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Human Anatomy and Physiology

Visually in 24 Hours

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1/72

The Autonomic Nervous System

Rapid Learning Medical Series

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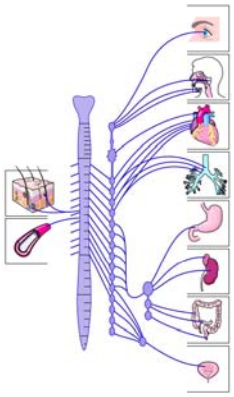
2/72

Learning Objectives

By completing this tutorial, you will learn about:

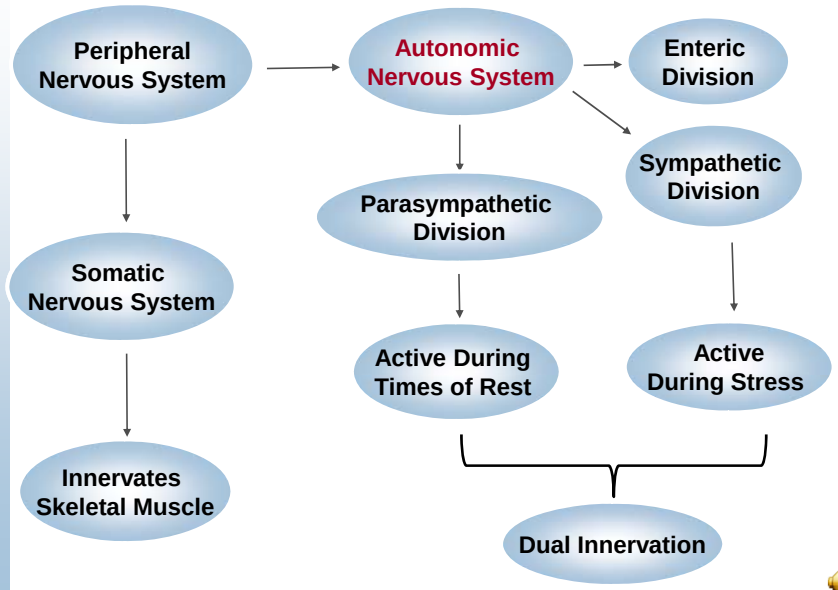


Sympathetic Nervous System

- An Overview of the Autonomic Nervous System
- The Parasympathetic Division
- The Sympathetic Division
- Higher Order Functions

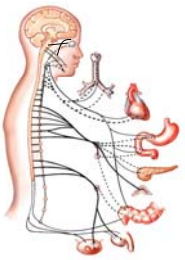
3/72

Concept Map



4/72

Autonomic Nervous System Overview



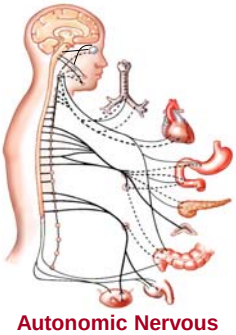
Autonomic Nervous System

5/72

Autonomic Nervous System

The physiological actions of the human body, such as heart rate, blood pressure and digestion, occur with little or no conscious thought. These involuntary actions that maintain homeostasis within the body are performed by the **autonomic nervous system.**

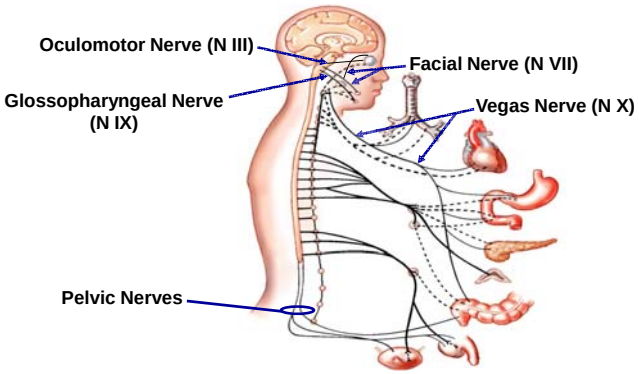
The autonomic nervous system is made up of afferent and efferent neurons that connect the autonomic nervous system to visceral effector organs.



Autonomic Nervous System

6/72

Parasympathetic Division

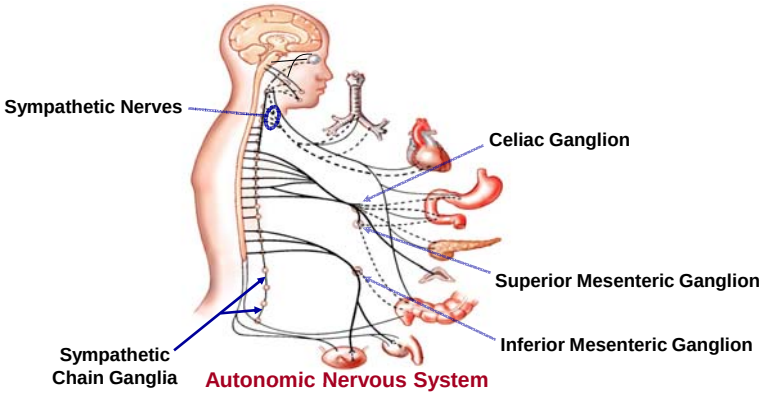


Autonomic Nervous System
Parasympathetic Division

The autonomic nervous system includes all the nerves that innervate the internal organs, blood vessels and glands. The parasympathetic division of the autonomic nervous system is active during periods of rest and digestion.

7/72

Sympathetic Division



Autonomic Nervous System
Sympathetic Division

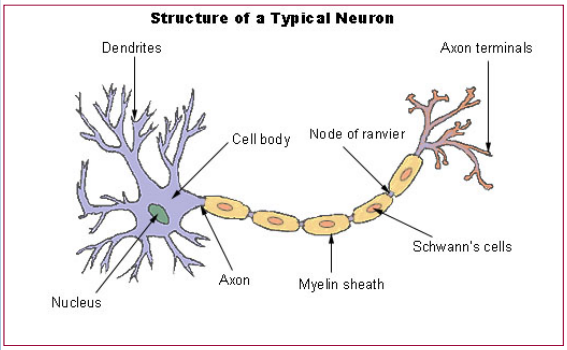
The sympathetic division of the autonomic nervous system is active during times of physical or mental stress on the body. As the system`s activity increases, skeletal muscles and heart rate are prepared for a fight-or-flight response. The sympathetic division involves a sympathetic chain ganglia and sympathetic nerves, unlike the parasympathetic division. In addition to the parasympathetic and sympathetic divisions, the autonomic nervous system also includes the enteric division.

8/72

The enteric division is located within the walls of the digestive tract.

Sensory Information is Necessary for Autonomic Action

Sensory information enters the central nervous system for organs under the regulation of the autonomic nervous system. The sensory information is delivered into the central nervous system through primary sensory neurons. These neurons project onto second-order neurons in the brain stem region.



9/72

Autonomic Nervous System Response

The autonomic nervous system generates a response, based on the information received from the sensory branch. For example, see the table below:

Sensory	Motor
Low Blood Oxygen Levels	Increase Breathing Rate
High Blood Pressure	Decrease Heart Rate
Food in Stomach	Increase Digestive Enzymes

10/72

Clinical Challenge: Exam Question

The key functions of the body, such as heart rate and breathing, are performed with innervation from the autonomic nervous system. Which of the following statements about the autonomic nervous system is correct?

