COMPARATIVE EXCRETORY SYSTEMS

Organisms use different **excretory systems** to get rid of their metabolic wastes. They are generally composed of a network of tubules that provide a large surface area that allow exchange of water and solutes, including nitrogenous wastes. Simple and primitive systems evolved in microorganisms and invertebrates before complex kidneys in vertebrate animals: cell membrane, contractile vacuole, protonephridia or flame bulb system, metanephridia, and Malpighian systems.

Cell Membrane

Microorganisms like bacteria, protozoa, and fungi are bound by cell membranes through which meta
They exchange materials with the
membrane. In some cells such as tl
human white blood cells, the cell mem
food particles or foreign materials
involution of the cell membrane forming vesicles.

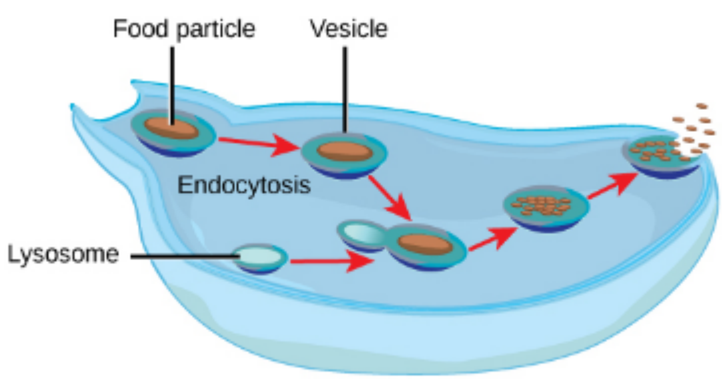

Figure 6.4 The cell membrane is used to exchange materials with the environment. An *Amoeba* takes in food via endocytosis and expels wastes through exocytosis.

(Photograph retrieved from https://opentextbc.ca/biology/chapter/22-3-excretion-systems/

The vesicle formed from endocytosis is then fused with a **lysosome** wherein enzymes digest the engulfed particle. The resulting wastes and excess water get excreted through exocytosis upon fusion of the vesicles with the cell membrane.

Contractile Vacuoles

Many freshwater protists such as *Paramecium* possess a specialized cytoplasmic organelle called a *contractile vacuole* that expels excess water out of the cell to prevent lysis. The freshwater environment of the *Paramecium* is hypotonic and results in the osmotic movement of water into the cell. Radial canals which surround the contractile vacuole function to absorb excess water in and channel this to the contractile vacuole. with water, the contractile vacuole contracts water out of the cell. Upon relaxation, water is a the contractile vacuole and the pumping activity In this way, the contractile vacuole functions [illegible]atic maintenance of normal water volume or *turgor pressure*, and therefore in osmoregulation.

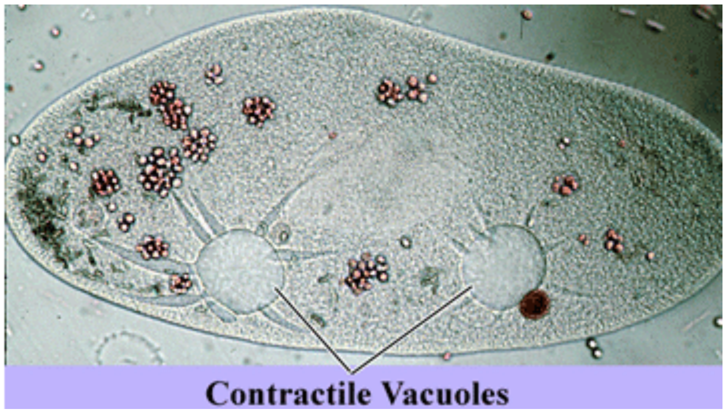

Figure 6.5 Contractile vacuole in *Paramecium* functions in osmoregulation.

(Photograph retrieved from http://www.linkpublishing.com/video-transport.htm

Protonephridia or Flame Bulb System

The evolution of more complex multi-cellular systems was accompanied by the evolution of more complex organs that perform excretory function. The excretory systems of flatworms (Phylum Platyhelminthes) such as Planaria are composed of units called **protonephridia** (singular, protonephridium) (Figure 6.6).

