Chapter 15

Introduction to The Autonomic Nervous System

Sympathetic N.S.

Parasympathetic N.S.

Adrenergic and Cholinergic Fibers

Neurotransmitters
Autonomic Nervous System

- Portion of the nervous system that operates in comparative secrecy (involuntary)

- ANS manages a multitude of unconscious processes responsible for the body’s homeostasis

- Walter Cannon studied the ANS // coined the expressions *homeostasis* and *fight or flight response*

- Homeostasis can not be maintained without the ANS

- An imbalance in homeostasis causes a disease state
General Properties of ANS

- a *motor nervous system* that controls glands, cardiac muscle, and smooth muscle

- also called the *visceral motor system*

- primary organs of the ANS
  
  - viscera of thoracic and abdominal cavities
  
  - also some structures in the body wall
    
    - cutaneous blood vessels
    - sweat glands
    - piloerector muscles
General Properties of ANS

- carries out actions *involuntarily* // without our conscious intent or awareness

- visceral effectors do not depend on the ANS for their function
  
  • only to adjust their activity to the body’s changing needs // e.g. the heart

- *denervation hypersensitivity* /// exaggerated response of cardiac and smooth muscle if autonomic nerves are severed
Visceral Reflexes

- unconscious, automatic, stereotyped responses to stimulation involving visceral receptors and effectors
- slower responses than somatic reflexes
The Visceral Reflex Arc

- **receptors** – nerve endings that detect stretch, tissue damage, blood chemicals, body temperature, and other internal stimuli

- **afferent neurons** – leading to the CNS

- **interneurons** – in the CNS

- **efferent neurons** – carry motor signals away from the CNS

- **effectors** – make adjustments to homeostasis *(not a skeletal muscle)*

  • ANS modify effector activity  //  effectors are not dependent upon ANS for their function!!!
Visceral Reflex to High BP

- high blood pressure detected by arterial stretch receptors
  - (1) afferent neuron
  - (2) carries signal to CNS, efferent
  - (3) signals travel to the heart
  - (4), heart slows reducing blood pressure
- example of homeostatic negative feedback loop
Divisions of ANS

- two divisions

- often innervate same target organs // may have cooperative or contrasting effects

- sympathetic division /// prepares body for physical activity – exercise, trauma, arousal, competition, anger, or fear
  - E.g. increases heart rate, BP, airflow, blood glucose levels, reduces blood flow to the skin and digestive tract

- parasympathetic division /// calms many body functions - reducing energy expenditure and assists in bodily maintenance
  - E.g. digestion and waste elimination // “resting and repair” / e.g. digesting state
Divisions of ANS

- **autonomic tone** - normal background rate of activity that represents the balance between the two systems
  - **parasympathetic tone**
    - Example: maintains smooth muscle tone in intestines
    - Example: holds resting heart rate down to about 70 – 80 beats per minute
  - **sympathetic tone**
    - Example: keeps most blood vessels partially constricted and maintains blood pressure
Divisions of ANS

- ANS division often provide a contrasting tone to same tissues:
  - **sympathetic division** excites the hearts but inhibits digestive system and urinary bladder activity
  - **parasympathetic** division inhibits the heart rate but excites the digestive and urinary bladder activity
Neural Pathways

• ANS has components in both the central and peripheral nervous systems

  – **controlling nuclei** located in the **hypothalamus** and/or other **brain stem regions**

  – **motor neurons** in the **spinal cord (lateral horns) and peripheral ganglia**

  – nerve fibers reach effector tissue by traveling through the **cranial and spinal nerves**

• In a **somatic motor pathway**

  – a motor neuron from the brainstem or spinal cord issues a myelinated axon that reaches all the way to the skeletal muscle (**not the case with ANS**)
The ANS Neural Pathway

- signal must travel across **two neurons** to get to the target organ

- must cross a synapse where these two neurons meet in an autonomic ganglion

- **Pre-ganglionic neuron** – the first neuron has a soma in the brainstem or spinal cord (myelinated fiber)

