The Brain & Homeostasis

- Today, scientists have a lot of information about what happens in the different parts of the brain; however, they are still trying to understand how the brain functions.
- We know that the brain coordinates homeostasis inside the human body. It does this by processing information which it receives from the senses.
- The brain makes up only 2% of the body’s weight, but can contain up to 15 percent of the body’s blood supply, and uses 20 percent of the body’s oxygen and glucose supply.
- The brain is made up of 100 billion neurons.
- Early knowledge of how the brain functions came from studying the brains of people who have some brain disease or brain injury.

The Brain & Technology

- Innovations in technology have resulted in many ways of probing the structure and function of the brain. These include:
  - The electroencephalograph (EEG) which was invented in 1924 by Dr. Hans Berger. This device measures the electrical activity of the brain and produces a printout (see Fig. 12.8, P. 398). This device allows doctors to diagnose disorders such as epilepsy, locate brain tumors, and diagnose sleep disorders.
  - Another method is direct electrical stimulation of the brain during surgery. This has been used to map the functions of the various areas of the brain. In the 1950s, Dr. Wilder Penfield, a Canadian neurosurgeon, was a pioneer in this field of brain mapping.
  - Advances in scanning technology allow researchers to observe changes in activity in specific areas of the brain. Scans such as computerized tomography (CAT scan), positron emission tomography (PET scan), and magnetic resonance imaging (MRI scan) increase our knowledge of both healthy and diseased brains.

CAT, PET, and MRI Scans

- **CAT scans** take a series of cross-sectional X-rays to create a computer generated three-dimensional image of the brain and other body structures.
- **PET scans** are used to identify which areas of the brain are most active when a subject is performing certain tasks.
- **MRI scans** use a combination of large magnets, radio frequencies, and computers to produce images of the brain and other body structures.
The Neuron

A typical nerve cell or neuron consists of three main parts:
1. Cell body
2. Dendrites
3. Axon

See Fig. 12.6, P. 395

Parts of a Neuron

- **Cell Body**
  - The largest part of a neuron.
  - It has a centrally located nucleus which contains a nucleolus. It also contains cytoplasm as well as organelles such as mitochondria, lysosomes, Golgi bodies, and endoplasmic reticulum.

- **Dendrites**
  - Receive signals from other neurons.
  - The number of dendrites which a neuron has can range from 1 to 1000s depending on the function of the neuron.

- **Axon**
  - A long cylindrical extension of the cell body.
  - Can range from 1 mm to 1 m in length.
  - When a neuron receives a stimulus, the axon transmits impulses along the length of the neuron. At the end of the axon, there are specialized structures (axon terminals) which release chemicals that stimulate other neurons or muscle cells.

All axons in the PNS are surrounded by Schwann cells.
- Schwann cells insulate (or myelinate) individual axons creating a covering called the myelin sheath.
- The gaps between adjacent Schwann cells are called nodes of Ranvier.

Types of Neurons

- There are three types of neurons:
  - Sensory neuron
    - Carries information from a sensory receptor to the CNS.
  - Motor neuron
    - Carries information from the CNS to an effector such as a muscle or gland.
  - Interneuron
    - Receives information from sensory neurons and sends it to motor neurons.

See Figs. 12.7, P. 396
How The Neuron Works

Resting potential:

- Neuron at “rest”
- Not carrying an impulse
- Neuron surface is polarized
  - Outside is overall positively charged, while inside is overall negatively charged
  - Outside of neuron membrane is positively charged
- Caused by higher concentrations of positive ions than negative ions outside in the tissue fluid.

Diagram of neuron in resting potential

- Some Na⁺ ions and K⁺ ions are present inside, but the overall charge is negative
- Membrane of neuron has gated channels to move Na⁺ and K⁺ ions.
- The larger negatively charged ions in the cell (proteins, amino acids, etc.) cannot diffuse out.
- The Na⁺ and K⁺ ions outside are attracted to the negative ions inside the cell and start to diffuse in.

Action Potential

- Action potential is when a neuron’s membrane has been stimulated to carry an impulse. The membrane depolarizes (polarity reverses)
- Stimulation causes a wave of depolarization to travel along the neuron, from the dendrites, through the cell body to terminal brushes.

- When the neuron receives an impulse the membrane becomes highly permeable to sodium.
- The gated K⁺ channels close and the gates of the Na⁺ channels open → Na⁺ ions move into the axon, making the interior more positive than the outside of the neuron.
- This causes a depolarization in this area of the neuron, causing the polarity to be reversed area of the axon.
- The sodium rushes in displacing the potassium. For a very short time the polarity of the affected region changes and becomes positive on the inside and negative on the outside
- This action sets off a chain reaction where the membrane next to the affect one becomes permeable. In this fashion the impulse is transferred the length of the neuron.
A Few More Points About A. P.