A. The autonomic nervous system is completely controlled at the conscious level.

B. The parasympathetic division is also known as the fight-or-flight system.

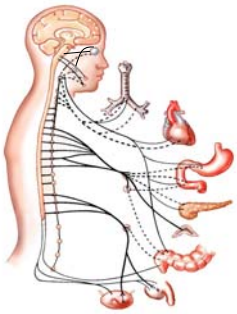
C. The sympathetic nervous system includes sympathetic chain ganglia.

D. Cranial nerves play no role in the function of the autonomic nervous system.

E. The actions and overall function of the autonomic nervous system requires no sensory information or impulses.

11/72

Clinical Challenge: Exam Answer



Autonomic Nervous System

The physiological actions of the human body, such as heart rate, blood pressure and digestion, occur with little or no conscious thought. These involuntary actions that maintain homeostasis within the body are performed by the autonomic nervous system.

The autonomic nervous system is made up of afferent and efferent neurons that connect the autonomic nervous system to visceral effector organs.

This question tests your general knowledge of the autonomic nervous system. The correct answer for this question was:

C) The sympathetic nervous system includes sympathetic chain ganglia.

12/72

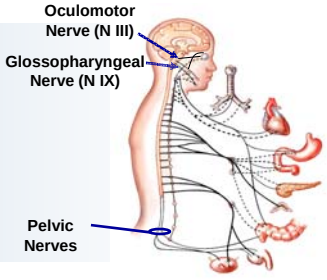
Clinical Note: Raynaud's Disease

Raynaud's Disease is a common disorder that typically affects young women. In this disease, there is an excess transient sympathetic stimulation of the small arteries of the hands and feet. When the affected body parts are exposed to cold temperatures, this leads to changes in skin color. Initially, the skin turns pale then blue; as the blood flow returns to normal, the skin then turns fiery red.

The majority of cases have no known cause but, in some cases, it is associated with disorders, such as scleroderma and polymyositis. Treatment includes avoiding cold triggers with the use of mittens, etc., quitting smoking, and decreasing caffeine intake. In some cases, a sympathectomy can be performed to cut the sympathetic innervation to the affected area.

13/72

Parasympathetic Division

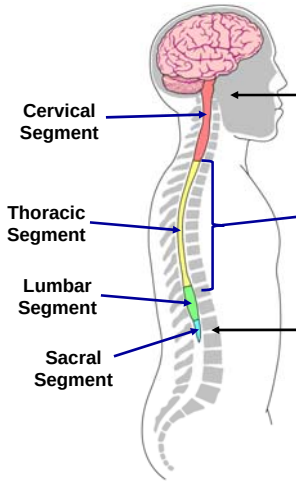


Autonomic Nervous System
Parasympathetic Division

1. Organization
2. Anatomical Innervation
3. Function

14/72

Organization of the Autonomic Nervous System - 1



Lateral View

Thoracolumbar Division of the Autonomic Nervous System

Craniosacral Division of the Autonomic Nervous System

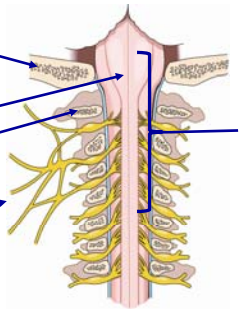
In addition to their different functions, the Sympathetic and Parasympathetic Branches differ in their location of origin in the body. The sympathetic division is primarily located in the thoracolumbar region of the spinal cord.

The parasympathetic division is primarily located in the craniosacral region of the spinal cord.

15/72

Organization of the Autonomic Nervous System - 2

Unlike the somatic nervous system, in which one long neuron reaches the target tissue from the spinal cord, at least two neurons are required for the autonomic nervous system. The first neuron originates in the spinal cord and then projects onto the second neuron to complete the pathway. The first neuron originates in the central nervous system (spinal cord) and is known as the Preganglionic Neuron.
The second neuron, known as the Ganglionic neuron, releases a signal to the effector organ, for example the heart, or a post-ganglionic neuron.

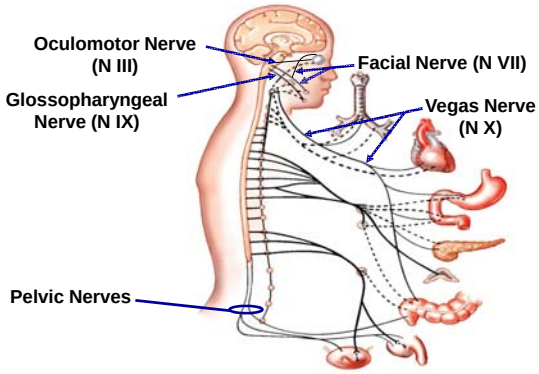


Anterior View of the Cervical Spinal Cord

16/72

Ganglia of the Parasympathetic Division

In the parasympathetic division, the preganglionic nerve fibers exit the central nervous system as the cranial nerves. These cranial nerves then synapse in ganglia, with the short ganglionic neuron. The ganglia of the parasympathetic division are: pterygopalatine, ciliary, submandibular, and the otic ganglion.

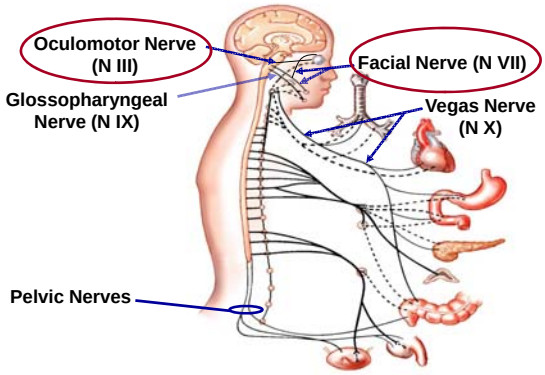


Autonomic Nervous System
Parasympathetic Division

17/72

Targets of the Parasympathetic Division - 1

The oculomotor nerve synapses at the ciliary ganglion with the ganglionic fiber. This fiber then targets the intrinsic eye muscles to decrease the size of the pupil and shape of the lens. The facial nerve synapses with two ganglia, the pterygopalatine and the submandibular. The targets are the glands of the nose, tear glands and salivary glands.

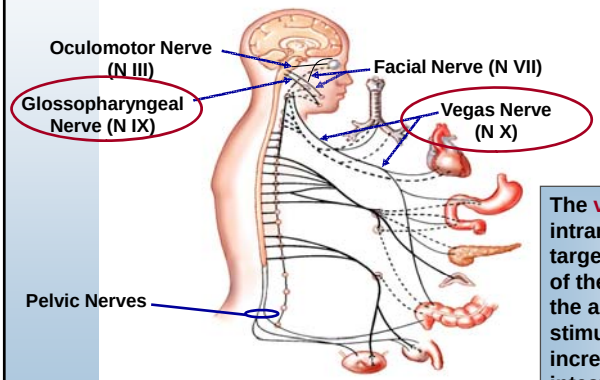


Autonomic Nervous System
Parasympathetic Division

18/72

Targets of the Parasympathetic Division - 2

The glossopharyngeal nerve synapses at the otic ganglion, with the ganglionic fiber. This fiber then targets the parotid salivary gland and stimulates secretion and vasodilation.



