Shayna Goodman

Nervous System Final

Nervous Tissue- old material, overview of nerve cells

A. **Neuroglia**-support, protect, and nourish neurons, hold brain tog
    1. Do not conduct nerve impulses = **action potentials**
B. **Neurons**- dendrite(s), cell body, and axon
    1. Conduct **action potentials**
        a. electrochemical waves that propogate (self-generate) along neurons
        b. uni-directional flow
    2. 3 types of neurons
        a. **unipolar**- one projection-splits into dendrite and axon
            1.most abundant of **sensory neurons**
        b. **bipolar**- 2 projections-axon and dendrite
            1. associated with **special senses**
        c. **multipolar**- many dendrites
            1. association neurons=**interneurons**
            2. most abundant of **motor neurons**

Neuroglial Cells

A. Functions:
    1) support neurons
    2) protect neurons
    3) nourish neurons
    4) act as phagocytes- eat debris
    5) circulate CSF
    6) secretes CSF
B. Not all types of glial cells do all functions
C. They do **not** send action potentials
D. 4 types of neuroglial cells in **CNS**
    1) **astrocytes**
        a) most abundant of glial cells
        b) star-shaped
        c) connect neurons to capillaries
        d) feed neurons- deliver nutrients
    2) **oligodendrocytes**
        a) produce myelin sheath that surrounds certain neurons in the CNS
        b) oligodendrocytes grow around axons or dendrites of a cell
            1) myelin is a phospholipid, white in color
        c) cells w/ oligodendrocytes are myelinated, w/o = unmyelinated

3) **microglia**
a) small cells
b) found b/t neurons and along blood vessels
c) phagocytes- act as macrophages
d) increase when there's tissue damage
1) ex-concussion- blood enters CSF, nerve cells die, microglia clean out interstitial space

4) **ependymal cells**
a) ciliated cells lining ventricles of brain and central canal of spinal cord
b) found around **choroid plexus** (cluster of capillaries) of lateral and 3rd ventricles to help secrete CSF
c) ciliated ependymal cells helps circulate CSF through 4th ventricle (CSF is returned to bloodstream in 4th ventricle and **sagittal sinus**- no net loss or gain)

E. 2 types of neuroglial cells in **PNS**
1) **satellite cells/ capsule cells**
a) form capsules around cell bodies in ganglia to separate them (ganglia = group of nerve cell bodies found outside CNS)
b) capsules separate cell bodies from connective tissue

2) **neurolemmocytes**
a) produce myelin sheath in PNS

Nervous System Nerves

Central nervous system - brain and spinal cord (central=along midline)
Neural tube forms 3 ventricle brain and spinal cord with central canal.
3 ventricle brain forms 5 ventricle brain.
1) **Forebrain/prosencephalon**—>a) **telencephalon—> cerebrum**
b) **diencephalon—> thalamus, hypothalamus, epithalamus**

2) **Midbrain/mesencephalon—> mesencephalon—> midbrain**

3) **Hindbrain/rhombencephalon**—>a) **metencephalon—>** anterior**-Pons,** posterior**-cerebellum**
b) **myelencephalon—> medulla oblongata**

Peripheral nervous system
Cranial nerves- grow out of brain- 12 bilateral pairs
Spinal nerves- grow out of spinal cord- 31 bilateral pairs
CNS and PNS-ways to describe nervous system based on position

Shayna Goodman

How do cranial nerves get out of skull?

Cranial Nerve	Ventricle of Brain	Name of Nerve	Sensory, Motor, or Mixed	Function	Skull Exit
I	Telencephalon	Olfactory nerve	special sensory	smell (nose to brain)	Nasal foramena of cribriform plate of the ethmoid
II	Diencephalon	Optic nerve	special sensory	vision	Optic foramen
III	Mesencephalon	Occulomotor nerve	mixed	**Motor**-innervates intrinsic and 4/6 extrinsic eye muscles (superior, medial, and inferior rectus and inferior oblique). Leaves midbrain to go to muscles. (Contols movement of eye muscles, not what we see. Intrinsic-ex: iris, muscles of lens) **Sensory**-propioception-muscle tells you how contracted it is, enters midbrain from muscles receiving stimulation.	Superior orbital fissure
IV	Mesencephalon	Trochlea nerve	mixed	**Motor**-to 1/6 extrinsic eye muscles (superior oblique) **Sensory**-propioception	Superior orbital fissure

V	B/t mes and metencephalon	Trigeminal nerve a) superior = **opthalamic** branch	general sensory	Touch, temp, pressure, propioception. Found from upper eyelid to top of skull	Superior orbital fissure
		b) middle = **maxillary** branch	general sensory	Found from lower eyelid to upper lip and branches innervate upper teeth and roof of mouth=hard palate.	Foramen rotundum
		c) inferior = **mandibular** branch	mixed-general sensory and motor	**General sensory**- lower lip to upper chin, including lower teeth. **Motor**- to muscles of mastication (can raise jaw)	Foramen ovale
VI	Metencephalon	Abducens nerve	mixed	**Motor**-to 1/6 extrinsic eye muscles (lateral rectus) **Sensory**- propioception	Superior orbital fissure
VII	Metencephalon	Facial nerve	mixed	**Motor**- to muscles that raise and lower eyebrows, corners of eyes, corners of lips (innervates salivary glands) **Sensory**- propioception of facial muscles **Special sensory**- gustation from anterior 2/3 of tongue	enters- Internal auditory meatus, exits- stylomastoid foramen (to reach facial muscles)

