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Nervous and Chemical Integration

1. Introduction

Animals constantly monitor both their internal and their external environment and make the necessary adjustments in order to maintain themselves optimally and thus to develop and reproduce at the maximum rate. The adjustments they make may be immediate and obvious, for example, flight from predators, or longer-term, for example, entry into diapause to avoid impending adverse conditions. The nature of the response depends, obviously, on the nature of the stimulus. Only very rarely does a stimulus act directly on the effector system; almost always a stimulus is received by an appropriate sensory structure and taken to the central nervous system, which "determines" an appropriate response under the circumstances. When a response is immediate, that is, achieved in a matter of seconds or less, it is the nervous system that transfers the message to the effector system. Such responses are usually temporary in nature. Delayed responses are achieved through the use of chemical messages (viz., hormones) and are generally longer-lasting. The nervous and endocrine systems of an individual are, then, the systems that coordinate the response with the stimulus. Semiochemicals, which constitute another chemical regulating system, coordinate behavior and development among individuals. They comprise pheromones (intraspecific coordinators) and allelochemicals (interspecific coordinators), which include kairomones and allomones.

2. Nervous System

Like that of other animals, the nervous system of insects consists of nerve cells (neurons) and glial cells. Each neuron comprises a cell body (perikaryon) where a nucleus, many mitochondria, and other organelles are located, and a cytoplasmic extension, the axon, which is usually much branched, the branches being known as neurites. Axons may be long, as in sensory neurons, motor neurons, and principal interneurons, or very short, as in local interneurons. Often, insect neurons are monopolar, lacking the dendritic tree characteristic of vertebrate nerve cells, though bipolar and multipolar neurons do occur (Figure 13.1). Motor (efferent) neurons, which carry impulses from the central nervous system, are monopolar, and their perikarya are located within a ganglion. Sensory (afferent) neurons are usually bipolar but may be multipolar, and their cell bodies are adjacent to

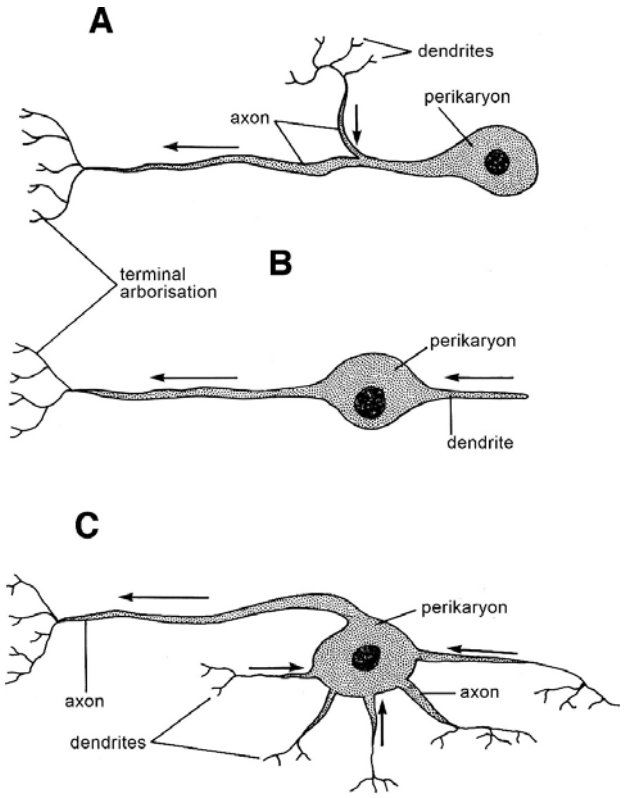

FIGURE 13.1. Neurons found in the insect nervous system. Arrows indicate direction of impulse conduction. (A) Monopolar; (B) bipolar; and (C) multipolar. [After R. F. Chapman, 1971, *The Insects: Structure and Function*. By permission of Elsevier/North-Holland, Inc., and the author.]

the sense organ. Interneurons (also called internuncial or association neurons) transmit information from sensory to motor neurons or other interneurons; they may be mono- or bipolar and their cell bodies occur in a ganglion. Interneurons may be intersegmental and branched, so that the variety of pathways along which information can travel and, therefore, the variety of responses are increased.

Neurons are not directly connected to each other or to the effector organ but are separated by a minute space, the synapse or neuromuscular junction, respectively. Impulses may be transferred across the synapse either electrically or chemically (Section 2.3). The normal diameter of axons is 5 μm or less; however, some interneurons within the ventral nerve cord, the so-called "giant fibers," have diameters up to 60 μm. These giant fibers may run the length of the nerve cord without synapsing and are unbranched except at their termini. They are well suited, therefore, for very rapid transmission of information from sense organ to effector organ; that is, they facilitate a very rapid but stereotyped response to a stimulus and for some insects are important in escape reactions (Hoyle, 1974; Ritzmann, 1984).

Neurons are aggregated into nerves and ganglia. Nerves include only the axonal component of neurons, whereas ganglia include axons, perikarya, and dendrites. The typical structures of a ganglion and interganglionic connective are shown in Figure 13.2. In a ganglion there is a central neuropile that comprises a mass of efferent, afferent, and association axons. Frequently visible within the neuropile are groups of axons running parallel, known as fiber tracts. The perikarya of motor and association neurons are normally found in clusters adjacent to the neuropile.

Surrounding the neurons are glial cells, which are differentiated according to their position and function. The peripheral glial (perineural) cells, which form the perineurium,