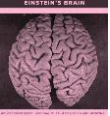
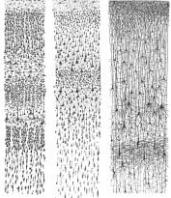

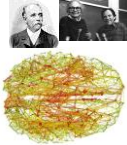


Welcome to Clinical anatomy of the head, neck and neuronal pathways
Lecture #8


Alemeh Zamani, Ph.D.
Department of Anatomy
MUNI, MED
Spring 2021

Future Lectures

Week #10 Somatosensory and viscerosensory; pain pathways and connections of stress analgesia


Week #11 Pathways of the somatomotor system, connections of the cerebellum and basal ganglia; spinal reflex motoric; eye movements

Week #13 Arrangement and function of the autonomic nervous system



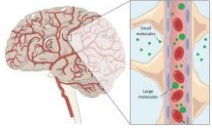
Today's lecture will cover:

- 1- Nervous System Barriers
- 2- Plasticity and Regeneration of Nervous System
- 3- Visual and Auditory Pathways
- 4- Vestibular, Olfactory, and Gustatory Pathways



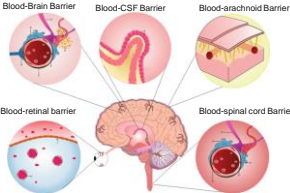
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Nervous System Barriers

- o Blood-Brain Barrier
- o Blood-Spinal Cord Barrier
- o Blood-Cerebrospinal Fluid Barrier
- o Blood-Nerve Barrier
- o Blood-DRG Barrier



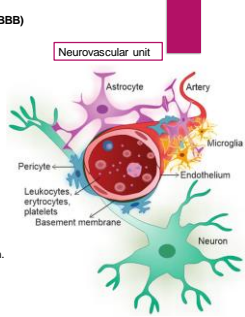
Blood-Brain Barrier Blood-CSF Barrier Blood-erachnoid Barrier
Blood-retinal barrier Blood-spinal cord Barrier

Blood-Brain Barrier - Tatiana Baricello

Blood-Brain Barrier (BBB)

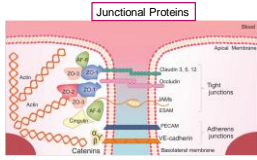
Neurovascular unit

- > BBB is formed by a tight monolayer of brain endothelial cells.
- > Function of BBB is maintaining brain homeostasis by regulating transport to the brain.
- > The plasticity of BBB is regulated within a dynamic system called Neurovascular unit.
- > BBB represents a significant roadblock in delivering drugs to brain.

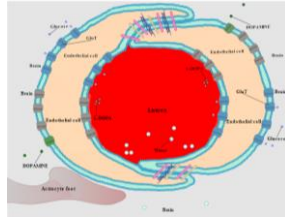


Blood-Brain Barrier - Tatiana Baricello

Blood-Brain Barrier



Transporter Proteins



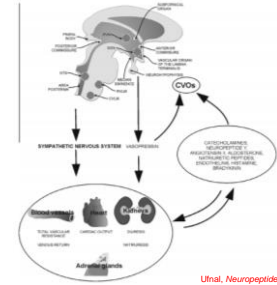
- ❖ Junctional proteins and transporters:
- small inorganic molecules (O₂, CO₂, NO, and H₂O)
 - ions, peptides, amino acids, proteins, carbohydrates, hormones, vitamins, etc.

Neuroscience Online, the Open-Access Neuroscience Electronic Textbook

Circumventricular organs (CVOs)

Non-barrier regions (hormonal control)

- Pituitary gland
- Median eminence
- Area postrema
- Preoptic recess
- Paraphysis
- Pineal gland
- Endothelium of choroid plexus



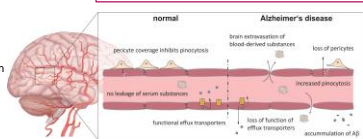
Ufhal, Neuropeptides 2014

Blood-Brain Barrier Dysfunction

Disruption of BBB can lead to:

- Changes in permeability
- Modulation of immune cell transport
- Trafficking of pathogens into the brain

Dysregulated BBB transport in Alzheimer's disease



BBB dysfunction is associated with neurological disorders:

Neurodegenerative diseases, Cerebrovascular diseases, Brain infections, Inflammatory diseases, Brain tumors, Neurotrauma, Mental or psychological stress

Stork, Neuroforum 2017

Blood-Spinal Cord Barrier (BSCB)