- **Post-ganglionic neuron** - soma form the ganglion and its axon extends the rest of the way to the target cell (unmyelinated fiber)

• Note: *a ganglion is a collection of soma outside the CNS*
Somatic versus ANS Pathways

ANS – two neurons from CNS to effectors

- preganglionic neuron whose cell body is in CNS
- postganglionic neuron cell body in peripheral ganglion
Sympathetic Nervous System

• also called the **thoracolumbar division** because it arises from the thoracic and lumbar regions of the spinal cord

• relatively **short preganglionic** and **long postganglionic** fibers

• preganglionic neurosomas in **lateral horns** and nearby regions of the gray matter of spinal cord
Sympathetic Nervous System

- These fibers exit spinal cord by way of spinal nerves T1 to L2

- lead to nearby sympathetic chain of ganglia (paravertebral ganglia)
  - series of longitudinal ganglia adjacent to both sides of the vertebral column from cervical to coccygeal levels
  - usually 3 cervical, 11 thoracic, 4 lumbar, 4 sacral, and 1 coccygeal ganglion
  - sympathetic nerve fibers are distributed to every level of the body
  - May travel by various pathways
Sympathetic Nervous System

- each paravertebral ganglion is connected to a spinal nerve by two branches – communicating rami

- preganglionic fibers are small myelinated fibers that travel from spinal nerve to the ganglion by way of the white communicating ramus (myelinated)

- postganglionic fibers leave the ganglion by way of the gray communicating ramus (unmyelinated)

  - forms a bridge back to the spinal nerve

- postganglionic fibers extend the rest of the way to the target organ
Sympathetic Chain Ganglia

- Cardiac n.
- Thoracic ganglion
- Communicating ramus
- Sympathetic chain
- Splanchnic n.
- Phrenic n.
- Vagus n.
- Bronchi
- Superior vena cava
- Rib
- Heart
- Diaphragm

© From A Stereoscopic Atlas of Anatomy by David L. Basett. Courtesy of Dr. Robert A. Chase, MD
Preganglionic Pathways

- Preganglionic neuron
- Postganglionic neuron
- Somatic neuron

Somatic motor fiber

To somatic effector (skeletal muscle)

Soma of preganglionic neuron

Soma of somatic motor neuron

Splanchnic nerve

Collateral ganglion

Postganglionic sympathetic fibers

To liver, spleen, adrenal glands, stomach, intestines, kidneys, urinary bladder, reproductive organs

To iris, salivary glands, lungs, heart, thoracic blood vessels, esophagus

Sympathetic nerve

Spinal nerve

Preganglionic sympathetic fiber

Postganglionic sympathetic fiber

White ramus

Gray ramus

Communicating rami

Soma of postganglionic neuron

Sympathetic trunk

Sympathetic ganglion
Sympathetic Nervous System

- after entering the sympathetic chain, the postganglionic fibers may follow any of three possible courses
  - some end in ganglia which they enter and synapse immediately with a postganglionic neuron
  - some travel up or down the chain and synapse in ganglia at other levels
- these fibers link the paravertebral ganglia into a chain
- only route by which ganglia at the cervical, sacral, and coccygeal levels receive input
  - some pass through the chain without synapsing and continue as splanchnic nerves
Preganglionic Pathways

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
nerve fibers leave the sympathetic chain by spinal, sympathetic, and splanchnic nerves

- spinal nerve route
  
  • some postganglionic fibers exit a ganglion by way of the gray ramus

  • returns to the spinal nerve and travels the rest of the way to the target organ

  • most sweat glands, piloerector muscles, and blood vessels of the skin and skeletal muscles
Sympathetic Nervous System

- sympathetic nerve route

  - other nerves leave by way of sympathetic nerves that extend to the heart, lungs, esophagus and thoracic blood vessels

  - these nerves form carotid plexus around each carotid artery of the neck

  - issue fibers from there to the effectors in the head // sweat, salivary, nasal glands, piloerector muscles, blood vessels, dilators of iris

  - some fibers of superior and middle cervical ganglia form cardiac nerves to the heart
Sympathetic Nervous System

