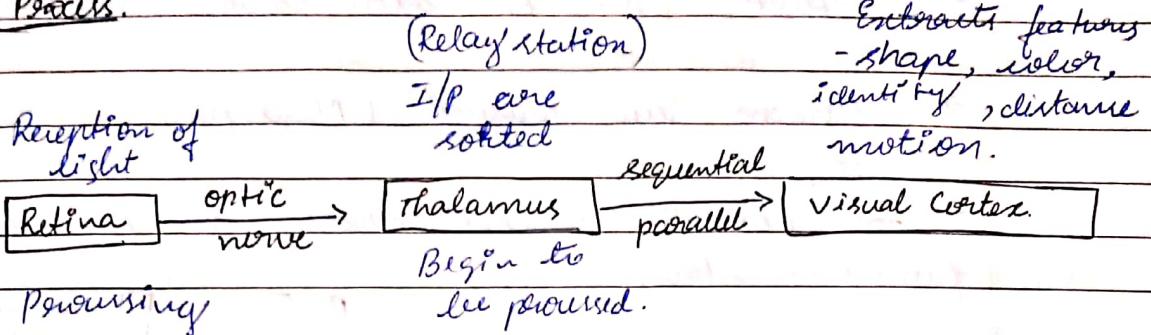


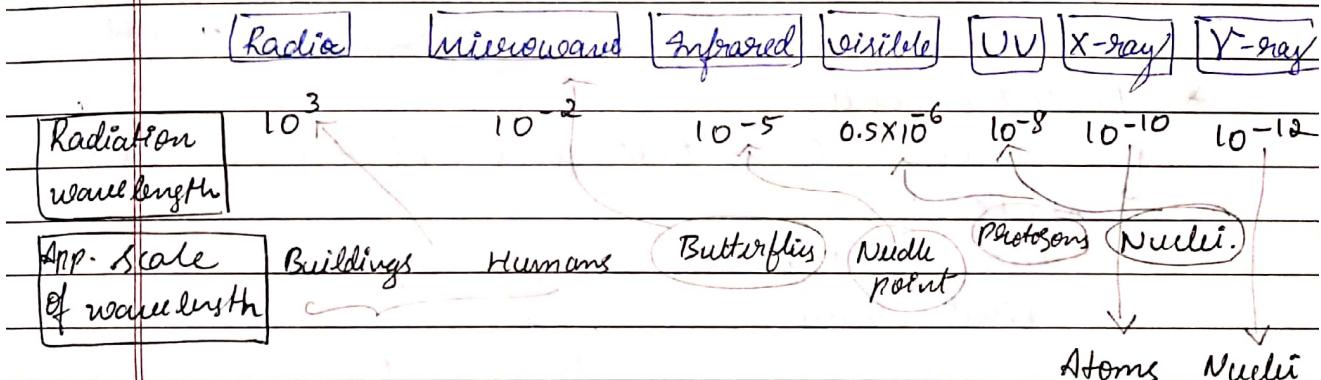
→ Visual system carry out task in both in parallel and sequential.

(back of the brain)

* Process:



* Electromagnetic spectrum:



* The Eye:

→ Brain is not sensitive to light (most part).

∴ light is converted to signal in the retina

→ Light is connected through lens using auxiliary cells.

→ Light sensitive cells called photoreceptors → convert light energy into neuronal activity.

→ Eye adjusts to different illumination by controlling pupil diameter.

→ Human eye - 10 million photo receptors

→ Photoreceptors are unevenly distributed but packed in the center of gaze called the fovea.

→ Around 1 million axon carry info. from retina

→ Human eye around 1 mega pixel.

Retina

→ Eye has 10 distinct layers simplified into 3 functional stages

→ O/p neurons of the retina - Retinal ganglion cells

Photo-reception

rods and cones
(photoreceptor)

Internal transmission

bipolar, horizontal, amacrine cells

output

Ganglion cell

Ganglion ↑ light

interneurons layer

* Photo transduction:

Retina - 2 distinct function (cones, rods)

a. Rods:

Detect light in low light levels

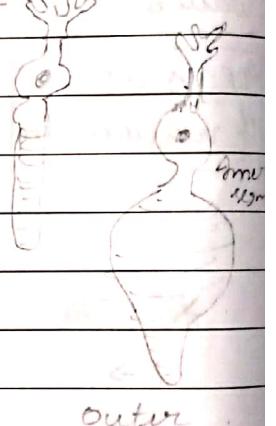
Synaptic terminal

Outer segment

+

Inner segment

+



b. Cones:

Detect light in higher light levels + color.

Synaptic terminal

Outer segment

→

inner segment

→

Synaptic terminal

photons → chemical, chemical → electrical, electrical → chemical

→ Rods out number cones (20 to 1)

→ Photo transduction - light energy to change in membrane potential (photons)

→ Photoreceptors react to electromagnetic energy unlike chemical energy

Certain molecules absorb particular wavelength and

changes shape.

→ An rods light tie chemical - protein Rhodopsin

G_i-protein (opsin) + ligand (retinal) → Rhodopsin
 Coupled receptor
 (form of vitamin A (carrots!))

Like any GPCR's binding ligand to the receptor activates G_i-proteins in the membrane which in turn stimulates downstream enzymatic generation of cytoplasmic second generation molecules. second messenger molecules → changes conductance of ion channels.

In Rhodopsin ligand retinal opsin is already bound to GPCR G-protein (unlike usual GPCRs)
 (one photon is sufficient)

Light absorbed by retinal → 11-cis retinal to all trans retinal.

only light dependent step in the visual system.

changes in opsin back bone

"transduciu" ← Activation of G-protein.

cyclic GMP by ← change in cytoplasmic conc' of 2nd messenger molecules.
 action of cGMP phosphodiesterase

modulation of cGMP ion channels.

changes in membrane potential

RodsDark =cyclic
GMPopen ion channels
(Na⁺, Ca⁺⁺)↓ Na⁺ influxDepolarizes the
photoreceptors
↓

Release neuro transmitter

Cones

Light = (deplete)

cyclic closes ion channels
GMP ↓Hyper polarize the
photo receptors
↓stop releasing neuro-
transmitter

One photon is sufficient to convert 11-cis retinal to all-trans retinal. This is due to biochemical cascade.

