Page No.
Date / /

Module-4

Biological signal generation and Propagation

- Nerve cell Structure & Signal Propagation
- Mechanism of vision & hearing
- Cell Signaling
- Circadian Rhythm.

Nerve cell Structure

Cells of the Nervous system

- Two main types
  - Neurons
  - glia

Neurons

- Neurons are excitable cells
- conduct the impulses that make possible all nervous system functions

- They are the wiring of the nervous System's information circuits.

- The human brain is estimated to contain about 100 billion or about 10 % of the total number of nervous system cells in the brain.

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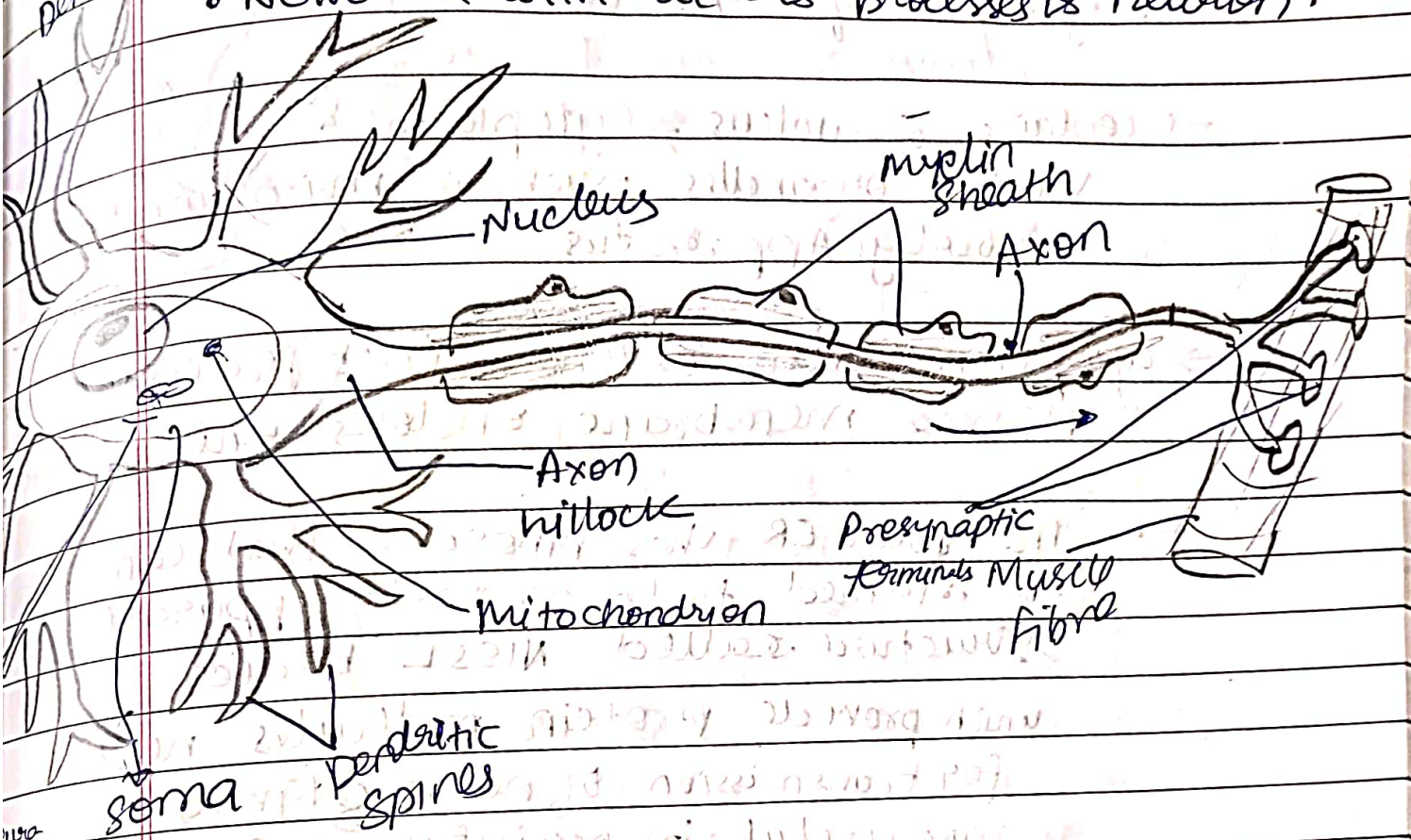
Peacock
Page No.
Date / /

Structure of Neuron :-

- Nerve cell with all its processes is neuron.



All neurons consists of

- **Cell Body**
  - Also termed SOMA or PERIKARYON
- **Dendrites Process**
  - are thread like and often known as nerve fibers.
- **Axon Process**
  - are also thread like and often known as nerve fibers

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Page No. Peacock
Date / /

Cell body of a Neuron :—

→ Largest part of the neuron

→ contains a nucleus, cytoplasm & various organelles such as mitochondria & Golgi Apparatus

→ cytoplasm also extends into processes & plasma membrane encloses entire neuron

→ The rough ER has ribosomes that can be stained to form easily apparent structure called NISSL Bodies which provide protein molecules needed for transmission of nerve signals & are useful in maintaining & regenerating nerve fibers

Dendrites

- usually branch extensively from cell body
- The distal ends of dendrites of sensory neuron may be termed as receptors b'coz it receives the stimuli that initiate nerve signal
- They receive stimuli and conduct electrical signal toward the cell body and/or axon of the neuron.

