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Excretion and Osmo-regulation

Excretion is the elimination from the body of waste metabolic substances which if permitted to accumulate would poison the cells.
These waste metabolic substance include

- carbon dioxide,
- bile pigments,
- nitrogenous waste and
- toxic substance such as drugs, though are not products of metabolism.

Osmoregulation is the maintenance of the correct concentration of the body fluids at a stead state. These two processes, excretion and osmoregulation are both aspects of homeostasis carried out by the kidney in mammals

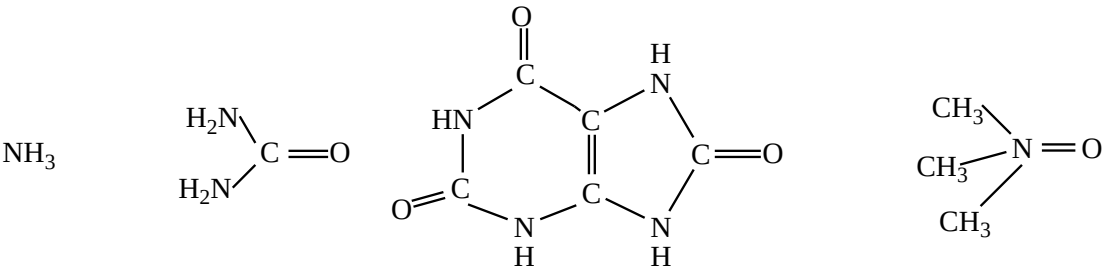
The significance of excretion and Osmoregulation:

Functions of excretion and osmoregulation are:

- The removal of metabolic waste substances that would otherwise be poisonous to the body.
- Regulate the ionic content of the body fluids such as sodium, potassium, chloride and so on to ensure efficient metabolic and physiological process.
- Regulate the water content of the body fluids
- Regulate the pH of the body fluids

Nitrogenous excretory products

Nitrogenous waste products are produced by catabolism of proteins and nucleic acids. The immediate nitrogenous waste product of the deamination of proteins is **ammonia**. This may be excreted immediately or converted into the major nitrogenous compound, urea, trimethylnitrogen oxide and uric. The structures of these wastes are:



Ammonia Urea Uric acid Triethyl nitrogen oxide

The exact nature of the excretory product is determined by the metabolic capability of the organism (i.e., which enzymes are presents); the availability of water to the organism (i.e.; its habitat), and the extent to which water loss in controlled by the organism.

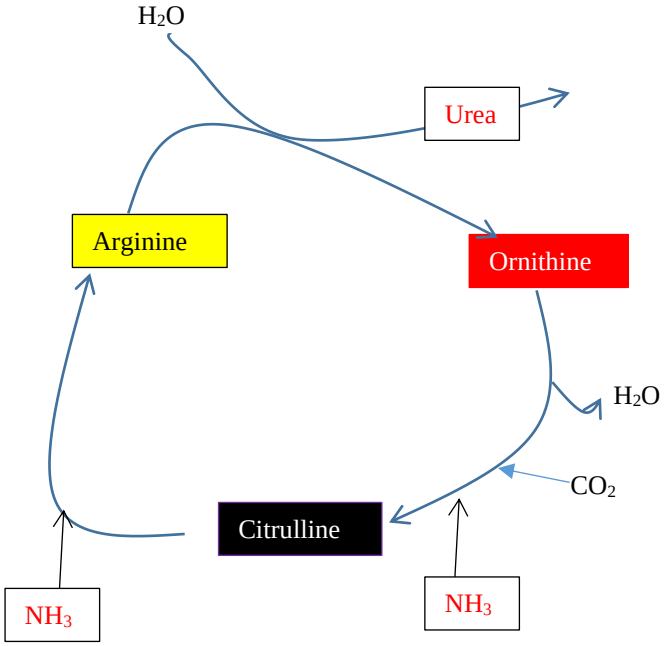
Ammonia

It is an extremely soluble molecule and very poisonous is excreted with a lot of water it's thus, the main nitrogenous excretory products of aquatic invertebrate and all freshwater organism since these organisms have a lot of available water. Examples of organism that excrete mainly ammonia are protozoan e.g. amoeba, cnidarian, Platyhelminthes, larval amphibian, aquatic crustacean and echinoderm.

Urea

Urea is formed in the liver of vertebrates by the interaction of ammonia, produced by deamination, and carbon dioxide, produced by respiration in a cyclical reaction known as the urea or **ornithine cycle.** It is **less soluble and less toxic than ammonia** and is the main nitrogenous excretory product in cartilaginous fish, certain bony fish; adult amphibian and mammal.

The ornithine cycle



Uric acid

Uric acid and its salts are ideal excretory product for terrestrial organism and a pre-requisite for organism producing a shelled egg since they combine a high nitrogen content with low toxicity and low solubility.. They are stored in cells, tissue and organs without producing any toxic or adverse osmoregulatory effect, and they require a **minimal amount of water** for their excretion. It is the main excretory products in birds and insects where it is removed as solid pellets.

The disadvantage of excreting uric acid is that it requires more energy for production than urea than ammonia.

Trimethylamine oxide

This is produced by the addition of methyl groups to ammonia, formed by deamination, and the subsequent oxidation of inter-mediate molecules. Trimethylamine oxide gives fish its characteristic smell.

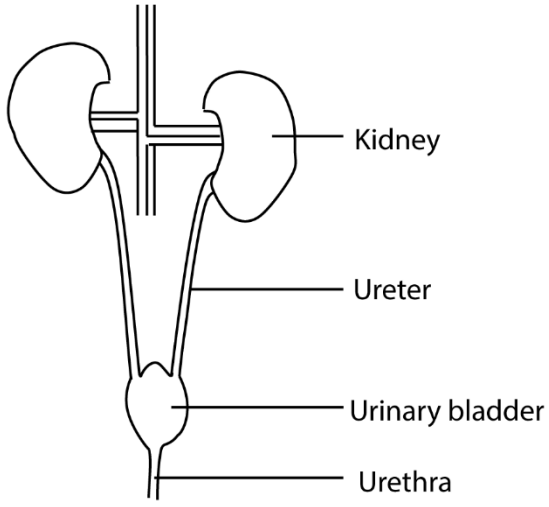
Excretory organs in animals

These include

- skin excretes water, urea and salts
- lungs excrete carbon dioxide
- Liver removes old red blood cells and formation of bile pigments

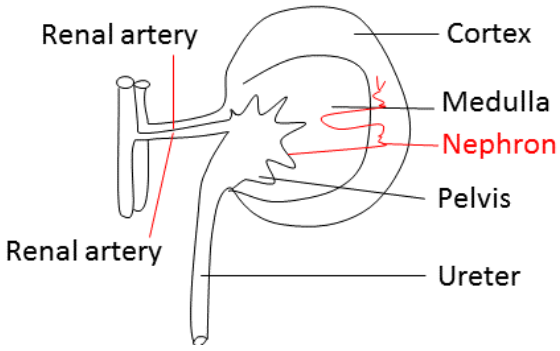
The mammalian urinary system

The urinary system



The mammalian urinary system is composed of two **Kidneys,** that control the composition of the body fluids by selecting, and removing unwanted substance from blood**; ureter,** convey urine from the kidneys to the urinary bladder; **urinary bladder,** stores urine temporarily before it is passed out of the body the **urethra.**

