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

1) anatomy and function of neurons

2) input - sensory apparatus

3) output (mostly muscles)

4) putting it all together - processing/integration/etc.

First a quick overview of the nervous system.

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

Essentially, three steps **[Fig. 28.1A, p. 564]**:

sensory input → processing (integration) → output (usually, but not always, *motor* output)

Physically, the nervous system is divided into two parts:

CNS - central nervous system, which includes the brain and spinal cord.

PNS - peripheral nervous system, which is everything else (e.g., nerves in your limbs).

Some more terminology:

nerve - a bundle of neurons wrapped with connective tissue

ganglion (plural = ganglia) - a cluster of nerve cell bodies (see below for neuron structure).

Anatomy and function of neurons.

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

Cell body - this contains the nucleus, mitochondria, other organelles, etc.

Dendrites - usually a tree like structure that brings the signal into the nerve cell.

The shape of dendrites can vary quite a bit. Sometimes they can be very long.

Axons - usually very long; they take the signal out of the nerve cell.

Like with dendrites, the actual shape can vary quite a bit.

Neurons can have a variety of shapes, depending on where they're located.

Supporting cells:

Myelin sheath - helps increase the speed of the signal.

In the PNS this is formed by *Schwann cells*.

In the CNS this is formed by *oligodendrocytes*.

We already discussed the importance of they myelin sheath:

In multiple sclerosis this sheath is destroyed, which causes the nervous system to break down.

We'll examine the exact function of the myelin sheath shortly.

Astrocytes

These help to maintain the blood/brain barrier.

This prevents the passage of many substances, which ensures that a constant environment is maintained.

They also offer support and nutrients to the neurons.

Function of neurons.

Neurons transmit a signal from one part of the body to another through the length of a neuron.

The details:

Neurons are “electrically” charged - there is a voltage across the plasma (cell) membrane.

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).

When the cell is resting there is more K^+ inside and more Na^+ outside.

The (-) ions are also important in helping to keep the cell slightly negative, but we can ignore the details.

Overall, the inside of the cell is about -70 mV (milli-volts).

This voltage is set up and maintained by a K/Na pump using active transport.

Otherwise diffusion would get reset everything **[Fig. 28.3, p. 566]**.

Suppose something happens to stimulate our cell. One of three things can happen **[Fig., not in book]**.

K^+ ions can move out - this hyperpolarizes the cell (it becomes more negative).

A few Na^+ ions move in - this depolarizes the cell (it becomes more positive).

A lot of Na^+ ions move in - this results in an action potential.

The voltage changes very rapidly to (+), then changes back to (-).

Action potential in more detail.

An overview.

Na channel opens rapidly in response to depolarization

Na^+ rushes in and makes cell positive.

K channel opens slowly in response to depolarization.

K^+ rushes out and makes cell negative.

Na channel closes slowly in response to depolarization.

Prevents more Na^+ from rushing in.

The entire process is over in a few milliseconds!

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

When the inside voltage rises to a threshold (-55mv), this sets of a chain reaction:

Many Na channels open all at once.

This causes voltage to spike (climbs to + 35mv)

The Na channels then close. This stops Na^+ from moving in.

The K channels open at the same time.

K^+ moves out, this changes the cell back to negative very quickly.

K^+ now needs to be moved back in, and Na^+ needs to be moved back out

This uses the K/Na pump, which restores the ions to their usual state.

Comments:

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 neuron **[Fig. 28.5, p. 568]**.

Because the Na gates are closed right after Na^+ rushes in, and because K^+ had made the cell negative, the signal can't travel backwards.

Speed of an action potential is controlled by:

Diameter of neuron. The thicker, the faster.

Squid, for example, have huge neurons. Action potentials can travel up to 100 m/s.

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]**.

Vertebrates (including humans) have Schwann cells; our action potentials can move at speeds up to 150 m/s.

Synapses:

These are "connections" between different neurons. Two types:

Electrical - these just allows action potential to travel from one cell to the next. We won't worry about these (found in some insects and other animals, but 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 (depends on the chemical (= neurotransmitter)).

Starting an impulse.

Inhibiting an impulse.

Some details on chemical synapses:

Pre-synaptic neuron **[Fig. 28.6, p. 569]** contains many vesicles filled with neurotransmitter.

When an action potential arrives, Ca^{++} ions move in and cause the vesicles to fuse with the cell membrane

The contents of the vesicles are then released into the gap.

Post-synaptic neuron:

This has receptors that are specific to certain types of neurotransmitter.

Depending on which receptor is activated different ions are allowed to move in or out of the post-synaptic neuron:

For example, Na^{+}, K^{+}, or Cl^{-} might be allowed to cross the membrane.

This can increase or decrease the voltage of the post-synaptic neuron.

If the voltage is increased, it makes the cell more likely to start an action potential.

If the voltage is decreased, it makes the cell less likely to start an action potential.

Comments:

Again, 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.

If this doesn't happen, the result can be uncontrolled neuron activity and/or muscle movement.

Integration of multiple input (how does the post-synpatic neuron figure out what to do?:

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]**

It sums up all the impulses.

Of the voltage at "axon hillock" reaches the threshold (-55mv), the neuron will fire.

Types of neurotransmitters (just a brief overview):

Acetylcholine - excites muscles, but can inhibit in other areas (e.g., around the heart).

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

A few more examples:

Dopamine and serotonin affect sleep, mood, learning, attention.

Excess dopamine → schizophrenia

Insufficient dopamine → Parkinson's disease

Many drugs (illicit and otherwise) mimic neurotransmitters:

LSD - mimics serotonin.

Morphine, heroin - bind to sites meant for endorphins.

Morphine is a powerful (but addictive) pain-killer used in hospitals.