The Concept of Excretion

Objectives

After going through this lesson, the learners will be able to understand the following:

- Excretion
- Need of removal of excretory products
- Excretory products in animals
- Ammonotelism, Ureotelism and Uricotelism
- Excretory organs in different animals
- Excretion in human beings

Content Outline

- Introduction
- Excretion
- Excretory products
- Ammonotelism
- Ureotelism
- Uricotelism
- Excretory organs in different animals
- Excretion in human beings (Human excretory system)
- Summary

Introduction

Many chemical reactions occur in the cells of living organisms all the time to carry out the life processes. The sum of these reactions is called metabolism. Metabolism is the fundamental property of all living systems. A lot of useful products as well as toxic (poisonous) by-products are produced during these metabolic reactions. These toxic substances are harmful if allowed to accumulate and hence they have to be removed properly and periodically, out of the body. The removal of metabolic waste products from the body of an organism is known as excretion. Water and mineral ion content must also be kept constant for our cells to work effectively. The conditions inside our body must be very carefully controlled if the body is to function effectively.

Excretion

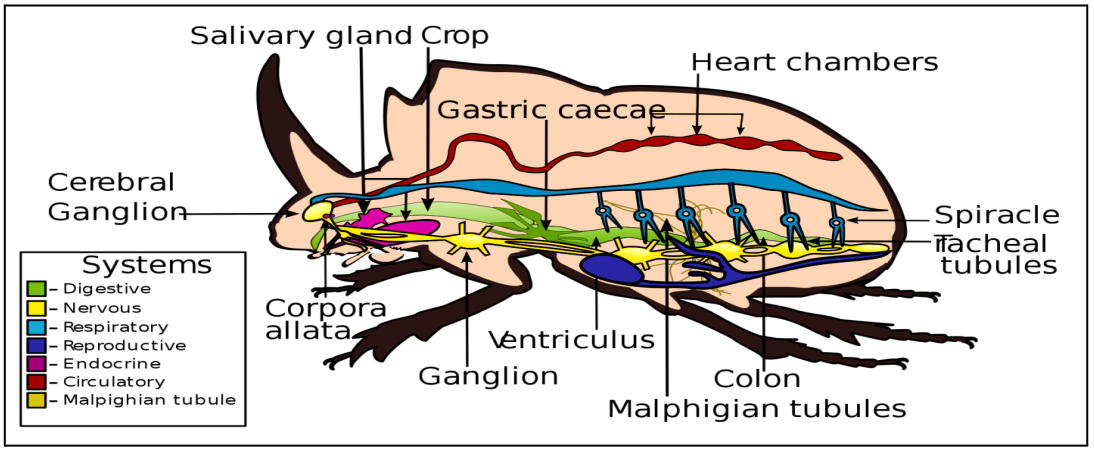
Excretion is a process by which metabolic wastes like ammonia, urea and uric acid etc. along with excess of water, salts and pigments are eliminated out of the body of an organism. In vertebrates this is primarily carried out by the lungs, kidneys and skin. This is in contrast with secretion, where the substance may have specific tasks after leaving the cell. **Excretion** is an essential process in all forms of life. The main aim of excretion is to keep a constant internal chemical composition of the body.

Excretion in lower order of animals:

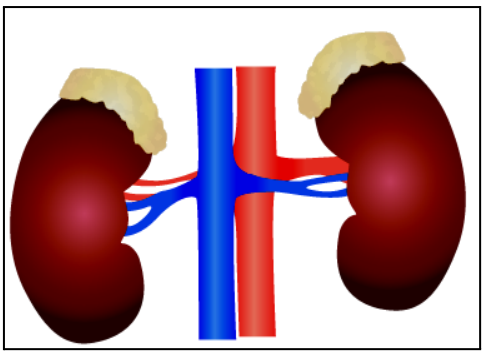
The unicellular organisms like Amoeba throw out their wastes by diffusion from their body surface. Protozoan's have no organs for excretion. As they live in an aquatic habitat, their wastes are eliminated by diffusion through the plasma membrane.

Amoeba

Simple multicellular organisms like Hydra throw out solid waste matter through their mouth. Higher multicellular organisms have well-defined specialized excretory organs. These organs could be simple tubular structures as in flatworms and leech. The excretory organs of insects (e.g., grasshopper, cockroach and housefly) are also tubular. They remove nitrogenous wastes from the body fluid and help organs like malpighian tubules etc. in maintaining the water balance in the body.