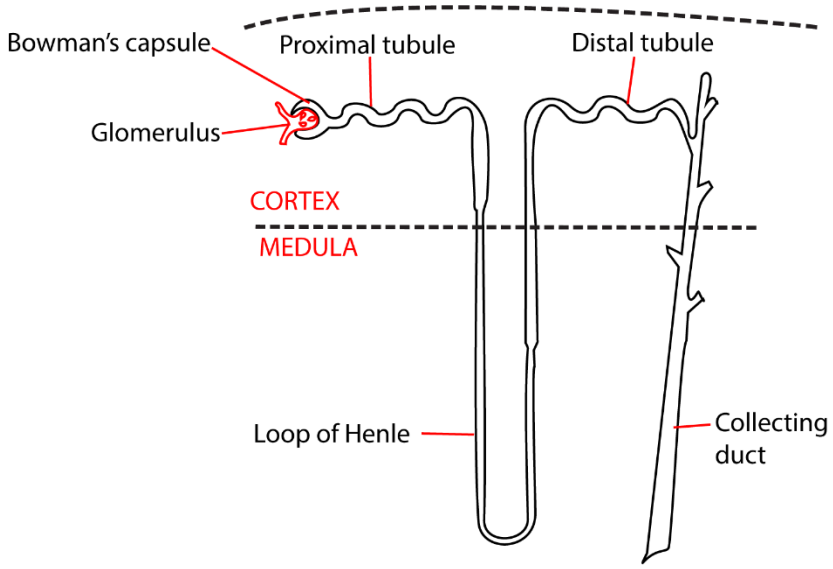
The Kidney



The kidney consists of two main regions: an outer **cortex** and inner **medulla.** Each kidney contains between one and two million microscopic structures called **nephrons.** The nephron is the basic unit of the kidney in which the kidneys regulatory functions such as producing urine are carried out.

Structure of a nephron

The main parts of the nephron are shown in the figure below. Part of the nephron lies in the cortex, and part of it in the medulla.



The nephron consists of a cup-shaped **Bowman's capsule** which is like a hollow rubber ball that has been pressed on one side. The invagination contains a dense network of capillaries called a **glomerulus.** The inside of the capsule, the **capsule space,** is separated from the lumen of the capillaries' by only two layers of cells: the epithelium of the capsule and the endothelium of the capillaries. These two layers of cells are highly specialised.

Leading from the Bowman's capsule is a tubule, about 60μm in outer diameter, whose lumen is continuous with the kidney capsule space. The first part of the tubule is located in the cortex of the kidney and is coiled: It is called the **proximal convoluted tubule.**

The proximal convoluted tubule leads to a U-shaped **loop of Henle,** named after its discoverer. FG S. Henle, a German microscopic specialist in 19th century. It consists of a straight **descending limb** which enters down into the medulla, where it does a hair - pin bend and returns to the cortex as the **ascending limb.** The ascending limb of the loop of Henle leads on to the final part of the nephron, the **distal convoluted tubule.** This, as the name applies, is coiled and it opens into a **collecting duct.** Several nephrons share the same collecting duct.

The collecting ducts converge at the **pelvis** of the kidney, emptying their contents into the **ureter** which conveys them to the bladder as urine. The tubules and collecting ducts are lined with a single layer of epithelial cells mainly of the cuboidal type.

Each nephron has its own blood supply. Blood from the renal artery is carried to the glomerulus by the **afferent arteriole** and leaves it by then **efferent arteriole.** The latter splits into a capillary network which envelops the tubules of that particular nephron. Blood from the capillaries drains into the renal vein. Blood flows first to the glomerulus and then capillaries surrounding the tubules before leaving the kidney.

The kidney processes for urine formation

- **Ultra-filtration:** All small molecules. such as water, glucose and urea, are filtered out of blood plasma in the **glomerulus** and produce a filtrate in **Bowman's capsule** which passes into the tubule of the nephron. The high filtration pressure results from the fact that in each Bowman's capsule the afferent arteriole has a larger diameter than efferent arteriole. As a result of this pressure, substances are forced out of blood into capsule space. Big molecules like proteins and blood cells are retained in blood by the **basement membrane** of the glomerular capillaries and do not appear in the filtrate.

- **Selective re-absorption:** All substances useful to the body and required to maintain the water and salt composition of the body fluid at a stead state are removed from the filtrate and re-absorbed into the blood capillaries,

    - Glucose, water, salts, amino acids are absorbed in the proximal convoluted tubule.
    - Water is mainly absorbed in the loop of Henle
    - In the distal convoluted tubules substances like water and salts are absorbed according to need as fine adjustment of body fluids.
    - Collecting duct mainly absorb water

- **Secretion:** Substances such as ammonia, uric acid and urea not required by the body that were not filtered are secreted into the filtrate, by cells of the nephron before it leaves the kidney as urine, for example K^+, H^+ and NH_4^+ in the distal convoluted tubes. Potassium ions are secreted and re-absorbed: their concentration in the blood depends on the balance between the two opposing processes.

Basic mechanism of absorption and secretion in the **tubules.**

- **Active transport:** e.g. glucose is absorbed from proximal tubules by active transport.

- **Differential permeability:** Various regions of the nephron are selectively permeable to ions, water and urea, for example the distal tubules are relatively impermeable compared to proximal tubule; the permeability of the collecting duct can be modified by hormones.

- **Concentration gradients:** A concentration gradient varying from 300mosmkg^{-1} of water in the cortex to 1200 mOsmkg^{-1} of water at the **papillae**, is maintained within the interstitial region of the medulla in human and results in passive absorption of water.

- **Passive diffusion and osmosis:** Sodium and chlorine ions and urea molecules will diffuse either into or out of the filtrate, according to the concentration gradients, wherever will pass out of the filtrate into a concentrated fluid in the interstitial region of the kidney wherever the nephron is permeable to water.

- **Hormonal control:** The regulation of water balance in the body and salt excretion is achieved by the effect of hormones acting on the distal tubule and collecting duct, such as anti-diuretic hormone, aldosterone, etc.

The role of the loop of Henle in production of concentration urine.
The loop of Henle concentrates urine by a counter current flow mechanism. Here urine flows down the descending loop and then exactly in opposite direction in ascending loop.

(i) The descending loop of Henle is fully permeable to water and sodium chloride here water is absorbed by osmosis.

(ii) The ascending loop of Henle is impermeable to water thus less water is absorbed from the filtrate. However, sodium and chloride ions are removed by active transport and returned to the medulla. This coupled with sluggish medullary blood, that reduces the rate of removal of salts from the medulla, maintain a high salt concentration in the medulla enabling maximum absorption water from the descending loop of Henle and the collecting duct.

In summary;

- Down the descending loop of Henle, the concentration of urine increases due to passive reabsorption of water.
- In ascending loop of Henle, the concentration decreases due to removal of sodium and chloride ions by active transport.
- Down the collecting tubule concentration increases due to passive absorption of water.
- Organism living in dry area have big medulla and long loops of Henle to maximise water reabsorption and conservation.

