

ADAPTATION TO ION AND WATER AVAILABILITY

INTRODUCTION

- CELL MEMBRANE IS A PHOSPHOLIPIDS BILAYER HAVING A HYDROPHOBIC TAIL AND A HYDROPHILIC HEAD, WITH THE HYDROPHILIC HEAD FACING OUTSIDE AND HYDROPHOBIC TAILS INSIDE THE MIDDLE OF THE MEMBRANE. THE CELL MEMBRANE IS DESCRIBED AS SEMI PERMEABLE

THE FLUID MOSAIC MODEL OF THE CELL MEMBRANE.

The fluid mosaic model of cell membrane was proposed by Singer and Nicolson(1972) . The fluid model described the cell membrane as one in which globular proteins are integrated with the lipid bilayer, with some proteins molecules penetrating the bilayer, completely and others partially. These integral proteins are thought to be amphipathic, their non-polar portions buried in the hydrocarbon core of the bilayer and their polar portions protruding from the

- From the core to form a hydrophilic surface with charged amino acid side groups in the aqueous phase.
- The uncharged hydrophilic side groups on the other hand are associated with the hydrocarbon side bilayer. The hydrophobic nature of these side groups is important in keeping the integral proteins from leaving the lipid bilyer

THE PHYSICAL PRINCIPLES GOVERNING MOVEMENT OF SOLUTES.

- The movement of substances across the plasma membrane can be passive or active.
- Diffusion
 - simple
 - facilitated.

Active transport

NB. The active transport system exhibits a high degree of selectivity. The sodium pump fails to transport lithium ions which have ionic properties very similar to those of sodium.

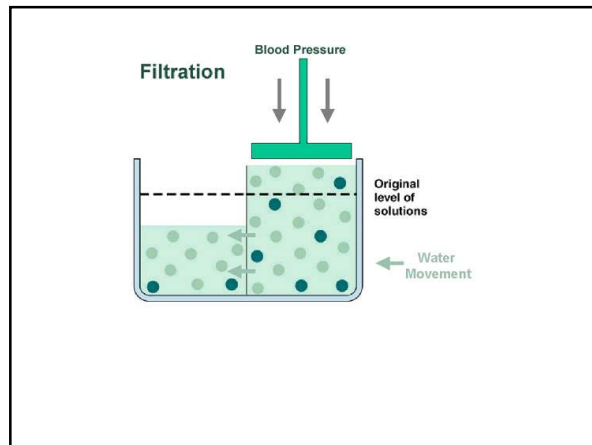
- Active transport can be selectively inhibited by specific blocking agents. The caidiac glycoside ouabain, applied to the extracellular surface of the membrane blocks the potassium-dependent active extrusion of sodium binding sites of the pump
- Energy for active transport is released by hydrolysis of ATP by enzymes (ATPase) present in the membrane.

PHYSICAL PRINCIPLES GOVERNING MOVEMENT OF SOLVENT

- The permeability of any solute or solvent in any biological system, depends upon passage through the lipid bilayer membrane. The process of filtration and osmosis, can be seen as special cases of diffusion across the membranes in which only the solvent is moving across the membrane through water channels and the solutes molecules, retained.

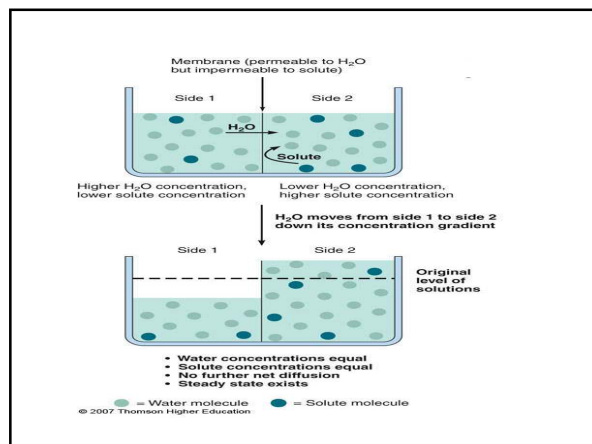
FILTRATION

- Filtration is a mechanical or physical operation which is used for the separation of solids from fluids, by interposing a medium through which only fluid can pass. Filtration across a membrane occurs when there is a greater hydrostatic pressure on one side of the membrane than the other



OSMOSIS

- osmosis is the diffusion of water molecules through a semi-permeable membrane from an area of high water potential (low solute potential) to an area of low water potential (high solute potential). This is a physical process in which the solvent moves without energy input



Osmole

- The ability of solutes to cause osmosis and osmotic pressure is measured in terms of osmoles, and the osmole is a measure of solute concentration in terms of the number of dissolved particles. An osmole is a unit of measurement, and is essentially one mole of an osmotically active substance.