Amplification

1 Rhodopsin

↓

100's of G proteins

↓

Each activates many phosphodiesterases (cGMP)

↓

Each degrades 1000's of cGMP.

* Color vision:

Types of cones, (tachomat for 3 color vision)

① Short wave cones (S cones): detect blue light

$$\lambda = 420 \text{ to } 440 \text{ nm}$$

② Middle wave cones (M cones): detect green light

$$\lambda = 535 \text{ to } 550 \text{ nm}$$

③ Long wave cones (L cones): detect red light

$$\lambda = 565 \text{ to } 580 \text{ nm}$$

Rod cells peak $\lambda = 498 \text{ nm}$.

All cones receptor type contain GPCR protein, "photopin" also known as cone opsin which is able to transduce light in a similar manner to rods through the conversion of 11-cis retinal to all-trans retinal.

"Retinal ganglion cells are the only cell type in the retina capable of generating action potentials"

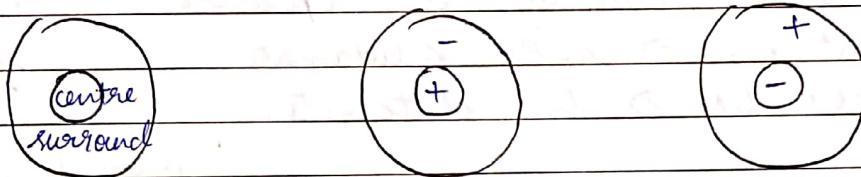
The color sensitivity is due change in number of amino acids for each one type

→ birds and fish have extra one with diff. absorption spectrum (tetrachromat).

Amacrine cell types respond to stimulation with graded change in their membrane potential.

* Retinal Processing

Receptive field: the region of visual space where stimulated evoke response in the cell.



+' response recorded, '-' response abolished when illuminated

The Retinal Circuit

Direct path of information flow - Direct pathway, t/p photoreceptor cell → bipolar cell → o/p RGC.

Neuronal responses are modulated by lateral connections of horizontal and amacrine cells.

"Dark, rather than light, is the preferred stimulus for a photoreceptor".

* Information flow from photo receptors to the bipolar cells:

Photoreceptor release neurotransmitter when depolarized. Retina is part of CNS : main neurotransmitter is amino acid, glutamate.

Each photoreceptor cell is in contact [direct pathway lateral pathway]

Consider direct pathway:

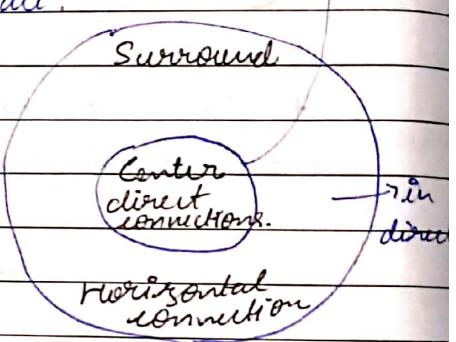
Based on responses to glutamate released by photoreceptors bipolar cells are classified as [ON OFF]
OFF bipolar cells | ON bipolar cells

Glutamate-gated cation channels mediate a depolarizing excitatory postsynaptic potential (EPSP) by hyperpolarizing (after Na^+ influx)

ON - protein-coupled receptors respond to glutamate released by the photoreceptors

ON & OFF meaning cells depolarize in response to light off \Rightarrow more glutamate.
light ON \Rightarrow less glutamate.

Each Bipolar cell is connected by cluster of photoreceptors directly and also by horizontal cells to a ring of photoreceptors that surround the center cluster.



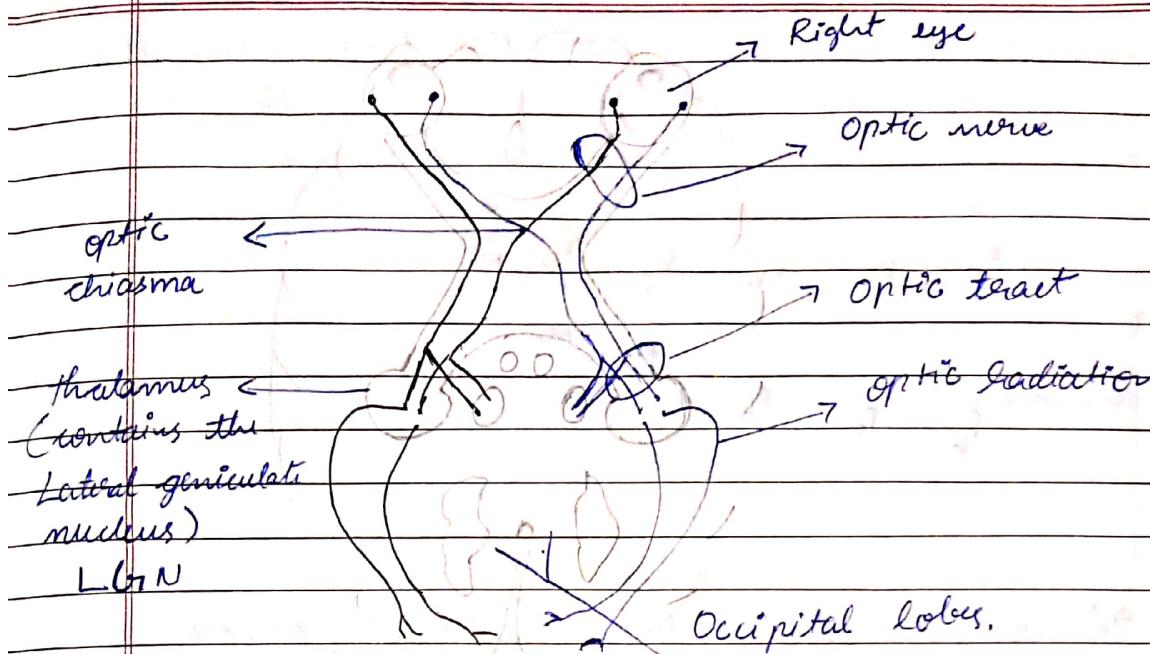
- \rightarrow 1 million retinal ganglion cells.
- \rightarrow 30 specific amacrine cells.
- \rightarrow 1 dozen bipolar cells.