VIII	Between metencephalon and myelencephalon	Auditory nerve/ Vestibulocochlear nerve	special sensory	equilibrium- (vestibule) audition- (cochlea)	enters Internal auditory meatus (stays in petrous portion to go to hearing apparatus)
IX	Myelencephalon	Glossopharyngeal nerve	mixed	Goes to tongue and throat. **Motor**- to swallowing muscles. (Innervates salivary glands) **Sensory**- propioception **Special sensory**- gustation from posterior 1/3 of tongue	Jugular canal
X	Myelencephalon	Vagus nerve	mixed	exits skull, goes down neck to chest cavity-touches e/t in between, sends nerves to stomach, heart...and ends at anus. **Motor**-to pharyngeal muscles-skeletal muscles in neck and throat. Can help modify peristalsis-ex: speed it up. Part of parasympathetic nervous system-ex: innervates heart to slow down heart rate. **Sensory**-from visceral organs-ex: sense when stomach or bladder is full **Special sensory**- gustation-innervates epiglottis for taste (most taste has to do with tongue though)	Jugular canal

XI	Myelencephalon	Accessory nerve (spinal)	mixed	comes from medulla oblongata. **Motor**- innervates neck muscles-ex: trapezius and sternocleidomastoid (upper shoulder and back muscles- turning head pulls mastoid process and muscle splits into 2 bands-1 to sternum and 1 to clavicle) **Sensory**- propioception to these muscles.	Superior branch- Jugular canal Inferior branch- Foramen magnum
XII	Myelencephalon	Hypoglossal nerve	mixed	**Motor**-to muscles of tongue **Sensory**- propioception	Hypoglossal canal

Summaries:

1) **Superior orbital fissure**
Cranial nerves III, IV, VI, and superior branch of V

2) **Jugular canal**
Cranial nerves IX, X, and superior branch of XI, internal jugular vein

3) **Foramen magnum**
medulla oblongata, meninges (dura mater, arachnoid, pia mater), inferior branch of cranial nerve XI, vertebral arteries and veins

4) **Foramen rotundum**- maxillary branch of cranial nerve V

5) **Foramen ovale**- mandibular branch of cranial nerve V

6) **Carotid canal**- internal carotid artery

7) **Hypoglossal canal**- cranial nerve XII

8) **Optic foramen**- optic nerve (cranial nerve II)

9) **Nasal foramena**- branches of cranial nerve I

10) **Crista galli**- where meninges attach

11) **Internal auditory meatus**
Cranial nerve VII and VIII

12) **Stylomastoid foramen**- Cranial nerve VII

13) **Transverse foramen**- vertebral arteries and veins

14) **External auditory meatus**- sound waves

15) **Mental foramen**- mental nerve

16) **Nasal cavity**- air

17) **Intervertebral foramen**- spinal nerves

18) **Special sense only**
Cranial nerves I, II, and VIII

19) **Special senses**
Cranial nerves I, II, VII, VIII, IX, and X

20) **Gustation**
Cranial nerves VII, IX, and X

21) **Eye muscles**
Cranial nerves III, IV, and VI

22) **Salivary Glands**
Cranial nerves VII and IX

Questions:
1) Where does medulla end?
Between cervical vertebrae 1 and 2 (atlas and axis)

2) Where does spinal cord begin?
Between cervical vertebrae 1 and 2 (atlas and axis)

3) Where does spinal cord end?
Between lumbar vertebrae 1 and 2 (L1 and L2)

4) What is **cauda equina**?
Makes up lower lumbar nerves and sacral nerves-runs through lumbar vertebrae after spinal cord ends
It ends as one nerve= **filum terminale**.

5) What is found running through atlas?
Medulla oblongata and meninges

6) What is found running through axis and the rest of cervical vertebrae and thoracic vertebrae?
Spinal cord and meninges

Spinal Cord

1) 31 pairs of spinal nerves- all sensory and motor, exit s.c. via **intervertebral foramena**
cervical, thoracic, lumbar, sacral, and coccygeal (covered by **meninges** for short distance as exit cord)
2) **central canal**- filled with CSF
3) **gray matter**- deep
    A) made up of unmyelinated axons, cells bodies, and synapses
    B) have **dorsal** and **ventral horns of gray**
4) **white matter**- superficial
    A) made up of myelinated axons
    B) have posterior, lateral, and anterior columns
        1) contain **tracts**- group of nerve cells that connect one part of CNS with another
            a) 2 types:
                1) **ascending/sensory**- begins in spinal cord and ends in brain
                2) **descending/motor**- begins in brain and ends in spinal cord
5) **roots of nerve**
    A) **dorsal root/sensory root**- where nerve enters
    B) **ventral root/ motor root**- where nerve exits
6) **sensory neuron/ afferent neuron**- unipolar, myelinated until enters gray matter via dorsal root. Cell body found in dorsal root ganglion outside spinal cord. Nervous system receives sensory info from skin (general sensory- touch, temp, pressure, propioception), tendon, muscle, or joint capsule (Pacinian-like corpuscles)
7) **association neuron/ interneuron**- lie b/t sensory and motor in gray matter. Multipolar. Cell bodies in gray matter. Unmyelinated.
8) **motor neuron/ efferent neuron**- multipolar. Myelinated *after* it enters ventral root. Cell bodies in ventral horn of gray. Goes to effector organ- muscle or gland to stimulate it. Where meets muscle = **neuro-muscular junction**. ACH is released stimulating sarcolemma of muscle cell to depolarize.
9) **neurological pathway=** sensory+association+motor neurons. Spinal cord can work automatically for reflexes- info does not need to travel to brain for processing, so can react quickly.
sensory- income
integration- analyze what comes in (if goes to brain)
motor-doing something about it
feel pain after drop hot pan.
10) **collateral branch**- lets brain know what's going on

