporary relief. Several theories have been propounded from time to time to explain the mechanism of thirst. The classical theories include 1) Dry mouth theory 2) General sensation (dehydration) 3) Thirst center theory. In 1950, Andersson and his colleagues at Stockholm, Sweden established the importance of diencephalon (medial hypothalamus) in thirst.

The volume of fluid ingested depends also on the amount of water absorbed from the gastrointestinal tract. The hypothalamus is known to be involved in the regulation of water intake. If the temperature regulating center in the anterior hypothalamus is warmed, as it is during exercise or in a hot environment, the animal will drink more than it does normally. Cooling the hypothalamus has opposite effect and destruction of the anterior hypothalamus also results in reduced water intake.

Anderson and McCann (1955) have shown that the center controlling thirst and drinking behaviour is located in the medial hypothalamus. They permanently implanted electrodes in a certain region of the hypothalamus of goats. When electrical stimuli were applied to the conscious goat, the animal would immediately seek and drink water although no water deficit existed. These investigators were also able to inject minute amounts of hypertonic solutions in the same region of the hypothalamus and they found that this also caused the animal to drink. These results suggest that the cells of the hypothalamus are sensitive to changes in osmo concentration and that such osmotic stimuli cause thirst and drinking behaviour.

Urinary Excretion of Water and Its Hormonal Control

If an animal is deprived of water, the rate of water excretion in the urine decreases; and conversely if an excess of water is ingested, urinary volume will rise. The excretion of water by the kidney is controlled primarily by the antidiuretic hormone (ADH) of the posterior pituitary gland. The release of ADH from the posterior pituitary gland is believed to be caused primarily by changes in the osmoconcentration of the plasma.

Transport of Water Across Gut Membrane

The absorption of water from the gut is very efficient. The transport of water across the mucosa cannot be attributed to hydrostatic and osmotic pressure differences, but depends upon metabolic processes. Glucose is required to induce water transport against an osmotic gradient : without glucose there is only a passive transfer of water; the fact that water is never transported alone suggests that water transfer is driven by osmotic forces resulting from active transport of some ions.

Loss of Water from The Body

Water is lost from the body through the following routes.

1. Faeces
2. Urine
3. Skin
4. Respiratory tract

The loss of water from the skin and respiratory tract varies considerably with the environment and species. Loss of water through these routes is higher at high environmental temperature. However some species are better sweaters than others. Dogs, for example, lose almost all the water required for thermoregulation through the respiratory passage as it contains little or no sweat glands.

Special Features of Water Metabolism in Camel

Most domestic animals including camel are required to strike a balance between the water intake and water outgo. Camel is exposed both to the heating effect of the sun and to relatively dry air for extended period. In order to preserve the body water, the camel shows a wide variety of adaptations. During such exposures the water loss through the urine is reduced considerably. Camel is resistant to water losses to the magnitude of 30%. As a result, the camel can go without drinking for periods for perhaps 6 to 8 days under desert conditions that would be fatal in a single day to a man without water. The ability of the body to store water is rather limited. Camel is reputed to store water during the times of opulence in the hump and the stomach but these views have been refuted by several studies. Schmidt Nielson states that camel, like other mammals drinks to replenish lost water and to restore the normal water content of the body and there is no evidence that it over drinks in anticipation of future needs.

Body Fluids

A major proportion of the body is made up of fluid. The fluid compartments of the body are distinguished into two parts.

1. *Intracellular fluid* : It provides the medium in which metabolic reactions take place.
2. *Extracellular fluid* : It serves to nourish the cells and remove waste products.

The water in the body acts as a constituent of the body fluids. These body fluids are distributed in different compartments of the body. Thus extracellular fluid is further composed of two components. The blood plasma and the interstitial fluid. The plasma and the cellular elements of the blood fill the vascular system and together they constitute the total blood volume. In the adult domestic animal the amount of body water is about 70% of the body weight, 50% of the body weight is intracellular fluid, 15% is interstitial fluid and 5%

plasma. However, it is important to remember that the fluids in different compartments are in dynamic equilibrium with one another and there is a continuous interchange of fluid between the different compartments.

