HOMEOSTASIS

LEARNING OUTCOMES

(i) Understand the terms homeostasis, internal and external stimuli, receptors, central control, coordination system, effectors and negative feedback.

(ii) Describe the structure of kidney and its functions, structure of nephron with associated blood vessels, ultrafiltration, reabsorption and formation of urine.

(iii) Explain the terms osmoregulation and thermoregulation.

(iv) Explain types of kidney problems (Kidney stones and Renal failure) and cures (Lithotripsy, Kidney transplant and Dialysis-peritoneal and hemodialysis).

BASIC TERMS

Homeostasis

- The protection of internal environment from the harms of fluctuations in external environment is termed as homeostasis.
- The homeostasis keeps the internal fluctuations in a narrow range.
- Most susceptible components of internal environment that may be affected by fluctuations in external environments are water, solutes and temperature.

Control & Coordination

- The coordination makes possible the integration of functions essential to organismic behaviour.
- Coordination is must for any organism to survive. In the unicellular organisms, coordination exists between various cellular processes. In multicellular organisms, although there is division of labour among cells, yet every cell can respond to changes in its immediate vicinity.
- Control and coordinating systems in living organisms are either nervous system or hormones or both.
- External environment may show changes within broad range.
- Intracellular and extracellular internal environments also keep fluctuating but in narrow range. Here, in addition to solute and water various essential metabolites, hormones etc. are kept in required range. This control is brought about by control system.
- Living control system has three components i.e. receptor, control center and effector.

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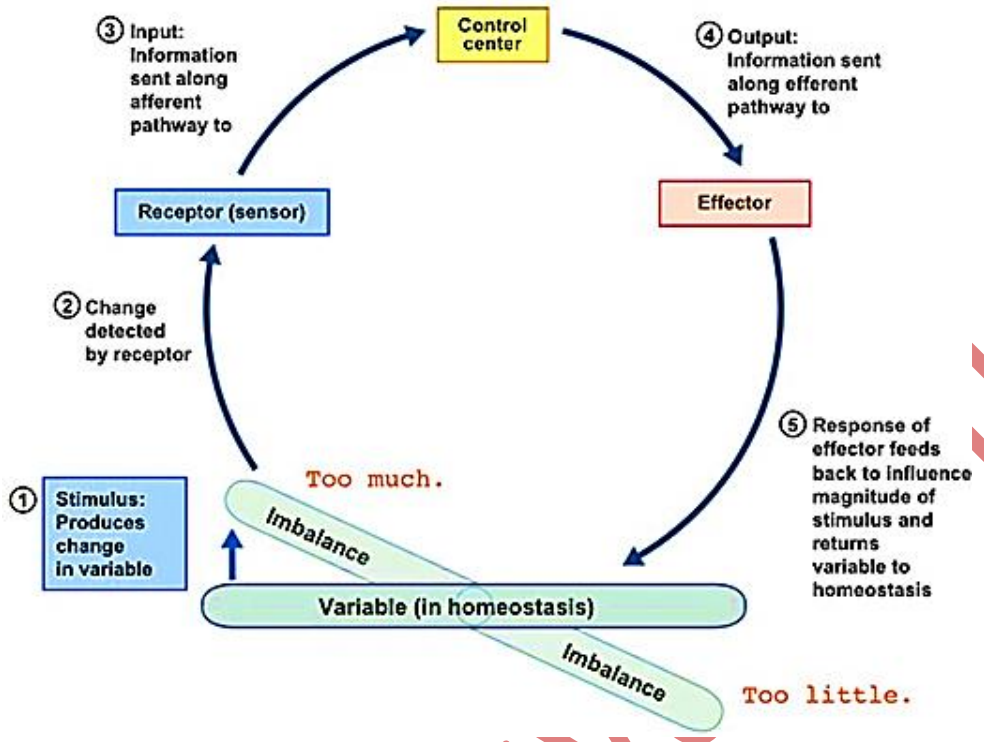


Stimulus

- Any change in internal or external environment is called stimulus.
- Change in temperature of atmosphere and light are examples of external stimuli.
- Change in solute or water concentration in blood are examples of internal stimuli.

Receptors

- These are the structures which detect change in external or internal environment.
- The receptors may be cells (e.g. rod and cone cells of eye), neuron endings (e.g. Pacinian corpuscles) and organs (e.g. nose, ear).
- Receptors are also classified on base of type of stimuli e.g. chemoreceptors, mechanoreceptors, thermoreceptors etc.