Teacher's Signature.....

Peacock
Page No.
Date / /

Axon of the neuron

- Axon is a single process
- usually extends from a tapered portion of cell body at a location termed as Axon hillock.
- Axon conduct impulses away from the cell body.
- Even though neurons have only one axon that axon often has one or more side branches termed as axon collaterals
- The distal tips of axons form branches called telodendria which each terminate in a synaptic knob which contain mitochondria & numerous vesicles.

Size of axon

- some are a meter long and some are only a few millimeter
- Their diameter also varies. The larger the diameter the faster the impulse.
- An axon can be myelinated or not. However only axons can have myelin sheath dendrites do not

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Parts

1. Axon
   i) generally long
   ii) arises from axon hillock
   iii) axon cylinder has axoplasm, neurofibrils & mitochondria.
   iv) axons end in terminal buttons
   v) carry impulses away from cell body

2. Dendrite
   i) multiple and short
   ii) contain nissl granules
   iii) carry impulses towards soma

3 Cell body : Neurocyton or soma
   i) nucleus - pale, large, spherical, central
   ii) neuroplasm - has neurofibrils, nissl granules, mitochondria, golgi apparatus, neurosecretory material

Classifying

Neurons

Two ways
- Structural
- functional

Structural classification of Neurons

- can be classified according to the no. of extensions form cell body, there are 3 types
  - Multipolar
  - Bipolar
  - Unipolar

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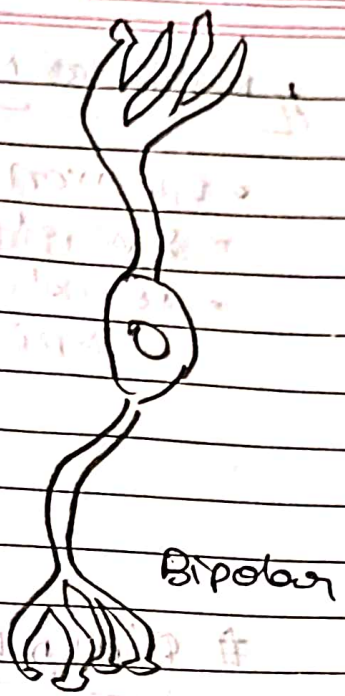
Anaxonic neuron



Bipolar

Classification of Neuron

1. (a) Golgi body type I
   (b) Golgi body type II

2. Anatomic classification
   a) Unipolar
   b) pseudounipolar
   c) Bipolar
   d) Multipolar
   e) Apolar

3. Physio anatomic classification
   a) afferent
      i) somatic
      ii) visceral
   b) efferent
      i) somatic
      ii) visceral

4. Depending on Myelination
   a) myelinated
   b) unmyelinated

Teacher's Signature.....

Page No. Peacock
Date / /

Multipolar Neurons

- one axon
- several dendrites
- found in brain & spinal cord

Bipolar Neurons

- one axon
- Branched dendrites
- Are the least numerous kind of neuron
- found in:
  - inner ear
  - retina
  - olfactory pathway

Unipolar Neurons

- Also termed as pseudounipolar neurons
- have single process extending from cell body.
- are always sensory neurons conducting information toward the CNS.

- The single process branches to form a central process extending from cell body
- Are always sensory neurons, conducting information toward CNS.

- This single process to form a central process toward CNS & a peripheral process (away from CNS) which together for an axon

  - It conducts impulses away from dendrites found at distal end of peripheral process

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Peacock
Page No. 8
Date / /

Functional classification of Neurons

can be classified according to direction in which they conduct impulses, there are 3 types
- Afferent
- Efferent
- Interneurons

Afferent Neurons

- They are sensory.
- They transmit nerve impulses to spinal cord or brain.

Efferent Neurons

- Motor
- Transmit nerve impulses away from the brain or spinal cord or toward muscles or gland

Interneuron

- conduct impulses from afferent neurons to or toward motor neurons
- located entirely within CNS (brain & spinal cord.