The volume and composition of body fluids are altered as a result of certain diseases during adaptation to high attitude or heat and in many stressful situations.

Regulation

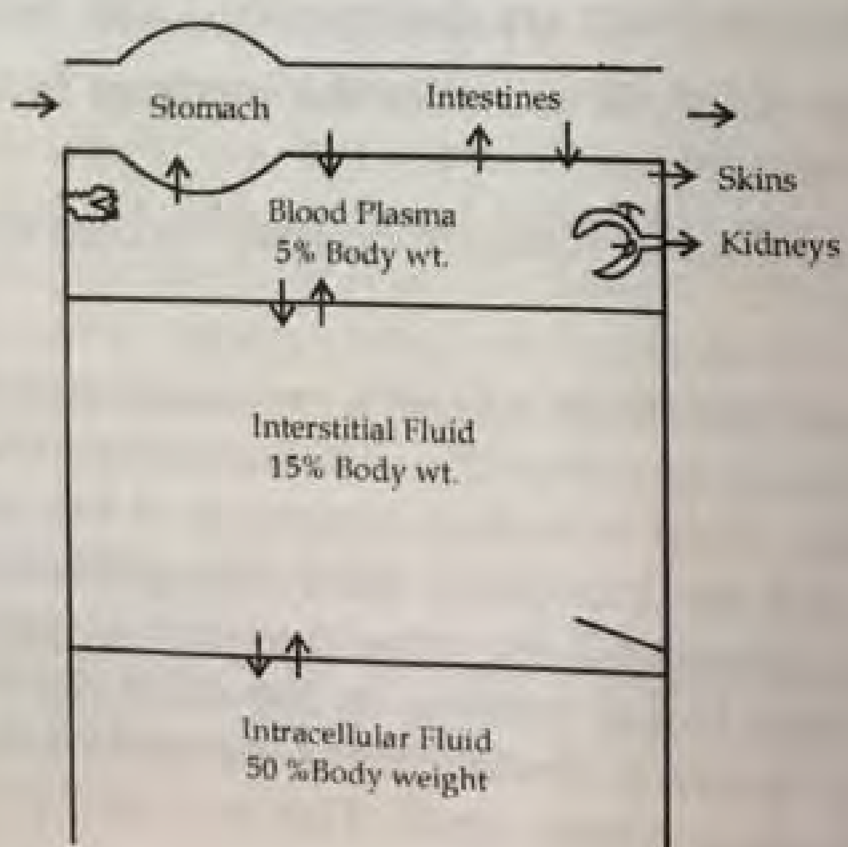
Under normal conditions body fluid regulation is affected mainly by hormonal mechanisms involving particularly the secretions of the adrenal and posterior pituitary glands.

Interstitial Fluid

The main difference between plasma and interstitial fluid is much smaller quantity of protein in the interstitial fluid. This arises from the relative impermeability of the capillary walls to plasma proteins.

Intracellular Fluid

The intracellular fluid is quite different from the extracellular fluid. There is considerably more protein within the cells. The main electrolyte in the intracellular fluid is potassium instead of sodium. Magnesium is also important to a lesser extent and its importance stems from the fact that it serves as an essential cofactor in many intracellular reactions occurring within the cells.



Measurement of Body Fluid Volumes

Body water : Total body water can be determined directly by drying the whole animal and measuring the loss of weight. However this method is inconvenient and necessitate the death of the animal.

The method most commonly used to estimate total body water are based on the dilution technique. The dilution technique involves the injection of a compound into the body which is distributed in all compartments of body containing water, which is freely permeable, non toxic and can be determined easily. The total body water is calculated by the following formula.

$$= \frac{\text{Amount injected}}{\text{Conc. per ml of plasma at } t^{\circ}}$$

Unfortunately while the compound is being distributed throughout the fluid compartment, it may also be excreted or metabolized and corrections must be made for these losses occurring during the distribution time.

