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Chapter 14: The Autonomic Nervous System

- **Branches of the Peripheral Nervous System**
  - 1) **The Somatic Nervous System (SNS)**: system responsible for voluntary muscle movements and reflex arcs that involves skeletal muscle tissue
    - A branch of the PNS
      - Mostly voluntary
  - 2) **The Autonomic Nervous System (ANS)**
    - A branch of the PNS = an efferent branch
      - Almost all effectors are visceral → involuntary
    - *General function*: helps maintain a stable internal environment
      - Ex: regulation of heart rate, blood vessel diameter, pupil size, body temperature, increases/decreases stomach secretions
- **The ANS vs The SNS**
  - Two systems have 3 distinct differences:
    - 1) **Effector organs**
      - **SNS** → innervate skeletal muscle tissue
      - **ANS** → innervate visceral organs, cardiac muscle, smooth muscle & glands
    - 2) **Efferent pathways and ganglia**
      - **SNS** → single neuron extends from CNS to effector
        - Motor neuron cell bodies in CNS, axons in PNS extend to skeletal muscle
        - Thick and heavily myelinated fibers
      - **ANS** → consists of two-neuron chain to reach effector; thinner and less myelinated fibers
        - **Preganglionic neuron**: cell body in CNS, preganglionic axon synapses with second motor neuron (postganglionic neuron)
          - Thin, lightly myelinated fibers
        - **Postganglionic neuron**: cell body is outside the CNS, postganglionic axon extends to effector organ
          - Thin, unmyelinated fibers
      - ****Ganglia in the ANS** are sites of synapse between the preganglionic neuron and the postganglionic neuron
        - Entirely *motor ganglia*
        - No involvement with the dorsal root ganglia (entirely sensory in nature)

- 3) **Neurotransmitter effects**
    - <u>**SNS**</u> → all release **acetylcholine** (ACl) at synapses
        - Effect is excitatory on the muscle tissue
            - Cause a depolarizing event to occur
    - <u>**ANS**</u> → release **norepinephrine** or **acetylcholine**
        - Effect can be excitatory *or* inhibitory
            - Can be depolarizing and hyperpolarizing
        - Will largely depend on the effector organ and what receptor types binds to the neurotransmitter

➔ **Two Divisions of the ANS: The Parasympathetic Division**

- ***"Rest and Digest"*** → keeps body energy use as low as possible when we are relaxed
- ***Function***: directs "housekeeping" activities → digestion, elimination of waste, low blood pressure & heart rate, pupils constricted
- ***Origin of Fibers***: the brain and the sacral spinal cord
    - Preganglionic fibers are *long*, postganglionic fibers are *short*
        - If fiber is long = ganglia will be closer to the effector organ than to the spinal cord
- ***Location of Ganglia***: in or near the effector organ
- ***Cranial Portion*** of Parasympathetic Division
    - *Function*: supplies parasympathetic fibers to head, neck, thoracic & abdominal regions
    - Preganglionic fibers run in oculomotor, facial, glossopharyngeal, and vagus (extends down to the body cavities) cranial nerves
        - **Oculomotor nerve**: innervates smooth muscle in eyes & muscle associated with lens
            - Effects?
        - **Facial nerve**: stimulates large glands of head (salivary glands, nasal glands, lacrimal glands)
        - **Glossopharyngeal nerve:** activates parotid salivary gland
        - **Vagus nerve**: provide fibers to neck and almost every organ in thoracic & abdominal cavities
            - Makes up 90% of innervation
            - <u>Cardiac plexus</u>: supplies fibers to heart
                - When stimulated = slow heart rate
            - <u>Pulmonary plexus</u>: supplies fibers to lung
                - Maintain slow respiratory rate per minute when activated

- Esophageal plexus: serves esophagus
    - Fibers extend into abdominal cavity from esophageal plexus → innervates liver, gallbladder, stomach, small intestine, pancreas, proximal half of large intestine
- ***Sacral Portion*** of Parasympathetic Division
    - Form **pelvic splanchnic nerves**
    - *Function*: serves pelvic organs and distal portion half of large intestine

