

TOPIC 8: PERIPHERAL NERVOUS SYSTEM: EFFERENT DIVISION

I. Introduction

- A. Efferent division is communication link by which the CNS controls activities of **effector organs** (e.g., muscles, organs, glands, etc.).
- B. Organization (Fig 7.1)
 - 1. Autonomic
 - a) involuntary branch
 - b) two parts:
 - (1) sympathetic (activity)
 - (2) **parasympathetic** (routine housekeeping)
 - 2. Somatic
 - a) voluntary branch; affects skeletal muscle

II. Autonomic Nervous System

- A. Structure common to both Sympathetic and Parasympathetic (Fig 11.2)
 - 1. Every pathway in each autonomic pathway consists of a two neuron chain
 - 2. Cell body of first neuron lies in the CNS
 - 3. Its axon synapses with cell body of 2nd neuron in chain in a **ganglion**
 - 4. Axon of 2nd neuron innervates the **effector organ**.
- B. Structure: Sympathetic Only (Fig 11.3)
 - 1. Originate in the thoracic (chest) and lumbar (abdominal) regions of spinal cord
 - 2. **Adrenal medulla** (inner part of adrenal) is a modified sympathetic ganglion (Fig 12.5)
 - a) secretes **hormones into blood** when stimulated
- C. Structure: Parasympathetic Only (Fig 11.6)
 - 1. Originate in the cranial (brain) and sacral (pelvic) areas of the CNS.
 - 2. Ganglia close to effector organs
- D. Neurotransmitters (Fig 11.7)
 - 1. Sympathetic
 - a) 1st neuron in chain releases **acetylcholine**
 - b) 2nd neuron in chain releases **norepinephrine**
 - c) adrenal medulla releases mostly **epinephrine** into blood
 - 2. Parasympathetic
 - a) 1st neuron in chain releases **acetylcholine**
 - b) 2nd neuron in chain releases **acetylcholine**
 - 3. **SO:** onto effector organs, sympathetic releases norepinephrine and epinephrine, while parasympathetic releases acetylcholine.
- E. Response of effector organs to sympathetic and parasympathetic
 - 1. depends on effector organ & its receptors, as well as neurotransmitter!!!
 - 2. Acetylcholine receptors
 - a) located on 2nd neuron in in all autonomic neuron chains
 - b) on membrane of effector organs
 - 3. Norepinephrine and epinephrine receptors distributed on effector organs
 - a) **alpha:** binds norepi preferentially, usually causes constriction/contraction
 - b) **beta-1:** binds norepi and epi equally, found primarily in the heart, causes stimulation of heart
 - c) **beta-2:** binds mostly epi, usually causes local dilation/relaxation

- F. Function of Sympathetic and Parasympathetic (Fig 11.1)
1. Most organs are innervated by both sympathetic and parasympathetic systems. These tend to act in opposition to each other to give the exact response needed in effector organ. They are like getting temperature in shower just right by adjusting hot and cold knobs.
 - a) exceptions
 - (1) innervated blood vessels receive only sympathetic (except those in penis and clitoris, which also have parasympathetic)
 - (2) sweat glands innervated by sympathetic only
 - (3) salivary glands innervated by both, but different kinds of saliva produced by each
 2. Most of the time both systems active at low levels. This is called sympathetic tonic activity and parasympathetic tonic activity.
 3. Shifts in balance between parasympathetic and sympathetic can be accomplished discretely for individual organs to meet specific demands.
 4. Or one system can dominate body wide for a massive response
 - a) Usually occurs when sympathetic dominates in “fight or flight” situation. When sympathetic dominates:
 - (1) blood vessels to most organs constricted = reduced blood flow to digestive organs, etc. (caused by alpha receptors binding norepi)
 - (2) blood vessels to heart dilated (caused by beta-2 receptors binding epi)
 - (3) increased heart rate and increased force of contraction of whole heart (caused by beta-1 receptors binding epi and norepi)
 - (4) blood vessels to skeletal muscle dilated (caused by beta-2 receptors binding epi)
 - (5) airways in lung dilated (caused by beta-2 receptors binding epi)
 - (6) glucose released (caused by beta-2 receptors in liver binding epi)
 - b) parasympathetic dominates in quiet situations, involved in regulating normal "housekeeping" functions (digestion, etc)
- G. Human Male Sexual Cycle
1. Erection
 - a) The penis contains spongy tissue derived from veins and capillaries; during sexual arousal fills with blood; increased pressure closes off veins that drain blood from penis = vasocongestion = erection
 - b) Erection controlled by **spinal reflex** between highly sensitive mechanoreceptors in the penis and the “erection generating center” in the spinal cord
 - c) Efferent response is parasympathetic which leads to vasodilation of blood vessels which leads to vasocongestion = erection
 - d) In ways that are not well understood, various regions in brain can either enhance or retard erection reflex
 2. Emission of sperm from testis
 - a) When stimulation becomes intense, the penis-spinal reflex described above switches to a sympathetic efferent response that causes smooth muscle in penis and testes to contract to emit sperm & seminal fluids into urethra.
 3. Expulsion of sperm from penis
 - a) Urethra filling with semen triggers sympathetic response that activates skeletal muscle at the base of the penis and smooth muscle in penis