The best compounds for measurement of total body water are heavy water (deutrium oxide) and radioactive water (tritium oxide). Isotopically labelled water distributes itself in a fashion identical to the normal water of the body. Other compounds used include antipyrine, sulfanilamide, thiourea and urea.

Blood Volume

It is not possible to determine the volume of blood in the body merely by bleeding an animal to death. A considerable amount of blood is left in the vessels even after the animal dies of haemorrhage. Clotting and vasoconstrictor mechanisms retain a large amount of blood in the vessels. Some people attempted to wash out the blood retained in the vessels after bleeding. The amount of wash fluid was subtracted from the total volume. However, this method suffers from the defect that the animal must be killed. Moreover, the blood volume data so obtained are not necessarily both accurate and precise.

Indirect methods using dilution technique have been used quite successfully. Evans blue dye (T-1824) or radioactive iodine (^{131}I) are substances which have been most commonly used for this purpose.

Extracellular fluid: Dilution techniques using inulin has been most commonly used but sucrose, thiocyanate, thiosulphate and others have also been useful.

Intracellular fluid volume : Intracellular fluid volume cannot be calculated directly but rather it must be calculated as the difference between total and extracellular fluid volume.

Adaptations to Water Lack

Several animals can survive better than others when deprived of water for long periods. Such animals are better adapted to lack of water. Desert camel and donkey are two examples of species adapted for such conditions. Cattle appear to have no special water conservation mechanism but there are important differences. Zebu cattle can dissipate larger quantities of heat by evaporation of larger quantities of water from their body surface than European cattle. Partly this is due to more and larger sweat glands in Zebu cattle as compared to European cattle.

Camel and donkey can survive water deficit more because they conserve more water. Both camel and sheep produce relatively dry faeces and can reduce their excretion of urine considerably. During the day, when the heat stress is greatest, the camel permits its body temperature to rise thereby storing heat and saving the water which would have been required to dissipate the heat. In the camel the summer fur, which is most prominent on the dorsal surfaces of the animal, is very effective in reducing heat gain and therefore relieves the animal of the necessity of using water to dissipate that heat. Another important point is that camel is able to rehydrate quickly.

Dehydration : Dehydration may result due to lack of drinking water under moderate environmental conditions, or due to severe diarrhoea, vomiting etc. The first sign of dehydration is a tendency to seek and drink water. Most animals will not eat during moderate or severe dehydration and hence part of the body weight loss is loss of tissue substance used for energy metabolism.

Acid Base Balance

The water and other solutes contained in the body fluids occurs in the form of ions. Among these ions H^+ is the most important for determining the acid base status of the fluids. The unit for measurement of acidic or basic nature of a solution is known as pH. pH is defined as the negative logarithm of hydrogen ion concentration. The pH of any solution may vary from 1 to 14. The pH of water (pure) is 7. Solutions having pH less than 7 are called acidic. The solutions having pH more than 7 are alkaline in nature. The pH of the extracellular fluids is usually 7.4.

Acid is defined as any substance that can donate a proton. Base is a substance that can accept a proton.

Buffer solution is one that resists a change in pH on the addition of acid or alkali. The ability to prevent large change in pH is an important property of most biological systems. The cytoplasmic fluids which contain dissolved proteins, organic substances and inorganic salts resists excessive change in pH. The blood plasma is a highly effective buffer solution almost ideally designed to keep the range of pH of blood within 0.2 pH units of 7.2 to 7.3; outside this range are not compatible with life. Acid base balance in the body means the regulation of pH of the body fluids. Only slight changes in pH from normal values can cause marked alterations in the rates of chemical reactions in the cells, some being depressed and others accelerated. For this reason the regulation of hydrogen ion concentration is one of the most important aspects of homeostasis.

The normal pH of arterial blood is 7.4, while the pH of the venous blood and of interstitial fluids is about 7.35 because of extra quantities of carbon dioxide which form carbonic acid in these fluids. The importance of buffers is biologically fluids is best understood from recognising that many of the metabolites constantly being produced and utilized in the cell are weak acids. The maximum catalytic action of enzymes in the body cells is also pH dependent. A small change in pH may greatly reduce their activity.