➔ **Two Divisions of the ANS: The Sympathetic Division**

- ***"Fight or flight"***: activated when we are excited/scared/embarrassed
- ***Function***: mobilizes the body → constriction of visceral blood vessels, dilates bronchioles of lungs, increases glucose release to blood, pupils dilate, etc
- ***Origin of Fiber****s*: thoracolumbar region of spinal (T1-L2)
    - Preganglionic fibers are short, postganglionic fibers are long
    - Cell bodies of this division form lateral horns of spinal cord
- ***Location of Ganglia***: close to the spinal cord
- Sympathetic division is more complex than parasympathetic
    - Innervates smooth muscle, cardiac muscle, and glands in body cavities
    - ***Also*** innervates smooth muscle and glands in superficial regions
        - Sweat glands, arrector pili, smooth muscle in blood vessel walls
    - Anatomy: sympathetic division forms the **sympathetic trunk - extends from the neck to the pelvis but the ganglia are only found in the thoracic lumbar region of the spinal cord**
        - Preganglionic fibers leave spinal cord via the ventral root
        - Fibers then pass through **white ramus communicans (structure that connects the spinal nerves to the sympathetic trunk)**, enter **sympathetic trunk ganglion**
            - *White rami communicans*: carry preganglionic fibers to sympathetic trunk
        - Sympathetic trunk found on *both sides* of spinal cord
- At trunk ganglion, preganglionic and postganglionic fibers can form synapses 1 of 3 ways:
    - 1) **Preganglionic neuron and postganglionic neuron synapse at same level**
        - Synapse is found in the trunk ganglion at the same level as where the preganglionic fiber exits the spinal cord
    - 2) **Preganglionic neuron and postganglionic neuron synapse at higher or lower level**

        - Preganglionic fiber leaving via the ventral root and then traveling through the white rami communicans to the sympathetic trunk ganglion and then it travels up to the next level or the next sympathetic trunk ganglion and at this ganglion is where the synapse with the postganglionic fiber which will then travel out towards it effector
    - 3) **Preganglionic neuron and postganglionic neuron synapse at a distant <u>collateral ganglion</u> in abdomen and pelvis**
        - Preganglionic neuron will pass through the ventral root, through the white ramus communicans, into the sympathetic trunk ganglion and will continue straight through it without synapsing and travel to the collateral ganglion which is where the synapse occurs

◆ **<u>Sympathetic Pathways with Synapses in Trunk Ganglia</u>**
- If synapse forms in trunk ganglia → postganglionic fibers enter ventral or dorsal ramus of adjoining spinal nerves via **gray rami communicans**
    - Rami will only carry sympathetic fibers
    - *Gray rami communicans*: carry postganglionic fibers from sympathetic trunk ganglion to periphery
    - From here → travel to effectors
- <u>Pathways to the Head</u>
    - Preganglionic fibers emerge from T1-T4, synapse with postganglionic at **superior cervical ganglion**
    - *Function*: serves skin and blood vessels of head, stimulate dilator muscles of eyes, inhibits nasal and salivary glands, innervates muscle to upper eyelid, sends branches to heart
- <u>Pathways to the Thorax</u>
    - Preganglionic fibers emerge from T1-T6
    - Most postganglionic axons pass through cardiac, pulmonary, & esophageal plexuses of the parasympathetic region to effector organ

◆ **<u>Sympathetic Pathways with Synapses in Collateral Ganglia</u>**
- Preganglionic fibers from T5-L2 synapse in collateral ganglia
- Form splanchnic nerves:
    - **Greater splanchnic nerve, lesser splanchnic nerve, least splanchnic nerves**
    - **Lumbar splanchnic nerves** and **sacral splanchnic nerves**
    - *Function*: serves abdominal viscera (deep organs in the abdomen)

        - **These ganglia usually reach effector organ by traveling with a blood vessel
    - <u>Pathways to the Abdomen</u>
        - Pathways primarily going to be the greater, lesser, and least splanchnic nerves
        - Fibers T5-L2 innervate abdomen
        - *Function*: serves the stomach, most of intestines, liver, spleen, and kidneys
    - <u>Pathways to the Pelvis</u>
        - Fibers T10-L2 innervate pelvis
        - Pathways will be the lumbar and sacral splanchnic nerves
        - *Function*: serves the bladder, reproductive organs, distal half of large intestine
        - ****The effect of sympathetic innervation on the abdominopelvic visceral organs is mostly inhibitory****

➔ **Visceral Reflex Arcs**

- Visceral reflex arcs have 5 components:
    - 1) **Receptor in viscera**
        - Stimulus will activate this receptor and will send an afferent message to the CNS via the sensory neuron
    - 2) **Sensory neurons**
        - Non-encapsulated nerve endings
        - Sensory neuron cell bodies are found in the dorsal root ganglia and sensory ganglia of the spinal nerves
        - *Function*: send sensory information about changes in chemical composition, stretch, temperature, & irritation of viscera
    - 3) **Integration center - interprets sensory information and makes a decision at which point will send out a motor response**
        - May be preganglionic neuron
        - May be a dorsal horn interneuron
        - May be within walls of gastrointestinal tract
    - 4) **Motor neurons - form a two-chain system with pre- and postganglionic neurons**
        - Preganglionic *and* postganglionic neurons
    - 5) **Visceral effector**
        - Smooth muscle, cardiac muscle, and glands
        - Sends out response