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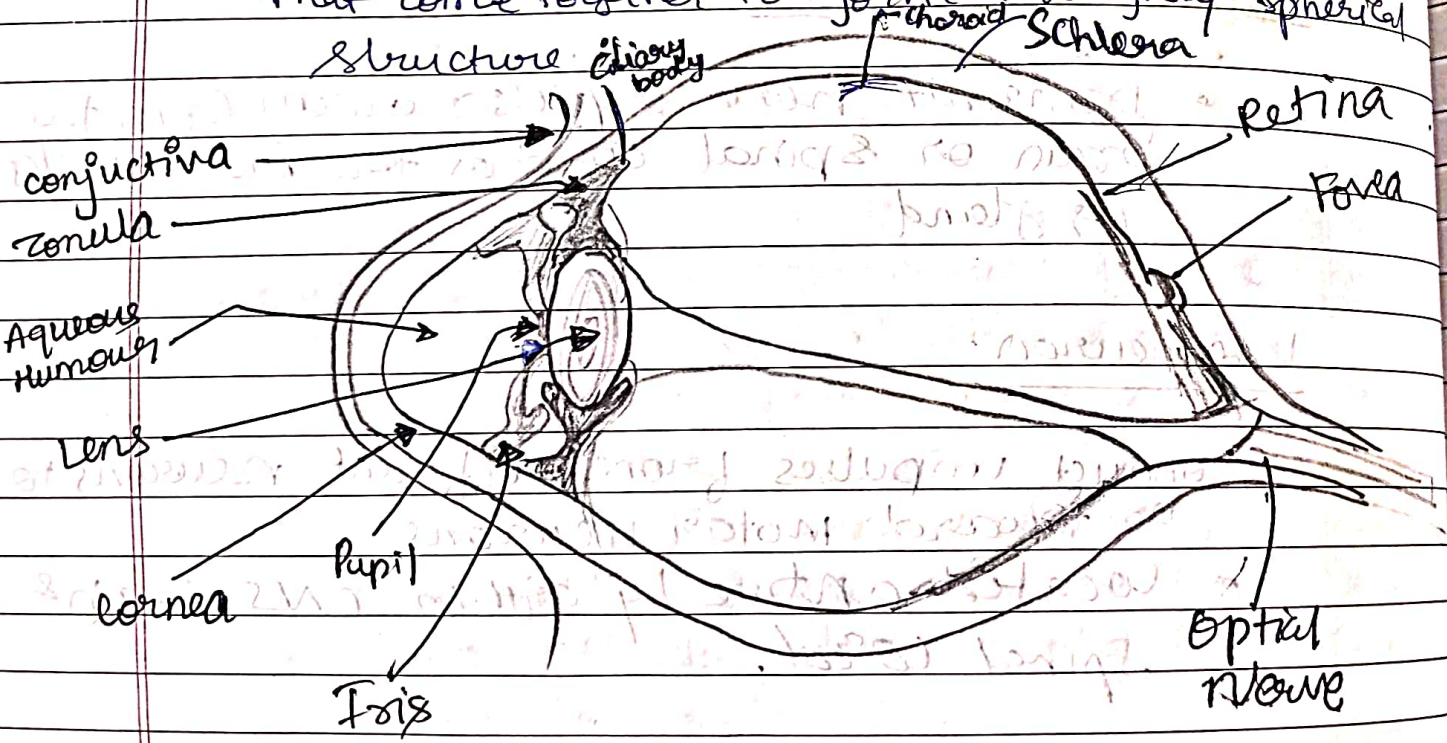
Vision (Eye)

The Visual System

The human visual system can be regarded as consisting of two parts:
The eyes act as image receptors which capture light & convert it into signals which are then transmitted to image processing centres in the brain.

The Eye

The human eyes are the most complicated sense organs in the human body.
It is made of several muscles and tissues that come together to form a roughly spherical structure.



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Peacock
Page No. 8
Date / /

* External Structure of Eye :—

- **Sclera** : It is a white visible portion. It is made up of dense connective tissue & protects the inner part

- **conjuctiva** : It lines the sclera and made up of stratified squamous epithelium It keeps our eyes moist & clear & provides lubrication by secreting mucus & tears.

- **Cornea** : It is transparent, anterior or front part of our eye, which covers pupil & the iris. The main function is to refract the light along with lens.
The cornea & aqueous humour act as a primary lens which perform crude focusing of incoming light signal.

- **Iris** : It is the pigmented, coloured portion of the eye, visible externally The main function of the iris is to control diameter of the pupil according to the light source.

- **Pupil** : It is the small aperture located in the centre of the iris. It allows the light to enter and focus on the retina.

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- The muscle called zenula controls the shape & positioning (forward & backward) of the eye lens. This provides the control over how light entering the eye is focused.

- Iris allows dynamic control of amount of light entering the eye so that eye can work well in wide range of viewing conditions from dim to very bright light.

* Internal components of eye

- Lens: It is transparent, biconvex, lens of an eye. The lens is attached to the ciliary body by ligaments. The lens along with cornea refracts light so that it focuses on retina.

- Retina: It is the innermost layer of the eye. It is light sensitive & acts as a film of camera. Three layers of neural cells are present in them i.e., ganglion, bipolar & photoreceptor cells. It converts the image into electrical nerve impulses for the visual perception by the brain.

- A small central region of retina called the fovea is particularly sensitive because it is tightly packed with photo-sensitive cells. It provides very good resolution and is used for close inspection of objects in visual field.

- Optical Nerves: It is located at posterior portion of the eyes. The optic nerves carry all the nerve impulses from retina to the human brain for perception.

- Aqueous humour: It is watery fluid present b/w the cornea & lens. It nourishes the eye & keeps it inflated.

- Vitrous humour: It is transparent, jelly-like structure present b/w lens & retina. It contains 99% water, collage, proteins etc. The main function of vitrous humour is to project eyes & maintain its spherical shape.

Note:- There are two general classes of light sensitive cells in the brain: rods & cones. Rods cells are very sensitive and provide visual capability at very low light levels. Cone cells perform best at normal light levels. There are roughly 120 million rod cells & 6 million cone cells in the retina. There are many more rodes than cones b'coz they are used at low light levels & so more of them are required to gather sufficient light.....

The cones are concentrated towards & the rods away from centre.

→ within fovea the cone cells are very tightly packed & blood vessels and other cells are pulled aside to expose them directly to the light.

→ The concn of cones in fovea mean that in normal light we have our best visual acuity in the centre of visual field.