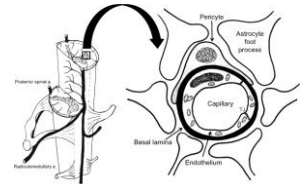
Composed of continuous type of microvessels

More permeable for cytokines and tracers compared to BBB:

- Lower level of occludin and ZO-1
- Less number of pericytes

Pathological conditions:

- Spinal cord injury
- Amyotrophic lateral sclerosis
- Radiation-induced myelopathy



Bartanusz, Annals of Neurology, 2011

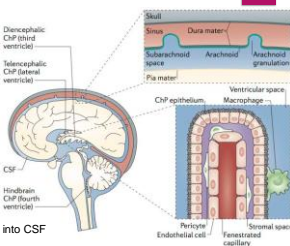
Blood-CSF Barrier

Epithelial cells of choroid plexus:

- Secrete cerebrospinal fluid (CSF)
- Form blood-CSF barrier

Role of blood-CSF barrier

- To restrict the passage of substances from blood into CSF

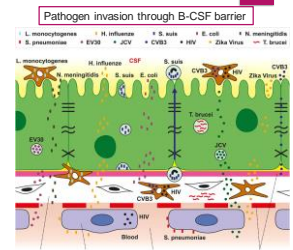


Lun, Nature Reviews Neuroscience 2015

Blood-CSF Barrier Dysfunction

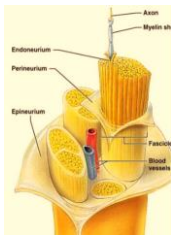
Blood-CSF barrier permeability alteration:

- Infectious disease
- Stroke
- Trauma
- Neurodegenerative disease
- Autoimmune disorders
- Tumors of choroid plexus
- Schizophrenia and chronic stress

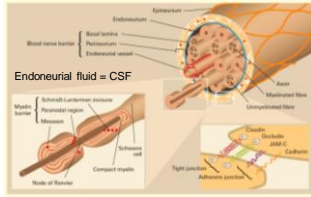


Solar, Fluids Barriers CNS, 2020

Blood-Nerve Barrier (BNB)



❖ Perineurial cells interaction with Schwann cells critical for nerve development and regeneration

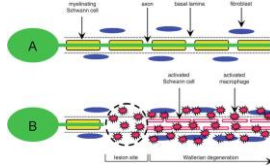


Blood-nerve exchange is maintained by endothelial cells of endoneurial vessels.

Reinhold, Experimental neurology 2020

Wallerian Degeneration

Injury of nerves and axons



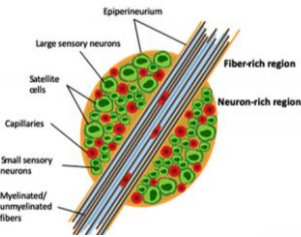
- Proliferation of Schwann cells
- Invasion of circulating macrophages
- Alteration of the blood-nerve barrier
- Changes in the endoneurial extracellular matrix
- Elevation of cytokine production

Blood-Dorsal Root Ganglion (DRG) Barrier

Present in DRG

- Somata of sensory nerves
- Nociceptive neurons

More permeable than the BNB

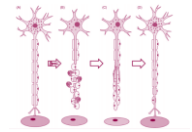


Peripheral nerve injury induces cellular and molecular changes in the DRG that contribute to induction and maintenance of neuropathic pain.

Reinhold, Experimental neurology 2020

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Plasticity and Regeneration of Nervous System

❖ Neuronal plasticity is defined as the ability of NS to modify the activity and organization of neuronal circuitry according to internal or external stimuli:

Brain never stops changing ...

- Alterations in the level of the neurotransmitters
- Change in the protein content at synapses



Short-term and long-term potentiation and depression, milliseconds to hours or even longer

- **Adaptational plasticity**
Continuous adjustment in response to environmental challenges
- **Repairation plasticity**
Positive or negative changes during functional or structural recovery of damaged neuronal circuits

Repairation Plasticity



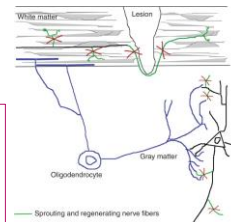
The correction of developmentally miswired neuronal connections or rehabilitation after stroke or traumatic brain injury depend crucially on the adult brain's capacity for plasticity.