ISOSMOTIC, HYPEROSMOTIC AND HYPOSMOTIC SOLUTIONS

- Aqueous solutions have to be described in terms of the concentration of their various solutes. Molarity is a commonly used measurement in both chemical and biological science, but biological studies also use another kind of concentration measure which is that of osmolarity.

MEASUREMENT OF OSMOTICITY

- Osmoticity is a term use to compare the osmolarity of a solution with the osmolarity of another solution. Osmoticity can be measured using the freezing point depression
- Since osmotic pressure is often difficult to measure directly, colligative properties of solutions especially freezing point depression and vapour pressure lowering are used in the measurement of osmotic effects. For this reason the results of many osmoregulatory studies used freezing point depression , to express osmotic concentrations.

- NB

In unusual environments, osmosis can be very harmful to organisms. For example, freshwater and salt water aquarium fish placed in water of a different salinity than that in which they are adapted.

TONICITY

- Tonicity is a measure of the osmotic pressure of two solutions separated by a semi-permeable membrane.
- There are three classifications of tonicity that one solution can have relative to another.
 - Hypertonic
 - Hypotonic
 - Isotonic

ION AND WATER REGULATION IN MAMMALS

- The capacity of the mammalian kidney to conserve water, rid the body of nitrogenous and other wastes, and maintains a narrow ion and acid-base variation is essential to maintain life. Only with the concentrating powers of the mammalian kidney could mammals have invaded so many diverse and severe environment(Romer and Parson, 1986) understanding the mammalian kidney is a key factor in understanding the success of mammals.

- The kidney is an excretory organ. The functions of an excretory organ are all related to one basic principle: to maintain a constant internal environment, any material an organism takes in must be balanced by an equal amount removed. This in turn, requires that the excretory functions must have a variable capacity that can be adjusted to remove judiciously controlled amounts of each of the tremendous variety of different substances(Knut Schmidt-Nielsen, 1995).

The major functions of the mammalian kidney are as follows;

Removal of foreign substances or their metabolic waste products which if allowed to accumulate could lead to poisoning.

Removal of metabolic end products such as carbon dioxide

Maintenance of proper body volume(water content).

Maintenance of proper concentrations of solutes

ANATOMY OF THE KIDNEY

- Mammals have two kidneys which are located in the upper abdominal cavity on either side of the vertebral column, behind the peritoneum. The kidneys are bean-shaped.
- Each kidney has an indentation called the hilus on its medial side. The renal vein returns blood to the inferior vena cava. In a frontal section of the kidney, three areas can be distinguished.

- The lateral and middle areas are tissue layers. The outer tissue layer is called the renal cortex; it is made of renal corpuscles and convoluted tubules.
- The inner tissue layer is the renal medulla, which is made of loops of Henle and collecting ducts.
- The third area is the renal pelvis; this is rather a cavity

STRUCTURE / FUNCTION OF THE NEPHRON

- All vertebrate kidney consist of a large number of micro anatomical units, nephrons. The nephron is the structural and functional unit of the kidney.
- A renal corpuscle consists of a glomerulus surrounded by a Bowman's capsule. The glomerulus is a capillary network that arises from the afferent arteriole.

- In glomerular filtration, blood pressure forces plasma dissolved substances, and small proteins out of the glomeruli and into Bowman's capsule. This fluid is no longer plasma but glomerular filtrate. The blood cells and larger proteins are too large to be forced out of the glomeruli, so they remain in the blood. Waste products are dissolved in blood plasma, so they pass into the glomerular filtrate. Useful materials such as nutrients and mineral are also dissolved in plasma and are present in the filtrate.

- NB.
Filtration is not selective with respect to usefulness; it is selective only with respect to size. This is known as ultrafiltration.
The glomerular filtration Rate(GFR) is the amount of glomerular filtrate formed by the kidneys in one minute, and averages 100 to 125ml per minute. GFR may be altered if the rate of blood flow through them changes.

SOLUTE AND WATER RETENTION: PROXIMAL TUBULE

- Over 80% of the glomerular filtrate is reabsorbed in the proximal tubule, including all the glucose, amino acids, minerals, vitamins, hormones, small proteins and about 80% of the sodium chloride and water.
- Glucose, amino acids and ions diffuse into the cells of the proximal convoluted tubule from the filtrate and are actively transported out of the cells into the spaces.
- The constant removal of these substances from the proximal tubule cells creates a diffusion gradient.