- **splanchnic nerve route**

  - some fibers that arise from spinal nerves T5 to T12 pass through the sympathetic ganglia without synapsing
    
    - continue on as the splanchnic nerves
    
    - lead to second set of ganglia – *collateral (prevertebral) ganglia* and synapse there
• collateral ganglia contribute to a network called the abdominal aortic plexus

  – The AAP wraps around abdominal aorta

  – Form three major collateral ganglia in this plexus (note: lab objectives)

  • celiac, superior mesenteric, and inferior mesenteric

  • These nerves of postganglionic fibers follow similar named arteries to their target organs
Plexus of Sympathetic Nervous System

• **solar plexus**
  – collective name for the celiac and superior mesenteric ganglia
  – nerves radiate from ganglia like rays of the sun

• **neuronal divergence** predominates
  – each preganglionic cell branches and synapses on 10 to 20 postganglionic cells
  – one preganglionic neuron can excite multiple postganglionic fibers leading to different target organs
  – have relatively widespread effects
Efferent Pathways

- Pons
- Eye
- Salivary glands
- Heart
- Lung
- Stomach
- Spleen
- Pancreas
- Small intestine
- Large intestine
- Rectum
- Kidney
- Bladder
- Penis Scrotum
- Uterus
- Ovary
- Liver and gallbladder
- Spleen
- Pancreas
- Small intestine
- Large intestine
- Adrenal medulla
- Sympathetic chain ganglia
- Postganglionic fibers to skin, blood vessels, adipose tissue
- Celiac ganglion
- Superior mesenteric ganglion
- Inferior mesenteric ganglion
- Sympathetic chain ganglia
- Preganglionic neurons
- Postganglionic neurons

Regions of spinal cord:
- Cervical
- Thoracic
- Lumbar
- Sacral
Preganglionic Pathways

1. Somatic motor fiber to somatic effector (skeletal muscle)
2. Sympathetic nerve to iris, salivary glands, lungs, heart, thoracic blood vessels, esophagus
3. Splanchnic nerve to liver, spleen, adrenal glands, stomach, intestines, kidneys, urinary bladder, reproductive organs

- Preganglionic neuron
- Postganglionic neuron
- Somatic neuron
Summary of Sympathetic Innervation

- effectors in body wall are innervated by sympathetic fibers in spinal nerves
- effectors in head and thoracic cavity are innervated by sympathetic fibers in sympathetic nerves
- effectors in abdominal cavity are innervated by sympathetic fibers in splanchnic nerves
Ganglia and Abdominal Aortic Plexus

- Diaphragm
- Esophagus
- Celiac ganglia
- Adrenal gland
- Celiac trunk
- Renal plexus
- First lumbar sympathetic ganglion
- Aortic plexus
- Aorta
- Superior mesenteric ganglion
- Superior mesenteric artery
- Kidney
- Inferior mesenteric artery
- Inferior mesenteric ganglion
- Pelvic sympathetic chain
- Adrenal medulla
- Adrenal cortex
Adrenal Glands

- paired adrenal (suprarenal) glands on superior poles of the kidneys

- Adrenal gland is actually two separate glands with different functions
  - adrenal cortex (outer layer) // secretes steroid hormones
  - adrenal medulla (inner core) // essentially a sympathetic ganglion
Adrenal Glands

– Adrenal medulla (inner core)

• consists of modified postganglionic neurons without dendrites or axons

• stimulated by preganglionic sympathetic neurons that terminate on these cells

• Adrenal medulla secretes a mixture of hormones into bloodstream

  − catecholamines // 85% epinephrine (adrenaline) // 15% norepinephrine (noradrenaline) // norepinephrine also function as neurotransmitters

  − sympathoadrenal system = the closely related functioning adrenal medulla and sympathetic nervous system
Chapter 15

The Parasympathetic Nervous System
Parasympathetic Division

- **parasympathetic division** is also called the **craniosacral division**
  - arises from the brain and sacral regions of the spinal cord
  - fibers travel in certain cranial and sacral nerves