Reaction to injury differs in neurons of CNS and PNS

Adult mammalian CNS has a limited regenerative capacity

- CNS**

 - Damage to neurons, glial, and endothelial cells
 - Breakdown of the blood-brain barrier
 - Activation of glial cells and a robust inflammatory response



Silver, Cold Spring Harb Prospect Biol 2015

CNS Pathology After a Traumatic Injury

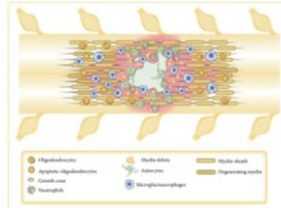
Glial environment of the adult CNS presents a major hurdle for successful axon regeneration

Inhibitory molecules for CNS regeneration:

- o Chondroitin Sulfate Proteoglycans (from astroglial scar)
- o Myelin-Associated Inhibitors (from oligodendrocytes)
- o Inhibitory Signaling Pathways (Ibuprofen inhibits RhoA)

Pro-regenerative molecules

NGF, TGF- β , PDGF, EGF, BDNF, and oncomodulin

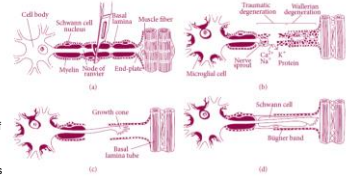


Mietto, Mediators of Inflammation 2015

Peripheral Nerve Pathology After a Traumatic Injury

Regeneration of PNS neurons depends on

- o type of injury
- o age of the organism
- o localization and function of neurons



Navarro, Progress in Neurobiology 2007

Schwann cells: overexpress a broad panel of inflammatory mediators

Macrophages: phagocytosis of cellular debris

Cellular and Molecular Mechanisms During PNS Regeneration

Regeneration-Associated Genes

- o c-Jun
- o activating transcription factor-3 (ATF-3)
- o SRY-box containing gene 11 (Sox11)
- o small proline-repeat protein 1A (SPRR1A)
- o growth-associated protein-43 (GAP-43)
- o CAP-23

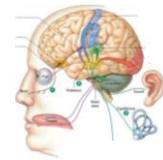
❖ Neuroma = Result of disorganized growth of cone branches in an unsuccessful search of a receptor or endoneurial tube is not reached, = painful lump



Ginsell, BioMed Research International 2014

Today's lecture will cover:

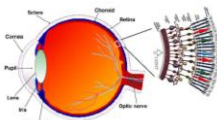
- 1- Nervous System Barriers
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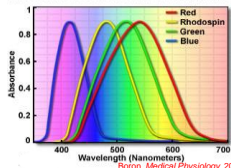
Visual Pathways

Perception of motion, depth, form and color

Structure of the human eye

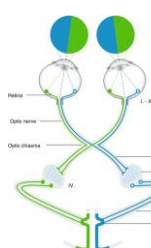


Absorption Spectra of Human Visual Pigments



Burton, Medical Physiology, 2003

Neuronal Elements of Visual Pathway

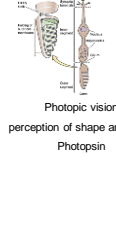


Rod (100-130 million)

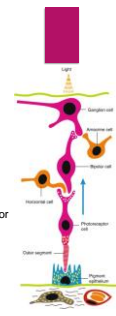


Scotopic vision dim light Rhodopsin

Cone (5-7 million)



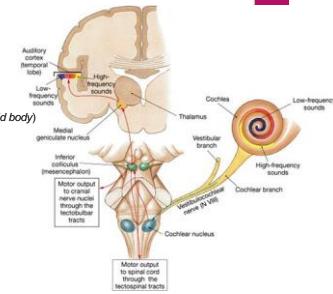
Photopic vision perception of shape and color Photopsin



Joukai, Anatomy of the Human Visual Pathway

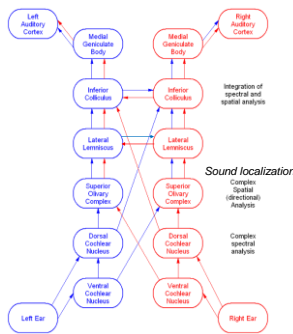
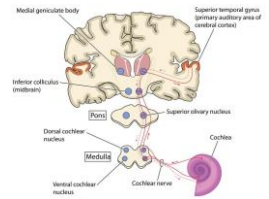
Diagram of the Major Auditory Pathways