Kidney as osmoregulator

The amount of water reabsorbed is geared to the body's needs. When a person loses a lot of water or takes excess salt, osmotic pressure of blood rises and detected by osmoreceptors of the hypothalamus. This causes Antidiuretic hormone (ADH) to be released. **ADH** causes reabsorption of water from distal convoluted tubule thus diluting blood. When the required dilution is not achieved, drinking of water is initiated by osmoreceptors in the hypothalamus.

Drinking, particularly if excessive, results in the osmotic pressure of the blood to fall below normal value. The osmoreceptors are less stimulated leading to less ADH being produced. Less water is thus reabsorbed from the tubule leading to copious dilute urine (diuresis).
Inability of a person to produce insufficient amounts ADH causes diuresis; the disease condition is called diabetes insipidus.

Note that production of hypertonic/hypotonic urine is determined by the distal convoluted tubules by the presence of absence of ADH. Presence of ADH leads to reabsorption of water from the filtrate leading to hypertonic urine.

Control of sodium levels in blood
Another hormone called aldosterone responsible for maintaining a more or less constant sodium level in the plasma has a secondary effect on water reabsorption.

Any loss of sodium which causes a decrease in in blood volume causes a group of secretory cells called **juxtaglomerular** complex between the afferent arteriole and the distal convoluted tubule to release an enzyme **renin**.

- Renin causes a plasma globulin produced by the liver to form a hormone **angiotensin**.
- Angiotensin stimulates the release of **aldosterone** from adrenal cortex.
- Aldosterone stimulate active uptake of sodium ions and consequently water from glomerular filtrate restoring the volume of blood.

pH control
Proteins, hydrogen carbonate and phosphate buffers in blood prevent excess hydrogen ions (H^+), produced by metabolic activities from decreasing the pH of blood. Carbon dioxide released into

the blood during respiration is regulated by this system and prevented from causing changes in blood pH prior to excretion in the lungs.

However, changes in pH of blood is counteracted by the distal convoluted tubules. In the distal convoluted tubules, carbon dioxide reacts with water to form hydrogen ions and hydrogen carbonate.

$$H_2O + CO_2 \rightleftharpoons H^+ + HCO_3^-$$

When the blood pH decrease, the distal convoluted tubules secretes H^+ into tubules and retain HCO_3^-. H^+ react with ammonia for form ammonium ions (NH_4^+) that is excreted in urine.

When the pH of blood rises, the tubules secretes HCO_3^- ions and retain H^+ lowering pH.

Excretion and osmoregulation in other organisms.

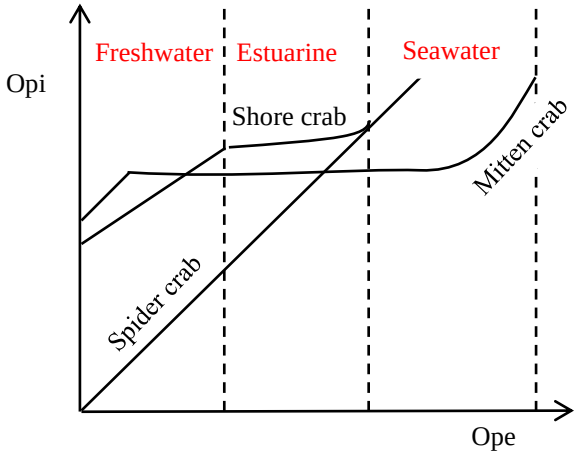
1. Marine invertebrates:

The internal osmotic pressure (Opi) of some of these organisms is equal to external osmotic pressure (Ope). This implies that their body fluids are isotonic to sea water, these organisms do not need osmoregulatory mechanism so long as they remain in the open seas.

However, some species of crab are capable of osmoregulation enabling them to move to estuarine water and fresh water. There are therefore three crabs to consider;

a. Spider crabs (Maia) are confined in sea water because they lack any form of osmoregulation mechanisms.
b. Shore crab (Carinas) is capable of some form of osmoregulation when it moves from sea to estuarine, where it maintains fairly high Opi above Ope but its osmoregulation mechanisms fails in freshwater. Hence it lives in sea water and estuarine only.
c. Mitten crab. This type can osmoregulate in seawater and fresh water maintaining its Opi. It can therefore live in seawater, estuarine and fresh water.

A graph showing variation of Opi of different species of crabs with Ope of the medium



2. Fresh water animals

The problem facing a fresh water animal is that opi is greater than ope. This danger, here is dilution of the tissue fluid resulting from osmotic influx of water across the exposed partially permeable surfaces of the body.

There are two possible solutions to this problem:

1. Water might be eliminated as fast as it enters the body fluid by means of the kidney or some equivalent device, salt being re-absorbed from the water before it leaves the body.

   Osmoregulation in Amoeba
   The internal osmotic pressure (OPi) of amoeba is always higher the external osmotic pressure (OPe) , osmotic influx of water can cause their membranes to burst.

   a. Excess water collects in the contractile vacuole;
   b. The salts from water are actively removed and returned to the cell.
   c. when the contractile vacuole is full, it migrates and fuse with the cell membrane and burst to release water to the surrounding.

2. Salts might be actively taken up from the external medium, thereby counteracting the diluting effect of the inflowing water. For instance, the fresh water bony fish such as carp, trout and stickleback are liable to osmotic influx of water across the gills and the lining of the mouth cavity and pharynx. The fresh water bony fish must get rid of water and save salts.

This is achieved in three main ways:

- The rate filtration in the kidney **(glomerular filtration rate)** is very high, to allow rapid excretion of water. This high filtration rate is achieved by the glomeruli being exceptionally large and numerous.
- As the renal fluid flows along the kidney tubules, salts, (i.e.; sodium and chloride ions) are extensively re-absorbed back into the blood stream with the result that urine is markedly hypertonic to blood.

- **Chloride secretory cells:** In the gills take up sodium and chloride ions from water by active transport into the blood stream. The result is that chloride ions is about 800 time as concentrated in animal blood as it is in the surrounding fresh water.

Thus, to summarise, fresh water way fish solve their osmotic problem by combining the expulsion of water with the active uptake of salts.

Marine vertebrate:

The hypertonic marine water exposes the marine vertebrate to chances of loss of water by osmosis. However, marine bony fish such as mackerel and cod are able to overcome this by three processes.

1. The glomerular filtration rate in the kidney is relatively low. The glomeruli are small and few compared to those of the freshwater fish.
2. Salts are actively extruded by chlorine secretory cells in the gills
3. Nitrogenous waste is excreted in form of urea and trimethylamine oxide) that require relatively little water for its elimination
4. Marine cartilaginous fish (elasmobranchs and shark) such as dog fish and sharks have solved their osmoregulatory problems by retaining urea to increase the osmotic potentials of their body fluids to slightly above that of sea water. As a result, the little water that flows in readily expelled by the kidneys
5. They have membranes that are impermeable to urea.

