Online Physiology 2130 – Nervous System

Introduction

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Thank you for opening this resource for Physiology 2130, and welcome. This resource has been created by the Education Team at WebStraw. The Education Team consists of students that have previously taken and/or students that are currently taking Physiology 2130.

Purpose

This resource focuses on key concepts that are important for students to understand to succeed within this course. This resource was created by students for other students. Our goal is to help students (1) further develop their understanding of course content and (2) achieve greater academic success. (3) Our resource is also open access meaning there are no financial or legal barriers to students who wish to access and use our resource.

Instructions

These study resources consists of several parts. The first part includes a condensed review of the major takeaways from each physiology module. This is followed by a series of questions and fill in the blank worksheets that should be completed after you have gone through the module and course material, in order to verify your understanding.

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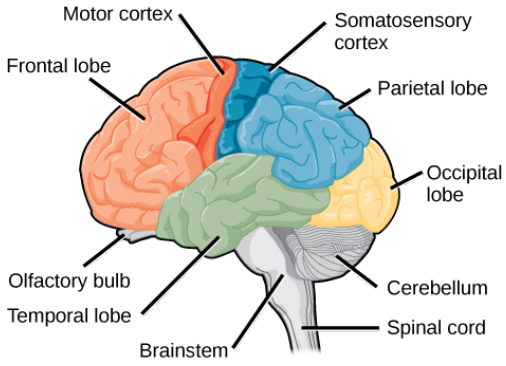
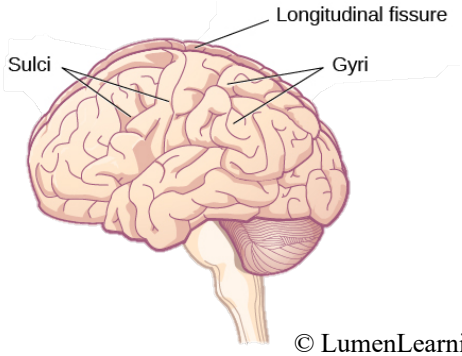
We wish you the best of luck on your exams!
The WebStraw Team

Note to Instructors: If this resource has been created for your course and you would like to collaborate with us, please email us at team@webstraw.ca

Module 6 – Nervous System

Human Brain





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Neurotransmitters (NTs)

Four types of NTs classified according to their chemical makeup:

- **Acetylcholine (ACh)**
- **Biogenic Amines**
  - Catecholamines
    - Dopamine
    - Norepinephrine
    - Epinephrine
- Amino Acids
  - Excitatory Amino Acids
    - Glutamate*
    - Aspartate
  - Inhibitory Amino Acids
    - Gamma-ammino-butyric acid (GABA)*
    - Glycine
- **Neuropeptides**
  - Endogenous opioids
  - Vasoactive Intestinal Peptide (VIP)

Excitatory NTs excite or "turn on" a neuron and Inhibitory NTs "shut off" the nerve cell.

* = most common

Types of Brain Cells

1. **Neurons**

   Bipolar Neurons
   - Two processes extending from cell body. Found in retina of the eye

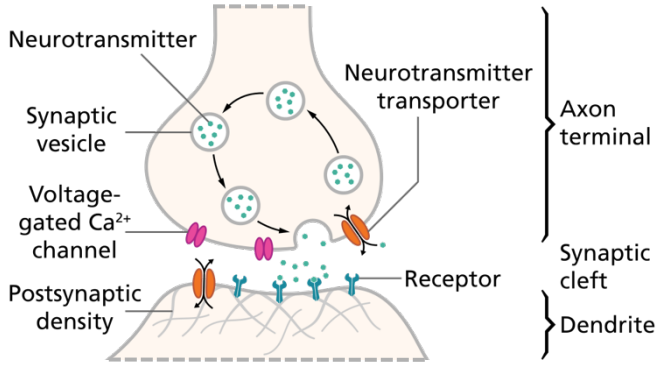
   Unipolar Neurons
   - One process extending from cell's body. Located in peripheral nerves outside of the CNS and sensory in nature. Cell body lies off to one side of the axon

   Multipolar Neurons
   - Contain many branching dendrites and one axon. Most common in the CNS.

2. **Glial Cells**

   "Support" cells of the brain: maintain delicate internal environment of the CNS
   - Roughly 5X more glial cells than neurons
   - Regulate passage of substances b/w blood and the brain's interstitial space
   - Several types: astrocytes, microglia, and oligodendrocytes.

