* The basic elements of the nervous system is the nerve cells which are produced into long processes called **axons** along which the nerve impulses travel. The bodies of the nerve cells may be aggregated to form **ganglia** while bundles of axons may form the **nerves**. The **central nervous system** consists of a brain situated dorsally in the head and a ventral chain of segmental ganglia from which nerves run to the peripheral sense organs and muscle systems. The **stomatogastric nervous system** consists of a number of small ganglia connected to the brain and their associated nerves, and controls the movements of the alimentary canal.

THE NERVE CELL

* The nerve cells are also often called **neurons**. The neuron consists of a cell body containing the nucleus, and long cytoplasmic projections which extend to make contact with other neurons. The cell body is known as the **soma** or **perikaryon**, while the projections are known as **axons**. Frequently the axon has branches called **collaterals**, and end in a terminal aborization. Nerve impulses are transmitted from one cell to the next along the axons. Part of each neuron is specialized for the reception of the impulse. This specialized structure is called a **dendrite**. The dendrite may arise directly from the perikaryon or may arise from an axon in which case there is very little to differentiate it from an axon. The site at which the neurons are closely apposed so that the activity of one is influenced by the other is called the **synapse**.

* Most insect neurons are **monopolar**, having only a single axonal projection from the perikaryon. Some peripheral sense cells are **bipolar** with a short distal dendrite receiving stimuli from the environment and a proximal axon extending to the central ganglia. Some **multipolar** cells occur in the hypocerebral and frontal ganglia and are also associated with stretch receptors.

* The sense cells which perceive external stimuli are mostly peripheral with dendritic processes extending to the cuticle and axons which conduct towards the CNS and hence are called **afferent** or **sensory axons**. Other axons conduct from the CNS to the effector organs are called **efferent** or **motor fibers**. The perikarya lie within the CNS. Afferent fibers may synapse directly with efferent fibers, but often there may be 1 or more neurons between the two called **internuncial neurons** or **interneurons** (also called **association neurons**).

* Each neuron is almost wholly invested by one or more cells which form an insulating protective sheath around it. These cells are called **glial cells**. The glial cells probably serve to insulate the axons and it is believed that the glial cells pass nutrient materials to the neurons.

THE SYNAPSE

* The **synapse** is the place where two neurons communicate with each other; that is, it is where one neuron transmits a message to another neuron. This often involves the transmission of a chemical, a **neurotransmitter**, across the space between the two neurons. An impulse travels down the **axon** of the **presynaptic neuron**. When the impulse reaches the distal end, it triggers the release of the **neurotransmitter** from **vesicles**. The **neurotransmitter** crosses the **synapse** and stimulates an impulse in the **dendrite** of the **postsynaptic neuron**. To prevent the **neurotransmitter** from causing a continuous reaction, an enzyme is also quickly released into the synaptic space which breaksdown the neurotransmitter. A common neurotransmitter in insects is **acetylcholine (ACH)**; the enzyme that breaks this down is **acetylcholinesterace (ACHesterase)**. In general, **neurotransmitters** are released directly into the synapse, are fast reacting, and then are quickly broken down or re-uptake. **Neuromodulators** are usually released in the vicinity of the synapse, are slow reacting, and are not quickly broken down or re-uptake (e.g., dopamine, histamine, octopamine). **Neurohormes** are from the hemolymph.

THE CENTRAL NERVOUS SYSTEM

* The perikarya of motor and interneurons are aggregated to form ganglia within which they are grouped around the periphery. The central area of the ganglia is occupied by the **neuropile** which is a complex of afferent, interneural, and efferent fibers. There are no cell bodies within the neuropile. The outer part is the **perineurium**.

* The most anterior ganglion is the **brain** or **cerebral ganglion** lying dorsal to the oesophagous in the head. It is believed to contain several fused segmental ganglia, but the actual number is a matter of controversy, and also contains fused with it the presegmental **archecerebrum**. From the brain the **circumoesophageal connectives** pass, one on each side of the oesophagous, to the first of a chain of ganglia lying ventrally in the haemocoel. The ganglia are joined to each other longitudinally by connectives made up only of axons and supporting cells.

* **THE BRAIN** - The brain can be divided into 3 regions: the **protocerebrum**, the **deutocerebrum**, and the **tritocerebrum**.