In vertebrates, the main organs of excretion and maintenance of water balance are the kidneys.

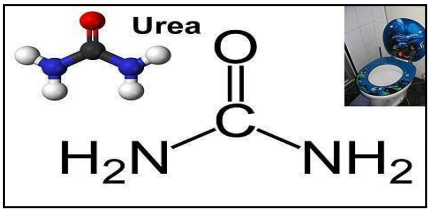


Excretory Products

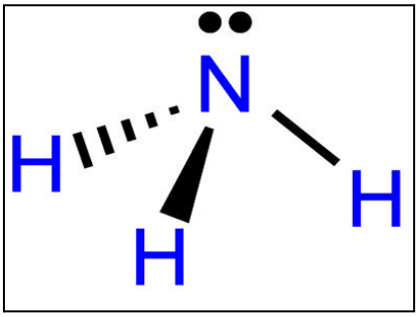
All living systems are like a giant chemical lab. Thousands of chemical reactions happen in their bodies between various biomolecules. All these metabolic reactions have by-products some of which are harmful and have to be eliminated through the process of excretion.

The major excretory products are carbon dioxide (produced in the process of tissue respiration), excess water (formed due to oxidative phosphorylation of glucose), nitrogenous compounds like ammonia, urea, uric acid (formed due to catabolism of proteins and amino acids), pigments, drugs and inorganic ions like Na^+, K^+, phosphates and sulphates etc. Other excretory products include chemicals from medicines, toxic substances, vitamins and circulating hormones that have already served their purpose.

The dual function of excretory systems is the elimination of the waste products of metabolism and to drain the body of used up and broken down components in a liquid and gaseous state. In humans and other amniotes (mammals, birds and reptiles) most of these substances leave the body as urine and to some degree exhalation, mammals also expel them through sweating.

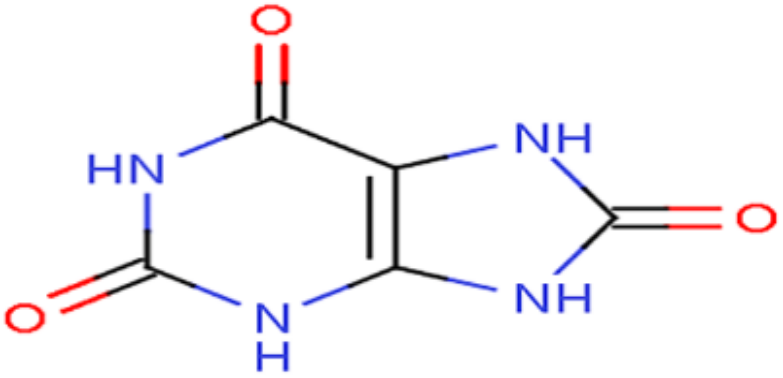


Ammonotelism

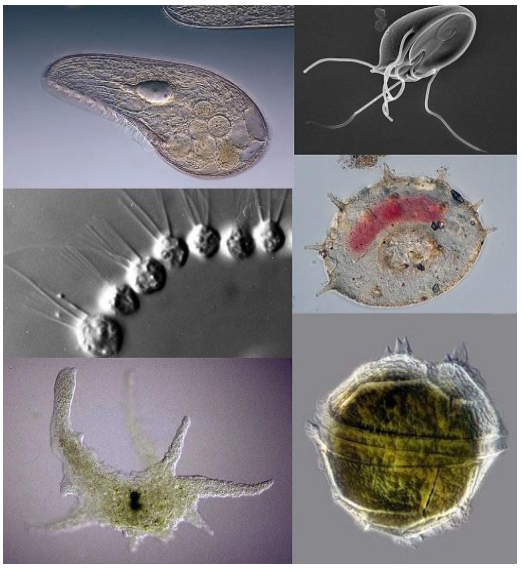


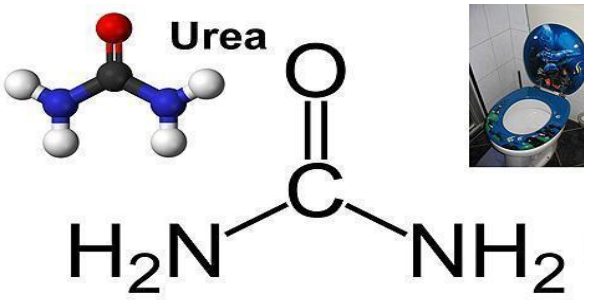
(Ammonia (NH3) is the excretory product)

