

BENG 100 Frontiers of Biomedical Engineering
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Chapter 9

SUMMARY

- Excretion of molecules by the liver and kidney, and biotransformation of compounds in the liver, are responsible for elimination of wastes (such as urea), elimination of toxins (such as drugs), and maintenance of homeostasis.
- Biotransformation occurs primarily within hepatocytes, the primary functional cells of the liver.
- The kidneys received 25 % of the cardiac output: this high flow rate of plasma feeds 1 million nephrons—which are organized collections of tubules, blood vessels, and interstitial spaces.
- The nephrons create, by filtration, an ultrafiltrate of plasma, which is processed during flow through the tubules to reabsorb vital compounds and secrete unneeded compounds.
- Filtration occurs in the glomerulus, which creates an ultrafiltrate of blood by pressure driven flow.
- Reabsorption and secretion of compounds within the renal tubules is determined by the properties of tubular epithelial cells.
- Differences in osmotic pressure between the tubular fluid and the interstitial fluid create the driving force for water reabsorption, which is regulated by hormones such as ADH due to its effects on water permeability.

KEY CONCEPTS AND DEFINITIONS

afferent arterioles – the branch of the artery that supplies blood into the glomerulus of each nephron.

bile – a greenish brown alkaline fluid that aids digestion of lipid substances and is secreted by the liver and stored in the gall bladder

biotransformation – the alteration of a substance, such as a drug by chemical reactions within the body usually from a toxic state to a less toxic state.

bowman's space – a capsule shaped membranous structure surrounding the glomerulus of each nephron in the kidneys of mammals that extract wastes, excess salts and water from

the blood.

clearance – is the imaginary volume of the renal blood plasma for which a substance X is completely cleansed (or cleared) per unit time.

countercurrent multiplication – the process by which mammalian kidney is able to produce hyperosmolar urine.

dialysance - The number of milliliters of blood completely cleared of any substance by an artificial kidney or by peritoneal dialysis in a unit of time.

dialysate – fluid used on the other side of membrane during dialysis to remove impurities.
distal tubule – a portion of the kidney tubule connecting the ascending limb of the loop of Henle to the collecting duct.

efferent arterioles – a blood vessel that carries blood filtered through the glomerular capillaries away from the nephron.

fenestrated – having larger openings to allow larger molecules to diffuse.

glomerulus – a cluster of blood capillaries around the end of the kidney tubule where waste products are filtered from the blood.

glomerular filtration – the filtration of blood plasma that flows from the afferent arteriole through the glomerulus to the efferent arteriole.

glomerular filtration rate - the volume of fluid filtered from the renal glomerular capillaries into the Bowman's capsule per unit time

hemodialysis - a type of renal dialysis whereby the blood of person who suffers from kidney failure is cleansed outside the body.

hepatocyte – a liver cell

homeostasis – the process whereby the organism is able to maintain a stable internal environment through physiological processes.

kidney – a bean shaped organ present in mammals, birds and reptiles designed to excrete nitrogenous waste from the organism's body.

mass balance – a method of accounting for material entering and leaving a system which operates on the conservation of mass principle that states that matter can neither disappear or be created.

metabolite – a small molecule that is formed in or needed for metabolism.

micturate – to urinate

loop of Henle – part of the kidney tubule that forms a long loop in the medulla region of the kidney, from which water and salts are reabsorbed into the blood.

nephron - a functional unit of the kidney consisting of a glomerulus and its associated tubules from which urine is produced.

oncotic pressure – a term used to refer to the osmotic pressure difference when it arises due to the presence of proteins instead of ion electrolytes.

osmolarity – a measure of the total number of solutes per liter of solution.

plasma clearance – See clearance

plasma clearance rate – See clearance

proximal tubule – the first portion of the kidney tubule with striated border that connects and carries fluid from the glomerulus to the loop of Henle.

rate constant – a proportionality constant in an expression relating concentration of reactants with the reaction rate.

renal artery - an artery that arises from the abdominal aorta and supplies blood to the kidneys.

renal pelvis – the broadened top part of the ureters into which kidney tubules drain.

renal vein - a vein that carries filtered blood away from the kidneys.

kidney tubule – a small tube in the kidney that filter blood and produce urine.

tubular reabsorption – a process whereby water and solutes such as glucose, amino acids and ions are transported back into the blood from tubular fluid in kidney tubules.

tubular secretion – a process whereby materials from the peritubular capillaries are transported into the tubular fluid in the renal tubules.

ultrafiltrate – a term used in renal physiology to describe material that is unfiltered and remains in the liquid phase after filtration.

ultrafiltration – a term used to describe in kidney physiology glomerular filtration where very small particles are separated from proteins, cells and other larger components of the blood.

ureters – the duct by which urine passes from the kidney to the bladder or cloaca.

urethra – the duct by which urine passes to the outside of the body from the bladder. It is also the duct through which semen passes to the outside in males.

urinary bladder – a hollow muscular distensible sac that serves as a reservoir for urine prior to excretion by urination.

QUESTIONS

1. Give three examples of chemical reactions in the body that produce water molecules.
2. Why is a high-pressure capillary system required in the kidney?
3. Describe the characteristics of the glomerular membrane and its permeability to various substances.
4. Write a short essay that distinguishes the process of excretion from secretion.
5. A substance is present in the urine. Does this prove that it is filtered in the glomerulus?
6. The concentration of urea is always higher in urine than in plasma. Does this suggest that urea is secreted?
7. For the following steps in urine formation, state where it occurs and what is the purpose:
 - a) tubular reabsorption and b) tubular secretion.
8. The nephrons of some animals, particularly those adapted to survive in the desert, have loops of Henle that are much longer, relatively, than those of humans. What is the potential benefit of a longer loop of Henle?
9. Explain why some clinicians might describe the HH equation as $\text{pH} = \text{constant} +$ (Kidney/Lung)?
10. At steady-state, how much sodium chloride is excreted per day in the urine of an individual who is consuming 12 g of sodium chloride per day: a) less than 12 g; b) 12 g; or c) more than 12 g?