TOPIC ONE: GENETICS.

Meaning of Genetics

- The term genetics refers to the study of inheritance of characteristics which are passed on from parents to offsprings during reproduction.
- Inheritance is also known as heredity which is the study of characteristics or traits inherited by organisms from their parents and the variations in these characteristics.
- Genetics helps us to understand the similarities and differences that exist among members of the same species.

Concepts of Genetics.

- Through **reproduction** offsprings are produced which resemble their parents due to inheritance of parental characteristics.
- Such **inherited characteristics** include height, skin colour, hair texture, hair colour, tongue-rolling intelligence, eye colour, shape of face, nose, ears, blood groups, body physiological activities etc; in animals; height, type of leaves, size of leaves, type and colour of flowers, type of fruits, root system in plants.
- However, the characteristics in offsprings usually show slight differences from those of parents. These differences are referred to as **variations**.
- Variations arise due to an offspring inheriting different combinations of hereditary factors from two parents and also due to environmental factors such as temperature, food, irradiations, water, mineral salts in soil, pH, salinity, topography, wind, atmospheric pressure etc.

Variations

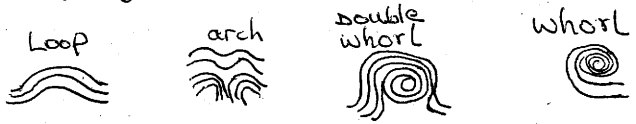
- Variations are observable differences among members of same species or among organisms eg type of sex, height, size, earlobes, skin colour blood groups, weight etc in human beings.

Types of variations

1. Discontinuous variations

- A characteristic with definite / distinct / discrete / seperate groups or categories or units with no intermediate forms; eg

(a) Tongue rolling – either rollers or non-rollers.
(b) Sex – either male or female
(c) ABO blood groups – either A or B or AB or O.
(d) Ear lobes – either free or attached.
(e) Long hair in nose or ears – either present or absent.
(f) Sex in some plants eg male paw or female pawpaw.
(g) Finger print patterns – either Loop, arch, whorl or double whorl.



- characteristics exhibiting discontinuous variation are controlled by **one or two major genes**. The physical expression of the trait **is not influenced by the environment**.

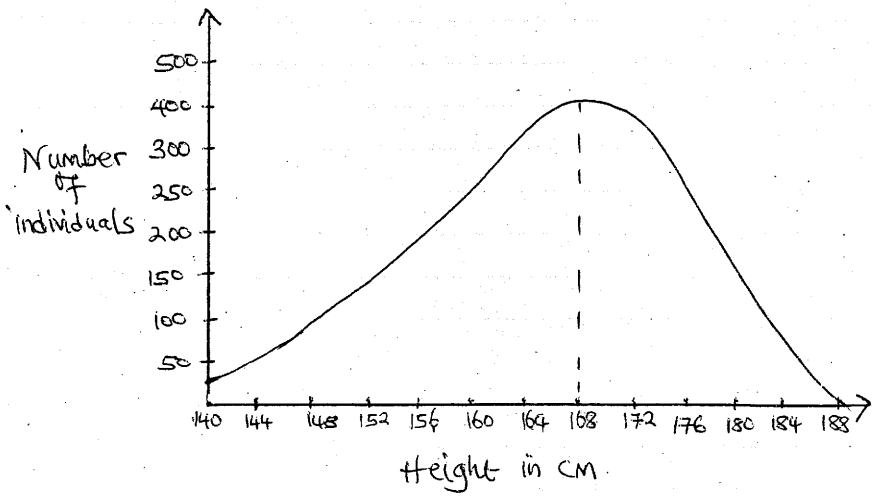
2. Continuous variations

- characteristics for which there is a continuum or range from one extreme end to another eg

(a) Height – shortest to tallest.

(b) Weight – lightest to heaviest; with intermediates.
(c) Skin colour in humans – from lilly white to charcoal black
(d) Length of internodes – from shortest to longest.
(e) Size of leaves / fruits – from smallest to largest.

- when these parameters are plotted on a graph against the number of the individuals, it produces a normal distribution curve eg normal distribution curve of height in a class of students



- characteristics that show continuous variations are controlled by **many genes** / polygenes. The physical expression of these genes is <u>influenced by environmental factors</u> eg a plant possessing genes for tallness may fail to grow tall if grown in poor / infertile soils.

Causes of Variations

① Gamete formation

- During gamete formation, two processes contribute to variations, namely :-

(a) Independent assortment

- During metaphase of meiosis I, homologous chromosomes, which had come together in pairs, segregate into daughter cells independently of each other. This produces a different variety of gametes. The total number of combinations $= 2^n$ where n = number of chromosomes (haploid) eg 2^{23} in humans = 8,388,608; in humans.

(b) Crossing-over

- occurs in prophase of meiosis I when the homologous chromosomes in intimate association break and rejoin at certain points called chiasmata. During reconstitution of the chromatids, exchange of genetic information occurs resulting in variation.

② Fertilization

- Allows parental genes to be brought together in different combinations. In this way, different qualities of the parents can be combined in the offspring.

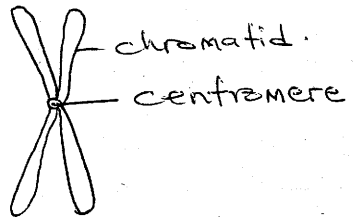
③ Mutations

- Spontaneous changes in the genetic make up of an individual. Leads to great variations. ④ Environmental conditions.

The chromosome

- chromosomes are thread-like structures found in the nucleus.

- Each chromosome constitutes of two parallel strands called chromatids. Each pair of chromatids is connected at a point called centromere.



Properties of chromosomes

i) chromosomes occur in pairs in body or somatic cells hence diploid number, but in gametes the chromosome number is haploid ie half the number compared to somatic cells.

ii) In each pair of chromosomes, called homologous chromosomes / homologues, the members are alike in appearance but different in genetic constitution.

NB - During sexual reproduction, each parent contributes one of the chromosomes of the homologous pair.

iii) chromosomes are of definate and constant number in each cell for every species of plant or animal eg

Organism	No. of chromosomes in somatic cells	No. of chromosomes in gamete cells
Sheep (Ovis auries)	56	28
Cow (Bos taurus)	60	30
Fruitfly (Drosophila melanogaster)	8	4
Maize (Zea mays)	20	10
Wheat (Triticum vulgare)	14	7
Tobacco (Nicotiana tobacum)	12	6

iv, Chromosomes are present in the nucleus all the time, but they only appear or become visible when viewed under the light microscope during cell division ie Mitosis and Meiosis

v, In mitosis, chromosomes have the following properties :

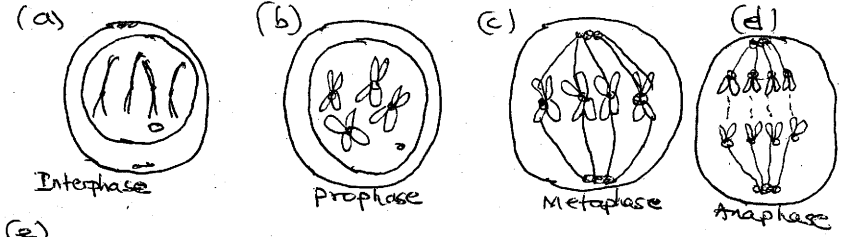
(a) Interphase - chromosomes thicken and duplicate but still appear as thin, coiled thread-like structures.

(b) prophase - chromosomes split into chromatids except at the centromeres.

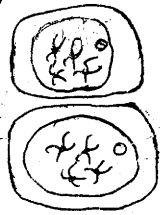
(c) Metaphase - chromosomes allign at the equator of the spindle fibres.

(d) Anaphase - sister chromatids seperate at centromeres and move to opposite poles of the cell.

(e) Telophase - chromosomes reach their destinations / opposite poles and two daughter cells are produced.



(e)



Telophase

vi, During meiosis, chromosomes exhibit the following behaviours / properties as outlined in each phase :-

(a) prophase I - Synapsis leading to bivalents, chromosomes split into chromatids ; chiasma formation and crossing over.

(b) Metaphase I - Homologous chromosomes align together at equator of spindle fibres

(c) Anaphase I - Chromosomes of each homologous pair migrate to opposite poles of the cell.

(d) Telophase I - Daughter produced each with haploid number of chromosomes ;

(e) prophase II - Homologous chromosomes pair in bivalents, The homologous chromosomes shorten and thicken, split into chromatids, join at chiasmata, crossing over takes place leading to variation.

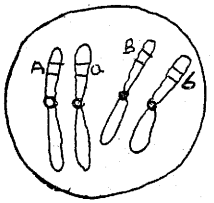
(f) Metaphase II - homologous chromosomes allign at equator of spindle fibres ; during this time nucleolus and nuclear membrane disintegrate.

(g) Anaphase II - Homologous chromosomes migrate to opposite poles of the cell.

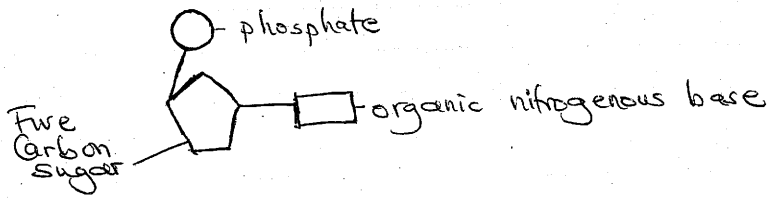
(h) Telophase II - cytoplasm divides into two in animal cells / Cell plate divides the cell into two in plant cells and two daughter cells with haploid number of chromosomes are produced. Nucleolus and nuclear membrane reappear.

Genes and DNA

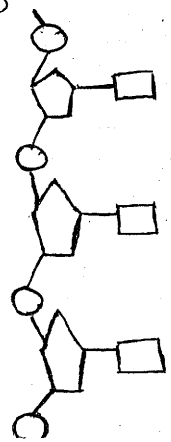
- chromosomes contain hereditary factors called genes ; which are transmitted from parents to offsprings.
- Genes occupy specific positions on the chromosomes known as gene loci (Singular = gene locus) as shown below :-



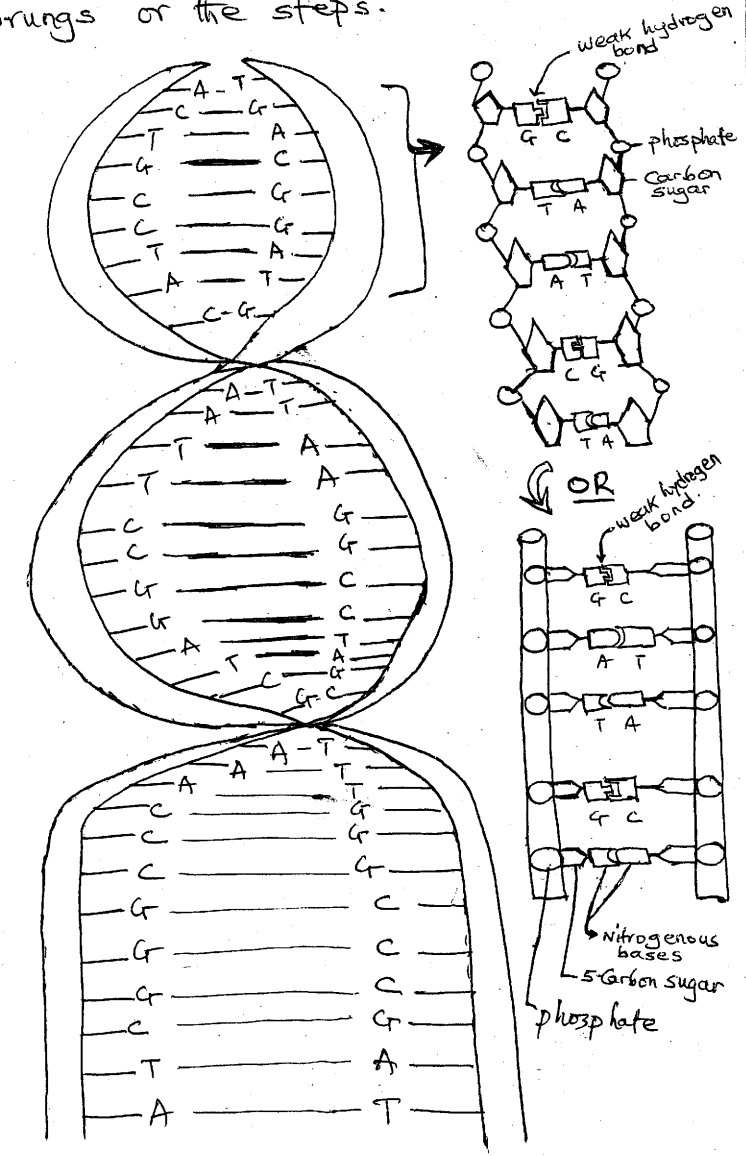
- A gene is chemical in nature in form of a nucleic acid molecule called DNA (Deoxyribonucleic acid). (According to Oswald Avery, 1944).
- DNA is a complex molecule composed of three units :-
(a) A five-carbon sugar (a pentose or a ribose)
(b) A phosphate molecule
(c) A nitrogenous base, either Adenine (A), Guanine (G), Cytosine (C) or thymine (T).



- A combination of these three units is called a nucleotide as shown in the diagram above.
- A DNA strand consists of several nucleotides joined together as shown in the diagram below:-



- A DNA molecule consists of two DNA strands twisted to form a double helix structure which resembles a twisted ladder with the bases acting as the wrungs or the steps.



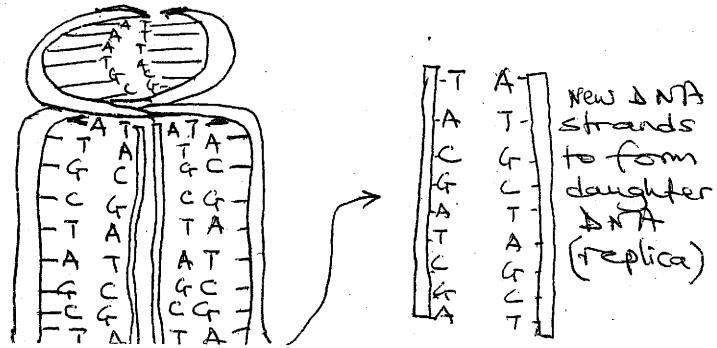
- Therefore a gene is a section of the DNA on the chromosome made of bases along the DNA strand.

The Role of DNA

① stores genetic information in coded form.
② Enables transfer of genetic information unchanged to daughter cells through replication
③ Translates the genetic information into characteristics of an organism through Protein synthesis.

DNA Replication

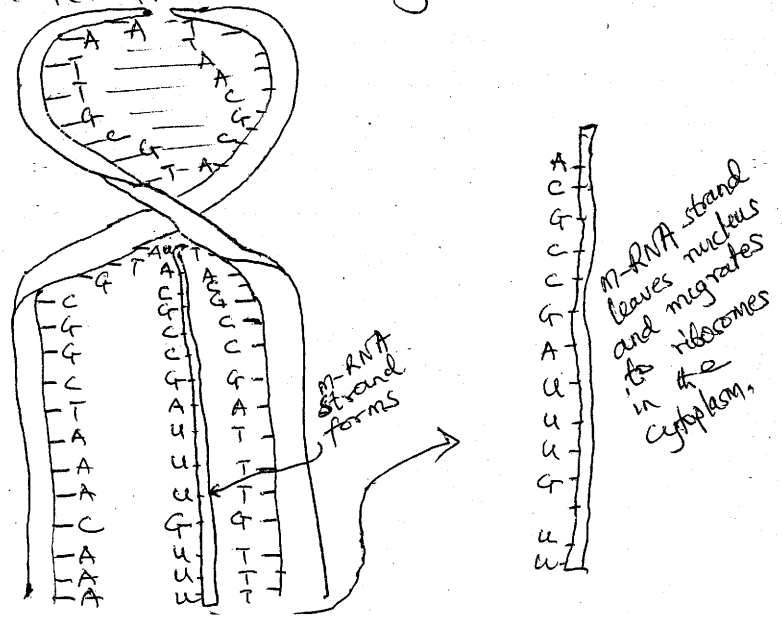
- Abilify of DNA to replicate enables inheritance of characteristics from parents to offsprings or progenies.
- DNA replication follows the following sequence of events :-
  (i) Double helix of DNA unwinds.
  (ii) The two DNA strands unzip by the breaking of the weak hydrogen bonds.
  (iii) Base sequence is Copied to form new DNA strands by allignment of free nucleotides along the open strand. Parent DNA acts as the template. The daughter DNA is called the replica.
- DNA replication occurs during interphase to avail enough DNA for daughter cells. Here the chromosomes shorten, thicken and later split into chromatids.



Role of DNA in Protein synthesis..

- The DNA molecule is responsible for protein synthesis in cells. This is important because structural proteins determine the structure of the cell and therefore the structure of the organism while functional proteins (hormones and enzymes) control functioning of the cell. Therefore DNA molecule is important in the life of an organism.
- The sequence of the bases along DNA strands act as the alphabet or code that spells out the sequence of amino-acids.
- Every set of three bases along DNA strands is responsible for bringing into position a particular amino acid in a polypeptide chain. The set of triplet bases is known as a Codon and it Codes for a particular amino acid of a protein molecule.
- Examples of DNA Codons include :-
  (i) AAA codes for aminoacid phenylalanine.
  (ii) TTT Codes for aminoacid lysine
  (iii) CAA Codes for amino acid valine
  (iv) CTA Codes for amino acid aspartic acid.
- A type of nucleic acid molecule known as messenger ribonucleic acid (m-RNA) - a type of ribonucleic acid (RNA) - Copies the genetic information from the DNA molecule in the nucleus to the ribosomes in the cytoplasm where protein synthesis occurs.
- In formation of m-RNA, an appropriate section of the DNA molecule strand acts as the template. The double helix of the DNA unwinds or unzips and free nucleotides align themselves opposite the template. The base sequence of

the template is copied onto a new strand which then becomes a new m-RNA strand.
- In the RNA strand, Thymine is replaced by the base uracil (U). This copying of DNA base sequence into m-RNA strand is known as **transcription**.
- The m-RNA leaves the nucleus and enters the cytoplasm where it aligns alongside a ribosome. Using the genetic coded information from DNA in form of codons or triplet codes (base triplets, transfer-RNA molecules (t-RNA) found in the Cytoplasm aligns amino-acids or assembles amino-acids to form a protein polypetide chain.
- The assembling of amino-acids in ribosomes to form proteins using m-RNA codons is called **translation**.
- Protein molecules determine the inherited characteristics in an organism.



Differences between DNA & RNA

DNA	RNA
1. Double stranded	Single-stranded
2. Has deoxyribose sugar	Has ribose sugar
3. Has thymine	Has uracil
4. Restricted to nucleus	formed in nucleus but works in Cytoplasm

The First Law of Heredity

- The first law of heredity was developed by an Austrian monk Gregor Mendel from his experiments on breeding peas (Pissum sativum).
- Unlike his predecessors, he was successful because :-
(i) He used favourable materials ie peas which is normally self-fertilised. Hence he could easily cross-pollinate it.
(ii) Pea plant used has several contrasting traits.
(iii) He studied inheritance of one characteristic at a time unlike his predecessors who attempted to determine wholesome heredity of each organism.
(iv) He kept accurate data on all his experiments and quantified his results and from the analysis of his data he was able to formulate definate hypotheses.

Mendel's Experiments on Monohybrid Inheritance.

- Mendel Crossed peas with some acting as males and others acting as females by removing stigmas and leaving stamens intact for the males and by removing stamens and leaving stigmas and pistil intact for the females.

-He then carefully protected the plants against any foreign pollination and he dusted pollen grains of the "male" peas on stigmas of the "female" peas.

Results

Expt:1

Dwarf peas were crossed with dwarf peas of which both were pure breeding ie producing offsprings of their own kind or type only over several generations.

Phenotypes - Dwarf peas (♀) × Dwarf peas (♂)
Genotypes - tt × tt
Gametes - (t)(t) × (t)(t)

Fusion/fertilisation

F_1 offsprings genotypes - tt tt tt tt
F_1 generation phenotypes - All dwarf.

Expt:2

Tall peas crossed with tall peas of which both were were pure breeding.

Phenotypes - Tall peas (♀) × Tall peas (♂)
Genotypes - TT × TT
Gametes - (T)(T) × (T)(T)

Fusion

f_1 genotypes - TT TT TT TT
F_1 phenotypes - All tall

Expt 3. Tall peas (pure breeding) were crossed with dwarf peas (pure breeding).

Phenotypes - Tall peas (♀) × Dwarf peas (♂)
Genotypes - TT × tt
Gametes - (T)(T) × (t)(t)

Fusion

F_1 genotypes - Tt Tt Tt Tt
F_1 phenotypes - All tall.

-Dwarf peas disappeared in the F_1 generation.
- The offsprings from the above cross were selfed and the results was as shown below :-

Phenotypes - Tall peas (♀) × Tall peas (♂)
Genotypes - Tt × Tt
Gametes - (T)(t) × (T)(t)

Fusion

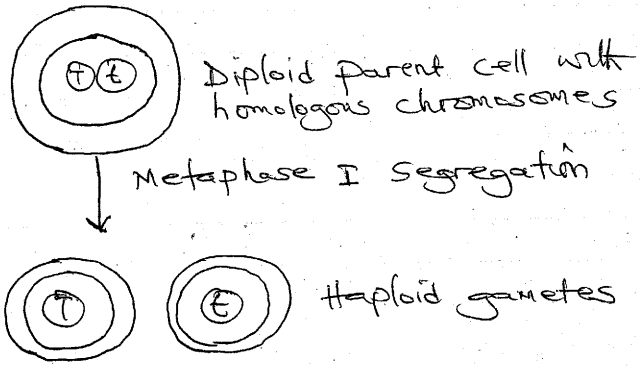
F_2 genotypes - TT Tt Tt tt
F_2 phenotypes - Tall Tall Tall dwarf
F_2 phenotypic ratio: 3 Tall : 1 dwarf
F_2 genotypic ratio: 1 TT : 2 Tt : 1 tt.

-He observed that dwarf peas reappeared in the F_2 generation.

Conclusion

-Mendel therefore concluded that "Inheritance of one characteristic is controlled by a pair of hereditary factors. Of the pair of such factors, only one can be represented

in a single gamete". This is the first law of Genetics / first Law of heredity.
- It has now been established that genes occur in pairs on chromosomes. These alternative forms of a gene on chromosomes are called alleles or allelomorphs. The genes seperate each into its own gamete during meiosis or gametogenesis. ie



Use of Punnet square / checkerboard

This is an alternative method to the annotated diagrams and genetic crosses as used in experiments 1-3 of Mendel above.

Example

Phenotypes – Tall peas (♀) × Tall peas (♂)
Genotypes – Tt × Tt
Gametes – T t × T t

Fusion of gametes:
F_2 genotypes

♀ \ ♂	T	t
T	TT	Tt
t	Tt	tt

F_2 genotypic ratio – 1TT : 2Tt : 1tt
F_2 phenotypic ratio – 2 Tall : 1 dwarf.

Ratios & Probabilities

- The phenotypic ratio in monohybrid inheritance in F_2 generation after selfing F_1 offsprings is 3:1 eg 3 tall : 1 dwarf in the peas experiment.
- This can be expressed in probability as
  (i) $\frac{3}{4}$ or 75% chances of obtaining tall plants in F_2 and
  (ii) $\frac{1}{4}$ or 25% chances of obtaining dwarf plants in F_2 generation.
- other examples include
  (i) probability of obtaining heterozygous tall peas Tt is $2(\frac{1}{2}\times\frac{1}{2}) = \frac{1}{2}$ or 50%
  OR from punnet square $= \frac{2}{4} = \frac{1}{2} = 50\%$.

  (ii) Probability of obtaining tall plants in F_2 generation is $TT(\frac{1}{2}\times\frac{1}{2}) + 2Tt(2\times\frac{1}{2}\times\frac{1}{2})$
  $= \frac{1}{4} + \frac{1}{2}$
  $= \frac{3}{4}$ or 75%.

  OR from punnet square $= \frac{3}{4}$ or 75%.

  (iii) Probability of obtaining dwarf plant in F_2 generation $= tt(\frac{1}{2}\times\frac{1}{2}) = \frac{1}{4}$ or 25%.
  OR from punnet square $= \frac{1}{4}$.

Defination of Genetic terms

① Monohybrid inheritance
- Transmission of just a pair of contrasting traits from parent to offspring eg tall and dwarf traits for height in peas.

② Allele
- Alternative forms of a gene on chromosomes eg gene T and gene t on homologous chromosomes.

③ Genotype
- Genetic constitution of an organism eg TT for tall, tt for dwarf.

④ Phenotype
- outward appearance of an organism due to a given trait or characteristic eg tall, dwarf, black, red, wrinkled, smooth etc.

⑤ F_1 generation / First filial generation
- Members or offsprings from first genetic crossing.

⑥ F_2 generation / Second filial generation
- Members or offsprings from a cross/selfing between F_1 offsprings.

⑦ Homozygous condition / Homozygosity.
- A condition where genes in an allele are identical eg TT, tt. The offspring is an homozygote.

⑧ Heterozygous condition / Heterozygosity.
- A condition where genes in an allele are not identical ie one is dominant and the other is recessive for the trait eg Tt for hetero-zygous tall.

⑨ Dominant gene.
- The gene which is phenotypically expressed in both homozygous and heterozygous states or conditions; eg gene T in TT and Tt states.

⑩ Recessive gene
- The gene that is phenotypically expressed only in homozygous recessive condition eg gene 't' is expressed only in tt not in Tt.

⑪ Genetic cross
- Diagramatic illustration of inheritance either by use of annotated diagrams and crosses or

by use of Punnet squares.

⑫ Complete dominance.
- Condition in which one gene is completely dominant ie expressed in both homozygous and heterozygous conditions and the other in the allele is recessive ie expressed only in homozygous recessive conditions. In such a case we use two contrasting forms of a letter to denote the gene eg for height where gene for tall is dominant to gene for dwarf; we can use letter T to represent the gene for height and hence Letter Capital 'T' for gene for tall and small 't' for gene for dwarf.

⑬ Reciprical Cross
- A cross with same results for the offsprings irrespective of the sex of the parents eg Tall female peas x dwarf male peas gives same offspring result as dwarf female peas crossed with tall male peas

⑭ Diploidy / Diploid condition.
- Condition in a cell where the chromosome sets are in pairs / homologous chromosomes are in pairs for the total number of the chromosomes. This is a diploid (2n) genetic constitution. Is the case in all somatic/body cells.

⑮ Haploidy / Haploid condition.
- Condition in a cell where the cell has a single set of chromosomes or half the number of chromo-some sets compared to somatic cell as in gametes. This is called haploid or (n) genetic constitution.

NB - Working out Ratios and probabilities from crosses:-

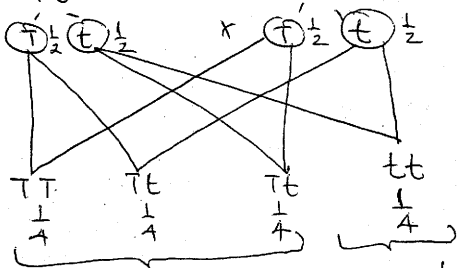
Example :-

Phenotypes — Tall peas × Tall peas

Genotypes - Tt × Tt

Gametes - T ½ t ½ × T ½ t ½

Random Fusion



Probabilities — Tall ¾ — dwarf ¼ etc.

Other Examples of complete dominance in Monohybrid inheritance :- The fruitfly (Drosophila Melanogaster).

- This insect is commonly used in experiments involving breeding and has many observable characteristics that show discontinuous variations eg
  - (i) Wing length — Long wings dominant over Vestigial wings
  - (ii) Eye Colour - Red eyes dominant over white eyes
  - (iii) Body Colour - Grey/ebony dominant over black.
  - (iv) Size of abdomen - Broad abdomen dominant over narrow abdomen.
- The fruitfly is preferred in genetics experiments because :-
  - (i) Has few and contrasting traits
  - (ii) Has small manipulable number of chromosomes
  - (iii) Easy to rear in the laboratory.
  - (iv) Has a high rate of reproduction and sexual maturity.
  - (v) Lays many eggs resulting in a large sample of offspring increasing sample size of study.

  - (vi) Has a short generation time/span (10–14 days) hence many generations can be studied in a short period.
  - (vii) Offsprings can be crossed out will with their parents ie back crossing.
  - (viii) The flies are safe to handle as they do not transmit any known human disease.

Worked Example in complete dominance

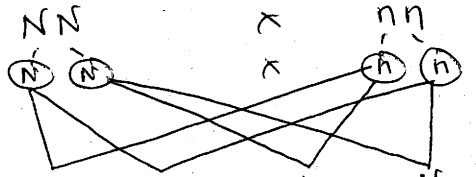
1. In a breeding experiment pea plants with smooth seed coats were crossed with pea plants with wrinkled seed coats. All the F_1 offsprings had seeds with smooth seed coats. The F_1 offsprings were selfed. A total of 1860 offsprings with wrinkled seeds were obtained.

(a) Work out the F_1 genotypes. Use letter N to represent the gene for seed coat texture.

Phenotypes - smooth seed coat × wrinkled seed coat

Genotypes - NN × nn

Gametes - N N × n n



Fusion :

F_1 genotypes — Nn Nn Nn Nn

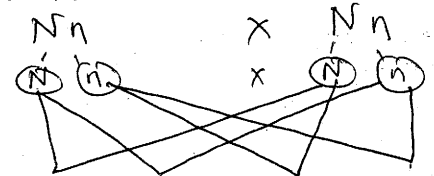
F_1 phenotypes — All with smooth seed coats.