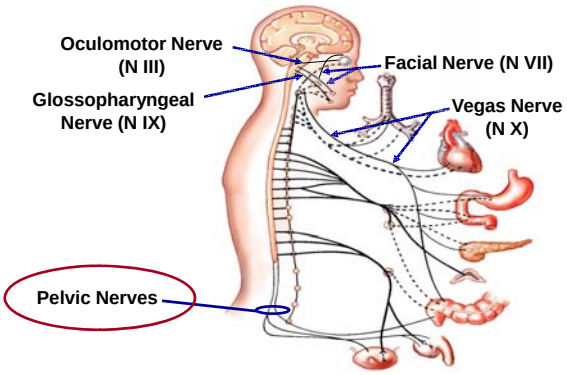
Autonomic Nervous System
Parasympathetic Division

The vagus nerve synapses with the intramural ganglion. There are many targets, including: the visceral organs of the neck, thoracic cavity and most of the abdominal cavity. This leads to stimulation of secretion and an increase in motility in the stomach and intestine.

The parasympathetic stimulation also causes glycogen synthesis in the liver.

19/72

Targets of the Parasympathetic Division - 3



Autonomic Nervous System
Parasympathetic Division

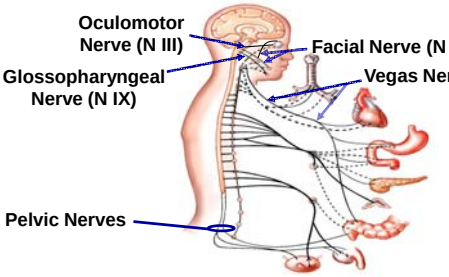
From nuclei in the sacral spinal cord, the pelvic nerves enter an intramural ganglia. The target organs are the visceral organs in the inferior portion of the abdominopelvic cavity. This parasympathetic innervation contracts the walls of the bladder and causes erection and vasodilation in both sexes.

20/72

Parasympathetic Division: General Functions

The parasympathetic nervous system is known as the "Wine and Dine" or "Rest and Digest" system. It functions by decreasing the heart rate, increasing glandular activity, and increasing intestinal activity for digestion and absorption.

Overall, the functions of the parasympathetic division lead to relaxation, food digestion and absorption that leads to increased blood nutrients.

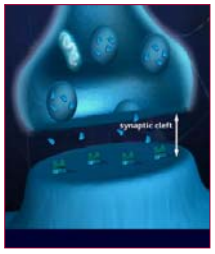


Autonomic Nervous System
Parasympathetic Division

21/72

Parasympathetic Division Neurotransmitters

The sympathetic and parasympathetic divisions oppose each other but in a complementary fashion. For example, one can think of the sympathetic division as the 'accelerator' and the parasympathetic division as the 'brake'. The neurotransmitters are released by post-ganglion neurons.



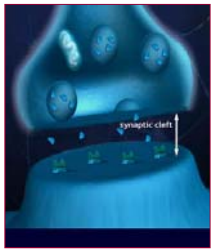
The parasympathetic division uses the neurotransmitter, acetylcholine. Its function includes, most frequently, opposing effects of norepinephrine.

22/72

Parasympathetic Division Receptors

There are two types of receptors in the postsynaptic neuron used by the parasympathetic division: nicotinic and muscarinic. The nicotinic receptor subtype is located on all the ganglionic neurons. Upon exposure to the neurotransmitter, acetylcholine, these receptors lead to excitation of either the ganglionic neuron or the muscle fiber.

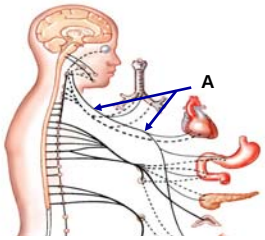
Muscarinic receptors are located at cholinergic neuroeffector junctions (small narrow synaptic clefts). Once stimulated, these are longer-acting than nicotinic receptors.



23/72

Clinical Challenge: Exam Question

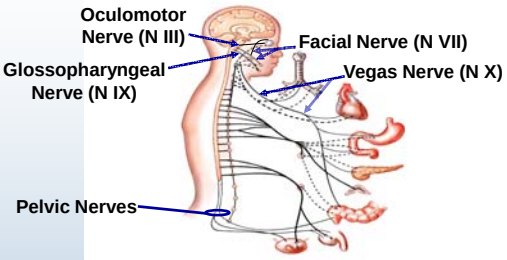
Which component of the parasympathetic division of the autonomic nervous system is identified in the image below?



A. The parasympathetic ganglia chain.
B. The pterygopalatine ganglion.
C. The vagus nerve.
D. The oculomotor nerve.
E. None of the answers is correct.

24/72

Clinical Challenge: Exam Answer



Autonomic Nervous System
Parasympathetic Division

The vagus nerve synapses with the intramural ganglion. There are many targets, including: the visceral organs of the neck, thoracic cavity, and most of the abdominal cavity. This leads to stimulation of secretion and an increase in motility in the stomach and intestine.

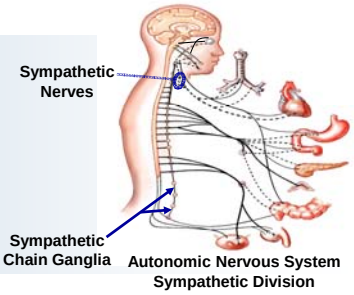
The parasympathetic stimulation also causes glycogen synthesis in the liver.

This question tests your knowledge of the cranial nerves that are involved in the parasympathetic division; the correct answer for this question was:

C) The vagus nerve.

25/72

Sympathetic Division

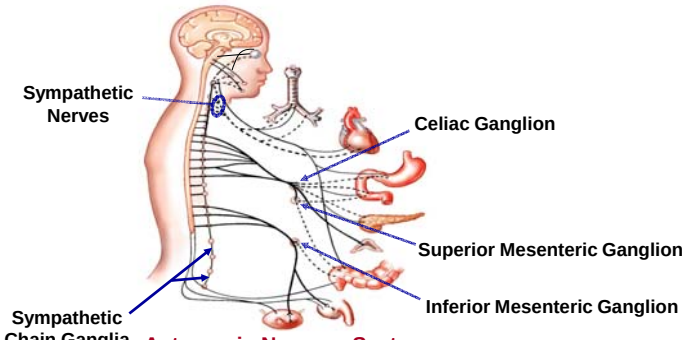


Autonomic Nervous System
Sympathetic Division

1. Organization
2. Anatomical Innervation
3. Function

26/72

Sympathetic Division Illustrated

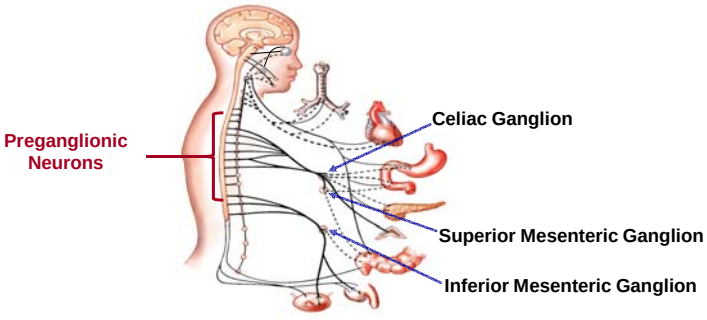


Autonomic Nervous System
Sympathetic Division

The sympathetic division is different anatomically than the parasympathetic division, although they target similar organs of the body. Unlike the parasympathetic division, the sympathetic division includes a chain of ganglia that lay lateral to the vertebral column itself. This division has longer and more prominent post-ganglionic fibers.