→ TO be seen at high resolution the image of an object must fall on fovea.

→ In dim light, such as that of a starlit night, the images we see come entirely from rods in our eyes. under these condn fovea effectively acts a second blind spot.

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Peacock
Page No.
Date / /

Retinal circuitry

Although 120 million rods & 6 million cone cells in the retina there are less than a million nerve fibres which connect them to the brain.

→ There can't be one-to-one connection b/w photoreceptors & nerve fibres

→ In outer part of retina, as many as 600 rods are connected to each nerve fibre while in fovea there is an almost one-to-one connection b/w cones & fibres.

→ The bipolar receives & transmit signals from receptors to one ganglion. bipolar gathers signal from several receptors while in fovea there is usually one for each cone. The horizontal cells connect adjacent receptors & amacrine cells link multiple ganglions.

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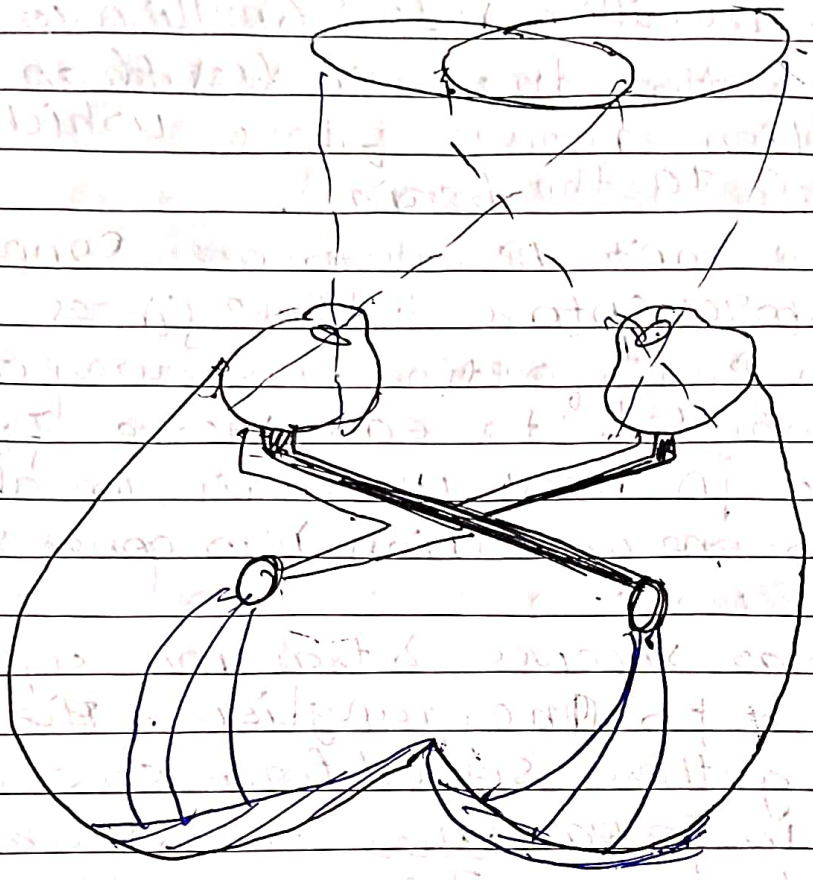
Visual Processing in the brain



The signal produced in retina are propagated backward through nead along optic fibre tract. which is linked via lateral geniculate nucleus to the visual cortex. The signal from right side of each eye propagated to right side of brain & those left side of each eye to left side of brain.

From optical chiasma the optic fibres terminate in the lateral geniculate bodies from these optic radiations extend into primary areas of visual cortex. These are general interceptive area of brain.

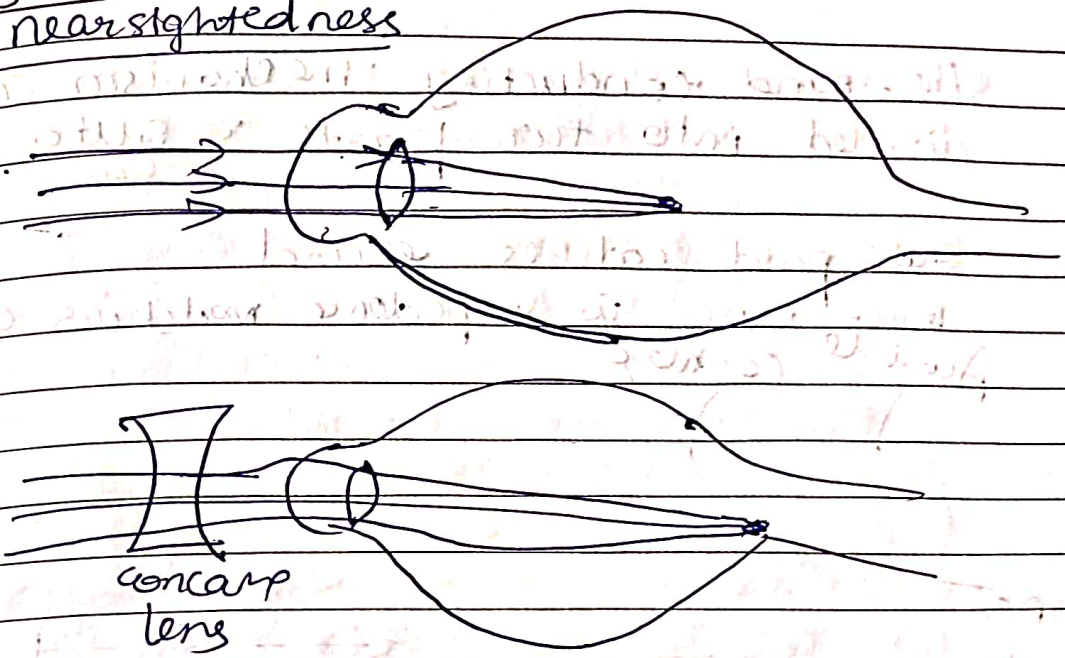
Teacher's Signature.....