Chemical Synapse



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1. Presynaptic neurons synthesize NT's that are stored in synaptic vesicles
2. AP in presynaptic neuron depolarizes membrane, activating voltage-gated Ca^{2+} channels, causing Ca^{2+} to flow into axon terminal
3. Ca^{2+} causes synaptic vesicles to fuse to the wall of the synaptic terminal, leading to exocytosis and release of the NT
4. NT diffuses across synaptic cleft and acts on chemical receptors found on postsynaptic cell membrane
5. Receptors cause the opening of chemically gated ion channels
6. Postsynaptic membrane potential changes, causing a depolarization or hyperpolarization depending on the NT

Ionic Basis of Postsynaptic Potentials

Excitatory Postsynaptic Potentials (EPSPs)

- Excitatory NT causes opening of chemically gated channels selective for only (+) ions
- Influx of predominantly Na^+ ions into the cell causes *local depolarization* of the membrane
- Diminishes w/time and distance from point of origin and called a *graded* potential
- EPSP needs to depolarize axon hillock to generate AP

Inhibitory Postsynaptic Potentials (IPSPs)

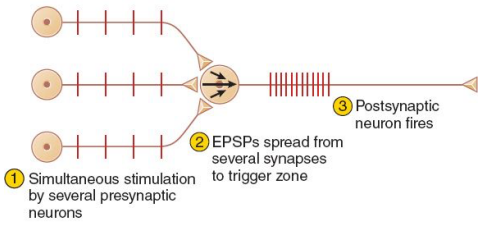
- Causes opening of chemically gated channels & varies depending on type of NT
- Either Cl^- let into the cell or K^+ let out of cell
- Leads to hyperpolarization of membrane, making it less likely to fire an AP

Spatial and Temporal Summation

Can be used to increase the strength of an EPSP (or IPSP)

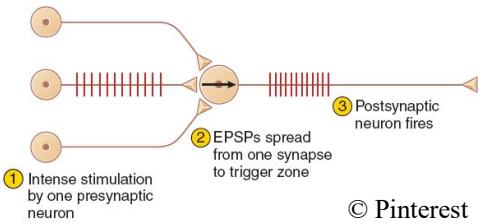
Spatial Summation

- When EPSPs/IPSPs occurring simultaneously at different points along the postsynaptic neuron combine to cause an AP



Temporal Summation

- When multiple EPSPs/IPSPs from one presynaptic neuron occur close enough in time to combine and trigger an AP on the postsynaptic neuron



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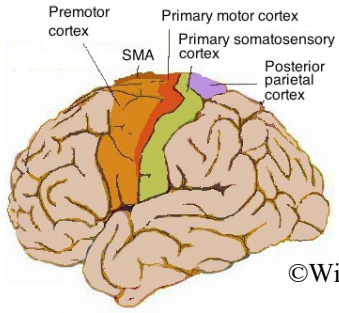
Motor Cortex

Region of the cerebral cortex responsible for the planning, control, and execution of voluntary movements. Allows the brain to discern the position of our muscles and limbs in space.

Arrangement of Motor System



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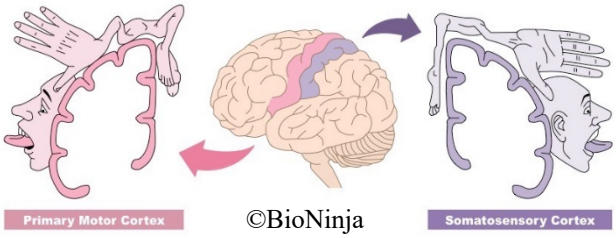
- Primary motor cortex located on the precentral gyrus in the frontal lobe
- Arrange in very specific manner: motor homunculus (topographical representation of body)
- A specific area of the motor cortex activates a particular muscle



