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The Circulatory System

1. Introduction

The circulatory system of insects, like that of all arthropods, is of the "open" type; that is, the fluid that circulates is not restricted to a network of conducting vessels as, for example, in vertebrates, but flows freely among the body organs. An open system results from the development, in evolution, of a hemocoel rather than a true coelom. A consequence of the open system is that insects have only one extracellular fluid, hemolymph, in contrast to vertebrates, which have two such fluids, blood and lymph. The occurrence of an open system does not mean that hemolymph simply bathes the organs it surrounds because usually thin granular membranes separate the tissues from the hemolymph itself. Insects generally possess pumping structures and various diaphragms to ensure that hemolymph flows throughout the body, reaching the extremities of even the most delicate appendages. As the only extracellular fluid, it is perhaps not surprising that the hemolymph, in general, serves the functions of both blood and lymph of vertebrates. Thus, the fluid fraction (plasma) is important in providing the correct milieu for body cells, is the transport system for nutrients, hormones, and metabolic wastes, and contains elements of the immune system, while the cellular components (hemocytes) provide the defense mechanism against foreign organisms that enter the body and are important in wound repair and the metabolism of specific compounds.

2. Structure

The primary pump for moving hemolymph around the body is a middorsal vessel that runs more or less the entire length of the body (Figure 17.1). The posterior portion of the vessel has ostia (valves) and is sometimes known as the heart, whereas the cephalothoracic portion, which is often a simple tube, may be termed the aorta (Figure 17.1A). In some insects the heart is the only part that contracts, but in many others the entire vessel is contractile. The vessel is held in position by connective tissue strands attached to the dorsal integument, tracheae, gut, and other organs and by a series of paired, usually fan-shaped, alary muscles. Normally, the vessel is a straight tube, though in many species the aorta may loop vertically. Anteriorly the aorta runs ventrally to pass between the corpora cardiaca and under the brain. Generally the dorsal vessel is closed posteriorly; however, in Diplura,

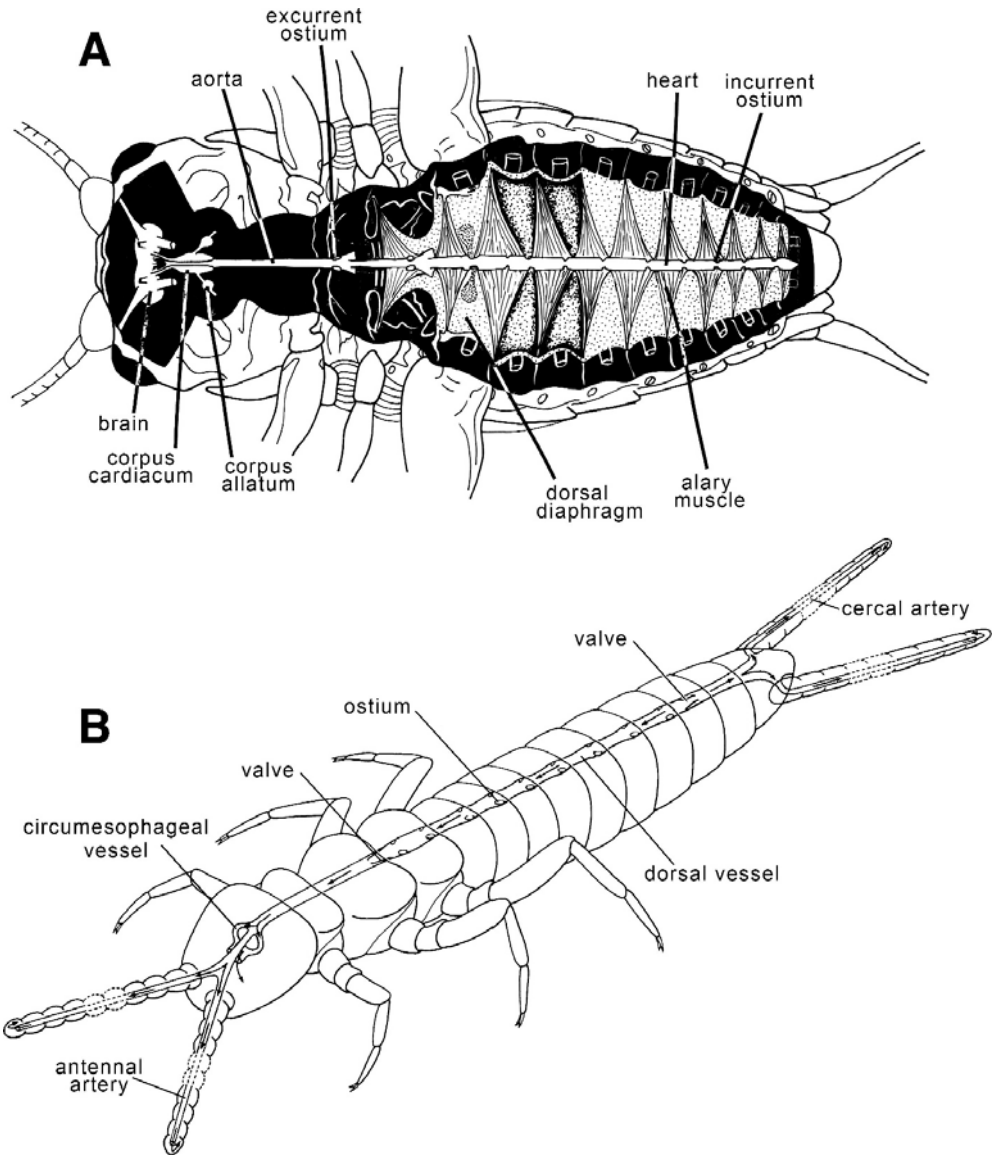

FIGURE 17.1. (A) Ventral dissection of the field cricket, *Acheta assimilis*, to show dorsal vessel and associated structures; and (B) circulatory system of *Campodea augens* (Diplura) showing anterior and posterior arteries running off the dorsal vessel. [A, after W. L. Nutting, 1951, A comparative and anatomical study of the heart and accessory structures of the orthopteroid insects, *J. Morphol.* **89**:501–597. By permission of Wistar Press. B, from a figure kindly supplied by Dr. Günther Pass.]

Archaeognatha, Zygentoma, and some Ephemeroptera the dorsal vessel connects at its rear with arteries that run along the cerci and median caudal filament (Gereben-Krenn and Pass, 2000). In Diplura an artery also supplies each antenna (Figure 17.1B), and in Dictyoptera and some Orthoptera there are pairs of segmental arteries in the abdomen (Hertel and Pass, 2002). However, except as noted, in pterygotes circulation to appendages is achieved by means of accessory pulsatile organs and septa (see below).

In most insects the dorsal vessel is well tracheated. The heart may not be innervated or may receive paired lateral nerves from the brain and/or segmental ventral ganglia. Ostia may be simple, slitlike valves or deep, funnel-shaped structures in the wall of the heart, or internal