brain bee

REVIEW

Brain Basics

- **100 billions neurons** in brain
- average brain weight = **3 lbs**
- **dendrite**: primary site for receiving and integrating information from other neurons
- **axon**: fiberlike extension of neuron by which it sends information to target cells
- **action potential**: electrical charge that travels along the axon to the neuron's terminal where it triggers release of a ***neurotransmitter***
- **neurotransmitter:** a chemical released by neurons at synapse for purpose of relaying information to other neurons via receptors
- **nodes of Ranvier:** gaps occurring in the myelin sheath that allow for faster conduction of action potential

Brain Anatomy

- four lobes
  - **FRONTAL**: initiating and coordinating motor movements; higher cognitive skills (problem solving, thinking, planning); personality; emotion; etc.
  - **PARIETAL**: sensory processes, attention, language
  - **OCCIPITAL**: vision
  - **TEMPORAL**: auditory information, memory
- **cerebrum**: largest part of the human brain
- **cerebral cortex**: sheet of tissue covering the outermost layer of the cerebrum
- **ventricles**: hollow spaces in brain containing cerebrospinal fluid
- **gray matter**: cell bodies of neurons
- **white matter**: axons of neurons (white in appearance because of fatty myelin that covers axons)
- **corpus callosum:** large white matter structure linking the left and right cerebral hemispheres
- **important anatomical structures**
  - **thalamus**: gate and modulate flow of information to cortex

EXAMPLE: visual information from retina is not sent directly to visual cortex but instead is relayed through lateral geniculate nucleus of thalamus

- **hypothalamus**: responsible for hormone production (ex: **GnRH, CRH**), communicates with ***pituitary gland***

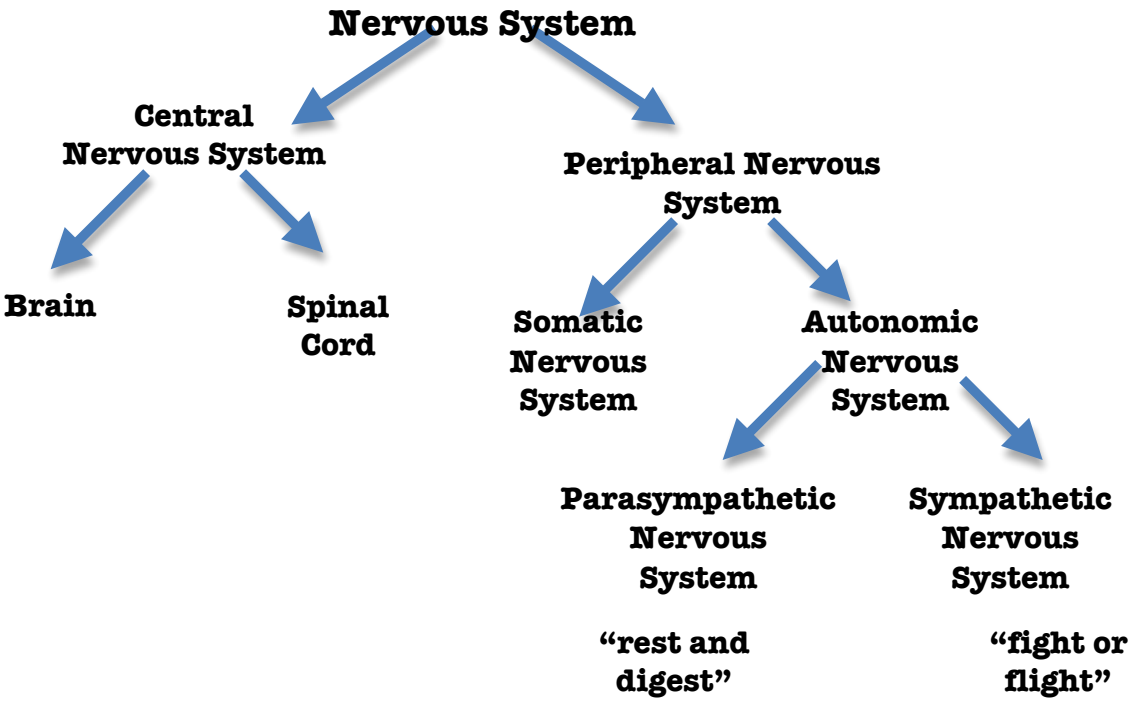
**also location of several important groups of cells:

1) **ventrolateral preoptic nucleus**: nerve cells containing GABA and galanin, important for sleep

2) nerve cells containing **orexin** (important in wakefulness)

3) **suprachiasmatic nucleus**: small group of nerve cells that acts as a master clock