Control Centre

- It integrates data from receptor with data stored as set point.
- Control centre of most of the activities of humans is brain.

Effectors

- These are the structures which respond to stimulus.
- Effectors are either muscles or glands. Muscles show response by contraction while glands through secretions.

Feedback Mechanism

- Feedback mechanism is a type of interaction in which a controlling mechanism is itself controlled by the products of reactions it is controlling.
- For proper body functions, two opposing systems are needed, if there are accelerators, there must be inhibitors.
- Negative feedback is an inverse response to change in environment e.g. increase in body temperature will stimulate that system which lowers body temperature.
- Positive feedback involves a change in some variable that triggers mechanisms that amplify rather than reverse the change e.g. labour contractions during child birth.

NATURE OF EXCRETORY PRODUCTS IN RELATION TO HABITAT

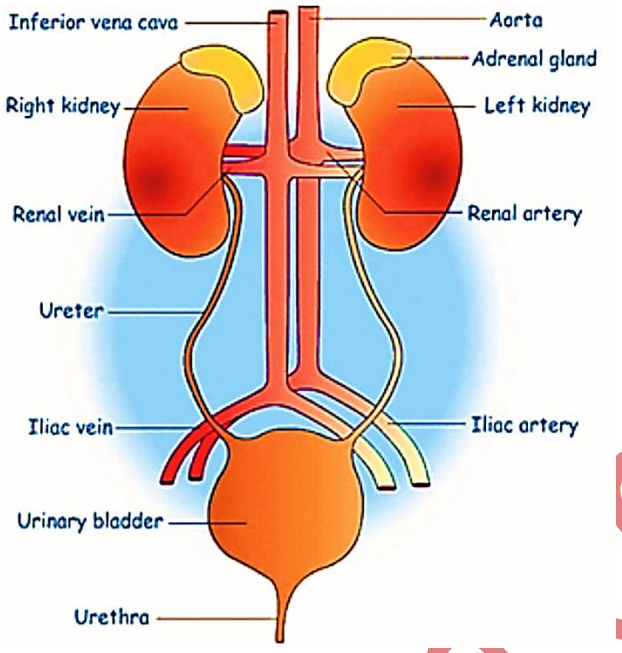
- Ammonia being very toxic, must be kept at very low concentration infect achieved by dissolving it in large amount of water, which is possible in hypotonic environment e.g., available to fresh water organisms.
- In limited water supply this is not possible, so other alternatives of ammonia are excreted like urea which requires less water. Ammonia is converted to urea by Urea Cycle.
- Ureotely and uricotely are evolutionary adaptations of nitrogenous waste in the habitat of terrestrial animals.

Habitat	Water supply	Nitrogenous waste	Toxicity	Amount of water/ 1g N to be excreted.	Related Terms For Animals	Examples
Aquatic	Maximum	Ammonia	Most toxic	500ml/1gN	Ammonotelic	Hydra, planaria
Terrestrial	Moderate	Urea	Less toxic	50ml/1gN (1/10 that of ammonia)	Ureotelic	Human
Terrestrial	Minimum	Uric acid	Least toxic	1ml/1gN	Uricotelic	Reptiles, birds

STRUCTURE AND FUNCTIONS OF KIDNEY IN HOMEOSTASIS

EXCRETORY & URINARY SYSTEM

- Excretory system of humans includes both liver and kidneys.
- Liver is involved in production of nitrogenous wastes (e.g. urea) while kidneys filter urea from blood and remove it outside the body in form of urine.
- Urinary system in humans is specialized for formation of urine and its removal outside the body. This urinary system includes kidneys and associated tubules like ureters, urinary bladder and urethra.
- Following filtration of blood and further processing through tubular system, urine is collected in the central cavity of the kidney called renal pelvis. Pelvis is proximal enlarged end of ureter.
- Urine leaves the kidney through a duct ureter.
- Ureters of both kidneys drain into urinary bladder through uretral orifice. Urinary bladder stores urine before its removal.
- Urine leaves the body during urination/ micturition, from the bladder through a tube called the urethra.
- Urethra empties near vagina in females or through penis in males.
- Sphincter muscles (Urethral sphincter) near the junction of urethra and urinary bladder control the urine in bladder. This is an example of dual sphincter.