- origin of **long preganglionic neurons**
  - midbrain, pons, and medulla
  - sacral spinal cord segments S2-S4
Parasympathetic Division

- pathways of long preganglionic fibers
  - fibers in cranial nerves III, VII, IX and X
  - fibers arising from sacral spinal cord
    - pelvic splanchnic nerves and inferior hypogastric plexus

- terminal ganglia in or near target organs
  - long preganglionic, short postganglionic fibers

- Less neuronal divergence than sympathetic division
  - one preganglionic fiber reaches the target organ and then stimulates fewer than 5 postganglionic cells
Parasympathetic Cranial Nerves

- **Oculomotor nerve (III)**
  - narrows pupil and focuses lens

- **Facial nerve (VII)**
  - tear, nasal and salivary glands

- **Glossopharyngeal nerve (IX)**
  - parotid salivary gland

- **Vagus nerve (X)**
  - viscera as far as proximal half of colon
  - cardiac, pulmonary, and esophageal plexus
Efferent Pathways

• remaining parasympathetic fibers arise from levels S2 to S4 of the spinal cord

• form pelvic splanchnic nerves that lead to the inferior hypogastric plexus

• most form pelvic nerves to their terminal ganglion on the target organs
  – distal half of colon, rectum, urinary bladder, and reproductive organs
Chapter 15
Neurotransmitters of the ANS
Neurotransmitters and Receptors

• How can the same type of ANS neuron create different outcomes on different target tissue?

  1) variety of neurotransmitters

  2) different types of receptors for similar neurotransmitters
• ACh is secreted by all preganglionic neurons in both divisions of the ANS

• Ach is secreted by the postganglionic parasympathetic neurons

• Any fiber that secretes Ach is called a cholinergic fibers

• Any receptor that binds Ach is called a cholinergic receptor
2 types of cholinergic receptors

- muscarinic receptors
  - use the second messenger mode of action / not ion channel
  - all cardiac muscle
  - smooth muscle
  - gland cells have muscarinic receptors
  - Note: can be either excitatory or inhibitory due to sub-classes of muscarinic receptors
• **Second type of cholinergic receptors**

  – **nicotinic receptors**

    • Sodium ion channel mode of action
    
    • on all ANS postganglionic neuron’s soma
    
    • adrenal medulla
    
    • neuromuscular junctions of skeletal muscle
    
    • **Note: always excitatory when ACh binding occurs**
Norepinephrine (NE)

- NE is secreted by nearly all sympathetic postganglionic neurons
  - called adrenergic fibers
  - receptors for it called adrenergic receptors
Norepinephrine (NE)

• alpha-adrenergic receptors
  – usually excitatory // 2 subclasses use different second messengers (α₁ & α₂)

