The Nervous System

• The evolution of the human nervous system is the most complex of all organisms on Earth.
• How the human brain works is still one of the least understood of all our body systems.
• The ability for humans to learn and solve problems has increased our intellectual powers and has set us apart from other organisms.
Evolution of the Brain

• Over the past two million years of human evolution the human brain has doubled in size.

• Compared to other primates, newborns have very large heads relative to their body size.

• Some researchers believe that humans have reached their maximum brain size.

• Why???
Maintaining Dynamic Equilibrium

• M.D.E. – are the constant changes that take place within all body systems to keep body functions maintained at a healthy and stable balance.

• Homeostasis –
  Homeo = same
  Stasis = state
The Nervous System

• The body’s nervous system is an elaborate high speed communication system to virtually all parts of the body.

• It’s function:
  – To send and receive information through a series of networks to monitor both the internal and external environment of the body.
The Two Major Components

• The **Central Nervous System (C.N.S.)**
  – Brain
  – Spinal Chord

• The **Peripheral Nervous System (P.N.S.)**
  – All nerves leading into and out of the Central Nervous System (C.N.S.)
The C.N.S.

- The C.N.S. receives sensory information and initiates motor control.
- The C.N.S. is protected from damage by three mechanisms.
  - **Bone** – The brain is protected by the outer skull, and the spinal chord is protected by the vertebrae.
  - **meninges** – a sealed impermeable membrane that isolates the CNS.
  - **Cerebrospinal fluid** cushions and nourishes the CNS.
Spinal Chord & Vertebral Column

- The spinal chord extend down from the base of the brain, through the vertebral column, down to the lower lumbar area.
- The ‘information highway’ which all stimuli are sent and/or received by the brain.
The Peripheral Nervous System

• The P.N.S is made up of the **Autonomic Nervous System** and the **Somatic Nervous System**.

• The Autonomic Nervous system, as implied by the name, is not consciously controlled. The body automatically regulates what action is needed.
Autonomic Nervous System

• **Sympathetic Nervous System**
  – Triggers the ‘fight-or-flight’ reaction to immediately prepare the body to deal with a threat.
  – Sugars are released, also the heart and respiration rates are increased.

• **Parasympathetic Nervous System**
  – Opposes the sympathetic. It triggers the body to cool down after a threat has passed.

‘the natural high’
Autonomic Nervous System

- Involuntary responses
- Pathways go to the glands, blood vessels and organs.
- Digestion, elimination, heart rate, salivation, perspiration, breathing, sexual arousal

Sympathetic Nervous System

- Fight or Flight (being chased by Zombies)
- Muscle breakdown (catabolic)
- Releases muscle destroying and fat storing hormones
- Cortisol, Adrenaline (noradrenaline)
- Increased heart rate, blood pressure, sweating, blood vessels and pupils dilate, blood flow to the limbs.
- Decrease in digestion and sexual function
- Naturally active during the day
- Everyday stress: Traffic, deadlines, kids, family, relationships.

Parasympathetic Nervous System

- Rest and Digest (sleeping and healing)
- Muscle building (anabolic)
- Releases muscle building hormones
- Growth hormone, DHEA, Melatonin, Testosterone, Estrogen
- Repairs the body and responsible for sexual arousal
- Stimulates digestion and elimination
- Naturally active at night (specifically between 10 pm and 2 am)
- Fixes the damage the Sympathetic Nervous System does to the body.

http://garyfisk.com/anim/autonomous.swo
Somatic Nervous System

- Consists of two components:
  - The sensory nerves that carry information from the body’s organs to the C.N.S.
  - The motor nerves that transmit responses from the C.N.S. to the muscles.
- The somatic system is under our voluntary, conscious control, with however one exception.....????????
- Reflexes
Structure and Function of the Brain

- There are 8 parts you need to label and list function of:
  - Cerebrum
  - Cerebellum
  - Medulla oblongata
  - Thalamus
  - Hypothalamus
  - Midbrain
  - Pons
  - Corpus callosum

Links:
Overview Videos – click on one or more

https://www.youtube.com/watch?v=snO68aJTOpM
http://www.youtube.com/watch?v=ivk_irrH1WY
http://www.youtube.com/watch?v=UabDiuTtU0M
http://www.youtube.com/watch?v=x4PPZCLnVkA
How We Know What We Know

• There have been a number of technologies developed and being developed that helped improve our current understanding of the Structure and Function of the nervous system.

• Some are used to diagnose and possibly treat various nervous system disorders.
  – Make sure you understand which technologies would be used for what purposes. (Structure and Function)
EEG – Electroencephalograph

- Instrument used to detect the electrical outputs of the cells of the brain. (Function)
- Remember the brain runs on ‘electricity’

https://www.youtube.com/watch?v=kNdM9JhTPJw
CAT (CT) Scan – Computerized Axial Tomography

- **CAT Scan (CT)** - is a digital imaging technique used to generate a three-dimensional image from a series of two-dimensional X-ray images taken around a single axis of rotation.