- Small proteins which passed into the tubule during ultrafiltration are removed by pinocytosis at the base of the microvilli.
- The reabsorption of calcium ions is increased by parathyroid hormone (PTH). The parathyroid gland secretes PTH when the blood calcium level decreases.
- The hormone aldosterone, secreted by adrenal cortex, increases the reabsorption of sodium and potassium ions.
- Many of the negative ions e.g. chloride ions that are returned to the blood are reabsorbed following the reabsorption of positive ions.

- The function of the loop of Henle is to conserve water. The longer the loop of Henle, the more concentrated the urine that can be produced.
- The loop of Henle has three distinct regions each with its own function. These regions are
 - The descending limb which has thin walls;
 - The thin ascending limb- this is the lower half of the ascending limb and has thin walls;
 - The thick ascending limb

The descending limb is highly permeable to water and permeable to most solutes
In the last two regions of the kidney nephron, fine tuning of the body fluid composition is achieved. The proximal tubule always function in the same way, removing, for example, the same proportion of water and salts all the time
Fine control of the precise amounts of water and salts reabsorbed is important in osmoregulation. This is one role of the distal convoluted tubule and collecting duct.

ROLE OF ANTIDIURETIC HORMONE (ADH-VASOPRESIN)

- The body maintains the solute potential of blood at an approximately steady state by balancing water uptake from the diet with water lost in evaporation, sweating, egestion and urine. The precise control of solutes potential, however is achieved primarily by the effect of a polypeptide called antidiuretic hormone (ADH)
- Diuresis is the production of large amounts of dilute urine

- When blood becomes more concentrated, ADH is released and vice versa.
- ADH increases the permeability of the collecting duct to urea.
- Failure to release sufficient ADH leads to a condition known as diabetes insipidus

SPECIFIC ADAPTATIONS FOR WATER CONSERVATION IN KANGAROO RATS

- The kangaroo rats and pocket mice that are abundant in the North American desert live primarily on dry seeds and other dry plant material, and their intake of free water is minimal. They can live indefinitely in dry food, yet never drink. An examination of their water balance will therefore explain the mechanisms through which a mammal can live and In water balance seemingly without water intake.

ION AND WATER BALANCE IN NON-MAMMALIAN VERTEBRATES.

- The physiological systems of animals operate within fluid environment.
- Metabolism also poses the problem of disposal wastes.
- An organism maintains a physiological favorable environment by osmoregulation, regulating solute balance and the gain and loss of water and excretion, the removal of nitrogen-containing waste products of metabolism.

- All animals face the same problem of osmoregulation.
- Water enters and leaves cells by osmosis, the movement of water across a selectively permeable membrane.
- If two solutions separated by a selectively permeable membrane have the same osmolarity, they are said to be isoosmotic.
- There is no net movement of water by osmosis between isoosmotic solutions, although water molecules do not cross at equal rates in both directions.

NITROGEN METABOLISM

Cellular deamination and transamination

- The dominant reactions involved in removing amino acids nitrogen from the body are known as transamination.
- This class of reactions funnels nitrogen from all free amino acids into a small number of compounds; then, either they are oxidatively deaminated, producing metabolic organ utilizing amino acids for tissue protein synthesis, heme formation, pyrimidine and purine synthesis, ketone body and carbohydrate formation.

DISTRIBUTION OF NITROGENOUS WASTES

- Because most metabolic wastes must be dissolved in water when they are removed from the body, the type and quantity of wastes products may have a large impact on water balance.
- Animals that excrete nitrogenous wastes as ammonia need access to lots of water. This is because ammonia is very soluble. This is common in most aquatic species

- Ammonia excretion is much less suitable for land animals. Because ammonia is so toxic, it can be transported and excreted only in large volumes of very dilute solutions
- Most terrestrial animals and adult amphibians and some marine bony fishes excrete mainly urea.
- The main advantage of urea is its low toxicity, about 100 000 times less than ammonia
- This reduces the amount of water needed for nitrogen excretion.

- Land snails, insects, birds, and many reptiles excrete uric acid as the main nitrogenous waste.

Like urea, uric acid is relatively non toxic, and is largely insoluble in water and can be excreted as semi solid paste with very little water loss

The type of nitrogenous waste also depends on habitat.

THANKS FOR LISTENING