The Retinofugal projection

\rightarrow Neural pathways leaving the eye is referred to as "retinofugal pathway"

5 major parts of retinofugal projection,

- ① optic nerve
- ② optic chiasma
- ③ optic tract
- ④ lateral geniculate nucleus
- ⑤ optic radiation



optic nerve: Nerve fibers leaving each retina. Input from the left visual field is ultimately destined for the visual cortex in the right cortical hemisphere and vice versa.

optic chiasma: Nerves from left and right eyes in a structure called the optic chiasma where nerves from both eyes combine.

This crossing of fibre bundle from one side of the brain to the other is called a decussation.

The Lateral Geniculate Nucleus

Lateral geniculate nucleus (LGN), a cluster of neurons in the thalamus that is important for visual processing. The LGN is in the ventrolateral, part of the thalamus.

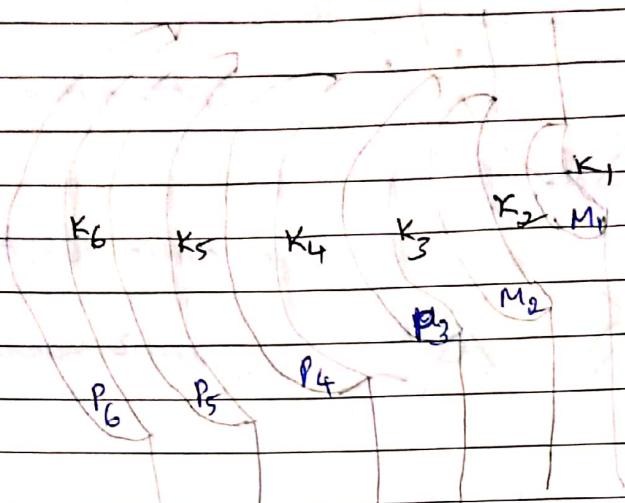
LGN in left hemisphere - I/P from right visual field
 LGN in right hemisphere - I/P from left visual field

I/p = ipsilateral = same side

Contralateral = opposite side

Innervate: Supply with info.

Lateral Geniculate body



→ 2 ventral layer - larger neurons - Magnocellular or m-type neuron

Centre surround receptive fields, firing in response to moving objects.

→ Remaining 4 in dorsal layer - small neurons. Parvocellular or P-type neuron.

Small center surround receptive fields, firing in response to objects shape

→ Tiny neurons in between each layer called the Koniocellular neurons.

Involved in representing certain color info.

LGN input → Retina + visual cortex (80%)

These cells type of LGN are innervated by specific axons from retinal ganglion cells (parallel processing).

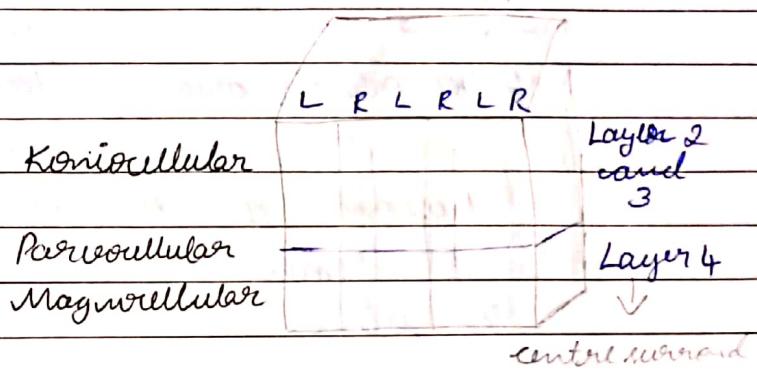
Primary visual cortex (V1) (Striate cortex)
LGN $\xrightarrow[\text{nerve}]{\text{optic}}$ visual cortex (high level processing)

Cortex is like bunch of laminar sheets one over the other here 6 sheets in exact.

Cortex covers the cerebrum with this tissue. It is about 2 mm thick.

Primary visual cortex is the first area in the cortex to receive visual information via LGN.

Connections in the cortex are in orderly pattern referred to as retinotopy. (ODC) Ocular dominance column



Visual Pathway

→ Eye can pivot and move around, controlled by the ocular motor muscles.

Dorsal



Anterior



Posterior



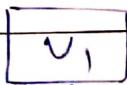
("WHAT")

Ventral Pathway

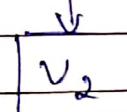
Receptive field

Complexity

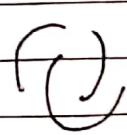
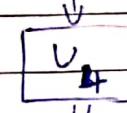
Ventral



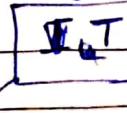
Local edge



longer feature



Curvature



More complex features

inferior temporal

DORSAL Pathway ("WHERE", "HOW")

MT
 middle temporal area direction of movement
 of the visual field
 (direction, velocity)

PPA (dorsal part)
 Posterior parietal area particular parts of
 visual space
 (focusing on particular region)

Lesions of the Visual Cortex.

- Local damage to VI : SCOTOMA = blind spot.
 ↳ blind spot.
- deeper into the ventral pathways local damage
 will lead to AGNOSIA
 ↳ Object. ↳ Face. (PROSOPAGNOSIA)
- Damage area of MT : AKINETOPSIA
 ↳ motion blindness.
- Damage of Parietal cortex: Visual neglect
- Damage to both hemisphere of PPA:
 Balint's syndrome → Simultagnosia (inability
 to experience world as a whole).

AUDITION

- Speed of sound on Earth - 343 m/s.
- Human hearing frequency range - 20 - 20,000 Hz
- "A sound wave is a variation in the medium's pressure"

Ear

- * Structural components of the ear:
① outer ear ② middle ear ③ inner ear.

The outer ear: (pinna)

To collect sound from wide range of environment. The shape of outer ear in humans filter sounds differently that come from different elevations, which help us localize (sound up and down).

The middle ear: (pinna → middle ear)

Air filled cavity → 2½ cms inside the skull.

Sound waves → auditory canal → ear drums

(ossicles) Air filled middle ear

Eardrum (tympanic membrane) \rightarrow moves inward and outward at the same frequency as the sound wave.

Ossicles are the smallest bones in the human body.

\hookrightarrow 3 types;

① Malleus
(hammer)

② Incus
(anvil)

③ Stapes
(stirrup)

Malleus is attached to tympanic membrane, it moves when tympanic membrane moves.

Malleus moves \rightarrow incus moves \rightarrow stapes move

The foot plate of stapes move against the second membrane covering oval window. When stapes move against this membrane it creates wave in the fluid inside cochlea that represents pressure fluctuations of the sound wave in air.