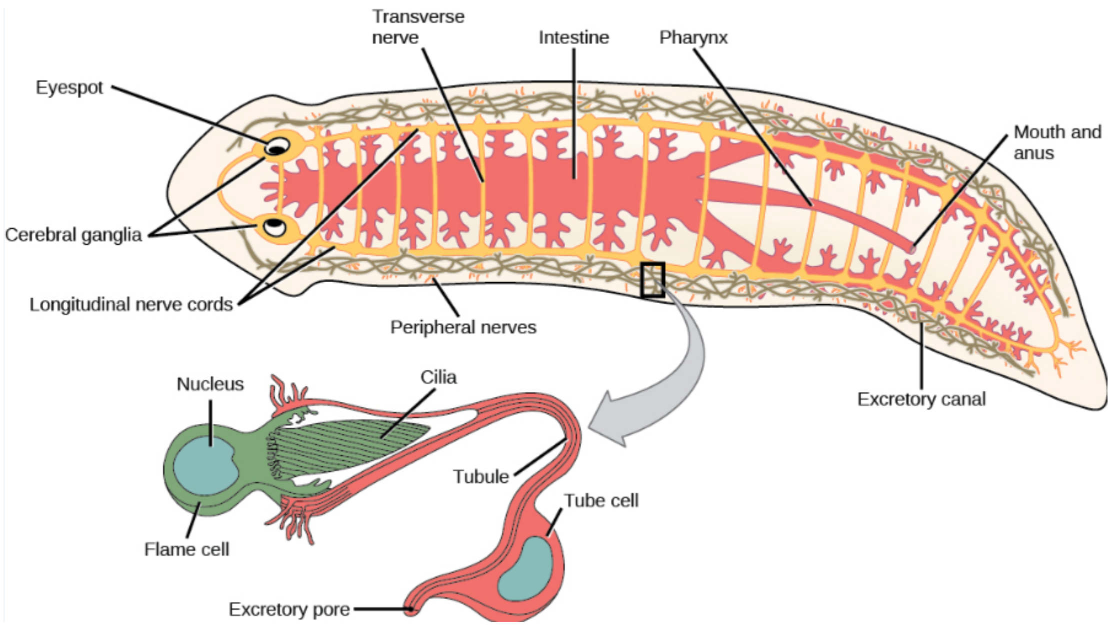

Figure 6.6 Protonephridia in *Planaria* are made up of a network of tubules with flame cells.

(Photograph retrieved from https://archive.cnx.org/resources/ee4890fe94ca2db15dfc8d69fbae42666e3c4f89/Figure_28_03_01.jpg ART:

Protonephridia, also known as *flame bulb system* refer to network of tubules on each side of the flatworm body. These tubules lack internal openings but have external openings or excretory pores at the body surface called *nephridi* internal portion of the protonephridium that is in c the interstitial fluid consists of a tube cell cap flame bulb or cell that has a cluster of cilia proj the tubule. The name flame bulb was derived from the cilia that is similar to a flickering flame.

During filtration, the movement of the cilia p and solutes from the body fluids through slits in the and the filtrate is released into the tubule networ molecules and ions are removed by reabsorption while and nitrogenous wastes move outward through the tub and excreted as urine via the nephridiopore. The freshwater flatworms is low in solutes, helping k osmotic uptake of water from the environment.

Aside from flatworms, protonephridia are also rotifers, some annelids, mollusk larvae, and lancel these animals, the function of the protonephridia vari

Metanephridia

The excretory tubule of most annelids is referred to as metanephridia (Figure 6.7). Metanephridia occur in pairs in each body segment of an earthworm and begin with a ciliated funnel-shaped structure called a *nephrostome*. The metanephridia of an earthworm performs both excretory and osmoregulatory functions. Coelomic fluid is drawn into the nephrostome by movement of the cilia. As the body fluids move through the network, some molecules and ions are reabsorbed while other ions and nitrogenous wastes are secreted into the tubule. The bladder stores the nitrogenous wastes as urine and later on excreted from the body surface via the nephridiopore.

As the filtrate moves along the tubules, useful ions and solutes are reabsorbed by active transport and from there diffuse into nearby capillaries. The nitrogenous wastes are left behind in the urine which get excreted through nephridiopores in the body wall.

Many annelids thrive in damp soil and thus excrete a hypoosmotic urine similar to flatworms. The net uptake of water from the soil is balanced by the release of more water in the urine.

Filtration also happens in the metanephridial system of many mollusks and in the crustacean excretory organs called antennal glands. Urine is also delivered out of the body wall through nephridiopores.