An animal is said to have acidosis if the pH of the blood is less than 7.4 and alkalosis if the pH of the blood rises above 7.4.

Body Defences Against Changes in pH

Body has several mechanisms to resist the changes in the pH of body fluids.

1. *Buffer systems* : Many buffer systems are present in the body fluids that immediately combine with any acid or alkali and thereby prevent excessive changes in hydrogen ion concentration.
2. *By altering the rate of pulmonary ventilation* : If the hydrogen ion concentration does change measurably, the respiratory center is immediately stimulated to alter the rate of pulmonary ventilation.

As a result the rate of carbon dioxide removal from the body fluids is automatically changed, and this causes the hydrogen ion concentration to return towards normal.

3. *By changes in the urinary pH:* When the hydrogen ion concentration changes from normal, the kidneys excrete either an acid or alkaline urine, thereby also helping to readjust the hydrogen ion concentration of body fluids back towards normal.

Body Buffers

Buffers are chemical compounds that prevent marked changes in hydrogen ion concentration when either an acid or a base is added.

Bicarbonate Buffer System : A typical buffer system consists of a mixture of carbonic acid (H_2CO_3) and sodium bicarbonate ($NaHCO_3$) in the same solution. Carbonic acid is a weak acid. When a strong acid, such as hydrochloric acid is added to a buffer solution containing bicarbonate salt, the following reaction takes place.

$$HCl + NaHCO_3 \rightarrow H_2CO_3 + NaCl$$

From this equation it can be seen that the strong hydrochloric acid is converted into the very weak carbonic acid. Therefore HCl lowers the pH of the solution only slightly.

On the other hand if a strong base such as sodium hydroxide is added to a buffer solution containing carbonic acid the following reaction takes place.

$$NaOH + H_2CO_3 \rightarrow NaHCO_3 + H_2O$$

This equation shows that the hydroxyl ion of the sodium hydroxide combines with the hydrogen ion from the carbonic acid to form water and that the other products formed is sodium bicarbonate. The net result is exchange of the strong base NaOH for the weak base $NaHCO_3$.

Thus, the mixture of carbonic acid and sodium bicarbonate acts as a 'buffer' to prevent either a marked rise or fall in pH. Fortunately this buffer is present in all the fluids of the body, both extra cellular and intracellular and it plays an important role in maintaining normal acid base balance.

The Phosphate Buffer System

Another buffer system, the phosphate buffer system acts in almost identically the same manner as the bicarbonate buffer system, but it composed of the following two elements : H_2PO_4 and HPO_4. This system is especially important in the tubular fluids of the kidney because phosphate usually becomes greatly concentrated in the tubules. The phosphate buffer is also extremely important in the intracellular fluids because the concentration of phosphates in these fluids is many time than that in the extracellular fluid.

The Protein Buffer System

By far the most plentiful buffer of the body is the proteins of the cells and plasma. There is a slight amount of diffusion of hydrogen ions through the cell membrane and even more important carbon dioxide can diffuse readily through cell membranes and bicarbonate ions can diffuse to some extent. The diffusion of these two elements of the bicarbonate buffer system causes the pH of the intracellular fluids to change approximately in proportion to the change in pH in the extracellular fluids. Thus, all the buffer systems inside the cells help to buffer the extracellular fluids as well.

The method by which the protein buffer system operates is precisely the same as that of the bicarbonate buffer system. It will be recalled that a protein is composed of amino acids bound together by peptide linkages, but some of the different amino acids, have free acidic radicals in the form of - COOH, and some have free basic radicals in the form of - NH_3OH. Therefore, proteins can combine with either acids or bases and thereby provide a very high degree of buffering. Haemoglobin is the second most important blood buffer.