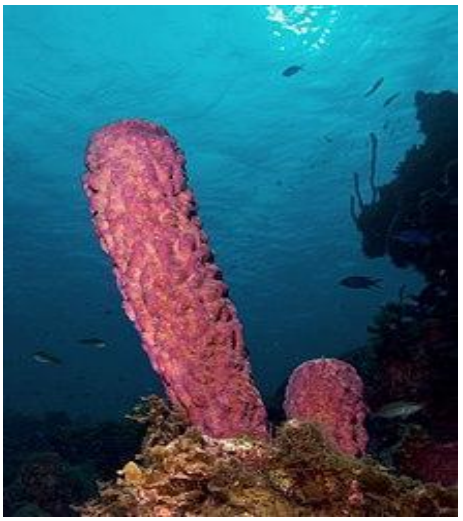
Ammonotelism is the type of excretion in which the main nitrogenous waste is ammonia and ammonium ions. It is found in many aquatic animals like protozoans, sponges, coelenterates, crustaceans, aquatic insects, echinoderms, bony fishes, tadpole larvae and some adult amphibians like salamanders etc. Ammonia (NH_3) is the basic nitrogenous catabolic product which is formed by oxidative deamination of excess amino acids (produced by catabolism of proteins) in the presence of an oxidase enzyme.



It is a very toxic substance (because it has high pH) to tissues. It must be either metabolized or expelled out of the body immediately it is formed, so that its concentration remains low in the blood. It is extremely soluble in water. A very large amount of water is needed for the excretion of ammonia; about 0.3 to 0.5 L of water is needed per gram of nitrogen to maintain ammonia levels in the excretory fluid below the level in body fluids to prevent toxicity. Thus, the marine organisms excrete ammonia directly into the water and are called Ammonotelic.







Ureotelism (Urea is the Excretory Product)

The excretion of urea is called ureotelism. The animals showing ureotelism are called ureotelic animals. It is found in those land animals which can lose large amounts of water without any ill- effect and those animals which can retain a considerable amount of urea (about 2.5%) as a major osmolyte to maintain osmolarity of their blood. It is a common

method of excretion in terrestrial and semi aquatic amphibians like frogs, toads, all mammals including man and aquatic mammals like whale and seals, desert mammals like camels, kangaroo rats, cartilaginous fishes such as sharks and rays, aquatic and semi-aquatic reptiles like alligators and turtles etc. Man urea accounts for about 80-90% of total nitrogenous waste products.

In these animals, urea is mainly formed by detoxification of ammonia, a process (urea cycle) which occurs in the liver and kidney. These animals are called **ureotelic**.

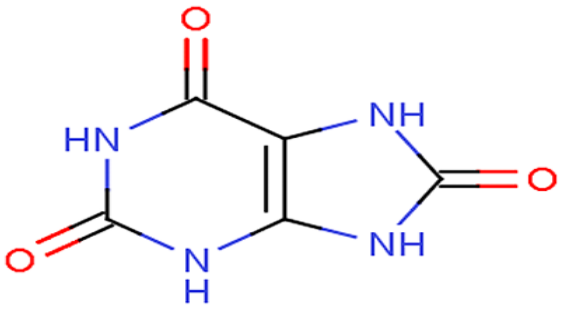
$2NH_3 + CO_2$ --- (*Urea cycle*) --- Urea + H_2O

Urea is a less toxic compound than ammonia; two nitrogen atoms are eliminated through it and less water is needed for its excretion. It requires 0.05 L of water to excrete 1 g of nitrogen, approximately only 10% of that required in Ammonotelic organisms.

Urea is about 100,000 times less toxic than ammonia. It can remain in the body tissues for a longer period without causing any ill effects inside the body. It needs less water to be expelled out.

Uricotelism (Uric Acid is the Excretory Product)

Uricotelism is the type of excretion in which the main nitrogenous end product is uric acid. This method is used by birds, insects, land reptiles like lizards and snakes and land snails like *Helix*. These animals are called uricotelic.



