Nervous Tissue

- overview of the nervous system
- properties of neurons
- supportive cells (neuroglia)
- electrophysiology of neurons
- synapses
- neural integration

Overview of Nervous System

- endocrine and nervous system work together to maintain homeostasis
  - endocrine system - communicates by chemical messengers (hormones) secreted into blood
  - nervous system - employs electrical and chemical means to send messages from cell to cell
- nervous system carries out its task in three basic steps:
  - Sensory receptors detect external/internal stimuli and transmit messages to spinal cord and brain
  - brain and spinal cord processes this information
  - Brain and spinal cord send commands (or not) to carry out a response

2 Major Subdivisions of Nervous System

- Central nervous system
  - Brain
  - Spinal cord
- Peripheral nervous system
  - Nerves
  - Ganglia

Subdivisions of Nervous System

- Central nervous system
- Peripheral nervous system
- Sensory division
- Motor division
- Visceral sensory division
- Somatic sensory division
- Visceral motor division
- Somatic motor division
- Autonomic Nervous System
- Sympathetic division
- Parasympathetic division

Universal Properties of Neurons

- excitability (irritability)
  - respond to stimuli
- conductivity
  - Cells produce electrical signals that are conducted to other cells
- secretion
  - when electrical signal reaches end of nerve fiber, a chemical neurotransmitter that can stimulate next cell

Structure of a Neuron

- soma — Cell body, neurosoma, cell body, or perikaryon
  - nucleus
  - cytoplasm contains organelles
    - Nissl bodies
  - Cytoskeleton: microtubules & neurofibrils (bundles of actin filaments)
  - no centrioles — no further cell division
- Dendrites

2 types of cells make up nervous tissue:
1. Neurons
2. Neuroglial cells (aka Glial cells)
**Structure of a Neuron**

- **axon (nerve fiber)** –
  - cylindrical, relatively unbranched for most of its length
  - specialized for conduction of nerve signals
- **axoplasm** – cytoplasm of axon
- **axolemma** – plasma membrane of axon
- one axon per neuron
- Schwann cells and myelin sheath enclose axon
- terminal ends
- synaptic knob

**Classification according to Structure**

- **multipolar neuron** – one axon and multiple dendrites
- **bipolar neuron** – one axon and one dendrite
- **unipolar neuron** – single process leading away from the soma
- **axonic neuron** – many dendrites but no axon

**Neuroglial Cells**

- about a trillion (10¹²) neurons in nervous system
- neuroglia outnumber neurons by as much as 50 to 1!!!!!!!!!!!!!

**Neuroglia or glial cells:**

- 6 types (4 types occur in CNS & 2 types occur in PNS)
- support and protect neurons
- bind neurons together and form framework for nervous tissue

**Functional Classes of Neurons**

- **Peripheral nervous system**
  - **Sensory (afferent) neurons.**
  - **Motor (efferent) neurons.**
- **Central nervous system**
  - **Interneurons (association neurons)**

**Axonal Transport**

- **axonal transport** – two-way passage of proteins, organelles, and other material along an axon
  - **anterograde transport** – movement down the axon away from soma
  - **retrograde transport** – movement up the axon toward soma
- **microtubules** guide materials along axon
  - motor proteins (kinesin and dynein) carry materials “on their backs” while they “crawl” along microtubules

**Six Types of Neuroglial Cells**

- 4 types occur only in CNS
  - **oligodendrocytes**
    - form myelin sheaths in CNS
  - **ependymal cells**
    - line cavities of the brain
    - secrete cerebrospinal fluid (CSF)
  - **microglia**
    - small, wandering macrophages (derived from WBCs)
    - search for cellular debris to phagocytize
  - **Astrocytes** (most abundant glial cell in CNS)
    - BBB
    - Nerve growth factor
    - For scar tissue
Neuroglial Cells of CNS

Figure 12.6

Neuroglial Cells

- 2 types occur only in PNS
  - Schwann cells
    - produce a myelin sheaths
    - assist in regeneration of damaged fibers
  - satellite cells
    - surround cell bodies in ganglia of PNS

Myelin Sheath in PNS

Myelination in PNS

Myelination in CNS

Speed of nerve signal along a nerve fiber depends on two factors:
1. diameter of fiber
2. presence or absence of myelin sheath

Signal conduction occurs along the surface of a fiber
- larger fibers have more surface area and conduct signals more rapidly
- myelin acts as a conductor
Regeneration of Nerve Fiber