The cochlea - Sound waves to neuronal signal

Coiled up structure (basilar membrane) vibrates in response to sound $\xrightarrow{\text{sound}} \text{mechanical energy}$
 $\xrightarrow{\text{neurons (hair cells)}}$

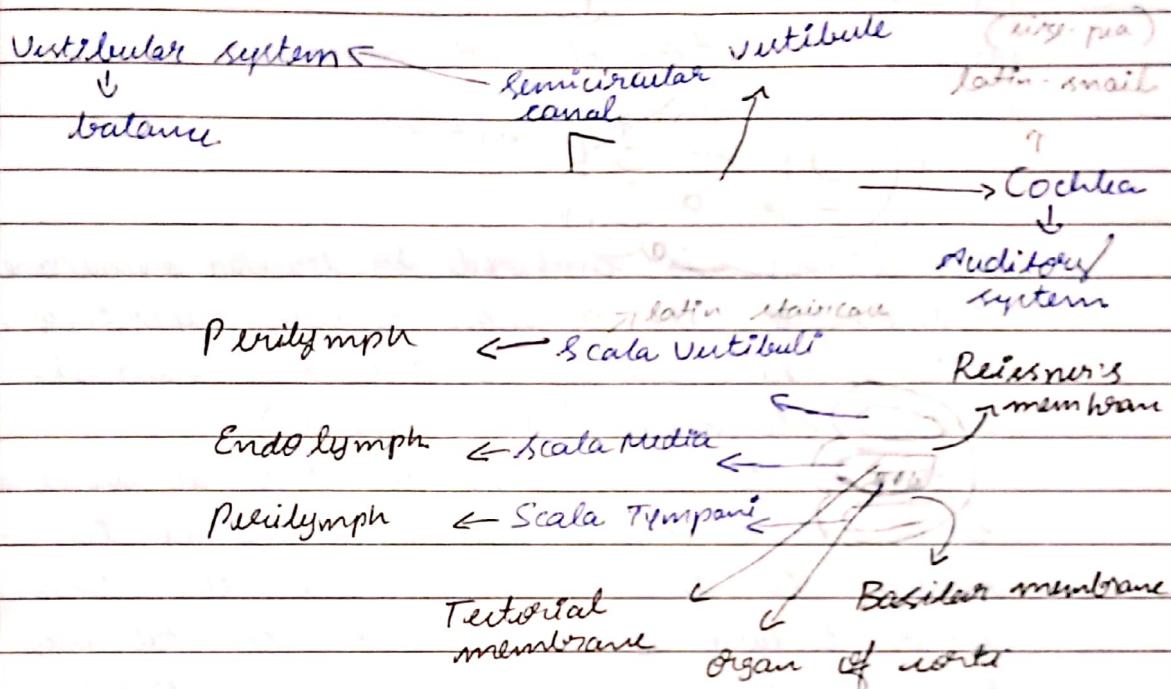
\downarrow
electrical signals

Sound $\xrightarrow{\text{pressure}}$ Tympanic membrane \rightarrow ossicles move
 $\xrightarrow{\text{initiate}}$ Sensory neurons \leftarrow Fluid move in cochlea \leftarrow Oval window move \downarrow mechanical

As sound wave travel reduction in vibration that happens when waves cross air fluid interface is dealt by middle ear. Ossicles in the middle ear increase the pressure output by a factor

of about 30 · (Even amplifies weak sound)
 ↳ Process of protecting from loud sound is called gating.

Inner ear



2 fluids in cochlea:

- 80 ms [① Perilymph: low K^+ , high Na^+
 ② Endolymph: high K^+ , low Na^+]

Physiology of the Cochlea

When sound wave hit the middle ear \rightarrow ossicles move \rightarrow footplate of the stapes push onto the oval window membrane \rightarrow displace perilymph in the scala vestibuli and scala tympani \rightarrow basilar membrane vibrate (relative to tectorial membrane) \rightarrow shearing force on hair cells of the organ of Corti \rightarrow ion channels in hair cells open and close \rightarrow depolarizes or hyperpolarizes the cells (much to electrical signal) \downarrow by hair cells.

Sound wave → vibrates bones

Bones → vibrate fluids

Fluids cause ↓ membrane to fluctuate

Cells move

↓
Ion channels open

Depolarization.

Hair cell is anchored in basilar membrane and surrounded by a non-sensory supporting cell.

Top of hair cell - 60 or so tiny hair like structures called stereocilia (hair bundle).

Attached to bottom of the tectorial membrane when sound causes basilar membrane to vibrate relative to tectorial membrane, the stereocilia tilt either toward or away from the tall edge of the hair bundle. When stereocilia are tilted toward their tall edge from the shearing force, a set of non-selective cation channels open. Tilting away from their tall edge closes these ion channels.

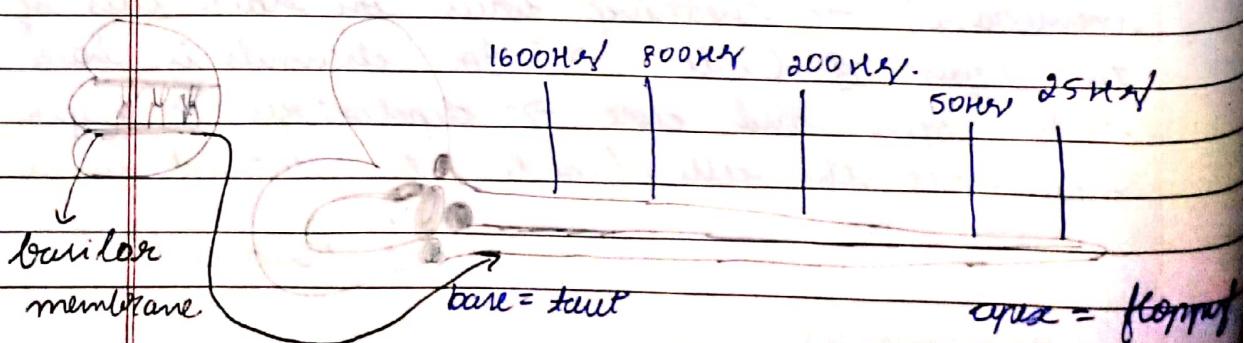
10-1 of ion channels are open during depolarization

Toward tall edge = open = depolarized

Away from tall edge = closed = hyperpolarized

Hair cells → neurotransmitter → spiral ganglion cell → action potential.