Nerve Cells

Individual nerve cells covered by **endoneurium**. Bundled into **fasicles** which are covered with **perineurium**. Fasicles make up a nerve covered with **epineurium.**

Sensory Neurons of the Skin- handout

1) **thermoreceptor**- free nerve ending. Close to basement membrane. Thermoreceptor for **heat**. Found in papillary layer and collateral branch in reticular layer of dermis.
2) **thermoreceptor**- free nerve ending. **Cold** receptor. Positioned in reticular layer of dermis and hypodermis- lower than hot receptors.
    A) **myelin sheath** is on all nerves to send info to CNS quickly.
3) **mechanoreceptor**- something mechanical happens to cause it to send its signal. Has free nerve endings that pass into epidermis. Associated with **hair follicles**. Every hair follicle has a nerve ending, so can sense pain if pull out hair. Hair is the first line of defense. Slightest brush against someone b/f real contact is felt by hair.
4) **thermoreceptor/ nociceptor**- for **pain**. Nerve endings go parallel to basement membrane. These respond to pain and itch and chemical irritants.
5) **Merkel's ending = Merkel's cell + Merkel's disk**. **Mechanoreceptor** for **touch**- tactile sense. Found on plantar and palmar surfaces of toes and fingers.
6) **Pacinian Corpuscles**- encapsulated **mechanoreceptor**. Located on sensitive parts of body- fingers, toes, breasts, and external genitals. Respond to **pressure** and **vibrations**. Pressoreceptor/ baroreceptor. For **heavy touch.** Found in papillary layer, but mainly in reticular. Could prob be found in hypodermis.
    A) **Pacinian- like corpuscles** in organs that can be deformed by pressure- ex: 1) **joint capsules**- helps with propioception and 2) **urinary bladder**- ureter pushed against wall when bladder is full.
7) **Meissner's corpuscle**- **mechanoreceptor** for **light touch**. Numerous on plantar and palmar surfaces of fingers and toes, lips, external genitals, and papillae mammae. Some parts of body have more nerves, so they're more sensitive.
8) **Ruffini corpuscle**- spindle, nerve endings wrapped around collagen, responds when collagen is stretched, so when your skin is pinched, you know it. Know when there's **tension** in skin.
    A) **Ruffini-like corpuscles** found in tendons = **Golgi-tendon organs**. Know when tension builds up in tendons.
9) **Krause End Bulb/ Musculocutaneous corpuscle**- **mechanoreceptor** found in **mucous membranes** and **membranes of skin**. Likely encapsulated. Found in conjunctiva, mucous membrane of tongue, mucousa of mouth and pharynx, and mucousa of genitals.

Major Parts of Brain

1) **Medulla Oblongata**- myelencephalon
    A) has ascending and descending tracts
    B) responsible for vital functions
        1) blood pressure
        2) body temp
        3) respiratory rate
        4) heart rate
    C) responsible for some non-vital functions
        1) coughing
        2) sneezing
        3) swallowing
        4) yawning

D) contains nuclei (group of nerve cells responsible for a particular function) for part of CN VIII, IX, X, XI, and XII

E) 2 structural changes occur here:

1) transposition of gray and white matter

a) superior to MO- gray-superficial, white-deep

b) inferior to MO- gray-deep, white-superficial

2) some tracts cross midline here- become contralateral

2) **Pons**- anterior metencephalon

A) has ascending and descending tracts

B) contains nuclei for part of CN V, VI, VII, and part of VIII

C) connection between medulla and midbrain

D) 2 centers for respiration (while medulla sets basic rate)

1) **apneustic center**- shuts off inspiration- breathing in

2) **pneumotaxic center**- makes a smooth transition between inspiration and expiration- breathing out, facilitates expiration

3) **Cerebellum**- posterior metencephalon

A) 3 functions:

1) coordination of motor activity (not initiation)

2) equilibrium-balance

3) posture- subconscious propioception

B) (lines in cerebellum- lateral view-called vermis, from medial view = arbor vitae)

4) **Midbrain**- mesencephalon

A) has ascending and descending tracts

B) has nuclei for cranial nerves III, IV, and part of V

C) responsible for eye motion

D) 2 reflex centers in midbrain:

1) **superior colliculi**

a) visual startle response

b) activates eye muscles to focus on stimulus

2) **inferior colliculi**

a) auditory startle response

b) activates neck and head muscles to turn to stimulus

midbrain+Pons+medulla = **brain stem**

5) **Thalamus**- diencephalon (CN II)

A) relay station for all senses except smell (all senses must pass through thalamus to get to cerebrum except smell b/c olfactory nerve goes to cerebrum directly- primary sense)

B) decides what info to send to cerebrum for interpretation

1) example- feel temp, pressure, and weight of shoe when put it on, but don't have to remind yourself minute by minute b/c sensations remain in subconscious. Only feel s/t when situation changes like shoes heat up. Impt stuff can be filtered out to brain.)

C) helps with interpretation of pain, temp, light touch, and memory.