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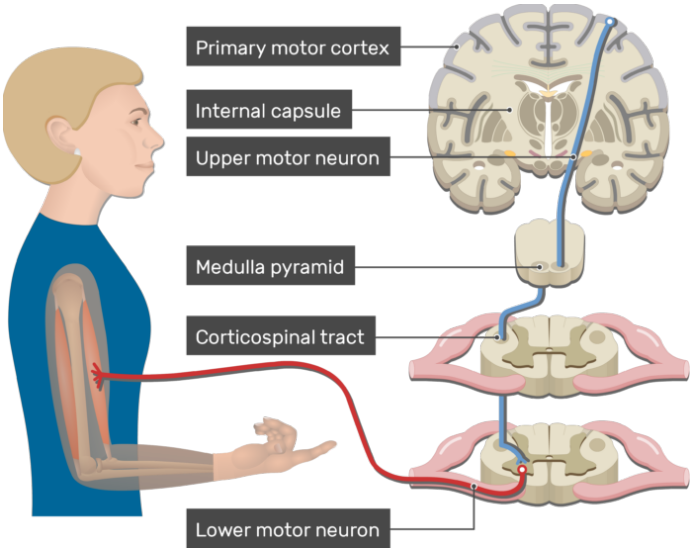
Corticospinal Tract

- The major motor pathway from the primary motor cortex to the motor neurons that innervate the muscle cells
- 80% of nerve fibers cross to the contralateral (opposite) side of the body in the medulla of the brain stem while the other 20% remain on the ipsilateral (same) side of the body until the very end (synapse) before crossing over



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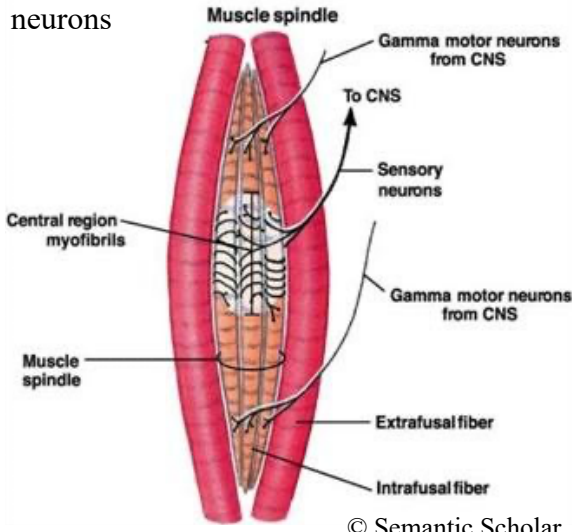
Muscle Spindle

- Found inside a whole muscle and adjacent to extrafusal fibers
- Detect length and stretch of a muscle
- Consists of intrafusal muscle fibers, central sensory region, two sets of gamma motor neurons



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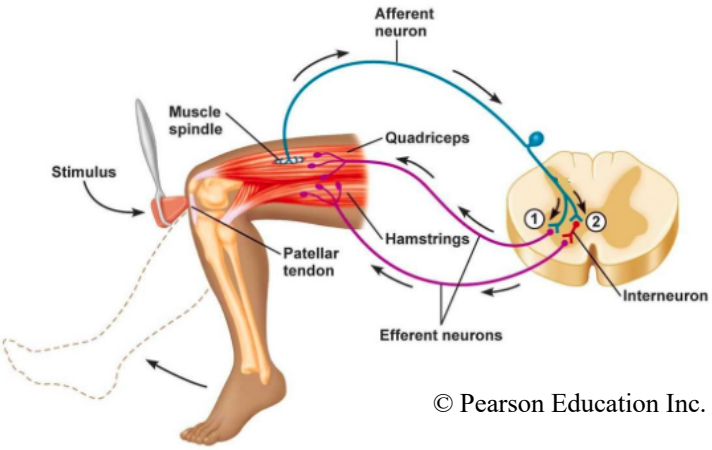
Alpha-Gamma Coactivation

- Signal sent through alpha motor neurons to extrafusal muscle fibers
- Commands sent simultaneously through gamma motor neurons causing intrafusal fibers to contract at the same rate as the whole muscle
- Ensures that muscle spindles continue to send information to the brain about muscle and limb position during muscle contraction (proprioception)

Reflex Arc (Stretch Reflex)

Example of a stretch (tendon tap) reflex – the quadriceps muscle

1. Tapping on the knee causes small stretch of the quadriceps muscle and muscle spindles attached
2. Muscle spindles send action potentials in the afferent neuron to the spinal cord
3. Signal sent back through the efferent neuron and activates the motor nerve of the quadriceps and inhibits hamstring muscles
4. The hamstrings are at rest, but the quadriceps contracts and the lower leg kicks out



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Functions of the Cerebellum

- Contributes to the generation of accurate limb movements
- Corrects ongoing movements
- Modifies the strength of some reflexes