Adaptation of desert frogs to desert condition

An **adaptation** is a physical or behavioural change that an animal or plant possesses to help it cope with its environment. Here are some of the ways frogs have adapted to their new desert homes:

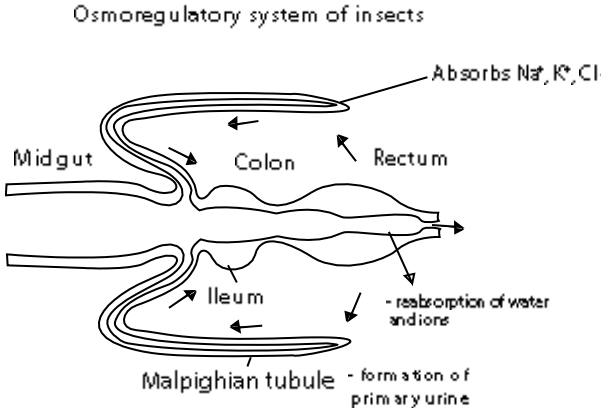
- Desert frogs burrow underground during the dry months, in order to escape the searing sun. They can stay underground for many months while they wait for the next rains to fall.
- Whilst underground, many species produce a type of **cocoon** with many layers of their shed skin that covers their entire body (except for the nostrils). This helps to reduce water loss.
- Most desert frogs only **reproduce** in response to a significant rainfall event. Females can then lay eggs in **temporary** pools. Some even lay their eggs in mud. These eggs then hatch when they are eventually flooded with water, and the tadpoles can swim straight into the water! Smart.
- One particular type of frog, the Northern Sandhill Frog, doesn't even need water to hatch its eggs. These babies hop right over the tadpole stage, hatching out of their eggs as tiny, fully formed versions of their adult parents.
- Chiloleples, the desert frog flourishes in the desert because it is nocturnal that hides during day when temperatures are high and becomes active during night when temperatures are low

Terrestrial animals

Like marine bony fish, terrestrial animals are liable to lose water, but whereas in a fish this is caused by osmosis, in a terrestrial animal it is caused by evaporation from the permeable surfaces exposed to the atmosphere.

Means of reduction of excess water loss from terrestrial animals.

1. They have a water proof integument, e.g. insects.
2. They have is low glomerular filtration rate.
3. They produce a non-toxic nitrogenous waste; for example, amphibians and mammal excrete **urea** which, being less toxic than ammonia requires less water for its removal. Reptiles and insects excrete uric acid in a semi-solid form. In insects the uric acid is produced by the **Malpighian tubules** a bunch of narrow tubes leading of the gut.



4. **Reabsorption of water**
   In insects, water is mainly reabsorbed in the rectum while in mammals and birds, reabsorption occurs in the loop of Henle. **High reabsorption in desert animals is due to long loop of Henle while kangaroo rat which produces 4 times concentrated urine as that of human has unusually high ADH.**

5. **By behavioural means.**
   Many animals avoid or at least reduce, the problem of water loss by modifying or changing their habitats. For instance, kangaroo rat and earth worm burrow during hot days. Certain animals go into a state of dormancy during summer or dry season, a phenomenon called **aestivation.**

6. **By using metabolic water**. E.g. a desert animal such as kangaroo rat tends to metabolise fats rather than carbohydrate to obtain a high yield of water.

7. **They have tissues that tolerant to water loss** e.g. the camel tissues are exceptionally tolerant to dehydration.

Water regulation in plants:

Plants can be classified into three groups according to how much water is available to them in their nature environment.

- **Hydrophytes:** are plants which live partially or completely submerged in fresh water. e.g. water lilies, obviously, such plants have no difficulty getting enough water. Hydrophytes have the following adaptations to get rid of excess water
  - Poorly developed root system to reduce water absorption.
  - Numerous stomata on the upper epidermis of the leaf to increase water loss.
  - Have thin epidermis on the leaves
  - Have poorly developed xylem to reduced water transported in plant
  - Broad leaves

- **Mesophytes:** grow in normal, well - watered soil. Most land plants in temperate regions belong to this category. Usually the water which they lose by transpiration is readily replaced by uptake from the soil, so they require no special means of conserving water.

- **Xerophytes:** live in dry places such as the hot desert where the water potentials in the soil and air are very low. These plants face the possibility of drastic dehydration and have ways of preventing this.

Adaption of xerophytes to drought

- **Life cycle adaptation.**

Most species can survive dry periods in the dormant stages e.g. desert ephemerals. Germination, growth and flowering takes place during a few weeks following a burst of rain, after the seeds have been dispersed, the parent plant die and the seeds remain dormant in the dry soil until the next rains come.

Adaptation relating to transpiration and water uptake. Many species have adaptations which minimise transpiration and/or maximise water uptake.

These include:

- Extremely long **vertical roots** absorb water deep in the soil e.g. Acacia.
- **Superficial** roots have an advantage of absorbing water quickly before it has a chance of evaporation e.g. cacti.
- Some plants have got succulent leaves and/or stem to store water e.g. giant saguaro cactus of North America.
- The number of stomata in some plant e.g. in prickly pear has been reduced; in others the stomata are sunk down **pits** in which air tends to accumulate, this reducing the rate of transpiration from the leaves. Some plants achieve the same thing by having a hairy epidermis which holds humid air against the leaf surface. These devices are accompanied in some plants by **folding of leaves**, an adaptation seen in marram glass, which thrives on dry coastal sand dunes.

- Cuticlar transpiration in xerophytes is reduced by having **small leaves** with low surface area and by having a **thick cuticle** which is impermeable to water. In some plant leaves have been modified into thorns.
- Some plants may suffer from water shortage in winter because freezing of soil which decrease water availability from the soil, causing **physiological drought.**
  One way of circumventing this problem is to **shed the leaves** by deciduous trees before winter sets in, thereby reducing the leaf surface area.

Crassulacean acid metabolism: a physiological adaptation

In Crassulacean, prevent excess loss of water by closing their stomata during day and then opening then at night. These plants have got the ability of taking up carbon dioxide and fix it into malic acid at night when the stomata are open. When day break comes, the stomata close and carbon dioxide is released for photosynthesis.

Summary of challenges faced by vertebrates when they moved from water and evolutionary solutions

	Challenges	Solution
1.	Obtaining gases	Development of lungs
2	Excessive evaporation	Impervious body coats e.g. shells, skin and cuticle and secretion of non-toxic wastes
3	Reproduction	Internal fertilization
4	Support and locomotion	Development of limbs
5	More predators	Many defence mechanisms

Excretion in plants

Plants do not possess special excretory organs like the animals because:

1. Most of plant wastes are gaseous (oxygen from photosynthesis and carbon dioxide from respiration) and are lost by diffusion through stomata.
2. There is very little accumulation of toxic wastes e.g. nitrogenous wastes because plants are inactive
3. Excess water passes to the exterior via similar routes and is eliminated by processes of guttation (droplet exudation) and transpiration (evaporation of water from plant surfaces).
4. Plants use waste plants (oxygen for respiration and carbon dioxide for photosynthesis)
5. The plant wastes are stored in cellular vacuoles, and lost in leaves that fall off. Some other waste products are stored in the xylem, like resins and gums.