(b) Work out the F_2 genotypes

Phenotypes - smooth seed coats × smooth seed coats

Genotypes - Nn × Nn

Gametes - N n × N n



Fusion :

F_2 genotypes - NN Nn Nn nn

F_2 phenotypes - smooth seed coats; wrinkled seed coats

(c) Determine the probability of obtaining the following in F_2 generation

i) A ~~plant~~ with smooth seed coats – $\frac{3}{4}$ or 75%

ii) A plant with wrinkled seed coats – $\frac{1}{4}$ or 25%

(d) State the F_2

i) genotypic ratio
1NN : 2Nn : 1nn

ii) phenotypic ratio
3 smooth : 1 wrinkled.

(e) Work Out :-

i) The total number of plants in F_2 generation

$\frac{1}{4} \longrightarrow 1860$

$\frac{4}{4} \longrightarrow ?$

$\frac{4}{\cancel{4}} \times \frac{\cancel{4}}{1} \times 1860 = 7440.$

ii) The number of plants with smooth seed coats

$\frac{4}{4} \longrightarrow 7440$

$\frac{3}{4} \longrightarrow ?$

$\frac{3}{\cancel{4}} \times \frac{\cancel{4}}{\cancel{4}} \times \overset{1860}{\cancel{7440}} = 5580$
1

OR

$\frac{1}{4} \longrightarrow 1860$

$\frac{3}{4} \longrightarrow ?$; $\frac{3}{4} \times \frac{4}{1} \times 1860 = 5580.$

(f) Identify with a reason

i) The dominant trait
- Smooth seed coat
- Reason :- Expressed both in the parent and in the F_1 offsprings ie homozygous and heterozygous states respectively.

ii) The recessive trait
- Wrinkled seed Coat
- Reason :- Expressed only in the homozygous recessive state in the parent.

Incomplete Dominance / Co-dominance / Partial Dominance

- A type of transmission of traits / inheritance in which the two genes in the allele are equally expressed in the phenotype due to blending.
- For example in the 4'oclock plant (*Mirabilis jalapa*) some plants have red flowers, others have white flowers. When a red-flowered plant is crossed with a white-flowered plant, all the F_1 plants produce pink flowers due to blending of the gene for red flowers and the gene for white flowers; ie,

Phenotypes – Red flowered plant × white flowered plant
Genotypes – RR × WW
Gametes – R R × W W
Fusion –
F_1 genotypes – RW RW RW RW
F_1 genotypes – All with pink flowers.

-In codominance / partial dominance / incomplete dominance since the two genes have equal degree of expression in the phenotype, each gene is denoted using its own capital letter ie two different capital letters from the alphabet eg R for gene for red and W for gene for white.
- When the F_1 offsprings are selfed, the F_2 plants obtained were a mixture, some with white flowers, some with red flowers but majority had pink flowers in a ratio of 1 red : 2 pink : 1 white ie

Phenotypes — Pink flowered × pink flowered
Genotypes — RW × RW
Gametes — R W × R W
Fusion —

F_2 genotypes	RR	RW	RW	WW
F_2 phenotypes	Red	pink		white

F_2 genotypic ratio : 1RR : 2RW : 1 WW
F_2 phenotypic ratio: 1 Red : 2 pink : 1 white

-The reappearance of red and white flowers in the F_2 generation and absence of red and white flowers in the F_1 generation is due to codominance / partial dominance / incomplete dominance between the genes for red and white flowers as a result of them blending.

Codominance in human beings :- Inheritance of ABO blood groups

- Blood groups A, B, AB and O are determined by a pair of alleles ie multiple alleles / many gene pairs.
- There are three genes responsible for coding for antigens on RBCs ie genes A, B and O.
- Gene A codes for antigen A, gene B codes for antigen B and gene O codes for no antigen (hence zero antigen) on RBCs.
- Genes A and B are co-dominant ie have equal degrees of phenotypic expression. Gene O is always recessive except in homozygous recessive OO condition. The table below shows the antigens, the blood groups, antibodies and the genotypes for the corresponding genes:-

Gene	Antigen on RBC	Antibody in plasma	Blood group	Genotypes	Donor	Recepient
A	A	b	A	AA or AO	A	A, AB
B	B	a	B	BB or BO	B	B, AB
O	None/zero	a and b	O	OO	O	A, B, AB, O
A&B	A and B	None	AB	AB	AB	AB

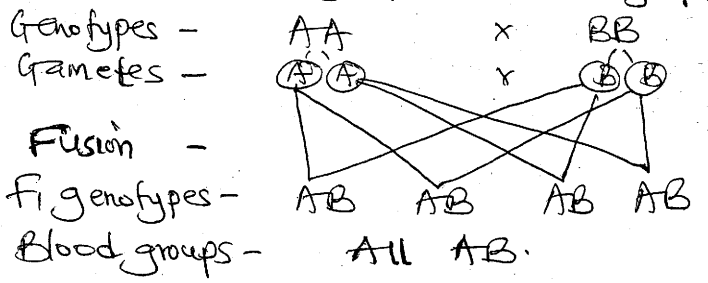
-The inheritance of blood groups follows the Mendelian fashion eg

① Parents — Husband with Blood group AB × Wife with Blood group AB
Genotypes — AB × AB
Gametes — A B × A B
Fusion
F_1 genotypes — AA AB AB BB

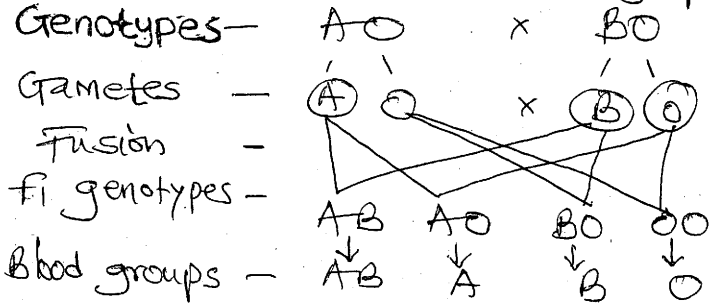
F1 genotypes → AA AB AB BB
Blood groups A AB B

② Father with blood group A and mother with blood group B.

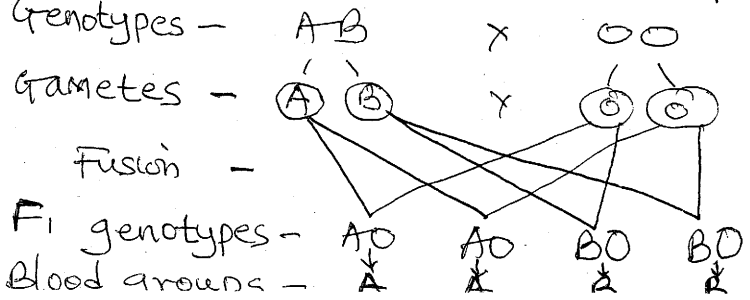
(a) parents - Husband homozygous × wife homozygous
Blood group A Blood group B



(b) Parents – Heterozygous husband with blood group A × Heterozygous wife with blood group B



③ Parents – Father with Blood group AB × Mother with blood group O



- knowledge of blood groups is important in
(a) Blood transfusion to ensure compatibility between donor and recepient.
(b) Determining disputed parentage / paternity eg parents who are both blood group AB can not bear a child who is blood group O.

NB - The most reliable method of determining disputed parentage is DNA finger printing or DNA matching.

Inheritance of the Rhesus factor / Antigen-D

- The rhesus gene codes for the rhesus antigen or antigen-D on RBCs. Possession of the rhesus antigens makes on Rhesus positive (Rh+ve) whereas absence of the rhesus antigens on RBCs makes one Rhesus negative (Rh⁻ve).
- The Rhesus positive is dominant to the Rhesus negative due to a dominant gene which is dominant over the gene for its absence.
- In a marriage, if a wife is Rhesus negative and the husband is Rhesus positive, all their children will be Rhesus positive. Hence as from the second pregnancy the foetuses die from the Haemolytic disease of the newborn or Erythroblastosis foetalis due to damage of RBCs of the foetuses by increased high number of anti-rhesus antibodies produced by the mother's blood following exposure to Rhesus antigens from foetal RBCs during the first pregnancy.
- However, this can be prevented by administration of anti-globulins 72 hours after the first birth.

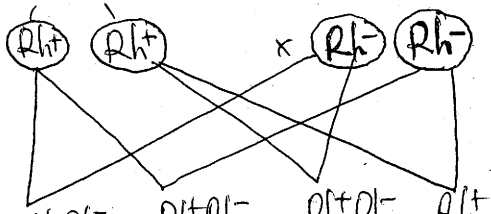
- Below is an illustration of the inheritance

Parents – Rhesus positive husband × Rhesus negative wife

Genotypes – Rh^+Rh^+ × Rh^-Rh^-

Gametes – Rh^+ Rh^+ × Rh^- Rh^-

Fusion –



F1 genotypes – Rh^+Rh^- Rh^+Rh^- Rh^+Rh^- Rh^+Rh^-

F1 phenotypes – All Rhesus positive.

Determining unknown Genotypes

① Use of test Cross

- Involves the crossing of an individual with unknown genotype with an homozygous recessive individual.

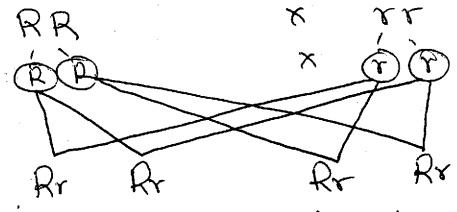
(a) If the F1 offsprings show the dominant trait/phenotype, then the unknown genotype is homozygous for the trait eg in peas

Phenotype – Red flowered (unknown genotype) × White flowered (homozygous recessive)

Genotype – RR × rr

Gametes – R R × r r

Fusion



F1 genotypes – Rr Rr Rr Rr

F1 phenotypes – All red flowered.

- All F1 show the dominant trait hence the unknown genotype is homozygous RR.

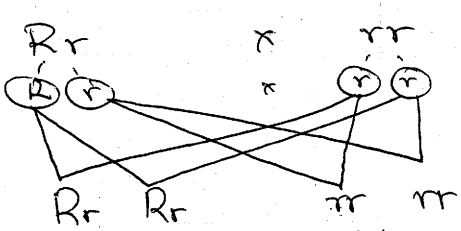
(b) If the offsprings show a mixture of traits in a ratio of 1:1, then the unknown genotype is heterozygous for the trait eg in peas

Phenotype – Red flowered (unknown genotype) × White flowered (homozygous recessive)

Genotype – Rr × rr

Gametes – R r × r r

Fusion



F1 genotypes – Rr Rr rr rr

F1 phenotypes – 2 red : 2 white

1 red : 1 white

Hence the unknown genotype is heterozygous Rr.

② Use of Back Cross

- Involves crossing an individual with unknown genotypes with one of its parents with homozygous recessive traits.
- If the offsprings show the dominant trait only, then the unknown genotype is homozygous dominant.
- If the offsprings are in a ratio of 1:1 for the traits, then the unknown genotype is heterozygous for the trait.

③ Selfing

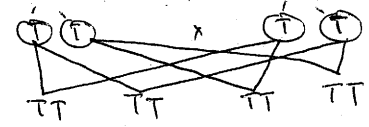
- If the offsprings show the same phenotype, then the unknown genotype is homozygous for the trait; eg

Phenotypes – Tall peas × Tall peas

Genotypes – TT × TT

Gametes – T T × T T

Fusion



F2 genotypes – TT TT TT TT

F_1 phenotypes - All tall.

- If the F_2 offsprings are in a ratio of 3:1 for the trait, then the unknown genotype is heterozygous for the trait eg

Phenotypes - Tall peas x Tall peas
Genotypes - Tt x Tt
Gametes - (T) (t) x (T) (t)
Fusion
F_2 genotypes - TT Tt Tt tt
F_2 phenotypes - 3 tall : 1 dwarf

Sex Determination

- Sex determination in higher animals is controlled by a pair of chromosomes called sex-chromosomes. For example in human beings, there are 46 chromosomes (in 23 pairs / 23 pairs of homologous chromosomes), in every body / somatic cell. The genes that determine the sex of the child are located on the x and y chromosomes (so named because of their shapes). The x and y chromosomes are called sex chromosomes. The remaining 22 pairs of chromosomes are responsible for other inheritable characteristics and are called **autosomes**.
- A male human being carries xy combination and hence is heterogametic ie some sperms carry x-chromosome, others y-chromosome.
- A female human being has the xx combination and hence is homogametic ie every ovum carries an x chromosome hence chromosomes of the same type.
- After meiosis, a mans spermatozoa will either carry x or y chromosome whereas

the female's ovum carries only x chromosome.

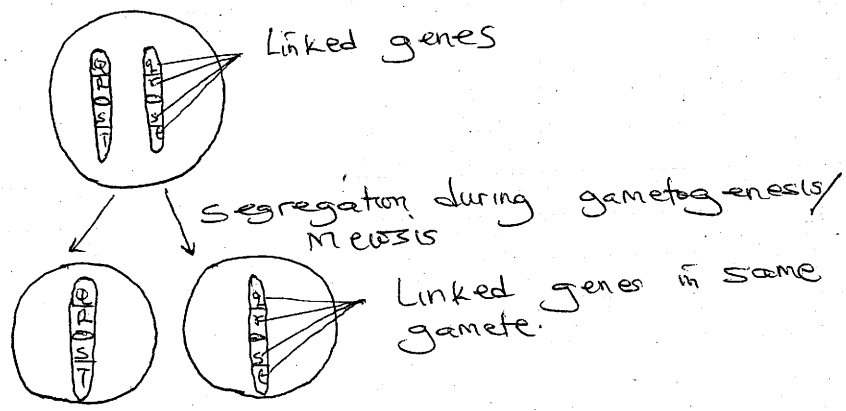
- The sex of the child therefore will be determined by which sperm fertilises the ovum.
- If the ovum is fertilised by the sperm with x-chromosome, the resultant child will be xx hence a baby girl. If the ovum is fertilised by a sperm with a y-chromosome, the resultant child will be xy hence a baby-boy.
- Hence in human beings, it is the males who determine the sex of the child because they are heterogametic.
- The probability of bearing a boy or girl is ½ or 50% as shown below:-

Parents - Husband x Wife
Genotypes - xy x xx
Gametes - (x) (y) x (x) (x)
Fusion -
F_1 genotypes - xx xx xy xy
2 girls 2 boys
Phenotypic ratio - 1 girl : 1 boy.

- In other animals, the male is homogametic whereas the female is heterogametic eg in birds male is xx and female is xy. In some insects eg grasshoppers the male is xo whereas the female is xx ie y is missing in males. In fruitflies, the male is xy and the female is xx. The heterogametic parent therefore determines sex of the offspring.

Linkage

- Genes found on the same chromosome are called linked genes. All the linked genes constitute a linkage group. The location of genes on the same chromosome and therefore their being transmitted together into same gametes is called linkage
- Linked genes do not segregate but are transmitted together into the same gametes eg



- Examples of linked genes in Drosophila include genes for winglength, abdomen size and body colour located on the same chromosome. Therefore these characteristics are usually inherited together.

Sex-linked genes.

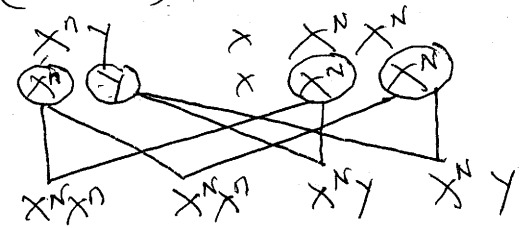
- Are genes located on the sex-chromosomes and are transmitted together with those that determine sex.
- Majority of the genes are located on the X-chromosomes with the corresponding alleles absent on Y-chromosome due

to missing arm/chromatid. Hence the Y-chromosome has very few genes and is almost empty.
- Sex-linked genes produce sex-linked traits or characteristics in human beings such as:-
  (i) Haemophilia
  (ii) colour-blindness
  (iii) Hairy pinna/ears and nose
  (iv) Duchene Muscular dystrophy (DMD) in Males/Muscle wasting.
  (v) Baldness/premature baldness.

(i) Colour blindness

- Inability to distinguish between certain colours by some people eg red-green colour-blindness.
- The gene for normal colour vision is dominant to the gene for colour blindness and the genes are sex-linked and located on the X-chromosome.
- For example, if a colour-blind man marries a woman with normal colour vision, the following would be the F_1 genotypes:-

Parents - Colour blind man (husband) × Wife with normal colour vision.



F1 phenotypes: X^NX^n X^NX^n | X^NY X^nY

Carrier daughters; sons with normal colour vision

All phenotypically with normal colour vision.

—All sons have normal colour vision because the X-chromosome inherited from the mother has the dominant gene. The daughters inherit one of their X-chromosome from the father which has the recessive gene and the other from the mother which has the dominant gene hence are carriers — phenotypically normal but with a potential of transmitting the recessive gene to their offsprings.

—If one of the carrier daughters marries a man with normal colour vision, the following would be offspring genotypes

Parents - Carrier daughter (wife) × Husband with normal colour vision

Genotypes - X^NX^n × X^NY

Gametes - X^N X^n × X^N Y

Fusion

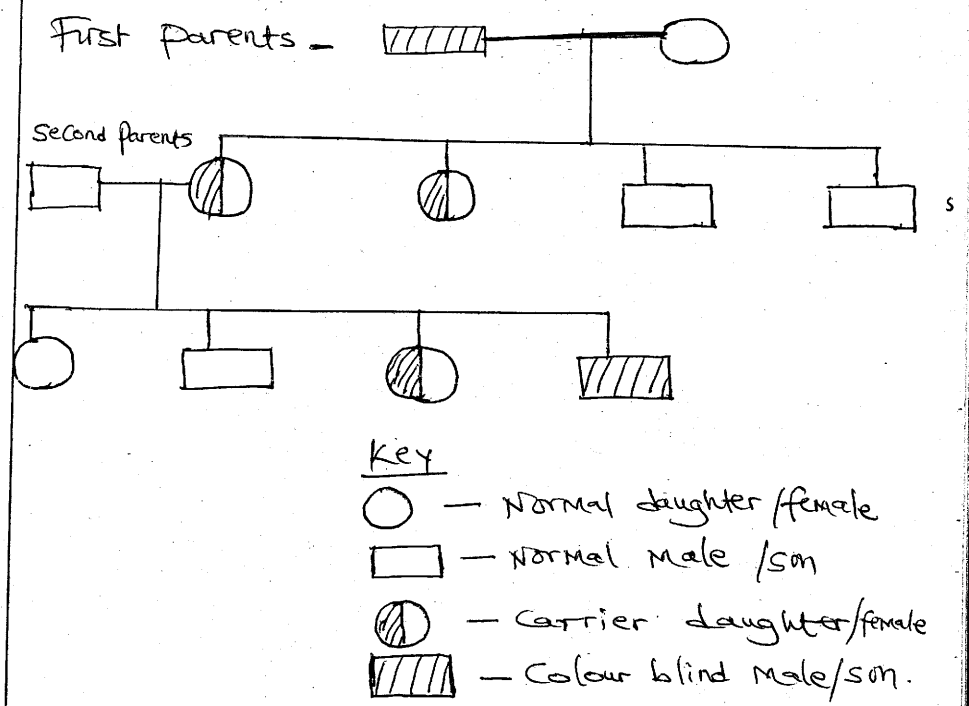
F_1 genotypes (offspring genotypes) X^NX^N X^NY X^NX^n X^nY

Offspring phenotypes - normal daughter; normal son; carrier daughter; colour blind son.

—The probability of obtaining a colour-blind son is therefore $\frac{1}{4}$ or 25%. The son becomes colour blind because the only X-chromosome

inherited from the mother has a recessive gene. The corresponding allele is absent on Y-chromosome.

—The two successive generations can be represented by a pedigree diagram as shown below:-



ii, Haemophilia

—A blood disorder characterised by excessive bleeding which takes a long period of time for blood to clot when a blood vessel is injured.

—It is caused by absence of certain clotting factors in blood.

— Haemophilia is a sex-linked trait caused by a recessive gene located on the X-chromosome.

-for example, if a normal man for blood clotting marries a carrier wife / female :-

Parental phenotypes - Normal male x carrier female

Genotypes - $X^H y$ x $X^H X^h$

Gametes - X^H, y x X^H, X^h

Fusion

F1 genotypes - $X^H X^H$, $X^H X^h$, $X^H y$, $X^h y$

F1 phenotypes - Normal female, Carrier daughter, Normal male, Haemophiliac male.

Probability of obtaining an haemophiliac from the cross is $\frac{1}{4}$ or 25%.

(3) Hairy pinna

-characterised by presence of long hairs from pinna in males. The gene for hairy pinna is located on the y-chromosome. For example, if a man with hairy pinna marries a wife, below is the genetic cross.

Parental phenotypes - male with hairy pinna x wife

Genotypes - $X\ y^H$ x $X\ X$

Gametes - X, y^H x X, X

Fusion

F1 genotypes - XX XX Xy^H Xy^H

-The probability of obtaining females with hairy pinna is zero because daughters do not inherit y-chromosome from fathers and the gene is located only on y-chromosome.

NB:- Genes located on x-chromosome bring about development of secondary sexual characteristics in females whereas genes located on y-chromosome bring about development of secondary sexual characteristics in males, as from puberty.

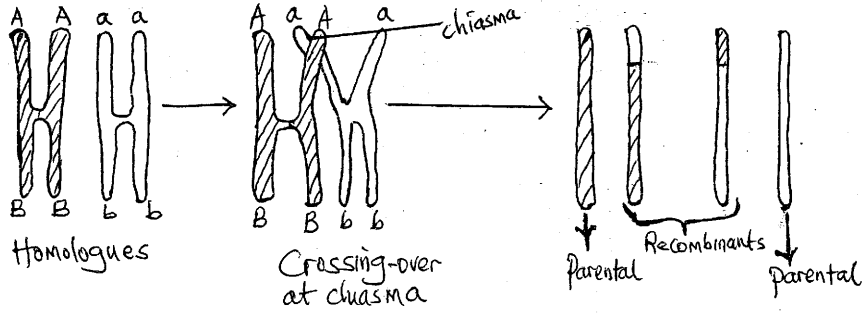
Effects of Crossing over on linked genes

-Although linked genes are expected to remain together and be transmitted together, experimental evidence has shown that during crossing over in meiosis I (during prophase I), sections of the bivalents intertwine and may break off before rejoining. During rejoining, sections from different chromatids may rejoin on different chromatids thus seperating the linked genes.

-Fusion of few gametes whose genes have changed places will produce new combinations known as recombinants.

-Hence recombinants will exhibit variations different from parental characteristics.

-Crossing over also leads to mutations which in turn leads to variations eg



Mutations

- Mutations refer to spontaneous changes in the genetic make up of an individual. This occurs in a natural population resulting in individuals with unusual characteristics Called mutants eg strains of insects resistant to DDT; bacteria resistant to penicillin; albinos in populations of human beings.
- Mutations normally arise due to recessive genes transmitted in the normal Mendelian fashion.

Causes of Mutations

① Mutagenic chemicals / Mutagens such as mastard gas, colchicine, thalidomide, DDT.
② Radioactive emissions ie X-rays; gamma rays (γ-rays) which have very high penetrating and disintegrating properties; alpha particles (α-particles); Beta-particles (β-particles);
③ Natural radiations ie Cosmic rays and Ultra-violet (UV) rays.
④ Exposing gametes to extremely high temperatures above 90 °C.
- The most important type of mutations are those which occur in gamete cells because they are inherited by offsprings.

Types of Mutations

① Chromosomal Mutations
   (a) chromosomal deletions
   (b) Chromosomal duplications
   (c) Chromosomal inversions
   (d) Chromosomal translocations
   (e) Non-disjunctions.

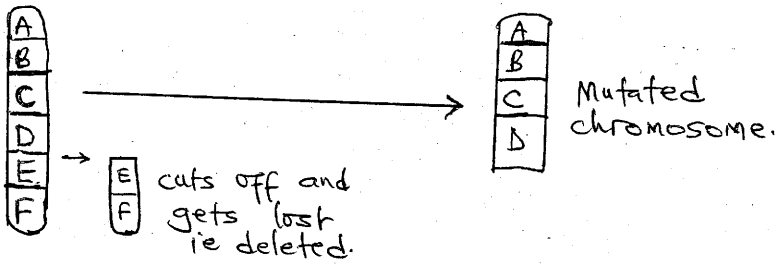
② Gene-Mutations
   (a) Gene insertions
   (b) Gene deletions
   (c) Gene substitutions
   (d) Gene inversions

Chromosomal Mutations

- Refers to change in chromosomal structure or chromosomal number in cells. Includes five types :-

(a) chromosomal deletions

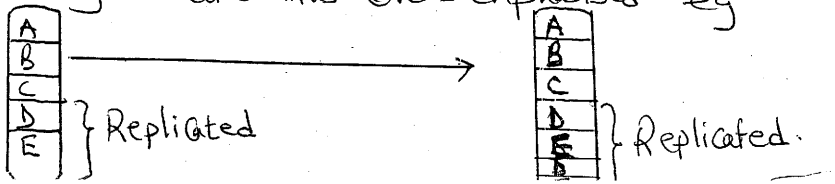
- occurs when some sections of homologous chromosomes break off and fail to reconstitute to any of the chromatids and gets lost with its genes.



- Most chromosomal deletions are fatal or lethal as vital genes responsible for synthesis of vital proteins may be lost.

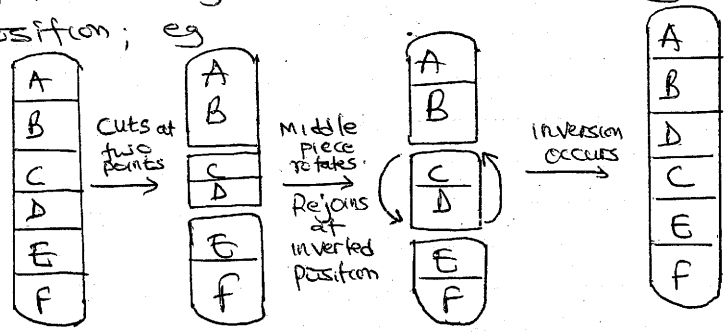
(b) Chromosomal duplications.

- Occurs when some sections of a chromatid replicates and adds an extra length to itself.
- Certain genes are thus over-emphasised eg



(c) Chromosomal inversions

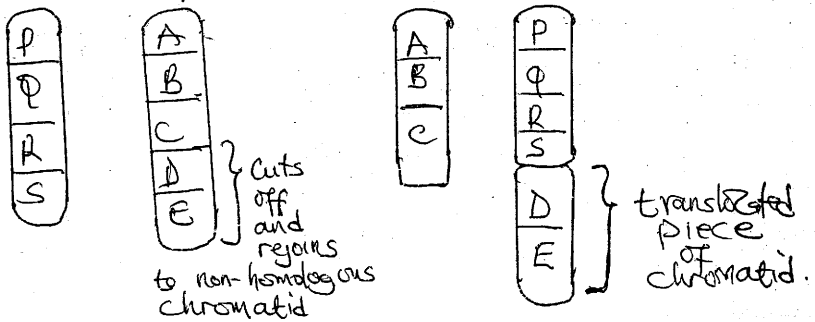
- occurs when a chromatid breaks at two points and when rejoining, the middle piece rotates and joins at inverted angle or position; eg



- This has the effect of reversing the gene sequence along the chromatid. This may bring together genes whose combined effect may be advantageous or disadvantageous to the organism.

(d) Translocations

- occurs when a section of a chromatid breaks off and becomes attached to another chromatid of non-homologous pair eg

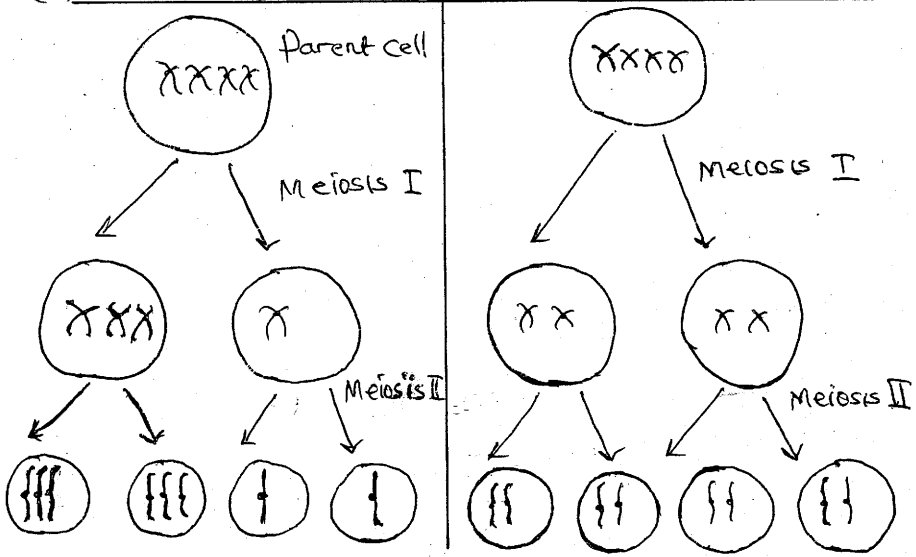


- This results in movement of genes from one homologous chromatid to another.

