Introduction to the Nervous System

- Brain
- Spinal cord
- Ganglia
- Nerves to face
- Nerves to upper limb
- Nerves to lower limb

CNS

PNS
Divisions of the Nervous System

- **Sensory**
  - Stimulus (input)
  - Sensory division conducts action potentials from the periphery to the CNS.
  - PNS: Nerves and ganglia
  - CNS: Brain and spinal cord

- **Motor**
  - Response (output)
  - Motor division conducts action potentials to the periphery.
  - Somatic nervous system
  - Autonomic nervous system

- **CNS**
  - Brain
  - Spinal cord

- **PNS**
  - Nerves to face
  - Ganglia
  - Nerves to upper limb
  - Nerves to lower limb
Central Nervous System
The central nervous system (CNS) consists of the brain and spinal cord and is responsible for integrating, processing, and coordinating sensory data and motor commands.

Peripheral Nervous System
The peripheral nervous system (PNS) includes all the neural tissue outside the CNS.

1. Receptors are sensory structures that detect changes in the internal or external environment.
2. The sensory division of the PNS brings information to the CNS from receptors in peripheral tissues and organs.
3. Information processing includes the integration and distribution of information in the CNS.
4. The motor division of the PNS carries motor commands from the CNS to peripheral tissues and systems.
5. Effectors are target organs whose activities change in response to neural commands.

Somatic sensory receptors provide position, touch, pressure, pain, and temperature sensations.

Special sensory receptors provide sensations of smell, taste, vision, balance, and hearing.

Visceral sensory receptors monitor internal organs.

The somatic nervous system (SNS) controls skeletal muscle contractions.

The autonomic nervous system (ANS) provides automatic regulation of smooth muscle, cardiac muscle, glands, and adipose tissue.

- Smooth muscle
- Cardiac muscle
- Glands
- Adipose tissue
Nervous System Functions

Functions of the Nervous System:
- Detect the Environment (Sensory)
- Integrate Information (Control Center)
- Maintain homeostasis (Control Center)
- Control muscles and glands (Effector)
- Mental activity: thinking, feeling, remembering, learning (Effector)

Examples:
- Painful Stimulus - Withdrawal Reflex
- Temperature Regulation
- Motor coordination

Disruption to Function: Parkinson’s Disease

Info re: Disease
Video 1: Deep Brain Stimulation

Video 2:
http://www.youtube.com/watch?v=QFtgV1vqwiE
Nervous System

Nervous system is divided into 2 main parts:
- **Central Nervous System (CNS):** brain & spinal cord
- **Peripheral Nervous System (PNS):** nerves to and from the CNS
Brain and Spinal Cord are protected by bone and connective tissue “meninges” and a cushion of cerebrospinal fluid (CSF)
The Central Nervous System = Brain and Spinal Cord

ANATOMY SUMMARY

CENTRAL NERVOUS SYSTEM

Cranium
Cerebral hemispheres
Cerebellum
Cervical spinal nerves
Thoracic spinal nerves
Lumbar spinal nerves
Sacral spinal nerves
Coccygeal nerve

SECTIONAL VIEWS OF THE CNS

Cranium
Dura mater
Venous sinus
Arachnoid membrane
Pia mater
Brain
Subdural space
Subarachnoid space

(b) Meningeal layers of the brain cushion and protect delicate neural tissue.

FIGURE QUESTION

Moving from the cranium in, name the meninges that form the boundaries of the venous sinus and the subdural and subarachnoid spaces.

2758533 Anna Davis

Central canal
Gray matter
White matter
Spinal nerve
Spinal cord
Body of vertebra
Autonomic ganglion
Spinal nerve

(a) Posterior view

(c) Posterior view of spinal cord and vertebra
Brain:

- Surface anatomy includes cerebral hemispheres, cerebellum, brain stem (midbrain, pons, medulla) and spinal cord
- Contains almost 98% of the body’s nervous tissue:
  - $10^{10}$ to $10^{11}$ neurons (10%)
  - $10^{13}$ glia (90%)
- Trillions of connections between neurons
- Cortical regions have different processing functions
Spinal Cord

- Spinal cord is enclosed within the vertebral column from the foramen magnum to L₂
- Organization of the spinal cord provides for two-way communication to and from the brain
  - Dorsal roots contain sensory nerves bringing info in
  - Ventral roots contain motor nerves taking info out to muscles
- Cervical and Lumbar Enlargements (?)
- Peripheral Nervous System:
  - Spinal nerves (31 pairs) enter and exit through intervertebral foramen
    - Somatic (to skeletal muscles)
    - Autonomic Nervous System (to glands, organs, blood vessels)
Peripheral Nervous System