27/72

Organization of the Sympathetic Division - 1

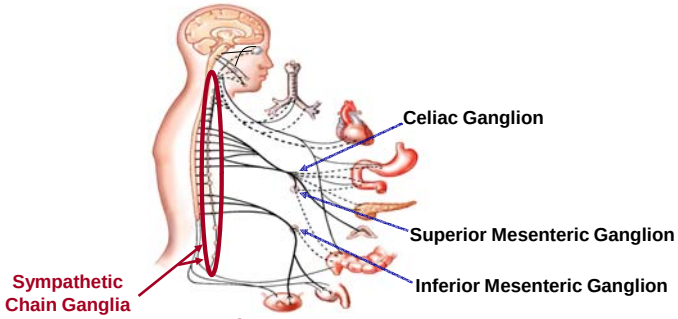


Autonomic Nervous System
Sympathetic Division

The preganglionic neurons are located in the lateral gray horn segments of the 1st thoracic spinal segment, through to the 2nd lumbar. The axons of these preganglionic neurons enter the ventral roots of their associated spinal segment to synapse with the ganglionic neurons.

28/72

Organization of the Sympathetic Division - 2



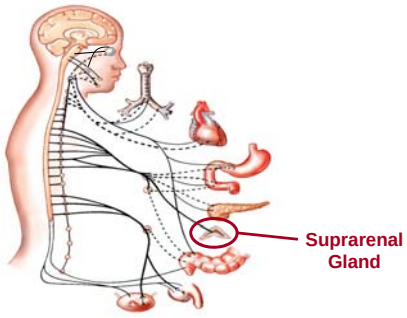
Autonomic Nervous System
Sympathetic Division

The **sympathetic chain ganglia** are located near the vertebral column, and this is where the ganglionic neurons are located.

Within the sympathetic division, there are two different types of ganglia: (1) sympathetic chain ganglia, which physically lay lateral to the vertebral column. The neurons in these ganglia control effectors within the body wall, head and neck, and (2) collateral ganglia, which are located anterior to the vertebral column. The neurons in these ganglia innervate effectors in the abdominopelvic cavity.

29/72

Organization of the Sympathetic Division - 3

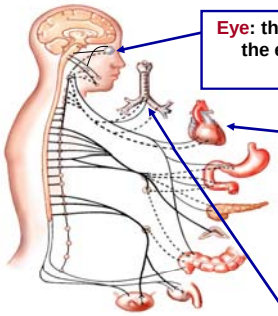


Autonomic Nervous System
Sympathetic Division

The **suprarenal gland** is located on the top of each kidney. This gland contains specialized neurons, and near its center is the suprarenal medulla. The suprarenal medulla is a modified sympathetic ganglion, and when the neurons located here are stimulated, they release catecholamine hormones into the blood circulation.

30/72

Sympathetic Division Targets - 1



Eye: the sympathetic innervation of the muscles of the eye leads to dilation of the eye, as well as relaxation that results in far vision.

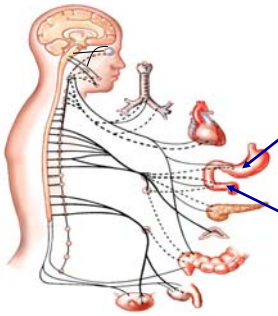
Heart: the activation of sympathetic innervation of the heart increases the heart rate and strength of contraction. The coronary blood vessels of the heart are dilated as part of this activation.

Lungs: activation of the sympathetic innervation of the bronchial muscle causes dilation of the airways.

Autonomic Nervous System
Sympathetic Division

31/72

Sympathetic Division Targets - 2



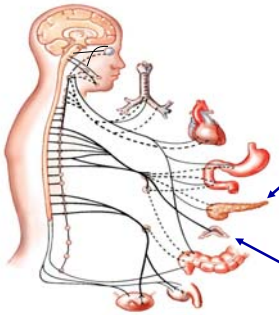
Stomach: the activation of sympathetic innervation of the stomach leads to decreased motility and tone in the stomach, as well as a decrease in gastric juice secretion.

Small Intestine: the activation of sympathetic innervation of the intestines leads to decreased motility and tone. These are the opposite of what normally takes place during the digestion and absorption of food.

Autonomic Nervous System
Sympathetic Division

32/72

Sympathetic Division Targets – 3



Autonomic Nervous System
Sympathetic Division

Pancreas: the sympathetic innervation of the pancreas inhibits the secretion of enzymes and insulin. Alternatively, this innervation leads to an increase in the secretion of glucagon, which increases the available glucose in the bloodstream.

Suprarenal Gland: the sympathetic innervation of the adrenal medulla portion of the adrenal gland promotes the secretion of epinephrine and norepinephrine. These are both key fight-or-flight hormones.

33/72

Sympathetic Division: Abdominopelvic Innervation

Autonomic Nervous System
Sympathetic Division

Sympathetic innervation of the abdominopelvic organs has the following effects: (1) Kidney – constriction of blood vessels that leads to a decrease in urine production, (2) Bladder – relaxation of muscular wall, (3) Ureter – increased motility, (4) Uterus (females) – inhibits contraction if not pregnant, (5) Sex organs – in males, contraction of smooth muscle of the vas deferens and the prostate. In the female, there is a reversal of uterine peristalsis.

34/72

Clinical Challenge: Exam Question

The sympathetic division innervates the stomach and the intestines in the abdominal cavity. This innervation is delivered through ganglia in the region. Which of the following statements about the sympathetic innervation to the stomach and intestines is correct?

A. The sympathetic innervation of the stomach and intestines is delivered, in part, through the celiac ganglion.

B. The lumbar splanchnic nerves innervate the stomach.

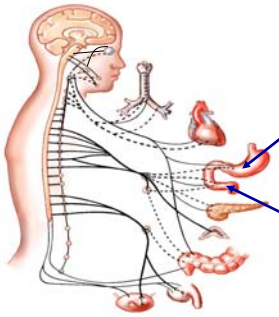
C. Collateral sympathetic innervation of the stomach stems from the cardiac plexus.

D. Activation of the sympathetic innervation to the stomach causes increased motility.

E. Activation of the sympathetic innervation of the intestines leads to increased motility of the intestines.

35/72

Clinical Challenge: Exam Answer



Autonomic Nervous System
Sympathetic Division

Stomach: the activation of sympathetic innervation of the stomach leads to decreased motility and tone in the stomach, as well as a decrease in gastric juice secretion.

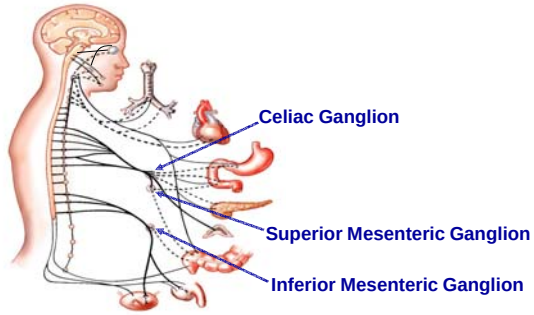
Small Intestine: the activation of sympathetic innervation of the intestines leads to decreased motility and tone. These are the opposite of what normally takes place during the digestion and absorption of food.

