MJC 4 (Physiology)

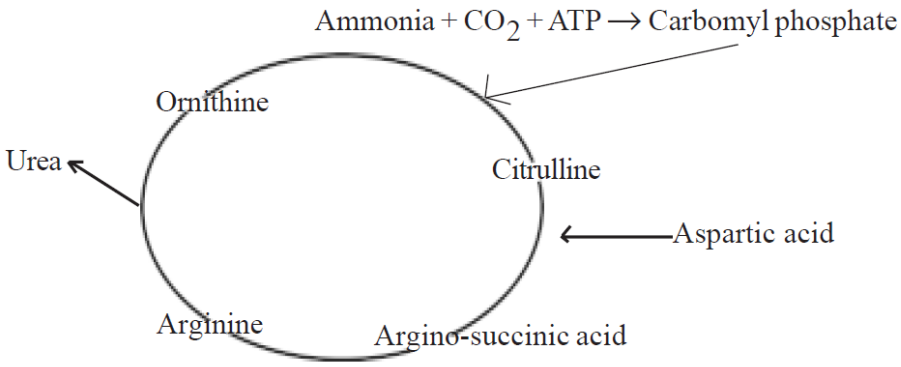
Physiology of Excretion

As a result of continuous synthesis and breakdown of materials many waste products are formed in cells. The process by which the cellular nitrogenous wastes are eliminated is called excretion. Three main nitrogenous wastes are ammonia, urea and uric acid. Various vertebrates excrete different form of nitrogenous wastes, according to the nature of their habitat and availability of water.

Ureotelism

Ureotelism is an adaptation for a semi-terrestrial habitat. Urea requires only a small quantity of water to form urine and never involves much water loss; Further, urea is much less toxic than ammonia and it can be retained in blood for some time before it is transported and eliminated through the excretory organs. Though the concentration of urea in the blood is small, it can be stored safely in the bladder in high concentration. Thus, ureotelism is conditioned by the shortage of water, characteristic of the terrestrial habitat.

Urea Biosynthesis (Ornithine Cycle)



Liver is the principal organ of urea biosynthesis. In the ornithine cycle, ammonia, formed by deamination in cells and tissues, combines with carbon dioxide to form carbamyl phosphate. This compound is subjected to a cyclic chemical reaction as provided in the figure. Three molecules of ATP are spent to convert the toxic ammonia into a molecule of urea.

Nephron

Nephron is the structural and functional unit of the kidney. There are about a million nephrons In general, the kidney performs the following vital functions in the body:

1. *Excretion of waste products* resulting from protein metabolism.
2. *Regulation of acid-base balance* by excretion of H^+ ions (acidification) and bicarbonate ions.
3. *Regulation of salt-water balance* by hormones secreted both intra-and extra-renally.
4. *Formation of renin and erythropoietin* and thereby playing a role in the regulation of blood pressure and erythropoiesis respectively.

Mechanism of urine formation

Urine is continually formed by each nephron and the processes involved in the formation of urine are Glomerular ultra filtration, Tubular Reabsorption, Tubular Secretion.

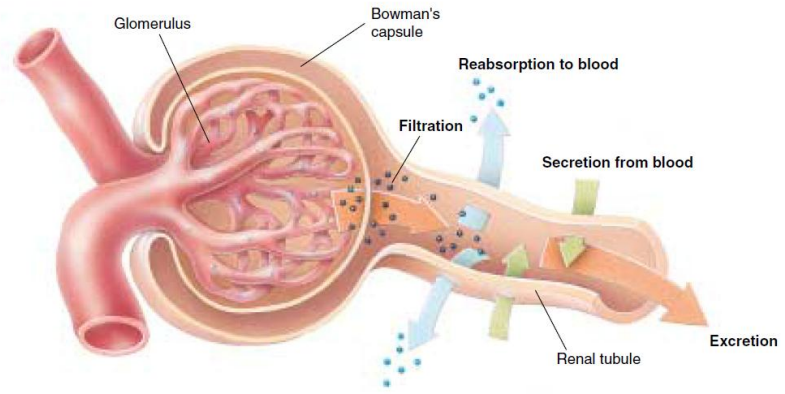


FIGURE 58.19
Four functions of the kidney. Molecules enter the urine by *filtration* out of the glomerulus and by *secretion* into the tubules from surrounding peritubular capillaries. Molecules that entered the filtrate can be returned to the blood by *reabsorption* from the tubules into surrounding peritubular capillaries, or they may be eliminated from the body by *excretion* through the tubule to a ureter, then to the bladder.

Glomerular ultra-filtration

Ultrafiltration of blood takes place in the malpighian body which acts as a biological filter. A malpighian body comprises Bowmann's capsule and glomeruli.