Nervous system

Sensory nervous system
- Contains receptors
- Transmits information from receptors to the CNS

Motor nervous system
- Transmits information from CNS to the rest of the body
- Sends motor information to effectors

Somatic sensory
- Receives sensory information from skin, fascia, joints, skeletal muscles, special senses

Visceral sensory
- Receives sensory information from viscera

Somatic motor
- "Voluntary" nervous system: innervates skeletal muscle

Autonomic motor
- "Involuntary" nervous system: innervates cardiac muscle, smooth muscle, glands

Figure 8.39 Organization of Somatic and Autonomic Nervous System Neurons
(a) The cell body of the somatic neuron is in the CNS, and its axon extends to the skeletal muscle. (b) The cell body of the preganglionic neuron is in the CNS, and its axon extends to the autonomic ganglion and synapses with the postganglionic neuron. The postganglionic neuron extends to and synapses with its effector organ.
Autonomic Nervous System (ANS)

Automatic - Not Voluntary?
EX: Control of heart rate, respiration rate

Article about monks changing body temperature:
Nervous System = All Neural Tissue

Contains 2 kinds of cells:

- **Neurons**
  - Excitable cells that send and receive electrical signals, connect with each other to form circuits, detect, integrate and respond to signals.
  - “Major players of nervous system (only 10% of cells = 10 billion)”
  - Classified by function (sensory, interneuron, motor) and structure (unipolar, bipolar, multipolar, etc.)

- **Glia**
  - cells that support and protect neurons and have new and exciting functions of their own (90% of cells)
  - 4 types in CNS, 2 types in PNS

How do tell the difference between the two?
Histology - Processing Nervous Tissue for Study
Stains identify cell structures, specific cells.
Neurons

- Composed of a body, axon, and dendrites, terminal
- Long-lived, amitotic, high metabolic rate (ATP). Without ATP (oxygen) you are “brain dead” within 5 minutes.
- Form anatomic and functional connections with other neurons to generate thoughts, behavior, actions
- Electrically active with voltage-gated channels that can produce action potentials (means of fast communication)
- Axons often wrapped by glial cells to enhance speed of action potential propagation therefore enhance communication effectiveness.

Identify: cell body, processes (dendrites/axons), axon hillock (initial segment), axon terminals, myelin sheath, neurolemma, nodes of Ranvier
Neuron Structure

Vocabulary:
- Dendritic spine
- Nissl substance
- Trigger zone/Axon hillock
- Schwann cell
- Neuron cell body
- Node of Ranvier
- Internode
- Myelin sheath
Diversity of Neurons/Classifications

Structural Classifications of Neurons
- **Unipolar** - consists of 1 process (divides from cell body into proximal & distal branches); Most unipolar neurons are sensory neurons (e.g. dorsal root ganglion neuron).
- **Bipolar** - consists of 2 processes (1 axon + 1 dendrite); rare (found in retina & olfactory mucosa); All bipolar neurons are sensory neurons.
- **Multipolar** - consists of 3+ processes (1 axon + dendrites); most common type. Most multipolar neurons are interneurons, some are motor neurons.

Functional Classification of Neurons
1. **Sensory (afferent)** - transmit impulses from sensory receptors towards the CNS (e.g. Pacinian corpuscle in skin)
2. **Motor (efferent)** - carry impulses away from the CNS to effector/target organs (e.g. muscle)
3. **Interneurons (association)** - neurons that anatomically placed between sensory and motor neurons.
CNS (4 types):
- astrocytes
- microglia
- ependymal cells
- Oligodendrocytes

PNS (2 types):
- satellite cells
- schwann cells

(b) Glial cells and their functions
Glia: Astrocytes are the most abundant cells in nervous tissue

Functions:
- “Glue” - old idea when not much was known
- Star shaped
- Wrap capillaries:
  - help form blood-brain barrier and transport substance to and from capillaries
  - Play a role in blood flow regulation that can be imaged to reveal what the brain is doing using (FMRI): http://www.youtube.com/watch?v=Cwda7YWK0WQ
  - Promote neurogenesis of neural stem cells http://www.hhmi.org/news/stevens2.html
- Wrap neurons and their synaptic endings and help regulate interstitial fluid composition of the brain: by taking up K, glutamate, other waste
- Connect with each other via gap junctions to form an astrocyte network through which signals can pass (e.g. calcium signals) Activity in one astrocyte spreads to all coupled astrocytes.
  - Slow calcium signals that travel via gap junctions may play a role in information processing.
- Closely associated with migrating neurons during development and thought to play a role in guiding migration of neurons (e.g. Bergmann glia in cerebellum)
- Act as phagocytes
- Form glial scar with brain injury (reactive astrocytes only)
- Low astrocyte counts are found in the frontal cortex in depressed people who die young
- Glioma: http://www.scientificamerican.com/article.cfm?id=ted-kennedy-diagnosed-wit