1. **Protocerebrum** - The protocerebrum is bilobed and is continuous laterally with the **optic lobes**. In hypognathous insects it occupies a dorsal position and is the most complex part of the brain. Anterodorsally, on either side of the midline, is a mass of cells forming the **pars intercerebralis**. The anterior cells of the pars contribute fibers to the ocellar nerves, while fibers from the more lateral cells enter the **protocerebral bridge** (**pons cerebralis**). Also within the pars intercerebralis are neurosecretory cells, the axons of which cross over within the brain and extend to the **corpora cardiaca**. At the sides of the pars intercerebralis are the **corpora pedunculata** which is believed to be the site of summation of simultaneous excitation from a number of different sources and are usually associated with complex behavior.

2. **Deutocerebrum** - The deutocerebrum contains the antennal lobes (with nerve connections to the antennae) which are divided into dorsal sensory and ventral motor areas. Fiber tracts connect the antennal lobes with the corpora pedunculata and other fibers run to the tritocerebrum.

3. **Tritocerebrum** - This is a small part of the brain consisting of a pair of lobes beneath the deutocerebrum. From it the circumoesophageal connectives arise and run to the suboesophageal ganglion. Anteriorly there are nerves that connect it with the frontal ganglion and the labrum (labral nerve).

4. **Optic Lobes** - The optic lobes are lateral extensions of the protocerebrum to the compound eyes. Each lobe consists of 3 neuropile masses known as the **lamina ganglionaris**, the **medulla externa**, and the **medulla interna**. Axons of the **retinula cells** pass through the basement membrane and enter into the lamina ganglionaris. The fibers going from the lamina ganglionaris to the medulla externa cross over to form the **outer chiasma**; accordingly they also cross over between the external and internal medullae to form the **inner chiasma**. These fibers then pass into the protocerebrum.

* **THE VENTRAL NERVE CORD** - The first ganglion of the ventral chain is the **suboesophageal ganglion**. This is a compound ganglion, lying ventrally in the head, arising from the fusion of the ganglia of the **mandibular, maxillary, and labial segments**. It sends motor and sensory nerves to the mandibles, maxillae, and labium and an additional one or two pairs to the neck and salivary glands. Typically there are 3 thoracic ganglia, each with 5 or 6 nerves on each side which innervate the muscles and sensilla of the thorax and its appendages. The largest number of abdominal ganglia occurring in larval or adult insects is 8, as in Thysanura, some Siphonaptera, and in many larval forms, but the last ganglion is always compound, being derived from the ganglia of the last 4 abdominal segments. In the majority of adult insects some further degree of fusion, particularly of the abdominal ganglia, occurs and in the extreme case all the ventral ganglia may be fused together into one large ganglionic mass as in *Musca*. The abdominal ganglia are usually smaller than the thoracic ganglia and in general fewer nerves arise from them. Between the paired connectives joining the ganglia is a small **median nerve** which runs from the back of each ganglion and branches transversely to the spiracles and alary muscles. In the thorax the median nerve does not proceed posteriorly beyond the lateral branches, but in the abdomen it usually goes completely from one ganglion to the next.

* **GIANT FIBERS** - Within the ventral nerve cord of some insects (cockroaches, some Orthoptera, some Odonata, and some Diptera) are a number of axons which are much bigger than the majority called **giant fibers**. They are believed to be concerned with the co-ordination of rapid evasive movements and are particularly fitted for this by their large diameter and lack of synapses, both features tending to increase the rate of nervous connection.

STOMATOGASTRIC NERVOUS SYSTEM

* Above the oesophagous in front of the brain is the **frontal ganglion** which is connected by a nerve to the tritocerebral lobe on either side. Sometimes a **median frontal nerve** extends forward to the wall of the pharynx. Also there is usually a **median recurrent nerve** running posteriorly from the frontal ganglion along the oesophagous beneath the brain, joining the **hypocerebral ganglion** just behind the brain. Laterally the hypocerebral ganglion connects with the **corpora cardiaca** and axons pass to it from the brain via the **nervi corpora cardiaci**. Usually one or two nerves leave the hypocerebral ganglion posteriorly running backwards over the surface of the alimentary canal to the **ingluvial ganglia** on the posterior end of the foregut. The frontal ganglion may control swallowing movements. The hypocerebral ganglion has some control, but most of the movements of the foregut and midgut are directly controlled by the ingluvial ganglia.