Malpighian Tubules

The insect excretory system differs from other
because it employs secretion rather than filtra
fluids. This consists of the *Malpighian tubules*
which are fingerlike extensions of the digestive t
connected anterior to the hindgut. Urine is n
filtration because of the lack of pressure differen

hemolymph (circulatory fluid) in the body cavity ar

Instead, the cells lining the tubules actively

molecules and potassium (K^+) ions from the hemol

tubule lumen. The secretion process creates an osm

that causes water to move into the tubules. The flu

the hindgut (intestine and rectum) where most of the useful ions and water are reabsorbed from the tubules into the blood leaving the wastes in the filtrate. The filtrate

that are excreted together with the fece

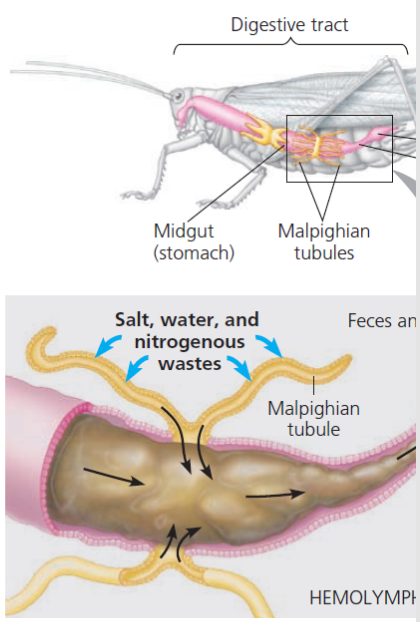

Figure 6.8 The Malpighian tubules are exte

tract that gather water and wastes from

system.

(Photograph taken from: Reece, J.B., L.A. Urry, M.L

Minorsky, and R.B. Jackson. 2014. Campbell Bi

Education, Inc. 1279 pp.; picture can be redrawn

Different from other invertebrates, excrete urine that is either isosmotic body fluids. This reflects the efficiency of the insect hindgut in reabsorbing water to prevent the risk of dehydration in dry environments.

Kidneys

Vertebrates have a more complex osmoregulatory and excretory organs, the **kidneys** (Figure 6.9). In spite of the variation in kidneys among fishes, amphibians, reptiles, birds, and mammals, there are some notable common features.

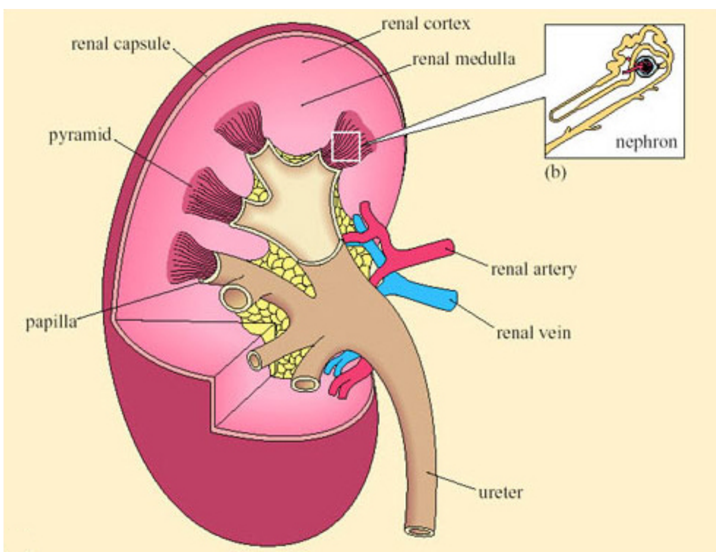

Figure 6.9 The vertebrate kidney. Diagrammatic representation of the gross structure of a human kidney and an enlarged diagram of the nephron

(Photograph retrieved from: http://www.open.edu/openlearn/nature-environment/natural-history/animals-the-extremes-the-desert-environment/content-section-3.2; picture can be redrawn.)

Vertebrate kidneys usually contain specialized tubules made of epithelial cells that function in the regulation of salt and water balance through active transport of sodium and other ions across their membranes. Additionally, all kidneys also function in the excretion of wastes. The osmoregulatory and excretory functions of the kidneys are highly regulated by the actions of nerves and hormones. Most vertebrate kidneys involve filtration, with the exception of purely secretory kidneys found in some marine fish. Furthermore, filtration in the kidneys is facilitated by mechanical forces, such as the **hydrostatic pressure** exerted by blood entering the capillaries of the kidneys.

Different animals have evolved mechanisms for osmoregulation and excretion in highly dissimilar environments, and with different life histories. These functions are necessary for survival and maintenance of homeostasis.