D) signals that stay in thalamus- subconscious, those that go to cerebrum- conscious

6) **Hypothalamus**

A) connected to pituitary and controls its secretions

1) secretes ADH and oxytocin which is sent to posterior pituitary until hypothalamus sends signal to release it

2) secretes 7 inhibiting factors and 7 releasing factors that control the release of anterior pitutitary's hormones

B) receives sensory info from viscera- ex-sense when stomach is full

C) rage and aggression

D) controls body temp

E) hunger and thirst center

1) has **osmoreceptors**

a) cells of hypo sensitive to change in osmolality levels

b) controls salt and water levels- helps with thirst

F) involved in fluid regulation

1) lacks blood-brain-barrier, so allows more exchange between plasma and CSF

2) hypo samples plasma for salt content, temp, and nutrient level, so switches on hunger and thirst centers

G) involved in wakeful state

H) **biorythms**- cycles such as sleep-wake, menstrual, seasonal

I) in charge of **autonomic nervous system**

7) **Cerebrum**- telencephalon (CN I)

A) 3 functions:

1) interpretation of all sensory input- **CONSCIOUSNESS**

2) initiation of motor functions

3) seat of higher brain functions- math, language, art, recognition of shapes, planning, and memory

B) part of limbic and reticular formation systems

C) most sensitive to lack of oxygen. Furthest from heart, so most difficult to send blood there, especially if hypoglycemic and stand up quickly. If you go anoxic, you only have a few minutes. Then brain starts to suffer. Cerebrum suffers first = conscious. Cells don't store ATP- only have a 30 second supply, so need to constantly be supplied with oxygen and glucose.

8) **Limbic System**

A) widely distributed-includes thalamus, hypo, Pons, midbrain, cerebellum, and cerebrum

B) responsible for emotional status from moment to moment, sense of well-being (ex-foot throbbing, but can continue with life)

9) **Reticular Formation**

A) widely distributed like limbic system

B) responsible for conscious state- when you are awake nervous system is heightened

1) Posterior Column- Medial Lemniscus System (ascending tract)

A) Sensory info comes from skin (Meissner's corpuscles or free nerve endings) or muscle or tendon.
B) Goes through spinal cord to medulla oblongata to midbrain to thalamus to cerebrum
C) 3 neurons:

1) **primary neuron/ 1st order neuron**- goes through dorsal root to dorsal horns of gray and up through posterior column of spinal cord. It ends at **nucleus gracilis** of medulla oblongata (medial region). (There's a radiation of neurons to other parts of brain at nucleus gracilis.)
2) **secondary neuron**- starts at nucleus gracilis of medulla oblongata and goes **contralateral** there. Then goes up **medial lemniscus** of midbrain to thalamus.
3) **tertiary neuron/ 3rd order neuron**- starts at thalamus of cerebrum until **somatosensory cortex** of cerebrum-involved with voluntary action-**consciousness**.

D) **somatosensory cortex**- found in **post-central gyrus** (posterior to **central sulcus** of cerebrum)
E) **fasciculus gracilis**- slender rope of spinal nerves that runs up posterior column (lamination = layering- at every level of spinal cord) through nucleus gracilis of medulla.
F) **fasciculus cuneatus**- slender rope lateral to fasciculus gracilis that also runs up posterior column, but through nucleus cuneatus of medulla.
G) functions of tract:

1) **light touch**
2) **2-point discrimination**
3) **stereognosis**- ability to distinguish objects based on their shapes
4) **conscious propioception**
5) **kinesthesia**- ability to tell you're moving and in what direction
6) **weight discrimination**- ability to tell difference in objects based on weight
7) **vibrations**

2) Anterior Spinothalamic Tract (ascending)

A) Sensory info comes from skin (Meissner's corpuscle)
B) Goes from spinal cord to medulla oblongata to midbrain to thalamus to cerebrum.
C) 3 neurons:

1) **primary neuron**- enters dorsal horn of gray and stops
2) **secondary neuron**- synapses in dorsal horn of gray. Goes contralateral at the same level the neuron enters in white matter. Goes through **anterior spinothalamic region** of white matter of spinal cord to medulla oblongata and midbrain until it reaches thalamus.
3) **tertiary neuron**- starts at thalamus and ends at somatosensory cortex of cerebrum-consciousness

D) function- **tactile impulses- crude touch and pressure** (not fine)

3) Lateral Spinothalamic Tract (ascending)

A) Sensory info comes from skin (free nerve ending)
B) Goes from spinal cord to medulla oblongata to midbrain to thalamus to cerebrum.
C) 3 neurons:
    1) **primary neuron**- enters dorsal horn of gray and stops
    2) **secondary neuron**- synapses in dorsal horn of gray. Goes contralateral at the same level the neuron enters in white matter. Goes through **lateral spinothalamic** region of white matter of spinal cord to medulla oblongata and midbrain until it reaches thalamus.
    3) **tertiary neuron**- starts at thalamus and ends at somatosensory cortex of cerebrum- consciousness
D) function- **pain and temperature (IMPT!)**

4) Anterior Spinocerebellar Tract

A) sensory info comes from muscle or joint capsule.
B) spinal cord to medulla oblongata to cerebellum
C) 2 neurons:
    1) **primary**- enters dorsal horn of gray.
    2) **secondary**- goes **contralateral** in spinal cord, takes anterior tract through midbrain through **superior cerebellar puduncle** to cerebellum. Goes **contralateral** again in cerebellum so ends up on same side as it started.
D) function- **subconscious propioception**, since never reaches cerebrum