Exercise

1. Marine cartilaginous fish solves its osmoregulatory problems by
   A. Swallowing seawater and having few glomeruli
   B. Actively extruding salts.
   C. Retaining urea to increase the osmotic potential of the body fluids.
   D. Excreting trimethylamine oxide
2. Production of uric acid in insects is an adaptation for
   A. Conserving water
   B. Minimising energy loss
   C. Conserving mineral salts
   D. Removing excess water
3. The U-shape of the loop of Henle serves to
   A. Speed up the filtration
   B. Increase the contents of the filtrate
   C. Reduced the concentration of the filtrate
   D. Create a region of high salt concentration

4. Which one of the following parts of the nephron contributes to the production of hypertonic urine?
   A. Bowman's capsule
   B. Proximal convoluted tubule
   C. Distal convoluted tubule
   D. Loop of Henle

5. In which part of the mammalian kidney is blood likely to be most viscous as it flows?
   A. In afferent vessel
   B. In the capillaries of proximal convoluted tubule
   C. In efferent vessel
   D. In capillaries of distal convoluted tubule

6. Which one of the following is an adaptation of the kidney in freshwater?
   A. Large glomeruli
   B. Long Loop of Henle
   C. Well-developed collecting duct
   D. Few glomeruli

7. Which one of the following is an adaptation in organism for aquatic conditions?
   A. Development of pollen tube
   B. Shelled eggs
   C. Internal fertilization
   D. Flagellated sperm

8. Production of hypertonic urine in animals is mainly achieved by
   A. Bowman's capsule
   B. Loop of Henle
   C. Proximal convoluted tubule

D. Distal tubule

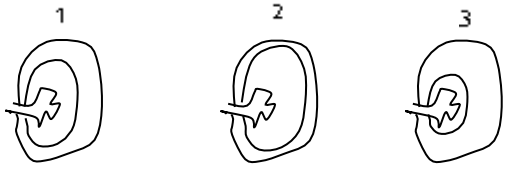
9. Hydrophytes do not have wax-covered leaves because
   A. They need much air for fast respiration
   B. They do not need to conserve water
   C. The wax would make the leaves heavy and sink
   D. Their leaves cannot synthesise wax.
10. The influx of water in fresh water bony fish is offset by possession of
   A. Numerous, large glomeruli and reabsorption of salts from the renal fluids
   B. Numerous, small glomeruli and extrusion of salts from the body
   C. Few large glomeruli and uptake of salts
   D. Many small glomeruli and uptake of salts
11. Which one of the following sets of characteristics is an adaptation in mammals to desert conditions?
   A. Uric acid production and short loop of Henle
   B. Long loop of Henle and production of urea
   C. Ammonia production and long loop of Henle
   D. Short loop of Henle and urea production
12. Which one of the following adaptations would **not** assist animals living in a desert?
   A. Use of metabolic water
   B. Possession of large number of glomeruli
   C. Possession of long loop of Henle
   D. Production of nontoxic nitrogenous wastes
13. Which of the following is a method halophyte use to survive physiological drought?
   A. Reducing the number of stomata on their leaves
   B. Reversing the normal stomatal rhythm
   C. Storing water
   D. Having waxy cuticle
14. In order to survive in the sea, a marine bony fish
   A. Loses water by osmosis and absorb salts
   B. Swallows water and absorb salts
   C. Swallows water and extrudes salts
   D. Gain water by osmosis and extrudes salts.
15. Antidiuretic hormone is produced by the
   A. Adrenal gland and decreases urine production
   B. Pituitary gland and decreases urine production
   C. Adrenal gland and increase urine production
   D. Pituitary gland and increases urine production

16. Which one of the following would results into the production of concentrated urine by an animal?
   A. Possession of large glomeruli
   B. Possession of long loop of Henle
   C. Failure to produce ADH
   D. Possession of many glomeruli

17. Which of the following concentration of proteins is correctly matched? High in
    A. The glomerular filtration in urine
    B. The blood plasma, usually absent in glomerular filtrate and urine
    C. Both blood plasma and glomerular filtrate but low in urine
    D. Blood plasma, glomerular filtrate and urine
18. If the osmotic pressure of the external solution is lower than that of the cell, the external solution is said to be
    A. Hypotonic to the cell solution
    B. Hypertonic to the cell solution
    C. Isotonic to the cell solution
    D. More concentrated than the cell solution.
19. Which one of these plasma constituents is reabsorbed in the distal convoluted tubule?
    A. Urea
    B. Chloride
    C. Glucose
    D. proteins
20. Which one of the following is **not** an adaptation of animals living in desert environment?
    A. Use of metabolic water
    B. Ability to reduce filtrate volume
    C. Possession of a long loop of Henle
    D. Production of ammonia
21. The physiological importance of the hair-pin counter current multiplier system in mammalian kidney is to ensure that
    A. Much water is excreted out through the kidney
    B. Much water is reabsorbed
    C. Glucose is not lost in urine
    D. All urea is excreted in urine
22. Which one of the following methods is used by marine fishes to overcome the problem of dehydration?
    A. Increase in glomerular filtration rate
    B. Extensive reabsorption of salts from renal fluid
    C. Extrusion of salts by chloride secretory cells.
    D. Elimination of nitrogenous waste in form of insoluble compounds.

23. Blood plasma contains proteins but glomerular filtrate does not. Why does this difference in composition occur?
    A. Blood osmotic pressure is maintained by the presence of plasma proteins
    B. Proteins are actively transported from the kidney tubule back into the blood capillaries
    C. Proteins cannot pass through the membrane of the glomerular capillaries
    D. There is high hydrostatic pressure in the blood within the glomerular capillaries.

24. The diagram below shows vertical section of kidneys of three mammals, coypu, brown rat and kangaroo rat, showing the relative sizes of cortex and medulla.



Coypu occur in fresh water and never short of water to drink. Brown rats are able to go some days without drinking. Kangaroo rats are able to live in desert without drinking at all. Which kidney belongs to which animal?

	1	2	3
A	Brown rats	Coypu	Kangaroo rats
B	Kangaroo rats	Coypu	Brown rats
C	Brown rats	Kangaroo rats	Coypu
D	Kangaroo rats	Brown rats	Coypu

25. Hydrophytes do not have wax-covered leaves because
    A. They need much air for respiration
    B. They do not need to conserve water
    C. The wax would make the leaves heavy and sink
    D. Their leaves cannot synthesize wax
26. Which one of the following is a method used by marine bony fish to overcome the problem of possessing body fluids that are hypotonic to the surrounding?
    A. Increase in glomerular filtrate
    B. Extensive reabsorption of salts
    C. Retention of urea
    D. Elimination of nontoxic nitrogenous wastes

27. Which one of the following is a way of **minimising** water loss in a desert animal?
    A. Drinking a lot of water
    B. Possession of few glomeruli
    C. Feeding on succulent vegetation
    D. Having a short loop of Henle.
28. Counter current flow in bony fish achieves a high level of gaseous exchange because it
    A. Increases the concentration gradient
    B. Decreases the distance across which gases diffuse.
    C. Increases the speed of water flow over the gills
    D. Maintains a high concentration gradient
29. Where in the host is a parasite lacking sense organ and osmoregulatory devices likely to be located?
    A. On the skin
    B. Under the hair
    C. In the alimentary canal
    D. In the intercellular fluid

