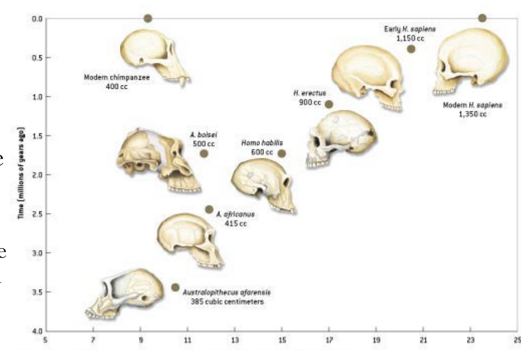
Unit 4: Animal Systems
The Nervous System

Biology 30
Mr. Oosterom

12.1
The Structure of the Nervous System

- Humans have the most complex nervous System of all organisms on earth
  - This is the result of millions of years of evolution.
- The evolution of the more complex vertebrate brain exhibits a number of trends
  1. The ratio of the brain to body mass increases.
  2. There is a progressive increase in the size of the area of the brain, called the **cerebrum**, which is involved in higher mental abilities.
- Over the past two million years, the human brain has doubled in size.



Structure of the Nervous System

- The human nervous system is very important in helping to maintain the homeostasis (balance) of the human body.
- The human nervous system is a high speed communication system to and from the entire body.
- A series of sensory receptors work with the nervous system to provide information about changes in both the internal and external environments.
- The human nervous system is a complex of interconnected systems in which larger systems are comprised of smaller subsystems each of which have specific structures with specific functions.

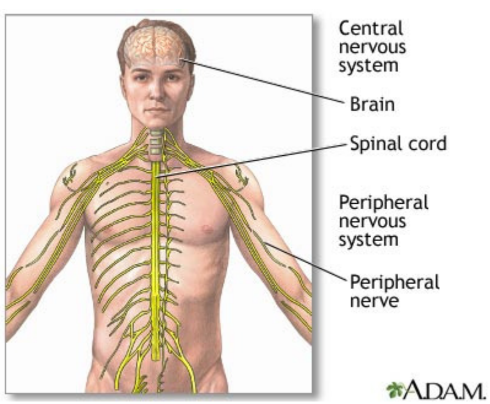
Two Major Components

- Central Nervous System (CNS)
  - Made up of the **brain** and **spinal cord**
- Peripheral Nervous System (PNS)
  - The PNS is made up of all the **nerves** that lead into and out of the CNS.

Central Nervous System

- The CNS, brain and spinal cord, receives sensory information and initiates (begins) motor control.
- This system is extremely important and therefore must be well protected. Protection is provided in a variety of ways
  - Bone provides protection in the form of a skull around the brain and vertebrae around the spinal cord.
  - Protective membranes called **<u>meninges</u>** surround the brain and spinal cord.
  - Cerebrospinal fluid fills the spaces between the meninges membranes to create a cushion to further protect the brain and spinal cord.

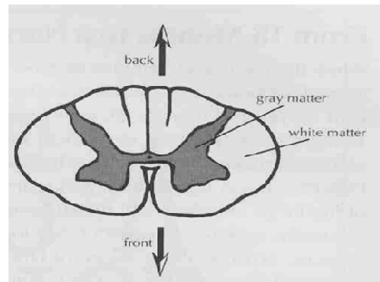
CNS



- The spinal cord extends through the vertebrae, up through the bottom of the skull, and into the base of the brain.
- The spinal cord allows the brain to communicate with the PNS.
- A cross section of the spinal cord shows that it contains a central canal which is filled with cerebrospinal fluid, and two tissues called **<u>grey matter</u>** and **<u>white mater</u>**.