5) Posterior Spinocerebellar Tract

A) sensory info comes from muscle or joint capsule.
B) spinal cord to medulla oblongata to cerebellum
C) 2 neurons:
    1) **primary**- enters dorsal horn of gray.
    2) **secondary**- takes posterior tract through midbrain to **inferior cerebellar puduncle** to cerebellum- **remains ipsilateral**
D) function- **subconscious propioception**, since never reaches cerebrum

6) Anterior Corticospinal Tract

A) Goes from cerebrum to midbrain to Pons to medulla to spinal cord
B) conscious
C) descending motor tract
D) 2 neurons:
    1) **upper motor neuron**- goes from motor cortex of cerebrum which is in the pre-central gyrus all the way to the ventral horn of gray
    2) **lower motor neuron**- goes **contralateral** from ventral horn of gray through motor root to go to muscle
E) function- controls skeletal muscles of neck and trunk

7) Lateral Corticospinal Tract

A) principal pathway for voluntary motion- **IMPT!**
B) Goes from cerebrum to midbrain to Pons to medulla to spinal cord
C) conscious
D) descending motor tract
E) 2 neurons:

1) **upper motor neuron**- goes from motor cortex of cerebrum which is in the pre-central gyrus all the way to the medulla where it becomes contralateral in decussation of the medulla to ventral horn of gray
2) **lower motor neuron**- goes from ventral horn of gray through motor root to go to muscle

F) function- controls skilled movements of hands and feet

Dorsal Fasciculus Tract/ Intersegmental Tract

A) **segment**- where spinal nerve exits cord
B) Sensory nerves send collateral branches to upper and/ or lower segments = **intersegmental tract.** Different levels of spinal cord communicate with each other via intersegmental tract- **IMPT!**
C) This allows better control. Several levels of cord control the same muscle.
D) **plexus =** interbranching network of spinal nerves, when nerves interbranch with each other.

1) **cervial plexus**- C-1- C-4 (cutting cord at C-2-instant death, C-3-quadriplegia, C-7-paraplegia)
2) **brachial plexus**- C-5- T-1 (muscles of arms and shoulders)
3) **T-2- T-11**- intercostal nerves, don't form a plexus, no interbranching
4) **lumbar plexus**- T-12- L-5

Nervous system based on **position**:
1) **CNS**- brain and spinal cord
2) **PNS**- cranial and spinal nerves

Nervous system based on **function**:
1) **somatosensory/ motor**- voluntary (some reflexive though)
2) **ANS- autonomic nervous sytem**- takes care of things you don't need to think about

A) **sympathetic**- speeds things up, lights you up
B) **parasympathetic**- slows things down, rest

Sympathetic Pathway

1) cluster of nerve cells in medulla = **cardioaccelerating center**
2) cell body moves down cord = **cardioaccelerating nerve**
3) two nerve cells needed to get info to heart:
    A) **preganglionic neuron**
        1) found from spinal cord to ganglia = short
        2) uses ACH as a neurotransmitter
        3) called **cholinergic** neuron
    B) **postganglionic neuron**
        1) goes from ganglia to heart = long
        2) uses norepinephrine as its neurotransmitter
        3) **adrenergic** neuron
4) norepinephrine lands on P cell, initiating faster heart rate
5) sympathetic nerves can also innervate the surface of eye (diameter of pupil), blood vessels, bronchiol tree- any place where multi- unit smooth muscle is found (things we don't think about)
6) sympathetic nervous system gets a boost from a gland
    a) at bottom of spinal cord are sacral nerves- go to gland of kidney = **adrenal gland** (which is part of the sympathetic nervous system) via **neuroglandular junction**.
    b) in response to sympathetic signal, adrenal medulla releases epinephrine and norepinephrine
7) when sympathetic nervous system is activated, the whole system is activated by (all neurons fire)
8) advantages to release of norepinephrine by adrenal medulla:
    A) circulates through blood and reaches cells that are not directly stimulated by post-ganglionic neurons. Reaches more cells than stimulated by nerve cells directly.
    B) circulating norepinephrine lengthens sympathetic response = "holy mackerel response"-pay attention when in danger-breathe faster, heart rate speeds up
9) enzymes can take apart norepinephrine:
    A) **MAO = monoamineoxidase**- **IMPT!**
    B) **catechol-o-methyl transferase**- **IMPT!**
10) ACH is broken down by **acetylcholine esterase**
11) **epinephrine cascade or amplification system**:
    A) **epinephrine** binds to **receptor** on cell membrane
    B) this causes activation of enzyme in cell membrane- **adenylate cyclase**
    C) adenylate cyclase converts **ATP** into **cyclic AMP** (secondary messenger)
    D) c-AMP activates **protein kinase**
    E) protein kinase then activates **phosphorylase A** and it becomes **phosphorylase B**
    F) meanwhile **insulin** binds to **receptor** on cell membrane, activating a **carrier protein**
    G) the carrier protein brings in **glucose** that can't get in b/c it's hydrophilic (polar) and cell membrane is hydrophobic (non-polar)
    H) **phosphorylase B** phosphorylates **glucose**- binds phosphate to it
    I) this is the first step in **glycolysis**- substrate for the next step until eventually **ATP** forms
    J) this takes place instantaneously when there's sympathetic activation
    K) to stop cascade, break down epinephrine via:
        1) **MAO = monoamineoxidase**- **IMPT!**
        2) **catechol-o-methyl transferase**- **IMPT!**
    L) also need to break down c-AMP via **phosphodiesterase**
        1) **caffeine** inhibits phosphodiesterase to lengthen sympathetic response