Behaviours Influenced by the Limbic System

1. Eating
2. Drinking
3. Locomotion
4. Autonomic responses (changes to heart rate & blood pressure)
5. Attack responses
6. Sexual behaviours
7. Memory

Functions of the Hypothalamus

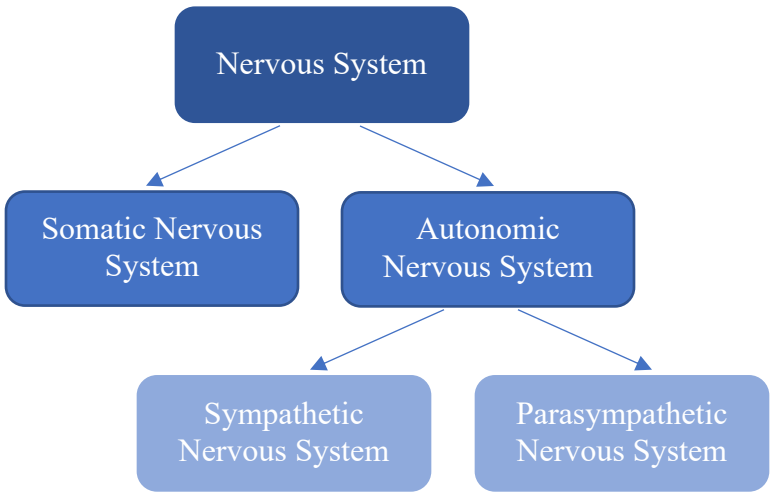
1. Temperature control
2. Body water regulation
3. Regulation of food intake
4. Cardiovascular regulation
5. Regulation of the circadian clock
6. Coordination of emotional behaviours
7. Control of hormones released from the anterior & posterior pituitary gland

Autonomic Nervous System

- Is not under voluntary control
- Divided into sympathetic (SYN) and parasympathetic (PSYN) nervous systems
- SYN: activates body functions needed for *fight or flight* situations
    - Increase heart rate and blood pressure
    - Dilate airways and blood vessels to muscles
    - Shuts down digestive system
- PSYN: responsible for storage and conservation of energy. Associated with *rest and digest*
    - Decreases heart rate and blood pressure

Pathways of the Autonomic Nervous System

- Nerves of the SYN exit the spinal cord in the thoracic and lumbar (central) regions of the cord
    - The preganglionic neurons synapse in ganglia onto a second, postganglionic nerve that travel to the effector/organ of interest
- Nerves of the PSYN exit at the brain stem and lower sacral region of the spinal cord
    - The preganglionic nerves synapse onto a postganglionic nerve close to the effector/organ of interest, which will then synapse onto the target organ



Neurotransmitters

SYN

ACh **NE**

Short preganglionic neuron

Long postganglionic neuron **(ACh released in some cases)**

PSYN

ACh **ACh**

Long preganglionic neuron

Short postganglionic neuron (near target organ)

Mneumonic:

To remember that PNS efferents exit the spinal cord at the brain stem and lower sacral region, think "***para***" means "***beside***". Parasympathetic efferents exit in the regions ***beside*** where the sympathetic efferents exit (which is in the middle of the spine). This also works for the location of the synapse onto the post-ganglionic neuron. For the PNS, the pre-ganglionic neuron synapses ***beside*** (closer to) the target organ.

Functions of the ANS

	SYN Response	**PSYN Response**
Adipose (fat) tissue	Stimulates lipolysis (fat breakdown)	No effect
Adrenal glands	Increased adrenaline and cardiac output	No effect
Lungs	Dilates bronchioles	Constricts bronchioles
Salivary glands	Thick mucus → Dry mouth	Watery saliva
Pupils	Dilates	Constricts
Heart	Increases heart rate & force of contraction	Slows heart rate
Kidney	Increased secretion of renin to increase blood pressure	No effect
Bladder	Retention of urine	Release urine
Digestive system	Increased activity of digestive tract	Decreased activity of digestive tract
Blood vessels, arterioles, veins	Constriction in non-exercising organs and dilation in skeletal and cardiac muscle (the working muscles)	No effect

Review Questions

1. Which of the following is a FALSE statement regarding glial cells?
    a. There are many more glial cells than neurons
    b. There are several different types
    c. They regulate the environment of the brain
    d. They are involved in processing sensory information