Grey Matter

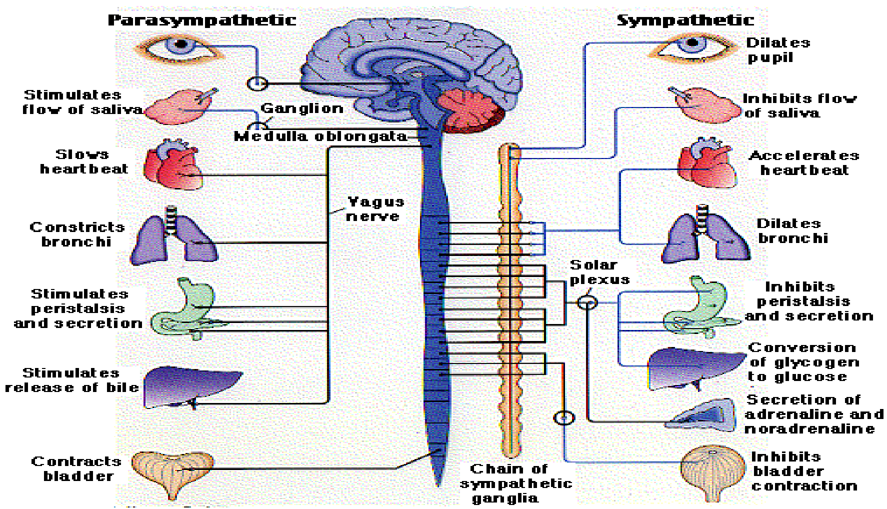
- The grey matter is made of neural tissue which contains three types of nerve cells or neurons:
  1. Sensory neurons
  2. Motor neurons
  3. Interneurons
- Grey matter is located in the center of the spinal cord in the shape of the letter H.
- The white matter of the spinal cord surrounds the grey matter. It contains bundles of interneurons called **tracts**



Peripheral Nervous System

- Made up entirely of nerves
- The PNS is made up of two subsystems:
  1. Autonomic Nervous System
  2. Somatic Nervous System
- The autonomic nervous system is not consciously controlled and is often called an involuntary system. It is made up of two subsystems:
  1. Sympathetic Nervous System
  2. Parasympathetic Nervous System
- The sympathetic and parasympathetic systems control a number of organs within the body.

Sympathetic vs. Parasympathetic



See Also:

Page 394

Figure 12.5

Fight-or-Flight

- The sympathetic nervous system sets off what is known as a "fight - or - flight" reaction.
  - This prepares the body to deal with an immediate threat.
  - Stimulation of the sympathetic nervous system causes a number of things to occur in the body:
    1. Heart rate increases
    2. Breathing rate increases
    3. Blood sugar is released from the liver to provide energy which will be needed to deal with the threat.

Parasympathetic N.S.

- The parasympathetic nervous system has an opposite effect to that of the sympathetic nervous system. When a threat has passed, the body needs to return to its normal state of rest.
- The parasympathetic system does this by reversing the effects of the
  - Heart rate decreases (slows down).
  - Breathing rate decreases (slows down).
  - A message is sent to the liver to stop releasing blood sugar since less energy is needed by the body

Somatic Nervous System

- Made up of **sensory nerves** and **motor nerves**.
- Sensory nerves carry impulses (messages) from the body's sense organs to the central nervous system.
- Motor nerves carry messages from the central nervous system to the muscles.
- To some degree, the somatic nervous system is under conscious control.
- Another function of the somatic nervous system is a reaction called a **reflex**

Receptors, Effectors and Neurons

5 skin receptors

1. Pain
2. Heat
3. Cold
4. Pressure
5. Touch

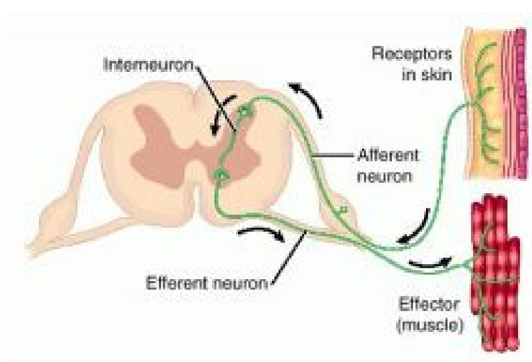
4 special sensory organs

1. Nose
2. Eyes
3. Ears
4. Tongue (taste)

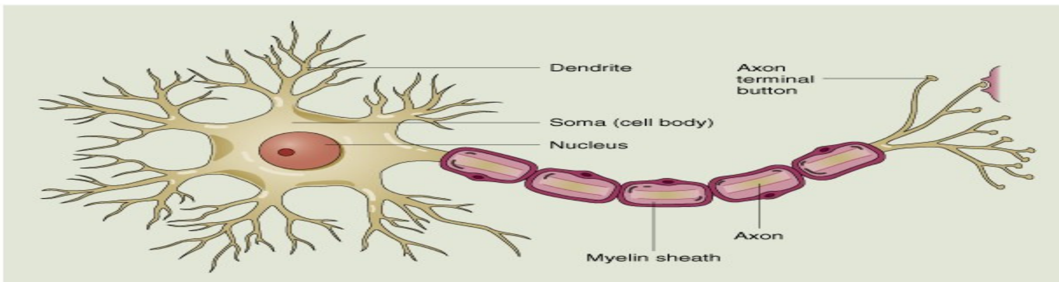
- **Receptors**
  - Take in stimuli (pain, smell etc.) from the environment and relay it to the CNS for processing.
- **Effectors**
  - The muscles and glands of the body , which respond to nerve impulses sent to them from the CNS via the PNS.