- (Structure)
PET SCAN

• Positron emission tomography (PET) is a nuclear medicine imaging technique which produces a three-dimensional image or map of functional processes in the body.
Magnetic resonance imaging (MRI)

- Commonly used in Radiology to visualize the **structure and function** of the body.
- provides detailed images of the body in any plane.
- provides much greater contrast between different tissues of the body than does CT, making it especially useful in neurological (brain),
Your Turn!!

- Review Read Pages 392-395, and 397-401.
- Preview Read Pages 395-397
Neurons

Cells of the Nervous System
• **Neurons** – specialized cells that transmit signals to/from the CNS at speeds up to 200 mph.
  
  – consists of a **cell body (or soma)** with branching **dendrites** (signal receivers) and a long projection called an **axon**, which conducts the signal. The signal terminates at the **axon terminals** which transmits an electro-chemical signal across a **synapse** (the gap between the axon terminal and the receiving cell).
The Neuron

- **Axon Terminals** (transmitters)
- **Schwann's Cells** (they make the myelin)
- **Node of Ranvier**
- **Myelin Sheath** (insulating fatty layer that speeds transmission)
- **Dendrites** (receivers)
- **Cell Body**
- **Nucleus**
Types of Neurons

1. **Sensory Neurons** - carry messages from the body's sense receptors (eyes, ears, etc.) to the CNS.

2. **Interneurons** – links the sensory and motor neurons, receives information from sensory neurons and other interneurons, and initiates reflex responses.

3. **Motor Neurons** - carry signals from the CNS to the muscles and glands.
A Reflex Arc Shows How Neuron Types Work Together.

The afferent and efferent fibers often pass in the same nerve.
Intro To Reflex Lab

• Patellar Reflex (Knee) -
  http://www.youtube.com/watch?v=qpw31bvoLpg

• Achilles Reflex -
  http://www.youtube.com/watch?v=BEQ6BbLLucA

• Babinski Reflex -
  http://www.youtube.com/watch?v=kOq5Np0eZ6A
How the Nerves work?

• Electrical signals travel through the body as a wave of depolarization along the neurons entire length of the cell.
• This is due to a series of Na\(^+\)/K\(^+\) ions moving across membrane channels changing the charge of the cell and its’ environment.
Neuron at rest

- The exterior of a membrane is positively charged compared to the inside. Due to the action of the sodium potassium pumps.
- Outside = Sodium (+)
- Inside = Chlorides (-) and Potassium (+)
- The difference established is called the **resting potential**.
Crossing the Threshold

- When a stimulus is strong enough to elicit a response, a wave of depolarization will occur along the entire length of the axon.
- This is the all-or-none principal.
Depolarization

- K⁺ gates close and Na⁺ gates open
- Na⁺ rushes into the cell making the interior more positive. This change in charge is called the **action potential**.
- The opening of one gate causes the gate next to it to open (hence - the all-or-none)
Repolarization – (really two parts)

• Almost immediately after depolarizing....
• 1\textsuperscript{st} half of repolarization-
  – Na\textsuperscript{+} gates close, K\textsuperscript{+} gates \textbf{open} letting the K\textsuperscript{+} rush outside. (Outside + again, Inside – again)
• 2\textsuperscript{nd} half of repolarization OR \textbf{Return to Rest}
  – The pump turns back on to pump Na\textsuperscript{+} back out and pump K\textsuperscript{+} back in.
Refractory Period

• The time it takes for the neuron to fire (depolarize) and then return to a resting potential (repolarize) is known as the refractory period.
  – During this short period of time the neuron cannot fire. (0.001s)
- http://outreach.mcb.harvard.edu/animations/actionpotential_short.swf
- http://outreach.mcb.harvard.edu/animations/actionpotential_short.swf
- http://bc.swhfreeman.com/thelifewire/content/chp44/4402s.swf
- http://www.youtube.com/watch?v=UabDiuTu0M
Stimulation of Nerves

- Sensory neurons can be stimulated by multiple things (heat, light, physical etc...)
- Motor neurons and neurons of the CNS usually are stimulated through neurotransmitters. (chemicals released from the axon terminals)
The Synapse

Where the Neurons Communicate
Neural Communication

- Neurons do not touch one another. The axon and dendrite of a neighboring neuron have a tiny space between the cells called the **Synapse**.
The axon of one neuron synapses with the dendrites of other neurons.
A gap called the synaptic cleft separates the presynaptic membrane from the postsynaptic membrane (dendrite or target cell)
Transmitters move across the synapse to send messages from one neuron to the other. Receptor molecules pick up the message.
Presynaptic neurons send signals to a **TARGET CELL/RECEPTOR**. This could be another neuron (postsynaptic), or muscles, other organs, etc....
Two types of response

• **Excitatory response** – will cause an action potential (depolarization) of the post-synaptic neuron.