Uric acid is formed from ammonia and purines (adenine and guanine) mainly in the liver and is a high energy dependent. In insects, uric acid is formed in malpighian tubules.It is least soluble nitrogenous waste (thousands of times less soluble in water than ammonia or urea) and can be stored in cells and body tissues without toxic effects. It contains four nitrogen atoms and only a small amount of water (about 0.001 L per 1 g of nitrogen) is needed for its excretion. A single molecule of uric acid can remove four atoms of nitrogen making uricotelism more efficient than ammonotelism or ureotelism. Uric acid is less toxic than ammonia or urea. It does not harm if it remains in the body for a long period. Excretion of uric acid is a great advantage to land animals that have limited access to water.

Uricotelic organisms typically have white pasty excreta. Some mammals including humans excrete uric acid as a component of their urine but it is only a small amount.

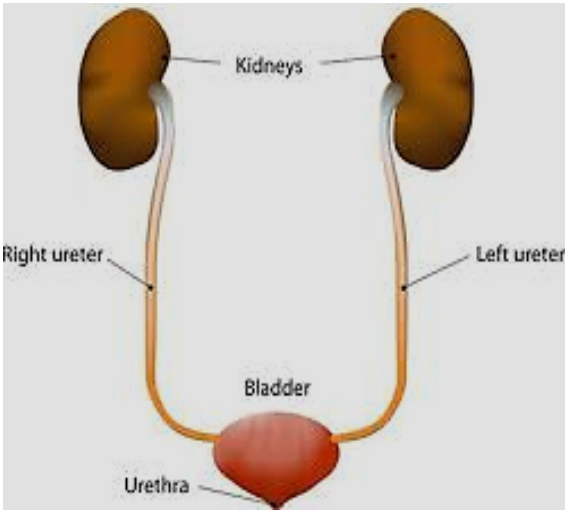
Excretory Organs in Different Animals

Animal Group	Main Nitrogenous Waste	Way of Elimination
Protozoans	Ammonia	Diffusion through cell membrane
Porifera	Ammonia	Diffusion via plasma membrane
Coelenterata and Ctenophora	Ammonia	Diffusion across plasmalemma of all cells
Platyhelminthes (Flatworms), rotifers	Ammonia & Fatty acids	Diffusion through body surface, protonephridia or flame cells
Nereis	Ammonia	Nephridia and nephrostomes
Nematoda	Ammonia	Diffusion across body wall
Earthworm	Ammonia in all and urea in landforms	Nephridia with nephrostomes
Leech	Ammonia, some urea	Nephridia with multiple nephrostomes
Scorpion & spider	Guanine and uric acid	Coxal glands and malpighian tubules
Crustacea (Prawn)	Ammonia	Antennary or green glands

Insects	Uric acid in land & Ammonia in aquatic forms	Malpighian tubules, nephrocytes and adipocytes
Mollusca (Mussel)	Ammonia in aquatic forms & uric acid in landforms	Kidneys (metanephric systems)
Echinodermata	Ammonia	Dermal branchiae, papulae podia etc.
Vertebrata (Fishes, Amphibians, Reptiles, Birds and Mammals	Ammonia, urea and uric acid	One pair of kidneys, Gills, Lungs, Liver, Skin, Intestine and accessory excretory organs
Hemichordata	-----	Proboscis gland (glomerulus)
Urochordata	-----	Neural gland
Cephalochordata	-----	Protonephridia

