Note: We will not be following the book exactly. Most of the material will be covered, but in a different order:

1) brief overview
2) anatomy and function of neurons
3) input - sensory apparatus (given time)
4) output (mostly muscles)
5) putting it all together - processing/integration/etc.

Nervous system, overview:

Purpose - to control/respond to the environment, internally or externally.

Essentially, three steps (see also fig. 28.1A, p. 564):

sensory --> processing (integration) --> motor output (usually)

Physically, the nervous system is divided into:

CNS - central nervous system (brain and spinal cord)
PNS - peripheral nervous system (everything else)

Some more terminology:

nerve - bundle of neurons wrapped with connective tissue
ganglion (plural = ganglia) - cluster of nerve (neuron) cell bodies (usually in PNS, but sometimes also considered to be in the CNS).

Nervous system, part I - anatomy and function of neurons.

Neurons have three basic parts **[Fig. 28.2, p. 565]**:

1) cell body - contains nucleus, etc.

2) dendrites - tree like structure that take the signal from the tips (of dendrites) to the cell.

3) axons - these can be very long and take the signal from the cell body to the end of the axon.

Can have a variety of shapes, depending on the location.

Supporting cells:

myelin sheath

- in the PNS this is formed by Schwann cells.

- in the CNS this is formed by oligodendrocytes.

- An example of their importance: multiple sclerosis causes deterioration of the myelin sheath, thus resulting in serious loss of coordination (we'll examine the function of the myelin sheath shortly).

astrocytes

- maintain a blood/brain barrier. This prevents the passage of many substances into the brain, which ensures that a constant chemical environment is maintained.

- they also offer support and nutrients to the neurons

Function of neurons:

To transmit a signal from the dendrites to the axon. This is accomplished as follows:

- across the plasma (cell) membrane there is an electrical potential. This is set up by positive and negative ions that exist in different concentrations in or outside the cell.

- inside the cell, it's slightly negative **[Fig., not in book]**

  - we have four ions to consider: K+, Na+, Cl-, and A- (A- represents all other (-) ions).

  - more K+ inside, more Na+ outside.

  - more Cl- outside, A- is only inside. (A is all other (-) ions). For the most part we can ignore the (-) ions.

  - overall, the membrane potential is -70 mV (if outside is set to neutral and if this is then measured).

  - this gradient is maintained by a K/Na pump (active transport) otherwise diffusion would get rid of these inequalities **[Fig. 28.3, p. 566]**.

- stimulus - can do one of three things **[Fig., not in book]**:

  - hyperpolarize cell. The potential becomes more negative due to an efflux (= moving out) of K+ ions (the cell opens a K+ channel to enhance diffusion)

  - depolarize cell. The potential becomes less negative, by opening a Na+ channel. This causes influx of Na+.

- action potential. If the depolarization is strong enough (reaches a threshold), the result is an action potential.

- Action potential:

    - this causes a brief reversal of membrane polarity. Important: The resting state polarity is quickly restored --> the entire process is over in a few milliseconds.

    - an overview (remember this):

        - Na channel opens rapidly in response to depolarization (rushes in --> changes polarity).

        - K channel opens slowly in response to depolarization.

        - Na channel closes slowly in response to depolarization.

    - details **[Fig., similar to 28.4, p. 567]**:

        - when depolarization reaches the threshold, this sets off a chain reaction whereby many Na channels open all at once. This causes further rapid depolarization (steps 1 & 2 in figure).

        - then, Na channel closes (also in response to depolarization (this is actually a separate "gate")) (step 4).

        - also, K channels now open, allowing K to move out. K moves out very rapidly, reversing the polarity, even causing a slight undershoot (i.e., hyperpolarization) (also step 4).

        - at this time, both Na gates are closed, thus a new stimulus can't cause an action potential. K continues to move out (steps 4 & 5)

    - because depolarization in one part causes depolarization in adjacent parts of the cell membrane, a signal can be made to travel the length of the "axon". Signal will travel length of axon **[Fig. 28.5, p. 568]**.

        - remember that right after depolarization, the Na gates are closed, so that the signal won't travel backwards.

Speed of this signal is controlled by:

    - diameter of neuron. Squid have huge neurons.

- Schwann cells. These allow signal to "skip" from one location to the next, bypassing the need to travel the entire length of the axon **[Fig., not in book]**.

- speed varies from several cm/second to 100 m/s in squid, to 150 m/s in animals with Schwann cells.

Synapses:

- "connections" between different neurons. Two types:

  - electrical - this just allows action potential to travel from one cell to the next. We won't worry about these (not very common in vertebrates).

  - chemical - a gap exists. Essentially, a chemical is released into the gap between two neurons. As this chemical diffuses across the gap, the neuron at the receiving end can respond by starting an impulse, or by inhibiting an impulse (depends on the chemical).

chemical connections:

- pre-synaptic neuron **[Fig. 28.6, p. 569]**:

  - contains many vesicles filled with neurotransmitter.

  - when an action potential arrives, these (vesicles) fuse with the membrane and their contents are released into the gap (this release is caused by an influx of Ca^+ ions, which move in in response to the action potential traveling down the neuron).

- post-synaptic neuron:

  - receptors on the post-synaptic neuron are specific to certain types of neurotransmitter. Depending on which receptor is activated, an ion channel opens up allowing, for example, Na^+, K^+, or Cl^- to cross.

  - In other words, these gates are chemically activated, not electrically.

  - As a result, the voltage of the membrane in the post-synaptic neuron is either decreased (i.e., neuron is excited and brought close to a threshold (action potential)), or increased (neuron is inhibited - hyperpolarized).

- comments:

        - this system ensures one-way communication

        - the neurotransmitter is broken down very quickly by enzymes, both in the gap and in the post-synaptic neuron.

    - integration of multiple input:

        - obviously, the post-synaptic neuron can get signals from many other neurons. Some excite, some inhibit **[Fig. 28.7 p. 570]**.

        - how does the neuron "decide" what to do? **[Fig., not in book]**

            - sum up impulses. Overall value (& frequency) of impulses coming in determines if neuron fires.

            - voltage at "axon hillock" determines if neuron will fire.

Types of neurotransmitters:

- acetylcholine - excites muscles, but can inhibit in other areas.

    - note that the action of a neurotransmitter depends not only on the type of neurotransmitter, but also on where it is released.

- some general comments and examples:

    - dopamine and serotonin affect sleep, mood, learning, attention.

        - excess dopamine --> schizophrenia

        - insufficient dopamine --> Parkinson's disease

        - LSD, etc. --> function by mimicking other neurotransmitters and binding to the receptors for these neurotransmitters in the brain.

        - morphine, heroin --> bind to sites meant for endorphins (pain-killers produced by pituitary).