(e) Non-disjunction

- Abnormality due to addition or loss of one or more chromosomes during Meiosis or gametogenesis.
- In human beings, non-disjunction leads to the following abnormalities :-
  (i) Down's Syndrome / Mongoloid idiocy / Mongolism
  (ii) Klinefelter's syndrome
  (iii) Turner's syndrome
  (iv) Polyploidy
- The diagrams below illustrate non-disjunctions compared to normal meiosis :-

(a) Non-disjunction | Normal meiosis



(i) Down's Syndrome / Mongoloid idiocy.

- Abnormality due to an extra chromosome number 21. Symptoms include : Mental retardation, drooping eyes, slit eyes, short stabby fingers, cardiac Malfunctions, thick tongue and reduced resistance to diseases.

- Common among children borne to mothers over 40 years and fathers of over 50 years.

(ii) Klinefelter's syndrome

- Abnormality due to an extra set of sex-chromosomes eg XYY males (super-males) or XXY males (sterile, mentaly retarded males) and XXX females (super-females). The XXY and XYY males are sterile, taller with little or no facial hair.
- For Klinefelter's individuals their cells (Somatic cells) have 47 chromosomes (ie 44 autosomes + XXY or 44 autosomes + XYY or 44 autosomes + XXX) whereas normal human beings have 46 chromosomes in somatic cells (ie 44 + XX or 44 + XY).

(iii) Turner's Syndrome

- Abnormality due to loss of one X-chromosome in sex cells such that the female has a genetic constitution of 44 + XO (45 chromosomes) instead of 44 + XX (45 chromosomes). This leads to sterility / infertility and abnormal dwarfness. YO zygotes fail to develop.

(iv) Polyploidy

- State of increased number of sets of chromosomes in gametes or body cells eg triploidy (3n), tetraploidy (4n), pentaploidy (5n) instead of the normal haploidy (n) in gametes or diploidy (2n) in somatic cells.

- It arises from fertilisation preceded by non-disjunction
- It is common in plants and rare in animals.
- In plants, it can be induced by chemicals such as Colchicine (which interfers with formation of spindle fibres).
- Some of the benefits of polyploidy in plants include :- increased resistance to diseases, resistance to pests, resistance to drought, increased yield and general hybrid vigour.

Gene Mutations

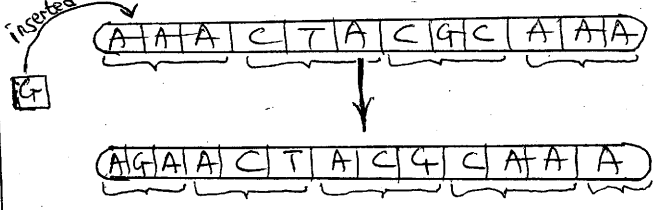
- Refers to alterations or change in the structure or chemical nature of a gene ie change in DNA base sequence.
- It also refers to as point mutation.
- Such changes result in an alteration of the amino-acid sequence in the protein for whose synthesis the gene is responsible. This will produce great changes in the structure and development of the organism. For example, a completely abnormal protein may result causing improper functioning of the stricture of that organism.
- The change in DNA molecule is passed into m-RNA. This will consequently alter the sequence of amino acids during protein synthesis. This results in unintended protein molecule or may cause confusion, defection or death.

-There are four types of gene mutations, namely :-

(i) Gene insertions
(ii) Gene deletions
(iii) Gene substitutions
(iv) Gene inversions.

(i) Gene insertions

-Refers to addition of an extra base onto the existing DNA strand. This affects or alters the nature of m-RNA synthesised and subsequently the alignment of amino-acids on the protein to be formed eg

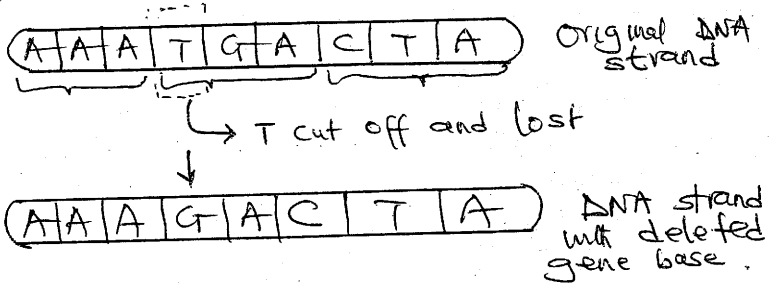


-By addition of Guanine, no polypeptide is formed because none of the intended amino-acids have been linked / bonded.

(ii) Gene deletions

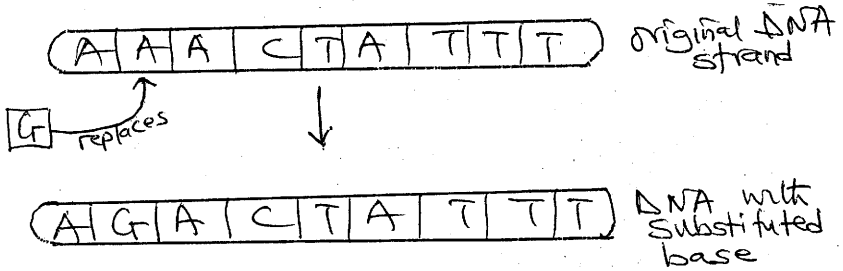
-Involves removal of a gene portion / bases from a DNA strand. For example, if the base thymine (T) is deleted from its position in the DNA strand, shown below, the gene / base sequence will become altered at that point. Hence the sequence of the amino-acids on the polypeptide chain is altered resulting in production of a

wrong protein.



(iii) Gene substitutions.

-Involves replacement of a portion of a gene (DNA base(s) with a new DNA/gene portion (base(s). For example if adenine (A) is substituted by Guanine (G) in the DNA strand below, the base sequence is altered at this particular point or portion.

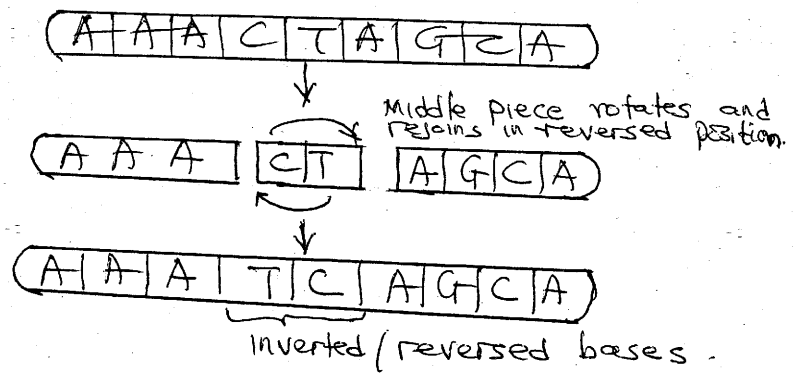


-This leads to a defective or wrong protein.

(iv) Gene inversions

-Involves a portion of DNA strand cutting at two points and the middle piece rotates at 360° and rejoins in a reversed position.
-This alters the gene base sequence

and hence arrangement of amino acids on a protein for whose synthesis the gene is responsible eg



Examples of Disorders due to gene Mutations in Man.

- Includes :-
  (i) Albinism
  (ii) sickle cell anaemia
  (iii) Haemophilia
  (iv) Colour-blindness
  (v) Chondrodystrophic dwarfism/Achondroplasia.

i) Albinism.

- Condition where synthesis of skin pigment, Melanin, fails to form leading to a light skin, white hair and pink eyes. Such individuals are called albinos.
- Melanin is a derivative of amino-acids tyrosine and phenylalanine and is synthesised through a series of reactions each controlled by a specific gene

- In albinism, one of these genes, gene "A", is substituted by a recessive gene "a". Gene "a" in homozygous state causes albinism ie in aa condition enzyme tyrosinase fails to be synthesised leading to no Melanin formation. A normal pigmented person is genotypically AA whereas a carrier is Aa and an albino is aa.
- The Cross below shows inheritance of albinism from heterozygous parents

Parental phenotype – Male with normal pigmented skin × female with normal pigmented skin

Genotypes – Aa × Aa

Gametes – A, a × A, a

Fusion

F1 genotypes – AA, Aa, Aa, aa

F1 phenotypes – Normal pigmented children, albino.

- Probability of bearing an albino from carrier parents is therefore ¼ or 25%. Probability of any of the children becoming a carrier is 50% or ½
- Albinos suffer from sunburns but can lead normal life by using sunglasses and sunscreen lotions.

(2) Sickle-Cell anaemia.

- Blood disorder characterised by crescent-shaped Red blood cells.
- It is caused by gene substitution in which

normal haemoglobin A is substituted with abnormal haemoglobin S leading to such crescent-shaped red blood cells.

- Normal haemoglobin A (HbA) is a derivative of amino-acid glutamic acid whereas haemoglobin S (HbS) is a derivative of amino-acid valine.
- The genotypes of respective individuals are as follows :-

(i) Person with normal haemoglobin A (Whose RBCs are biconcave-shaped)
→ HbA HbA

(ii) Heterozygous Carrier / Sickle-cell trait (whose RBCs are a mixture of normal bi-concave-shaped and crescent shaped) = HbA HbS. Sickle-cell traits do survive to sexual maturity since they have the mixture of normal and sickle-shaped RBCs. However, they experience mild cases of anaemia and general body weakness during strainous activities. But they have an adaptive advantage of resisting malaria.

(iii) Sickle-cell anaemics - HbS HbS. These do survive but experience problems of severe joint pains, arms, legs, stomach pains since the crescent-shaped RBCs are unable to squeeze through capillaries causing clogging. Under close medical attention, the persons can survive but usually they die from other infections.

- Example of inheritance is illustrated below :-

Parental phenotypes - Man with sickle-cell trait (heterozygous) × woman with sickle-cell trait (heterozygous)

Genotypes - HbA HbS × HbA HbS

Gametes - HbA, HbS × HbA, HbS

Fusion

F1 genotypes - HbA HbA, HbA HbS, HbA HbS, HbS HbS

F1 phenotypes - normal haemoglobin; sickle-cell traits; sickle-cell anaemic

- The probability that any child is sickle-cell anaemic is $\frac{1}{4}$ or 25%; and that the child is a carrier is $\frac{1}{2}$ or 50%.

Differences between Haemoglobin A and Haemoglobin S.

Haemoglobin A	Haemoglobin S
① Has glutamic acid in polypeptide chain.	Has valine in polypeptide chain.
② No crystalisation under low oxygen concentration.	Crystalises under low oxygen concentration.
③ Efficient loading of oxygen	Inefficient loading of oxygen.
④ RBCs biconcave shaped.	RBCs crescent-shaped.

(3) Haemophilia

- Blood disorder characterised by excessive bleeding in the event of a blood vessel getting injured.
- It is caused by gene substitution in which the gene for normal blood clotting on the X-chromosome

is substituted by a recessive gene. The trait is sex-linked and located on x-chromosome. The substitution leads to absence of clotting factors mainly factor VIII (Anti-haemophiliac globulin, AHG) and factor IX. This leads to severe bleeding even from minor injuries / cuts.
- Remedies include introduction of clotting factors VIII and IX from blood from healthy donors who are normal for blood clotting
- To-be Married couples should also undergo genetic counselling.

④ Colour blindness.

- Disorder characterised by inability to distinguish between certain colours eg green-red colour blindness.
- It is caused by gene substitution in which gene for normal colour vision is replaced / substituted by gene for colourblindness. The gene is located on the X-chromosome hence the trait is sex-linked. This causes inability to distinguish between certain colours.

⑤ Chondrodystrophic Dwarfism / Achondroplasia

- Abnormality due to gene substitution in which a dominant gene arises in gametes and is phenotypically expressed in both homozygous and heterozygous states. It leads to abnormal development of cartilage such that the head and arms develop normally but the trunk becomes abnormally short and the

legs also abnormally short and bow-shaped.
- 80% of achondroplasias survive to sexual maturity but 20% die at infancy

Effect of Environment on Heredity.

- Environment interacts and shapes the genotype to bring about the phenotype.
- such environmental factors include food/nutrients, light, moisture/water, pH and other climatic factors.
- for example
(i) Identical twins reared in seperate places with different environmental factors show differences in IQ. (Intelligence Quotient)
(ii) Adopted children reared together show similarities in IQ.
(iii) Genotypically tall plants grow dwarf if grown in poor soils.
- However, the genotype has equal effect on the phenotype eg a plant with genes for chlorophyll may not turn green in the absence of light. But again, a plant without genes for chlorophyll can not turn green even if it is exposed to conditions of light.
- Therefore genotype x Environment → phenotype.

NB - Much as environment is an important factor, it can not influence discontinuous variations such as type of sex, finger-print patterns, blood groups etc. It only has effect on continuous variations such as height, weight, skin colour etc

Practical applications of Genetics

① plant and animal breeding.

—Human beings breed plants and animals with desirable qualities by selectively choosing them. This is known as artificial selection.

—This can be done either by inbreeding or cross-breeding. But cross-breeding is preferred to inbreeding because it leads to variations.

—Offsprings from disimilar genetic lines posses benefitial characteristics from both parents. Such individuals are known as hybrids and display hybrid vigour. Hybrid vigour refers to superior qualities displayed by offsprings from disimilar genetic lines compared to either of their parents.

eg (i) Resistance to diseases and pests
(ii) Resistance to drought
(iii) High yield
(iv) Early maturity

—other minor qualities of hybrid vigour farmers look for include:- high plant-meat conversion in beef cattle, multicoloured flowers, increased length of reproduction / egg laying; ease of harvesting eg. Ruiru 11 Coffee etc.

—Examples of some cross-bred crops and animals include:-

(a) Hereford × Zebu

Early maturity (A), high yield (B), poor resistance to diseases/pests/drought (d) — slow maturity (a), low yield (b), high resistance to diseases/pests/drought (D)

(A)(B)(d) × (a)(b)(D)

AaBbDd. Cross-breed with early maturity, high yield and high resistance to diseases/pests/drought.

(b) Polyploidy in wheat

14-chromosome wheat (Low yielding) × 14-chromosome wheat (Low yielding)

28-chromosome wheat (High yielding).

② Blood grouping and Transfusion.

—The knowledge of blood groups ensures compatibility between donors and recepients so as to avoid agglutination.

—Blood groups also can be used to determine disputed parentage or Paternity to some degree. For example parents who are both blood group O can not bear a child who is blood group O. However the most accurate method used in such cases is DNA matching.

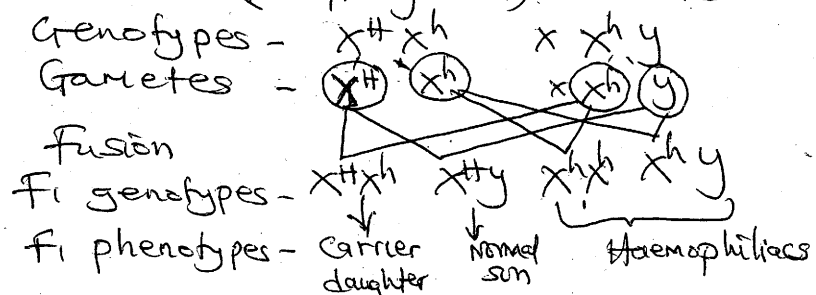
③ Genetic Counselling

—Advice given to couples or fiances on genetic issues such as genetic diseases and disorders like haemophilia and sickle-cell

- Example : Jane is a carrier of haemophilia. Between these two men whom will she be advised to marry?
(a) John who is haemophiliac or
(b) Peter who is normal for blood clotting

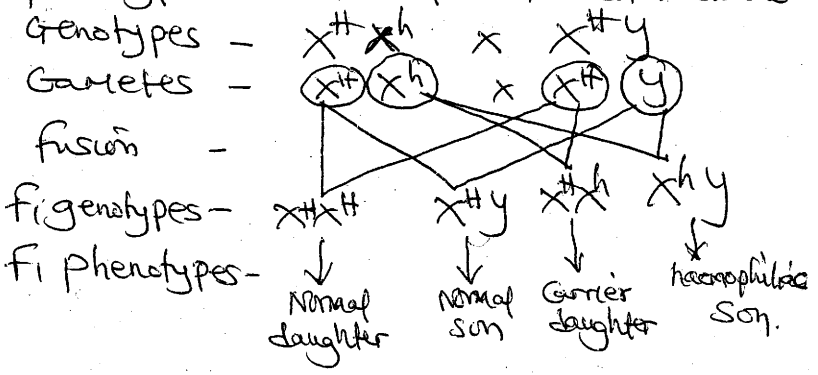
solution

(a) phenotypes — Carrier wife x Haemophiliac (phenotypically normal) husband



- Probability of bearing an haemophiliac in this Marriage is $\frac{2}{4} = \frac{1}{2} = 50\%$.

(b) phenotypes — Carrier wife x Normal husband



- Probability of bearing an haemophiliac in this Marriage is $\frac{1}{4}$ or 25%. Hence Jane would be advised to marry Peter in this case.
- During genetic counselling the

following steps are followed :-
(i) Diagnosis to establish the problem eg through lab tests, family history, medical examination, amniocentesis to determine chromosomal abnormalities, physical examination, genetic screening for any defective genes - this will help the counsellor to explain the condition to the patient; and also analyse risk involved.
(ii) Give advice to the patient ie genetic counselling.
(iii) Give options available eg use of contraceptives, A.I; adoption etc.

- Genetic counsellors encounter the following challenges / limitations :
(i) stigmatisation among same patients
(ii) children suing parents for genetic disorders
(iii) some options available pose some ethical and socio-cultural implications such as abortion.

(4) Genetic Engineering.

- Genetic engineering refers to the identification of a desirable gene in an organism, isolating it, altering it and transferring it from one living organism to another.
- It also refers to the manipulation of genes to get intended or desired proteins.
- Genetic engineering has been applied in the following fields :-
(a) Farming
(i) Genetically modified (GM) Maize and soya

have been produced which have resistance to insect pests. This has been achieved by inserting resistance genes from a bacterium called Bacillus thuringensis (Bt) into the genomes of these crops. This enables the crops to produce toxins which kill these insects.

ii, Gm tomatoes whose genes responsible for softening of the fruits before they are fully mature has been deleted. This results in the tomatoes staying longer on the stems hence realising fuller development of flavour without softening.

iii, Bovine somatotrophin hormone which increases milk production and weight in beef producing cattle by 10-15%. When the gene for the hormone is isolated and inserted into a bacterium, the bacterium produces alot of the Bovine somatotrophin hormone during fermentation. The hormone is extracted and injected into the animals.

All these examples, among others, constitute biotechnology which can assist farmers in improving yield; obtaining varieties of crops or breeds of animals resistant to diseases/pests; etc. For example using this technology Internal Resistant Maize for Africa (IMRA) project is aiming at producing maize resistant to the pest - maize stem borer. This is aimed at improving food security. Transgenic Maize containing Bt gene for resistance is the focal point of the project.

(b) Medicine

i, various hormones are being produced by Gm organisms eg

- Insulin is being produced by a strain of bacteria Escherichia coli into which the human insulin gene has been inserted.
- Human somatotrophic hormone for treatment of dwarfism is now extracted from Gm strain of E. coli.

ii, Medicinal proteins in milk

- sheep have been genetically modified to produce milk containing medicinal proteins used to relieve haemophilia and hereditary emphysema; ie
- Genes for blood clotting factors are transferred into sheep embryos. Female sheep born will have ability to produce milk containing clotting factors as these genes interact with genes for milk production. The clotting factors are then isolated and used for relieving haemophiliacs of haemophilia.
- Hereditary emphysema is due to presence of uninhibited enzyme called enzyme elastase which dissolves elastic tissues of alveoli causing their collapse. In normal people, a protein called Alpha-anti-trypsin (AAT) circulating in blood inhibits activity of this enzyme. AAT is produced in sheep's milk the same way as the clotting factors (IX).

iii, production of vaccines

- In production of vaccine against Hepatitis B the gene for the protein coat of the virus

is isolated and transferred into a fungus (yeast) which is then cultured to produce the protein. The protein is isolated and purified and injected into humans as antigens which stimulate production of antibodies against Hepatitis B.

- Some genetically modified (GM) plants eg bananas are being targeted for the production of orally administered vaccines against cholera and rabies.

iv, Gene therapy

- Gene therapy refers to the replacement of faulty genes with normal ones aimed at correcting genetic disorders.
- For example, in treatment of cystic fibrosis in lungs and Ducheme muscular Dystrophy (DMD), a virus is used to convey the normal gene / Correct gene into the affected somatic cells. This somatic gene therapy is known as germ-line gene therapy. The technique is also targeting correction of defective genes in cells of embryos.

(d) Environment

- GM Pseudomonas bacteria are capable of decomposing hydrocarbons in petroleum and are therefore used in controlling pollution due to oil spillage in soil and in water bodies.

(e) Crime detection and disputed parentage / paternity

- DNA being unique to each individual, DNA base sequence film prepared on a

film plate - a technique known as DNA fingerprinting - can be used in crime detection. Specimens from scenes of crime eg hair, blood stains, semen can be analysed to identify the culprits.
- DNA finger-printing can also be used in conclusively determining disputed parentage.

6. Cloning

- This is a type of reproduction where a group of cells arise from a single individual cell without fertilization. This is therefore a form of asexual reproduction. The offsprings are called **clones** eg "Dolly" the sheep.
- In the process, a nucleus from a fertilised ovum is removed and replaced with a diploid nucleus from the mammary glands eg of another sheep. The ovum is implanted into the sheep's uterus.
- Although the technique has not fully succeeded in animals eg Dolly sheep died before its 10th birthday, it has worked successfully in plants in **tissue culture techniques** which has resulted in a variety of bananas and Pyrethrum.

7. Human Genome

- Human genome refers to the total genetic content of any cell of an organism. It comprises all the genes in all the chromosomes.
- In humans, there are up to 100,000 genes and now there is a project aimed at :-

(a) Gene mapping

-This will help in identifying specific positions occupied by specific genes on a chromosome eg cystic fibrosis gene is located on chromosome no. 7, sickle-cell anaemia gene on chromosome no. 11 and haemophilia gene on x-chromosome in humans.

(b) Sequencing of the gene

-It involves analysis of DNA to reveal the order of the genes bases in all the chromosomes. This is aimed at:-

(i) Identification of defective genes hence facilitating their correction.

(ii) Identification of genes susceptible to certain diseases so that the individuals concerned can take preventive measures.

(iii) Predicting the protein that a gene produces hence providing an opportunity to produce drugs to enhance or inhibit the activity of such proteins.

Ethical issues and fear of the unknown.

-Transgenic plants/crops when eaten may introduce genes for antibiotic resistance into the gut bacteria eg Escherichia coli. These genes may be spread to other bacteria through faeces in the environment. This can or may happen through transgenic rice made resistant to some viruses. E. coli is used to transmit the gene of resistance into the rice plants.

-Eugenics : replacement of defective genes raises the ethical issue of whether to eliminate people with defective genes.

-Biological warfare ie use of genetic guns is another ethical issue. GM micro-organisms resistant to antibiotics may be used against certain population during wars. Hence genetic research needs regulation.

2. EVOLUTION

Meaning of Evolution

- Evolution is the gradual change of living organisms from simple life forms to complex life forms over a long period of time.
- Evolution as a study explains :-
  (a) The origin of living things
  (b) The diversity of life forms
  (c) The unity of life forms.

The Origin of Life

- Explained by several theories, among them:-
  i, special creation theory
  ii, chemical and organic evolution theory

i, Special Creation Theory

- Narrated in the Bible, Quran and folklore.
- According to special creation theory :-
  i, Life was brought into existence by a supreme Being called God, from nothingness.
  ii, The life forms were created in a perfect form and have remained unchanged over time;
  iii, This knowledge is based on faith and can not be disputed.
- This belief can not be contradicted by science since it is not scientifically testable.

(2) Chemical Evolution Theory

- This is the scientific view about the origin of life. According to the theory, it is believed that simple chemicals such as water (H_2O), ammonia (NH_3) and methane (CH_4) combined through catalytic effect to form the first living molecules / Biomolecules.

- This period of chemical evolution is believed to be 3500 – 400 million years ago.
- According to the theory, long after the formation of the universe and the earth, catalytic effect of lightning or some other form of catalyst combined the simple elements such as Nitrogen, carbon, oxygen, hydrogen to form simple molecules such as H_2O, CO_2, CH_4, H_2 and NH_3.
- This was suggested following scientific evidence from S.L. Miller's laboratory experiments in 1953 in which he was able to produce 4 out of the 20 amino acids. In Miller's experiment, simple molecules – H_2, H_2O, CH_4 and NH_3 were subjected to conditions of high temperature, high pressure and catalytic effect of electric current and they combined to form the amino-acids. The conditions are believed to reflect those that existed when life started.
- From Miller's experiments, it can be theorised that millions of years ago, simple molecules in the atmosphere such as Nitrogen, hydrogen, carbon(IV)oxide combined in various proportions to form simple compounds such as water (H_2O), Methane (CH_4) and ammonia (NH_3).
- Further combinations of such compounds possibly resulted in formation of complex self-replicating molecules

resembling the present-day DNA which forms genetic material in cells.
- Successive replications of these molecules and further developments probably led to the formation of simple forms of the first living cells.
- These first cells may have resembled the present-day viruses and bacteria.
- The theory of chemical evolution holds the following views on the origin and the nature of life :-

(i) Life came into existence through combinations of chemicals
(ii) The initial life forms were simple and have changed over years to form the present complex organisms. The change of simple life forms to the current complex life forms over a long period of time is known as **organic evolution**

NB :-

- It is theorised that the universe came into existence 15 billion years ago; the solar system formed 6 billion years ago; and our planet earth formed 4 billion years ago from debris of a burnt-out star. Since then, the earth has undergone cooling and structural changes on its outermost crust which eventually provided environment for development of the first living organisms
- Fossil records of primitive prokaryotes date to 1000 million years ago. These

were possibly the first single-celled organisms. Multicellular organisms arose from these simple forms over a long period of time.

Evidences for organic evolution

- The evidence for (organic) evolution can be divided into two groups :-
  (a) Direct evidence ie fossil records or palaeontology
  (b) Indirect evidences ie
    (i) Comparative anatomy and taxonomy;
    (ii) Comparative embryology
    (iii) Cell biology / cytology
    (iv) Geographical distribution of organisms
    (v) Comparative physiology and serology

i) Fossil Records

- Fossils are remains of ancestral forms of organisms that were accidentally preserved in naturally occuring materials eg Sedimentary rocks, plant resins etc
- The study of fossils is called **Palaeontology**.
- Common methods of preservation of fossil records include petrifaction (changing into rock), preservation in amber, plant resins and as impressions in Karsts and moulds.
- The study of fossils is important in the study of evolution in the following ways :-

1. Gives direct evidence of the types of organisms eg plants and animals that existed during a given geological age. For example fossil records of Monera are found to be the earliest followed by protoctista and fungi. plants and animals appeared later.
2. Fossil records reveal the phylogenetic relationships between organisms of different groups.
3. Fossil records show gradual increase in complexity of organisms over time. For example lower strata fossils are simple whereas fossils on upper strata are more complex in terms of structure. This has been used to reconstruct complete fossil records of some animals eg human beings (using skull sizes), horse (using the forelimbs in terms of complexity of height and hooves) and sea urchin (Micraster spp).

- The age of fossils is determined using carbon-14 dating. The age of a rock with very old fossils is determined using Potassium-argon method.
- However, fossil records have the following limitations :-
1. There are several missing fossil records due to : (a) partial fossilisation
   (b) may have been eaten by scavangers
   (c) only a few fossil records may have been discovered
   (d) unsuitable fossilisation conditions
2. Distortion of parts during sedimentation.
3. Destruction of fossils by geological activities

such as earthquakes, faulting, folding, vulcanicity, upliftings and mass movements.

Fossil Record of Human beings

- scientists believe that Man evolved from a **primate stock** of ape-like creatures as suggested by Charles Darwin in his book "Descent of Man". since this proposal by Charles Darwin, scientists have been trying to get archeological and palaeontological evidence to support this theory, though there are still missing links.
- The scientists believe that the primate stock gave rise to two families - family **pongidae** which includes anthropoid apes like gorillas, chimpanzees, and orangutans; and family **Hominidae** - the humans.
- The **earliest primate** to have evolved is believed to be the **proconsul**, which lived in Africa 20 million years ago and later spread to Asia.
- The **earliest hominid** is believed to have been the **Sahelanthropus tchaldensis** dated 7 million years old discovered in Chad in the year **2002** and another one in Kenya dated 6 million years old.
- However, the best studied genera of the family Hominidae are:-
  1. Genus **Australopithecus**
  2. Genus **Homo**
- Genus Australopithecus shows no evidence of culture and is believed to have emerged 4 million years ago. Representative species include the following:-

i) Australopithecus anamensis from L. Turkana dating 3.9 million years old;
ii) Australopithecus afarensis "Lucy" discovered in Hadar, Ethiopia dating 3.6 million years
iii) Australopithecus africanus and Australopithecus robustus of South Africa dating 2 million years old;
iv) Australopithecus boisei discovered in Oldwai Gorge in Tanzania by Mary leakey dating 1.3 million years old
v) Zinjanthropus boisei - "the nut cracker man" also discovered in Olduvai Gorge in Tanzania dating 1.8 million years old. This resembled Australopithecus robustus of South Africa.