➔ **ANS Neurotransmitters**

- **<u>Acetylcholine (ACh)</u>**
  - Effect is not entirely excitatory or inhibitory → depends on receptor it binds
  - Released by **cholinergic fibers** at:
    - 1) All ANS preganglionic axons
    - 2) All parasympathetic postganglionic axons at synapse with effector
  - **<u>Cholinergic Receptors that bind ACh</u>**
    - 1) **Nicotinic receptors**
      - *Found on*: all postganglionic neurons (sympathetic & parasympathetic), hormone-producing cells of the adrenal medulla, sarcolemma of skeletal muscle cells** (technically somatic not autonomic)
      - *Effect*: binding of ACh here is *always stimulatory*
        - Binding will always open ion channels and will depolarize the postsynaptic fiber
    - 2) **Muscarinic Receptors**
      - *Found on*: all parasympathetic effectors and some sympathetic effectors
      - *Effect*: binding of ACh here is stimulatory <u>or</u> inhibitory
        - Ex: binding of ACh to muscarinic receptors of heart is inhibitory
          - Heart rate will slow
        - Ex: binding of ACh to muscarinic receptors of smooth muscle of gastrointestinal tract is stimulatory
          - Smooth muscle will contract more which will help propel food through the GI tract; also helps push out waste
- **<u>Norepinephrine (NE)</u>**
  - Effect is not entirely inhibitory or excitatory → depends on receptor it binds
  - Released by **adrenergic fibers** at:
    - 1) Sympathetic postganglionic axons
  - **<u>Adrenergic Receptors that bind NE</u>**
    - 1) **Alpha receptors**
      - *Locations*: all sympathetic target (effector) organs
    - 2) **Beta receptors**

        - *Locations*: heart, adipose tissue, kidneys, lungs, blood vessels
    - Associated with adrenaline release
    - Binding of NE or epinephrine can be stimulatory <u>or</u> inhibitory
        - Ex: NE binding at beta receptors of heart increases activity
            - Heart rate will increase
        - Ex: epinephrine binding at beta receptors of bronchioles causes dilation
            - More air will enter the lung tissue, allows for increase oxygen uptake, and carbon dioxide disposal as well

➔ **Effects of the Sympathetic & Parasympathetic Divisions**

- Most organs have **dual innervation**
- <u>Antagonistic Interactions of the Divisions</u>
    - Divisions have **opposite effects** → whichever dominates will influence overall organ activity
    - Ex: increased sympathetic activity = increased heart rate, dilated airways, decreased digestion & elimination
    - Ex: increased parasympathetic activity = resting heart rate & airway diameter, increased elimination of waste
- **Vasomotor (Sympathetic) Tone**: continuous partial constriction of blood vessels
    - Sympathetic fibers supply blood vessels & control blood vessel diameter
        - Allows vessels to remain open and allows the diameter to be more efficiently changed
    - If blood pressure is <u>low</u> → **vasomotor fibers (found in blood vessels)** fire more rapidly
        - *Effect*: blood vessels constrict to increase blood pressure
    - If blood pressure is <u>high</u> → vasomotor fibers fire less rapidly
        - *Effect*: blood vessels dilate to decrease blood pressure
- **Parasympathetic Tone: effect of parasympathetic innervation on various visceral organs**
    - Present mostly in cardiac muscle tissue, smooth muscle tissue of digestive and urinary organs
    - *Effect*: slows heart rate, maintains normal activity of digestive & urinary organs
    - Sympathetic division <u>can override</u> parasympathetic tone and reverses all the effects
        - Only when absolutely necessary - “fight or flight”

- Unique Roles of the Sympathetic Division
    - 1) **Thermoregulatory response to heat**
        - *Effects*:
            - A) Blood vessels dilate in response to heat, constrict in response to cold
                - Truer for blood vessels that stick closer to the skin
            - B) Sweat glands activated in response to heat
                - Produce more sweat
    - 2) **Renin release from kidneys**
        - *Effects*: increases blood pressure
        - Renin = hormone that helps control blood volume and thus blood pressure
            - The higher the blood volume, the higher the blood pressure
                - More renin = increase in blood pressure
    - 3) **Metabolic changes**
        - *Effects*:
            - A) Increases metabolic rate of cells
                - Producing more ATP
            - B) Raises blood glucose levels
                - Supply cells with raw material used to synthesize ATP
            - C) Mobilizes fats used fuel use
                - Adipose tissue will be mobilized to be used as an easy access energy source during high levels of activity
- Localized vs Diffuse Effects of the Two Divisions
    - Parasympathetic division exerts <u>highly localized, short-lived control</u>
        - How?
            - (1) One preganglionic neuron synapses with <u>one (or a few)</u> postganglionic neurons
                - Less effectors will receive a message overall
            - (2) All parasympathetic fibers release ACh → <u>quickly broken down</u> by acetylcholinesterase
                - Making the effect of the parasympathetic division short-lived
    - Sympathetic division exerts <u>diffuse, long-lasting control</u> (affect more parts of the body overall)