# 18

# *Nitrogenous Excretion and Salt and Water Balance*

## 1. Introduction

Enzymatically controlled reactions occur at the optimum rate within a narrow range of physical conditions. Especially important are the pH and ionic content of the cell fluid, as these factors readily affect the active site on an enzyme. As the conditions existing within cells and tissues are necessarily dependent on the nature of the fluid that bathes them—in insects, the hemolymph—it is the regulation of this fluid that is important. By regulation is meant the removal of unwanted materials and the retention of those that are useful, to maintain as nearly as possible the best cellular environment. Regulation is a function of the excretory system and is of great importance in insects because they occupy such varied habitats and, therefore, have different regulatory requirements. Terrestrial insects lose water by evaporation through the integument and respiratory surfaces and in the process of nitrogenous waste removal. Brackish-water and saltwater forms also lose water as a result of osmosis across the integument; in addition, they gain salts from the external medium. Insects inhabiting fresh water gain water from and lose salts to the environment. The problem of osmoregulation is complicated by an insect's need to remove nitrogenous waste products of metabolism, which in some instances are very toxic. This removal uses both salts and water, one or both of which must be recovered later from the urine.

## 2. Excretory Systems

### 2.1. Malpighian Tubules—Rectum

The Malpighian tubules and rectum, functioning as a unit, form the major excretory system in most insects. Details of the rectum are given in Chapter 16, Section 3.4, and only the structure of the tubules is described here.

The blindly ending tubules, which usually lie freely in the hemocoel, open into the alimentary canal at the junction of the midgut and hindgut (Figure 18.1A). Typically they enter the gut individually but may fuse first to form a common sac or ureter that leads into the gut. Their number varies from two to several hundred and does not appear to be

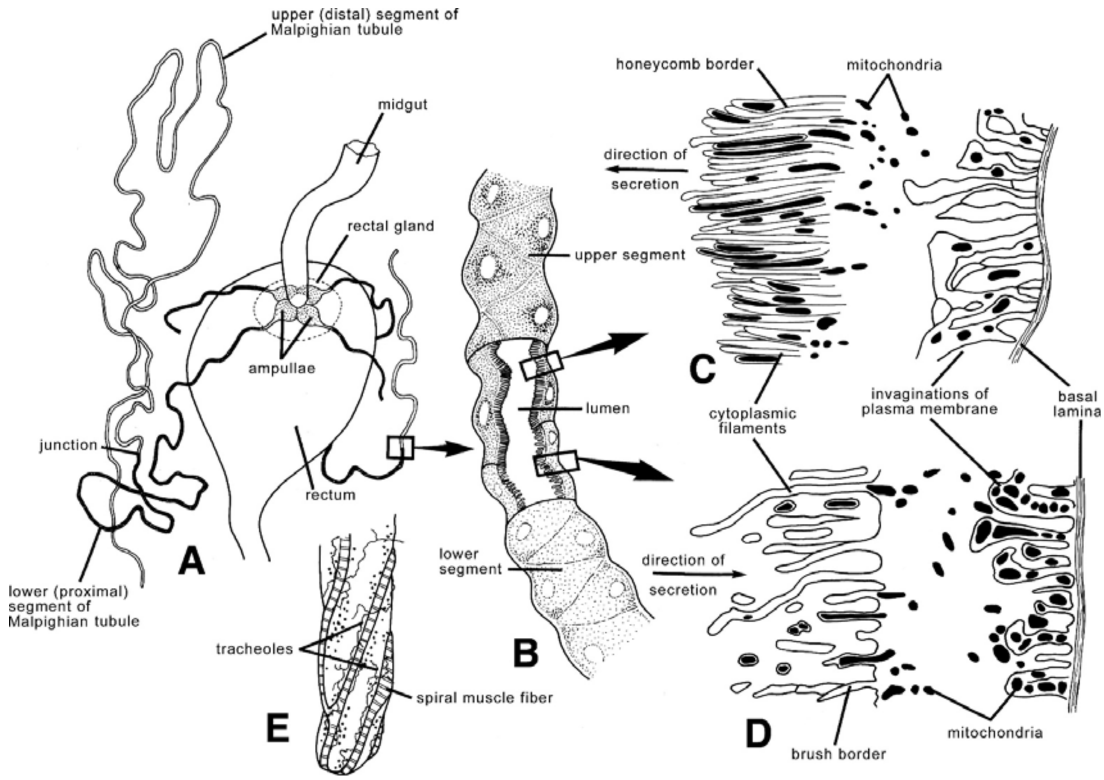


**FIGURE 18.1.** (A) Excretory system of *Rhodnius*. Only one Malpighian tubule is drawn in full; (B) junction of proximal and distal segments of a Malpighian tubule of *Rhodnius*. Part of the tubule has been cut away to show the cellular differentiation; (C, D) sections of the wall of the distal and proximal segments, respectively, of a tubule; and (E) tip of Malpighian tubule of *Apis* to show tracheoles and spiral muscles. [A, B, E, after V. B. Wigglesworth, 1965, *The Principles of Insect Physiology*, 6th ed., Methuen and Co. By permission of the author. C, D, from V. B. Wigglesworth and M. M. Saltpeter, 1962, Histology of the Malpighian tubules in *Rhodnius prolixus* Stal. (Hemiptera), *J. Insect Physiol*. **8**:299–307. By permission of Pergamon Press Ltd.]

closely related to either the phylogenetic position or the excretory problems of an insect. Malpighian tubules are absent in Collembola, some Diplura, and aphids; in other Diplura, Protura, and Strepsiptera there are papillae at the junction of the midgut and hindgut. With the tubules are associated tracheoles and, usually, muscles (Figure 18.1E). The latter take the form of a continuous sheath, helical strips, or circular bands and are situated outside the basal lamina. They enable the tubules to writhe, which ensures that different parts of the hemolymph are exposed to the tubules and assists in the flow of fluid along the tubules.

A tubule is made up of a single layer of epithelial cells, situated on the inner side of a basal lamina (Figure 18.1B–D). In many species where the tubules have only a secretory function (Section 3.2) the histology of the tubules is constant throughout their length and basically resembles that of the distal part of the tubule of *Rhodnius* (Figure 18.1C). The inner (apical) surface of the cells takes the form of a brush border (microvilli). The outer (basal) surface is also extensively folded. Both of these features are typical of cells involved in the transport of materials and serve to increase enormously the surface area across which transport can occur. Numerous mitochondria occur, especially adjacent to or within the folded areas, to supply the energy requirements for active transport of certain ions across the tubule wall. In many species various types of intracellular crystals occur which are