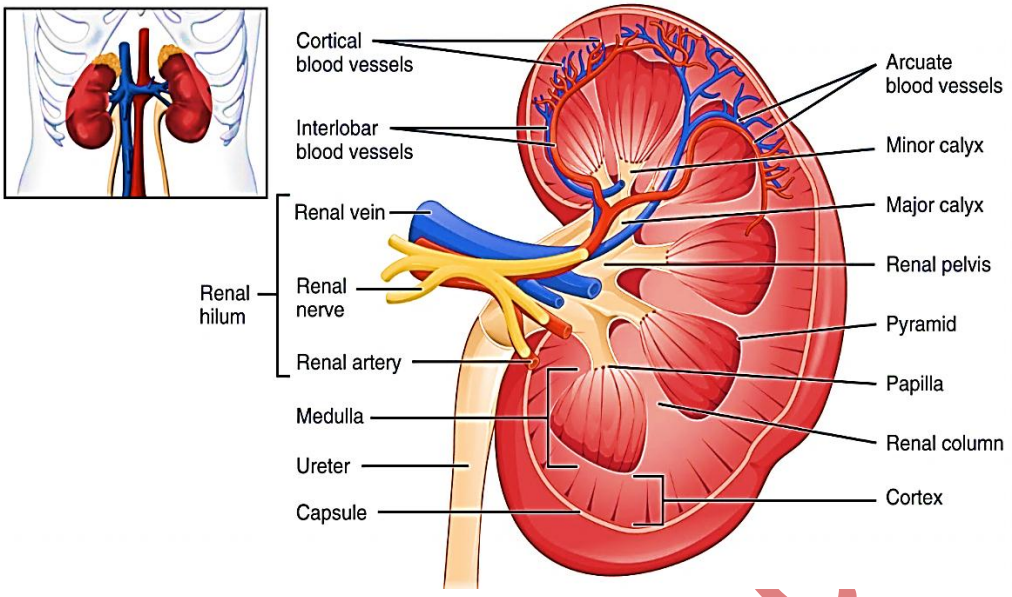
KIDNEYS

Introduction

- Humans have two kidneys placed in abdominal cavity, on both sides of vertebral column and attached with dorsal abdominal wall.
- Right kidney is slightly lower in position than left kidney due to longer right lobe of liver.
- A pair of kidneys consists of millions of functional units called nephrons or urinary tubules.
- Kidneys are not only the major excretory organs of humans but also act as an osmoregulator.
- Kidneys account for just less than ***1 %*** of the body weight, while they receive ***20%*** of blood supplied with each cardiac output.

Morphology

- Kidneys are bean shaped with inner concave and outer convex walls.
- Middle portion of kidneys by which all vessels enter, or leave is called renal hilus.
- Outer darker portion of kidney is called renal cortex while inner brighter portion is called renal medulla. Cortex contains renal corpuscles and convoluted tubules.
- Renal pyramids are conical parts of renal medulla containing blood vessels and collecting ducts. All the pyramids project into the pelvis.



Functions

- Kidneys are involved in filtration of wastes from blood, formation of urine and its removal outside the body through tubular system.
- Kidneys act as osmoregulatory organs and maintain solute and water level in blood and body.
- Kidneys also help to regulate blood volume and blood pressure.
- Kidneys also release a stimulus (erythropoietin) for production of RBCs.

NEPHRONS

- Basic structural and functional unit of a kidney is called ***nephron***.
- These are also called as urinary tubules.
- Each nephron is composed of renal corpuscle and renal tubule.

Types

- Nephrons are of two types i.e. cortical and juxtamedullary.
- Those nephrons that are present along the border of cortex and medulla, with tubular system looping deep in inner medulla are called juxtamedullary nephrons.
- The nephrons arranged along the cortex are called cortical nephrons.
- ***Juxtamedullary nephrons*** play important role in production of concentrated urine.