- Genus Homo seems to have arisen 2.4 million years ago and lived at the same time as Genus Australopithecus. It is believed to have given rise to the following species:-
  i) Homo rudolfensis, the oldest dating 2.5 million years old;
  ii) Homo habilis, discovered by Richard Leakey and Kamoya Kimeu at Koobi Fora in Eastern Lake Turkana, dating 2 million years old. This "handy man" had a cranial capacity of 700 cm^3; made tools such as axes, scrapers etc; Extincted 1.5 million years ago.
  iii) Homo erectus - the "erect man" seems to have emerged from Homo habilis 2 Million years ago. Discovered in Africa, Asia and Europe. Made tools; Lit fire; lived communally. Homo erectus looked close

to present man but had a prominent brow-ridge over the eyes; was small in stature and had a cranial capacity which was smaller ie 775-1200 cm^3.

(iv) Homo ergaster, recently discovered around shores of L. Turkana and nicknamed "Turkana boy" dated 1.56 million years old. Is believed to be the ancestor of present man due to similar body plan.

(v) Homo heidelburgensis dated 700,000 years old and Homo neanderthalensis dated 300,000 years old discovered in Germany in the Neanderthal valley.

(vi) Homo sapiens or "rationalising man", the present-day species of human beings thought to have arisen 130,000 years ago. A fossil record known as "Cro-magnon" man dated 40,000 years discovered in Europe is an example identical to modern man.

—The present species of human beings may have arisen 10,000 years ago.

—Homo sapiens is characterised by the following features which is an advancement over its predecessors ;-

1. High intellectual capacity / Advanced brain.
2. Ability to vocalise sound or communicate through language / Advanced speech
3. Making moral judgements
4. Rationalising and developing ideas.
5. Bipedal locomotion / upright gaity or stance
6. Manipulative and prehensible hand with non-opposable thumb
7. Well positioned eyes / Binocular vision

—These are evolutionary advancements which adapt man to his environment.

Evolutionary Differences between Man and Apes

	Apes	Man (humans)
1.	Small cranium with small brain capacity (500cm^3) hence low learning capacity.	Large cranium with large brain capacity (of 1350 cm^3) hence high learning capacity.
2.	Large incisors and canines for killing prey and for defense.	Small incisors and canines unsuitable for killing prey and defence.
3.	Pelvis narrow and elongated.	Pelvis broad and flattened.
4.	Locomotion quadripedal	Locomotion bi-pedal
5.	Opposable toe for arboreal locomotion	Non-opposable toe. meant for stability on the ground.

Advancement of Homo sapiens over Homo habilis

	Homo sapiens	Homo habilis
1.	High intellectual capacity	Low intellectual capacity
2.	Advanced speech or communication through language	No speech and does not communicate through language
3.	standing upright and bipedal locomotion	Bent posture and quadripedal locomotion.

(ii) Comparative anatomy and taxonomy

(a) Comparative taxonomy

—Members of the same phylum show similarities in structures / organs performing the same function eg presence of digestive

system, urinary system, four-chambered heart nervous system in members of phylum chordata. This points to a common ancestry.

(b) Comparative anatomy

- Refers to comparison in forms and structures in different organisms to establish similarities which point to a common ancestry. Includes

1. Presence of vestigial organs

- vestigial organs are those that in the course of evolution that have become greatly reduced in size and ceased to function, ie have become rudimentary. Examples include:-
  (i) Caecum and appendix in humans which are reduced in size and have no digestive function. In other animals such as rats they harbour bacteria which secrete enzyme cellulase to digest Cellulose to glucose.
  (ii) The Python and whale have no externally visible limbs but their original existence is evidenced by presence of rudimentary pelvic girdle.
  (iii) Reduced wings beneath body plumage of kiwi - a flightless bird.
  (iv) Vestigial tail in humans called Coccyx.
  (v) Body hair in human beings
  (vi) Ear muscles in human ears / pinnae
  (vii) Nictating membrane in eyes of mammals which is reduced and functionless. In birds, it is moved over the eye and acts as third eyelid.
- Vestigial organs seem to point to the fact that they were present and functional

in their ancestral forms hence pointing to a common ancestry.

2. The pentadactyl limbs in vertebrates eg man, horse, rat, mole, whale etc.

- Vertebrate limbs such as man, horse, whale, rat, bats, birds have bones arranged in similar way ending in five digits. But this pentadactyl limb is modified to perform different functions in different animals as follows:-
  (i) as a wing in bats and birds for flight
  (ii) as a digging hand in moles and rats
  (iii) as a flipper for swimming in whales & turtles
  (iv) as a fore-limb for running in horses & zebra
- Pentadactyl limbs have same embryonic origins but are modified to perform different functions. This points to a common ancestry.

3. Beaks and feet of birds

- Birds' feet and beaks have same embryonic origins but are modified to perform different functions such as
  (i) hooked beaks as in parrots for crushing seeds
  (ii) Sharp hooked beaks for tearing flesh as in hawks
  (iii) Chisel-shaped beaks for pecking wood as in wood peckers
  (iv) Long slender beaks for sucking nectar as in Sunbird
  (v) Notched beaks and webbed feet for Probing mud and wading / swimming respectively
  (vi) Sharp talons which are also hooked for grabbing prey as in hawks and other birds of prey.
- structures that have common embryonic origins but that have been modified TO

perform different functions in different habitats are known as homologous structures. The homologous structures exhibit a pattern of evolution known as <u>divergent evolution</u> or <u>adaptive radiation</u> - a pattern of evolution in which structures with a common embryonic origin evolve to perform different functions in different habitats Examples Pentadactyl limb, beaks and feet in birds; vertebrate hearts.
— In the course of evolution also, some structures have evolved / been modified to perform similar functions although they have different embryonic origins such as wings in bats or birds and insects- Such structures are known as <u>analogous</u> structures; and exhibit a pattern of evolution known as <u>Convergent evolution</u> - a pattern of evolution in which structures with different embryonic structures have evolved in the course of time to perform similar functions. Examples include :-

(i) Wings in bats or birds - pentadactyl limb - and wings in insects - an extension of exoskeleton. Both are for flight
(ii) Eye in Man and in Octopus. Both are for sight but have similar structure and different embryonic origins.
(iii) Structure of Cactus and Euphobia which have different origins ie North America and Africa respectively but look similar because they are adapted to dry conditions.
(iv) Flippers in whales (of pentadactyl origin) and fins in sharks both used for swimming.
(v) Limbs of mammals and those of insects.

- Comparative anatomy gives evidence of organisms with common ancestry such as those with homologous structures;

(c) Comparative embryology

- Involves the study of vertebrate embryos to establish evolutionary relationships.
— Embryos of different vertebrate groups ie fishes, amphibians, reptiles, birds and mammals are morphologically similar during their early stages of development. This similarity suggests a common ancestry.
— Therefore the closer the resemblance between embryos in early stages of development, the closer the phylogenetic relationships of the organisms. This is the recapitulation theory which states that "Ontogeny recapitulates phylogeny" (although this has been proven wrong).

(d) Cell Biology

— Cell Biology reveals common organelles in all eukaryotic cells. Such common organelles include Endoplasmic reticulum, ribosomes, cytochromes, golgi bodies, and common biological chemicals such as ATP and DNA. All these point to a common ancestry.
— All plant cells also contain cellulose cellwall, cellsap and chloroplasts. This points to a common ancestry.
— Blood pigments such as haemoglobin common among vertebrates, haemocyanin common among molluscs and chlorocruonin

common among crustaceans, point to a common ancestry.
- The differences that exist among organisms such as plants and animals suggest evolution along different lines.

(e) Comparative serology and physiology

1. Comparative serology

- Antigen-antibody reactions reveal same phylogenetic relationships among organisms with common ancestry. This is because phylogenetically related organisms contain similar blood proteins (antigens and antibodies) for example if human blood is injected into blood stream of a rabbit, the blood of the rabbit reacts by producing antibodies against the human blood. These antibodies, if extracted and reacted with human serum (containing antigens) leads to rapid agglutination. With the chimpanzee, the reaction is even more rapid if the procedure is repeated using this organism. But with a dog the reaction is a bit slower and with a frog, there is no agglutination. Hence the chimpanzee is a closer relative to Man in the evolutionary tree compared to a frog.

2. Comparative physiology

- Members within the same phylum have organs and tissues functioning the same way eg the heart, kidneys, lungs, blood in phylum chordata. This points to a common ancestry.

(f) Geographical distribution of organisms

- Present continents are believed to have been one large landmass joined together and organisms freely mixed together.
- Later drifting occured during continental drift hence organisms from a common ancestry seperated into different continents. This led to isolation of members of the same species resulting in different patterns of evolution eg
  (i) Llamas of South America (Andes) resemble camels of Africa and Asia although they are thought to have had a common ancestor in North America.
  (ii) Tigers of Asia resemble jaguars and Panthers of South America (Amazon forest) and Leopards and cheetahs of Africa.
  (iii) Amazon Monkeys have long tails whereas monkeys of Africa have short tails.
  (iv) Marsupials such as kangaroos, koala bears and spiny ant-eaters are unique in Australia. Australia is believed to have been the fist continent to drift away, about 200 million years ago; before evolution of placental mammals. That is why it has unique fauna and flora; ie animals and plants respectively.
- Initial interaction after continental drift was hindered by geographical barriers such as oceans, forests, deserts etc leading to formation of different fauna and flora.

NB
(i) The type of evolution / pattern of

evolution exhibited following Continental drift is divergent evolution / adaptive radiation in which organisms from common ancestry have seperated into different ecological and geographical areas in which they adapt differently resulting in different patterns of evolution.

(ii) Geographically isolated oceanic islands may have received their fauna and flora from neighbouring Continents and then evolved their own characteristics eg the Iguana Lizard which is 1.25 M Long is the only aquatic lizard in Galapagos Island.

Revision Questions

1. KNEC 235/1/1998 - state five evolutionary characteristics that adapt man to his environment (5MARKS)
2. Give a reason why each of the following is important in the study of evolution
   (a) Fossil records (1MK)
   (b) Comparative anatomy (1MK) KNEC 231/1/2000.
3. Discuss various evidences which show that evolution has taken place (20MKS) KNEC 231/1/98
4. state three evidences to support the theory of evolution. (3MKS) -235/1/1997.
5. The wing of a bird and that of an insect are analogous structures. This is an example of _____ pattern of evolution (1MK)
6. Two populations of same species of birds were seperated over a long period of time by an ocean. Both populations initially fed on insects only. Later it was discovered that one population fed entirely on fruits even if insects were available. Name this type of evolutionary change. (1MK)
7. Distinguish between homologous structures and analogous structures giving an example in each case. (2MKS)
8. With an example in each case define the following terms (6MKS).
   (a) Vestigial structures
   (b) Homologous structures
   (c) Analogous structures

Mechanism of Evolution

Among the theories explaining how evolution may have taken place include:-

(i) Lamarkian theory (1809)
(ii) Darwinian theory of Natural selection (1859)

(i) Lamarkian Theory of inheritance of acquired characteristics

- The theory was postulated by a French scientist Jean Baptiste Lamark in 1809.
- According to the theory, the young of a species may inherit certain physical characteristics which their parents acquired in the course of their daily lifes eg muscular body of weight lifters; hence the theory is based on inheritance of acquired characteristics.
- Lamark argued that whenever the environment demanded the need or use of a structure of an organism, the organ developed in response to the demand and its features

developed more eg the arm. used more by a blacksmith becomes more muscular than the other arm.

—The theory further suggests that these acquired characteristics so acquired in the lifetime of a parent are inherited by the offsprings in the subsequent generations resulting in the emergence of new forms of species, hence evolution. This is because the new forms acquire certain advantages over their parents in exploiting certain ecological niches eg

i) Long necks in giraffe may have developed as a result of ancestral forms stretching their short necks to reach higher levels of vegetation due to competition from other browsers. The long-neck trait so acquired was passed to successive generations giving them advantage over short-necked forms. Eventually a new species of long-necked giraffes was formed.

ii) Ostrich, emu, kiwi and other flightless birds lost their ability to fly since they occupied environments which did not require flight. Hence their wings became reduced and functionless. This also applies to the eyeless fish which live in dark caves in the sea which ~~thus~~ lost their eyes.

—Lamark's theory is only valid however to the level of environment directing phenotypic changes of an individual eg muscles enlarging in body builders. But, phenotypically acquired characteristics

can not be inherited. only traits in gametes are inherited or only changes in gamete cells can be inherited. secondly experimental evidence does not support this theory. For these two reasons, Lamark's theory is not accepted by biologists today.

ii) Darwinian theory of Natural selection

—The theory was proposed by a British naturalist Charles Darwin in 1859 in his book "The origin of species".

—According to the theory, nature selects individuals that are sufficiently well adapted to the environment and allows them to survive up to reproductive age, and rejects those that are poorly adapted (which perish before reaching reproductive age).

—He based his theory on the following obvious facts

i) There are **variations** within members of the same species/population. The variations are either genetic (from within the individual) or occur by chance ie through mutations. Through sexual reproduction these variations are transmitted to successive offsprings during genetic inheritance. Some of these variations confer an advantage to the individuals while others are disadvantageous.

ii) **Over-production** of individuals in nature. The number of offsprings far outnumber the parental generation. But only a few survive to reach sexual maturity. This is due to environmental pressures such

such as predation, diseases, competition for resources such as food, water and breeding sites. Hence the population of a species remains more or less constant in the natural environment.

iii, struggle for survival / existence.

- Due to over-production of individuals and limited resources available, there is competition for the same hence struggle for survival / existence.

iv, Survival for the fittest.

- In the struggle for existence, those individuals with favarouble / advantageous variations and hence well adapted to the environment are selected by nature and allowed to grow up to sexual maturity and reproduce. In this way they transmit their favourable traits / variations to their offsprings during genetic inheritance. The poorly adapted perish before reaching sexual maturity and do not transmit their traits. Hence there is survival for the fittest ie sufficiently well adapted. Examples of such good adaptations include Colour Camouflage against predation, resistance to diseases and pests, resistance to drought etc. According to Darwin, it is by chance that an organism is suited to a particular environment or environmental chances ie both the organism and environment do not control the direction of natural selection).

v, Inheritance of favourable traits / variations or characteristics.

- Variations of the "fittest" are passed to their offsprings during genetic inheritance since they live longer up to reproductive age. Those with unfavourable traits perish and hence their variations disappear with them.

vi, Development of a new species by natural selection.

- Those individuals selected by nature transmit their variations to their offsprings during genetic inheritance through reproduction. The gradual accumulation of the small variations over a long period of time leads to emergence of new forms of species.
- Therefore natural selection refers to that process in which nature selects individuals that are sufficiently well adapted and allows them to survive up to reproductive age and rejects those that are poorly adapted.

NB

① The "variations" that Darwin regarded as the raw materials for the process of evolution have been traced to changes that occur at the level of chromosomes or gene, changes called "mutations".

② Organisms with beneficial mutations are able to pass them to their offsprings during reproduction. So do individuals with unbeneficial mutations. But most of them may perish if the mutations are fatal or lethal.

③ Sexual reproduction is most important in evolution since it leads to new recombinations during meiosis while fertilization

spreads the genes widely in the population. Transmission of mutations can lead to emergence of new species.

④ Experimental evidence has shown that mutations result in variations within a population.

KNEC Revision Questions.

231/1/1991 - (a) What is meant by natural selection? (3MKS)

(b) Describe how natural selection brings about adaptation of a species to its environment. (17 MKS).

235/1/1998 – What is natural selection? (2 MKS)

235/1/1997 – What is meant by natural selection? (2 MKS)

235/1/1997 – state two advantages of natural selection to organisms (2 MKS).

Criticisms to Darwin's Theory.

i, Does not explain about presence of vestigial organs.

ii, In struggle for existence both the "fit" and "unfit" organisms survive as in human beings.

iii, Small variations are often environmental and seldom inherited.

iv, Does not take into account mutations which cause permanent changes.

v, According to the laws of heredity the "fittest" do not always pass only favourable variations to their offsprings.

Advantages of natural selection to organisms

i, Assists to eliminate disadvantageous traits and perpetuate advantageous traits.

ii, Allows better adapted organisms to survive adverse changes in the environment and less adapted organisms to be eliminated by changes in the environment.

KNEC Revision Questions.

KNEC 1989 – State the difference between Lamarkian and Darwinian theories of evolution. (2MKS)

KNEC 2000 – Give two reasons why Lamarkian theory of evolution is not accepted by Biologists today. (2MKS).

Natural selection in Action.

Scientists have given some evidence to show that evolution is still taking place. The following are some selected examples.

① Resistance to drugs, pesticides, antibiotics insecticides, fungicides and acaricides.

– Some strains of bacteria have developed resistance to certain drugs and antibiotics. The same applies to some protozoans eg Plasmodium which have developed resistance to antibiotics such as chloroquin.

– Some pests have also developed resistance to some pesticides; some insects have developed resistance to certain insecticides such as DDT (Dichlorodiphenyltrichloroethane); some ticks have developed resistance to certain acaricides and some fungus have developed resistance to certain fungicides.

– This is because within the populations of these organisms, some members develop genes for resistance to these chemicals which

enable them to secrete enzymes which digest these chemicals redendering them useless. These mutated organisms then pass these traits to their offsprings thus forming a population of resistant strains. With time new species may arise from such strains of mutated organisms.

NB

① It has been difficult to form vaccines against causative agents of diseases like Malaria because the plasmodium parasites mutate at a fast rate by changing protein coat antigens.

② Attempts by man to eradicate different species of pests and pathogens has resulted in evolution of more resistance species by mutation and natural selection.

② Melanism / Industrial Melanism.

- The peppered moth, Biston betularia, exists in two forms – the speckled white and the dark (Melanic) form.
- The existence of a species in more than one form is known as polymorphism.
- The Melanic forms may have developed by mutation.
- Since 1948, the numbers of the Melanic forms has been increasing in the industrialised city of Manchester city (Britain) due to factory smoke and soot which has darkened the stems / tree trunks. Hence they camouflage here against predation.
- The speckled-white moths have decreased in numbers because of predation, since the free trunks, formerly speckled-white by lichens, are now darkened; exposing

the speckled white moths to predation.
- Hence speckled-white moths have a selective disadvantage whereas the melanic forms have a selection advantage by nature
- Due to this agent of natural selection, ie selection pressure, it is believed that with time, the speckled-white moths may be eliminated leaving only the melanic forms. This melanism ie phenomenon in which the dark / melanic forms of moths are increasing in number due to selection advantage by nature whereas the speckled white moths are decreasing in number due to selection disadvantage by nature – illustrates speciation in the process due to evolution by natural selection.

③ Sickle-cell anaemia traits in Malaria zones.

- It is known that there is a high frequency of this mutant gene in places where malaria incidences are high. This is because those who are heterozygous $Hb^A Hb^S$ have immunity to Malaria, a situation called heterozygous advantage ie heterozygous individuals are selected for by nature.

④ Endangered species.

- Some plants and animals are endangered and some are now extinct due to natural selection through poaching, hunting, predation, overfishing etc such animals which are endangered or are extinct have / had a selection disadvantage eg
  i, White Rhinos of Africa because of their tusks.

(ii) crocodiles of Australia because of their skins etc
(iii) Dugog (a marine mammal) of ~~East~~ Africa
(iv) Elephants of Africa because of their tusks
(v) The whale of East Africa because of its oil and flesh.

- All these are endangered species.
- The following animals are now extinct:-
  (i) Flightless dodo of Mauritius which got extinct in 1693
  (ii) The Auk of America which got extinct in 1844.

K.N.E.C. Revision Questions.

(1) Explain why some bacteria develop resistance to drugs after they have been subjected to them for sometime (2mks) (KNEC 1999)

(2) Explain why some malarial parasites become resistant to anti-malarial drugs with time. (3mks).

(3) (a) Describe how mutations arise (5mks)
(b) Explain the significance of mutations in evolution (9mks).

3. SUPPORT AND MOVEMENT.

Introduction

- Support is the ability of organisms to bear their own weights and maintain their body forms.
- Support includes :-
  i, holding their body parts in their correct positions
  ii, facilitation of movement. In order to achieve this, organisms require a support framework.
- Movement is the displacement of parts of an organism or the whole organism eg growth movement of plants, movement of limbs of animals etc.
- Movement of the whole organism is called locomotion
- Movement is a characteristic of all organisms and takes place in response to both external and internal stimuli.

Necessity for Support and Movement in plants

(a) Necessity for movement

i, At cellular level, it enables swimming of the male gametes in bryophytes and pteridophytes and growth of pollen tube in spermatophytes bringing about fertilization.

ii, At organ level: ① tropic movements enable plant-

- leaves to be exposed to light for photosynthesis ie phototropism;
- roots to get anchorage ie geotropism
- stems to grow and expose leaves to light for photosynthesis ie geotropism and phototropism
- stems of climbers and tendrils to obtain support ie thigmotropism / haptotropism;
- pollen tube to grow to embryo sac bringing about fertilization in flowering plants ie Chemotropism.

② Nastic movements/responses enables plants to escape unfavourable stimuli such as high temperatures, humidity etc.

(b) Necessity of support in plants

i, Support tissues ensure that the leaf lamina is well spread-out to expose maximum surface area to light for photosynthesis

ii, Support tissues in flowers ensure they are exposed to agents of pollination such as insects and wind; hence facilitating fertilization

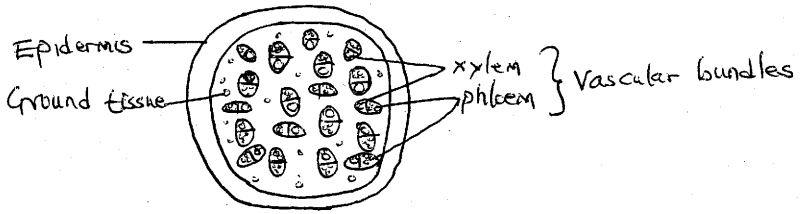
iii, Support tissues hold fruits and seeds in position for dispersal

iv, Most plants require strong support structures to resist breakage due to their own weights and weights of other organisms such as insects, monkeys, birds etc

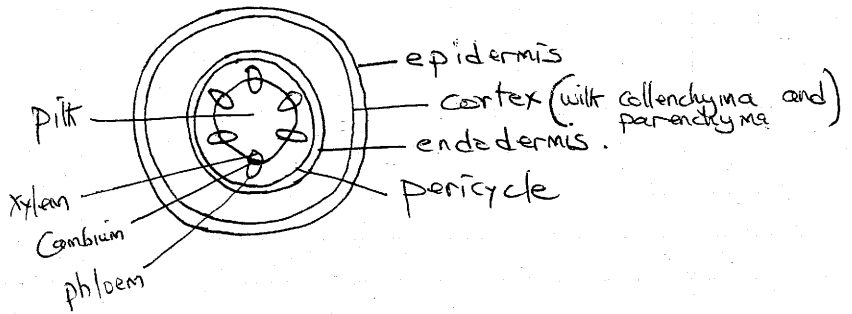
Arrangement of support tissues in plants

- Support tissues in plants include :-
  i, Collenchyma
  ii, Parenchyma
  iii, Sclerenchyma
  iv, Xylem vessels and tracheids, wood fibres.
- Their distributions are shown below :-

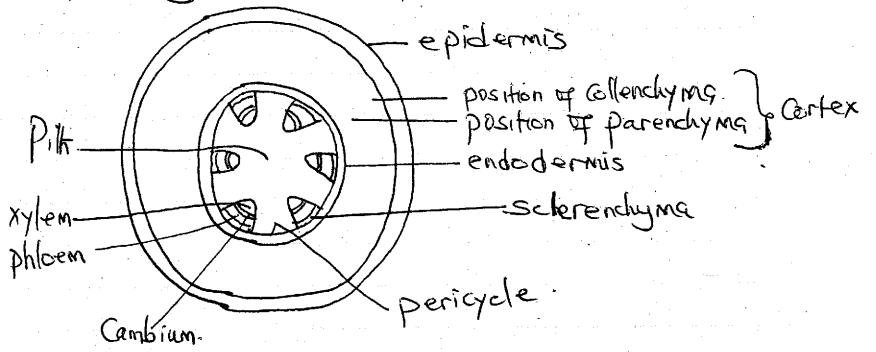
(a) T.s. of a young monocot stem showing position of xylem



(b) T.s. of a young dicot stem showing xylem.



(c) T.s. of an older dicot stem showing xylem, parenchyma, sclerenchyma and collenchyma.



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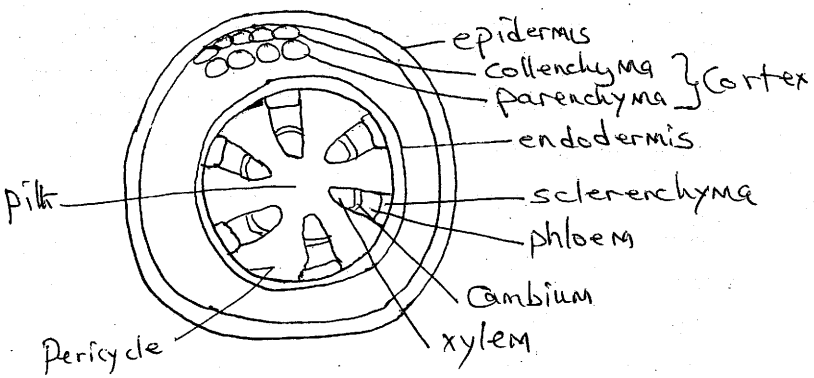
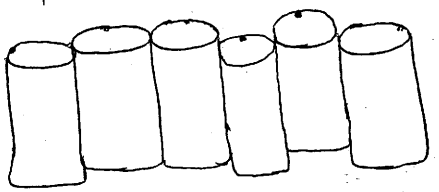


i) Parenchyma tissue

- Parenchyma tissue cells are spherical or elongated.
- They are unspecialised cells whose main function is packing and storage. When turgid, the cells provide mechanical support in herbaceous plants, leaves and young growing parts of a plant. This is due to turger pressure of the parenchyma cells.
- When the parenchyma cells lose more water by transpiration than they can absorb from the soil, wilting occurs and the flaccid cells become plasmolysed when their cellwalls shrink. Leaves and growing regions of the plant droop.
- When the plant is well watered again, the parenchyma cells absorb water by osmosis and they become turgid. The leaves spread out again and the stem becomes erect.
- Parenchyma cells are found in the cortex.

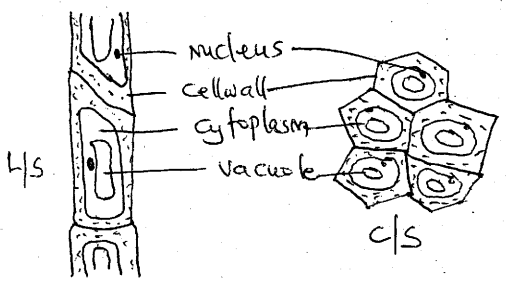


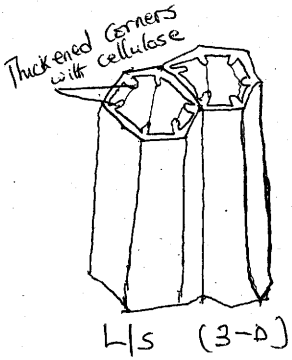
- The cells are made of living protoplasm and their walls are not thickened.

ii) Collenchyma tissue

- Collenchyma cells occur just beneath the epidermis although not all stems develop them.
- Their walls are thickened with cellulose (not lignin) for strengthening. The cellulose deposists are at the corners.
- They are living cells.

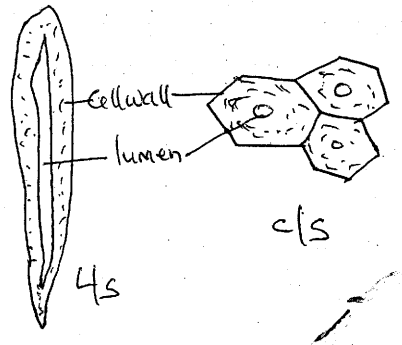
- Consists of longitudinally elongated cells
- Their function is to provide mechanical support to the stem, leaves of herbaceous plants and young woody plants.

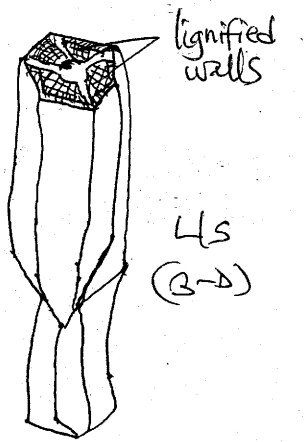




iii) sclerenchyma

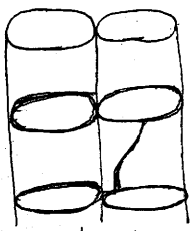
- Located around the vascular bundles in some plants forming sclerenchymatous pericycle eg sunflower.
- They are dead cells whose walls are thickened with lignin hence lignified walls for support.
- They occur as long fibres with tapered ends in wood. occur in groups to the outside of phloem.



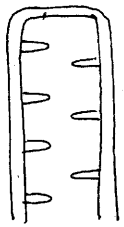


(iv) Xylem vessels and tracheids and fibres.

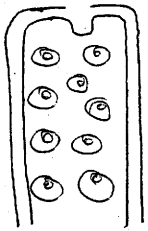
- Xylem vessels are thick-walled tubes with lignin deposits unevenly in rings, spirals or patches / reticulate.
- The main function of xylem vessels is transport of water and mineral salts but because their walls are lignified, they also give strength to and support to the stem. Hence xylem vessels and tracheids are mechanical or strengthening tissues also.
- Xylem contain tracheids, vessels and xylem fibres or wood fibres.
- Below are patterns of lignification in xylem vessels :-



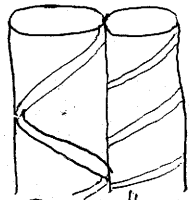
(a) annular thickening of xylem vessels.