Respiratory Regulation of Acid Base Balance

Because carbon dioxide combines with water to form carbonic acid, an increase in carbon dioxide concentration in the body fluids lower the pH toward the acidic side, whereas a decrease in carbon dioxide raises the pH toward the alkaline side. It is on the basis of this effect that the respiratory system is capable of altering the pH either up or down.

Balance between metabolic formation of carbon dioxide and pulmonary excretion of carbon dioxide: Carbon dioxide is continually being formed in the body by the different intracellular metabolic processes, the carbon in the foods being oxidized by oxygen to form carbon dioxide. This in turn diffuses into the interstitial fluids and blood and is transported to the lungs where it diffuses into the alveoli and is transferred to the atmosphere by pulmonary ventilation.

If the rate of metabolic formation of carbon dioxide becomes increased, its concentration as well as hydrogen ion concentration in the extracellular fluids is likewise increased. Conversely decreased metabolism decreases the carbon dioxide and hydrogen ion concentration.

On the other hand, if the rate of pulmonary ventilation is increased, the rate of expiration of carbon dioxide becomes increased and this decreases both the amount of accumulated carbon dioxide and the hydrogen ion concentration in the extracellular fluids.

Effect of hydrogen ion concentration on alveolar ventilation : Not only does the rate of alveolar ventilation affect the hydrogen ion conc of body fluids, but in turn the hydrogen ion concentration affects the rate of alveolar ventilation. This results from a direct action of hydrogen ions on the respiratory center in the medulla oblongata, that controls breathing. The condition called respiratory acidosis occurs when blood pH falls as a result of decreased respiration. Such a condition can be produced by asthma, pneumonia, emphysema or inhaling smoke.

Role of Kidney in the Regulation of Acid Base Balance

Kidneys assist in the regulation of body pH by the following means.