	Sympathetic	Parasympathetic
Heart Rate	up	down
Blood Pressure	up	down
Body Temp	up (increase in heat produced by brown fat)	down
Pupils	dilate	constrict
Airway	dilate (bronchdilation)	constricts
Blood Flow to Viscera	down (vasoconstriction)	up (vasodilation)
Blood Flow to Skeletal Muscles	up (vasodilation)	down (vasoconstriction)

Parasympathetic Pathway

1) 2 neurons:
    A) **preganglionic neuron (**neurons are part of **vagus nerve)**
        1) found from medulla oblongata to heart- long
        2) uses ACH as a neurotransmitter
        3) called **cholinergic** neuron
    B) **postganglionic neuron**
        1) found in heart wall- short
        2) uses ACH as its neurotransmitter
        3) **cholinergic** neuron
2) to defecate, use the whole parasympathetic system- can shut heart down b/c trying to open anal sphincter. Therefore, put ppl on stool softener after cardiac or abdominal surgery
3) CN III- to intrinsic eye muscles and lacrimal gland and CN VII and IX to salivary glands are parasympathetic, as well as vagus nerve that goes to many places in body besides heart, such as walls of blood vessels and airways.

	preganglionic	postganglionic
Sympathetic	short, cholinergic ACH	long, adrenergic norepi
Parasympathetic	long, cholinergic ACH	short, cholinergic ACH

The effect happens from end of postganglionic neuron, so norepinephrine speeds up heart and ACH slows it down.

Receptors

A) for **norepinephrine**
- 1) **alpha**
- 2) **beta**
  - a) **beta-1**
  - b) **beta-2**
    - 1) **beta blockers**- drugs that fit into receptors, so block action of norepi
    - 2) if someone has tachycardia- high heart rate, would use beta blockers to slow down heart

B) for **ACH**
- 1) 2 types
  - a) **muscarinic**
    - 1) from muscarinine from toadstool- poisonous mushroom, exogenous substance
  - b) **nicotinic**
    - 2) nicotine- found in tobacco plant
- 2) ACH fits into both kinds of receptors- they mimic ACH- but their substrates would not fit into each other's receptors b/c different shapes

Neurons- Handout

a) **bipolar neuron**
- 1) 1 dendrite, 1 axon
- 2) comes from embryonic nerve cells
- 3) all other nerve cell types differentiate from bipolar
- 4) associated with special sense organs in adults- nose, eyes, ears, tongue

b) **unipolar neuron**
- 1) 1 axon, 1 dendrite- but from one origin point
- 2) most common sensory neurons in PNS
- 3) cell bodies outside CNS in dorsal root ganglia

c) **multipolar neuron**
- 1) many dendrites, 1 axon
- 2) most abundant neurons in CNS- make up association and motor neurons
- 3) cell bodies in CNS

CSF

1) found in **central canal of spinal cord**, **ventricles of brain**, and **sub-arachnoid space**
- A) arachnoid- middle meninge
  - 1) meninges are dura mater, arachnoid, and pia mater- most inner
    - a) sub-dural space b/t dura mater and arachnoid
    - b) sub-arachnoid space b/t arachnoid and pia mater
  - 2) shaking baby syndrome- find blood in CSF in sub-arach. Can see it in autopsy. Also can see if shaking was habitual b/c would be healing in dura mater.

2) CSF formed in **choroid plexus** in **lateral and 3rd ventricles**

3) flows from lateral to 3rd to **cerebral aqueduct** (narrowing of ventricle) to 4th ventricle to subarachnoid space and down central canal.

4) fluid reabsorbed in **choroid plexus of 4th ventricle and sagittal sinus** (expanded vein) which is above cerebrum
5) production rate = return rate
6) **hydrocephalis**- cerebral aqueduct doesn't open, so distribution and reabsorption of CSF is stopped while production continues, so baby gets a huge head and a small brain. Skull is not fused yet, so there's a soft spot/ **fontanels**. This allows pliability as baby exits birth canal. To stop hydrocephalis, shunt can be implanted in utero to drain CSF. Baby needs to come out c-section if no shunt.
7) **No buffers** in CSF- if H+ goes up, pH goes down immediately to affect change. It activates the sympathetic nervous system- breathe more quickly. If there was buffer system, H+ would be hidden before there was a change- not good.

Blood-Brain-Barrier

1) formed from **capillary endothelium** from brain capillaries
2) cell membrane is a phospholipid bilayer- non-polar, hydrophobic
3) outer layer of adjacent cell membranes fuse together to form **tight junctions**
4) **fastidious growth requirements**- neurons need very rigid set of growth requirements- narrow range of temp, pH...
5) BBB helps control what enters CSF, so would restrict things from slipping through- ex: amino acids, glucose, and other polar substances need to be brought across by transport proteins. Only low molecular, lipid soluble drugs can cross.
6) Something like penicillin can't get in, so how do you get it in?
    A) give megadose- large concentration gradient, so some will get through
    B) spinal puncture- inject it into spinal cord directly and skip BBB
    C) switch to a drug that can cross- ex: chloramphenicol