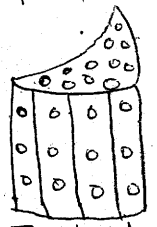
(b) Reticulate thickening



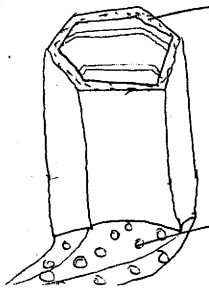
(c) pitted vessel



(d) Spiral thickening.



(e) Tracheids



- Xylem fibres / wood fibres are long tapering cells whose walls are greatly thickened and heavily lignified for support. They are found together with xylem vessels in vascular bundles and form wood of perennial plants.

Types of stems based on support tissues.

- Based on supportive / strengthening / mechanical tissues in plants we have the following types of stems :-
  (a) Woody stems
  (b) Herbaceous stems and climbing stems.
- Herbaceous and climbing stems have soft tissues which can be crashed easily.
- Herbaceous stems do not grow tall because they lack most supportive tissues - climbing stems only grow tall because they have developed compensatory structures / mechanisms like use of tendrils and twining around support structures.
- Generally herbaceous and climbing stems obtain support by :-
  (i) turgidity of Parenchyma cells
  (ii) Some use tendrils eg Passion fruits
  (iii) Some twine themselves around support structures eg Morning glory.
- Woody stems on the other hand have the strengthening tissues already discussed above.
- The collenchyma sclerenchyma and xylem vessels tracheids and fibres undergo thickening during secondary growth of the plant. Hence woody stems can grow to great heights and diameters. Even when water is removed, the support structures remain to hold the stem upright unlike in the herbaceous stems.

Support and Movement in Animals

- Animals have a firm and rigid framework for support known as the skeleton.
- The following are functions of the skeleton :-
  (i) Supports the animal's bodyweight
  (ii) Gives the body its shape.
  (iii) Provides surface for attachment of body muscles facilitating movement.
  (iv) Offers surface for attachment of internal organs
  (v) Protection of delicate tissues/organs eg brain protected by cranium.

Importance of Movement/Locomotion in animals

(i) Search for food, mates, water and shelter.
(ii) Migration from unfavourable conditions
(iii) Escape from predators
(iv) Dispersion/Colonization of new habitats.

How plants compensate for inability to move from one place to another/Locomote.

(i) Ability to utilize localised nutrients and ability to photosynthesize.
(ii) Ability to pollinate
(iii) Response to tactic, tropic and nastic stimuli
(iv) Ability to disperse seeds and fruits for propagation.

Types of skeletons

(i) Exoskeleton
(ii) Endoskeleton
(iii) Hydrostatic skeleton.

(i) Hydrostatic skeleton as in earthworms

- Consists of a fluid filled body cavity enclosed by a muscular body wall. Outer circular muscles and inner longitudinal muscles contract and relax against the fluid/hydrostatic skeleton to bring about movement.

(ii) Exoskeleton as in arthropods

- The exoskeleton is made of chitin. Chitin is not evenly distributed ie it is thin and flexible at the joints to facilitate movement.
- Exoskeleton is secreted by epidermal cells.
- When exoskeleton is still soft, it allows for growth of the arthropod eg insect. When it hardens, it limits growth. It is therefore shed regularly thus regulating growth in the arthropod/insect. The process is called moulting/ecdysis.
- Exoskeleton performs the following functions :-
  (i) supports internal structures, because it is hard;
  (ii) protects internal organs from mechanical damage.
  (iii) It is waterproof thus preventing or reducing water loss or dessication;
  (iv) Provides surface for attachment of muscles
  (v) Thin at joints to facilitate movement.
  (vi) Modified to wings for flight;
  (vii) It is modified to form hard mouthparts or jaws for biting or piercing or sucking or grinding.
  (viii) It is pigmented for camouflage
  (ix) It is also transparent in some parts thus allowing entry of light into eyes and for camouflage in water.
- Exoskeleton is generally light; to reduce density of the body as of insects;

(iii) The Endoskeleton

- Is a characteristic feature of all vertebrates where muscles are externally attached to a hard framework of bones or cartilage which is internally placed.
- Endoskeleton is made of living tissue unlike the exoskeleton. Hence the tissues grow and needs no moulting. The cells which make up the bones are osteocytes whereas those of cartilage are chondrocytes.
- The following are functions of endoskeleton:
  (i) Supports the animal's body weight and gives it its shape.
  (ii) Protects the delicate internal organs eg the heart, lungs and brain from mechanical damage.
  (iii) Provides surface for muscle attachment facilitating movement.
  (iv) Long and short bones produce blood cells ie Long bones produce WBCs; short bones produce RBCs whereas platelets are fragments of large cells of bones.
  (v) Bones act as reservoirs for Calcium and phosphate ions in the body.

Locomotion in a finned fish eg Tilapia

(a) Movement of fish such as Tilapia in Water

- Movement of fish in water is by swimming.
- It involves forward movement and control of the body position in water.
- Scales overlap backwards; the body is mucoid and stream-lined in shape to reduce friction or resistance to enhance movement;
- forward movement / propulsion is caused by

the tail. The tail is long to enable it to create enough force. Propulsion is achieved when the tail pushes sideways against the water. Side-ways movements is brought about by muscles/ myotomes arranged in segmented blocks on both sides of the vertebral column. The muscles contract alternately causing vertebral column to bend/swing sideways.
- When muscles on the right side relax, those on the left side contract and the body bends to the left side. When the muscles on the left side relax, those on the right side contract, and the body bends to the right.
- The fish uses its fins to control the position of its body in water. During forward movement the paired fins (pectoral and pelvic fins) lie flat on the body surface to reduce frictional resistance.
- To change direction the fish uses the paired fins. The paired fins are also used by fish to change its level in water hence control/prevent pitching.
- The fish spreads out the pectoral and the pelvic fins at 90° or at right angles to the body to enable it to brake.
- Fish also uses swim-bladder/air bladder/gas bladder to change its levels in water. When the bladder is filled with air, the fish becomes lighter/less dense/more bouyant; making it to rise in water. When air leaves the air bladder, the fish becomes heavier/more dense; making it to sink deeper in the water.
- Water currents may cause the side-ways

swaying of the body of the fish hence yawing. The dorsal and ventral fins prevent yawing and rolling.

KNEC 2010/PP2 → Describe how a finned fish such as tilapia moves in water (20 marks).

(b) Adaptations of a finned fish such as tilapia to movement.

- Fish live in water which is a viscuous medium. Water thus offers support but also gives alot of resistance to movement. Fish therefore has the following adaptations to locomotion / swimming / movement in water:-

(i) The vertebral column consists of a series of vertebrae, held together loosely for flexibility when swimming.

(ii) Has myotomes / myonemes / segmented muscle blocks on either side of the vertebral column whose antagonistic contractions and relaxations produce movements.

(iii) The sideways and backwards thrust of the tail and body against water, results in resistance of water pushing the fish sideways and forwards in a direction opposed to the thrust.

(iv) The head is not flexible / lacks the neck to maintain the forward thrust for fast movement.

(v) The body is streamlined to reduce resistance hence fast movement.

(vi) Presence of fins helps in the propulsion and balance in water.

(vii) The paired fins (pectoral and pelvic fins) control pitching (upward and downward movements and tendency to vertically plunge

downwards) hence maintain balance. They are also used for braking and steering / change of direction. During forward movement they lie flat on body to reduce friction.

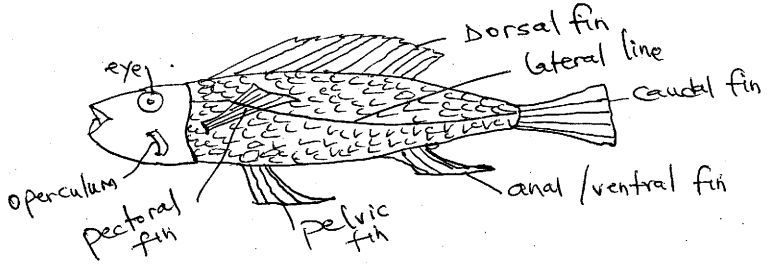
(viii) The unpaired fins (dorsal fins, ventral / anal fins and caudal fins) control yawing and rolling of fish hence helps to keep fish upright in water. This is because they increase the vertical surface area of the fish. The dorsal and anal fins are also called Median fins

(ix) The caudal / tail fin helps to propel fish forwards and steers the fish while in motion.

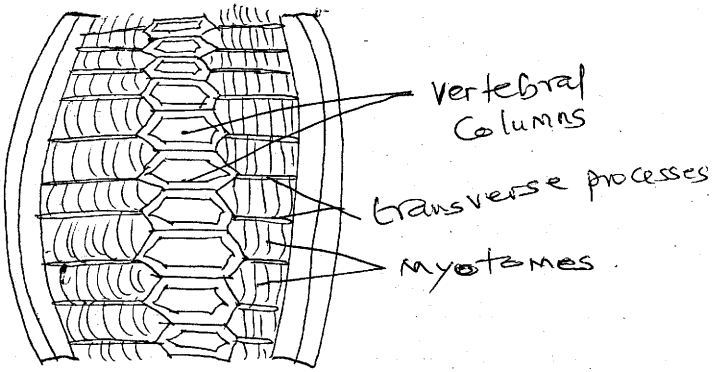
(x) The body of fish is mucoid / covered with mucus secreted by epidermal cells. The mucus lubricates the fish reducing friction allowing fast movement.

(xi) scales overlap and tip backwards / towards the back to reduce friction and enable fast movement.

(xi) Presence of swim bladder / gas bladder / air bladder which makes the fish buoyant. When it is filled with air it makes the fish light / less dense when the fish moves to higher levels of water. When air is moved out of the fish's swim-bladder, the relative density of the fish increases making the fish heavier hence it moves to lower water levels / deeper into water.



Vertebral Column of fish.



Tail power of fish.

- Refers to the relative percentage size of the tail compared to the total length of the fish. Calculated as follows:-

$$\text{Tail power} = \frac{\text{Length of the tail from anus to tip of tail}}{\text{Length of fish from tip of tail to tip of mouth}} \times 100\%$$

- Normally ranges between 42% - 50% in tilapia.
- Tail power is such high to help propel fish forwards in water.

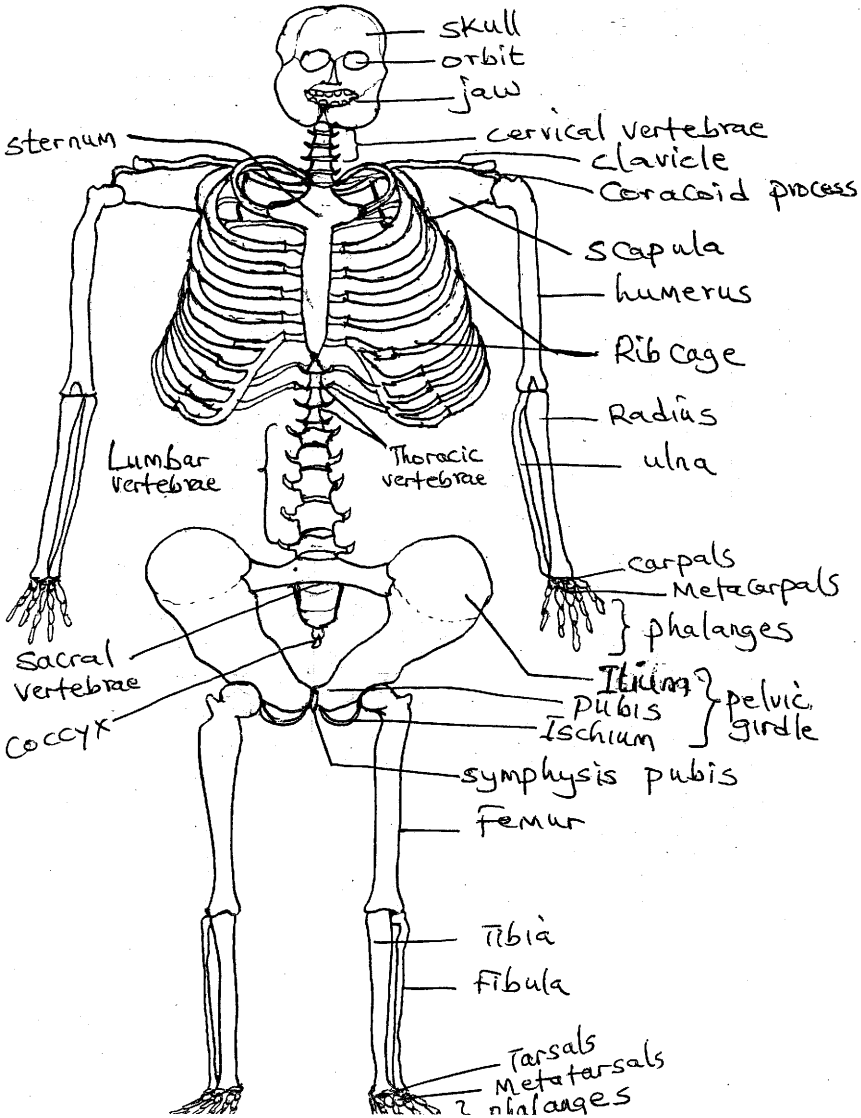
Support and Movement in Mammals.

- Bones and mammals work together to bring support and movement in mammals.
- The mammalian skeleton is divided into two parts:-

(a) The axial skeleton: consisting of
- i, The cranium / skull
- ii, The vertebral Column
- iii, Sternum
- iv, The rib-cage
- v, The clavicle.

(b) The appendicular skeleton. consists of
- i, Pelvic girdles - ischium, ilium and pubis
- ii, Femur; Tibia and fibula; Tarsals, Metatarsals and phalanges
- iii, Pectoral girdles - scapula, coracoid process and clavicle
- iv, Humerus; radius and ulna; carpals, Metacarpals and phalanges.

The human skeleton.

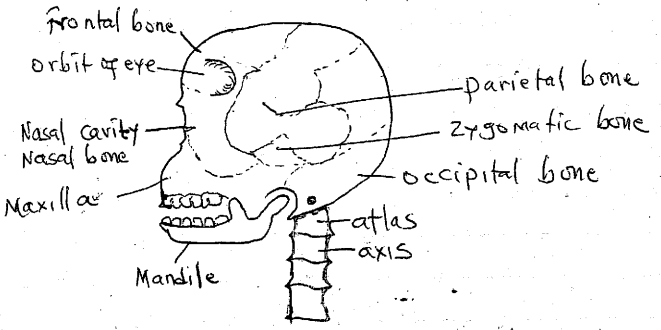


The Axial skeleton

- consists of the skull, rib-cage and vertebral column.

(a) The skull

- consists of many bones joined together to form the cranium.

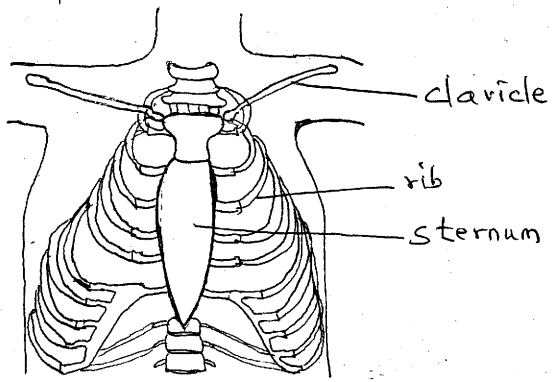


- There are perforations on the cranium to allow blood vessels and nerves to pass to and from the brain.
- The facial skeleton consists of the upper and lower jaws. The lower jaws / mandibles articulate with the cranium at a movable joint.
- At the posterior end of the cranium are two smooth rounded protuberances called the occipital condyles that articulate with the atlas (first cervical vertebra) to form a pivotal joint which allows nodding movements of the skull. The joint is also called "yes" joint.
- The functions of the skull include :-
  (i) Protects the olfactory organs middle and inner ear, eyes and the brain.
  (ii) Facial skeleton (jaws) allow chewing.

(b) Rib-cage and sternum

- The rib-cage is made of ribs which articulate with vertebral column to the back and the sternum

to the front.
- The articulating surfaces of ribs have cartilage
- The functions of the rib-cage include :-
  (i) Protects the delicate organs of the thoracic cavity ie the heart and the lungs.
  (ii) Provides surface for muscle attachment ie the intercostal muscles.
  (iii) Facilitates gaseous exchange by movement of the chest.
- The sternum is the breast bone. It is modified in birds to form the keel for attachment of the flight muscles. The function of the sternum include:
  (i) Attachment of muscles of the back and abdomen.
  (ii) Provides surface for articulation with ribs ventrally.



- The clavicle articulates with the sternum ventrally and scapula dorsally. Its function is to limit the movement of the scapula.

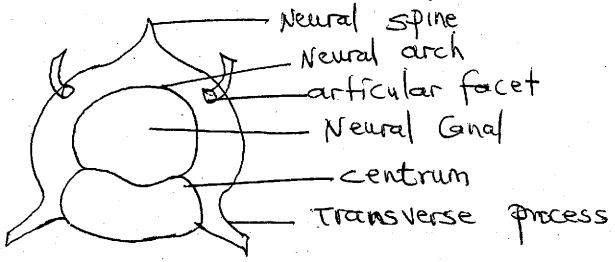
(d) Vertebral Column.

- The vertebral column consists of a series of bones called vertebrae (Singular = vertebra).
- In human beings there are 33 vertebrae

-The vertebrae are seperated from each other by cartilage called intervertebral discs which:-
(i) acts as a cushion that absorbs shock and reduces friction.
(ii) Makes intervertebral column flexible thus allowing certain degree of movement between the vertebrae.

-The vertebral column has five types of vertebrae, namely :-
(a) The cervical vertebrae
(b) The thoracic vertebrae
(c) The lumbar vertebrae
(d) The sacral vertebrae
(e) The caudal vertebrae.

-The vertebrae have a common basic plan as shown below:-



(i) The centrum is the solid structure of the vertebra. It supports the weight of the vertebra and hence the vertebral column. Together with the neural arch it protects the spinal cord.
(ii) The Transverse processes are processes lateral to the centrum. They are for muscle attachment.
(iii) The Neural spine is a process dorsal to the centrum. Also for muscle and ligaments attachment.
(iv) The Neural arch forms an arch around the neural canal. Together with centrum it protects

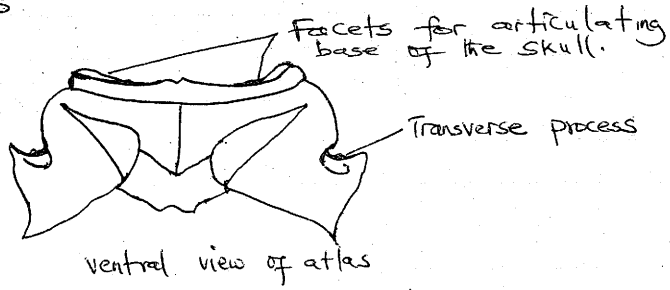
the spinal cord.
(v) Articular facets are surfaces for articulation for the vertebrae. Facets are also known as Zygapophyses (singular= zygapophysis).
-Anterior facets are known as Prezygapophyses. Prezygapophyses face upwards and inwards.
-Posterior facets are known as Postzygapophyses. Postzygapophyses face downwards and outwards.

The Cervical Vertebrae

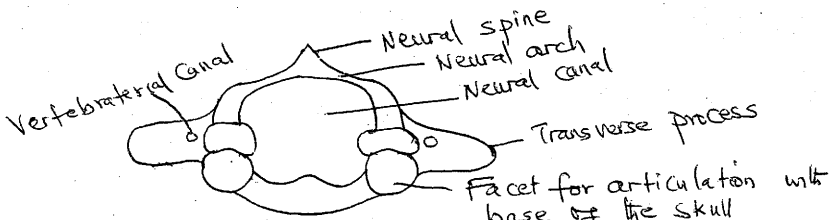
-Are found in the neck region.
-The cervical vertebrae are seven in mammals.
-All the seven cervical vertebrae have vertebrakerial canals in their transverse processes for the passage of the vertebral artery.
-The first two cervical vertebrae from the base of the skull are distinct from the rest of the vertebrae. They are the axis and the atlas.

(a) The Atlas.

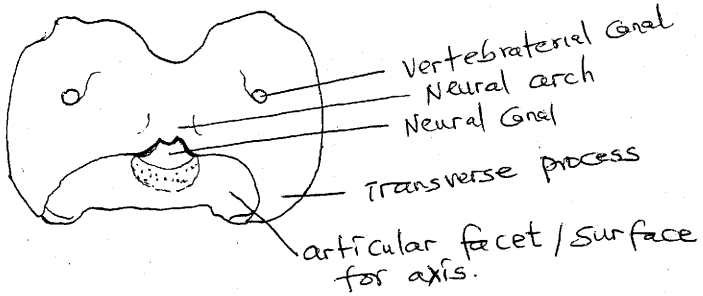
-Is the first cervical vertebra which articulates with the skull. It has the following features



Ventral view of atlas



Anterior view of atlas



Dorsal- posterior view of sheep atlas.

Features

(i) centrum is greatly reduced or lacking.
(ii) Lacks a neural spine or is greatly reduced
(iii) Have broad and flat transverse processes/ wing-like transverse processes for muscle/ attachment.
(iv) Has broad, inward curved, anterior articular surface for articulation with condyles of the skull which forms a hinge joint that permits nodding movements of the skull.
(v) posterior end has a wide articulation surface for the axis.
(vi) Has a wide neural canal for passage of spinal cord and to allow odontoid process of axis to fit in.

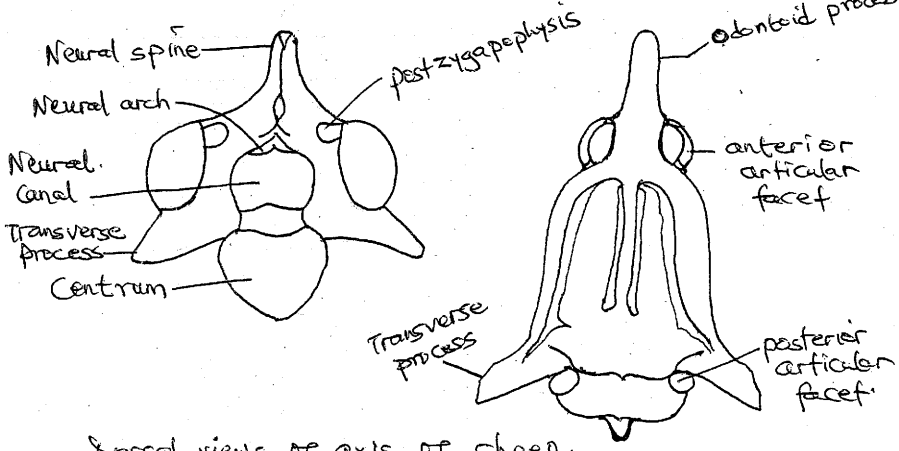
(b) The Axis

- Is the second cervical vertebra on the neck region.

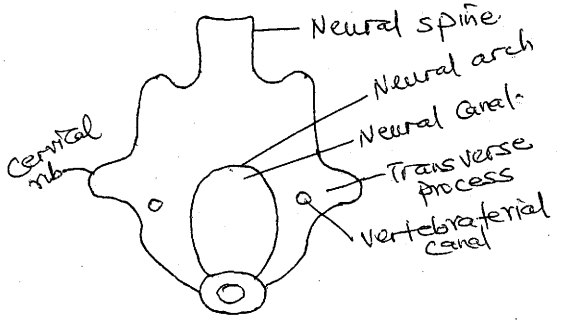
Features

(i) Has an odontoid process, which is a projection of the centrum at the anterior end. The process fits into the neural canal of the atlas where it articulates forming a pivot joint that

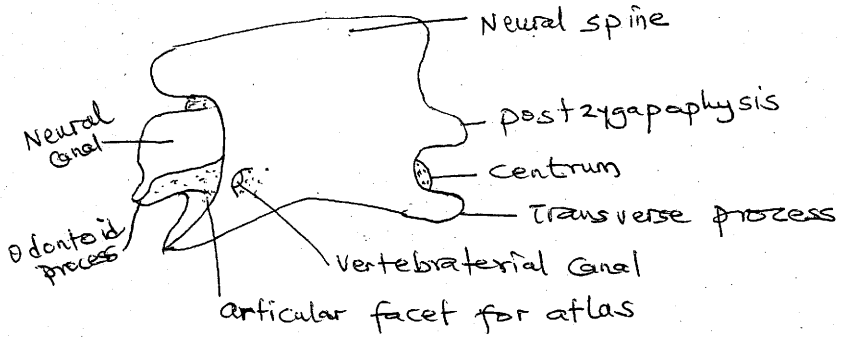
permits rotational movements of the atlas and the skull.
(ii) Has reduced and wing-like transverse processes for muscle attachment.
(iii) Neural spine is short and broad for attachment of muscles.
(iv) Has wide neural canal for passage of spinal cord.
(v) Has postzygapophysis for articulation with prezygapophyses of the third cervical vertebra.



Dorsal views of axis of sheep.



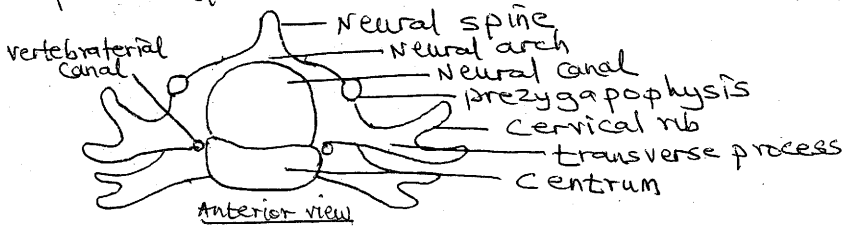
Anterior view of axis



Lateral view of axis of sheep

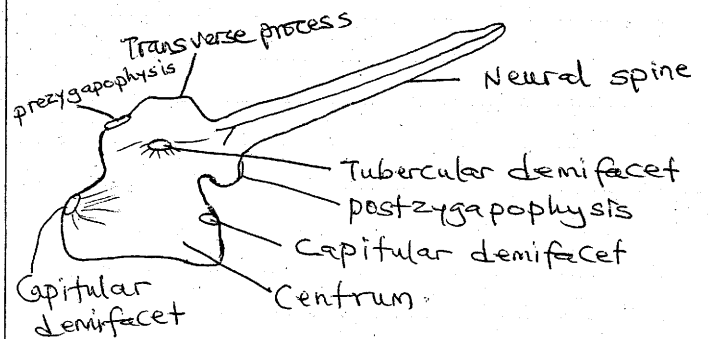
The other cervical Vertebrae

- Are found in the neck region region below the axis. The five have the following features:-
  (i) short, broad and branched transverse processes for attachment of neck muscles.
  (ii) Wide neural canal for passage of spinal cord.
  (iii) short / small neural spine for attachment of neck muscles.
  (iv) have postzygapophyses' articulating surfaces pointing downwards and outwards, while the surfaces of prezygapophyses point upwards and inwards
  (v) Have prezygapophyses and postzygapophyses for articulation with adjacent vertebrae.
  (vi) Wide centrum which together with neural arch protects the spinal cord.
  (vii) Have cervical ribs on transverse processes for muscle attachment.

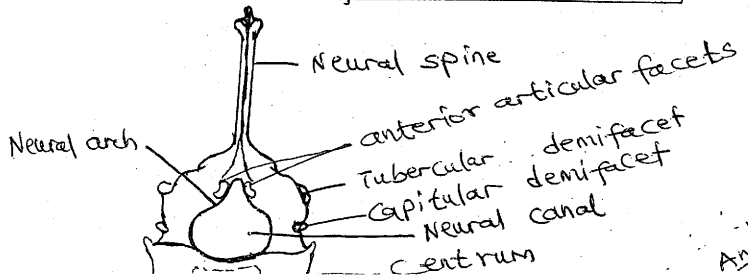


The Thoracic vertebrae

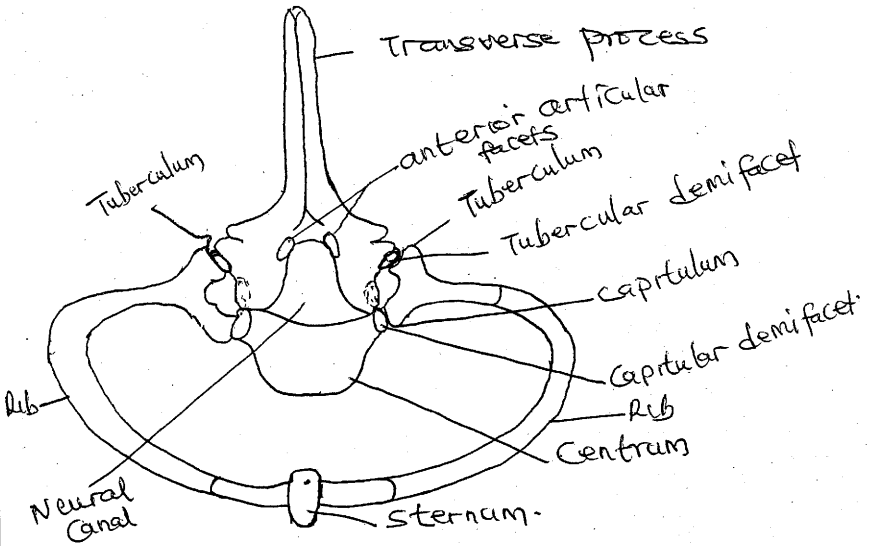
- Found in the thoracic region articulating with ribs.
- They are 12 in humanbeings. They have the following characteristics :-
  (i) Long neural spines pointing towards the posterior for attachment of muscles.
  (ii) Large / wide centrum which together with the neural arch, protects the spinal cord. The neural arch is small.
  (iii) Short transverse processes for muscle attachment.
  (iv) Centrum has capitulum / capitular facet or demifacet which articulates with capitulum of the rib; and tubercular demifacet which articulates with tuberculum of the rib.
  (v) has anterior facet and posterior facet for articulation with adjacent thoracic vertebrae.