- **substantia nigra**: part of the basal ganglia (important for movement); dopaminergic neurons here degenerate in **Parkinson's disease**
- ***hippocampus***: shaped like a seahorse, very important for **MEMORY**
- ***amygdala***: important in fear, emotion; responsible for **emotional aspect of memory**
- ***pons***: upper brainstem, **attached to cerebellum**
- ***medulla***: lower brainstem, involved in controlling breathing, heart rate, and blood pressure
- **cerebellum**: helps us **adjust motor output** to deal with changing conditions; important for coordination and balance; attached to the pons



Neurotransmitters

ACETYLCHOLINE (ACh)

- **first neurotransmitter** to be identified
- released by neurons connected to **voluntary muscles** causing them to contract
- antibodies **that block one type of ACh receptor** cause **myasthenia gravis** (disease characterized by **fatigue and muscle weakness**)
* *also important for memory

AMINO ACIDS

1) GABA

- inhibit firing of neurons
- activity increased by **benzodiazepines** (anti-anxiety drugs)

2) GLUTAMATE

- excitatory signals,
- ***activate NMDA receptors*** (important in ***learning/memory***; however overstimulation of these receptors can cause nerve cell damage or cell death)

CATECHOLAMINES

1) DOPAMINE

* * *important in three functions:

A. Movement

- deficits in dopamine associated with **Parkinson's disease** (symptoms include muscle tremors, rigidity, difficulty moving)
- most common treatment for Parkinson's is **LDOPA (or levadopa**), a precursor to dopamine

B. Cognition and Emotion

- abnormalities in dopamine have been identified in patients with **schizophrenia**
- in fact, many antipsychotic drugs inhibit dopamine receptors, increasing risk for **tardive dyskinesia** (movement disorder in which symptoms include aimless, uncontrollable movements; rapid eye blinking; etc).

C. Endocrine system

2) NOREPINEPHRINE

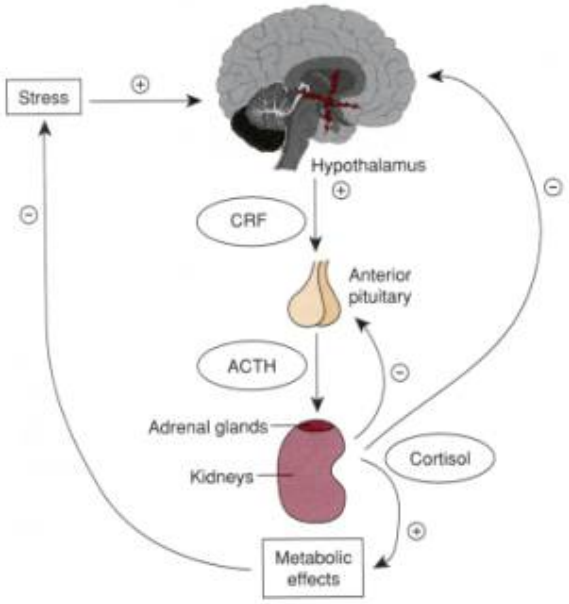
- released from ***adrenal medulla*** (innermost part of adrenal glands) in times of stress
- secreted by ***sympathetic nervous system*** to regulate heart rate/blood pressure

SEROTONIN

- important in sleep, mood, depression, and anxiety

HORMONES

- important in sleep, mood, depression, and anxiety
- ex. **cortisol (**released by adrenal glands in response to stress)



GASEOUS NEUROTRANSMITTERS

1) nitric oxide
2) carbon monoxide

SECOND MESSENGERS

- important in sleep, mood, depression, and anxiety
- ex: the enzyme **adenylyl cyclase** converts **ATP** to the ***second messenger cAMP***

Brain Development

Three stages:
1) **induction**
2) **proliferation**
3) **migration**

important terms:

plasticity: ability of the brain to modify itself and adapt to challenges of the environment

apoptosis: programmed cell death initiated in the cells

Vision

- **cornea**: does ¾ of focusing
- **lens**: does the remainder of focusing after light has passed through cornea
- **iris**: adjusts size of pupil
- **fovea**: centermost part of retina
-**macula**: area around fovea, important for reading/driving
* *__macular degeneration__ = leading cause of blindness in elderly
- **retina**: location of photoreceptors
* *two types of photoreceptors
a) ***cones***: color, bright light, acute detail
b) ***rods***: dim light
- pathway by which light travels:
cornea → lens → photoreceptors → bipolar cells → ganglion cells
- **axons of ganglion cells** form the **OPTIC nerve**, signal transduced from nerve to **LATERAL GENICULATE NUCLEUS** of thalamus (**acts as intermediate relay**), and then to ***primary visual cortex*** (**occipital lobe**)