30. Which of the following is an advantage of excreting nitrogenous waster in form of uric acid?
    A. is less soluble and less toxic
    B. Is excreted in semisolid state
    C. Cannot be stored in the body for long time
    D. Requires plenty of tater for its removal
31. Which of the following methods is used by marine fish to overcome the problem of dehydration?
    A. Increase in glomerular filtration rate
    B. Extensive reabsorption of salts from renal fluid
    C. Extrusion of salts by chlorine secretory cells
    D. Elimination of nitrogenous wastes in form insoluble compounds
32. *Chiloleples*, the desert frog flourishes in the desert because it
    A. It has a water proof skin
    B. Is nocturnal
    C. Has few and small glomeruli
    D. Reabsorbs metabolic water
33. Deciduous plants in temperate zone shade off their leaves during winter
    A. Because of water shortage
    B. To cut down the process of guttation
    C. Because of too much water availability
    D. To avoid freezing temperature
34. Which one of the following is **not** characteristic of animals which migrate from fresh water to seawater?
    A. Lack means of osmoregulation
    B. Have efficient means of osmoregulation
    C. Possess tolerant tissues
    D. Employ behaviour means of osmoregulation
35. Which of the following is **not** an adaptation for aquatic life by the plant?
    A. Poorly developed roots
    B. Lack of stomata
    C. Presence of tendrils
    D. Poorly developed xylem
36. Which one of the following groups of terrestrial animal conserves water most efficiently?
    A. Mammals
    B. Insects
    C. Birds
    D. Reptiles
37. Which one of the following adaptations of xerophytes does **not** reduce transpiration?
    A. Hairy leaves
    B. Leaves with thick waxy cuticle
    C. Small sizes leaves
    D. Succulent stems

38. Which one of the following nitrogenous wastes is suitable for elimination in a fresh water fish?
    A. Urea
    B. Uric acid
    C. Ammonia
    D. Trimethylamine oxide

39. Which of the following does **not** play part in regulation of salts concentration of mammalian blood?
    A. Kidney
    B. Skin
    C. Liver
    D. Pituitary gland
40. Which of the following methods is used by halophytes to conserve water?
    A. Shed leaves
    B. Store water
    C. Reduce number of stomata
    D. Have small leaves
41. Cartilaginous fish retain urea in the blood in order to
    A. Avoid dehydration
    B. Reduce entry of salts into the tissue
    C. Avoid loss of excess water by excretion
    D. Maintain an internal ionic concentration in balance with external medium
42. The excretory products in plants include
    A. oxygen and starch
    B. urea and oxygen
    C. oxygen and carbon dioxide
    D. carbon dioxide and urea
43. While many freshwater animals possess vacuoles, which contract to expel excess water, plants living in fresh water do not have such vacuoles because
    A. plant cell walls are impermeable to water
    B. plant cell sap is of much lower concentration than animal protoplasm
    C. water movement into plant is controlled by their roots
    D. the water potential inside and outside such plant cells is the same.

44. Which of the following is an advantage of excreting nitrogenous wastes in form of uric acid? Uric acid
    A. Is soluble and less toxic
    B. Is excreted in a semisolid state
    C. Cannot be stored in the tissue for a long time
    D. Requires plenty of water for its removal

45. The following are adaptations for survival among animals during periods of water shortage.

(i) Tolerance to water loss,

(ii) Biochemical production of water,

(iii) Reduction in water loss,

(iv) Evasion of hot environment.

Which one of the following is a correct set used by the camel?

A. (i) and (ii) only.

B. (i), (ii) and (iii}.

C. (i), (ii) and (iv).

D. (iii) and (iv) only.

The answer is B

To survive in the conditions of water shortage in deserts, the camel uses the following means:

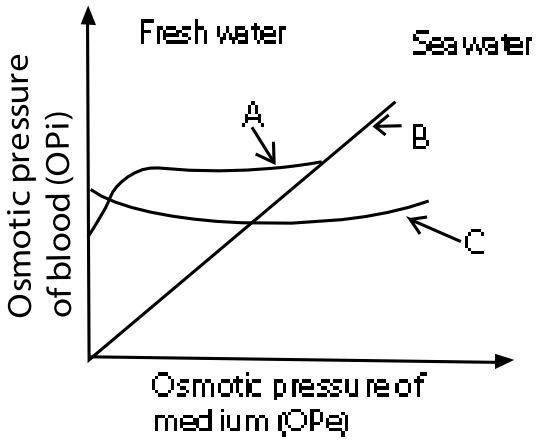
- Having tissue that are tolerant of water loss/ desiccation.
- Producing metabolic water: biologically produced water from fat metabolism
- Reducing water loss from the body.

Note: the camel never evades the hot environment in order to escape shortage but uses the above strategies to withstand condition in the desert.

Structure question (short answers)

46. (a) Marine invertebrates have body fluids which have the same solute concentration as seawater. State one advantage and one disadvantage of this situation. (1marks each)
Advantage
Disadvantage
(b) Halophytes live in salty marshes.
(i) What physiological problems do they face? (2marks)
(ii) suggest how the problem is overcome? (2marks)

47. The figure below shows the relationship between the osmotic pressure of blood and external medium of three animals A, B and C.



(a) Suggest the likely habitat for each animal, giving a reason in each case (6marks)

(b) Explain the osmoregulatory problems of each of the following animals

(i) Fresh water teleosts (2marks)

(ii) Marine teleosts (2marks)

48. (a) With reasons, give examples of animals which produce each of the following excretory products

(i) Ammonia (2 ½ marks)

(ii) Uric acid (2 ½ marks)

(b) State

(i) Why the pH of the body fluids in human is kept constant. (2marks)

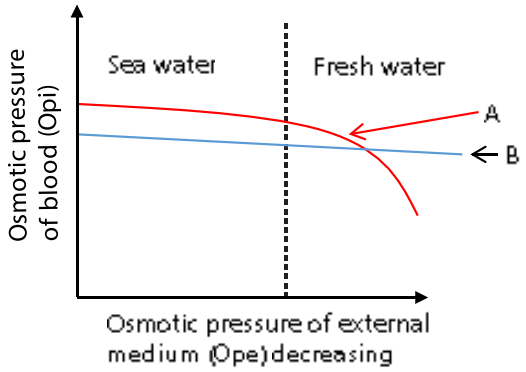
(ii) Three ways of keeping the pH in (b)(i) constant. (2marks)

49. (a) what is meant by water stress in relation to plants? (1mark)

(b) What is the effects of water stress in green plants?

(4marks)

50. Figure below shows the effect of changing the osmotic pressure of external medium (OPe), on the osmotic pressure of blood (OPi), of sea animals A and B



(a) Explain the effect of decreasing the OPe on OPi of each animal

(i) Animal A (3marks)

(ii) Animal b (3marks

(b) Using the information provided, suggest an ecological advantage of animal B over A

(c) What is the main osmotic problem faced by sea animals whose OPi is less than OPe

(2marks)

51. Explain the changes in the concentration of sodium ions in the renal fluid along the

(a) Descending limb of the loop of Henle (4mark)

(b) Ascending limb of the loop of Henle (03mark)

(c) Collecting duct (03marks)

52. (a) state three ways by which ions are regulated in mammals (3mark)

(b) The pH of blood and tissue fluids in humans remain constant at about 7.4 in spite of metabolic activities which produce hydrogen ions. Explain how this constancy is maintained by the kidneys. (7marks)

53. Explain the following observation in humans

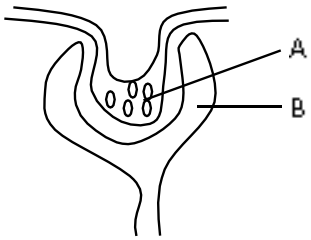
(a) Production of large volumes of dilute urine on a cold day.