1. Control of plasma HCO_3^- concentration.
2. Regeneration of HCO_3^-
3. Secretion of H^+ into the urine.

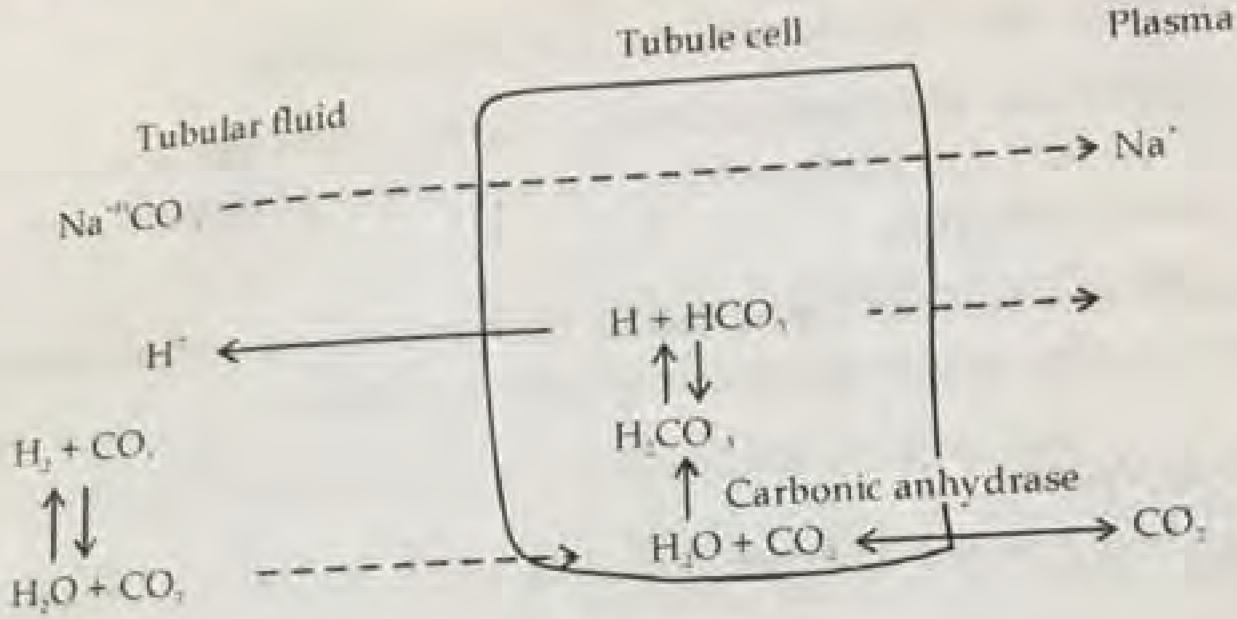
Control of Plasma HCO_3^- Concentration

Kidneys control the concentration of HCO_3^-. When plasma HCO_3^- is 28 mM/litre or less, all of the filtered HCO_3^- is reabsorbed. When plasma HCO_3^- exceeds 28 mM/litre, the concentration is referred to as the renal threshold HCO_3^- begins to appear in the urine. Bicarbonate reabsorption occurs in the proximal and distal tubules.

Most of the filtered HCO_3^-, (approximately 90%) is reabsorbed in the proximal tubule.

In the above figure sodium moves into the cell down an electrochemical gradient. Hydrogen ions, actively secreted in the tubule lumen react with HCO_3^- to form H_2CO_3, which dissociates forming CO_2 and H_2O. The CO_2 moves into the tubular cell and the reaction of CO_2 and H_2O to form H_2CO_3 is catalysed by the enzyme carbonic anhydrase.

The newly formed H_2CO_3 dissociates making available the H^+ for secretion and the H_2CO_3 is actively reabsorbed. Besides reabsorbed HCO_3^- the tubules also regenerate HCO_3^- to replace that which is depleted during the buffering of strong acids.



Urinary pH and the Secretion of H+ Ions

In the process of adjusting the hydrogen ion concentration of the extracellular fluid, the kidneys often excrete urine at pH as low as 4.5 or as high as 8.0. When acid is being excreted the pH falls, and when alkali is being excreted the pH rises. Even when the pH of the extracellular fluids is at the normal value of 7.4, a fraction of a millimole of acid is still being lost each minute. The reason for this is that about 50 to 100 millimole more acid must be removed continually. Because of the presence of this excess acid in the urine, the normal urine pH is about 6.0 instead of 7.4 i.e. the pH of the blood. A similar situation also exists in case of domestic animals too.

Electrolytes

Electrolytes such as sodium (Na), Potassium (K) present in body fluids and perform a variety of functions, which include.

i. Nerve impulse conduction

ii. As CO factor to facilitate enzymatic reactions. Molybdenum is a factor of enzyme Xanthine oxidase

iii. Muscle contraction (mainly Ca^{++}, K^+ & Na^+)

iv. Carbondioxide (CO_2) and Oxygen (O_2) transport

The extracellular fluid is rich in sodium, chloride and bicarbonate ions. The intracellular fluid is however rich in potassium, magnesium, phosphate and sulphate.

- The principal ICF solutes are K^+, Mg^{++}, organic phosphates and proteins.
- The principal ECF solutes are Na^+, Cl^- and HCO_3^-.
- Imbalance in the concentration of these solutes between ICF and ECF results for many of the clinical signs associated with the primary diseases.
- Some electrolyte imbalance, however, are potentially life threatening and require immediate treatment.

Total Body Water

Total body water content depends upon the body condition of animals.