Reflex Response

- The **neuron** or nerve cell is the structural and functional unit of the nervous system.
- Both the CNS and the PNS are made up of neurons.
- 90% of the body's neurons are found in the CNS.
- Neurons held together by connective tissue are called **nerves**.
- The nerve pathway which leads from a stimulus to a reflex action is called a **reflex arc**.



The Neuron



- A typical nerve cell or neuron consists of three parts

1. The 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
  - long cylindrical extension of the cell body.
  - Can range from 1mm to 1m 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 which release chemicals that stimulate other neurons or muscle cells.

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.

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.

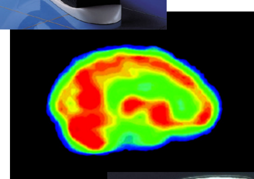
The Brain & Technology

- 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 Borger. 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.

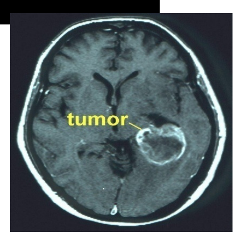
CAT, PET, and MRI Scans

- **CAT scans** take a series of cross-sectional X-rays to create a computer generated three dimensional images 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.



Parts of the Brain

- See page 399, figure 12.11

- The **medulla oblongata** is located at the base of the brain where it attaches to the spinal cord. It has a number of major functions:
  - It has a cardiac center which controls a person's heart rate and the force of the heart's contractions.
  - It has a vasomotor center which is able to adjust a person's blood pressure by controlling the diameter of blood vessels.
  - It has a respiratory center which controls the rate and depth of a person's breathing.
  - It has a reflex center which controls vomiting, coughing, hiccupping, and swallowing.

- Any damage to the medulla oblongata is usually fatal.

Cerebellum & Thalamus

- **Cerebellum**
  - Located towards the back of the brain, controls muscle co-ordination. This structure contains 50 percent of the brain's neurons. By controlling our muscle coordination, the cerebellum helps us maintain our balance.

- **Thalamus**
  - Known as a sensory relay center. It receives the sensations of touch, pain, heat and cold as well as information from the muscles. Mild sensations are sent to the cerebrum, the conscious part of the brain. Strong sensations are sent to the hypothalamus

Hypothalamus & Cerebrum

- **Hypothalamus**
  - Main control center for the autonomic nervous system.
  - Helps the body respond to threats (stress) by sending impulses to various internal organs via the sympathetic nervous system. After the threat is passed, it helps the body to restore to its normal resting state or homeostasis.
- **Cerebrum**
  - Largest part of the brain. It has a number of functions:
    - All of the information from our senses is sorted and interpreted in the cerebrum.
    - Controls voluntary muscles that control movement and speech
    - Memories are stored in this area.
    - Decisions are made here

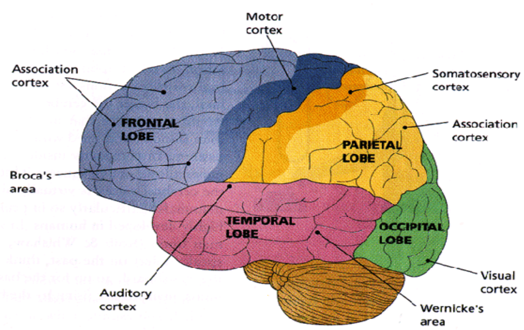
More on the Cerebrum

- The cerebrum is divided into two halves:
  - **Right and left hemispheres**.
  - Each hemisphere is covered by a thin layer called the **cerebral cortex**. This cortex contains over one billion cells and it is this layer which enables us to experience sensation, voluntary movement and our conscious thought processes. The surface of the cortex is made of grey matter.
- The two hemispheres are joined by a layer of white matter called the **corpus callosum** which transfers impulses from one hemisphere to the other.
- The cerebrum is also divided into four lobes.