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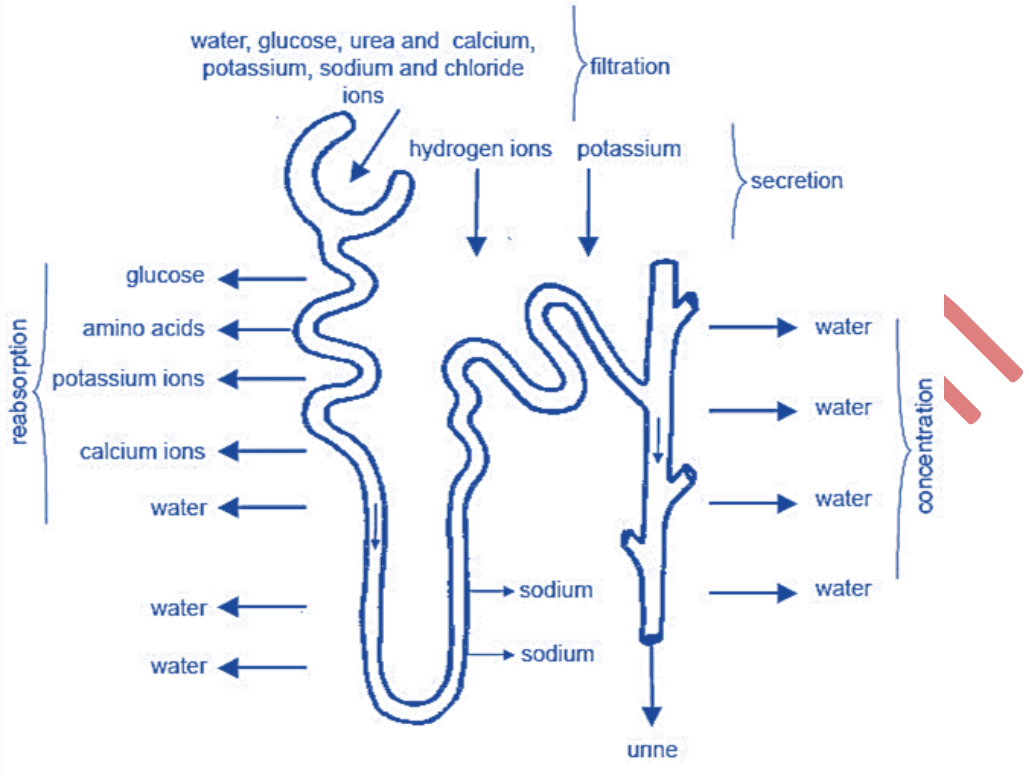
Structure & Functioning



Component	Anatomical Features	Physiological Features
Bowman's capsule	• Cup shaped • Blind end	Pressure Filtration
Glomerulus	• Cluster of blood capillaries inside Bowman's capsule • Porous walls • High blood pressure • Receives blood from afferent arterioles.	Pressure Filtration
Peritubular network	• Network of capillaries around tubular part • Receives blood from efferent arterioles • Vasa recta is additional loop in Juxtamedullary nephrons	Selective Reabsorption
Proximal convoluted part	• 1st convoluted part	• Selective Reabsorption • Maximum Reabsorption
Loop of Henle	• Descending/ Thin limb (Permeable to water) • Ascending/ Thick limb (Permeable to Na^+ ions)	• Selective Reabsorption • Counter Current Multiplier • Site of action of aldosterone • Tubular Secretion (Ascending

		Limb)
Distal convoluted part	2nd convoluted part	• Selective secretion
Collecting tubules	Changeable permeability for water	Reabsorption of water under action of ADH

Mechanism of Urine Formation

Urine formation involves following steps:

1. **Pressure Filtration/ Ultrafiltration**

- Blood passing through glomerulus is filtered into Bowman's capsule.
- Glomerulus walls are porous and the fraction of blood pressure reaching here provides the filtration pressure.
- The filtrate appearing in Bowman's capsule is called as glomerular filtrate, which contains various useful substances such as glucose, amino acids, salts etc.
- Composition of glomerular filtrate is same as plasma minus plasma proteins.

2. **Selective Reabsorption**

- It occurs at the tubular part of nephrons.
- Most of the useful constituents of glomerular filtrate (80%) are reabsorbed in proximal tubules and when filtrate leaves proximal tubules, it mostly contains nitrogenous wastes.
- Glucose, amino acids, vitamins and hormones are 100% reabsorbed while sodium chloride and water are 80% reabsorbed.

3. **Tubular Secretion**

- The tubular epithelium also secretes substances into the lumen.
- This secretion is very selective and is mainly of hydrogen ions to balance pH/ acid base balance of blood and filtrate.

CONCENTRATION OF URINE

- In restricted supply of water, the conservation of water is the principal function of the body. This is done by concentration of filtrate by counter current and hormonal mechanisms.
  Less H_2O/ Hyperosmotic Body Fluid → More ADH → More Reabsorption of H_2O → Less amount of concentrated urine.
- In the sufficient or excess supply of water, reabsorption of water from the filtrate is reduced, specifically due to inhibition of release of ADH in the presence of hypoosmotic body fluids. The reduction in reabsorption causes large volume of diluted urine.
  More H_2O/ Hypoosmotic Body Fluids → Less ADH → Less Reabsorption of H_2O → More amount of diluted urine
- Mammalian kidney including humans is adapted to conserve water by over 99.5% reabsorption of glomerular filtrate.