Excretion in Human Beings

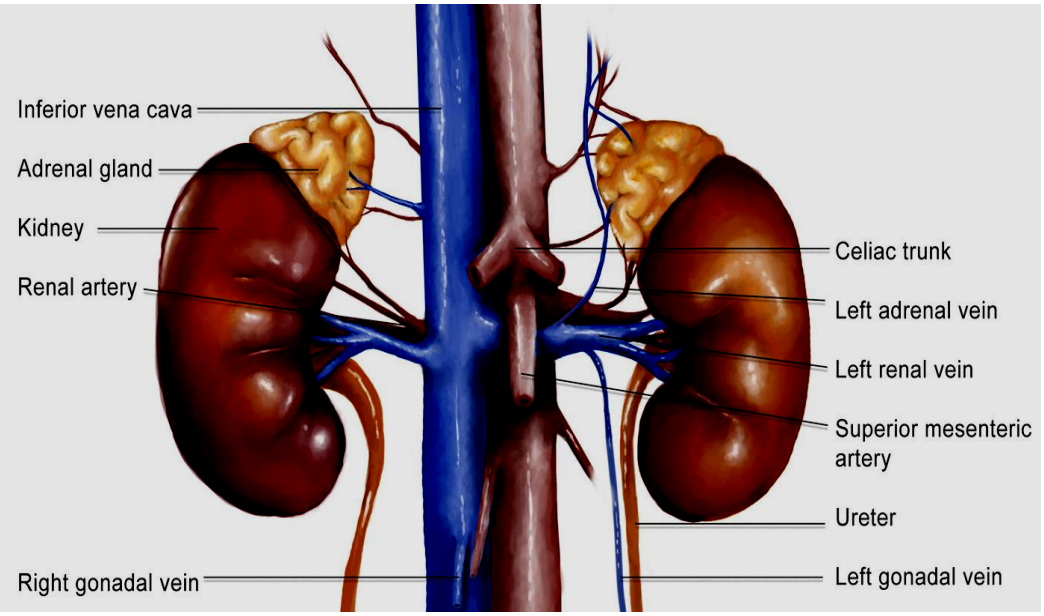
The human excretory system functions to remove waste from the human body. This system consists of specialized structures and capillary networks that assist in the excretory process. The human excretory system includes the kidneys and their functional unit, the nephron, a pair of ureter, urinary bladder and urethra. In the narrow sense, the term excretory system refers to the urinary system. Kidneys are the main excretory organ which excretes the excretory product urea in the form of urine. The urea was converted from ammonia by the liver and then transported into the blood. The kidney filters this urea in the form of urine.



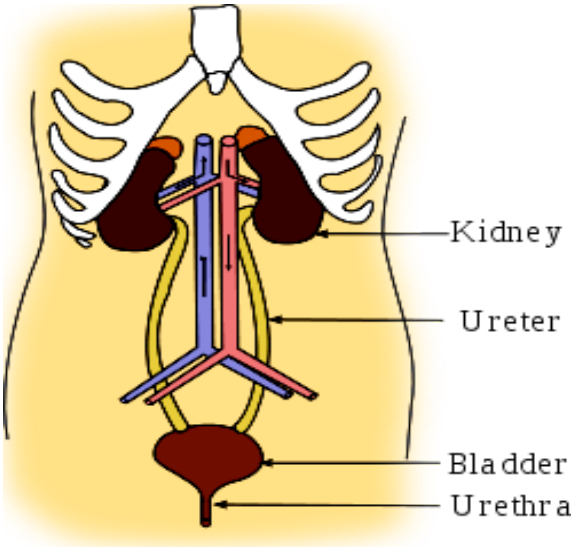
Kidney

(External structure)

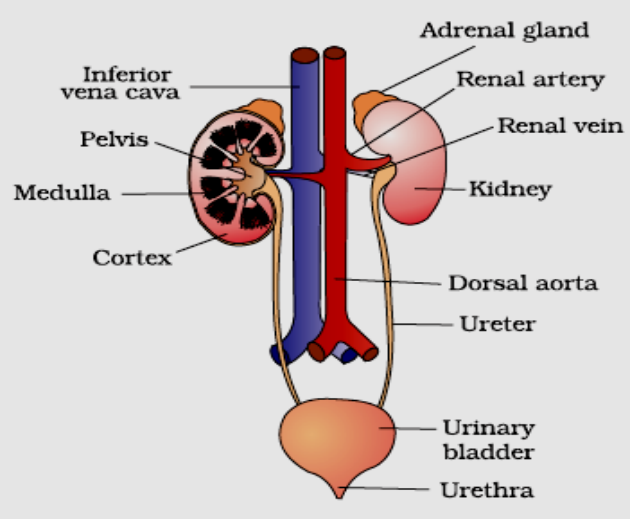
In humans, the kidneys are located upside in the abdominal cavity, one on each side of the spine, and lie in a retroperitoneal position at a slightly oblique angle. The asymmetry within the abdominal cavity, caused by the position of the liver, results in the right kidney being slightly lower and smaller than the left kidney and being placed slightly more to the middle position than the left kidney. The left kidney is approximately at the vertebral level T12 to L3, and the right is slightly lower. The right kidney sits just below the diaphragm and posterior to the liver. The left sits below the diaphragm and posterior to the spleen. On top of each kidney is an adrenal gland. The upper parts of the kidneys are partially protected by the 11^{th} and 12^{th} ribs.