• **Inhibitory response** – will raise the threshold level of the neuron, or prevent firing.
How it works!!

• A wave of depolarization reaches the pre-synaptic axon terminal and causes the opening of specialized calcium gates (Ca^{2+}).

• The calcium (Ca^{2+}) influx triggers the release of neurotransmitters through exocytosis into the synapse.
An action potential arrives and initiates synaptic transmission.

After synaptic transmission, acetylcholine and vesicles are recycled.

Figure 41.15 Synaptic Transmission Begins with the Arrival of an Action Potential
The Targets Response?

• The response by the target cell/organ/membrane, etc... will depend on the type of neurotransmitter that has been released.
  – Ex. Acetylcholine and Noradrenaline.
Common Neurotransmitters

• (i) acetylcholine
• (ii) noradrenaline
• (iii) glutamate
• (iv) GABA
• (v) dopamine
• (vi) serotonin

Design a table to describe the function of each of the following. YOU NEED TO KNOW THESE.

Include Cholinesterase

– Go back to the

“http://www.brainexplorer.org/neurological_control/Neurological_Neurotransmitters.shtm”
Disorders of the Nervous System
Multiple Sclerosis (MS)

• Believed to be an autoimmune disorder where the body attacks and breaks down or inflames the myelin sheath.

• It is a progressive disorder that currently has no cure. However new treatments have been shown effective in slowing the progression and dealing with symptoms.

• Symptoms vary depending on the regions of nervous tissue affected. (Blurred vision, weakness, change in sensation, etc...)
Normal nerve

Exposed fiber

Nerve affected by MS

Damaged myelin

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Alzheimer’s Disease

• An incurable, degenerative disorder of the brain causing dementia, memory loss, and changes in personality.
• Caused by protein deposits (amyloids) which interfere with transmission between neurons.
• Usually becomes diagnosed at 65+ years
• Unfortunately there are limited treatments that are not very effective.
Parkinson’s Disease

- A degenerative disorder of the CNS that affects motor skills and speech.
- Characterized by muscle rigidity and tremors.
- Symptoms are caused by a decrease in the formation of and action of dopamine.
Dopamine levels in a normal and a Parkinson’s affected neuron.

- Normal Neuron
  - Dopamine
  - Normal movement
- Parkinson’s affected Neuron
  - Receptors
  - Movement disorders
Meningitis

- is an inflammation of the protective membranes covering the brain and spinal cord.
- Caused by bacterial or viral infections, but also by other pathogens or even trauma
- Symptoms include: fever, stiff neck, severe headache.
- A spinal tap (CSF sample) is the best means of identification.
- Treatment is required immediately. Bacterial meningitis is highly lethal.
Huntington’s Disease

• A genetically inherited progressive disease that leads to a slow deterioration of the brain until death.

• Symptoms first appear around the age of 35 and include decrease in mental, emotional, and motor functions

• No cure

• Why is this still present??
Spinal cord injury

• The severity of any injury to the spinal cord depends upon the number of axons that survive:
  – the higher the number of normally functioning axons, the less the amount of disability.

• After injury, the most important consideration when moving people is to prevent further injury to the spine and spinal cord. This is done by immobilizing the neck and back.
Treatment

• Current Treatments
  – Traction
  – Rehabilitation/physiotherapy
  – Medication (Methylprednisolone, a steroid drug)

• Future/Experimental Treatments
  – Spinal cord grafts
  – Stem Cells
  – Whatever you invent........
4 Key Principles of Treatment

• Neuroprotection—protecting surviving nerve cells from further damage
• Regeneration—stimulating the regrowth of axons and targeting their connections appropriately (*Stem Cell – Future STSE*)
• Cell replacement—replacing damaged nerve or glial cells (*Stem Cell – Future STSE*)
• Retraining CNS circuits and plasticity to restore body functions
Stroke

• Stroke is a sudden loss of brain function caused by the interruption of blood flow to the brain causing brain cells (neurons) in the affected area to die.

• *Stroke is a leading cause of disability worldwide, and approximately 300,000 Canadians are living with the effects of a stroke.*
Signs

• **paralysis or numbness** of the face, arm, or leg (usually on only one side of the body)
• **loss of speech or trouble understanding speech**
• **loss of vision** (often in one eye only) or **double vision**
• **dizziness or loss of balance or coordination**
• **severe and unusual headache** (often described as "the worst headache of my life")
Treatments

• Get emergency medical immediately if symptoms of a stroke are shown. There are treatments to help restore blood flow to the brain if used within the first 3 hours.