Factors for Concentration

1. **Structural Adaptation**

   Juxtamedullary nephrons and vasa recta are structural adaptations for concentration of urine.

2. **Hypertonic Environment of Medulla**

   The interstitial fluid of kidney is gradually concentrated from cortical to medullary part. Thus, inner medulla is highly concentrated due to presence of urea and counter current multiplier.

3. **Counter Current Multiplier**

   Counter current multiplier causes gradual osmotic outflow of water from the filtrate back to kidney as it passes downward in the descending loop of Henle. Ascending loop of Henle does

not allow outflow of water from its filtrate, instead actively transports Na ions into kidney interstitium to sustain its high concentration.

4. Hormonal Control

- The active uptake of sodium in the ascending limb or thick loop of Henle is promoted by the action of aldosterone, the hormone secreted from adrenal cortex.
- ADH released from posterior pituitary lobe acts to actively transport water from filtrate in collecting tubules back to kidney.

THERMOREGULATION

- Maintenance of internal temperature within a tolerable range is designated as thermoregulation.
- Animals are classified into three groups on the base of thermoregulation i.e. ectotherm, endotherm and heterotherm.
- Animals that generate their own heat through heat production as by product during metabolism are endotherms e.g. humans, birds, some fishes and flying insects.
- Animals which produce metabolic heat at low level (that is also exchanged with the environment quickly) and absorb heat from surroundings are called ectotherm e.g. most invertebrates, fish, amphibians and reptiles.
- Animals which are capable of varying degrees of endothermic heat production but generally do not regulate their body temperature within a narrow range are heterotherms e.g. bats, humming bird etc.

Thermoregulatory Adaptations in Animals

Adaptation	Examples
Structural Adaptations	• Changes in sub-dermal fatty layer insulation. • Pelage • Sweat glands • Lungs modification for panting
Physiological Adaptations	• Regulation of blood flow to skin (Vasodilation, Vasoconstriction). • Activation of muscles for thermogenesis • Plumage fluffing • Activation of sweat glands for evaporative cooling
Behavioural Adaptations	• Change in habitat • Change in body posture

THERMOREGULATION IN MAMMALS/ HUMANS

Regulatory Strategies

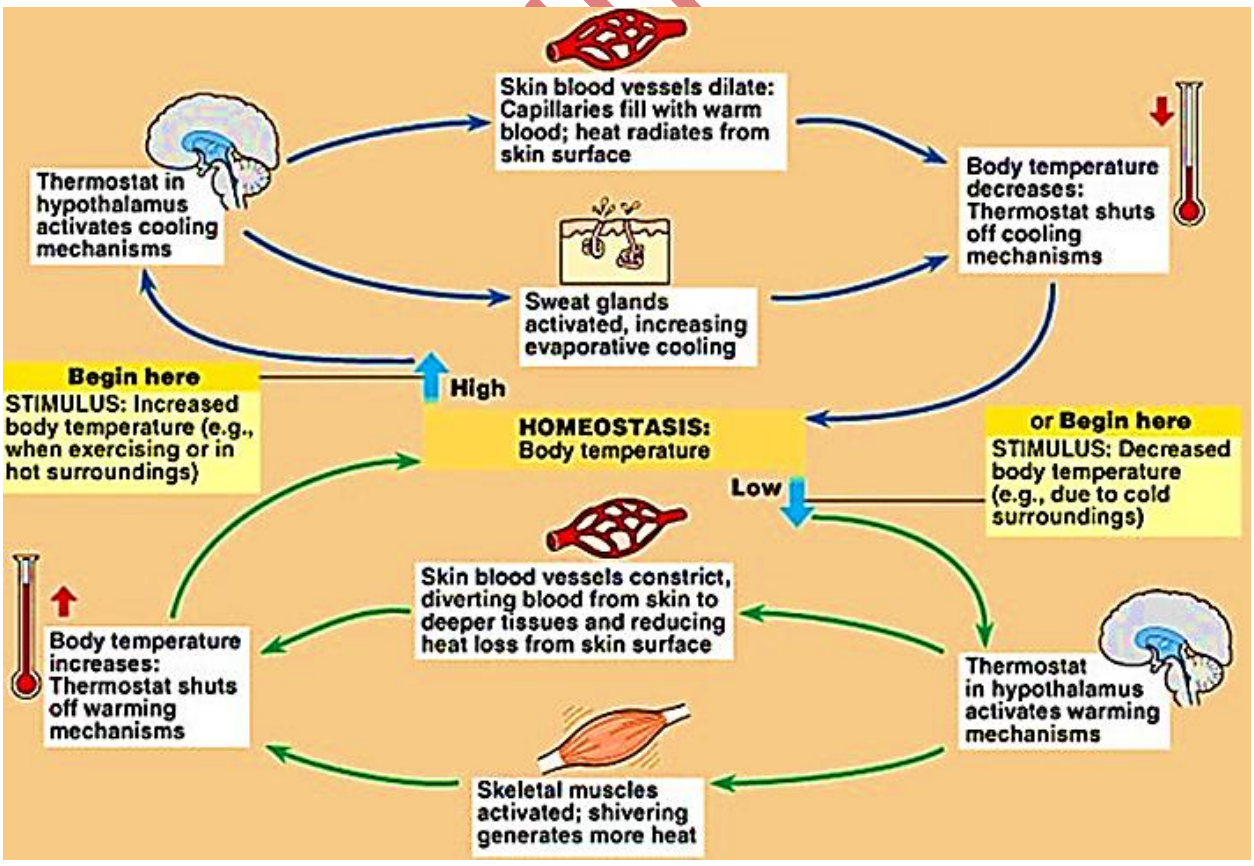
- Mammals including humans maintain their body temperature within a narrow range of about 36-38°C (36.1-37.8°C).
- Humans are endotherm.
- Hypothalamus is thermoregulatory centre in humans.