Lateral view of Thoracic vertebra

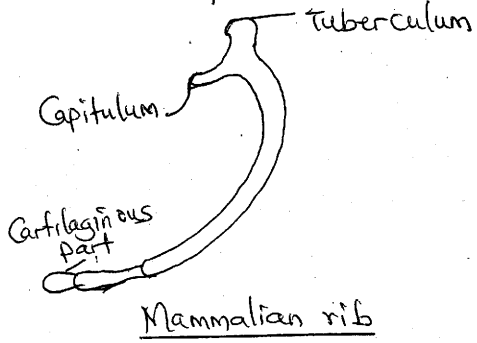


Anterior view of Thoracic vertebra



Articulation of thoracic vertebra with ribs.

NB - The wide centrum of the thoracic vertebra also supports the shoulders and the head.

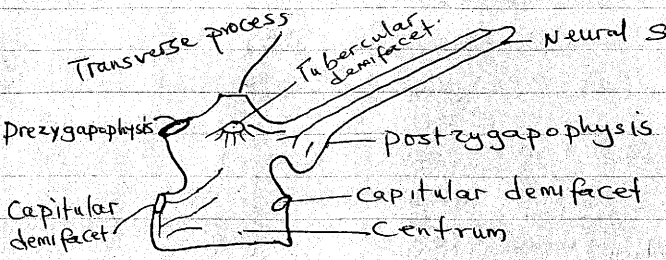


Mammalian rib

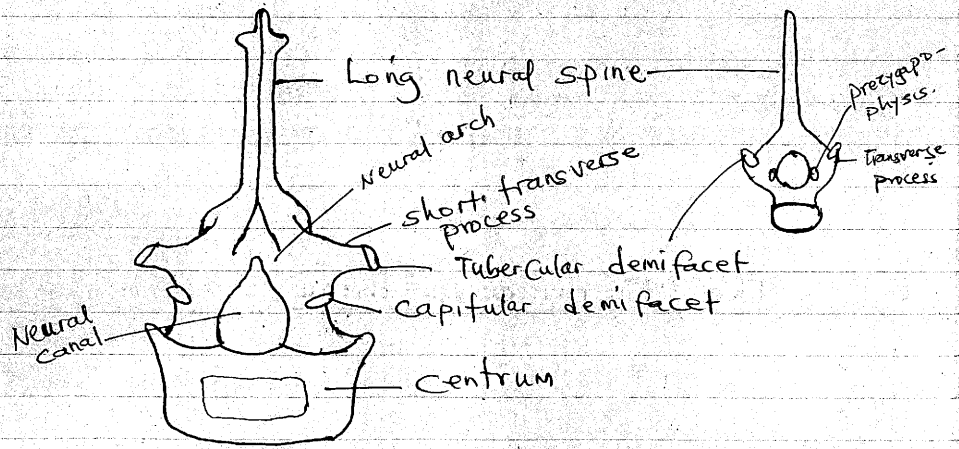
The Lumbar vertebrae

NB ① The short transverse process carry demifacets for articulation with the ribs.

② The wide centrum / large centrum also supports the shoulders and the head.

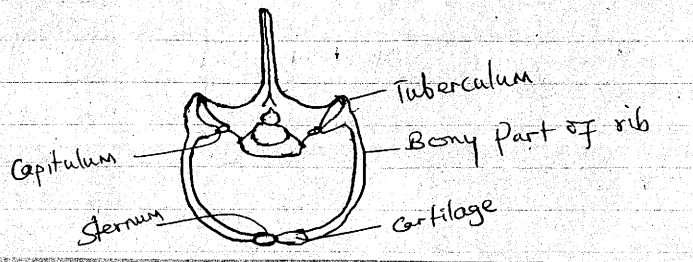


* Lateral view of Thoracic vertebra *

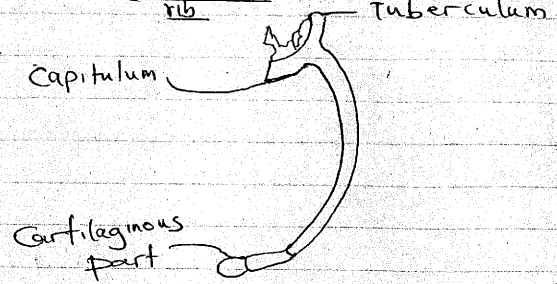


* Anterior view of thoracic vertebra *

-The diagram below shows how the thoracic vertebrae articulates with the ribs.

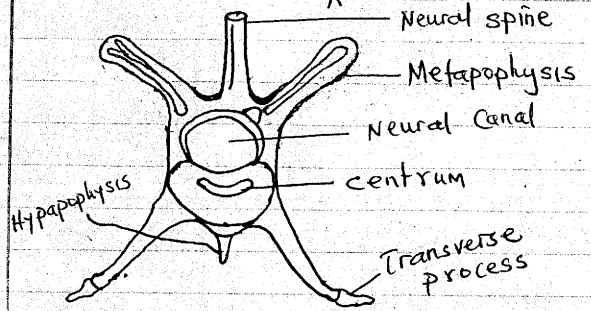


Mammalian rib

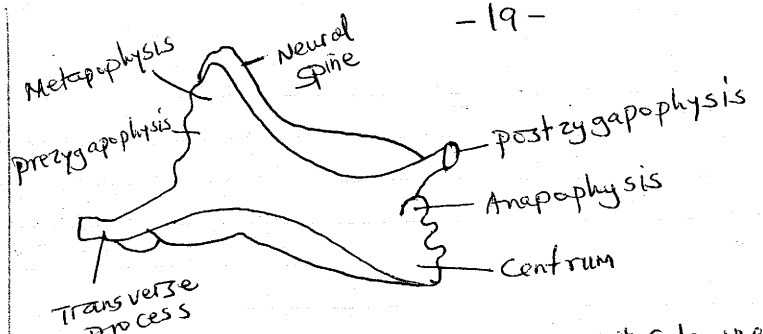


The Lumbar vertebrae

- Found in the lumbar region of the body. They are five in human beings.
- Have large/broad centrum to offer support and together with neural arch it protects the spinal cord.
- Have broad and long transverse processes projecting forwards and downwards from the centrum for attachment of muscles /abdominal muscles that maintain posture and flex the spine.
- Have broad & long neural spine for attachment of the powerful back muscles.
- On either side of neural spine are two projections called **metapophyses**. Also projecting dorsally near the transverse processes are **anapophyses**. In some animals such as rabbits another projection called **hypapophysis** arises ventrally to the centrum. All these projections offer additional surfaces for attachment of abdominal muscles.
- Have prezygapophyses & postzygapophyses for articulation with next vertebrae.



* Anterior view *



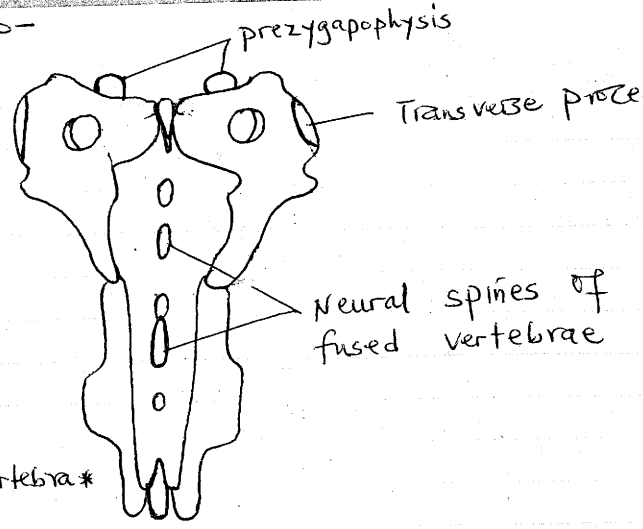
* Side view *

The sacral vertebrae

- Situated in the sacral region. Human beings have five while rabbits have four sacral vertebrae.
- Have large / broad centrum to offer support.
- Have narrow neural canal and small / reduced neural spines for passage of spinal cord and attachment of muscles respectively.
- Have anterior vertebrae with well-developed transverse process (which are wing-like) which are fused to articulate with the pelvic girdle.
- All sacral vertebrae are fused to form a rigid structure called the **sacrum**. The sacrum transmits the weight of a stationary animal to the rest of the body / Sacrum is firm and strong due to the fusion of the vertebrae to bear the body weight and spread it to the legs through the pelvic girdle.
- Sacrum has a large base & short neural spine for attachment of back muscles.

NB: The Sacral Vertebrae are fused for strength; to support the weight of the body.

K.N.E.C Quiz:- Describe how the Cervical, Lumbar and sacral vertebrae are adapted to their functions. (20 MKS) [2004].



Sacral vertebra

The caudal vertebrae

- Found in the tail region. The number of the caudal vertebrae differs from one animal to another depending on the size of the tail. In humans the tail is vestigial and four caudal vertebrae are fused to form the **Coccyx**.
- Caudal vertebrae have small / reduced neural spines and zygapophyses for attachment of the few muscles of the tail; and for articulation with next vertebrae respectively.
- Neural arch and neural canal are absent hence the entire bone is essentially the centrum.

The Appendicular skeleton

- Consists of the **pectoral & pelvic girdles** and **limbs** attached to them. The limbs attached to the pectoral girdle are forelimbs whereas hindlimbs are attached to the pelvic girdle.
- The limbs have bones designed on the same basic plan ending in five digits hence the **pentadactyl limb**.

Bones of the fore limbs

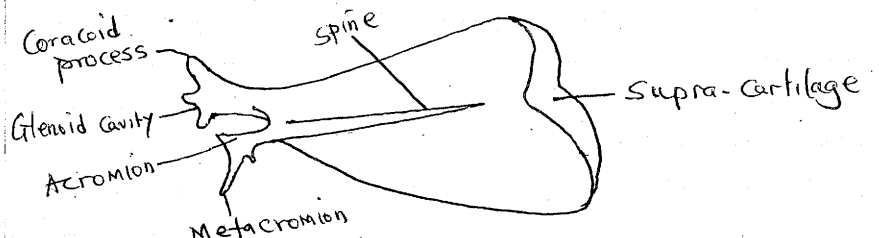
i) The pectoral girdle

- Consists of two halves (one on left another on the right) each of which consists of three bones :-
  (a) scapula
  (b) clavicle
  (c) Coracoid process.

- The two halves are attached to the upper part of the vertebral column and firmly attached to each other by muscles.

(a) The scapula

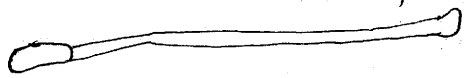
- The scapula is a flat, triangular-shaped bone which overlies a number of anterior ribs.
- At its apex is a concave cavity or depression called **glenoid cavity** which articulates with the head of the humerus to form the ball-and-socket joint.
- A spine runs along the outer surface and at its free end and close to glenoid cavity are two projections, the **acromion** and **metacromion** all for muscle attachment.
- The scapula is **hard** / ossified for support.
- It is **broad** to increase surface area for muscle attachment.
- Smooth surface of glenoid cavity minimises friction at the ball and socket joint (allowing movement of the arms).
- The **Coracoid process** is for muscle attachment.



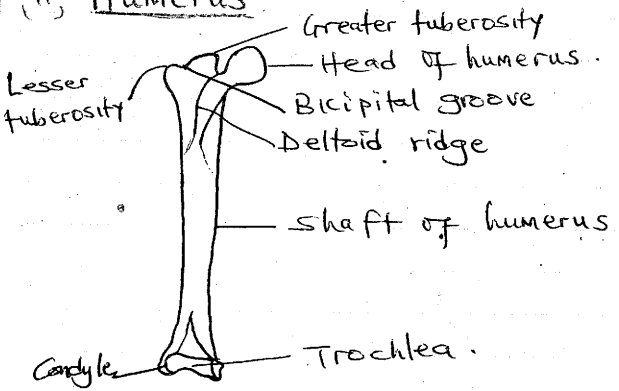
NB - Scapula is found in shoulder region. It also called shoulder blade

(b) The clavicle

- Articulates with the coracoid process of the scapula and overlies the head of the humerus.
- It limits the movement of the scapula.



ii) Humerus

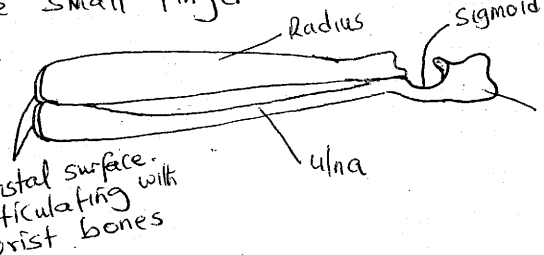


- Is the long bone of the **upper arm**. Has the following adaptations :-
- Has rounded / **ball-like head** of the humerus at its proximal end which articulates with the glenoid cavity of the scapula to form a ball-and-socket joint which allows the movement of arms.
- Has **roughened projections** - the greater and lesser tuberosities between which there is the **bicipital groove**, for tendon and muscle attachment.
- Has **trochlea** and condyles at its distal end which articulates with the radius and ulna at the sigmoid notch to form the elbow / hinge joint which permits movement of the fore-arm.
- Has **articular cartilage** which is **smooth**

at the ends to minimise friction.
- It is hard / ossified to provide support

(iii) Radius and Ulna

- Are bones of the fore-arm. Radius is on the side of the thumb and ulna is on the side of the small finger.

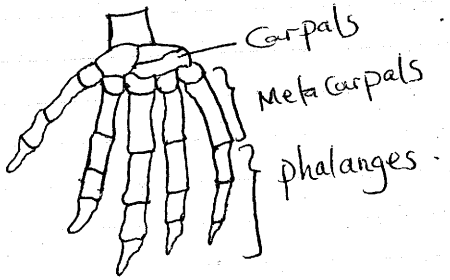


- Ulna has a projection on the proximal end known as **olecranon process** and a depression known as **sigmoid notch**: Olecranon process
  - (i) is for attachment of muscles & tendons
  - (ii) forms hinge joint with the adjacent bone ie the humerus.
  - (iii) prevents overstretching of the fore-arm backwards.
  - (iv) allows movement of the fore arm in only one plane (about 180°).
- The sigmoid notch articulates with the humerus to form the **hinge joint**. The articular surface has smooth cartilage to minimise friction.
- At the distal surface the bones have **smooth cartilage** which articulates with the wrist bones to allow movement of the hand.
- The bones are **hard** / ossified for support.

(iv) Carpals, Metacarpals and phalanges

- Are bones of the wrist (Carpals), palm (Metacarpals) and fingers (phalanges).

- The bones articulate with each other via **gliding joints**; allowing movement of the hand.
- Carpals also articulate with the radius and ulna to form the **wrist joint** which permits movement of the hand.



Bones of the hindlimb

- Bones of the hindlimb are
  - (a) Pelvic girdle – bones of the hip.
  - (b) the Femur – bone of the thigh
  - (c) the tibia } Bones of the leg.
  - (d) the fibula }
  - (e) Tarsals, Metatarsals and phalanges - bones of the foot.

(a) The Pelvic girdle

- Consists of two halves fused at the **pubis symphysis**. Each half consists of three fused bones :- the **ilium**, **ischium** and **pubis**

(i) The ilium

- Articulates with the **sacrum**. It has a depression called **acetabulum** which articulates with the head of femur to form the ball and socket joint (which permits movement of the femur in many planes).

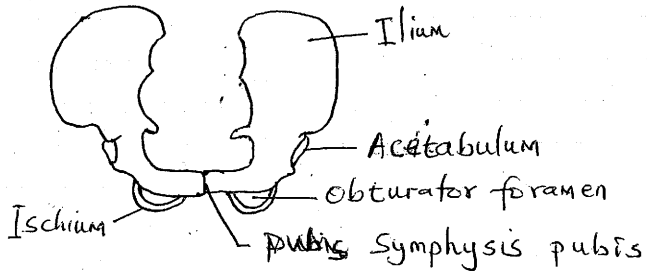
-The ilium also offers surface for attachment of muscles of the thigh.

ii. Ischium and pubis

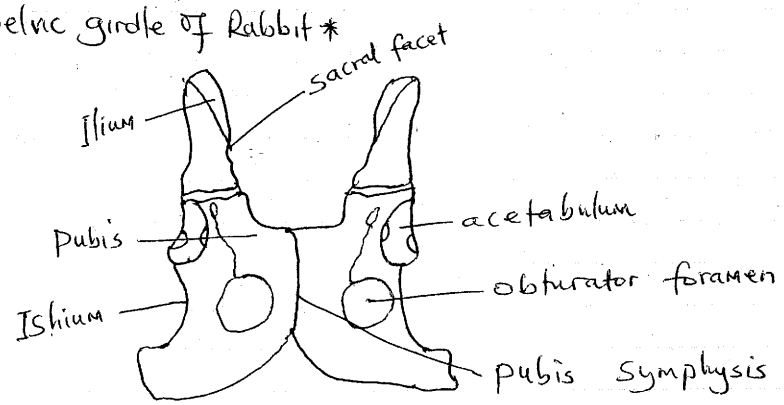
-Between the Ischium and pubis is a hole known as **obturator foramen** with a small aperture through which blood vessels and nerves pass. The Obturator foramen is made of **connective tissue** to reduce weight hence lighten the load supported by the hindlimbs.

-The **pubic symphysis** is made of cartilage which permits widening of the female's pelvic girdles during birth.

(a)
Human pelvic Girdle



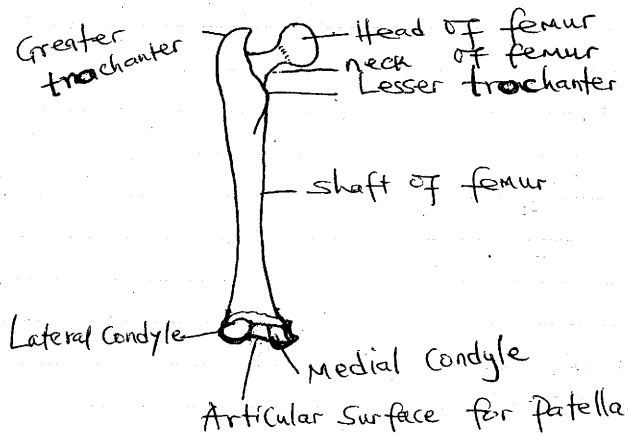
(b)
Pelvic girdle of Rabbit



(b) The Femur.

-Bone of the ~~thigh~~ thigh found between the knee and the hip. Has the following adaptations :-

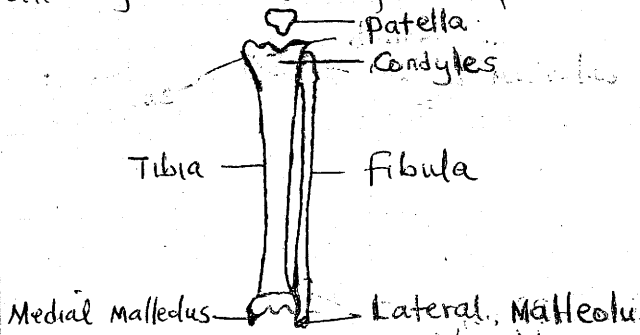
- Has a rounded head / ball-like head of the femur which fits into the acetabulum of the pelvic girdle to form the ball and socket joint of the hip. This permits movement of the upper hind limb.
- Has **trochanters** for muscle attachment.
- Has **rounded Condyles** at the distal end which articulates with the **patella** / knee cap to form the knee joint which is a hinge joint. This permits movement of the lower hind limb.
- The **patella** limits the movement of the lower hindlimb by preventing overstretching forwards.
- **Articular surface** are made of cartilage to reduce friction.
- Is hard / **ossified** to support weight of the trunk.



(c) Tibia and Fibula

-Are bones of the lower hindlimb / Leg between the knee and the foot.

- Tibia has slight depressions at its proximal end for articulation with condyles of the femur to form hinge joint.
- Distally the bones (tibia) has lateral condyles and medial condyles which articulate with tarsals allowing movement of the foot



- The bones are hard / ossified for support.
- Have smooth articular cartilage to reduce friction.

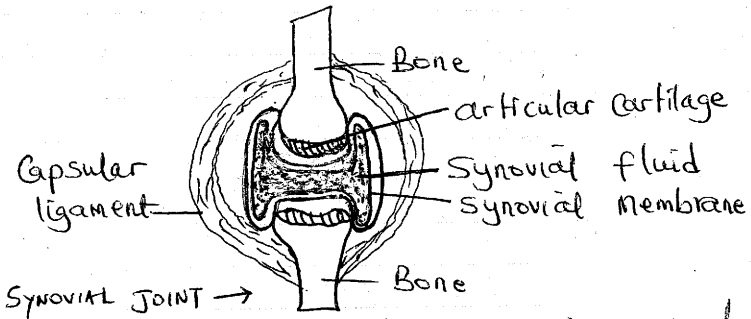
Joints

- A joint is a connection between two or more bones.
- There are three types of joints in mammals namely :-
  (a) Immovable joints eg fused bones of cranium and pelvic girdle;
  (b) Gliding joints (at wrist, ankle and between vertebrae
  (c) Movable joints.

Movable joints

- Also called synovial joints or diarthrosis.
- Characterised by the following :-

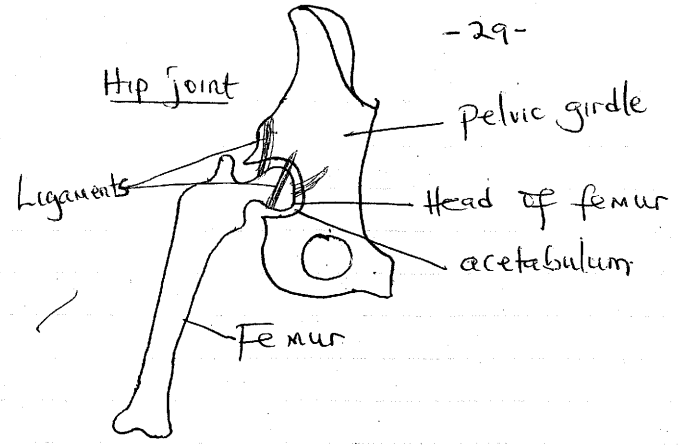
i, Bones with cartilage at their ends which cushions the joint area to reduce friction.
ii, Tough ligaments holding the bones together.
iii, A lubricating fluid known as synovial fluid.
Synovial fluid performs the following functions
  (a) Lubricates the joint area reducing friction.
  (b) Absorbs shock
  (c) Distributes pressure along the joint.
  (d) Nourishes cells at the joint area.

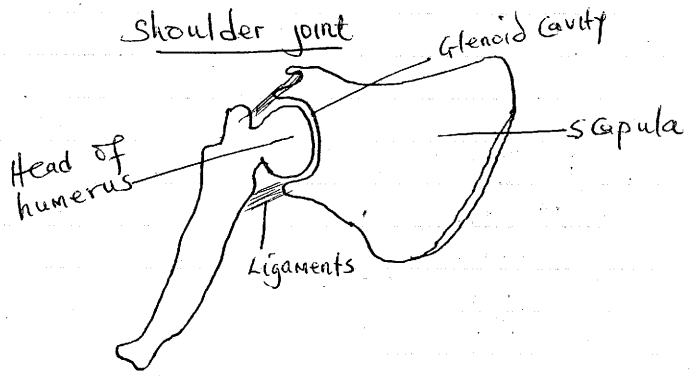


Types of synovial joints / Movable joints

(a) Ball and socket joint

- Characterised by :-
  i, Two bones, one with a rounded head / ball-like head and another with a depression / cavity / socket-like depression into which the head / ball-like structure of the other bone fits and moves freely.
  ii, Movement possible in all directions / many planes / about 360°.
  iii, Inability to bear heavy loads / weights.
- Examples include
  - The hip joint
  - The shoulder joint
- These joints allow movement of the limbs.





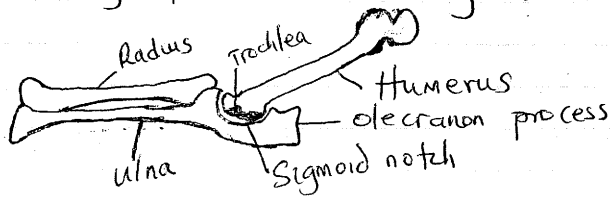
(b) Hinge joint

- Found at elbow, knee and phalanges.
- characterised by the following :-

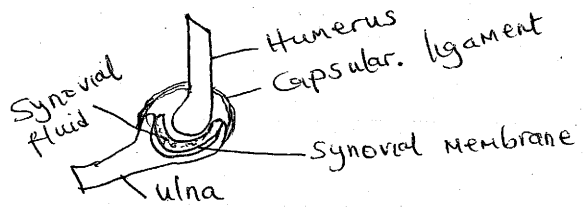
i, Depression / groove in one bone which allows smooth condyles of the other bone to fit and articulate and allow movement in one direction.

ii, Movement in only one direction / Maximum stretch of about 180° / Movement possible in only one plane or one direction.

iii, Ability to bear heavy loads.



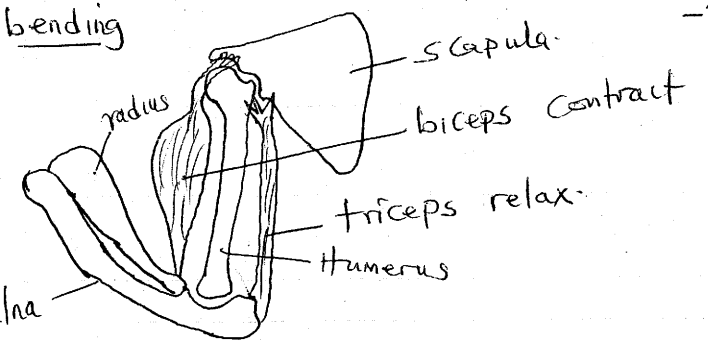
or



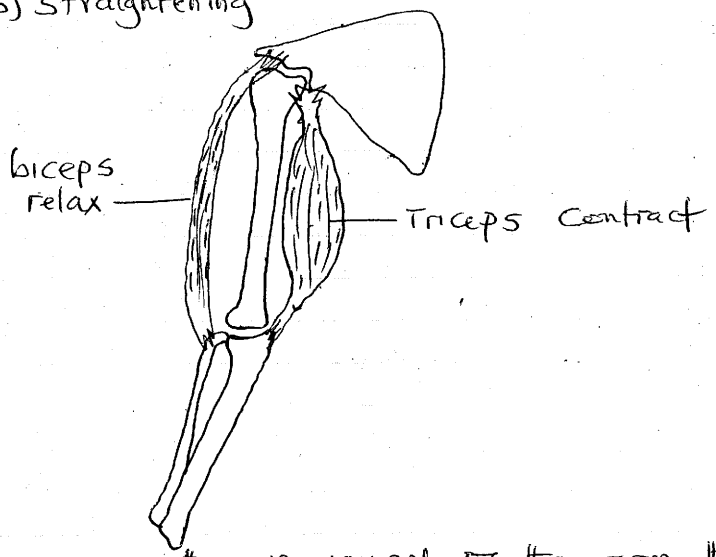
Movement at a joint

- At a movable joint the bones are held together by an inelastic tissue called **ligament**. The ligaments restrain movement of the bones thus preventing dislocation.
- At the joint muscles are attached to the bones by an inelastic tissue called **tendon**. A muscle is attached at two points; the **origin** on an immovable bone and the **insertion** on a movable bone.
- Muscles which operate joints are in pairs and are **antagonistic**. The muscle which brings about bending of a joint is called a **flexor** muscle; while the muscle that straightens the limb is called the **extensor** muscle.
- This can be illustrated by the biceps and triceps muscles operating the hinge joint of the elbow. The **biceps** are the **flexor** muscles which bend the fore-arm whereas the **triceps** are the **extensors** which straighten the fore-arm.
- When biceps muscles contract, the triceps muscles relax thus bending the fore-arm.
- When the biceps muscles relax, the triceps muscles contract straightening the arm.
- Movement occurs at the hinge joint / elbow joint which acts as the pivot / fulcrum and the forearm is the lead;

(a) bending



(b) straightening



- During the movement of the arm, the hinge joint at the elbow serves as the fulcrum/pivot, biceps provide the effort to lift the load (forearm).

structure and function of Muscles

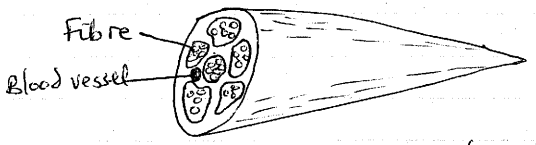
- Muscle is a tissue specialised for contraction.
- There are three types of muscles:-
  i, skeletal muscles
  ii, smooth muscles
  iii, cardiac muscles

Skeletal Muscle / striated muscle / striped Muscle

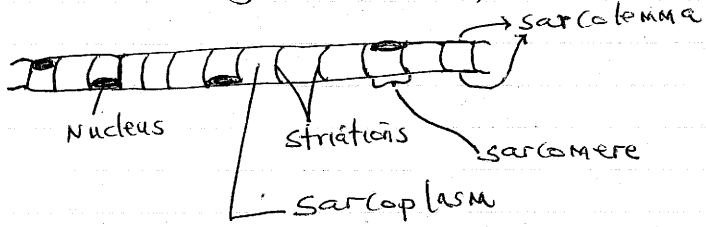
- These muscles are **attached on the skeleton** and play a role in locomotion / movement.
- The striated muscles are innervated by the voluntary part of the nervous system hence are known as **voluntary muscles**.
- skeletal muscles are **striated / striped** muscles because when observed under the microscope stripes running across them are observed.
- Skeletal muscle is made up of a bundle of long fibres (long tubular cells) running the whole length of the muscle
- Each fibre is an equivalent of one cell containing several nuclei ie are **multinucleated**.
- Each fibre contains many **myofibrils** running parallel to each other.
- The covering of a muscle fibre is known as **sarcolemma**. Hence skeletal muscle **have sarcolemma** and **sarcoplasm** is divided into **sarcomeres**.
- Are arranged in **blocks** / bundles OR Are cylindrical in shape
- Skeletal muscles are adapted to their function as follows:-
  i, Have actin and myosin / actomyosin which are contractile protein fibres in the sarcoplasm which facilitate contraction and relaxation.
  ii, Have a **high density of mitochondria** to provide energy for contraction. (Mitochondria are in sarcoplasm)
  iii, Made of **elongated fibres** to allow maximum change in length.
- The functional unit of the muscle is the myofibril which has ability to contract. Sodium and Calcium ions play a role in the contraction of muscles. The contraction of the muscle creates a force which is transmitted by the tendon to the

skeleton bringing about movement.