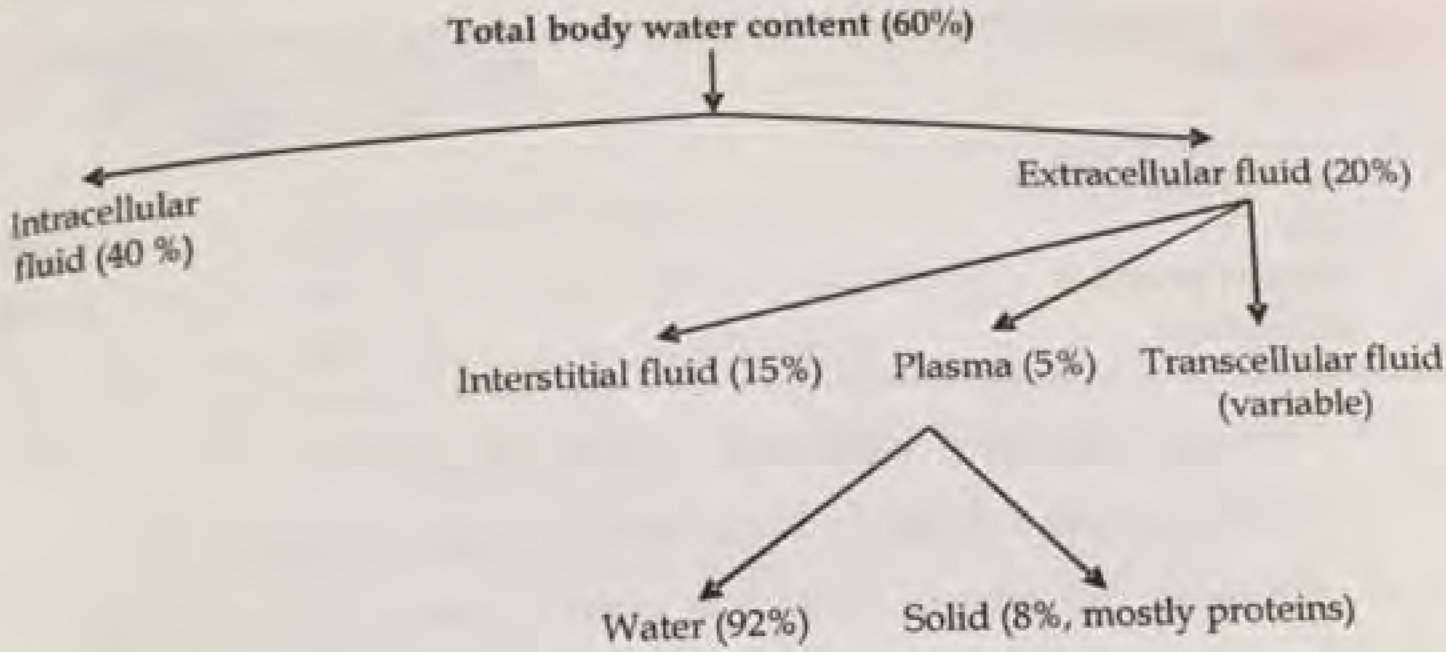
Total body water content	(% body weight)
Lean adult non-herbivores	70%
Very lean cattle	70%
Very fat animals	40%
Average animals	60%

Water in Lean Animals is Divided as Follows

50%	within cell
15%	in interstitial space
5%	in blood plasma

Fat tissue is exceptional in its low water content of 10% or less.

Parameter	Measured by
Total body water	^3H_2O, ^2H_2O, Antipyrine
Extracellular fluid	Thiosulfate, Inulin, I-iothalmate, ^{22}Na
Intracellular fluid	Total body water - Extracellular fluid
Plasma volume	Evans blue dye (T-1824), ^{125}I-albumin
Interstitial fluid	ECF volume - Plasma volume



Dehydration

Dehydration is defined as an excessive loss of body fluid.

- Animal is always faced with the problem of slow dehydration.
- Any serious dehydration involves the loss to both water and electrolytes.
- The first sign of dehydration is a tendency to seek and drink water and decrease in urine volume.
- This is generally seen when there is 1-2% of body weight loss as water.
- Dehydration to the extent of 10% of body weight is considered sever.
- A dog deprived of water under moderate condition will loss about 10% of its body weight in 5 days.
- Most animals will not eat during moderate or severe dehydration except donkey and camel.
- Donkey will eat before drinking and the camel continues to eat in a normal fashion despite what would be considered severe dehydration for other animals.