Parts of The Eye

1) 3 major layers:
    A) **sclera**- white of eye, not all the way around eye
        1) **cornea**- anterior part of sclera, thin and transparent
        2) **conjuctiva**- mucous membrane lining the anterior surface of eye, found around cornea
    B) **choroid layer**- deep to sclera, highly vascularized, not fully around eye. Anteriorly becomes
        1) **ciliary body/ muscles**- along with suspensory ligaments are intrinsic eye muscles that pulls on lens, produces aqueous humor
            a) **aqueous humor** found in **anterior chamber**, returned to circulatory sytem via **Canal of Schlemm**
        2) **iris**- color part of eye, causes **pupils** to dilate or constrict
            a) **smooth circular muscle fibers** constrict pupil when person is relaxed- **parasympathetic** conditions and in bright light conditions
                1) drugs cause pinpoint pupil b/c activate parasympathetic system
            b) **radial fibers** dilate pupils in darkness and due to shock- **sympathetic stimulation**
    C) **retina**- connects eyeball to brain
2) **optic nerve**- bundle of nerve cells from different parts of retina
3) **crystalline lens**- helps focus images on retina to facilitate clear vision

4) **anterior chamber**- b/t iris and cornea, filled with aqueous humor
5) **posterior chamber-** posterior to lens, filled with vitreous humor which is gelatinous
6) 6 extrinsic eye muscles
    a) **lateral rectus**- CN VI
    b) **superior rectus**- CN III
    c) **medial rectus**- CN III
    d) **inferior rectus**- CN III
    e) **inferior oblique**- CN III
    f) **superior oblique**- CN IV
7) **lacrimal gland**- located superior to eyeball- **IMPT!**
8) **photoreceptors**
    A) **rods**- active in dim light, see shades of gray
    B) **cones**- active in bright light- responsible for color
        1) concentrated in **fovea centralis of retina**- little depression in retina
            a) as move away from fovea centralis, cones decrease and rods increase in all directions, so side vision/ peripheral vision is not color- just shades of black. Center vision is color vision.
            b) **fovea**- point of highest **visual acuity** in eye- **IMPT!**
            c) located near **optic disk**- blind spot where CN II leaves back of eyeball

Pathway of Light through Eye

Light refracts when passes from air to a different medium.

cornea—> aqueous humor (anterior chamber)—> **(pupil)—> crystalline lens—> vitreous humor** (posterior chamber)—> **retina**
Where light crisscrosses in vitreous humor = **virtual image** (right-side up). **Real image** appears upside down along focal plane on retina. Brain makes it appear right side up.

Pathway of Light through Retina

1) **ganglia layer—> bipolar layer—> photoreceptor layer**
2) This initiates **depolarization/ action potential** which goes in opposite direction
photoreceptor layer—> bipolar layer—> ganglia layer
3) **photoreceptor layer**- has rods and cones that detect electromagnetic radiation and send signal to bipolar layer to ganglia layer.
4) **bipolar layer** has bipolar neurons
5) **ganglia layer** has multipolar neurons (cell bodies outside CNS) that lead to CN II
6) light is being **transduced**. A transducer converts one type of energy into another. Electromagnetic radiation turns into electrochemical signal -action potential- so eye is a transducer.
7) This system of neurons occurs at all points of retina, exiting at optic disk as CN II.
8) If image falls on optic disk, don't see anything.

Pathway of Light from Retina to Visual Cortex

1) **CN II—> optic chiasma—> optic tract—> thalamus** (specifically, lateral geniculate of thalamus)—> **visual cortex**
2) **visual cortex**- in **occipital lobe** of cerebrum (back of head), so blow to back of head can lead to blindness. This is where visual stimulus is interpreted and signal becomes **conscious** here.
3) thalamus also sends collateral branch to **superior colliculi of midbrain** for visual startle response.

Eye Disorders

1) **conjunctivitis**- inflammation of conjunctiva- **IMPT!**
2) **cataracts**- lens becomes hard or opaque due to age or too much UV light
3) **glaucoma**- increased intraoccular pressure b/c **canal of Schlemm** which returns **aqueous humor** is blocked
    A) **aqueous humor**- produced by **ciliary body**, gives eye its shape, rate of production= rate of return. Returned by **canal of Schlemm**.
    B) since canal is blocked, aqueous humor builds up leading to bug eyes.
    C) symptom of **hyperthyroidism/ Grave's disease**- polysaccharides get deposited in spaces in eye, causing osmotic pull of water into eye and eyeball stretches
4) **astigmatism**- irregular curvature in lens and/or cornea, resulting in blurred vision
5) **myopia**- near-sightedness- **IMPT!** Able to see close objects, but distant one are blurred b/c focal plane (place where image is in focus) is in front of retina, so blurred on retina
6) **hyperopia**- far-sightedness. Image in focus in back of retina, but light waves really don't go in back of retina- but imagine focal plane there, so image blurred on retina
7) **presbyopia**- old age vision. Elasticity of lens decreases over time, and since lens makes focal plane move, lens can't compensate quickly enough when move eyes, so can't focus

Parts of the Ear

1) **outer ear**
    A) **auricle/ pinna**- outside of ear
    B) **external auditory canal**- connects auricle to tympanic membrane
        1) transmits sound waves
        2) has wax that's watery to humidify/ moisten ear- prevents tympanic membrane from drying out
        3) warms air
    C) **tympanic membrane/ eardurm**- outer ear ends here
2) **middle ear**
    A) **tympanic cavity**- space which contains:
        1) **ossicles**
            a) transmit and amplify vibrations from tympanic membrane and deliver them to oval window
            b) 3 types
                1) **malleus**
                2) **incus**
                3) **stapes**

B) **Eustachian tube/ auditory tube**

1) equalizes pressure on either side of tympanic membrane. As altitude increases, atmospheric pressure decreases, so air pressure in middle ear cavity is too high which pushes tympanic membrane out, causing you to open Eustachian tube by swallowing or opening mouth, allowing air trapped in middle ear cavity to escape. **Safety valve**- allows us to change altitude without popping eardrum.

