Regulation

Neural vs. Hormonal

Overview

• The nervous system includes all neural tissue in the body.

Basic units are:

a. Neurons (individual nerve cells)

b. Neuroglia

• supporting cells
• separate & protect the neurons
• provide supporting framework
• act as phagocytes
• regulate composition of interstitial fluid
• a.k.a. glial cells
• outnumber neurons

Two Anatomical Divisions of The Nervous System

1. CNS: Central Nervous System

• Brain & Spinal Cord
• Responsible for integrating, processing, & coordinating sensory data and motor commands. i.e.- stumble example
• The brain is also the organ responsible for intelligence, memory, learning, & emotion

Nervous System

• The Neural System is only 3% of your body weight, but is the most complex organ system.

• Nervous impulses are fast acting (milliseconds) but short lived.
2. **PNS**: Peripheral Nervous System

- All nervous tissue outside CNS
- Carries sensory data to CNS, carries motor commands from the CNS.
- Bundles of nerve fibers carry impulses in the PNS are known as peripheral nerves or just “nerves”.
- Nerves attached to the brain are called cranial nerves. Nerves attached to the spinal cord are called spinal nerves.

PNS has 2 functional divisions

**Afferent Division (Sensory)**
- Bring sensory information to CNS from receptors in peripheral nervous tissue & organs.

**Efferent Division (Motor)**
- Carries motor commands from CNS to muscles & glands, these target organs are called **effectors**.

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The **Efferent Division** is broken into Somatic & Autonomic Components

**SNS** Somatic System: controls skeletal muscle contractions these can be voluntary (conscious) or involuntary (unconscious) (reflexes).

**ANS** Autonomic System:

* a.k.a. visceral motor units

*control autonomic, involuntary regulation of smooth muscle, cardiac muscle, & glandular activity.

The **ANS** has a:

sympathetic division

parasympathetic

antagonistic effects

- The **sympathetic** (Fight or Flight) increases heart rate, **parasympathetic** decrease heart rate, etc.

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**Neurons**
**Perikaryon:** contains
1. numerous mitochondria
2. free & fixed ribosomes
3. membranes of rough ER (give perikaryon a grainy appearance)
   - Some areas of perikaryon contain RER & free ribosome clusters which stain darkly. These are called **Nissl Bodies.** These give the tissue a grey color and are therefore present in "gray matter".
   - Typically, perikaryon lacks centrioles which are required for cell division, so the CNS is not generally repaired after an injury.

**Dendrites**
- Typically highly branched
- Sensitive processes
- Each branch has small processes of its own called dendrite spines
- Specialized to receive nervous impulses
- Impulse travel to soma

**Axon**
- Long cytoplasmic process
- Can propagate an action potential
- Impulses travel away from soma
- The axon has its own axoplasm and membranous axolemma
- The axonal trunk may have branches called collaterals

**The Synapses**
- A special site of intercellular communication
- Two cells at each synapse
  - a. pre-synaptic cell (synaptic terminals sends impulses)
  - b. post-synaptic cells (receives the impulses)
- Generally the impulse transmission proceeds by the release of chemicals called neurotransmitters.
- When a neuron forms a junction w/ a different cell type, it's called a neuroeffector junction.
Two main types of Neuroeffector Junctions

- neuromuscular junction (nerve cell communicates w/ a muscle cell)
- neuroglandular junction (nerve cell communicates w/ a gland cell)

Neurons are classified in two ways

1. Structurally
   a. anaxonic (no axon)
      * axons indistinguishable from dendrites
      * occur in brain & special sensory organs
      * function poorly understood
   b. bipolar
      * two distinct processes
      * a dendritic and an axonic end (30cm long total)
      * rare but found in sensory organs (eyes, nose, ear)
   c. unipolar
      * dendritic and axonal processes are continuous
      * cell body lies off to one side
      * most sensory cells of PNS are this type
      * can be one meter long
   d. multipolar
      * several dendrites, single axon
      * most common neurons in CNS
      * motor command carrying neurons are this type
      * can be 1 meter long

2. Functional Classification
   a. Sensory Neurons
      * Afferent division of PNS
      * Carry sensory impulses from sensory receptors → CNS
      * These neurons are called **afferent fibers**
      * there are ≈ 10 million sensory neurons in the human body
Somatic sensory neurons: monitor the external environment, and or position in it.

Visceral sensory neurons: monitor internal conditions and the status of the various organ systems.

Receptors are broadly categorized as:
- exteroceptors: provide information about external environment.
  - *Touch, temp., sight, taste, pressure, smell, hearing.*
- proprioceptors: monitor the position and movement of skeletal muscles & joints.
- interoceptors: monitor digestive, respiratory, CV, urinary, repro systems and provide some taste, deep pressure & pain sensation.

Motor Neurons
- Efferent division of PNS
- Motor commands: instructions from CNS → peripheral effectors
- Stimulates or modifies activity of peripheral tissue, organ, or organ system.
- there are ≈500,000 motor neurons in the human body.
- These are called efferent fibers

Somatic motor neurons: innervate skeletal muscles, voluntary control

Visceral motor neurons: innervate all peripheral effectors other than muscles.

c. Interneurons
- a.k.a. association neurons
- situated btn. sensory & motor neurons
- located only and entirely in the brain & spinal cord
- ≈20 billion interneurons (most abundant neurons)
- Responsible for:
  a. distribution of sensory information
  b. coordination of motor activity
# Neuroglia