Dynamics of filtration

The kidneys normally receive an abundant blood supply of about 1200ml/min or about 20 to 25 percent of the cardiac output. It flows through the capillaries of glomerulus where the blood pressure is comparatively high. The high blood pressure brings about effective filtration. The hydrostatic pressure (forward pressure 75mm/Hg.) of the blood in the afferent glomerular capillaries and the cumulative effect of the opposition pressures and renal intratubular pressure (10mm/Hg.) play an important role in producing the glomerular filtrate. The hydrostatic pressure of the blood is always greater than the opposing pressures existing in the plasma protein and renal capillaries. Thus, the available net filtering force (75-50mm/Hg. = 25mm/Hg.) is chiefly responsible for glomerular filtration. The fluid in the capsule which is obtained by the process is termed glomerular filtrate. The volume of the glomerular filtrate produced each minute is called **glomerular filtration rate** (GFR). In man it is about 125ml/min. In 24 hours, the total volume of glomerular filtrate is 170 to 180 liters.

Tubular Reabsorption

This is the second step in the urine formation. The glomerular filtrate contains many useful substances such as glucose, amino acids, mineral salts and vitamins dissolved in large amount of water. Reabsorption takes place in the uriniferous tubules. Reabsorption of useful substances is a differential or selective process. Substances such as glucose, sodium and calcium, are called "high threshold substance". They are actively reabsorbed in considerable quantities. Substances like urea and uric acid etc which are called "low threshold substances" are reabsorbed in small quantities by a simple diffusion process or passive reabsorption. Substances like creatinine are not reabsorbed. They are completely eliminated.

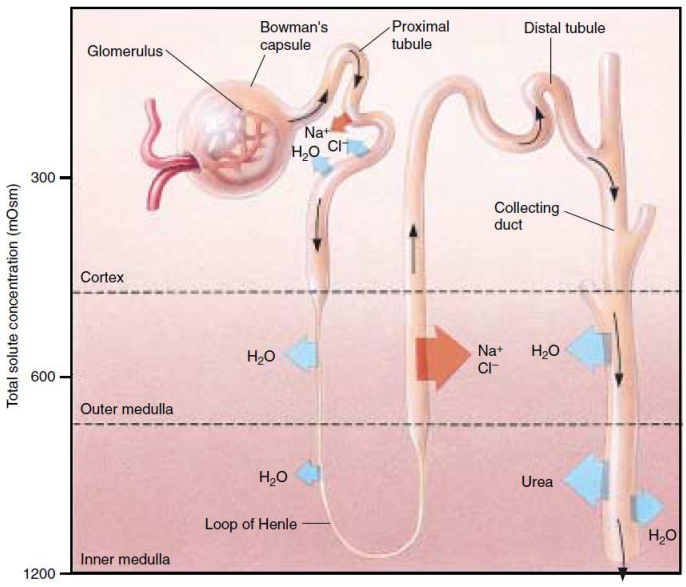
Reabsorption in Proximal Convoluted Tubule

Proximal convoluted tubule is responsible for the reabsorption of water, glucose, sodium phosphate and bicarbonates. The urine is found to be isotonic in the proximal convoluted

tubule. Isotonic condition of a solution indicates no passage of water across the membrane separating two such solutes.

Reabsorption in Henle's loop

Urine becomes more and more hypertonic as it passes through the descending limb of the loop of Henle's. This is due to the fact that the thin descending portions of the Henles loop are freely permeable to sodium. As the urine slowly passes through the thick ascending limb of the loop of Henle, it becomes less hypertonic since the sodium is actively transported from the ascending limb to the descending limb through the interstitial tissue space.



lute (hypotonic) as it enters the cortex, while the surrounding tissue becomes increasingly concentrated (hypertonic).

FIGURE 58.20
The reabsorption of salt and water in the mammalian kidney. Active transport of Na^+ out of the proximal tubules is followed by the passive movement of Cl^- and water. Active extrusion of NaCl from the ascending limb of the loop of Henle creates the osmotic gradient required for the reabsorption of water from the collecting duct. The changes in osmolality from the cortex to the medulla is indicated to the left of the figure.

Reabsorption in distal convoluted tubule

On entering the distal convoluted tubule, the urine becomes nearly isotonic to the surrounding tissue fluid due to the active transport of sodium and passive transport of water.

Reabsorption in collection tubule

As urine (isotonic) passes into the collecting tubule it becomes once more hypertonic by the osmotic reabsorption of water under the influence of the hormone ADH. The release of ADH is controlled by the osmoreceptors in the hypothalamus in response to changes in the osmotic pressure of the plasma circulating through the collecting tubule. Thus the urine formed contains 96% of water, 2% urea and 2% of the metabolic products.

A comparison of the amounts of various substances in 24 hrs in the glomerular filtrate and excretion

Substance	Amount filtered each day	Amount excreted in Urine each day
Water	180 ltrs	1-2 ltrs
Protein	2g	0.1g
Sodium	580g	5g
Chloride	640g	6g
Potassium	30g	2g
Bicarbonate	275g	0
Glucose	180g	0
Urea	53g	25g
Uric acid	8.5g	1g
Creatinine	1.6g	1.6g

Tubular Secretion

This is the final step in the formation of urine during which the walls of tubule actively remove additional waste substances which are harmful to the body from the blood that have escaped filtration.