Peacock
Page No
Date / /

Accomodation of eye

↳ process by which ciliary muscles change focal length of an eye lens to focus distant or near objects clearly on retina is called accomodation of eye

Myopia
Nearsightedness



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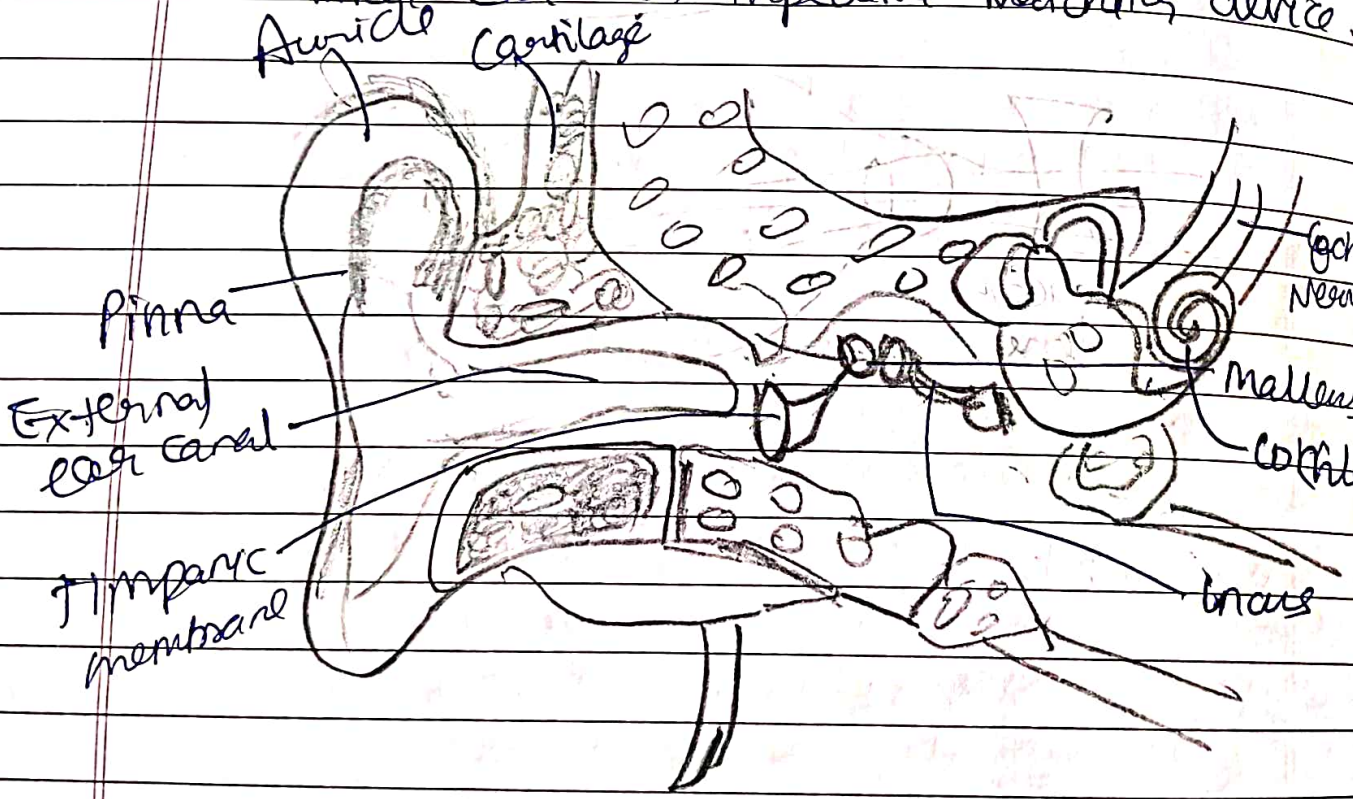
Ear (hearing)

Hearing is one of the major senses used to alert communicate pleasure & fear.

The fn of the ear is to convert physical vibration into an encoded nervous impulse.

The sound conducting mechanism is divided into two parts : Outer & middle ear

Outer part catches sound
Inner ear is impedance matching device.