3) **inner ear**- petrous portion of temporal bone

A) **semicircular canals**

1)There are 3 at right angle to each other, so if move head in any direction, fluid-filled chambers move and activate receptors- hair cells which send signals to brain (also, as your head changes position, muscles in neck and shoulders increase in tension- also tells you you're moving)

2) contain hair cells and have **osseous layer** with **membranous layer** within

3) responsible for **dynamic equilibrium**- balance when in motion

4) **balance**- interpreted in **parietal lobe** of cerebrum

B) **vestibule**

1) responsible for **static equilibrium**- when in motion, but not moving- ex-car, escalator, elevator...

2) **otoliths**- crystals of calcium carbonate stuck in goo. They move back as you accelerate forward, disturbing hair cells and letting you know you're moving forward (and vice versa)

C) **cochlea**- where you detect hearing

D) **auditory nerve**- goes to brain

Reflexes of Ear

1) **tympani reflex**

A) **tensor tympani** attaches to tympanic membrane- tightens membrane, so doesn't transfer vibrations to malleus- protects inner ear by limiting vibrations

2) **stapedius reflex**

A) **stapedius muscle**- attaches to stapes, locks stapes in position, so doesn't push on oval window, so scrunching face sets off these reflexes and protects inner ear by reducing transmissions of vibrations

Pathway of Vibrations in Ear- IMPT!

1) outer ear and middle ear- transmit vibrations

2) need **cochlea** for **audition**

3) **pinna—> ear canal—> tympanic membrane—> malleus—> incus—> stapes—> oval window—> perilymph—> round window**

4) cochlea has **bony labyrinth** and **membranous labyrinth**

A) **perilymph** is b/t labyrinths and **endolymph** is within membranous labyrinth

B) all along membranous labyrinth = **spinal organ/ organ of Corti**- responsible for transduction. Different sound frequencies travel different distances, low freq-travels further- hits spinal organ at end after high freq

C) **hair cells** attached to membranous labyrinth and **bipolar neurons** associated with hair cells

5) **round window**- **protective mechanism** for ear b/c gets rid of excess vibrations through air from middle ear cavity. If it was sealed, vibrations would reflect and would get cancellation of waves, causing loss of some sound info

6) Ear is **transducer** b/c takes sound vibrations and converts them to action potentials

Pathway of Cochlear Nerve to Brain- How Vibrations Cause This

1) Vibrations push against **membranous labyrinth**, moving **hair cells** until they come in contact with bony labyrinth and bend.
    a) loud music can damage hearing by causing hear cells to fall off
2) This sends a signal to **bipolar neuron** to **ganglion cell** all the way back to the brain. The ganglion cell makes up cochlear branch of CN VIII
3) **cochlea—> CN VIII—> Pons—> thalamus—> auditory cortex** in **temporal lobe** of cerebrum- reaches consciousness, relates it to past experiences, interprets sound waves...
4) Pons also sends signal to **inferior colliculi** of midbrain to initiate auditory startle response (smell interpreted in cerebral cortex in olfactory bulb)

Disorders of the Ear

1) **conductive deafness**- can't conduct signals
    A) causes
        1) plugging/ blockage of external auditory meatus (by fingertip, ball of wax...)
        2) hardened or perforated tympanic membrane- can't transmit vibrations
        3) **otosclerosis**- deposition of new bone matrix around stapes locking it into position, so can't push against oval window

2) **sensorineural**- damage to cochlea
    A) causes
        1) exposure to loud noises
        2) loss of hair cells
        3) tumor in CNS
        4) stroke
        5) drugs (ex- overdose on streptomyocin)

3) **presbycusis**- hearing of old age (high and frequency sounds lost)

How Motor Nerve Cell Sends Action Potential to Muscle- old material

1) motor nerve cell has same conditions as cell
    A) high sodium and low potassium outside
    B) low sodium and high potassium inside
    C) anions-proteins and phosphates inside
2) motor nerve cell synthesizes **ACH**- acteylcholine- which is a neurotransmitter.
    A) ACH gets packaged into transport vesicles by Golgi complex and shipped to surface
3) 3 stages of sending an action potential:
    A) **polarized neuron**
        1) inside cell- negative charge, outside cell- positive charge
        2) ion channels are closed and sodium is pumped out

B) **depolarized neuron**

1) ion channels open 1 at a time and sodium diffuses in
2) electrochemical phenomena = **action potential**- propagates along the neuron
3) At the end calcium goes into the cell, causing the transport vesicle to bind to the nerve cell membrane
4) transport vesicles open up and ACH is released into the synapse while Golgi membrane replenishes the cell membrane

C) **repolarized neuron**

1) cell goes back to original conditions
2) sodium is pumped back outside and potassium is returned to the inside
3) **refractory period** as nerve cell recovers and reestablishes original conditions-can't send signals

4) ACH diffuses across **neuromuscular junction**- small space b/t neuron and muscle cell
5) ACH binds to receptors on sarcolemma = **motor end plate**