This question tests your knowledge of the location of the sympathetic innervation to the stomach and intestines. The correct answer for this question was:

A) The sympathetic innervation of the stomach and intestines is delivered, in part, through the celiac ganglion.

36/72

Collateral Ganglia



Autonomic Nervous System
Sympathetic Division

The sympathetic division contains collateral ganglia that provide innervation to the abdominopelvic cavity.

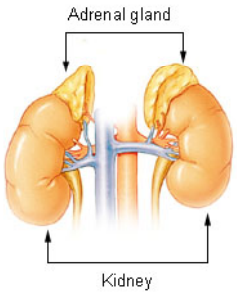
The collateral ganglia are: (1) celiac ganglion – post-ganglionic fibers extend from the celiac ganglion to the stomach, duodenum, liver and gallbladder, (2) superior mesenteric ganglion – is located near the superior mesenteric artery, and its fibers innervate the small intestine and the first portion of the large intestine, and (3) inferior mesenteric ganglion – located near the inferior mesenteric artery. The fibers that extend from this ganglion innervate the kidney, bladder and sex organs.

37/72

Sympathetic Division: Adrenal Gland

The adrenal glands are located on top of the kidneys; they receive their own blood supply and are divided into 2 regions. The gland is divided into the adrenal medulla and the adrenal cortex. Both of these regions receive nerve impulses from the sympathetic nervous system.

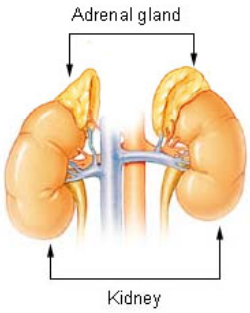
The adrenal cortex is the outermost layer of the adrenal gland, and its hormones include:
(A) Glucocorticoids (Cortisol).
(B) Mineralcorticoids (Aldosterone).
(C) Precursors to sex steroids.



38/72

Sympathetic Division: Adrenal Medulla

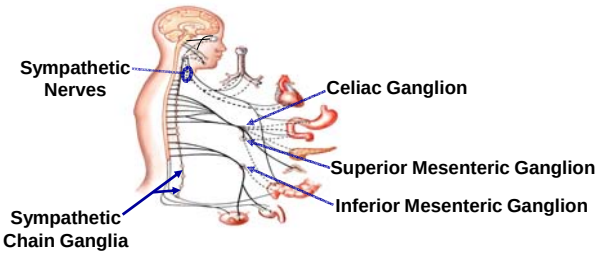
The adrenal medulla makes up the center of the adrenal gland. It produces the following hormones:
(A) Epinephrine – is a fight-or-flight hormone. When it is secreted, it prepares the body for action by increasing heart rate and delivering more blood to skeletal muscles.
(B) Norepinephrine – is both a hormone and neurotransmitter. As a hormone, it acts synergistically with epinephrine and also increases blood pressure by vasoconstriction.



39/72

Sympathetic Division Function

The sympathetic branch is known as the "Fight or Flight" response and becomes more active during stress. When activated, the sympathetic nervous system acts primarily on the cardiovascular system through epinephrine and norepinephrine. This action leads to an increase in heart rate, increased blood flow to skeletal muscles, and decreased blood flow to the gastrointestinal tract.

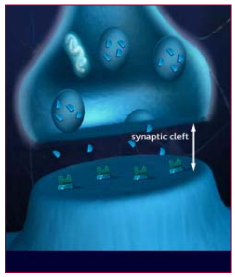


Autonomic Nervous System
Sympathetic Division

40/72

Sympathetic Division Neurotransmitters

The sympathetic division uses the neurotransmitter, norepinephrine, and it is released through cholinergic synapses. The stimulation of ganglionic neurons leads to the release of norepinephrine at the neuroeffector junctions. Acetylcholine release at preganglionic fibers stimulates the ganglionic neurons, which eventually leads to norepinephrine release.

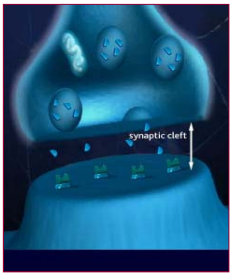


41/72

Sympathetic Division Receptors

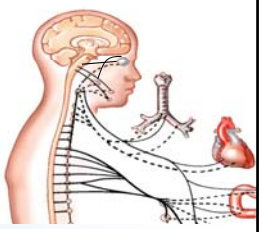
The action of sympathetic innervation is on receptors that are responsive to epinephrine and norepinephrine. There are two classes of receptors that respond to these signals: alpha receptors and beta receptors.

Alpha receptors are located primarily on the surface of smooth muscle cells in blood vessels. Activation of these receptors leads to constriction of the peripheral blood vessels. Beta receptors are located in the heart, liver and skeletal muscles.



42/72

Autonomic Nervous System Integration

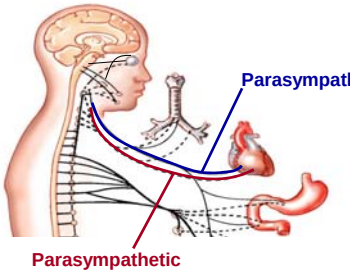


43/72

Dual Innervation

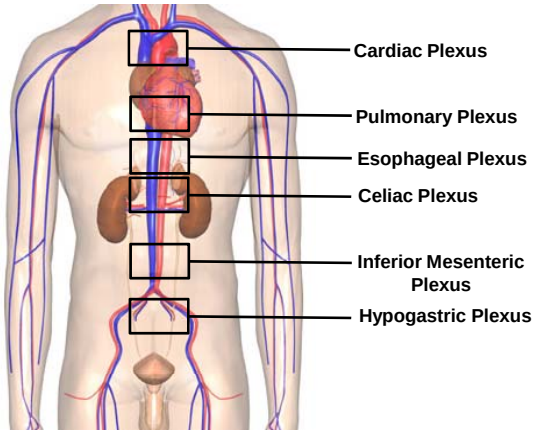
The sympathetic and parasympathetic divisions oppose each other but in a complementary fashion. Most of the major organs of the body receive projections from the sympathetic and parasympathetic divisions, known as dual innervation.

Each system is “on” or active when needed and, at the same time, will inhibit or shut down the opposing system.



44/72

Autonomic Plexuses - 1



Within the abdominopelvic cavities, both the parasympathetic and sympathetic fibers mix in special plexuses: cardiac, pulmonary, esophagus, celiac, inferior mesenteric and the hypogastric plexus.

45/72

Clinical Challenge: Exam Question

A 45-year-old male is diagnosed with an autoimmune disease that specifically targets the adrenal medulla in his adrenal glands. Which of the following symptoms are possible?

A. The outer portion of the adrenal glands is the adrenal medulla, which is targeted by this patient's disease.

B. Epinephrine secretion would be affected by this patient's disease.

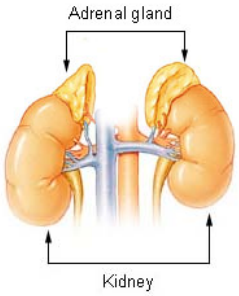
C. Epinephrine secretion would not be affected in this patient's disease because it is secreted from the adrenal cortex.