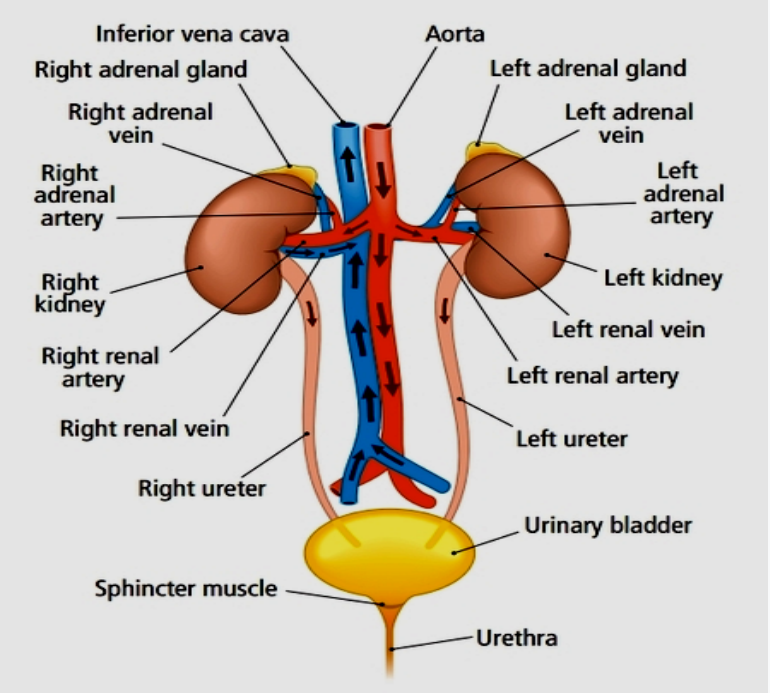
Location of excretory organs in the human body



The kidney is a bean-shaped structure with a convex and concave border. A recessed area on the concave border is the renal hilum, where the renal artery enters the kidney and the renal vein and ureter leave. The kidney is surrounded by tough fibrous tissue, the renal capsule, which is itself surrounded by perirenal fat, renal fascia, and fat. The superior pole of the right kidney is adjacent to the liver. For the left kidney, it is next to the spleen. Both, therefore, move down upon inhalation.



In adult males, the kidney weighs between 125 and 170 grams. In females the weight of the kidney is between 115 and 155 grams. The median renal length is 11.2 cm on the left side and 10.9 cm on the right side in adults. Median renal volumes are approximately 146 cm^3 on the left and 134 cm^3 on the right capsule and para-renal fat superior to the renal fascia.



Functions of the Kidney

Excretion: The main function of the kidney is to filter the blood taking out waste products and producing urine.

Osmoregulation: The kidneys control the amount of water in the body. They maintain a water balance in the cells of the body. If there is too much water in the body, the kidneys will excrete the excess water and if there is not enough water in the body, the kidneys will excrete much less water in an effort to conserve the remaining water in the body.

PH control: The kidneys can control the acidity and alkalinity of the blood by excreting H^+ (Hydrogen ions) or conserving hydrogen ions.

Hormone production: The kidneys produce the hormone erythropoietin (EPO). EPO stimulates the bone marrow to produce red blood cells (erythrocytes).

Summary

Many nitrogen containing substances, ions, CO_2, water, etc. that accumulate in the body have to be eliminated. Nature of nitrogenous wastes formed and their excretion vary among animals, mainly depending on the habitat (availability of water). Ammonia, urea and uric acid are the major nitrogenous wastes excreted.

Protonephridia, nephridia, malpighian tubules, green glands and kidneys are the common excretory organs in animals. They not only eliminate nitrogenous wastes but also help in the maintenance of ionic and acid-base balance of body fluids. In human beings, the kidneys are the main organs of excretion, which contain millions of nephrons. The nephrons are the main excretory units of the kidney. The kidney is a bean-shaped structure with a convex and a concave border. They are located upside in the abdominal cavity. Besides excretion the kidneys play an important role in controlling the amount of water in the body, pH control and hormone production.