Hearing

sound waves → external ear (pinna + auditory canal) → **tympanic membrane** (eardrum) → **malleus** (hammer) → **incus** (anvil) → **stapes** (stirrup) → **oval window** (separates middle ear from inner ear) → **cochlea** (separates frequencies)

- **hair cells** on the basilar membrane of the **cochlea** convert mechanical vibration to electrical signal
- this signal travels via the **auditory nerve** to the **auditory cortex** (temporal lobe)

Touch

- receptors on different part of body send “touch” message to cortex via spinal cord
- some parts of body (lips, hands) have more cortex devoted to them (and are thus more sensitive to touch)
- ***two point threshold***: distance between two points on skin necessary for individual to distinguish two distinct stimuli from just one

Pain

- **nociceptors**: sensory fibers that respond to stimuli that damage tissue and can cause pain
- **prostaglandins**: enhance sensitivity of receptors to tissue damage and ultimately can ***induce more intense pain sensations***, made by **cyclo-oxygenase (COX)** enzymes
- a**llodynia**: normally innocuous stimuli cause pain
- **analgesia**: loss of ability to feel pain

Learning and Memory

1)**declarative memory**: facts and events, "knowing what" → primarily **HIPPOCAMPUS**

- ***semantic memory***: general facts/data
- ***episodic memory***: events

2) **nondeclarative memory**: unconscious and unintentional memory (example: playing the piano), "knowing how"

- ***procedural memory***: skills and habits
- ***emotional memory***: attachment of emotional significance to memory → **AMYGDALA** plays large role
- "movement" memory: involves cerebellum

* * *important terms:

LTP: long lasting increase in strength of synaptic response following stimulation (occurs in **hippocampus**, involves **NMDA** receptors)

Language

- ***aphasia***: language disorder
- ***Broca's aphasia***: damage to left frontal lobe (Broca's area), inability to produce speech
- ***Wernicke's aphasia***: damage to left temporal lobe (Wernicke's area), inability to comprehend speech

Movement

- **skeletal muscle:** voluntary movements
- each skeletal muscle is made up of thousands of individual **muscle fibers** and each muscle fiber is **controlled by one alpha motor neuron**
- **motor unit**: an alpha motor neuron and all the muscle fibers it contains
- **Golgi tendon organs**: detect **FORCE** applied by contracting muscle, allowing brain to sense and control muscular force exerted during movement
- **muscle spindle**: detect changes in **LENGTH** of muscle when stretched

NOTE: not all movements are voluntary... best example of involuntary movement is reflexes. One important pair of reflexes are the **flexion (withdrawal) and **crossed extension reflexes**:
- right foot (for example) encounters sharp object
- right leg immediately is lifted from source of potential injury (**flexion)**
- opposite ("crossed") leg, here – the left leg, responds with increased extension to maintain balance (**crossed extension**)

Sleep

two phases of sleep:
- **non REM sleep** (includes slow wave sleep): relaxation of muscles, decrease heart rate/blood pressure/body temp, active suppression of arousal systems by cells in **VENTROLATERAL PREOPTIC NUCLEUS**
- **REM** (rapid eye movement) sleep: atonia (paralysis of body's muscles) except for muscles controlling breathing/eye movements, active dreaming
**during sleep, cycles alternate; REM becomes more prolonged until waking occurs

circadian system: regulates timing of sleepiness and wakefulness throughout day
** regulated by group of cells in hypothalamus called the **SUPRACHIASMATIC NUCLEUS**

Stress

stimulus (ex. seeing a bear) activates three systems...
1) **voluntary nervous system**: messages to muscle ("run away")
2) **autonomic nervous system**: excites sympathetic nervous system (pupils constrict, heart races, more blood to muscles, release of epinephrine aka adrenalin)
3) **neuroendocrine system**: release of stress hormones (ex. cortisol)

Imaging

- **positron emission tomography (PET):** measures **blood flow**, based on **detection of radioactivity** emitted when positrons undergo radioactive decay in brain
- **magnetic resonance imaging (MRI):** provides three-dimensional image of **brain structure** using **magnetic fields**
- **electroencephalography (EEG):** measures brain activity using electrodes placed on head

Diseases and Disorders

Autism: **impaired social skills**; verbal and nonverbal communication difficulties; narrow, obsessive interests or **repetitive behaviors**

Attention Deficit Hyperactivity Disorder (ADHD): excessively inattentive, **hyperactive, or impulsive behaviors**
medication: ***stimulants (ex. methylphenidate)***

Down Syndrome: most frequently occurring chromosomal condition; **low muscle tone, upward slant to eye, enlarged tongue, flat facial profile**
genetic cause? **extra copy chromosome 21**

Dyslexia: **most common learning disability**; unexpected difficulty in speaking and reading in children/adults who otherwise possess the intelligence