D. A and B are correct.

E. Only answer C is correct.

46/72

Clinical Challenge: Exam Answer



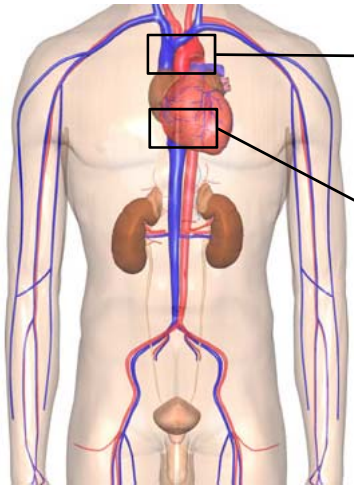
The adrenal medulla makes up the center of the adrenal gland. It produces the following hormones:
(A) Epinephrine – is a fight-or-flight hormone. When it is secreted, it prepares the body for action by increasing heart rate and delivering more blood to skeletal muscles.
(B) Norepinephrine – is both a hormone and neurotransmitter. As a hormone, it acts synergistically with epinephrine and also increases blood pressure by vasoconstriction.

This question tests your knowledge of the adrenal gland, including the hormones and neurotransmitter it secretes, as part of autonomic function. The correct answer is:

B) Epinephrine secretion would be affected by this patient's disease.

47/72

Autonomic Plexuses: Thoracic Cavity

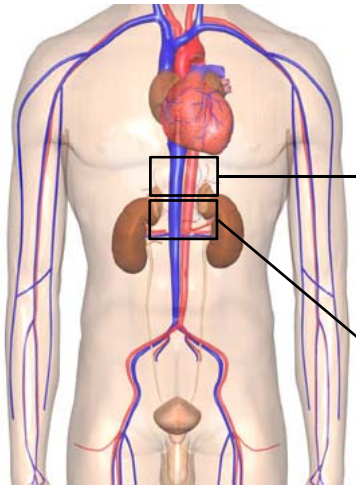


The cardiac plexus is located near the arch of the aorta. This plexus contains both sympathetic and parasympathetic fibers. The autonomic fibers that enter the thoracic cavity intersect at the cardiac plexus and the pulmonary plexus.

The pulmonary plexus is located at the level of the heart. It also contains both sympathetic and parasympathetic fibers.

48/72

Autonomic Plexuses - 2

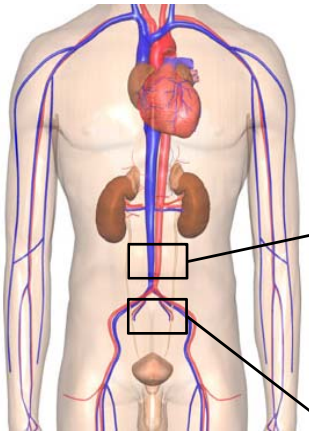


The **esophageal plexus** is located just above the diaphragm, at the esophageal hiatus in the diaphragm where it passes through to the abdominal cavity. This plexus contains descending branches of the vagus nerve and the splanchnic nerve.

The parasympathetic preganglionic fibers of the vagus nerve follow the path of the esophagus into the abdominal cavity to arrive at the **celiac plexus**. The celiac plexus is also known as the solar plexus.

49/72

Autonomic Plexuses - 3



The **inferior mesenteric plexus** is associated with the celiac plexus. This plexus is located adjacent to the inferior mesenteric artery at approximately the L3 vertebral level. From this plexus, the innervation for the viscera down to the initial segments of the large intestine extends.

The **hypogastric plexus** is located at the level of the wings of the ilium bones of the hip. Located within the hypogastric plexus is the parasympathetic outflow of the pelvic nerves, along with the sympathetic postganglionic fibers, sacral splanchnic nerves, and the sympathetic chain.

50/72

Parasympathetic vs. Sympathetic

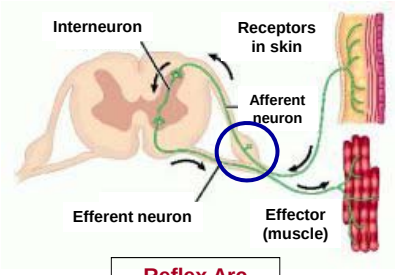
The parasympathetic division arises in the craniosacral areas. Unlike the sympathetic division, the parasympathetic division has a long pre-ganglion neuron that synapses upon a short post-ganglion neuron.

This post-ganglion neuron releases the neurotransmitter, acetylcholine, which brings about the responses associated with the parasympathetic division, such as a decrease in heart rate.

Pre-ganglion neurons in the sympathetic division are short. In fact, they synapse with the post-ganglion neurons in a region very close to the spine, known as the sympathetic chain.

51/72

Visceral Reflexes



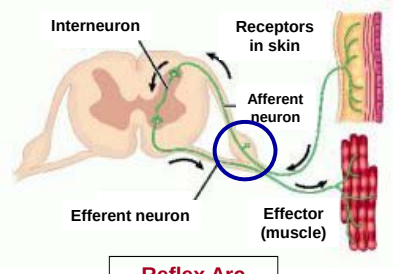
Reflex Arc

The visceral reflexes of the body allow for fast, automatic responses, which can be modified by signals from the brain. A visceral reflex arc is made up of the sensory neuron that delivers the sensory information from the peripheral receptor to the central nervous system. The outflow of the visceral reflex arc is made up of a preganglionic and ganglionic neuron.

Visceral reflexes can be divided into: (1) short reflexes, which do not involve the central nervous system at all and the interneurons are located in the autonomic ganglia, and (2) long reflexes, which involve an interneuron located in the central nervous system and involve multiple synapses.

52/72

Anatomy of Visceral Reflexes

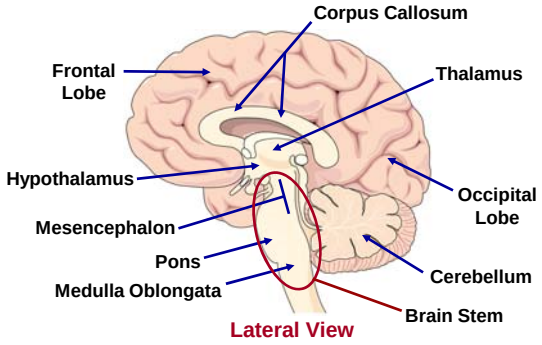


Reflex Arc

The visceral reflex is made up of the following:
(1) Receptor – Activation of the receptor: the end of a sensory dendrite that detects a change in temperature or senses pain.
(2) Afferent Neuron – the action potential passes the impulse from the receptor, along the afferent fiber, to the central nervous system.
(3) Interneuron processing – for a long reflex, this takes place in the central nervous system. For a short reflex, the interneuron is located within the ganglion.
(4) Visceral ganglionic neuron – transmits the motor impulse to the effector.
(5) Visceral effector – is the response of the effector, such as a muscle.