• beta-adrenergic receptors
  – usually inhibitory // 2 subclasses with different effects
  – both act through cAMP as a second messenger (β₁ & β₂)
<table>
<thead>
<tr>
<th>Target</th>
<th>Sympathetic Effect and Receptor Type</th>
<th>Parasympathetic Effect (All Muscarinic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye</td>
<td>Pupillary dilation (α)</td>
<td>Pupillary constriction</td>
</tr>
<tr>
<td>Iris</td>
<td>Relaxation for far vision (β)</td>
<td>Contraction for near vision</td>
</tr>
<tr>
<td>Ciliary muscle and lens</td>
<td>None</td>
<td>Secretion</td>
</tr>
<tr>
<td>Lacrimal (tear gland)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integumentary system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merocrine sweat glands (cooling)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apocrine sweat glands (scent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilosecrotor muscles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adipose tissue</td>
<td>Decreased fat breakdown (α)</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td>Increased fat breakdown (α, β)</td>
<td></td>
</tr>
<tr>
<td>Adrenal medulla</td>
<td>Hormone secretion (nicotinic)</td>
<td>No effect</td>
</tr>
<tr>
<td>Circulatory system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate and force</td>
<td>Increased (β)</td>
<td>Decreased</td>
</tr>
<tr>
<td>Deep coronary arteries</td>
<td>Vasodilation (β)</td>
<td>Slight vasodilation</td>
</tr>
<tr>
<td>Blood vessels of most viscera</td>
<td>Vasodilation (α)</td>
<td></td>
</tr>
<tr>
<td>Blood vessels of skeletal muscles</td>
<td>Vasodilation (β)</td>
<td></td>
</tr>
<tr>
<td>Blood vessels of skin</td>
<td>Vasodilation (α)</td>
<td></td>
</tr>
<tr>
<td>Platelets (blood clotting)</td>
<td>Increased clotting (α)</td>
<td></td>
</tr>
<tr>
<td>Respiratory system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronchi and bronchioles</td>
<td>Bronchodilation (β)</td>
<td>Bronchoconstriction</td>
</tr>
<tr>
<td>Mucous glands</td>
<td>Decreased secretion (α)</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td>Increased secretion (β)</td>
<td></td>
</tr>
<tr>
<td>Urinary system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidneys</td>
<td>Reduced urine output (α)</td>
<td>No effect</td>
</tr>
<tr>
<td>Bladder wall</td>
<td>No effect</td>
<td>Contraction</td>
</tr>
<tr>
<td>Internal urinary sphincter</td>
<td>No effect</td>
<td>Urine retention (α)</td>
</tr>
<tr>
<td>Digestive system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salivary glands</td>
<td>Thick mucous secretion (α)</td>
<td>Thin serous secretion</td>
</tr>
<tr>
<td>Gastrointestinal motility</td>
<td>Decreased (α, β)</td>
<td>Increased</td>
</tr>
<tr>
<td>Gastrointestinal secretion</td>
<td>Decreased (α)</td>
<td>Increased</td>
</tr>
<tr>
<td>Liver</td>
<td>Glycogen breakdown (α, β)</td>
<td>Increased</td>
</tr>
<tr>
<td>Pancreatic enzyme secretion</td>
<td>Decreased (α)</td>
<td>Increased</td>
</tr>
<tr>
<td>Pancreatic insulin secretion</td>
<td>Decreased (α)</td>
<td>Increased</td>
</tr>
<tr>
<td></td>
<td>Increased (β)</td>
<td>No effect</td>
</tr>
<tr>
<td>Reproductive system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penile or clitoral erection</td>
<td>No effect</td>
<td>Stimulation</td>
</tr>
<tr>
<td>Glandular secretion</td>
<td>No effect</td>
<td>Stimulation</td>
</tr>
<tr>
<td>Orgasm, smooth muscle roles</td>
<td>Stimulation (α)</td>
<td>No effect</td>
</tr>
<tr>
<td>Uterus</td>
<td>Relaxation (β)</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td>Labor contractions (α)</td>
<td>No effect</td>
</tr>
</tbody>
</table>
• Autonomic effects on glandular secretion are often an indirect result of their effect on blood vessels
  
  – vasodilation – increased blood flow results in an increased secretion
  
  – vasoconstriction – decreased blood flow results in a decreased secretion
Overview of ANS Function (2 of 3)

- Sympathetic effects tend to last longer than parasympathetic effects
  - ACh released by parasympathetics is broken down quickly at synapse
  - NE by sympathetics is reabsorbed by nerve
    - Slower process and some will diffuse to adjacent tissues
    - And much passes into bloodstream // Circulate in blood and can “hit” other adrenergic receptors
• Many substances are released as neuromodulators that modulate ACh and NE function

  – **sympathetic fibers** also secrete enkephalin, substance P, neuropeptide Y, somatostatin, neurotensin, or gonadotropin-releasing hormone

  – **parasympathetic fibers** stimulate endothelial cells to release the gas, nitric oxide – causes vasodilation by inhibiting smooth muscle tone

• function is crucial to penile erection - means of action of Viagra
Neurotransmitters and Receptors

(a) Parasympathetic fiber

- Preganglionic neuron
- Postganglionic neuron
- Target cell
- Nicotinic receptor
- ACh
- Muscarinic receptor

(b) Sympathetic adrenergic fiber

- Preganglionic neuron
- Postganglionic neuron
- NE
- Adrenergic receptor
- Target cell