Frequency detection



Different parts of basilar membrane vibrate differently based on the frequency present in the sound (tonotopic map)

Frequencies are encoded by which neuron in the cochlea
 - a is active, while how loud the sound is encoded by the level of activity of the neuron.

Subcortical auditory Pathways

Hair cell signal \rightarrow spiral ganglion cells + auditory nerve
 Auditory cortex \leftarrow thalamus \leftarrow midbrain \leftarrow nuclei in brainstem
 Auditory cortex

Complex of nuclei in brainstem \rightarrow Cochlear nucleus complex
 dorsal lateral (of brainstem)

? (optic tectum) superior colliculus

(midbrain) inferior colliculus

principal nucleus

(Integrates auditory signal from both superior olive ears)

medial geniculate nucleus (MGN)

direct and maintain our attention to sound

low freq.

sound intensity and loudness and timing differences b/w the sound perceived

Cochlear nucleus

high freq.

Auditory Cortex

The primary auditory cortex is located bilaterally in the temporal lobes, roughly near Brodmann areas 41 and 42.

Layers

Few cells	1
Pyramidal	2
Pyramidal	3
Infranuclear	4
Pyramidal	5
Pyramidal	6

Area A₁

Primary processing

Frequency

Time

Intensity

Type

Localization

Area A₂

Specialized Processing
phonemes

Localizing sound

Sound reaches ears at different time scales

→ Interaural Time difference = ITD's

→ Lots of neurotransmitter Endbulb of Held released.

→ Many receptors to receive the signal.

→ Allows rapid signal transmission

^{reverberate preferentially}
^{in sight} coincidence detector

Firing only when action potential from two ear converge at the same time

^{prefer} preferentially to left

Interaural Level Differences = ILD's

a - Propagation distance.

b - Reflection / absorption.

Smell, Taste, and the Remaining Senses.

→ Body position (Balance, proprioception), chemical senses are some of sense other than 5 classical sense.

→ Gustation = Taste, Olfaction = smell

Gustation: Receptor.

Chemical tastes: Sweet, salty, sour, bitter.
sugar, starch \leftarrow Na^+, K^+ Acid base, toxin
 \leftarrow food additive

Fifth taste - Umami (Glutamate, amino acids)

Sour - (ion channels) \rightarrow receptor (Na^+) \rightarrow depolarization
brain \leftarrow activation of gustatory fibers \leftarrow neurotransmitter

Carbonation: \rightarrow sour taste receptors enzyme (carbonic + bicarbonates \leftarrow catalyze $\text{CO}_2, \text{H}_2\text{O} \leftarrow$ anhydase)
(peristalsis) \rightarrow activate sour receptor \rightarrow nerve fiber train.

Fat: GPR40 and GPR120 (or proteins)

water taste: PPK28 (in insects)

Sweet and Umami: TR combination

Bitter: 40 T2R

Salt: Epithelial cation.

Gustation Perception

It is the cell, not the chemical receptor, which carries all of the neurobiological meaning. Using transgenic approaches, any molecule can be made to taste either good or bad.

Olfaction: Receptors

In order to perceive smell compound must be easily evaporated at normal room temperature.
There are around 1000 olfactory receptors.

Shape-pattern theory: "Scent perception depends on the amount of structural fit between an odorant's receptor shape and the odorant's shape."

- ① Concentration depends on perception
- ② Specific timing and order

Odor: Percept of a given cell

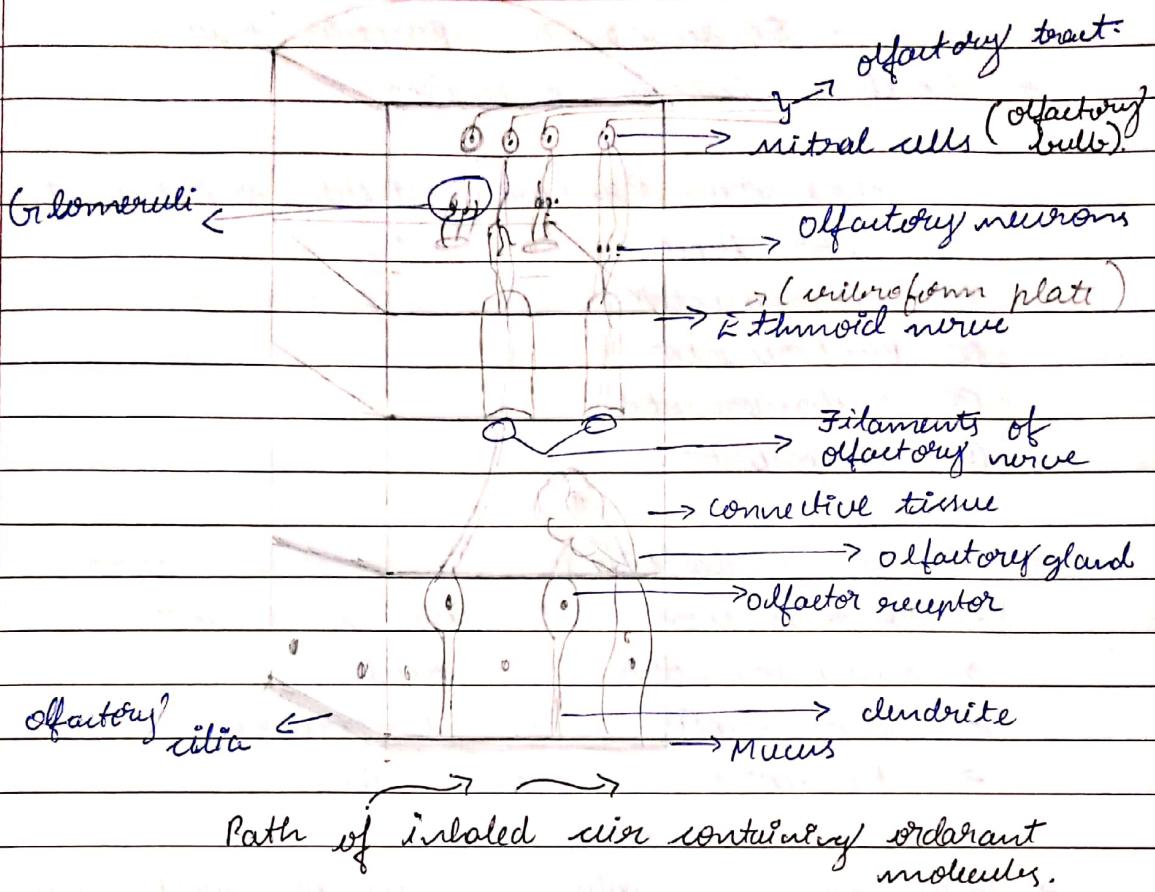
odorant: Volatile chemical that binds to olfactory receptors.