(b) Urine production almost stops as a result of serious blood loss.

(c) Presence of sugar in urine

(d) Feeling hungry faster in cold day.

54. The diagram shows part of a nephron of mammalian kidney



(a) Identify the part labelled B

(b) As blood passes through the blood vessels in the part labelled A, pressure is built up.

(i) What is the effect of this increase in pressure?

(ii) how is the high pressure in (b)(i) built up?

(c) The table below shows the percentage of various components in the blood plasma in the part labelled A, the fluid in the part labelled B and in urine of a human.

Compounds	% in plasma in A	% in fluid in B	% in urine in bladder
Protein	7	0	0
Glucose	0.2	0.02	0.05
Urea	0.03	0.03	2.0
Sodium ions	0.32	0.32	0.35
Chloride ions	0.37	0.37	0.6
Water	92	98	96

(i)Give a reason why there is no proteins in the urine.

(ii) Which component of urine shows the greatest percentage increase in concentration compared to the fluid B?

(iii) Give a reason why the component you have named in (ii) above has the greatest increase in concentration in urine

(iv) Suggest with a reason the healthy condition of the person from whom the figures were obtained.

Assay questions

1 Describe how a camel is able to overcome the water stress in its habitat. (09marks)

2 (a) Explain the factors that influence the type of nitrogenous waste excreted by animals. (16marks)

(b) Describe osmoregulation in terrestrial insects. (4marks)

2. Describe how terrestrial plants overcome the challenges of terrestrial environment. (20marks)

3. Describe how xerophytes survive conditions to unfavourable water balance. (20marks)

4. How are vertebrates adapted to terrestrial life? (20mark)

5. Describe nitrogenous excretion in animals under the following headings

(a) The source of waste nitrogen and need for its removal (4marks)

(b) The removal of waste nitrogen by freshwater animals and by terrestrial insects (5marks)

(c) The way in which the structure and function of mammalian kidney is adapted for the efficient removal of waste nitrogen.

Answers to objective questions

1.	C	11.	B	21.	B	31	D	41	A
2.	A	12.	B	22.	D	32	B	42	C
3.	D	13.	C	23.	C	33	B	43	C
4.	C	14.	C	24.	C	34	B	44	A
5.	C	15.	B	25	B	35	C	45	B
6.	A	16.	B	26	D	36	B	46	
7.	D	17.	B	27	B	37	D	47	
8.	B	18.	A	28	D	38	C	48	
9.	B	19.	B	29	D	39	C	49	
10.	A	20	D	30	A	40	B	50	

Answers Structured questions

46

A is an estuarine animal because it can only osmoregulation in ranges of OP e midway between fresh water and sea water.

B is a sea water (marine) animal because it cannot osmoregulate at all such that its OPi is always equal to OPe in all media.

C is fresh water animal because it can osmoregulate in fresh water ranges of OPe but not in sea water.

(b)(i) they face a danger of dilution of their tissues.

Explanation

The osmotic pressure of their body fluids is higher than the osmotic pressure of the surrounding waters.

As a result, there is an osmotic influx of water across the exposed semi-permeable surface of the body.

(i) They face a danger of dehydration of their tissues.

Explanation:

The osmotic pressure of their body fluids is lower than the osmotic pressure of the surrounding waters

As result, there is an osmotic outflow of water across the exposed semi-permeable surface of the body.

47 (a)(i) Ammonia is excreted by fresh water animal, e.g. protozoa and hydra, this is because excretion of n requires a lot of water due to its high solubility and toxicity.

(ii) Uric acid is secreted by organisms adapted to live in arid areas because it excretion requires very little water. Examples are insects and reptiles.

(b) enzyme work best at optimum pH.

pH influences excretion of some toxic substances.

(ii) pH is controlled by

Buffers such as globular protein

Rate of elimination of carbon dioxide in the lungs

Selective elimination of hydrogen ions or bicarbonate ions in the kidney.

48 (a) Water stress is a condition in which a plant has a high tendency to lose water than it can obtain it from environment.

(b)

Storage of water in the plant tissues such as leaves

Reduction of leaf sizes

Loss of leaves

Modification of leaves into spines

Closure of stomata

Reduction in the number of stomata

Shedding of leaves

Folding of leaves

Growth hairs on the leaves

Change of stomatal rhythm

49. (a)(i) Animal A
OPi, of A decreases with decrease in OPi, gradually in seawater but very rapidly to zero in freshwater.
Explanation
As OPi decreases, the cells of A absorb water from external environment by osmosis which decrease its OPi. This continues up to the point when OPi equals OPe. In freshwater, OPe of A decreases rapidly to equilibrium where OPe = 0.

(ii) Animal B
Opi first decreases gradually in seawater but later becomes constant with further decrease in OPe in freshwater.

Explanation
Decrease in OPi is due to absorption of water from the external environment by osmosis as OPe in freshwater.

Later, the animal resist further decrease in OPi, despite reduction in OPe by regulating of mineral ions concentration in its body by retention of ions from swallowed water and excretion of nearly pure water.

(b) Animal B can colonise both seawater and freshwater. Animal A can survive only in seawater but not in freshwater.

(c) has a tendency to lose water to external solution leading to cell plasmolysis.
High energy expenditure to maintain its OPi.

50 (a)There is increase in concentration of sodium ion in renal fluid in descending limb of Loop of Henle due to reabsorption of water by osmosis

(b) Concentration of sodium ion in the renal fluid in the thick ascending limb decreases due to being actively removed to the interstitial fluids.

(c) concentration of sodium ion may increase due to osmotic absorption of water or decrease due to active reabsorption of sodium ions facilitated by aldosterone hormone

51(a) Hormones regulates the concentration of ions by controlling their uptake in the gut, controlling their release from or storage in storage organs such as bones and by controlling their elimination by the kidney.

(b) Carbon dioxide reacts with water to produce hydrogen and hydrogen carbonate ions. When the pH of blood is low, the cells of distal convoluted tubule secrete hydrogen ions retaining hydrogen carbonate ions, thereby raising the pH. When the pH of blood raises above normal, the cells of distal convoluted tubules secrete hydrogen carbonate ions into renal fluid and retain hydrogen ions which lowers the pH.

52(a) On cold day, loss of excess water from the body through sweating and exposed mucous membranes reduced leaving the kidney as the only route through which excess water from the body is lost. Thus, the volume of urine increases.

(b) loss of blood lowers the blood volume; this reduces the filtration pressure and volume glomerular filtrate. Secondly extensive reabsorption to restore blood volume leads to low urine production.

(c) Glucose appears in urine when a person is deficient of insulin or reduction sensitivity of the cells to insulin leading to hyperglycaemia.

(d) On cold day, there is high demand for energy to maintain the body temperature which leads to feeling hungry fast.

53 (a) Capsular space

(b) Ultrafiltration occurs in which in which small molecules such as water, glucose and urea are filtered from blood while big molecules such as blood plasma and blood cells are retained in blood.

(c)(i) protein molecules are big and cannot pass through the basement membrane of glomerular membrane.

