CELLULAR COMPONENTS OF NERVOUS TISSUE

I. Nervous Tissue is composed of two major cell types, each of which has a distinct microanatomy.

A. **Neurons** (Figs. 12.1, 12.2) have amplified electrical excitability and have axonal processes which can initiate and propagate nerve impulses (action potentials).

B. **Supporting or accessory cells** are smaller cells with varying morphology which are intimately associated with neurons. Supporting cells have three fundamental functions.

1. Supporting cells form the framework which holds neurons in position and protects neurons from some types of damage.

2. Supporting cells pass nutrients and other materials from blood or cerebrospinal fluid to neurons.

3. Supporting cells surround all axons in the peripheral nervous system (PNS) and form the myelin sheaths around myelinated axons in both the central and peripheral nervous systems.

II. Neurons (Figs. 12.1 – 12.9)

A. Component parts of neurons can be recognized.

1. **Neuron cell bodies** are distinguishable from most body cells.

a. Neuron cell bodies are larger than most body cells.

b. Cytoplasm of neuron cell bodies contains granular basophilic structures (Nissl bodies = rER).

c. The nucleus of most neuron cell bodies is large and very euchromatic with a prominent nucleolus.

2. **Dendrites** are cell body extensions without the ability to generate action potentials.

a. The origin of a dendrite is similar to cell body cytoplasm and usually contains Nissl bodies.

b. A dendrite is usually tapered along most of its length.

c. A dendrite is usually larger than an axon.

3. **Axons** are cell body extensions which can generate an action potential.

   a. The origin of an axon from a cell body (the axon hillock) lacks basophilic structures (Nissl bodies). An axon can also originate from a cluster of dendrites located away from a neuron cell body and carry action potentials past the cell body.

   b. Most axons are only tapered where they arise from a neuron cell body or dendrite cluster and have a constant diameter for most of their length.

   c. Axons are usually smaller than most dendrites on the same cell body.

   d. In a myelinated axon, the myelin sheath is extracted in routine LM preparations, leaving a clear ring around the axon. If the Schwann cell nucleus is visible it is in the rim of cytoplasm outside the myelin.

4. **Synapses** allow signals to quickly pass from one cell to an adjacent cell. Although electrical synapses occur in some vertebrates, essentially all synapses in humans are chemical synapses in which a signal is transmitted in the form of a secreted chemical transmitter.

   a. The **presynaptic ending** in the synapse consists of a bulb-like structure which is usually and ending of an axon. The pre-synaptic ending contains numerous membrane vesicles filled with a chemical transmitter. Although the specific chemical used differs in different synapses, arrival of an action potential at the pre-synaptic ending triggers secretion of the transmitter.

   b. The **post-synaptic ending** in the synapse usually contains a surface membrane which appears thicker than normal in transmission electron micrographs. Part of the thickness is due to numerous receptors for the transmitter chemical. These receptors are on the surface of the post-synaptic membrane which faces the pre-synaptic ending. The receptors are usually coupled to ion channels.

   c. A particular synapse may be **stimulatory** or **inhibitory**. If the receptors trigger opening of sodium ion chennels, the effect will be to depolarize the post-synaptic cell surface and increase the chance of generating an action potential when the change reaches the axon in the post-synaptic cell. This type of interaction is therefore stimulatory. On the other hand, if the receptors are complexed with potassium ion or chloride ion channels, stimulating the receptors will hyperpolarize the post-synaptic cell and the overall effect is inhibitory. The sum of the stimulatory and inhibitory synaptic inputs determines whether the post-synaptic cell will respond with an action potential.

   d. The **synaptic cleft** between the pre-synaptic and post-synaptic endings is very regular because the pre-synaptic and post-synaptic endings are firmly attached through plasma membrane, glycocalyx, and extracellular components. This attachment also reduces entry of extraneous molecules into the synaptic cleft and loss of synaptic transmitters from the cleft prior to their interaction with receptors.