Strategies in Cold Temperature

- The rate of heat production is increased by increased muscle contraction by movements or shivering so called shivering thermogenesis.
- Hormones trigger the heat production as do thyroid hormones and are termed as non-shivering thermogenesis.
- Some mammals have brown fat, which is specialized for rapid heat production.
- Vasoconstriction occurs at skin which reduces rate of blood flow and also heat loss.
- Vasodilation occurs at trunk where most of the vital organs are located.
- Sweat glands are inhibited.
- Erection of hair in humans and raising of fur in others maintains body heat by trapping air and increasing insulation.
- Humans mostly rely on a layer of fat beneath skin acting as insulating layer. Similarly marine mammals like whales and seals inhabit much colder water and have a thick layer of insulating fat called blubber just under the skin.

Strategies in Warm Temperature

- Vasodilation occurs at skin which increases rate of blood flow and more heat loss.
- Heat dissipation occurs either through evaporation, radiation, conduction or convection.
- Sweat glands are activated which promote evaporative cooling. In some mammals, this evaporative cooling occurs in the respiratory tract (panting in dogs) or through saliva and urine (as in bats).



KIDNEY PROBLEMS AND CURE

KIDNEY STONES

- Stone formation in kidney and urinary bladder, results in obstruction to flow of urine, increases susceptibility to infection and thus eventually leads to kidney failure.

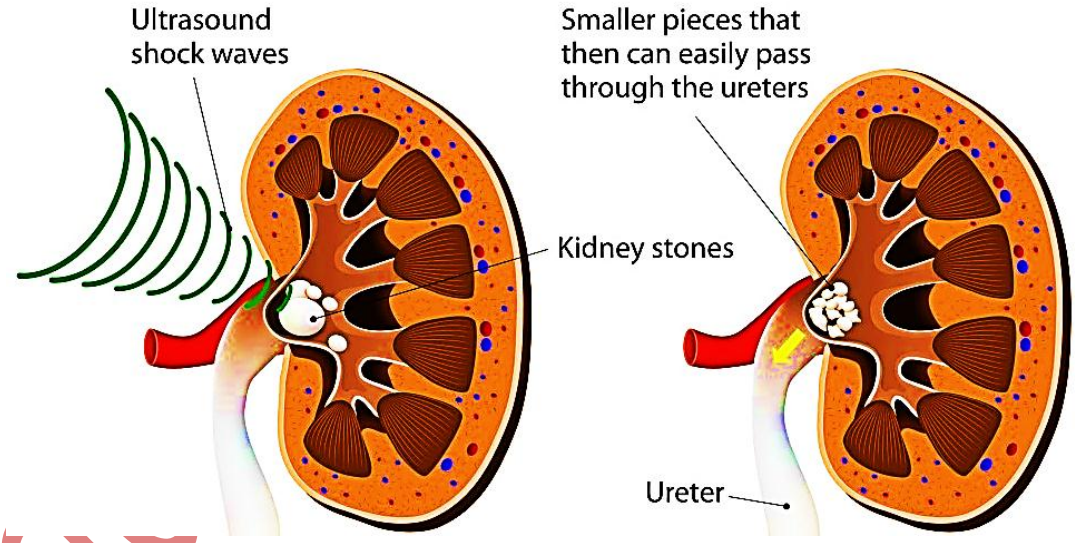
Types of Stones

- Different types of kidney stones are as follows:

Type of Stone	%Age	Cause
Calcium oxalate	70%	• Higher level of oxalates in blood. • Increased use of tomatoes and green leafy vegetables.
Calcium phosphate	15%	• Hypercalcemia (high level of Ca^{2+} in the blood) • Hyperparathyroidism
Uric acid	10%	• Increased uric acid level in blood • High protein intake in food

Cure

- Lithotripsy is used for non-surgical removal of smaller kidney stones.
- ***Extracorporeal shock wave lithotripsy*** **(ESWL)** is the one opted for small kidney stones. This is a minimal invasive surgery, in which kidney, pelvic or ureteric stones are broken down by bombarding ultrasounds or X- rays on them without giving any cut.
- Smaller stone pieces are flushed through ureter and then through urethra out of the body.
- ***Renal surgery*** is done for larger stones which can't be broken by lithotripsy technique. Direct surgical exposure and removal of stone is done.



RENAL FAILURE

- Failure of all the kidney functions i.e., excretory, osmoregulatory, hormonal (secretion of erythropoietin) and metabolic function is called renal failure.
- Nephrons are destroyed particularly at glomerular part, leading to accumulation of urea, other waste materials, bone weakening and anemia.

Causes

- Acute renal failure can occur due to blood clot or cholesterol deposits. Certain chemotherapy drugs, antibiotics and toxins such as alcohol, heavy metals and cocaine can also cause kidney failure.

- Most common causes of chronic renal failure are diabetes and hypertension. Other causes include long-term daily use of anti-inflammatory drugs and other analgesic medicines.

Cure

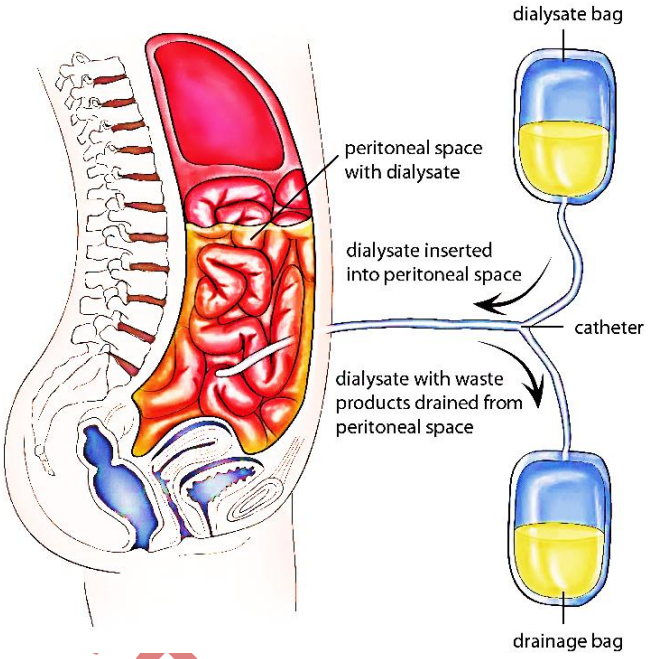
It is either dialysis or kidney transplantation.

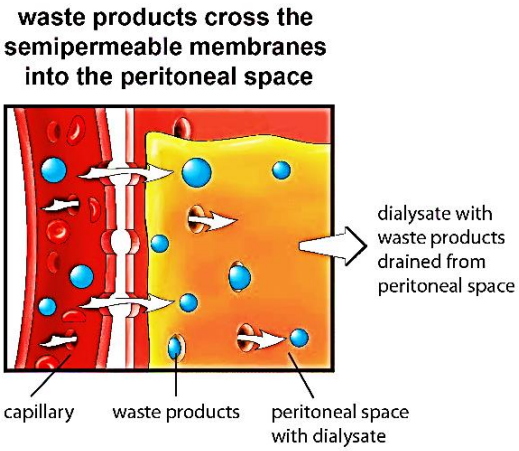
Dialysis

- The process of artificially removing nitrogenous wastes is called dialysis**.**
- The waste materials e.g. urea from the blood, either by pass kidneys through an artificial kidney (dialysis machine) or filtering it within the abdomen.
- Dialysis is of two types i.e. peritoneal dialysis and hemodialysis.