- * Odorene is translated into a functional protein, but pseudogome is not.

Olfactory Pathway

Nose - filter, warm, humidify air + smell
→ olfactory epithelium - specialized epithelial tissue whose primary function is to detect odors. - 3cm on each side. It contains 3 primary cell types.

- ① Supporting cells: metabolic and physical support
- ② Basal cells: precursor cells to the olfactory sensory neurons and thus present a pool of renewable neurons in a stem like state.
- ③ Olfactory sensory neurons (OSNs): small bipolar neurons located beneath a watery mucus layer



Somatosensory Receptors (touch)

→ touch = tactile perception

→ Somatosensory: Pressure, stretch, vibration, temperature

↳ Receptor types,

- ① Thermoreceptor
- ② Photoreceptor
- ③ Mechanoreceptor
- ④ Chemoreceptor.

* Sensory modalities:

→ Proprioception = body movement

→ Mechanoreception = touch

→ Thermoception = temperature

→ Nociception = Pain

* Heat, cold and pain - sensed by naked nerve endings of the skin → transient receptor potential channels or TRP (in plasma membrane)

non-selective to cation (Na^+ , Ca^{2+} , Mg^{2+})

→ Cutaneous sensations! Touch, pressure, heat, cold and pain.

→ Pain sensation = nociception

Somatosensory Pathways

3 long neurons are involved in somatosensory pathway:
Primary, secondary, tertiary neuron

① Primary neuron: Soma in the dorsal root ganglion of the spinal nerve.

② Secondary neuron: Soma in spinal cord or in the brain stem

③ Tertiary neuron: Touch, pain. It has cell body

in thalamus / cerebellum and ends in the postcentral gyrus of the parietal lobe

Movement and Action

3 types of muscles

- ① Cardiac muscle : Keeps heart pumping.
- ② Smooth muscle : control movement of internal organs.
- ③ Skeletal muscle : Control motor activity

→ Skeletal muscles are made up of highly organized horizontal stripes across the muscle mass called myocytes / myofibres / muscle fibers.

↳ multi nucleated + myo filaments (long band of proteins)

↳ (a) actin (b) myosin

Myocytes are made up of many contractile units of actin and myosin filaments, these repeating units are called sarcomeres.

* Anatomical arrangement of skeletal muscles:

- ① Axial : axial muscles in the centre or trunk of our body
- ② Proximal : Closer to the centre. (chest, thigh and upper arms)

- ③ Distal : furthest from the body (forearms, calves, hands, feet)

→ Muscle contraction involves myosin binding to actin which cause the myocyte to contract or shorten.

Lower motor Neurons

(α motor neurons)

- * Lower motor neurons: motor neurons have their cell bodies in the spinal cord and brainstem.

Upper motor neurones: Project down from cortex and inform motor activity through lower motor neurons.

- Each motor neuron innervates multiple muscle fibers
↳ this combination is called a motor unit.

- The collective set of motor neurons whose axons control all the muscle fibers in a single muscle are called motor neuron pool
"when performing a movement, small motor units are recruited first, followed by larger and larger motor units"

- * Henneman's size principle: Increasing the amount of muscle contraction (until) by exerting enough force for a given action.

- Most α neurons have their heads in the ventral horn of the spinal cord.

- * Four main divisions of the spinal cord:

① Cervical - head, neck

② Thoracic - trunk

③ Lumbar - Front legs

④ Sacral - back leg, bladder, bowel, sexual muscles

- * Main input source + (respond) to Lower motor neuron (α):

① Dorsal root Ganglion Cells

② Excitatory and inhibitory spinal interneurons

③ Upper motor neurone

Intrinsic Spinal Circuits

→ Reflexive: short, automatic and involuntary response to the sensory stimuli that occur without conscious control.

Spinal reflex is a closed loop control system.
Input = Dorsal root ganglion cells that respond to sensory stimulation from the environment.
These dorsal root ganglion cells synapse either directly onto a motor neuron or act through spinal interneurons to co-ordinate the motor neuron activity involved in reflexive action.

* Myotatic stretch reflex / stretch reflex!

Ex: when unexpected load is placed on a muscle, its key function is to resist the lengthening of a muscle. (corrective contraction of the same muscle).

Muscle stretch → muscle spindle (sensory organ) → part of sensory organ - proprioceptors which detect changes in muscle length and tension (monitor)

Muscle spindles are located deep within a muscle mass, they are composed of six to eight thin muscle fibres called intrafusal muscle fibres. These thin fibres don't contribute much to the muscle contraction or extension, they report on characteristics of a muscle - its length, and its rate of change in length. This report is conveyed to strong dendrites wrapped around the intrafusal fibres. (cone from dorsal root ganglion cell) whose axons synapse onto the alpha motor neurons in the spinal cord.

The proprioceptive report comes in the form of a stretch of the intrafusal muscle fibres which occurs when muscle mass itself is stretched. This stretch opens mechanically gated

ion channels in the wrapped sensory dendrites, which causes ions to leak in, depolarizing the dendrites and generating action potential in the cell. The action potential in the dorsal ganglion cell is carried through its afferent nerve fibre all the way to the spinal cord, where it synapses on an alpha motor neuron. Generally, this alpha motor neuron will innervate the same muscle in which a stretch was detected. Activation of the alpha motor neuron will induce an action potential in the neuron, which will course down its axon and cause its target muscle fibres to contract. Since the muscle fibres lie in the same muscle that generated the stretch signal, this is a corrective action.