See Fig. 12.12, P. 400

The Four Lobes

- Frontal Lobe
  - Involved in muscle control and reasoning. It allows you to think critically
- Parietal Lobe
  - receives sensory information from our skin and skeletal muscles.
  - It is also associated with our sense of taste
- Occipital Lobe
  - Receives information from the eyes
- Temporal Lobe
  - Receives information from the ears



12.2 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 .

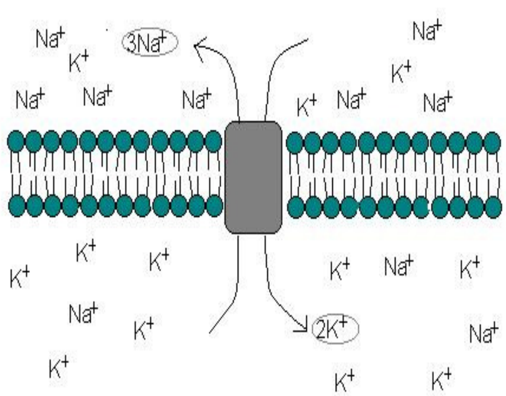
Diagram of neuron in resting potential

+++ + + + lots of Na^+, less K^+ + + + + ++++++++++++ **OUTSIDE THE AXON**

- - - - - - - - - - - - - + - - - - - - - - - - - - - - - - - - + - - - - - - - - - - - - - - - **INSIDE THE AXON** - - - - - - - - - -

- - - - + - - - - + - - - - - - - - - - - - - - - - - + - - - - - - - + - - - - - - - - - - -

- 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.



- Resting potential (-70 mV) is maintained by special gated channels in the neuron's membrane called sodium - potassium (Na^+ /K^+) pumps
- For every 3 Na^+ ions they pump out of the cell, in exchange they pull 2 K^+ ions back into the cell. (a 3 out, 2 in ratio).
- This maintains more positive ions outside the cell than inside, maintaining the resting potential polarization
- see fig C in Fig 12.13, p. 403

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.

Action Potential in Action

- Maintenance of membrane potential
- Action Potential
- Action Potential Chain Reaction
- Action Potential of a Myelinated Neuron

http://resources.scottoosterom.ca/ - Biology 3201 Resources

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.

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)

All-or-None Principle

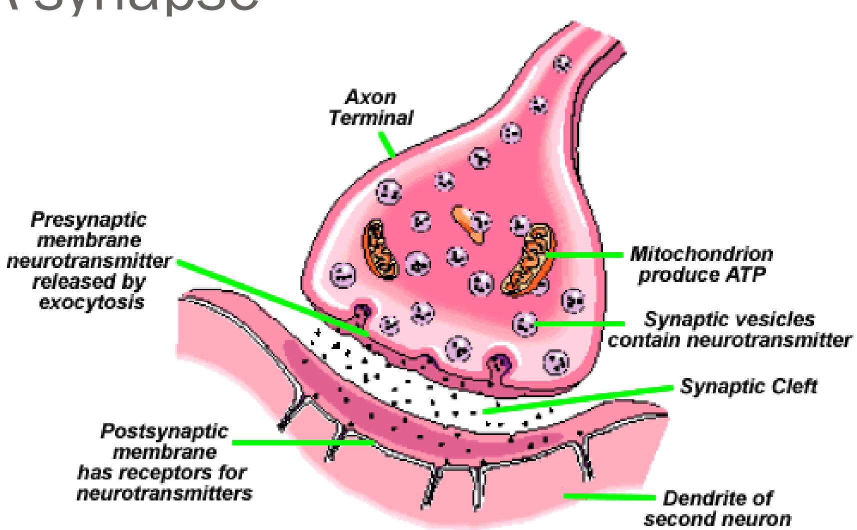
- Axons are governed by this principle.
- Neurons do not send mild or strong impulses. If an axon is stimulated above the threshold level, the axon will trigger an impulse along the entire length of the neuron.
- The strength of the impulse is the same along the entire neuron. Also, the strength of an 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

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 call **receptor sites**.

- 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

1. **GABA (Gamma Aminobutyric Acid)**
   - Most common inhibitory neurotransmitter in the brain.
2. **Dopamine**
   - works in the brain to elevate your mood **(happy happy!!!)** and works out in the body to help control skeletal muscles.
3. **Serotonin**
   - Involved in alertness, sleepiness, thermoregulation (body temp) and regulating your "mood".