53/72

Control of the Autonomic Division: Overview



Lateral View

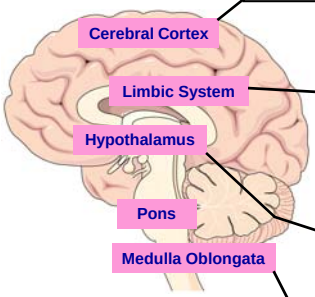
Centers in the brain stem control the parasympathetic and sympathetic nerve fibers. Within the brain stem are processing centers for the autonomic nervous system. The processing centers in the brain stem are in communication with the control center in the hypothalamus.

The control of the autonomic nervous system can be divided as follows: (1) sympathetic division is controlled from the posterior and lateral hypothalamus, and (2) the parasympathetic division is controlled from portions of the anterior and medial hypothalamus. The functions of the autonomic nervous system can be impacted by the cerebral cortex, and the limbic system through emotions.

54/72

Higher Levels of Autonomic Control

The cerebral cortex communicates at a subconscious level with both the hypothalamus and the pons, and it can dramatically influence the autonomic nervous system.



Lateral View

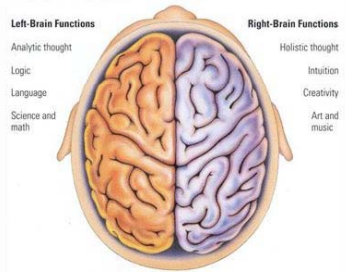
The limbic system inputs the emotional state into the autonomic nervous system. Anger or fear directly impact the action of the sympathetic division.

The hypothalamus is the control center for both the parasympathetic and sympathetic divisions of the autonomic nervous system.

The medulla oblongata contains centers, such as the cardiac and respiratory centers. These act as processing centers for both parasympathetic and sympathetic complex visceral reflexes.

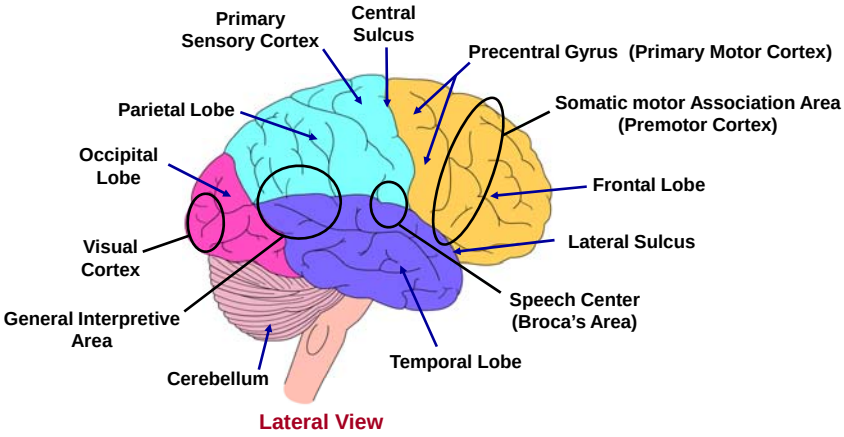
55/72

Higher-Order Functions: Learning and Memory



56/72

Specialized Regions and Centers of the Cerebral Cortex - 1



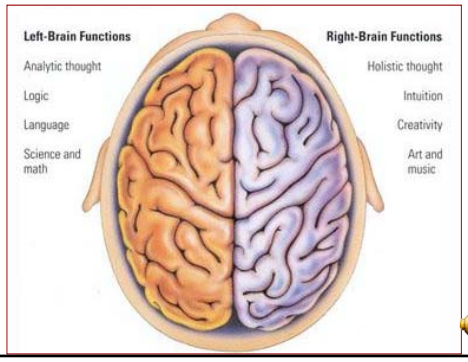
Lateral View

The cerebral cortex performs a number of higher-order functions; these require the action and communication of certain specialized regions in the brain. The specialized centers and regions that perform these are the: (1) general interpretive area, (2) visual cortex, (3) auditory cortex, (4) speech center, (5) primary motor cortex, (6) premotor cortex, and (7) primary sensory cortex.

57/72

Specialized Regions and Centers of the Cerebral Cortex – 2

Key centers within the cerebral cortex include:
(1) general interpretive area – information from the sensory association areas flows to this specialized brain center. This center is vital to interpreting words that are read and heard.
(2) speech center – this is also known as Broca's area. This functions as the motor center for breathing and vocalization patterns required to produce speech.
(3) prefrontal cortex – has been reported to be the most complex brain area. This area is responsible for complex learning and reasoning. It communicates with the limbic system to contribute to emotional context.

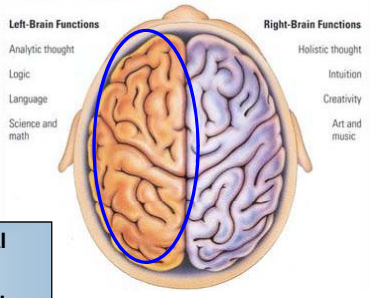


58/72

Brain Hemisphere Lateralization: Speech

Higher-order functions in the brain can be localized to one of the cerebral hemispheres; an example is the lateralization of speech. It has been estimated that approximately 70% of individuals have speech lateralized to the left hemisphere. The left hemisphere contains both Broca's and Wernicke's area, both of which are involved in speech. Evidence for this has come from anatomical and functional imaging studies.

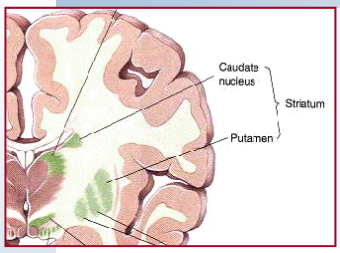
It has been estimated that in 90-95% of right-handed men and women, both handedness and speech are lateralized to the left hemisphere. In individuals who are left-handed, there is 60-70% left hemisphere dominance in spoken language.



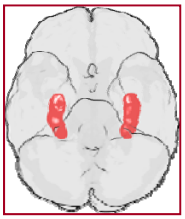
Broca's area and Wernicke's area share neural information. It is reported that the Wernicke's area interprets written or spoken words. Then, this information is projected to Broca's area. From Broca's area, projections to the primary motor cortex result in the words we speak in response.

59/72

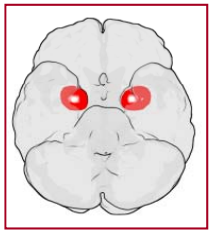
Memory Regions of the Brain



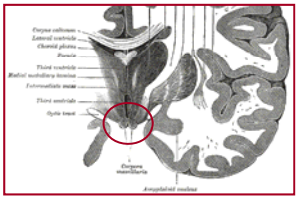
The Striatum



The Hippocampus



The Amygdala



The Mammillary Bodies

The brain regions that have been studied and attributed to the involvement of memory in the human brain include:

60/72

Short -Term memory

Based on experiments designed to test recall of information, the most effective short-term recall occurs with information or words in groups of 7±2. This is known as “chunking”.

For example, a definition in biology is more accurately recalled in short-term memory when groups of 5-7 words are memorized at once, as opposed to memorizing 2-3 sentences at once.

Short-term memory allows the recall of information for a few minutes or up to an hour or more. There is evidence to suggest that short-term memory involves changes in electrochemical events, as opposed to structural changes in the brain.