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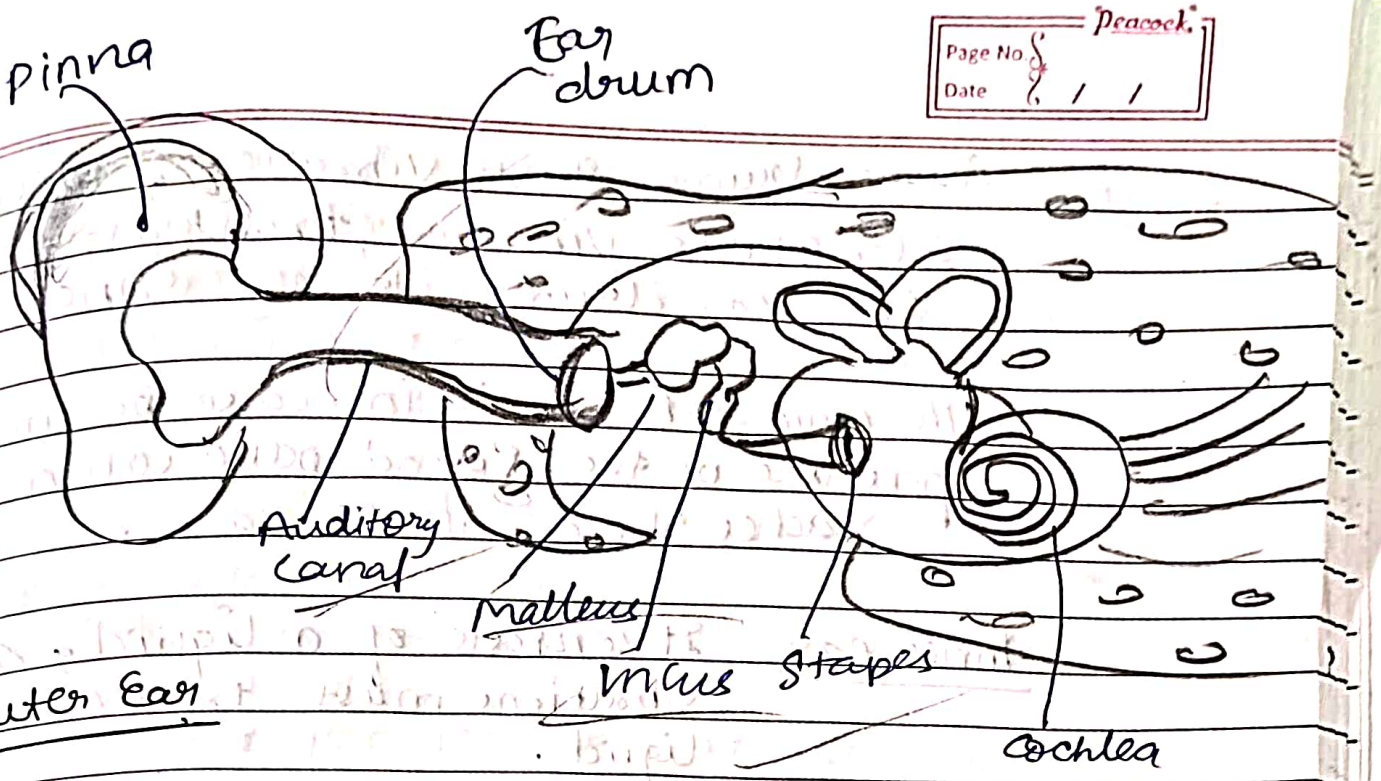

Outer Ear

Pinna : Outermost part . It protects foreign organisms and dust from entering. Its job is to collect as much sound wave as possible & channel it into the auditory canal

auditory canal : The sound waves pass through auditory canal & eventially meet ear drum. This have wax glands

Eardrum : The ear drum is a transparent membrane which is super sensitive to the vibration of the air . It is just like skin of drum.

Middle part of ears consists of 3 tiniest bones of human body & they are together are called ossicles : Malleus , Incus , stapes
(Hammer) (Anvil) (Stirrup)

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As ear drums starts vibrating, ossicles also starts vibrating, tranfering the vibration from ear drums to the inner ear.

The main job is to increase or amplify the pressure of the sound wave when it reaches the inner ear.

Inner ear It consists of a liquid, so vibrations must transfer into a liquid.

ossicles increases the sound pressure about 20 times.

when force gets transferred from ear drum to stapes it gets concentrated in a very tiny area.

Inner ear: TOP Part semi-circular rings which help us in maintaining our balance when walking or dancing or whatever we do

Snell like structure called cochlea.

cochlea contains liquid & it receives the vibration that (pressure pulses) convert these into electrical signals and all these electrical signals go through auditory nerves all the way to your brains where it gets finally interpretted as sound.

Teacher's Signature.....

Peacock
Page No. 8
Date / /

cochlea is sensitive to
1. Loudness
2. Frequency
3.

Ear

Ear performs two main fn :- hearing & eqm maintainance.

- Organ of corti (cochlea) is responsible for hearing fn
- macular (saccular & utricle) are responsible for static equilibrium
- cristae (semicircular canals) are responsible for dynamic equilibrium

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Cell signalling

It is the process by which cells communicate with other cells within their body or with the external environment

Types of cell signalling Molecules

- Intracrine Ligands: Produced by target cell & bind to the receptor within cell.
- Autocrine Ligands: They in internally & on other target cells & immune cells
- Juxtacrine Ligands: target adjacent cells.
- Paracrine Ligands: target cells in vicinity of orginal cells.
- Endocrine Ligands: Produce hormones

Stages of cell signalling

- Binding of signal molecule to receptor
- signal transduction where chemical signal activate the enzymes
- finally response is observed

Cell Signalling Pathways

They are either mechanical or biochemical. It is categorized based on distance it must travel.

