Structure of the Nervous System

I. Neurons and Glia

II. Neuronal "Compartments"
- A. Cell Body (Soma, perikaryon)
- B. Dendrites
- C. Axons (and axon hillock)
- D. Synapses

III. Glia
- A. Astrocytes and Microglia
- B. Oligodendrocytes and Schwann Cells
    - 1. Myelin

IV. Directions in a 3-Dimensional Organism
- A. Dorsal vs. Ventral
- B. Rostral vs. Caudal
- C. Medial vs. Lateral

V. Central Nervous System (CNS) and Peripheral Nervous System (PNS)
- A. Organization of the Spinal Cord
    - 1. Ventral and Dorsal Horn
    - 2. Reflex Arcs

- B. Autonomic Nervous System
    - 1. Sympathetic Nervous System ("Adrenergic")
    - 2. Parasympathetic Nervous System ("Cholinergic")

- C. Brain and Spinal Cord
    - 1. Overview of organization of human brain

Today I want to introduce some of the terminology that we use in describing the nervous system--both the definitions of the various cell types and parts of cells that make up part of the nervous system and the larger structures that comprise the n.s. So mostly I'll be defining terms and showing you some pictures to illustrate what I mean.

Apart from the blood and blood vessels and some connective tissue, the vertebrate nervous systtem consists of two general kinds of cells--nerve cells or neurons and glial cells (glia). Humans are estimated to have about 10^{11} or 10^{12} neurons (100 billion to 1 trillion) and about 3 times as many glia--with each type comprising about 50% of the weight of the n.s.--this implies that neurons are on average about 3 times as large as glia. We'll mostly be talking about neurons in this course, because more is known about them and because they are mainly responsible for the known functions of the nervous system, though more is being learned about glia all the time and it's becoming clear that their role has been underappreciated.

Fig. 1.3: Neurons are usually divided into 4 parts:

1. **Cell body** = soma or perikaryon = most other cell types; contains nucleus, ER, Golgi, mitochondria, lysosomes--the main functional organelles of the cell.

2. **Dendrites**--there are many, usually. Contain mitochondria, cytoskeleton like microfilaments, and some Golgi apparatus. Receiver of signals coming in to cell.

3. **Axons**--contain mitochondria, microfilaments and microtubules, vesicles. Conduct electrical signals away from cell body. *Initial segement* (also called the *axon hillock*) is the wide, electrically excitable region nearest to cell body.

4. **Nerve terminal**--enlarged ending of axon that stores and secretes (and sometimes synthesizes) neurotransmitters and forms the presynaptic part of the synapse between two cells.

Synapse means "clasp together".

Glia: (See Fig. 1.5)

Microglia = scavenger cells related to macrophages of blood.

Astrocytes = star shaped cells that are ubiquitous--are involved in buffering ion concentrations in extracellular spaces, transmitter uptake and signalling, nutrient support for neurons, etc.

Oligodendrocytes (in central nervous system) and **Schwann** cells (in peripheral) are cells that wrap axons in a sheath of membrane called myelin; they thus act much like an insulator on copper wire, speeding up electrical conduction. There are gaps between adjacent bits of myelin where the axonal membrane is exposed to extracellular fluid, and these are called *nodes of Ranvier* after the person who first described them (see Fig. 1.3G)

These neurons and glia are organized into a number of structures that make up the nervous system and that can be identified with the naked eye. The study and identification of these structures makes up the gross (meaning "large") anatomy of the nervous system. Anatomists define the axes of an animal as back to front, head to foot, and side to middle, but of course they don't use those words. Instead the axes of the body are defined as shown on Fig. 1.11--dorsal-ventral, rostral-caudal and medial-lateral.

The vertebrate spinal cord contains the main region of connection between the central nervous system (neurons in the brain and entirely within the spinal cord) and the peripheral nervous system (neurons at least partly outside the brain or spinal cord). When viewed in cross section (see Figs. 1.7 and 8.6), the spinal cord has an exterior region of "white matter" consisting mostly of myelinated axons, and a central region of "gray matter" consisting mostly of cell bodies. The gray matter looks a little like a butterfly and has a ventral half and a dorsal half--the two ventral lobes are called the ventral horns, and they contain the cell bodies of motor neurons, that send out axons through the ventral roots to muscle cells--these are the neurons that control skeletal movements. In the dorsal horn are the synapses of sensory neurons that send signals along their axons in through the dorsal roots. Some kinds of behavior can take place without the involvement of the brain. For example, some sensory neurons send their axons into the spinal cord through the dorsal roots and the axons make synapses directly onto motor neurons. The motor neurons get activated whenever the sensory neurons are activated, and so some muscles contract--pretty much automatically in response to the sensory signal. This arrangement is called a reflex arc--some common reflex arcs include the "knee jerk" reflex (Figs. 1.7 and 1.8) and the blink reflex. You don't think about these movements (or about pulling your hand off a hotplate), because your nervous system has a built-in reaction pathway.

The peripheral nervous system is made up of a variety of subdivisions. One is the sensory system that collects information about the state of the body—location of limbs, temperature, muscle contraction or relaxation, pain, etc.—and conveys it to the CNS; toward the CNS is referred to as "afferent". The spinal motor neurons and their targets, the skeletal muscles, make up the somatic motor system. Information from motorneurons to muscle moves away from the CNS and is said to be efferent. Another subdivision of the PNS is called the autonomic nervous system (ANS)—which is mostly made up of different kinds of motor neurons that innervate smooth and heart muscles. They are called autonomic because they mostly work without affecting our consciousness, so the idea is that they work independently of the rest of the nervous system, though it's now clear that one can affect the autonomic nervous system consciously. One branch of the ANS is the Sympathetic branch--these neurons release norepinephrine (or noradrenaline) as their transmitter and are therefore called "adrenergic". The other branch of the ANS consists of Parasympathetic neurons that release the transmitter acetylcholine and are called "cholinergic". Sympathetic and parasympathetic neurons often make synapses on the same "target" organs, but they have opposing effects. Some target organs include the heart, the blood vessels, smooth muscle in sweat glands, the iris, the smooth muscle of the gut--etc. Sympathetic activity tends to increase the heart rate, constrict blood vessels (causing an increase in blood pressure), stop peristaltic contractions in the intestines, dilate the pupils, and inhibit glandular secretions. What might cause such a response? This is the so-called "fight or flight" syndrome. It prepares an animal for dealing with threatening situations--stopping all nonessential functions and increasing the flow of blood and energy to muscles and heart and other essential organs. Parasympathetic neurons have the opposite effect, slowing heart rate, relaxing blood vessels, increasing peristalsis, constricting the pupils, and releasing fluid from sweat and salivary glands. This is sometimes called the "rest and digest "phenomenon.

Finally the brain and the neurons of the spinal cord make up the CNS, which is most neurons in vertebrates. These are involved with information processing and so-called higher order functions, including perception (vision, hearing, etc.), thinking, memory, consciousness, etc. Figs. 1. 11 through 1.14 show the basic organization of the human CNS.

While I mostly want you to get out of this section of the book is some familiarity with words or terms and concepts I'll be using over and over in the course. Some words--like axon, myelin, synapse, cell body--you should learn ASAP. But others, like autonomic ganglia, may not be relevant until we come back to them in greater detail later in the course (e.g., sympathetic nervous system). If you do encounter a term that seems vaguely familiar, or that you don't recognize at all, come back to today's notes, or look it up in the book or Sylvius CD to refresh your memory.