61/72

Long -Term memory

Long-term memory provides recall of information for years. The hippocampus region of the brain is required for both learning and the conversion of information from short-term memory to long-term memory. Structural changes in the brain, as part of long-term memory, are further supported by the fact that most amnesia patients have some loss of recent events but retain lifelong memories.

The Hippocampus

There are a number of models of learning; one example is the Multi-store model. In this model of memory, the repetition of learned information or tasks transfers it to long-term memory. Experiments on long-term memory have revealed the fact that there are likely structural changes in the brain, such as: Long-term potentiation, increase in the numbers of synaptic end bulbs, and an increase in neuronal branching patterns.

62/72

Clinical Note: Amnesia

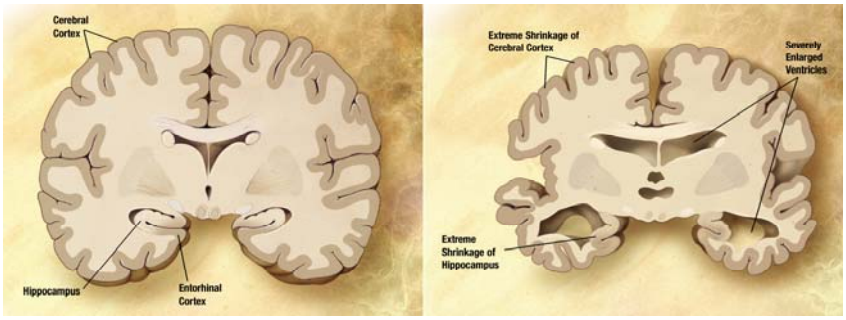
The Hippocampus

Amnesia is a condition in which there is a loss of memory caused by trauma to the brain or diseases of the central nervous system. Depending on which portion of the brain is affected, the memory loss can vary from short and long-term memories to difficulty in the memory of sounds if the auditory association areas are affected.

Amnesia can be classified as either retrograde amnesia in which lost memories involve past events, or anterograde amnesia in which the individual cannot store new memories. Post-traumatic amnesia can involve both retrograde and anterograde amnesia; its severity and duration depend on the severity of the initial injury.

63/72

Clinical Note: Alzheimer's Disease



Alzheimer's disease is a neurologic disorder that is characterized by a progressive loss of higher-order functions, including memory. This disease typically affects individuals in the age range of 50-65 years, although it can occur earlier. There are an estimated 2 million Americans with Alzheimer's disease in the United States.

The presence of abnormal plaques and neurofibrillary tangles have been reported to be involved in Alzheimer's disease, although it is still unclear whether their presence causes this disease or is a symptom of this disease. The treatment of Alzheimer's disease is supportive, with the use of acetylcholinesterase inhibitors and NMDA receptor antagonist aimed at slowing progression of the disease.

64/72

Diseases and Conditions of the Brain

Some examples of diseases and conditions that affect the brain are:
(1) Senility – also known as dementia; this is characterized by a loss of cognitive abilities beyond what's expected for the normal effects of aging.
(2) Alzheimer's disease - a degenerative terminal disease that is the most common form of dementia. This disease includes the formation of amyloid plaques and neurofibrillary tangles outside and around neurons in the brain.

(3) Cerebral Palsy – It is a motor condition that causes developmental problems and disability. The cerebrum is the area of the brain affected by this condition. Complications with intrauterine development contributes to the cause of cerebral palsy.
(4) Epilepsy – It is characterized by recurrent seizures. There are many types of epilepsy with different types of seizures. Anti-seizure medication can control and reduce the frequency of seizures in most patients.

65/72

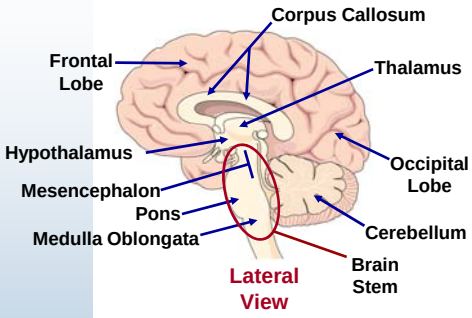
Clinical Challenge: Exam Question

The autonomic nervous system is controlled by centers in the brain, which communicate and are influenced by different brain regions. Which of the follow statements about the control of the autonomic nervous system is correct?

A. The pons is the master control center for the autonomic nervous system.
B. The cerebral cortex has no influence on the autonomic nervous system.
C. The sympathetic division of the autonomic nervous system is controlled by the posterior portion of the thalamus.
D. The parasympathetic division is controlled from portions of the anterior and medial hypothalamus.
E. The limbic system has no role in the control of or influence of the autonomic nervous system.

66/72

Clinical Challenge: Exam Answer



Centers in the brain stem control the parasympathetic and sympathetic nerve fibers. Within the brain stem are processing centers for the autonomic nervous system. The processing centers in the brain stem are in communication with the control center in the hypothalamus.

The functions of the autonomic nervous system can be impacted by the cerebral cortex, and the limbic system through emotions.

This question tests your knowledge of the control and integration of the autonomic nervous system. The correct answer for this question is:

D) The parasympathetic division is controlled from portions of the anterior and medial hypothalamus.

67/72

Clinical Terms: The Autonomic Nervous System - 1

- **Smooth Muscle – located in the bronchioles and blood vessels, are targeted by the ANS.**
- **Cholinergic – Related to the neurotransmitter, acetylcholine. It is a substance that leads to the release of acetylcholine.**
- **Pilocarpine – a parasympathomimetic alkaloid that can be used to treat certain glaucoma cases and as an antidote for atropine poisoning.**
- **Ganglion – Mass of nerve cell bodies that can either be a dorsal root ganglia or a autonomic ganglia.**

68/72

Clinical Terms: The Autonomic Nervous System - 2

- **Pupillary Light Reflex** – A visceral reflex test used to assess brain stem function.
- **Long Reflexes** – Polysynaptic reflexes that include central nervous system processing.
- **Short Reflexes** – A visceral reflex that involves an interneuron located in autonomic ganglia.
- **Autonomic Plexus** – Parasympathetic and sympathetic fibers mingle at a series of plexuses in the autonomic nervous system.

69/72

Learning Summary

The parasympathetic nervous system is known as the "Rest and Digest" system. It functions by decreasing the heart rate, increasing glandular activity, and increasing intestinal activity for digestion and absorption.

The physiological actions of the human body, such as heart rate, occur with little or no conscious thought. These involuntary actions that maintain homeostasis within the body are performed by the **autonomic nervous system.**

The sympathetic branch is known as the "Fight or Flight" response and becomes more active during stress. When activated, the sympathetic nervous system acts primarily on the cardiovascular system through epinephrine and norepinephrine.

Most of the major organs of the body receive projections from the sympathetic and parasympathetic divisions, known as dual innervation. Each system is "on" or active when needed and, at the same time, will inhibit or shut down the opposing system.

70/72

Congratulations

You have successfully completed the core tutorial

The Autonomic Nervous System

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71/72

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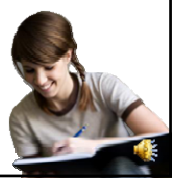
What's Next …

Step 1: Concepts – Core Tutorial (Just Completed)

→ **Step 2: Practice – Interactive Problem Drill**

Step 3: Recap – Super Review Cheat Sheet

Go for it!



72/72

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