Renal Failure

The reduction in the ability of the kidneys to filter waste products from the blood and excrete them in the urine is called as renal failure. The regulation of the water balance, salt balance and control of blood pressure are impaired due to kidney failure. The kidney failure also leads to uraemia (a built up of urea and waste products) and other chemical disturbances in the blood and tissues. This leads to various disorders and symptoms. Kidney failure can be acute (of sudden onset) or chronic (developing more gradually). In acute Kidney failure kidney function returns to normal once the causes have been discovered and treated. In chronic kidney failure the kidney function does not revive since it is caused by poor supply (flow) of blood, major illness, heart attack or pancreatitis. This damages the kidney tissue and its function. Heart transplantation is suggested for chronic type of failure.

Dialysis

Dialysis involves a technique used for removing waste products from the blood and excess fluid from the body as a treatment for kidney failure.

Why it is done?

The kidneys filter approximately 1500 liters of blood daily. From this volume of blood, the kidney reabsorbs important elements such as sodium, potassium, calcium, amino acids, glucose and water. In people whose kidney have been damaged this process may fail either suddenly (in acute kidney failure) or gradually in chronic renal failure. Waste starts to accumulate in the blood, with harmful, sometimes even life-threatening effects. In severe cases, the function must be taken over by artificial means of dialysis. Dialysis is called artificial kidney.

Kidney Machines

A kidney machine is a mechanical device through which a patient's blood passes. The blood leaves the body usually from an artery in the forearm and return to a nearby vein. Inside the machine the blood flows over or between membranes containing dissolved fluid (Dialysing fluid) and salt in concentrations normally found in blood. Solid constituents in the blood in excess of normal concentrations diffuse across the membrane into the dialyzing fluid. In this way waste like urea which accumulate in the body are extracted. Blood cells and protein remain in the blood. The process is called haemodialysis.

Kidney transplantation

Kidney transplantation refers to an operation in which a diseased kidney is replaced by a transplanted healthy kidney, either from a living donor or from a person who has just died (cadaver). One healthy donor kidney is sufficient to maintain the health of the recipient. Factors in improving the results of transplant surgery are

(1) To prevent rejection, effective immune suppressant drug treatment is given.

(2) Tissue typing is necessary to help in matching recipient and donor tissue for transplant surgery thus minimizing the risk of rejection of a donor organ by the recipient's immune system.
(3) After removal of organ from the donor it should be washed with an oxygenated fluid and cooled. This reduces the risk of damage.

Diabetes mellitus

Diabetes mellitus is the metabolic disorder of carbohydrate metabolism caused by insufficient or nil production of the hormone *insulin* by the *pancreas.* Insulin is responsible for the absorption of glucose into cells for their energy needs and into the liver and fat cells for storage as glycogen reserve. Insulin deficiency may be due to (1) pancreatic disorders (2) defects in the synthesis of insulin from Beta cells of Langerhans (in pancreas) (3) destruction of Beta cells and (4) genetic defects etc.

Symptoms

(1) The blood sugar level is more than 120mg. in diabetic patients.
(2) Untreated diabetes exhibits the following symptoms. **(a) Polyurea -** excretion of increased quantity of urine. **(b) Polydipsia** – excessive thirst leading to increased consumption of water. **(c) Polyphagia** – excessive appetite leads to increase intake of food. In spite of over eating, diabetic patient loses weight. (3) Weakness and body pain are the common symptoms.
(4) The body's inability to store or use glucose causes weight loss, insatiable hunger and fatigue.
(5) Diabetes mellitus also results in abnormal (fat) metabolism.
(6) Accelerated degeneration of small blood vessels.

Types of diabetes mellitus

Insulin-dependent type: This type develops due to heavy viral infection which reduces the production of insulin.
Non-insulin dependent: This is due to inadequate amount of insulin production. Obesity (over weight) is the major reason. This type usually of gradual onset and develops mainly in people over 40. Recently insulin resistant diabetes is commonly noticed and reported in younger persons too.

Causes for Diabetes

(1) Diabetes tends to run in families so it occurs in people who inherit the genes responsible for the insulin dependent form.
(2) Viral infection that damages the pancreas causing the deficiency of insulin.
(3) Obesity is the major cause leading to development of non-insulin dependent diabetes.
(4) Severe illness such as pancreatitis and thyrotoxicosis cause diabetes.
(5) Intake of drugs like corticosteroid drugs and diuretic drugs.

The preventive measures comprise

(1) Maintenance of normal body weight through adoption of healthy nutritional habits and physical exercise.
(2) Correction of over nutrition and obesity may reduce the risk of diabetes and its complications.
(3) Alcohol and smoking should be avoided.
(4) Control of high blood pressure, elevated cholesterol and high triglyceride levels.
(5) Susceptible persons can prevent diabetes by avoiding the risk factors.