Teacher's Signature.....

Peacock
Page No.
Date / /

Cell signalling function

- Intracellular receptors
- Ligand gated ion channels
- G-protein coupled receptors
- Tyrosine kinase

Circadian Rhythms ?

They are physical, mental & behavioral changes that follow a daily cycle. They respond primarily to light & darkness in an organism's environment. Sleeping at night & being aware during day is example of light related Circadian rhythms.
Circadian rhythms are found in most of living things including plants, animals etc.
Its study is known as chronobiology

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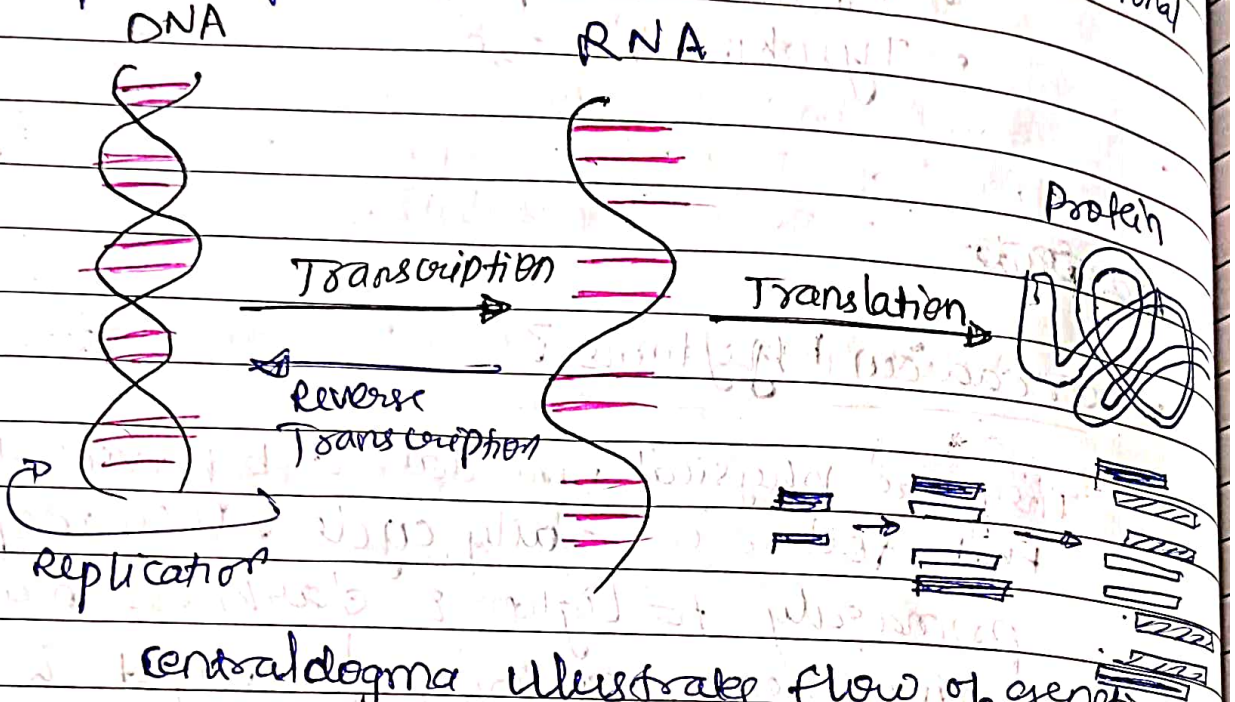
Central Dogma

It is the process in which genetic information flows from DNA to RNA to make a functional product protein



Centraldogma illustrates flow of genetic information in cells, DNA replication, coding for RNA through transcription process further RNA codes for proteins by translation.

The new DNA strands are formed with one strand of parent DNA & other is newly synthesized, this process is called semiconservative DNA replication

Transcription : Process by which information is transferred from one strand of DNA to RNA by enzyme RNA Polymerase. The DNA strand which undergoes this process consists of 3 parts promoter, Gene, terminator.

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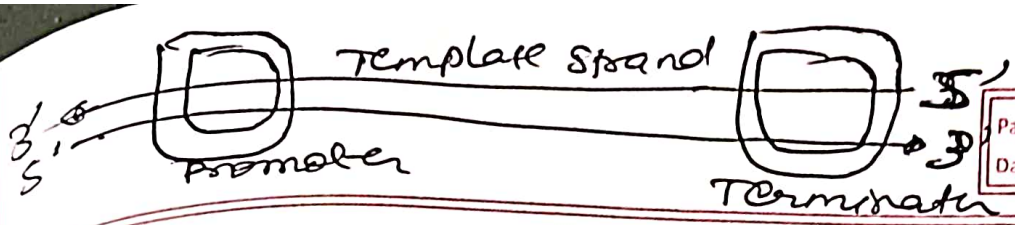

Peacock
Page No.
Date / /

Translation : It is the process by which RNA codes for specific proteins.
It is active process requires energy provided by charged tRNA molecules.
Ribosomes initiate translation process.

Generic code contains information of protein manufactured from RNA.
64 codons : 3 stop codons
one initiater codon (AUG coding for Methionine)

PCR (Polymerase chain Reaction)

It is a technique used in molecular biology to create several copies of a certain DNA segment. PCR has made it possible to generate millions of copies of small segment of DNA.