• However, 40-70% of individuals having a stroke do not arrive at the hospital within the first 3 hours.
Treatment

- Medications –
  - Short term - to break up the clot.
  - Long term – to prevent new clots.
The Sense Organs

Eyes and Ears
Maintaining Homeostasis

• The sense organs are critical in maintaining homeostasis.
• They provide a direct link to the CNS with the surroundings of the body.
  – Sensory deprivation has been shown to have critical impacts on the developing CNS.
  – **Sensory compensation** has also been identified in humans.
Binocular Vision

• Having two eyes in the front of our head provides us the ability to see in 3-dimensions.

• Following the current evolutionary believe binocular vision would have allowed our ancestors the capability to swing through the trees.
  
  – In order to achieve this we need to have depth perception.
Eye Components

1. **Sclera** - the thick white outer layer.
   - Cornea and Conjunctiva
2. **Choroid Layer** - The middle colored layer of the eye. It absorbs light and prevents internal reflections.
   - Iris
   - Ciliary body
   - Lens
3. **The Retina** - the inner layer of the eye broken into three layers.
   - 1. The ganglion cell layer
   - 2. The bipolar cell layer
   - 3. The **Rod and Cone** layer.
• 1. **Rods** - sensitive to light, but not to colors. (150 million cells)

• 2. **Cones** - require more light to be stimulated, but can see colors (red, green, blue) (6 million cells)
• Two fluid chambers are also of key importance:
• 1. The anterior compartment in front of the lens, is filled with aqueous humour, and used to help focus images.
• 2. The posterior chamber is filled with a clear gel, (vitreous humour) used to maintain the eyeballs’ shape.
How We See

• As light enters the eye the pupil dilates/contracts to regulate the amount of light that enters.

• Depending on the distance an object is from the eye, the muscles (ciliary body) changes the shape of the lens to focus the object clearly on the fovea centralis of the retina. (Accommodation).

• Light hitting the rods and cones transmit impulses to the brain.
Disorders of the Eye

Myopia
(nearsightedness)

Distant vision is blurred when light rays from distant objects come to focus in front of the retina.

Correction with a minus lens allows light to once again focus on the retina.

Or Concave lens
Hyperopia
(farsightedness)

Distance vision is blurred when light rays focus behind the retina.

Correction with a plus lens allows light to once again focus on the retina.

Or Convex lens
Astigmatism

• Caused by an irregular shaped cornea (normally) or lens that leads to light becoming bent in numbers of ways.
• Can be corrected with glasses or surgery.
Cataracts

- A cloudy or opaque deposit that builds up over the lens of time leading to blindness.

- Treated surgically by replacing the lens.
Glaucoma

- Caused by the buildup of aqueous humour between the lens and cornea.
- Fluid pressure can cause damage to the nerve fibers reducing our peripheral vision.
- Treated with drugs or surgery.
Color blindness

• Caused by a Recessive Sex-Linked genetic trait (we will cover this in Unit 3)
• Damage/faulty functioning of the cone cells of the retina.
Lasik vs. PRK

Lasik
- Man
- Cutting into the cornea and shaving the tissue

PRK
- Machine
- Laser cutting of outer surface.
The Human Ear
• The ear contains mechanoreceptors that translate the movement of air (through sound waves) into a series of nerve impulses that the brain interprets as sound.
Parts of the Ear

- The Ear is divided into three sections:
- 1. **Outer Ear** - consists of the *pinna* and *auditory canal*.
- 2. **Middle Ear** - consists of the *tympanic membrane*, the *ossicles*, (malleus, incus, and stapes), the *eustachian tube*, and the *round* and *oval window*.
- 3. **Inner Ear** - consists of the *cochlea*, *vestibule*, and *semicircular canals*. 
• http://www.youtube.com/watch?v=IVJF6Ug7s2U&feature=related
• http://www.youtube.com/watch?v=fm7t5S09iUg&feature=related
• http://www.youtube.com/watch?v=U_HUgzhmq4U– great one
Disorders of the Auditory System

• 1. Nerve Deafness - caused by damage to the hair cells, with some frequencies being more affected. - occurs over time and usually cannot be reversed.

• 2. Conduction Deafness - caused by damage to the outer or middle ear affecting sound transmission. - does not usually cause a total loss of hearing because sound waves can still be transmitted to the inner ear through skull bones. This form of hearing loss can usually be improved with hearing aids.
Treatments

• For Conduction Deafness- (blockage of sound)
  – Various medications to minor surgeries may solve the problem.

• For Nerve deafness – treatment will vary depending on the cause and severity.
  – Hearing aids
  – Cochlear implants
Additional Disorders

• 3. Chronic Ear Infections causing swelling.
  – Children often suffer from ear infections due to fluid buildup behind the eardrum.

• Treatment
  – **Shunts** can be inserted into the eustachian tubes to permit the fluid to drain.