- 1st order neuron**
 - o Spiral ganglion cells
- 2nd order neuron**
 - o Dorsal cochlear nucleus → nucleus of lateral lemniscus
 - o Ventral cochlear nucleus:
 - VPCN → ?
 - AVCN → superior olivary nucleus (trapezoid body)
- 3rd order neuron**
 - o nucleus of inferior colliculus
- 4th order neuron**
 - o medial geniculate nucleus (brachium of inferior colliculus)



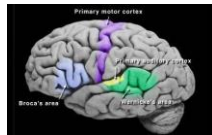
Auditory pathway:

- o Sensory hair cells
- o Cochlear branch of vestibulocochlear nerve (C.N. VIII, Auditory Nerve):
 - Spiral ganglion cells →**
- o **Brainstem: cochlear nucleus:**
 - DCN → nucleus of lateral lemniscus →
 - VPCN → nucleus of inferior colliculus
 - AVCN → superior olivary nucleus →
- o **Midbrain: nucleus of inferior colliculus →**
- o **Thalamus: medial geniculate nucleus →**
- o **Auditory cortex**



Auditory cortex

Temporal superior gyrus (Heschl gyrus)



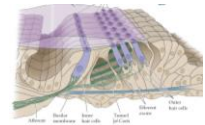
In Wernicke's area speech is comprehended.

Ascending and Descending Pathways

- Two functionally significant features of ascending pathway:
- o tonotopical organization
 - o bilateral projection

Descending pathway functions (superior olivary complex):

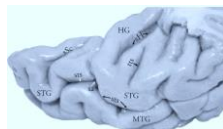
- o feedback system processing ascending information
- o enhance signals
- o suppress noise
- o focus on a particular speaker
- o inhibit other voices



Pathology

Bilateral lesions in cortical deafness

- o Hearing impairments
- o Impairments of speech comprehension
- o Speech repetition impairment
- o Impairment in recognition of familiar sounds and music



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Connections with the Cortex

Thalamus: Ventral posteromedial nucleus

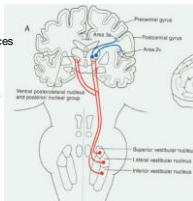
No primary vestibular cortex

Distributed among several multisensory areas in the parietal and temporal cortices

- o Area 2v at the tip of the intraparietal sulcus
- o Parieto-insular vestibular cortex (PIVC) at the posterior end of the insula
- o Area 7 in the inferior parietal lobule

Natural stimulation of the vestibular system during head motion and locomotion is always **multisensory** (visual, vestibular, somatosensory)

Conscious perception of movement and gravity



Brant, Vestibular cortex: its locations, functions, and disorders



Vestibular Impairment

Disturbance in the body's balance system

Symptoms:

Dizziness, vertigo, nausea, vomiting, intolerance to head motion, nystagmus, unsteady gait, and postural instability.

Acoustic Neuroma

Age-related dizziness and imbalance

Bilateral Vestibular Hypofunction

Cortical representation of vestibular information is important for cognition, emotion and the sense of self.

Cognitive and emotional disorders

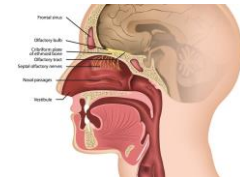
Symptoms:

feeling "spaced out", "body feeling strange"



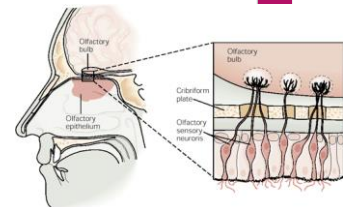
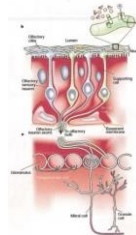
Olfactory Pathways

Humans are capable of discriminating a great variety of odors and flavors.



Olfactory Pathways

1st order neuron: bipolar olfactory neurons

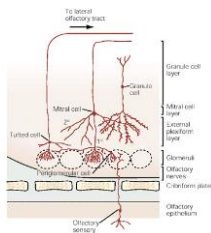
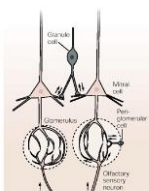


Olfactory neurons are distinctive among neurons in that they are short-lived, with an average life span of only 30-60 days, and are continuously replaced from the basal stem cell population.