<table>
<thead>
<tr>
<th>CNS: Cell Type</th>
<th>Function</th>
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<tbody>
<tr>
<td>Astrocyte</td>
<td>maintain blood brain barrier, provide structural support, regulate (ION, nutrient, dissolved gas) conc., absorb &amp; recycle neurotransmitters, assist in tissue repair</td>
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<tr>
<td>Oligodendrocyte</td>
<td>mylenate CNS axons, provide structural framework</td>
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<tr>
<td>Microglia</td>
<td>remove cell debris, wastes &amp; pathogens by phagocytosis</td>
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<tr>
<td>Ependymal Cells</td>
<td>line cavities (ventricles) in the brain &amp; spinal cord, assist in protection, circulation and monitoring of CSF</td>
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<table>
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<th>PNS: Cell Type</th>
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<tr>
<td>Satellite Cells</td>
<td>surround neuron cell bodies &amp; ganglia</td>
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<tr>
<td>Schwann Cells</td>
<td>cover all axons in PNS, responsible for mylenation, participate in injury repair.</td>
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Myelin sheath - A spiral membrane that surrounds the axon of some neurons. The membrane is composed of fatty (lipoprotein) membranes. There is an analogy with the insulation of electrical wires. In the PNS this sheath is produced by glial cells called Schwann cells. Neurons whose axons are myelinated are referred to as white matter while unmyelinated neurons are called gray matter.

Nodes of Ranvier - Gaps in the myelin sheath. The only place where the plasma membrane is exposed. These nodes function in saltatory conduction.

Multiple Sclerosis - A progressive destruction of the myelin sheath of neurons in the CNS. The sheaths deteriorate to hardened scars or plaques, in multiple regions, thus the name. The plaques interfere with nerve impulse transmission. The average age of onset is 33. The disease is unpredictable. Some people experience complete remissions, while others gradually accumulate neurological problems. MS does not necessarily shorten life.

The Transmembrane Potential

• The electrochemical gradient is the sum of all chemical and electrical forces acting across the membrane.

• The resting potential of a neuron, about -70 mV, is determined chiefly by the membrane permeability to potassium ions.
CELL MEMBRANE POTENTIAL

1. A cell membrane is usually polarized as a result of an unequal distribution of ions.

2. Distribution of ions.
   a) The distribution of ions is due to the presence of pores and channels in the membranes which allow passage of some ions, but not others. K+ pass more easily through cell membranes than do Na+.

3. Resting potential
   a) There is a high concentration of Na+ outside the membrane and a high concentration of K+ inside the membrane.
   b) There are large numbers of negative ions inside the cell.
   c) In a resting cell, more positive ions leave the cell than enter. Therefore, the outside of the membrane develops a positive charge.

4. Potential changes
   a) Stimulation of a membrane affects its resting potential.
   b) When it’s resting potential decreases, a membrane becomes depolarized.
   c) Potential changes are subject to summation.
   d) If threshold potential is achieved, an action potential is triggered.

   a) When a threshold stimulus is provided, the sodium channels open, and Na+ diffuse inward, causing depolarization.
   b) At the same time, potassium channels open, and K+ diffuse outward causing repolarization.
   c) This rapid change in potential is called an action potential.
   d) Many action potentials can occur before an active transport mechanism reestablishes the original resting potential.
NERVE IMPULSE

1. Impulse conduction
   a) Unmyelinated fibers conduct impulses that travel over their entire surfaces.
   b) Myelinated fibers conduct impulses more rapidly. (Saltatory conduction)

2. All-or-none response
   a) A nerve impulse is conducted in an all-or-none manner whenever a stimulus of threshold intensity is applied to a fiber.

Synaptic Transmission

• An action potential traveling along an axon is a nerve impulse. At a synapse between two neurons, information passes from presynaptic neuron to the postsynaptic neuron. A synapse may also involve other types of postsynaptic effector cells.

• A synapse may be either electrical (with direct physical contact between cells) or chemical (involving a neurotransmitter).

Electrical Synapses

• Electrical synapses are relatively rare in the CNS and PNS. At an electrical synapse, the presynaptic and postsynaptic cell membranes are bound by interlocking membrane proteins at a gap junction. Pores within these proteins permit the passage of local currents, and the two neurons act as if they shared a common cell membrane.

Chemical Synapses

• Chemical synapses are more common than electrical synapses. Excitatory neurotransmitters cause depolarization and promote action potential generation, whereas inhibitory neurotransmitters cause hyperpolarization and depress action potential generation.

• The effect of a neurotransmitter on the postsynaptic membrane depends on the properties of the receptor, not on the nature of the neurotransmitter.
**Cholinergic synapses** release the neurotransmitter acetylcholine (ACh).

**Adrenergic synapses** release norepinephrine (NE), also called noradrenaline. Other important neurotransmitters include dopamine, serotonin, and gamma aminobutyric acid (GABA).

**Drugs & Synaptic Function**
- Many drugs interfere with key steps in synaptic transmission process.

**These drugs may:**
1. Interfere with transmitter synthesis
2. Alter the rate of transmitter release
3. Prevent transmitter activation
4. Prevent transmitter from binding to receptors

**Botulinus toxin** blocks the release of Ach at the presynaptic membrane causing paralysis.

**The venom of a black widow spider** has the opposite effect. It causes a massive release of ACh that causes intense muscular cramps and spasms.

**Caffeine** depolarizes axon hillock.

**Nicotine** binds to ACh receptor sites and stimulates the postsynaptic membrane.

**Acetylcholine** - voluntary movement of the muscles

**Norepinephrine** - wakefulness or arousal

**Dopamine** - voluntary movement and emotional arousal

**Serotonin** - memory, emotions, wakefulness, sleep and temperature regulation

**GABA** (gamma aminobutyric acid) - motor behaviour