- Stretch reflex \rightarrow 1ms.
 - Only 1 synapse b/w incoming and outgoing
- Motor activity arising from dorsal root ganglion cells of the sensory system and the spinal interneurons need not engage with higher brain areas at all. They drive lower motor neuron activity entirely using circuit intrinsic to the spinal cord.
- When muscle mass stretches both intramuscular and extrafusal muscle fibres stretch. But alpha motor neuron (causes corrective action) contracts the extrafusal muscle fibre (alpha motor neuron doesn't synapse onto intrafusal muscle fibres). \therefore Length of the intramuscular muscle fibres is adaptively reset by another sensory motor circuit (gamma motor neuron)
 - When muscle stretches sensory dendrites wrapped around the ends of the muscle spindle also detect the stretch (secondary afferent dendrites)

Central Pattern Generators (CPGs)

- * Recurrence: Some chain of connected neurons loop back on to itself.

Central Pattern Generator (CPGs):

External sensory cues can modulate the activity of central pattern generators.

- CPGs that control walking are located in spinal cord.

Brain Control of Movement

- * Different nuclei in the brainstem and primary motor cortex that provide info to spinal cord circuitry:-

① Dorsolateral pathway: which runs through the dorsal (upper) and lateral (outermost) part of the spinal cord and controls voluntary movement of the distal muscles.

② Ventromedial pathway: ventral (lower) and medial (inner most) part of the spinal cord controlling the proximal and midline muscles which are essential for generating automatic functions of maintaining posture and generating locomotion.

→ Dorsolateral pathway is under the direct control of the cerebral cortex and the midbrain.

→ Ventromedial pathway is directly controlled by various nuclei in the brainstem.

- * To stand upright:

Signal originates in the right motor cortex and terminates in the left midline muscles. This means that at some point, the information must cross the midline (generally through interneurons).

when signal is leaving the right motor cortex, it travels down from brain through the upper motor neurons to the spinal cord. We also know that the left midline muscles got their info. directly from lower motor neurons. So information must pass from the upper motor neurons through the spinal cord interneurons and onto the lower motor neurons.

Upper motor Neurons

- * Primary motor cortex, M1 (Brodmann area 4): neurons with their cell body in M1 project directly to lower motor neurons in the spinal cord and brainstem. → voluntary control of muscle. Commands from M1 travel through the corticospinal path into the spinal cord and synapse onto alpha motor neurons and inter neurons to guide motor activity. Cells projecting out of M1 are known as Upper motor neurons.

M1 has 6 distinct layers (as most of the cerebral cortex).

- * Premotor cortex (anterior side of M1) (Brodmann area 6): involved in higher level motor behaviour than M1

- * Posterior parietal cortex (Brodmann area 7): lies posterior to M1 and is another high level motor area. Planning movements taking into account the location of the body in space, as well as location of various other objects with which the body might need to interact.

→ M1 are organized in a somatotopic map on the sensory cortex.

Corticospinal Neurons:

* Learn from the distal motor task.

- ① Different motor neurons fire when flexing vs extending.

Conclusion: Upper motor neurons are sensitive to direction of movement.

- ② There is a delay between activity in the motor cortex and activity in the muscle.

Conclusion: Motor cortex is activated before muscles, not in response to them.

- ③ Corticospinal activity scales with force required.

Conclusion: Upper motor neurons can limit their firing to the amount of force needed.

- ④ Specific actions produce reliable patterns of activity.

Conclusion: MI neurons do not habituate.

* Upper motor neuron activity:

- ① Direction
- ② Force
- ③ Amplitude
- ④ Sequence

Subcortical Brain Areas

The Hindbrain (Rhomboencephalon)

The hindbrain is a collection of structures that are responsible for many of our automatic functions. It consists of cerauatem (medulla, pons and midbrain) and the cerebellum.

- Lowest part of the brain contiguous with the spinal cord.
- Heart, respiration, swallowing.
- Cerebellum - latin - little brain - nerve structure
- * medulla is at very base of the brain - where spinal cord enters the skull. Medulla connects the higher levels of the brain to the spinal cord.
 - Maintenance of posture.
 - Basic protective motor reflexes (vomiting, coughing, sneezing and swallowing).
 - Autonomous nervous system function: Regulation of breathing, heart rate, blood pressure, digestion.

Pressure receptors in the medulla mediate vasoconstrictive reflexes to adjust the widening and tightening of our blood vessels.

Chemosensors regulate respiratory function by detecting the change in pH in our blood.

- * Pons: (latin - bridge) serves as bridge to midbrain. Pontine nuclei in pons are involved in: sleep, ^{conscious}, Respiration, Swallowing, Chewing, Bladder control, Eye movements, facial expressions, upright posture

- Central pontine myelinosis: disorder in which typically myelinated nerve projections in the pons lose their myelin wrapping and thus the ability

Brainstem: The midbrain, pons, medulla
↳ receives no i/p from rest of the body

classmate

Date _____

Page _____

to conduct nerve signals properly.

The Midbrain (Mesencephalon)

Located above hindbrain below forebrain.

→ vision, hearing, motor control, regulation of sleep and wake cycle, arousal and alertness, temperature regulation.

* **Tectum:** (latin - roof) makes up the top part of the midbrain and it controls the auditory and visual reflexes. In human tectum entirely of four small bumps - the colliculi (l - little hills).

→ inferior colliculi : uppermost part, control visual reflex.

→ Superior colliculi : auditory processing.

Auditory processing

→ reflexive action.

* **tegmentum** - transmitting commands for voluntary movement but also in producing them. Hunger, thirst, etc

* **Substantia nigra** (midbrain nucleus) (l - black substance): These neurons synthesize the neurotransmitter dopamine. Also contain high levels of melanin (pigment responsible for dark appearance).

The Cerebellum (Major hindbrain structure)

Cerebellum doesn't generate motor activity itself either, the cerebellum modifies both voluntary motor commands coming down from the cortex to the spinal cord and automatic motor influences coming from the brain fine tuning each based on environment context and learning outcomes.

→ 10% of the brains volume but contains 50% of the brains total neurons

* 2 major types of neurons in cerebellum.

- ① Purkinje cells ② Granule cells.

→ Purkinje neurons are a class of GABAergic interneurons with very large and characteristic dendritic arbor. (largest neurons in the brain).

→ Inhibitory (Purkinje)

→ Granule cells in the cerebellum are the smallest neurons in the brain and send out only four or five dendrites per cell. (excitatory + inhibitory)

→ Humans have 50 billion cerebellar granule cells that is $(3/4)$ of the total number of neurons in the brain.