(c) Sympathetic cholinergic fiber

- Preganglionic neuron
- Postganglionic neuron
- Target cell
- Nicotinic receptor
- ACh

Merocrine sweat gland (cooling)
Dual Innervation

- *most viscera receive nerve fibers from both parasympathetic and sympathetic divisions*
  - antagonistic effect – oppose each other
  - cooperative effects – two divisions act on different effectors to produce a unified overall effect

- both divisions do not normally innervate the same organ equally
Dual Innervation

- antagonistic effects (i.e. oppose each other)
  - 1st option // exerted through dual innervation of same group of cells
    - heart rate decreases (parasympathetic)
    - heart rate increases (sympathetic)
  - 2nd option // exerted because each division innervates different group of cells
    - pupillary dilator muscle (sympathetic) dilates pupil
    - constrictor pupillae (parasympathetic) constricts pupil
Dual Innervation of the Iris

- Brain
  - Parasympathetic fibers of oculomotor nerve (III)
  - Sympathetic fibers
  - Superior cervical ganglion
  - Ciliary ganglion
- Spinal cord
  - Adrenergic stimulation of pupillary dilator
  - Cholinergic stimulation of pupillary constrictor
- Iris
  - Pupil
- Sympathetic (adrenergic) effect
  - Pupil dilated
- Parasympathetic (cholinergic) effect
  - Pupil constricted
Dual Innervation

- **cooperative effects** - when the two divisions act on different effectors to produce a unified effect

- eg. ANS innervation of salivary glands
  - parasympathetics increase salivary serous cell secretion
  - sympathetics increase salivary mucous cell secretion
Regulation Without Dual Innervation

- some effectors receive **only sympathetic fibers**
  - adrenal medulla
  - arrector pili muscles
  - sweat glands
  - and many blood vessels throughout body

- How is blood flow, blood pressure, and routes of blood flow regulated with only sympathetic nerve fibers?

- (see next slide)
Regulation Without Dual Innervation

- control of blood pressure and routes of blood flow using only sympathetic innervation

- sympathetic vasomotor tone - a baseline firing frequency of sympathetics
  - keeps vessels in state of partial constriction
  - increase in firing frequency – vasoconstriction
  - decrease in firing frequency – vasodilation
  - can shift blood flow from one organ to another as needed

- sympathetic division acting alone can exert opposite effects on the target organ through control of blood vessels
  - during stress
    - blood vessels to skeletal muscles and heart dilate (not shown here)
    - blood vessels to skin constrict (illustrated here)

Note: this illustration shows blood vessels in skin / at the same time different blood vessels in skeletal muscles will dilate
Sympathetic Functions

ANS Function: blood vessels to skin vasoconstrict to minimize bleeding if injury occurs during stress or exercise

ANS Function: prioritizes blood vessels to skeletal muscles and heart in times of emergency
• ANS regulated by different levels of the CNS

  – cerebral cortex has an influence // prefrontal cortex hardwired to limbic system

  • anger, fear, anxiety

  • powerful emotions influence the ANS because of the connections between our limbic system (emotional brain) and the hypothalamus

  – hypothalamus - major visceral motor control center // exerts influence by connections to pituitary (hormones) or nerve tracks to nuclei in medulla oblongata (ANS)

  • nuclei for primitive functions – hunger, thirst, sex
– midbrain, pons, and medulla oblongata contain:

  • nuclei for cardiac and vasomotor control, salivation, swallowing, sweating, bladder control, and pupillary changes

– spinal cord reflexes

  • defecation and micturition reflexes are integrated in spinal cord

  • we control these functions because of our control over skeletal muscle sphincters…

  • if the spinal cord is damaged, the smooth muscle of bowel and bladder is controlled by autonomic reflexes built into the spinal cord
Preganglionic Pathways

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

To iris, salivary glands, lungs, heart, thoracic blood vessels, esophagus

Sympathetic nerve
Spinal nerve
Preganglionic sympathetic fiber
Postganglionic sympathetic fiber

To sweat glands, piloerector muscles, and blood vessels of skin and skeletal muscles