- Power of the nervous system
  - Oxygen and glucose are used by the mitochondria of the neuron to produce energy-rich molecules called ATP, which are used to fuel the active transport of Na\(^+\) and K\(^+\).
- Wave of Polarization
  - By using a wave impulse can move along the entire length of a neuron and the strength of the signal does not decrease.
  - Thus, a stimulus such as stubbing your toe gets to the brain at the same strength as a bump in the head.
- Threshold
  - the level of stimulation a neuron needs for an action potential to occur. (e.g. a particle of dust landing on your skin is below threshold, you don’t feel it but a fly landing on your skin is above threshold, you feel it)

Refractory Period

- The brief time between the triggering of an impulse and the time it takes to restore the neuron back to resting potential, so that it can carry another impulse.
- A neuron cannot transmit two impulses at once, it must first be reset before it can be triggered.

Repolarization of the Neuron

- Areas are depolarized only for a split second
  - As the impulse passes, gated sodium ion channels close, stopping the influx of sodium ions.
  - Gated potassium ion channels open, letting potassium ions leave the cell. This repolarizes the cell to resting potential.
  - The gated potassium ion channels close and the resting potential is maintained by the Na\(^+\)/K\(^+\) pumps, restoring this area of the axon back to resting potential.

All-or-None Principle

- Axons are governed by this principle.
  - Neurons do not send mild or strong impulses. If an axon is stimulated above the threshold level, the axon will trigger an impulse along the entire length of the neuron.
  - The strength of the impulse is the same along the entire neuron. Also, the strength of an impulse is not made greater by the strength of the stimulus. The neuron fires at the same strength all the time.
  - So what causes the sensation from a mild poke to be different from a hard jab?
  - Pain receptors are buried at different levels of the skin. The harder the jab, the more receptors fire off, increasing the sensation of pain.
Summary:

- An action potential is triggered by depolarization.
- Depolarization needs to reach threshold in order to trigger an action potential.
- All-or-None principle – if threshold is reached an action potential is triggered.
- The amplitude of the action potential remains the same regardless of the strength of the signal.

The Synapse

- The gap between the axon terminal of one neuron and the dendrite of another neuron or an effector muscle.
- Pre-synaptic neuron: The neuron that carries the wave of depolarization (impulse) towards the synapse.
- Post-synaptic neuron: The neuron that receives the stimulus from across the synapse.
- Synaptic vesicles: Specialized vacuoles found in the pre-synaptic neuron’s axon terminal membrane.

A synapse

The Synaptic Response

- When the axon terminals of the pre-synaptic neuron receive an impulse, special calcium ion gates in the membrane open.
- This triggers the release of neurotransmitter molecules from synaptic vesicles in the membrane.
- The neurotransmitters diffuse into the synapse area, binding with special sites on the postsynaptic neuron’s dendrites called receptor sites.

Neurotransmitters

- Neurotransmitters are either excitatory or inhibitory.
  - Excitatory neurotransmitter: The impulse will be passed on, starting up in the post-synaptic neuron and continuing through this neuron.
  - Inhibitory neurotransmitter: Blocks the transmission from going into the next neuron.

Neurotransmitters and their Effects

1. Acetylcholine
   - Can have excitatory or inhibitory effects, depending on the muscle on which it acts. Stimulates skeletal muscle but inhibits heart muscle.
   - Is the primary neurotransmitter of the somatic and parasympathetic nervous system.
2. Noradrenalin
   - The primary neurotransmitter of the sympathetic nervous system.
3. Glutamate
   - Neurotransmitter of the cerebral cortex; accounts for 75% of all excitatory transmissions in the brain.
Neurotransmitters and their Effects

4. **GABA (Gamma Aminobutyric Acid)**
   - Most common inhibitory neurotransmitter in the brain.

5. **Dopamine**
   - Works in the brain to elevate your mood (happy happy!!!) and works out in the body to help control skeletal muscles.

6. **Serotonin**
   - Involved in alertness, sleepiness, thermoregulation (body temp) and regulating your “mood”.

Resetting the Synapse

- For normal nerve-to-nerve communication across a synapse to occur, excess neurotransmitters must be dissolved following the transmission of a nerve impulse.
- Cholinesterase is an enzyme that dissolves the neurotransmitter acetylcholine into its component molecules: acetate and choline. These building blocks can then be recycled to form more acetylcholine for the next round of nerve signal transmission.
- For example, in muscle contraction, acetylcholine at a neuromuscular junction triggers a contraction, but for the muscle to relax afterward, rather than remaining locked in a tense state, the acetylcholine must be broken down by a cholinesterase.