B. Neurons are classified according to two sets of criteria.

1. **Cell shape** (number of cellular processes)

a. A **unipolar neuron** has a single process extending from the cell body. This is a developing neuron found in embryos.

b. A **bipolar neuron** has two processes (usually one axon and one dendrite) extending from the cell body. Many neurons exist in this condition at some point in their development, but neurons of this type are primarily associated with sense organs in adults. Many bipolar neurons have their dendrites at one end of an axonal process that transmits action potentials to the cell body. Another axon leaves the cell body and carries action potentials to synapses on other neurons.

c. A **pseudounipolar neuron** has a single process extending from the cell body, but this process splits into two processes shortly after leaving the cell body. Both branches of the process function as axons. The dendrites are at the distal end of the axon which carries action potentials in from the body perimeter. Neurons of this type occur in spinal ganglia in adults.

d. A **multipolar neuron** has one axon and two or more dendrites extending from its cell body. Most neurons in the adult central nervous system (CNS) and PNS are of this type.

2. **Functional interconnections** of neurons within the nervous system are not visible in routine histological preparations, but cells whose interconnections have been described by labelling and/or electrophysiology can be recognized based on cell shape and position.

a. **Sensory neurons** convey signals from peripherally located sensory structures to Central nervous system neurons. Olfactory sensory neurons are bipolar and spinal nerve sensory neurons are pseudounipolar.

b. **Motor neurons** convey signals from the CNS to peripherally located effecter organs (muscles or glands). Essentially all motor neurons are multipolar neurons.

c. **Interneurons** or **association neurons** connect two or more neurons within the CNS. Essentially all interneurons are multipolar neurons.

III. Supporting Cells

A. Supporting cells have some common features.

1. Supporting cells are small relative to neurons.

2. Supporting cells usually have extensively branched cellular processes which are not really distinguishable in routine histological preparations.

3. Supporting cells lack basophilic structures in their cytoplasm.

B. Types of supporting cells

1. Supporting cells in central nervous system tissues are called **neuroglia** or **glial cells** (Fig. 12.21).

   a. **Astrocytes** (**astroglial cells**)

      (1) Astrocytes may be divided into two major types.

         (a) **Protoplasmic astrocytes** (Fig. 12.19) have knobby cytoplasmic processes and occur in CNS gray matter.

         (b) **Fibrous astrocytes** (Fig. 12.20) have smooth cytoplasmic processes and occur in CNS white matter.

      (2) Astrocyte nuclei are the largest glial nuclei.

      (3) Astrocyte functions are unclear but these cells probably form the structural framework for the CNS during neuron migration in the embryo and probably transfer materials from blood vessels to the CNS in the adult.

   b. **Oligodendrocytes** (**oligodendroglial cells**)

      (1) Oligodendrocytes may be divided into two major types.

         (a) **Satellite oligodendroglial cells** surround neuron cell bodies in CNS gray matter.

         (b) **Myelinating oligodendroglial cells** (Fig. 12.22) form myelin sheaths around axons in CNS white matter.

      (2) Oligodendrocytes contain smaller nuclei than astrocytes but larger nuclei than microglia.

      (3) Myelinating oligodendrocytes form and maintain myelin, but functions of satellite oligodendrocytes are unclear.

   c. **Microglia** (Fig. 12.18)

      (1) Microglia are phagocytic cells (derived from monocytes) which occur throughout the CNS.

      (2) Microglial nuclei are smaller than astrocyte and oligodendrocyte nuclei.

   d. **Ependymal cells** (Fig. 12.23) are epithelial-like cells which line the central canal of the CNS. Some modified ependymal cells line the choroid plexi which form cerebrospinal fluid, but the functions of most ependymal cells are unclear.

2. Supporting cells in peripheral nervous system tissues

   a. **Schwann cells** form the myelin sheath around axons and surround unmyelinated axons in PNS nerves (Figs. 12.10 – 12.16).

   b. **Satellite Cells** (**Amphicytes**) (Fig. 12.17) surround neuron cell bodies in PNS ganglia.

IV. Classification of nervous tissue

A. **Central Nervous System Tissues** are internal to the meninges of the brain and spinal cord.

   1. **Gray matter** contains neuron cell bodies, dendrites, and axons, protoplasmic astrocytes, satellite oligodendrocytes, and microglia.

   2. **White matter** contains no neuron cell bodies but contains numerous axons along with fibrous astrocytes, myelinating oligodendrocytes, and microglia.

B. **Peripheral Nervous System Tissues** are external to the meninges of the brain and spinal cord.

   1. **Ganglion tissue** contains neuron cell bodies, axons, +/- dendrites, and satellite cells.

   2. **Peripheral nerve tissue** contains no neuron cell bodies but contains numerous axons (myelinated and/or unmyelinated) plus myelinating Schwann cells.