White ramus
Gray ramus
Communicating rami

Soma of postganglionic neuron
Sympathetic trunk

To liver, spleen, adrenal glands, stomach, intestines, kidneys, urinary bladder, reproductive organs

Soma of preganglionic neuron
Somatic motor fiber

Soma of somatic motor neuron

Somatic motor fiber

To somatic effector (skeletal muscle)
(a) Sympathetic division—innervation to most effector tissues

(b) Sympathetic division—innervation to most sweat glands

(c) Parasympathetic division
(a) Sympathetic division—innervation to most effector tissues
(b) Sympathetic division—innervation to most sweat glands
(c) Parasympathetic division
(a) Somatic nervous system

- Spinal cord
- Somatic motor neuron (myelinated)
- Effector: skeletal muscle

(b) Autonomic nervous system

- Spinal cord
- Autonomic motor neurons
- Sympathetic preganglionic neuron (myelinated)
- Autonomic ganglion
- Sympathetic postganglionic neuron (unmyelinated)
- Effectors: glands, cardiac muscle (in heart), and smooth muscle (e.g., in urinary bladder)

- Spinal cord
- Adrenal cortex
- Adrenal medulla
- Sympathetic preganglionic neuron (myelinated)
- Chromaffin cell
- Epinephrine and NE
- Blood vessel

- Spinal cord
- Parasympathetic preganglionic neuron (myelinated)
- Autonomic ganglion
- Parasympathetic postganglionic neuron (unmyelinated)
- Effectors: glands, cardiac muscle (in heart), and smooth muscle (e.g., in urinary bladder)
(a) Somatic nervous system
Diagram of the autonomic nervous system (b) showing the relationship between the spinal cord, autonomic preganglionic and postganglionic neurons, and effectors (glands, cardiac muscle in the heart, and smooth muscle in the urinary bladder).

- Spinal cord
- Autonomic motor neurons
- Sympathetic preganglionic neuron (myelinated)
- Autonomic ganglion
- Sympathetic postganglionic neuron (unmyelinated)
- Effectors: glands, cardiac muscle (in heart), and smooth muscle (e.g., in urinary bladder)
- NE
- Adrenal cortex
- Adrenal medulla
- Chromaffin cell
- Epinephrine and NE
- Blood vessel
- Parasympathetic preganglionic neuron (myelinated)
- Autonomic ganglion
- Parasympathetic postganglionic neuron (unmyelinated)
- Effectors: glands, cardiac muscle (in heart), and smooth muscle (e.g., in urinary bladder)
PARASYMPATHETIC DIVISION (craniosacral)

Key:
- Preganglionic neurons
- Postganglionic neurons

Terminal ganglia
- Ciliary ganglion
- Pterygopalatine ganglion
- Submandibular ganglion
- Glosopharyngeal (IX) nerve
- Otic ganglion

Distributed primarily to smooth muscle and glands of these organs:
- Eye
- Lacrimal gland
- Mucous membranes of nose and palate
- Parotid gland
- Lungs
- Liver, gallbladder, and bile ducts
- Stomach, Pancreas
- Small intestine
- Ascending colon
- Transverse colon
- Descending colon
- Sigmoid colon
- Rectum
- Urinary bladder
- External genitals
- Uterus

Spinal cord
- C1
- C2
- C3
- C4
- C5
- C6
- C7
- C8
- T1
- T2
- T3
- T4
- T5
- T6
- T7
- T8
- T9
- T10
- T11
- T12
- L1
- L2
- L3
- L4
- L5
- S1
- S2
- S3
- S4
- S5
- Coccygeal

Brain
- Oculomotor (II) nerve
- Facial (VII) nerve
- Vagus (X) nerve

Atrial muscle fibers
- SA/AV nodes
- Larynx
- Trachea
- Bronchi
- Liver, gallbladder, and bile ducts
- Stomach
- Pancreas
- Small intestine
- Ascending colon
- Transverse colon
- Descending colon
- Sigmoid colon
- Rectum
- Urinary bladder
- External genitals
- Uterus