Acid Base Balance

Chemical buffers of ECF

Principal buffers of ECF are

1. Bicarbonate buffer
2. Hb
3. Plasma proteins
4. Phosphate

Buffers	Activity if strong acid is added to blood
Bicarbonate buffer	53%
Hb	35%
Plasma proteins	7%
Phosphate	5%

- Hb is second most important buffer of blood
- Buffer system consist of weak acid and its conjugate base
- Hb molecule present in part in form of proteinate ion (Hb^-)

When Acid is Added

$H^+ + Hb^- \rightleftharpoons HHb$ (Reaction shift towards right)

Components of Phosphate Buffers

1. HPO_4^{--} (base)
2. $H_2PO_4^-$ (weak acid)
   - Phosphate buffers play minor role in the blood.
   - Phosphate buffers are important intracellular buffer because of their greater intracellular concentration and because their pK of 6.8, is closer to the pH in the intracellular fluid than in the ECF.

Intracellular K^+	Secretion of H^+ in urine
More	Decrease
Less	Increase

Isohydric Principle

- As a result of this principle, addition of an acid or base to a solution containing several buffers will result in a change in the ratios of all the buffer pairs.
- By isohydric principle, a fall in HCO_3^- concentration will result in a fall of all buffer bases of ECF and RBC. This condition of low blood concentration of buffer base is known as hypobasemia.
- The total amount of base in whole blood, including bicarbonate, Hb and other bases of lesser importance is known as buffer base (BB).

- Normal value of BB is 48 mEq/l of blood but this varies somewhat with Hb concentration.

Disturbance in Acid Base Balance

Order of Response in Acid Base Disturbance

1. First response - Reaction with buffers
2. Second response - Compensation (respiratory or renal that may be complete or incomplete)
3. Third response - Correction (complete or incomplete)

Metabolic Acidosis

- Decreased HCO_3^- results into fall of all buffer bases of ECF and RBCs.
- For each H^+ excreted, one HCO_3^- ion will be restored to the plasma.

Metabolic Alkalosis

Causes

- Persistent vomiting
- K^+ deficiency (H^+ excretion increases)
- Oxidation of ingested/injected salts of organic acids such as lactate or citrate
- Injection of bicarbonate solution

Respiratory Acidosis

The rise in PCO_2 represents a rise in carbonic acid and buffer reactions occurs with the non-bicarbonate bases. Hb is the most important of these bases and reaction with it will be

$$H_2CO_3 + Hb^- \rightleftharpoons HCO_3^- + HHb$$

This interaction between blood buffers results in an appreciable rise in plasma HCO_3^- concentration such reactions between blood buffers are known as interaction reaction.

This buffer action ameliorates the fall in pH caused by the rise in carbonic acid.

Respiratory Alkalosis

- Caused by hyperventilation
- Hyperventilation directly caused by ammonia toxicity and indirectly by hypoxemia acts reflexly via the peripheral chemoreceptors.
- Renal compensation: It begins in a few hours and reaches its maximal capacity after several days.

Evaluation of Acid-base Status

Blood variables involved in assessment of acid-base disturbance are pH, PCO_2, plasma HCO_3^-, whole blood buffer base and Hb concentration.

Systems of Clinical Evaluation of Acid Base Disturbance

1. Based on plasma HCO_3^- (pH- bicarbonate diagram)
2. Based on concept of base excess (Siggaard-Andersen namogram)

Siggaard-Andersen namogram would not provide further information, but the pH-bicarbonate diagram would be instructional in better visualizing the type of acidosis or alkalosis.

Other Methods of Evaluation of Acid-base Disorder

1. Blood gas analysis
2. Anion-gap method (useful in evaluation of metabolic acidosis)

   Anion gap = $[Na^+ + K^+] - [Cl^- + HCO_3^-]$

In case of diarrhea, loss of both Na^+ and HCO_3^- so no change in anion gap.

In renal diseases loss of HCO_3^- and gain of Cl^- so no change in anion gap.

- Hb and HCO_3^- are the important blood buffers.
- Proteins and organic phosphates provide intracellular buffering.
- Usually in blood total cations exceed the total anions, so there is an anion gap.
- Anion gap increases in metabolic acidosis and vice versa.