Scaffold for Neurons (Bergmann glia in cerebellum)
Microglia:

- 10-15% of glia in CNS
- Highly mobile
- Macrophages that populate the CNS early in development, derived from mesoderm not neuroectoderm as are the other glial cells. Cells of the immune system can’t access the CNS, so microglia serve as “brain macrophages” that find and destroy invaders, promote inflammation to destroy virus infected cells or cells that are cancerous.
- Microglial activation is one of the most common and earliest features of nearly all neuro-inflammatory disorders including Alzheimer’s disease, Parkinson’s disease, stroke, spinal cord injury, encephalitis and multiple sclerosis. Microglia contribute to either the onset, progression OR the resolution and repair observed during neuro-inflammatory disease.
- In vitro assays of microglial function have conclusively demonstrated these cells have the ability to acquire either neurotoxic OR neuroprotective functions and the key is to figure out what signals the pathway choice.

http://www.microglia.org/Microglia/Microglia.html
Ependymal Cells

- Together with capillaries form choroid plexus an epithelial-like structure that makes CSF (cerebrospinal fluid) the fluid that cushions the brain.
- Line ventricles (central cavities) of the brain and spinal cord
- Have apical cilia used to move fluid
Oligodendrocytes - CNS

**Oligodendrocytes:**
- Distinguished by fewer processes than astrocytes.
- Produce myelin sheaths in CNS - white matter of CNS.
- One oligodendrocyte can myelinate more than one axon.
- Oligodendrocytes are more susceptible to damage than astrocytes, but less than neurons.
- Diseases effects oligodendrocytes less than astrocytes, but includes multiple sclerosis & cancer.
PNS - Satellite Cells

- Surround neuron cell bodies in the PNS (e.g. dorsal root ganglia)
- Electrically coupled like astrocytes
- Functions are unclear; may contribute to sensory transmission (e.g. pain)
Schwann cells:

- Make myelin in the PNS - the insulation that makes AP propagation fast (150 m/s vs. 1 m/s)
- Each Schwann cell myelinates only one axon
- Makes a basement membrane around themselves.
- Important in regeneration of damaged peripheral neurons because they form a bridge for axon re-growth
- May form tumors
Disease:
• Diptheria toxin (bacterial) kills Schwann cells > sensory and motor problems
• Guillain-Barre (viral) – kills Schwann cells
• Multiple Sclerosis: autoimmune disease – demyelinates axons
Neurophysiology: Concepts to Understand

Review: *Movie: How Neurons Work*

Resting Potential

Excitation – Secretion Coupling (calcium)

Graded Synaptic Potentials
- Excitatory
- Inhibitory

Threshold

Action Potentials

Propagation

Circuits – Wiring of cells to each other matters!
Permeability is the property of the plasma membrane that determines precisely which substances can enter or leave the cytoplasm.

1. **Freely permeable membranes** allow any substance to pass without difficulty.
2. **Selectively permeable membranes** permit the passage of some materials and prevent the passage of others. The distinction may be based on size, electrical charge, molecular shape, lipid solubility, or other factors. Cells differ in their permeabilities, depending on what lipids and proteins are present in the plasma membrane and how these components are arranged.

3. **Impermeable membranes**. Cells may be impermeable to specific substances, but no living cell has an impermeable membrane.

**EXTRACELLULAR FLUID**

- Materials may cross the plasma membrane through active or passive mechanisms.

**Plasma membrane**

- Passive mechanisms do not require ATP.
  - **Diffusion** is movement driven by concentration differences.
  - **Carrier-mediated transport** involves carrier proteins, and the movement may be passive or active.

- Active mechanisms require ATP.
  - **Vesicular transport** involves the formation of intracellular vesicles; this is an active process.

**CYTOPLASM**
Figure 8.7 Generation of the Resting Membrane Potential

A higher concentration of $K^+$ exists inside the cell membrane, and a higher concentration of $Na^+$ exists outside the cell membrane. There are many more $K^+$ leak channels than $Na^+$ leak channels.