Alzheimer's disease: progressive, degenerative disorder attacking neurons, resulting in loss of memory, cognition, and behavioral changes
biological identifier = abnormal accumulation of **beta amyloid (neuritic plaques)** and **tau (neurofibrillary tangles)**
genetic cause? presenilin 1 and 2, APOE epsilon 4
treatment? drugs preventing breakdown of acetylcholine

Amytrophic Lateral Sclerosis (ALS) aka Lou Gehrig's disease:
progressive muscle weakness resulting in paralysis
biological identifier = **motor neurons in brain/spinal cord degenerate** (related to excess amount **GLUTAMATE?**)
genetic cause? mutation in gene coding for **superoxide dismutase**

Huntington's Disease: **involuntary jerking movements** of limbs, torso, facial muscles
genetic cause? **expanded triplet repeat** in gene that codes for **huntingtin**

Parkinson's Disease: **slowness of movement**, muscular rigidity, walking/balance impairment, resting tremor
biological identifier = **loss of dopamine** producing neurons in **substantia nigra**
treatment? **levadopa (LDOPA)** → converts to dopamine in brain
current research: uses rodent/non human primate model treated with **MPTP** (destroys dopaminergic neurons) to learn more about disease and possible treatment

Tourette Syndrome: **motor and vocal tics, males 3-4x** more likely to be affected
treatment? antipsychotics, **SSRIs** (***selective serotonin reuptake inhibitor***), stimulants (methylphenidate)

Schizophrenia: **hallucinations, delusions**, lack of motivation, flat affect
biological identifier: enlarged ventricles, abnormal levels of dopamine
treatment? **chlorpromazine** (first antipsychotic drug); other antipsychotics blocking dopamine receptors (may result in **tardive dyskinesia**, movement disorder similar to Parkinson's)

Obsessive Compulsive Disorder (OCD): repetitive thoughts/behaviors
treatment? SSRIs

Post Traumatic Stress Disorder (PTSD): following some type of trauma (war, car accident, etc); intense fear/helplessess
treatment? **beta blockers** (block ***norepinephrine*** receptors)

Panic Disorder: overwhelming sense of impending doom, sweating, weakness, dizziness
treatment? SSRIs, antidepressants

Major Depression: hopelessness, pessimism, loss of interest
treatment? antidepressants, SSRIs

Bipolar Disorder: cycling between deep depression and manic highs
treatment? **lithium**, anticonvulsants (Valproate)

Brain Tumors:
- **primary**: arise **within** brain
- **secondary** (**metastatic**): arise in **other parts** of body, enter brain through blood stream
→ Gliomas: type of **primary brain tumor**
* *release **glutamate** at toxic concentrations
treatment? surgery, drugs that relieve swelling

Multiple Sclerosis (MS): autoimmune disease; blurred vision, slurred speech, weakness, tremors, memory loss
biological cause: body **attacks myelin sheath** covering axon, leaving scleroses (scars) – hardened patches of tissue on axon

Traumatic Brain Injury (TBI): concussion, etc; cerebral edema (swelling due to excess water in brain), lesions (bleeding on surface), bruises

treatment? **removal of cerebrospinal fluid** (*reduces intracranial pressure*), hyperventilation (decreases blood volume), removal of parts of skull

Epilepsy: seizures, can be *idiopathic* (uncertain cause, i.e. genetic mutation) or *symptomatic* (known cause, i.e. head injury, stroke), characterized as *generalized* (loss of consciousness, wide area of brain) or *partial* (consciousness maintained, one area of brain)
treatment? antiepileptics

Stroke: **third leading cause of death**, clot in blood vessel cuts off blood supply to brain; paralysis, loss of speech common
treatment? **tissue plasminogen activator** (tPA) = dissolves clots; arterial stent; anticoagulants

Tardive Dyskinesia: involuntary, repetitive movements; may be side effect **of antipsychotics blockng dopamine receptors**

Myasthenia Gravis: autoimmune disorder in which **acetylcholine receptors are blocked**; results in muscle weakness + fatigue

Fetal Alcohol Syndrome: **leading preventable cause of mental retardation, fetal**; mental and physical defects in fetus associated with high levels of **alcohol consumption** during pregnancy

Korsakoff's Syndrome: cognitive decline/memory loss associated with **chronic alcoholism**

Narcolepsy: poor control of sleep-wake cycles leading to sudden bouts of sleep
biological cause: death of cells in hypothalamus containing **orexin**

REM Behavior Disorder: muscles fail to become paralyzed during REM sleep such that individual acts out dreams

Obstructive Sleep Apnea: airway muscles in throat relax during deep sleep, closing airway and resulting in difficulty staying asleep