(ii) urea

(iii) Urea is not reabsorbed because it a waste product and secondly it is secreted in the renal fluid.

(iv) has diabetes mellitus because the urine contains glucose

Answers to essay questions

1. Strategies of the camel to overcome water stress include:
    - It has tissues which are tolerant to desiccation. As such, it can go for as long as two months without drinking water.
    - It makes use of metabolic water. The fat in its hump is believed to suit this purpose. Fat metabolism produces a lot of water which the camel uses in conditions of water stress.
    - It has long loops of Henle in its kidneys so that it reabsorbs most of the water from its glomerular filtrate and produces concentrated urine
    - It has scanty glomeruli and therefore has a very low glomerular filtration rate so that very little water is filtered from its blood into the glomerular filtrate
    - It has a waterproof integument, the skin which reduces loss of water from the radiation and convection and not by evaporation as it is in other animals. 2

3 (a) Explain the factors that influence the type of nirogen waster excreted by animals.

(b) Describe osmoregulation in a terrestrial insect

Solution

- Availability of water; animals in fresh water bodies have enough water available for dissolving any water products. They are able to dilute and excrete ammonia. For animals

in terrestrial habitats, where acquisition of water is a problem, the nitrogen nous waters produced are less soluble. Animals excrete urea while insects which take in less water excrete uric acid.

- Solubility of nitrogen wastes; aquatic animals excrete more water-soluble ammonia while those in terrestrial habitat excrete less soluble urea or uric acid depending on the amount of water available to them. Terrestrial animals that are able to drink water excrete urea while those that depend on metabolic water such as insects excrete the insoluble uric acid
- Toxicity of the waste products; animals excrete nitrogenous waste with toxicity that either can be withstood by their tissues or that can easily be detoxified in the body. In most terrestrial animals, ammonia is very toxic. It is first converted to urea in the body by combining it with carbon dioxide. Urea is less toxic and can safely be excreted from the body without harming the body tissues. Freshwater animals however, excrete the toxic ammonia because they have enough water available for its dilution before excretion. Insect excrete uric acid which is least toxic.
- Animal body size; all organisms with big surface area to volume ratio excrete nitrogenous wastes that are more soluble in water and therefore can easily diffuse out through the body surface. For example, amoeba and other unicellular animals excrete ammonia. For large organisms, with small surface area to volume ratio, the other factors determine the nature of nitrogenous wastes excreted

(b) Water must be carefully conserved since most terrestrial insects are unable to drink and depend on metabolic water

- During excretion, the urine passes from the Malpighian tubules into the ileum and is mixed with faeces with which it is then excreted via the rectum. In the rectum, the rectal glands absorb all the water into the body and uric acid is then excreted in solid from. The water deficit is made up by metabolic water.
- The salt fraction is regulated by the Malpighian tubules. In the proximal half, sodium and potassium ions are extracted from the blood, but carefully returned in the distal half with precipitation of uric acid. The uric acid passes in the urine to the ileum for excretion via rectum.

4 Describe the how terrestrial plants overcome the challenges of terrestrial environment. Or (*20 marks*)

Solution

(i) (a). They have shinny leaf surfaces to reflect much of the incident light rays do avoid overheating.

(ii) They have a thick, waxy cuticle impermeable to water. This reduces water loss from the plants surface.

(iii) Plants have developed a vascular system so as to pump water from the roots to all parts of the plant.

(iv) Flowering plants have developed pollen tubes to deliver the pollen to the ovule so as to allow for fertilization in the absence of water.

(v) Some have leaves reduced into spikes, which reduces the surface area over which water can be lost through transpiration.

(vi) In some xerophytes, the stomata open at night and close during day to reduce water loss during day.

(vii) Some have stomata sunken into hairy leaf surface to reduce water loss by transpiration.

(viii) Some plants produce pores and others seeds which withstand the dry conditions and help the plant to survive the long dry periods.

(ix) Most xerophytes reproduce by vegetative propagation, during the need for favorable conditions for germination

(x) They have tissue tolerant to desiccation.

(xi) Some plants reproduce by spores which are resistant to harsh conditions.

(xii) Flowering plants have reduced the gametophyte which is prone to desiccation in lower plants.

(xiii) Plants have developed a specialized tissue to provide support to the plant.

(xiv) They develop a deep extensive root system to exploit as much area as possible for water absorption.

(xv) Some shed their leaves occasionally to reduce water loss.

(xvi) Some have short life cycles that avoid droughts.

(xvii) Some species of plants roll their leaves with the lower surface inside during dry conditions. This reduces water loss through transpiration.

(xviii) Some species of plants have reduced their leaves into thorns to avoid browsing animals.

4. Describe how xerophytes survive conditions of un favourable water balance

Solution

Unfavourable water balance is a condition in which a plant has a tendency of losing more water then it can obtain from the soil. Xerophytes are plants that withstand in dry conditions. They have the same adaptations as in number 3

5. How are vertebrates adapted for terrestrial life?

- The vertebral column and limbs provide body support and aid in movement
- They have bones, joint, ligaments and muscle to effect movements.
- They have lungs for gaseous exchange
- The have well developed osmoregulatory organ by which loss is conserved.
- They develop impermeable cuticle to prevent water loss
- Long loop of Henle and fewer glomeruli reduce water loss through excretion
- They developed behavioural and physiological means of maintaining body temperature
- Have internal fertilization that prevent loss of sperms
- Produce shelled eggs to reduce water loss

6. Describe nitrogenous excretion in animals under the following headings

(a) The source of waste nitrogen and need for its removal (4marks)
Nitrogenous wastes are formed by deamination of proteins in the liver and must be removed from the body because they are very poisonous to the cells.

(b) The removal of waste nitrogen by freshwater animals and by terrestrial insects (5marks)
In freshwater invertebrate's nitrogenous waste like ammonia are lost by diffusion through the membrane
In vertebrates, nitrogenous wastes mainly ammonia are excreted with a lot of water through the kidney

(c) The way in which the structure and function of mammalian kidney is adapted for the efficient removal of waste nitrogen.

(i) Has tubules that are long and coiled providing a large surface area for efficient reabsorption

(ii) The tubules are long to allow enough time for reabsorption.
(iii) The tubules are well supplied with blood capillaries that carry way absorbed material maintaining diffusion gradient for further absorption
(iv) The efferent vessels are narrower than afferent vessels to build up filtration pressure
(v) Cells of proximal convoluted tubules possess microvilli that increase surface area for reabsorption
(vi) The cells of proximal convoluted tubules have high number mitochondria to provide energy for reabsorption of glucose
(vii) The loop of Henle is U-shaped to maintain high concentration of solutes in the medulla that facilitate efficient absorption of water.
(viii) The permeability of the distal convoluted tubule to water is modified by hormones (i.e. ADH and Aldosterone) for efficient osmoregulation
(ix) The basement of membrane of the Bowman's capsule allows filtration of small molecules while retaining big molecules like proteins. This creates high hydrostatic pressure in blood to facilitate reabsorption of water
(x) The ascending limb of the Loop of Henle pumps NaCl from renal filtrate into the medulla maintaining high osmotic pressure in the medulla that facilitates reabsorption of water.
(xi) The glomerular capillaries are highly branched to provide a large surface over which filtration occurs

Thank U Dr. Bbosa Science