Principle of PCR

It is based on enzymatic replication of DNA
In PCR, a short segment of DNA is amplified using primer mediated enzymes.
DNA polymerase synthesizes new strands of DNA complementary to template DNA.

Teacher's Signature.....

Page No. Peacock
Date / /

Component of PCR

1. DNA Template
2. DNA polymerase (Taq Polymerase is used) (Thermostable)
3. oligonucleotide Primers
   Short stretches of single stranded DNA complementary to 3' ends of sense & anti-sense strands.
4. Deoxyribonucleotide triphosphate
   These provide energy for polymerization & form building blocks for synthesis of DNA.
5. Buffer system
   Mg & K provide optimum conditions for DNA denaturation & renaturation. It is also important for Fidelity, polymerase activity & stability

Peacock
Page No. 8
Date / /

Types of PCR

- **Real Time PCR** : DNA amplification is detected in real time with the help of fluorescent reporter.
- **Nested PCR** : It was designed to improve sensitivity & specificity.
- **Multiplex PCR** : Used for multiple target amplification in a single experiment.
- **Quantitative PCR** : It uses DNA amplification linearity to detect, characterize & quantify an known sequence
- **Arbitrary Primed PCR** It is DNA fingerprinting technique based on PCR It uses Primers the DNA sequence of which is chosen arbitrarily

PCR steps

1) **Denaturation** (at 94°C for 0.5 min to 2 min)
2) **Annealing** (at 54-60°C for about 20-40 sec) primers bind.
3) **Elongation** (at 72-80°C bases are added to 3' end of primers by Taq polymerase enzyme)

Teacher's Signature.....

Page No.
Date
Peacock

Application of PCR

- **Medicine**
  - Testing of genetic disease mutations
  - Monitoring the gene in gene therapy
  - Detecting disease causing genes in people
- **Forensic science**
  - Used as a tool in genetic fingerprinting
  - Identifying criminal from millions of people.
  - Paternity tests
- **Genetics & Research**
  - Compare genome of two organisms in genomic studies
  - In phylogenetic analysis of DNA from any source such as fossils.
  - Analysis of gene expression
  - Gene mapping.

Peacock
Page No. 8
Date / /

ELISA Technique

It is plate based technique used to detect and quantify peptides, antibodies, proteins & hormones

ELISA is basic assay technique, known as enzyme-linked immunosorbent essay that is carried out to detect and measure antibodies, hormones, peptides & proteins in the blood.

Antibodies are blood proteins produced in response to specific antigen. It helps to examine the presence of antibodies in the body, in case of certain infectious diseases.

Types of ELISA

1) Indirect ELISA : Antigen is coated to microtiter well
2) Sandwich ELISA : Antigen is coated on microtiter well.
3) Competitive ELISA : Microtiter well which is antigen coated is filled with antigen-antibody mixture

1) Indirect ELISA

- detects the presence of antibody in sample
- The antigen is attached to wells of microtitre plates
- A sample containing antibodies are added to antigen-coated wells for binding with antigen.

- The free primary antibodies are washed away and antigen antibody complex is detected by adding secondary antibody conjugated with an enzyme that can bind with primary antibody.

- All free secondary antibodies are washed away. A specific substrate is added which gives a coloured product
- The absorbance of coloured product is measured by spectrophotometry

Peacock.
Page No. 8
Date / /

2) Sandwich ELISA

- It helps to detect presence of antigen in a sample
- Microtitre well is coated by antibody.
- Sample containing antigen is added to well & washed to remove free antigens.
- Then an enzyme-linked secondary antibody which binds to another epitope on antigen is added. The well is washed to remove secondary antibodies.
- The enzyme specific substrate is added to plate to form a coloured product which can be measured.

3) Competitive ELISA

- It helps to detect antigen conc^n in sample
- Microtitre wells are coated with antigen
- Antibodies are incubated in soln having antigen.
- Soln of antigen antibody complex is added to microtitre wells. The well is then washed to remove any unbound antibodies
- More conc^n of antigen in the sample less free antibodies available to interact with antigen which is coated in the well.
- The enzyme linked secondary antibody is added to detect the no. of primary antibodies present in well
- The colour is measured by spectrophotometry

Teacher's Signature.....

Page No. Peacock
Date / /

Disease that can be diagnosed using ELISA

- Ebola
- AIDS
- Rotavirus
- Lyme disease
- Syphilis
- Zika virus

Advantages

i) Results fetched from ELISA gives an accurate diagnosis of particular disease since two antibodies are used.

ii) Can be carried out for complex samples as antigen is not required to get purified to detect.

iii) It is highly responsive since direct & indirect analysis can be carried out.

iv) It is rapid test yields results quickly

v) Possible detection for ELISA ranges from quantitative, semi-quantitative, standard, curve, qualitative, calibration curve models.

vi) Easier to perform & uncomplicated process as compared to other assays.

Teacher's Signature.....

Peacock
Page No.
Date / /

Applications of ELISA

1) Presence of antibodies & antigen in sample can be determined
2) It is used in food industry to detect any food allergens present
3) to determine conc^n of serum antibodies in a virus test
4) During a disease outbreak to evaluate the spread of disease. During recent COVID-19 outbreak rapid testing kits are being used to determine the presence of antibodies in blood samples.

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