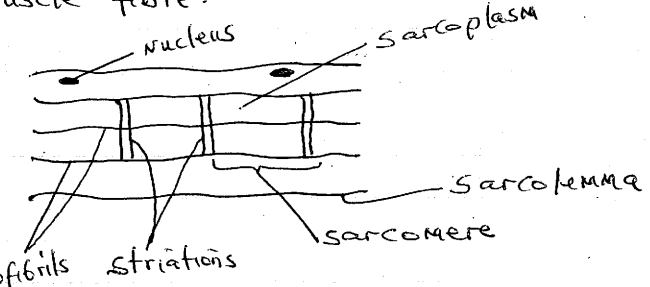
(a) A bundle of muscle



(b) Cross section through a bundle of Muscle



(c) A muscle fibre.

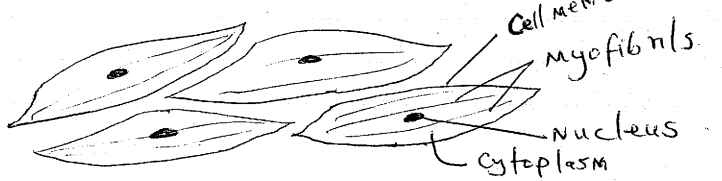


(d) Details of a muscle fibre.

Smooth / visceral / involuntary / unstriated / unstriped Muscles

- Smooth muscles are found on walls of tubular visceral organs eg gut, blood vessels, urinary tract, reproductive tract and respiratory tract.
- Have the following characteristics :-

- Made of spindle-shaped cells containing filaments known as myofibrils.

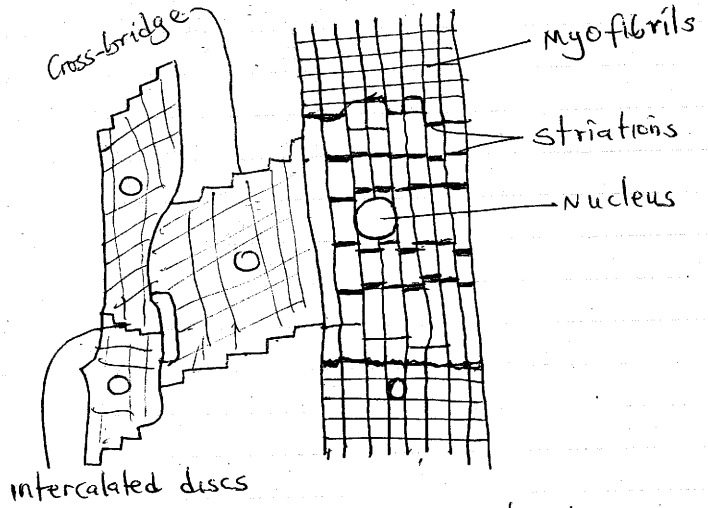


- Uninucleated / each cell with single nucleus.
- Made of short cells / short muscle fibres.
- Lack striations / Lack cross striations hence smooth.
- Lack ~~sarcolemma~~ sarcomeres
- Capable of slow involuntary contractions; because they are innervated by autonomic nervous system.
- Contract and relax slowly hence fatigue slowly unlike skeletal muscles which contract and relax rapidly / very fast hence fatigue equally fast.

Cardiac Muscles.

- This is the heart muscle. Have the following characteristics :-
- Each muscle consists of short cells with centrally placed nuclei and numerous striated myofibrils.
- The ends of the cells are marked by thickened (reinforced cell membranes which form tough junction with cells.) regions called intercalated discs. These also form cross bridges between fibres which hence transmit impulses rapidly throughout the heart and synchronize muscle contraction.
- The contractions of the heart muscle are generated from within the heart itself without nervous stimulation Therefore the heart muscle is said to be myogenic.
- The heart / cardiac muscles have a high density of mitochondria than skeletal muscle to sustain

the energy demands. Hence the cardiac muscles are capable of continuous rythmic contractions without fatigue throughout the life of the mammal.

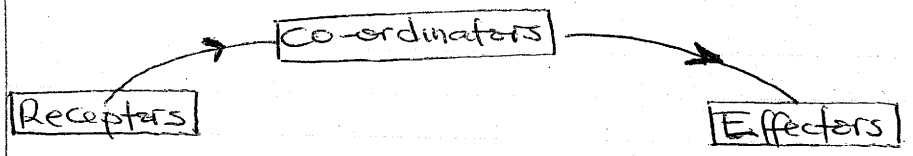


* Cardiac Muscle *

④ RECEPTION, RESPONSE AND CO-ORDINATION

Meaning of stimulus Response & irritability

- The ability of organisms to detect and respond to changes in the environment is called sensitivity or irritability.
- A variation in conditions which can produce a change in the activity of part or the whole organism is called **stimulus** (plural = stimuli).
- The change in activity in part of or in the whole organism due to a stimulus is called **response**.
- The parts of the body of an organism which receive stimuli are known as **receptors**. While those parts which bring about response are known as **effectors**.
- Common external stimuli which bring about responses in organisms are temperature, light, pH, humidity, mineral salt concentration in a habitat, population density and absence of or presence of predators.
- Internal stimuli include accumulation of wastes, concentration of gases, presence of parasites, changes in temperature and glucose concentration.
- In order for sensitivity and response to be effected, there must be receptors to receive stimuli, co-ordinators to integrate information received, transmission systems to conduct the stimuli and effectors to respond to the stimuli as illustrated below:-



- Irritability enables organisms to perceive/detect changes in their environments and to respond or react appropriately to them.

Response to a variety of stimuli

- When response of the whole organism or part of the organism is towards a stimulus, it is described as **positive** (+ve) and when it is away from the stimulus it is described as **negative** (-ve).
- The major responses include **taxis**, tropisms and nastisms.

Taxis

- This is a **locomotory response** of a motile cell (eg gamete) or whole organism in response to an external (unidirectional) stimulus.
- The stimulus is **unidirectional** (ie from one specific direction)
- Tactic responses/taxes are grouped according to stimuli eg

(a) **phototaxis** - This is a (locomotory) response to **variation in light intensity** and **direction** eg Euglena, spirogyra and fruit flies moving towards light (positive phototaxis) or maggots and termites moving away from light (negative phototaxis).

(b) **Aerotaxis** - This is the (locomotory) response to variation in **oxygen concentration** eg amoeba moving from a region of low O_2 concentration to a region of high O_2 concentration ie positive aerotaxis. Aerotaxis is also called oerotaxis.

(c) Hydrotaxis – Locomotory response by organisms in response to variation in Moisture / Moist conditions;

(d) Osmotaxis

– Response to variation in osmotic pressure as shown by marine crabs burrowing in sand to avoid dilution of the body fluids. This is negative osmotaxis.

(e) Rheotaxis

– Is the response to variation in direction of water or air currents. Fishes and planarians move against water current (negative rheotaxis). Butterflies and moths fly into wind currents in order to detect the scent of flowers.

(f) Chemotaxis

– Is the response to variation in chemical substances eg movement of the male gametes towards female gametes. sperms (antherozoids) of Mosses and ferns are attracted and move towards chemicals produced by ovum in the archegonia. Mosquitoes will fly away from insecticide repellants. This is positive and negative chemotaxis respectively.

(f) Thermotaxis

– Is a locomotory response to temperature changes eg paramecium moves from an area of low temperature eg 15°C to that of moderate temperature eg 25°C.

Survival value of Tactic responses

① Enable organisms escape from harmful stimuli eg excessive heat, predators.

② Enables organisms to seek favourable habitats and acquire resources eg nutrients and mates.

③ Chemotaxis enables fertilisation to take place.

Reception, Response and Co-ordination in plants

– Plants do not have any organised nervous and sensory systems as the animals. Their responses are in form of growth movements or tropisms; taxis and nastic responses.

Tropisms

– Are growth movements or curvatures of parts of plants in response to unidirectional external stimulus. These are shown by growth curvatures of parts of plants in response to certain stimuli.

– These growth movements are often slow because growth rate is controlled by plant hormones (auxins). Tropisms, are also named according to stimuli which evoke them.

Types of tropisms

① Phototropism

– Is a growth curvature in response to the direction and intensity of light. shoots are positively phototrophic while roots are negatively phototrophic.

② Chemotropism

– Is a growth curvature in response to a gradient of chemical concentration eg growth of pollen tube towards chemicals secreted by embryo sac.

③ Geotropism

– Refers to the growth curvature in response

to gravity. Roots are positively geotropic whereas shoots are negatively geotropic.

④ Hydrotropism

- Hydrotropism refers to growth curvature in response to water or moisture. plant roots are positively hydrotropic.

⑤ Haptotropism / Thigmotropism

- Growth curvature in response to contact with solid object. Shown by tendrils or climbing stems which twin around objects eg stems, branches. Roots show negative haptotropism when they grow avoiding solid obstacles eg rocks.

Survival value of Tropic responses

① **Phototropism** exposes leaves in position to maximise light absorption for photosynthesis.
② **Hydrotropism** enables plant roots to seek water
③ **Haptotropism** enables the plant to obtain mechanical support especially herbaceous plants.
④ **Geotropism** enables plant ~~not~~ roots to grow deep into the soil thus offering ~~firm~~ firm anchorage to the plant.
⑤ **Chemotropism** enables the pollen tubes to grow towards embryo sac facilitating fertilisation

Differences between tropisms & taxes

Tropisms	Taxes
1. Growth responses and are therefore more permanent	Locomotory responses and are therefore temporary.
2. Responses are slow	Responses are fast
3. Brought about by influence of growth hormones	Not brought about by influence of growth hormones.

Similarities between Tropisms & Taxes

- Are both adaptive responses that enable organisms to survive better in their environments
- Both are responses to similar stimuli eg temperature, light, water.
- Both are responses to unidirectional stimuli.

Nastic Responses

- These are non-directional movements of parts of plants in response to diffuse stimuli; eg folding of leaves in hot weather, opening and closing of flowers in response to intensity of light and closing of leaves of Mimosa pudica when touched.
- These movements are brought about by turgor pressure changes at the leaf and petal bases of these plants. At these bases are pressure sensitive swellings called pulvini which through loss or gain of turgidity bring about these movements.

Types of Nastisms

(a) Nyctinasty (Sleep movements)

- These are non-directional movements of plant parts in response to differences in light intensity and temperature changes of the day and night as seen in sunflower.

Nyctinasty includes

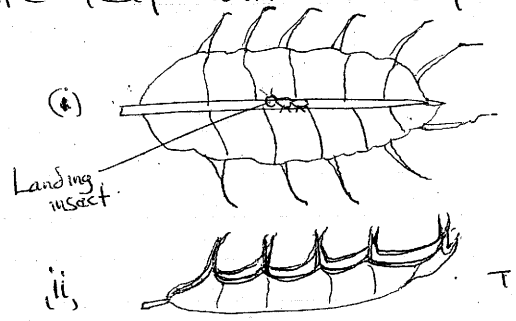
i) **Photonasty**:-
Nyctinastic response to changes in light intensity eg flower opening in presence of light and closing in absence of light.

ii) **Thermonasty**:-
Nyctinastic response to changes in temperature eg some flowers open with increase

in temperature and close with decrease in temperature.

(b) Haptonasty

- This is the movement response of some plant parts eg Mimosa pudica and Venus fly trap (Dionaea spp) to touch. When leaves / stem of Mimosa pudica are touched the leaves close rapidly.
- The insectivorous plant venus fly trap grows in nitrogen deficient soils. It obtains nitrogen by trapping and digesting insects. When the sensitive (trigger) hairs on the leaves are touched by a landing insect, the mid-rib cells lose water rapidly causing the trap to spring, hence closing the leaf with the spines interlocking.



(c) Chemonasty

- This is the response to the presence of specific chemical substances of nitrogenous compounds such as urea and NH_4^+ compounds found in insectivorous plants such as Sundew (Drosera). Therefore when an insect is trapped by the tentacles of Drosera, the insect provides the chemical stimulus for the release of digestive enzymes by the plant.

(d) Hydronasty

- Response by some plant parts to changes in humidity as in flowers of genus Dandelion which close when the air is moist.

Survival value of nastisms

1. Protection of inner delicate parts of a flower.
2. Reduction of transpiration.
3. Regulation of temperature.
4. A way of obtaining some limited mineral nutrients eg nitrogen by insectivorous plants.

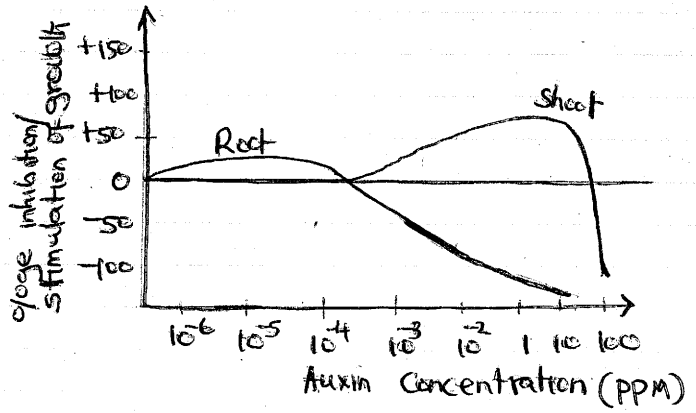
Co-ordination in plants

- Plant growth responses are co-ordinated by hormones such as auxins, gibberellins, cytokinins and florigens.
- Tropisms are growth responses mainly influenced by the hormone auxin.

Role of Auxins in Tropisms

- Auxins are a group of plants hormones which influence growth. The commonly studied auxin is **indoleacetic acid (IAA)**.
- Auxins are produced at the apical meristems of shoots and roots. The auxins move backwards by diffusion from cell to cell in one direction, and exert their effects in the region of cell elongation.
- Larger amounts of auxins are translocated in phloem from shoots towards the roots. There is higher auxin production in shoots than in roots.
- IAA stimulates growth in both shoots

and roots at the region of elongation. Very small quantities of auxins are required; but roots require a smaller concentration of auxins to stimulate growth compared to shoots. A higher auxin concentration therefore promotes growth in shoots but inhibits growth in roots; as shown in the figure below:-



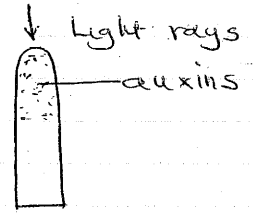
Auxins and phototropisms.

- Under uniform light distribution, auxins produced from the shoot apex are translocated evenly down the shoot, therefore causing equal growth rate in the zone of elongation leading to normal increase in height of the shoot.
- However, when the shoot is exposed to unidirectional light, the shoot tip bends towards the source of light. This is because light causes lateral migration of auxins from the lighted side to the darker side. This leads to higher concentration of auxin on the darker side.

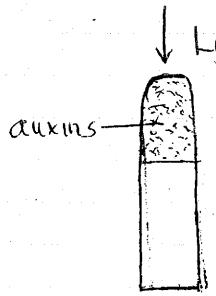
This higher concentration of auxins stimulates rapid cell elongation and hence faster growth rate on the darker side compared to the lighted side. Eventually the shoot curves towards the source of light. Thus explains the positive phototropic response in shoots.

- This is illustrated in the diagrams of experimental setups below:-

Expt 1- (a)

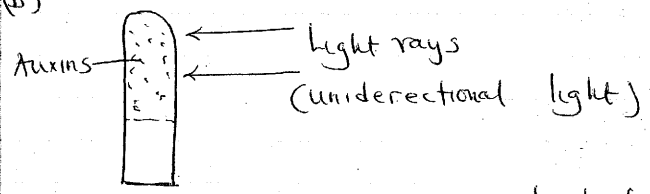


Before experiment :- equal distribution of auxins

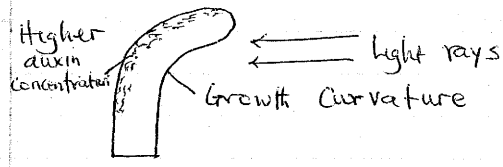


After experiment :- equal distribution of auxins.

(b)

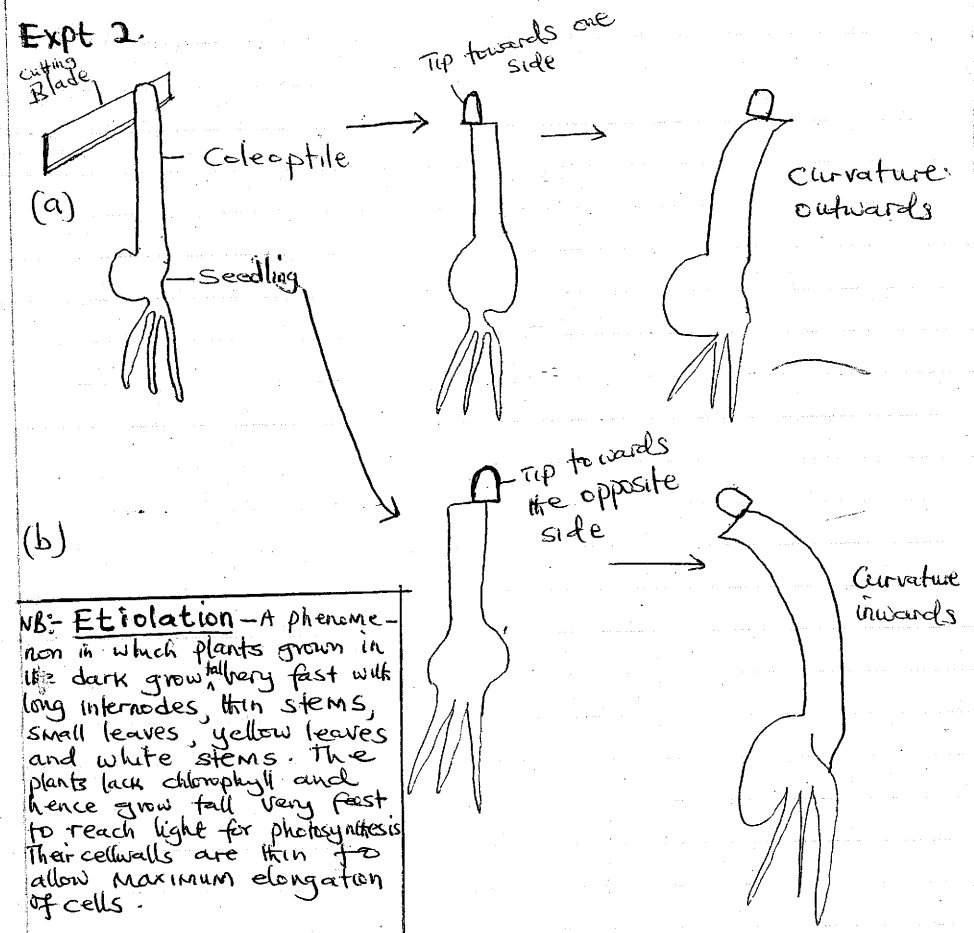


Before experiment :- equal distribution of auxins



After experiment :- More auxin concentration on darker side hence faster cell elongation leading to curvature.

Expt 2.

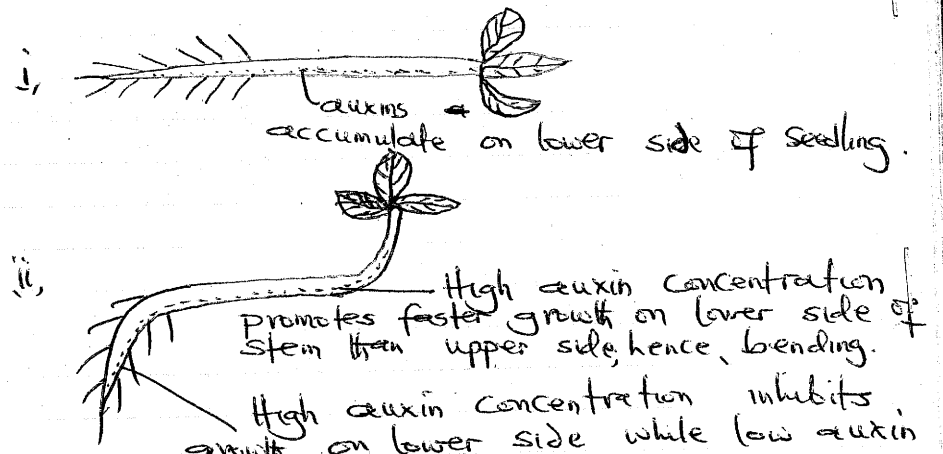


NB:- **Etiolation** - A phenomenon in which plants grown in the dark grow tall very fast with long internodes, thin stems, small leaves, yellow leaves and white stems. The plants lack chlorophyll and hence grow tall very fast to reach light for photosynthesis. Their cellwalls are thin to allow maximum elongation of cells.

Auxins and Geotropisms

- In plants shoots are negatively geotropic whereas roots are positively geotropic. This is brought about by auxin distribution due to gravity.
- If a seedling is placed in a horizontal position (in the dark), it has greater accumulation of auxins on the lower side; due to unilateral force of gravity.
- In stems, such a high auxin concentration promotes faster growth, but inhibits growth

in roots. Therefore, greater auxin concentration on the lower side in the shoot promotes faster growth on the lower side than on the upper side causing the shoot to bend upwards; while in the root, lower auxin concentration on the upper side promotes faster growth on the upper side than on the lower side, hence the roots bend downwards.



Auxins and Thigmotropism/Haptotropism

- In plants, when climbing stems or tendrils come to contact surface with suitable hard object, the contact surface causes them to curve and coil around the hard object/contact surface.
- The part of the stem in contact with the hard surface has a lower auxin concentration than the outer part. Contact surface causes lateral migration of auxins to the outer surface (away from contact surface) of the stem. The higher auxin

i, Somatic nervous system

- Refers to the nervous system that controls the voluntary activities of the body. Motor neurones of this system co-ordinate activities of skeletal muscles.

ii, Autonomic nervous system*

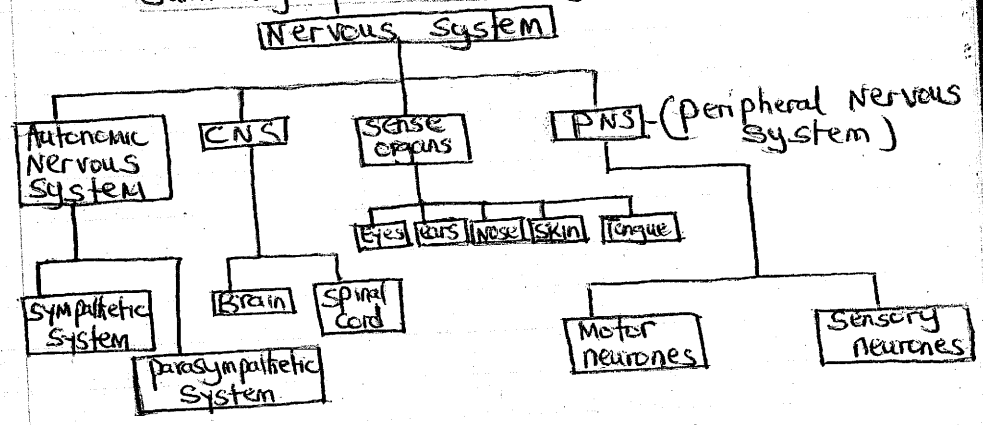
- Made up of motor neurones which control involuntary activities of the body. The motor neurones of this system serve smooth and cardiac involuntary muscles and hence control activities of the heart, iris of the eye, and alimentary canal, urinary bladder and other internal organs.
- The autonomic nervous system consists of two parts :-
  (a) sympathetic nervous system
  (b) parasympathetic nervous system. The two systems have neurones innervating the same effector organs but work antagonistically, eg

Sympathetic System	Parasympathetic System
1- stimulates pacemaker speeding up heart-beat	-Inhibits pacemaker slowing down heart beat
2- stimulates constriction of arteries.	- stimulates vasodilation of arteries.
3- Inhibits peristalsis	stimulates peristalsis.
4- Stimulates contraction of sphincter, bladder & anal muscles	- Inhibits Contraction of sphincter muscles of bladder/anus
5- Inhibits Contraction of bladder	-Stimulates Contraction of bladder.
6- Stimulates contraction of radial iris muscles causing dilation of pupil	- Stimulates contraction of circular iris muscles causing reduced iris size
7- Inhibits Contraction of walls of bronchioles causing dilation	-Stimulates constriction of bronchioles.

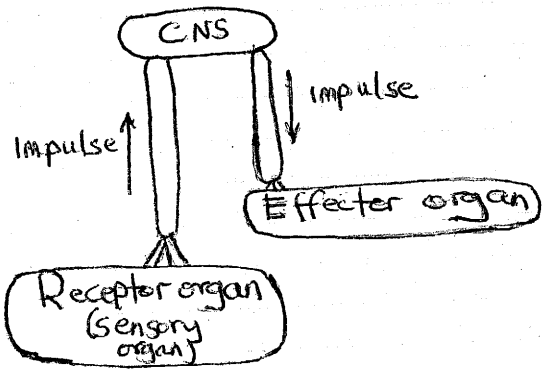
*NB - Autonomic nervous system not examinable in KCSE.

(c) Sensory organs - eyes, ears, tongue, skin and olfactory epithelium of nostrils. Made up of specialised sensory or receptor cells to detect specific stimuli ie chemicals (tongue and olfactory epithelium), sound waves (ears), light (eyes).

Summary of nervous system



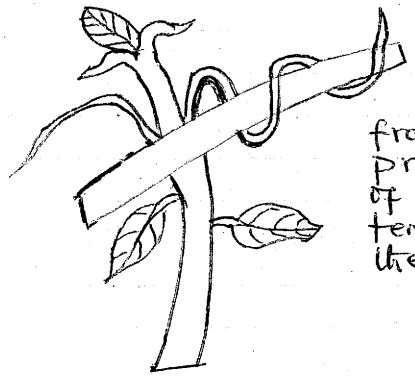
Relationship of CNS and motor organs



Structure and functions of Nerve cells

- The PNS and ANS are made up of small fibrous tissues called nerves.
- A nerve is composed of a bundle of tiny thread-like nerve cells called neurones

concentration on the outer part causes faster growth in the outer part than the part in contact with the object, hence the shoot continues to coil round the object.



High auxin concentration on the side away from contact surface promotes faster growth of this side causing tendril to curl round the object.

NB - Auxins work in conjuction with other growth hormones to bring about plant responses and overall growth.

RECEPTION, RESPONSE AND CO-ORDINATION IN ANIMALS

- Irritability is important in animals since it helps them to respond to changes within the environment (stimuli).
- Simple unicellular organisms such as amoeba and other protozoa respond to stimuli using the whole protoplasm of the cell.
- Platyhelminthes such as liverflukes have eyes, special cells called statocysts and chemoreceptors acting as sensory organs and ganglia for co-ordination.
- Annelids like earthworms have a fairly developed nervous system and sensory organs.

- Arthropods like insects have peripheral nerves around the body and a ventral nerve cord and which forms ganglion in the separate body segments. They also have eyes and antennae as sense organs.

Reception, response and Co-ordination in Mammals

- Irritability in vertebrates such as mammals is brought about by the nervous (neuro-secretory) and endocrine (hormonal) systems. The nervous system is the quickest means of communicaton in animals.

Components of the Nervous system in Mammals

- The nervous system is made up of the following :-
  (a) Central Nervous system (CNS)
  (b) Peripheral nervous system
  (c) Autonomic nervous system
  (d) Sense organs.

(a) Central Nervous system (CNS)

- Consists of the brain and the spinal cord. It receives and integrates impulses from the receptors and then relays them to the effector organs. It is the centre of co-ordination.