2. Which of the following is correct concerning cells found in the brain?
    a. The majority of the brain is made up of nerve cells (neurons)
    b. Glial cells make up roughly 90% of the brain
    c. Neurons can be divided into astrocytes, unipolar nerves and multipolar nerves
    d. In the central nervous system (CNS) myelin is produced by astrocytes

3. A patient fell backward off a ladder and hit the back of her head, damaging the occipital lobe. Which of the following symptoms might you expect due to the damage to her occipital lobe?
    a. Loss of hearing
    b. Loss of smell
    c. Loss of Vision
    d. Difficulty staying warm

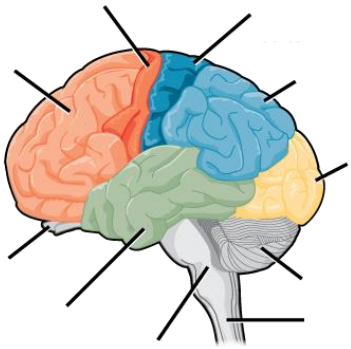
4. Which of the following statements concerning the functions of the autonomic nervous system is TRUE?
    a. Fat is broken down in adipose tissue during a SYN response
    b. The pupil constricts during a SYN response
    c. Urine is retained during a PSYN response
    d. Bronchioles are dilated in a PSYN response

5. The gamma motor neuron system:
    a. Is activated by the ventral corticospinal tract
    b. Causes intrafusal muscle fibers to contract
    c. Is not involved in proprioception
    d. Causes extrafusal muscle fiber to contract

6. Which of the functions would be affected if the cerebellum were inhibited?
    a. Body temperature regulation
    b. Pupil dilation
    c. Blood pressure
    d. Correction of ongoing limb movements

Answer Key:
1. D 2. B 3. C 4. A 5. B 6. D

Label the Brain



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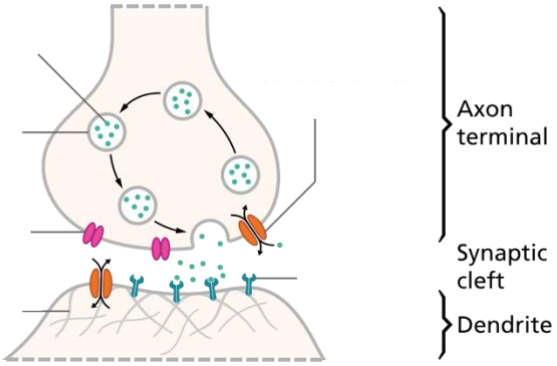
Label the Chemical Synapse



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Fill in the Blanks

	SYN Response	PSYN Response
Adipose (fat) tissue	Stimulates lipolysis (fat breakdown)	
Adrenal glands	Increased _____ and _____	No effect
Lungs	___ bronchioles	___ bronchioles
Salivary glands	Thick mucus → Dry mouth	
Pupils	Dilates	
Heart	Increases heart rate & force of contraction	
Kidney	Increased _____ to increase blood pressure	No effect
Bladder		Release urine
Digestive system	Increased activity of digestive tract	
Blood vessels, arterioles, veins	Constriction in _____ and dilation in _____ and _____	

Fill in the Blanks

	SNS	PNS
Origin of efferents		
Location of synapse onto post-ganglionic neuron	_____ target organ	_____ target organ
Length of pre-ganglionic neurons		
Length of post-ganglionic neurons		

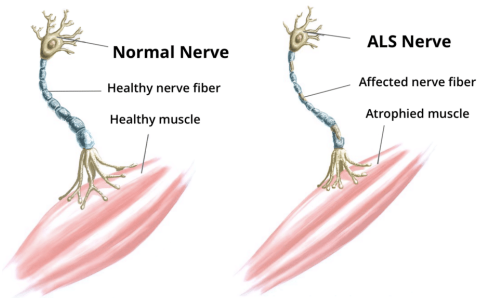
Conceptual Question

1. Think about the consequences of an anti-adrenergic drug and its effects on the nervous system. Which branch of the autonomic nervous system would be affected and in what way? Would both preganglionic and postganglionic neurons be affected?

Real Life Applications

Amyotrophic lateral sclerosis (ALS)

- Progressive deterioration of nerve cells in the brain and spinal column
  - Control muscles and allow movement
- Causes increasing muscle weakness, problems with breathing, swallowing, and speaking
- The cause of ALS is unknown and there is no cure
- Treatment aims to help keep your strength (e.g. physiotherapy, supportive devices for daily tasks)



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