→ Glutamatergic and excitatory

* 3 layers of cerebellar cortex:

a) The innermost layer contains the nuclei of the cerebellar granule cells pressed against deeper white matter.

b) Cell bodies of Purkinje cells

c) Axons of the granule cells as well as densely branching dendrites from the Purkinje cells.

* 3 prominent types of axonal projections in cerebellar cortex:

- a. mossy fibres b. climbing fibres c. parallel fibres

Mossy fibres and climbing fibres provide input to the cerebellum from the rest of the body. The mossy fibres originate in the brain stem and make excitatory connections onto cell bodies in the deep cerebellar nuclei as well as onto the

the granule cells in the cerebellar cortex.

Climbing fibres come exclusively from a particular region in the medulla called the inferior olive. These fibres have long axons which climb up the dendrites of Purkinje cells. Each Purkinje cell receives one very powerful input from a single climbing fibre.

Parallel fibres come from inside the cerebellum and are axons of the granule cells, which split into the topmost cortical layer, run in parallel to the folds of the cerebellar cortex and perpendicular to the Purkinje cell dendritic arbor.

→ Cerebellum: Co-ordination and timing of voluntary movements, sense of equilibrium, language, attention.

The Forebrain (Prosencephalon)

→ The cerebral cortex is the most part of the brain.

(Cerebrum)

* 4 main functional systems of the forebrain:

- ① Cerebral cortex
- ② The basal ganglia
- ③ The thalamus
- ④ The limbic system.

The Basal Ganglia

Cluster of subcortical nuclei located at the base of the forebrain. Basal ganglia are associated with voluntary movement and also involved in the learning and execution of actions that become habitual or automatic. (also emotional and cognitive)

Parkinson's disease (PD)

→ Rigidity and slowness of movement.

a. Due to difficulty initiating or. choreiform; chorea = and carrying out voluntary dance movement.

b. Reduction in dopamine extremitie and face prevents excitation of the c. Due to loss of striatal direct pathway.

→ Resting tremor

Huntington's disease (HD)

→ Allost involuntary movements.

b. Especially affect

c. Due to loss of striatal neurons in the indirect pathway.

The Thalamus ("Gateway to cortex")

- The thalamus is the largest part of the diencephalon. It sits near the center of the brain b/n the cerebral cortex and midbrain.
- Each of thalamus in human: 3 cm long, 2.5 cm wide and 2 cm high
- Thalamus acts as relay station b/n incoming signals from the sense organs in subcortical areas, to the cerebral cortex and back again.
- It is involved in :
 - (a) Top down regulation of processes : sleep, attention, consciousness.
 - (b) Bottom up transmission of information the cerebral cortex needs to guide those processes.
- Thalamus does not receive inputs from olfactory system (smell)
- Lateral geniculate nucleus → receives auditory information
Medial geniculate nucleus → receives visual information.
- Thalamus is also involved in arousal and level of awareness.
- * Fatal familial insomnia! Causes selective programmed degeneration of thalamic neurons. Patients die after months of being completely unable to fall asleep.

The Limbic System

It is just below and behind the basal ganglia and on either side of the thalamus.

* Protoreptilian brain = Basal ganglia, midbrain, cerebellum.

Paleomammalian brain = Limbic system.

Neomammalian brain = Cerebral cortex.

→ The limbic system is involved in: Rewards, threat reinforcements, punishment, emotional and motivational context (fear, pleasure, adrenaline), formation of memories (with emotional significance).

* Amygdala: (Greek - almond shaped): sits at the base of the thalamus, deep in each temporal lobe. It is composed of set of separate nuclei, each with distinct structural and functional characteristics.

Each amygdala sends neuronal projections to the hypothalamus, the thalamus. Info. regarding taste, touch, smell and vision come to amygdala from both the thalamus and the cortex. Olfactory info comes directly to amygdala's nuclei skipping thalamus entirely.

The Hippocampus

(Gr. seahorse)

The hippocampus is involved in declarative memory. 2 hippocampi sit on either side of the thalamus just below the amygdala.

Activity in hippocampus is necessary for converting short term memories into long term memories.

Cells in hippocampus and also in neighboring entorhinal cortex constitute a sort of positioning system in the brain.

The hippocampus is one of the 2 regions in the adult human brain where neurogenesis is found to occur. (another is subventricular zone (SVZ) of the lateral ventricles).

→ Regulates basic needs : 4 F's
Fighting , Flying , Feeding , Mating (F) !

The Hypothalamus

Hypothalamus is found in all vertebrates, in humans it is about the size of a small grape and sits below the thalamus and above the brainstem.

Hypothalamus is termed as human body's thermostat and it is involved heart rate, plasma-sodium concentration and temperature. The Hypothalamus's central role is the maintenance of internal homeostasis - a steady state of equilibrium and physiological constancy.

- * 3 prolonged response of hypothalamus (to disturbance)
 - ① Engaging the autonomic nervous system
 - ② The endocrine system
 - ③ The behavioral system

It sends commands to the brainstem and the spinal cord that activate autonomic pre-ganglionic neurons to mount a fight or a flight, or rest and digest response.

It also activates the basal ganglia and the cortex and controls hormone release via a structure called pituitary gland.

- Feeling hungry, thirsty, desire to have sex, parenting and attachment behaviour

Revisiting

→ Input from the LGN arrives only in layer 4 of primary visual cortex (V1).

→ Transgenic mouse likes the taste of lemon:⇒ The sour receptor is being expressed in cells that usually detect sweet things.

* Olfactory system:

Mucus layer → Olfactory sensory neurons → Olfactory nerve → Olfactory bulb → Primary olfactory cortex

→ The somatosensory neurons in the periphery that conduct pain are typically slow, thin, unmyelinated.

→ Heat - infrared radiation.

→ Muscles on one side of the body are controlled by commands from the contralateral motor cortex. Neurons in M1 control highly specific muscle movements like moving a finger or flexing a wrist while neurons in the premotor cortex direct complex multi muscle movements.

* Cerebral Cortex: (A layered sheet of Neurons)

Convoluted surface of meninges, about $\frac{1}{8}$ in of an inch thick.

→ Approximately 30 billion neurons. Each neuron can make about 10,000 synapses, approximately 300 trillion connections in total.

→ 6 layers of neurons.

* Corpus callosum: Bundle of nerve fibers connecting the 2 hemispheres of the brain and allowing for communication b/w them.