Kandel, Samell and taste: the chemical senses

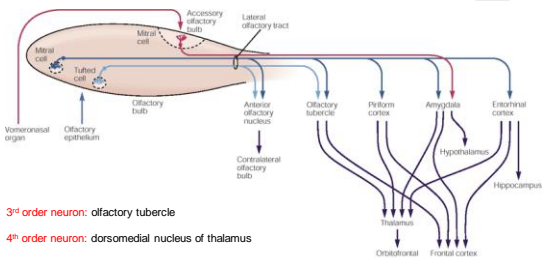
Olfactory Pathways

2nd order neuron: mitral cells → lateral olfactory tract



Olfactory Pathways

Olfactory information is processed in several regions of the cerebral cortex.

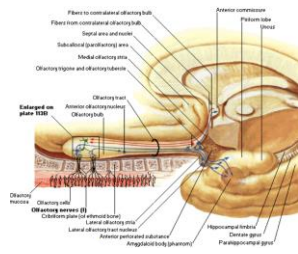


3rd order neuron: olfactory tubercle

4th order neuron: dorsomedial nucleus of thalamus



Olfactory Pathways



Olfactory nerve is divided to:

- o Lateral olfactory stria
- o Medial olfactory stria



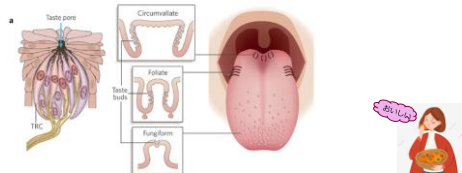
Pathology



Gustatory Pathways

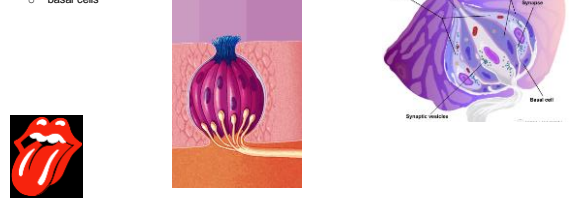
The distribution and types of human lingual papillae

Sense of taste



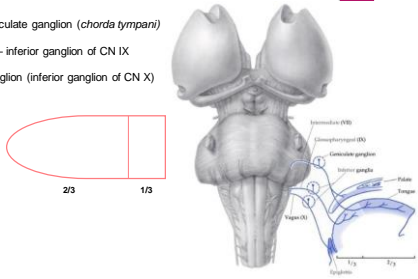
Taste buds

- o receptor cells (replaced about every 9-10 days by differentiating basal cells)
- o supportive columnar cells
- o basal cells



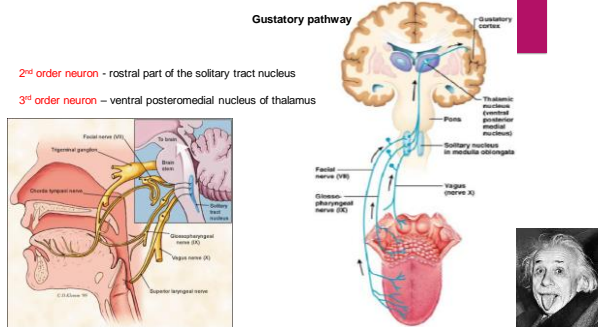
Gustatory pathway

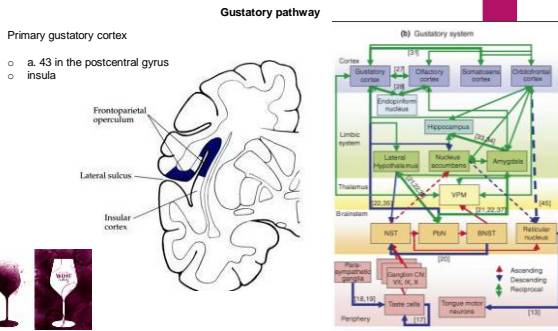
- 1st order neuron
- o CN VII (facial nerve) – geniculate ganglion (*chorda tympani*)
 - o CN IX (glossopharyngeal) – inferior ganglion of CN IX
 - o CN X (vagus) – nodose ganglion (inferior ganglion of CN X)



Gustatory pathway

- 2nd order neuron - rostral part of the solitary tract nucleus
- 3rd order neuron – ventral posteromedial nucleus of thalamus





Gustatory impairment

Gustatory dysfunctions:

- o quantitative disorders
 - a. Ageusia
 - b. Hypogeusia
 - c. hypergeusia
- o qualitative disorders
 - a. Dysgeusia
 - b. phantogeusia



Oral sources of altered taste function are common and can be evaluated by a **dentist**.

Maheswaran, J Pharm Bioallied Sci 2014

Reading list



Thank you very much for your attention