1. Peritoneal Dialysis

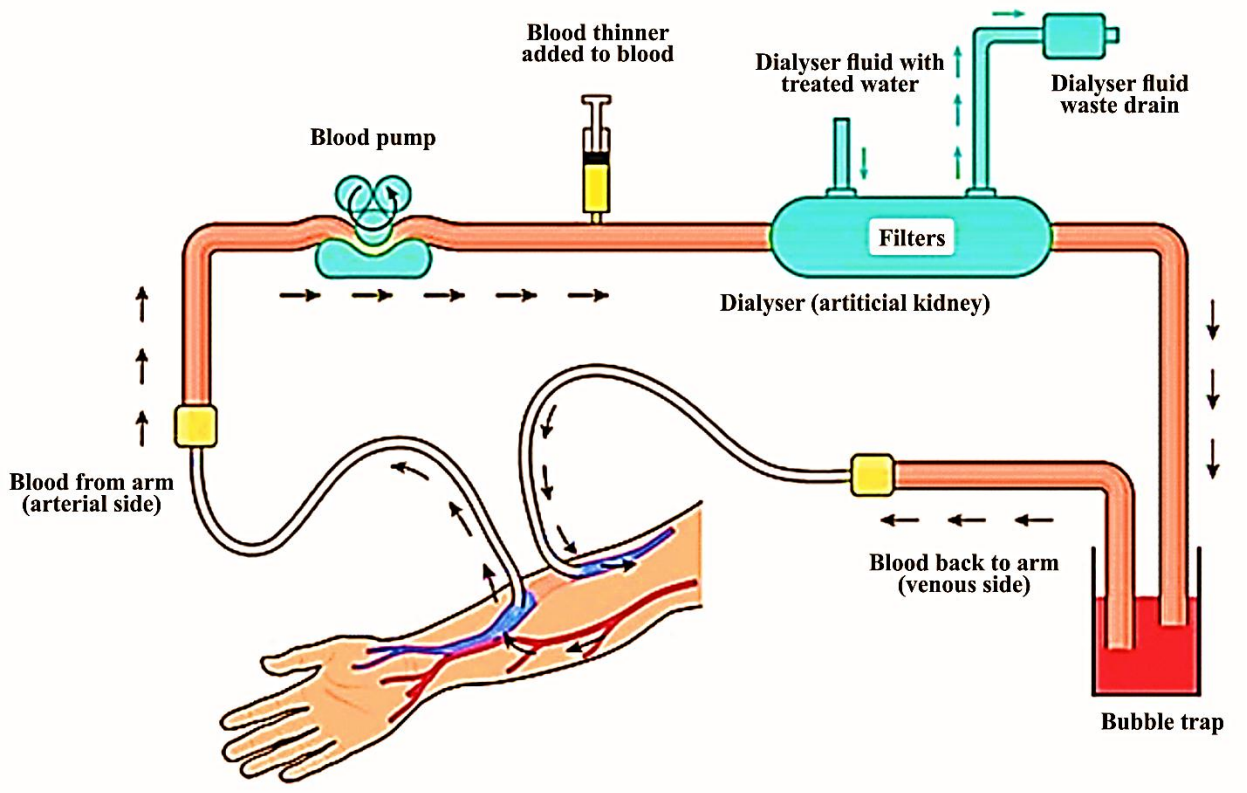
- ***Peritoneal dialysis*** uses the peritoneum (inner lining of abdomen) to filter the blood present in peritoneal blood vessels.
- Peritoneal cavity is filled with dialyzing solution. Waste materials having high concentration in blood are filtered through peritoneum into the peritoneal cavity containing dialyzing solution, which is removed afterwards.





2. Hemodialysis

- Hemodialysis means cleaning the blood.
- Waste material in blood is filtered by passing it through a machine which contains a dialyzer also called ***artificial kidney*****.**
- It is made of two spaces separated by a thin membrane. Blood flows inside the membrane in one direction and dialyzing fluid outside the membrane in another direction.



Renal Transplant

- It is considered permanent treatment. Since dialysis can only be done on temporary basis.
- Mostly opted in severe renal failure, called uremia or end-stage renal disease.
- Only a matched kidney (blood/HLAs and tissue matching) can be transplanted in an individual. So it needs donor-recipient matching.