- **soma is intact & some neurilemma remains**
- **fiber distal to injury degenerates**
  - macrophages clean up tissue debris at the point of injury and beyond
- **soma swells, ER breaks up, and nucleus moves off center**
  - due to loss of nerve growth factor from neuron’s target cell
- **axon stump sprouts growth processes**
- **regeneration tube** – formed by Schwann cells, basal lamina, and the neurilemma near injury
  - tube guides the growing sprout back to original target cells and reestablishes synaptic contact
- **NOT POSSIBLE IN CNS**

Resting Membrane Potential

- **RMP exists because of unequal electrolyte (ions) distribution between extracellular fluid (ECF) and intracellular fluid (ICF)**
- **Three factors about a resting neuron**
  - ions diffuse down their concentration gradient through the membrane
  - plasma membrane is selectively permeable and allows some ions to pass easier than others
  - electrical attraction of cations and anions to each other

Creating the Resting Membrane Potential (RMP)

- At rest, all cells have a negative internal charge and unequal distribution of ions:
  - **Results from:**
    - Large anions are trapped inside cell
    - Na+/K+ pump and limited permeability keep Na+ high outside cell
    - K+ is very permeable and is highly concentrated inside cell (i.e., moves down gradient to outside of cell)

Resting Membrane Potential Diagram:

- **Plasma membrane has ion channels**
  - Voltage-activated
  - Chemically activated
  - Passive

Depolarization occurs when MP becomes more positive
Hyperpolarization: MP becomes more negative than RMP
Repolarization: MP returns to RMP

Creating the Resting Membrane Potential Diagram:

1. Proteins
2. Sodium-potassium pump
3. K+ can leak out (diffusion)
- $Na^+$ concentrated outside of cell (ECF)
- $K^+$ concentrated inside cell (ICF)

**Resting Membrane Potential**

- $Na^+$ 145 mEq/L
- $K^+$ 4 mEq/L
- $Na^+$ 12 mEq/L
- $K^+$ 150 mEq/L

Large anions that cannot escape cell

---

**Resting potential**

- Polarized

---

**Nerve impulse or Action potential**

Stimulus

- Depolarized

---

**Action potential**

- Repolarization

---

**Action potential**

- Polarized
Action Potentials

- only a thin layer of the cytoplasm next to the cell membrane is affected
- action potential is often called a spike
- Characteristics of action potential
  - follows an all-or-none law!
  - nondecremental - do not get weaker with distance
  - irreversible - once started goes to completion and can not be stopped

Sodium and Potassium Gates

Figure 12.14
Refractory Period

- Refractory period - period of resistance to stimulation
- Two phases of the refractory period
  - Absolute refractory period
    - No stimulus of any strength will trigger AP
    - As long as Na⁺ gates are open
  - Relative refractory period
    - Only especially strong stimulus will trigger new AP

Saltatory Conduction

- Saltatory conduction - the nerve signal seems to jump from node to node

Nerve Signal Conduction Unmyelinated Fibers

- Voltage-gated channels needed for APs
  - Fewer than 25 per μm² in myelin-covered regions (internodes)
  - Up to 12,000 per μm² in nodes of Ranvier
- Fast Na⁺ diffusion occurs between nodes
  - Signal weakens under myelin sheath, but still strong enough to stimulate an action potential at next node
- Saltatory conduction - the nerve signal seems to jump from node to node

Local Potentials

- Neuron response begins at the dendrite
  - When neuron is stimulated at dendrite (or soma)
    - Opens Na⁺ gates and allows Na⁺ to rush in to the cell
    - Na⁺ inflow neutralizes some of the internal negative charge
  - Depolarization
    - For short distance on the inside of the plasma membrane
      - Producing a current that travels towards the cell's trigger zone - this short-range change in voltage is called a local potential
Characteristic of Local Potentials

- They are different than APs:
  - **graded** - vary in magnitude with stimulus strength
    - stronger stimuli open more Na⁺ gates!
  - **decremental** - get weaker the farther they travel from the point of stimulation
  - **reversible** - when stimulation ceases, K⁺ diffusion out of cell returns cell to normal resting potential
  - can be either excitatory (EPSP) or inhibitory (IPSP)

- Stimuli (neurotransmitters) make the membrane potential more negative – hyperpolarize it – becomes less sensitive and less likely to produce an action potential

EPSPs

- **Graded in magnitude**
- **Have no threshold**
- **Cause depolarization**
- **Have no refractory period**
- **Summate**

- [http://www.sinauer.com/neuroscience4e/animations5.2.html](http://www.sinauer.com/neuroscience4e/animations5.2.html)