- b) rhythmic contraction of these muscles at 0.8 second intervals increases pressure inside penis thereby forcibly expelling the semen = orgasm
- c) refractory period follows male orgasm; no erection possible. Seems to be caused by release of hormone called prolactin from pituitary gland.

H. Human Female Sexual Cycle

1. Sexual stimuli trigger spinal reflexes that cause parasympathetically induced vasodilation of blood vessel in vagina and clitoris (very similar to males)
2. Clitoris is composed of spongy vascular tissue like penis and becomes erect like penis;
3. as in males, brain can enhance or retard sexual spinal reflex
4. Vasocongestion of vagina causes release of lubricating secretions which allow smooth entry of penis
5. Vasocongestion also occurs in breasts (enlarging them) and face become flushed from increased blood flow in skin
6. Further vasocongestion of vagina reduces its inner circumference
7. Uterus raises upward lifting the cervix, creating a space for ejaculate deposition
8. If stimulation continues, sympathetic induced rhythmic contractions of pelvic muscles, especially in lower 1/3 of vaginal canal, at 0.8 second intervals = orgasm
9. No refractory period = multiple orgasms possible

III. Somatic Nervous System

- A. **Motor Neurons** innervate skeletal muscle; they constitute the somatic nervous system.
- B. Structure of motor neurons (Fig 11.13)
 1. Cell bodies are in ventral horn of the spinal cord
 2. Axon of motor neuron is continuous from spinal cord to termination in skeletal muscle.
 3. Axon terminals release **acetylcholine** (Ach)
- C. Control of Motor Neuron Function
 1. Ach release causes excitation and contraction of the muscle
 2. Can only **stimulate** skeletal muscle
 3. Control and level of activity exerted by relative balance of EPSP and IPSP from excitatory and inhibitory **presynaptic inputs**; thus the somatic nervous system is more of an “on-off” system compared to the autonomic nervous system, which is a dual control system.
 4. Some inputs are part of spinal-reflex pathways; others are part of descending pathways from parts of brain (especially motor regions of cortex, basal nuclei, cerebellum, and brain stem).
 5. Somatic nervous system is considered “voluntary” but much of skeletal activity is subconscious (posture, balance, walking).
- D. Neuromuscular Junctions: Structure (Fig 11.15a)
 1. Motor neuron has long myelinated axon
 2. Part of axon near muscle divides into many axon terminals which are unmyelinated.
 3. Each axon terminal forms a **neuromuscular junction** with one of many muscle cells (muscle cell is also called a **muscle fiber**)
 4. Muscle fiber is long and cylindrical
 5. Axon terminal has knob at end called **terminal button**.
 6. Terminal button fits into groove in muscle fiber, but does NOT touch muscle fiber.
 7. Part of muscle fiber under terminal button is called **motor end plate**
- E. Neuromuscular Junctions: Function (Fig 11.15b)

1. Motor neuron action potential (AP) reaches terminal button
2. Triggers opening of Ca^{++} channels; Ca^{++} enters terminal button
3. Ca^{++} triggers release of acetylcholine from terminal button
4. Acetylcholine diffuses across gap and binds receptors on membrane of motor end plate
5. Binding of Ach results in opening of cation channels; result: lots of Na^+ enters muscle cell, a little K^+ leaves cell, membrane depolarizes
6. Entry of Na^+ results in end plate potential, which is a **graded potential**., and is called an **end plate potential (EPP)**. Local current flow leads to AP in membrane of muscle fiber next to motor end plate; AP goes in both directions.
7. Ach is destroyed by acetylcholinesterase, terminating the muscle cell response.
8. NOTE: Unlike synaptic transmission, in which single EPSP is **not** enough to cause AP, the magnitude of EPP is nearly always sufficient to cause an AP in the muscle fiber. Also, **no** inhibitory responses at a neuromuscular junction (inhibition occurs at the presynaptic inputs of motor neuron).