(b) Peripheral Nervous System (PNS)

- It is made up of sensory nerves/neurones which transmit nerve impulses to CNS and motor neurones which transmit impulses from CNS to effectors.
- The motor neurones are of two types:-

i, Somatic nervous system

- Refers to the nervous system that controls the voluntary activities of the body. Motor neurones of this system co-ordinate activities of skeletal muscles.

ii, Autonomic nervous system*

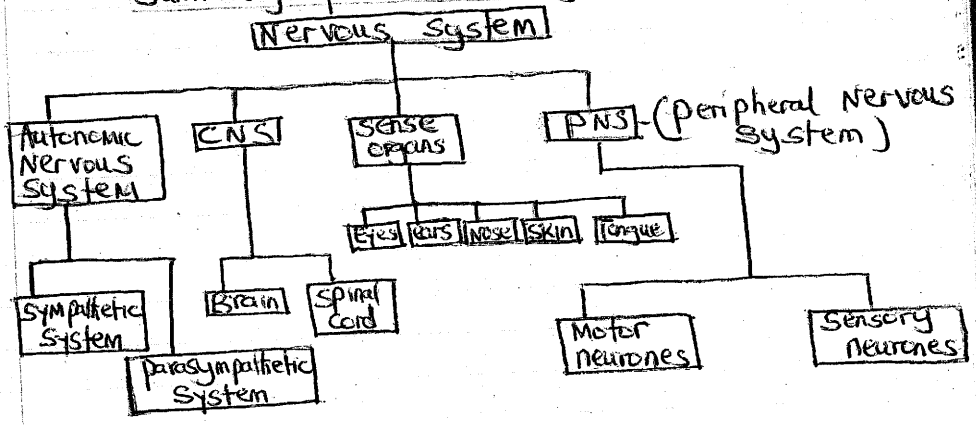
- Made up of motor neurones which control involuntary activities of the body. The motor neurones of this system serve smooth and cardiac involuntary muscles and hence control activities of the heart, iris of the eye, and alimentary canal, urinary bladder and other internal organs.
- The autonomic nervous system consists of two parts :-
  (a) sympathetic nervous system
  (b) parasympathetic nervous system. The two systems have neurones innervating the same effector organs but work antagonistically; eg

Sympathetic System	Parasympathetic System
1- stimulates pacemaker speeding up heart beat	-Inhibits pacemaker slowing down heart beat
2- stimulates constriction of arteries.	- stimulates vasodilation of arteries.
3- Inhibits peristalsis	stimulates peristalsis.
4- Stimulates contraction of sphincter, bladder & anal muscles	- Inhibits Contraction of sphincter muscles of bladder/anus
5- Inhibits Contraction of bladder	-Stimulates Contraction of bladder.
6- Stimulates Contraction of radial iris Muscles causing dilation of pupil	- Stimulates contraction of circular iris muscles causing reduced iris size
7- Inhibits Contraction of walls of bronchioles causing dilation	-Stimulates Constriction of bronchioles.

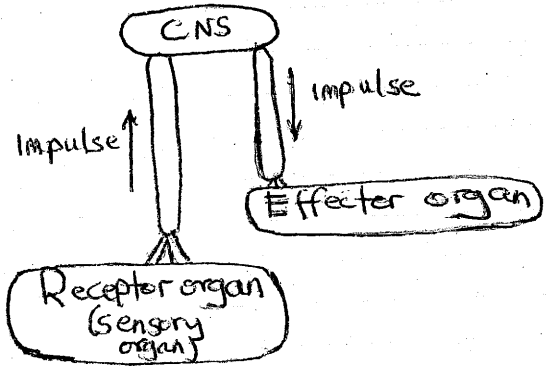
* NB - Autonomic nervous system not examinable in KCSE.

(c) Sensory organs - eyes, ears, tongue, skin and olfactory epithelium of nostrils. Made up of specialised sensory or receptor cells to detect specific stimuli ie chemicals (tongue and olfactory epithelium), sound waves (ears), light (eyes).

Summary of nervous system



Relationship of CNS and motor organs

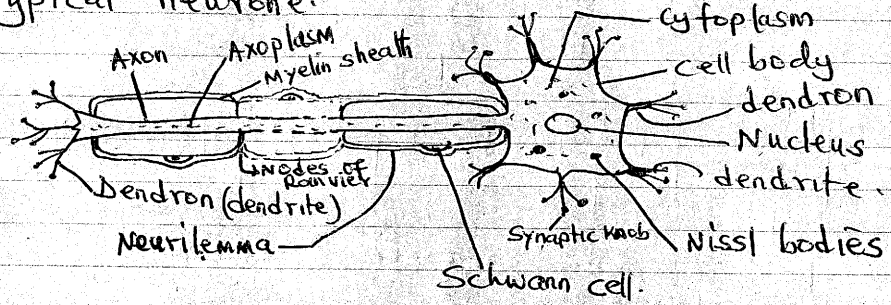


Structure and functions of Nerve cells

- The PNS and ANS are made up of small fibrous tissues called nerves.
- A nerve is composed of a bundle of tiny thread-like nerve cells called neurones

lying side by side. Each neurone carries or transmits special electrical messages known as impulses.

- The neurone is the basic functional unit of the nervous system specialised for conducting impulses in the animal body. Below is a typical neurone.



- Each neurone is made up of the following parts :-

(a) cell body - Main part of the cell. Also called Centron. Has a large nucleus and dense cytoplasm. Varies in shapes. It carries the cell organelles eg nucleus (which controls cell activities), nissl bodies (for protein synthesis).

(b) Axon - Long fibrous extension from the cell body. Also called nerve fibre. It contains **axoplasm** which is a specialised cytoplasm with ions for impulse transmission. The axon is bound by a thin membrane which is continuous with plasma membrane of the cell body.

(c) Myelin sheath (Medullated sheath) - A fatty sheath surrounding the axon. The myelin sheath helps to insulate the axon (thus preventing impulses from leaking out across

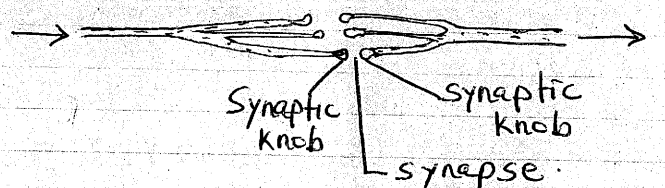
the membrane. The insulation thus increases the speed and efficiency of impulse transmission along the fibre (axon).

(d) Nodes of Ranvier - The myelin sheath is broken at one millimetre intervals by constrictions called nodes of ranvier. Thus help to propagate the nerve impulse and speed up the transmission of an impulse.

(e) Neurilemma - A thin membrane that covers the myelin sheath. Is the membrane of the schwann cell; which encloses the cell contents.

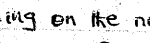
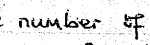
(f) Schwann cell - A specialised cell that secretes the myelin sheath.

(g) Synapse - A tiny space or junction between two neurones which transmit impulse in the same direction.



(h) Dendrons - These are fine fibrous projections or processes on the cell body. A dendron divides into finer processes called dendrites. Receptor dendrites receive / perceive impulse whereas terminal dendrites transmit impulse to another neurone via the synapse.

(i) Synaptic Knob - End of a dendrite through which impulse leaves or enters another neurone via the synapse. Transmitter substance is secreted from here ie Acetylcholine.

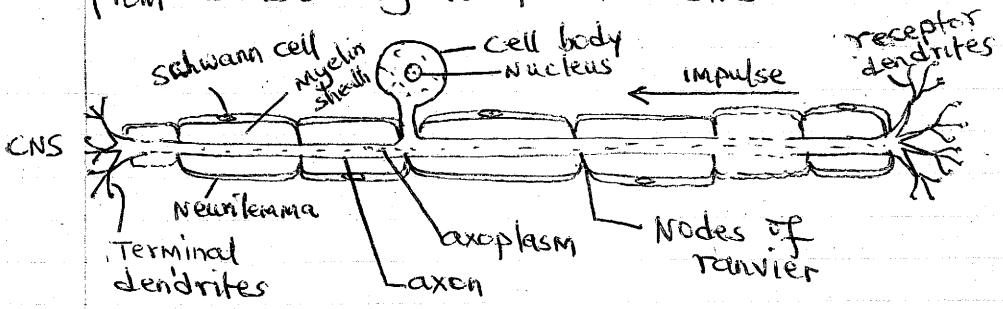
NB* Depending on the number of dendrites from cellbody, Nerve cells can be unipolar  Bipolar  or multipolar 

Types of Neurones

- There are three types of neurones, viz
(a) Sensory neurones (affarent)
(b) Motor neurones (efferent)
(c) Relay / intermediate / connector / associative neurones.

Sensory neurones

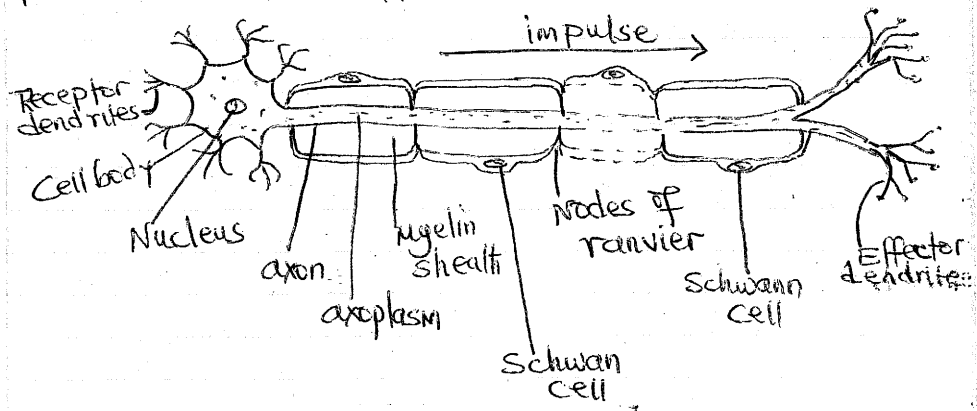
- This nerve cell links the sense organs such as eyes, ears, skin, nose and tongue with the central nervous system.
- Its cell body is situated off the axon / at a junction with the axon and outside the CNS.
- Its receptor dendrites are located in the sense organ, while the terminal dendrites are located in the central nervous system.
- Its function is to transmit nerve impulses from sense organs to the CNS.



Motor neurones

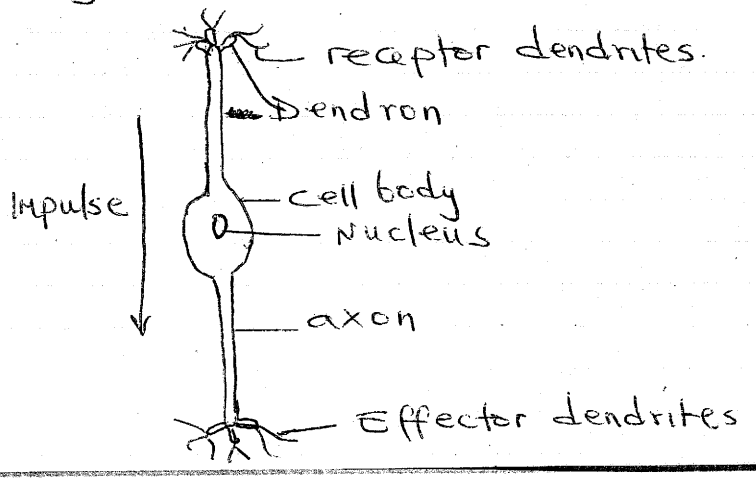
- This nerve cell links the CNS with the effectors (Muscles and glands).
- Its cellbody is located at one end of the axon and inside the CNS; whereas its motor end plate is located in a muscle or gland. It is therefore unipolar with a single long axon extending from the cell body.

- Its function is to transmit impulses from CNS to effectors.



Relay / intermediate neurones

- This nerve cell links the sensory neurones with the motor neurones through the small gaps called synapse / neurojunction.
- It is therefore a bi-polar or multi-polar nerve. The entire neurone is located within the CNS.
- They are non-myelinated.
- The main function of a relay neurone is to relay nerve impulses between the sensory and motor neurones.



Types of Nerves

- A nerve is a bundle of neurones running alongside each other. There are 3 types of nerves

(a) Sensory nerves – Contain only sensory neurones. Also called afferent nerve.

(b) Motor nerves - Contains only motor neurones. Also called efferent nerve.

(c) Mixed nerves – contain both sensory and motor neurones. Example is the spinal nerve before it branches out to dorsal (sensory) and ventral (motor) roots.

The central Nervous system (CNS)

- Consists of the brain, spinal cord and associated nerves.

(a) The Brain

- Is a delicate nervous organ which is encased in a bony structure called skull or **cranium**.
- The brain is enveloped by a system of membranes protecting it called **meninges**
- The meninges consists of **dura**, **pia** and **arachnoid**.

i) The dura matter - tough outer membrane covering the brain and spinal cord of the vertebrates. Composed of connective tissue and a rich network of capillaries.

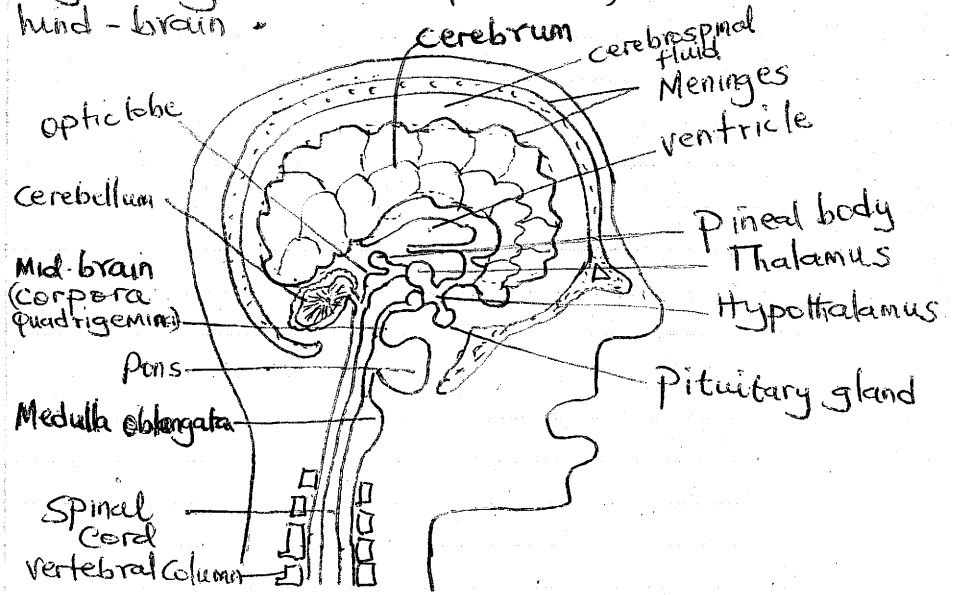
ii) Arachnoid layer - narrow space between the dura and pia matter, filled with cerebrospinal fluid from which O_2 and nutrients diffuse into brain cells.

iii) Pia Matter - Innermost membrane possesses many blood capillaries and lymph vessels.

- Within the brain there is a system of cavities called **ventricles** also filled with cerebrospinal fluid which is also continuous with the spinal fluid. The fluid is similar to lymph and nourishes brain tissue and nerves and also acts as a shock absorber.

Functions of the major Parts of the Brain

- The human brain is divided into three major regions – The forebrain, Mid-brain and hind-brain.



The fore brain

- Consists of the cerebrum, the thalamus, hypothalamus and pituitary gland.
- Cerebrum is the most developed part consisting of the left and right cerebral hemispheres.

(a) Functions of Cerebrum / Cerebral Cortex.

1. Receives ~~and~~ ~~intergrates~~ ~~interpretes~~ sensory impulses from all parts of the body
2. Integration of sensory impulses such

vision hearing and taste *Association areas receive, sort out integrate and store information.

③- Controls voluntary body movements eg limbs, lips and neck.

④- Controls learning, memory, intelligence and human individuality, and emotions.

⑤- Sends off motor impulses to effector organs such as muscles and glands.

⑥- Responsible for higher mental activities such as thinking, reasoning, analysis, Calculation.

(b) Function of the thalamus

1- Acts as a relay centre.

2- Contains receptors for pain and pleasure.

(c) Functions of hypothalamus

- Located below the thalamus.

1. Has receptors for homeostatic functions such as thermoregulation & Bmoregulation.

2- Controls appetite, speech, wakefulness and sleep.

(c) Functions of pituitary gland

- Projects downwards from hypothalamus.

1. It is the master endocrine gland controlling the rest of the endocrine glands.

The Mid-brain / Corpora quadrigemina

- Is the connecting stalk between fore brain and hind brain.

1. Relays impulses between nerves from the spinal cord and forebrain; for information and storage.

2. Has influence on body posture and movement control.

The Hind brain

- Mainly Constitutes the Cerebellum and Medulla Oblongata

(a) Functions of Cerebellum

1. Maintenance of body posture and balance.

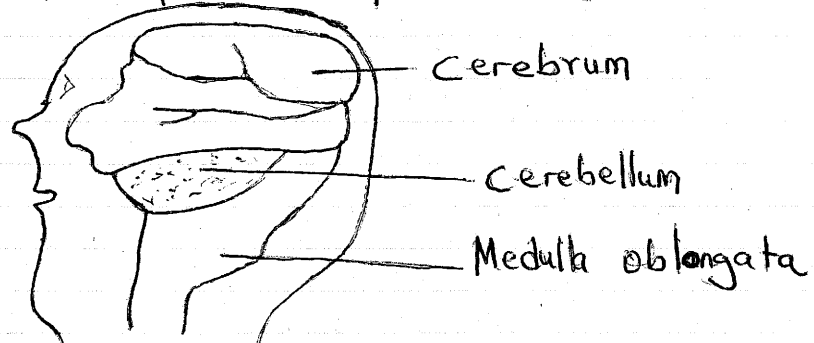
2. Controls all body movements.

(b) Functions of Medulla oblongata

1. Controls involuntary movements such as
   - breathing
   - salivation
   - peristalsis
   - swallowing
   - vomiting
   - heartbeat / heart rate.

2. Controls dilation or constriction of blood vessels thereby influencing blood pressure.

Surface view of the brain



Optic lobe- Responsible for eye movements.

Cranial Nerves

- These are nerves arising from the brain and form part of the peripheral nerve system associated with receptors and effectors in the head and neck.

- In human beings, there are 12 pairs of cranial nerves confined to the head and neck.

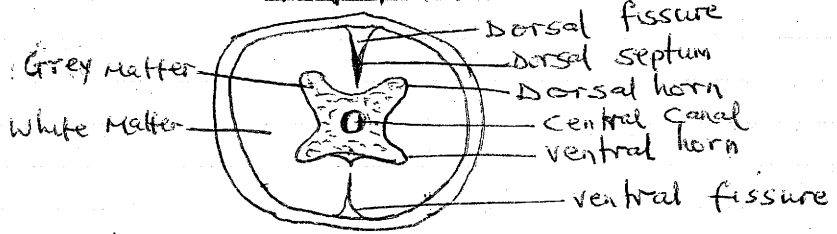
- The Cranial nerves may be purely sensory, motor or mixed such as optic, auditory, olfactory, and facial nerves. others innervate the jaws.

- The tenth Cranial nerve - the vagus nerve - innervates heart, lungs, diaphragm and gut hence Called wandering nerve.

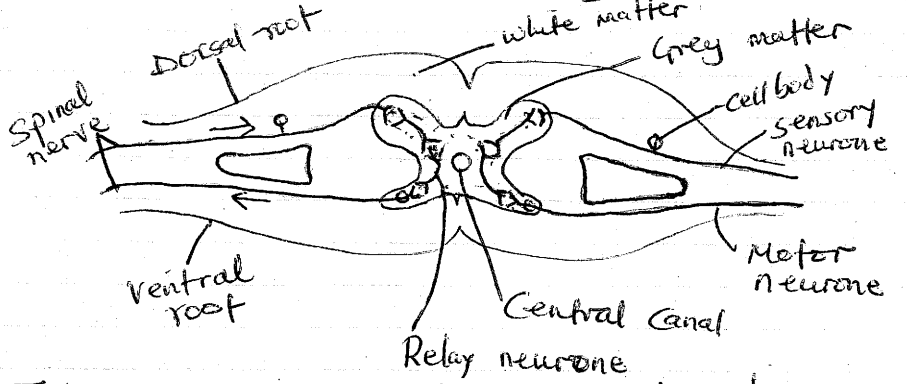
The Spinal Cord

- Is the posterior extension from the brain to the tail.
- It is enclosed in meninges and protected by the vertebral column.
- It is made up of grey matter and white matter.
- Grey matter is H-shaped and surrounds a central canal filled with **cerebrospinal fluid**. The **grey matter** relays information between the sensory and motor neurones. It consists of cell bodies and dendrites of relay and motor neurones; giving it the darker appearance.
- The **white matter** surrounds the grey matter and consists of the axons of the sensory and motor neurones. The myelin sheaths of these neurones give it the white shiny appearance.
- Arising from the the spinal cord are dorsal and ventral roots of spinal nerves.
- Spinal nerves innervate the skeletal muscles of the **limbs** and the **trunk**.
- In association with cranial nerves, the spinal nerves control all **organs** of the body below the head eg urinary bladder, the gut, liver, kidney and lungs.

T/s of spinal cord.



T/s of spinal cord showing cranial nerves



- There are **31 spinal nerves** in humans with sensory neurones entering through the dorsal root and motor neurones leaving through the ventral root. The nerves pass through openings of the vertebral column known as foramens.

Reflex Actions

- A reflex action is a **rapid automatic response** to certain stimulus.
- There are two types of reflex actions :- simple reflex actions and conditioned reflex actions.

(a) Simple reflex actions

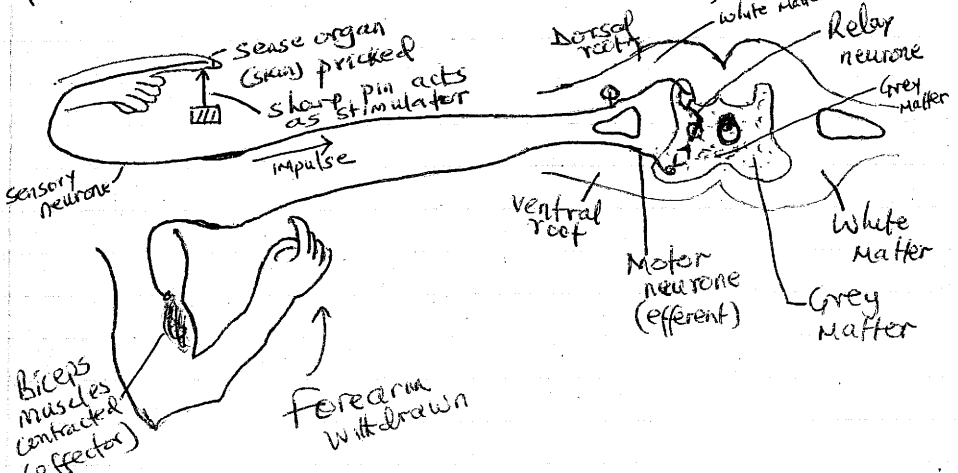
- Is a **specific single** and **automatic** response to a particular stimulus. It is the simplest innate reflex and does not depend on learning.
- Examples of reflex actions include :-
  - Withdrawal of finger from hot/sharp object (withdrawal reflex)
  - blinking of the eye when an object passes close to it
  - Coughing and Sneezing
  - The knee jerk reflex when the knee is tapped.
  - Secretion of tears when an onion is cut

- Swallowing
- Enlargement of the pupil in different light intensities.

— The **structural basis** of a reflex action is called the <u>reflex arc</u>, which is the pathway followed by the nerve impulse.

— The simplest reflex arc is made up of the three neurones : the <u>receptors</u> (sensory), <u>relay</u> and <u>motor</u>. They link the receptor organ with the effector through the spinal cord.

— Example :- When a finger is pricked, the pain receptors in the skin of the finger are stimulated. Nerve impulses are triggered off and transmitted via the sensory neurone to the grey matter of the spinal cord. The impulse is then transmitted to the relay neurone via a synapse; to the motor neurone through another synapse. Eventually through the ventral root, the impulse is transmitted to the effector which is the bicep muscle of the upper arm. The biceps contract and the forearm is withdrawn or raised.



(b) Conditioned Reflex Action

— This is an **automatic response** which can be evoked from an animal by **unrelated stimulus** substituted for the one which normally elicits the response.

— This reflex is formed from <u>past experience</u> and involves <u>modification of behaviour</u> through learning.

— For example, in a simple reflex action, a dog normally salivates when it sees food presented to it. But if a bell is rung just before food is presented to the dog and the procedure repeated several times, the dog will learn to associate bell ringing with food. Therefore it will salivate as soon as it hears the sound of the bell whether food is presented or not.

— Psychologist Ivan Pavlov who carried out these experiments named the response **Conditioned reflex action**.

— Conditioned reflex <u>weakens with time unless reinforced</u> time after time by repeated stimulus or repeating the original experience. This forms the basis of learned behaviour.

— Examples of conditioned reflexes include walking, playing, cycling, writing, swimming, and driving.

— Everyday practical <u>applications</u> of conditioned reflexes include training of dogs, learning processes, advertisements.

— In conditioned reflex the <u>primary motor component remains</u> the same but the primary sensory component is substituted by a secondary ~~sensory~~ component.

Differences between simple reflex actions and Conditioned reflex actions.

Simple reflex action	Conditioned reflex Action
1. Single stimulus to bring about a response.	-Repeated stimulus to bring about response.
2. Simplest form of behaviour independent of experience.	-Involves modification of behaviour and dependent of experience.
3. Sensory and motor Components are the same at all times.	-Primary sensory Component is replaced by secondary sensory compment but motor Component remains unchanged.
4. Response is immediate	Response takes time due to learning

Differences between Voluntary and reflex Actions

Reflex Action	Voluntary Action
1. Initiated from spinal cord (hence unconscious)	-Initiated from the Conscious Level of the brain
2. Impulse only travels to and from spinal cord	-Impulse travels to the brain then down to spinal cord.
3. Impulse takes the shortest route (reflex arc)	-Impulse pathway is much longer.
4. Response is immediate	-Response can be delayed.
5. Response may be in smooth or skeletal muscles	-Response is in skeletal muscles only.

Transmission of Nerve impulse

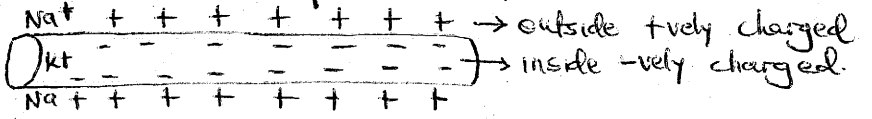
(a) Resting potential

— A nerve impulse is an electrical charge or wave of electrical disturbance arising from changes in ionic concentrations across the surface membrane of a nerve fibre

(axon or dendrite).

— The ions involved are mainly sodium ions (Na^+) and potassium ions (K^+) and anions (chloride, Cl^-, and organic ions).

— A non-conducting nerve fibre is described to be in a **resting potential**. In this state there are **more Na^+ outside** the axon membrane than inside and **more K^+ inside** the axon membrane than outside. There are also **more anions** (Cl^- and organic ions) **inside** within the axoplasm than outside the axon membrane. The net effect of this unequal ions distribution is that the **outside** of the axon membrane is more **positive** and the **inside** more **negative** hence the membrane is said to be **polarised**.



— During resting potential, Na^+ are actwely pumped out (extruded) by a mechanism known as **sodium-pump**. Meanwhile K^+ can diffuse freely in and out of the axoplasm.

(b) Acton potential

— An action potential is a **localised change** in **electrical potential** between the inside and outside of the nerve fibre when stimulated.

— The inside becomes **positively** charged while the **outside** becomes **negatively** charged, a process called **depolarisation**.

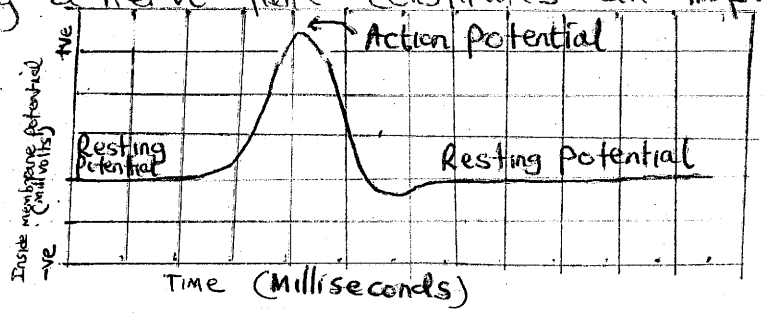
— Upon stimulation, the sodium pump temporarily ceases, the axon membrane becomes more

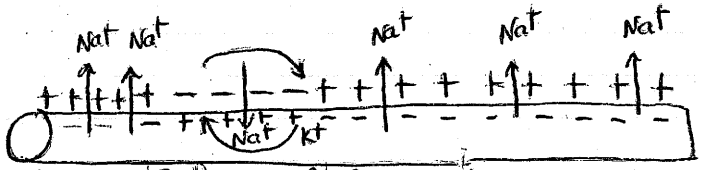
permeable causing an influx of Na^+ into the axoplasm. This raises the concentration of Na^+ relative to the outside causing K^+ to diffuse out.

— This localised charge stimulates the depolarisation of the membrane adjacent to it, thus propagating the depolarisation process. This is immediately followed by a **recovery** to the polarised state.

— The movement of the action potential along a nerve fibre constitutes an **impulse**.

As in inside of membrane of axon →





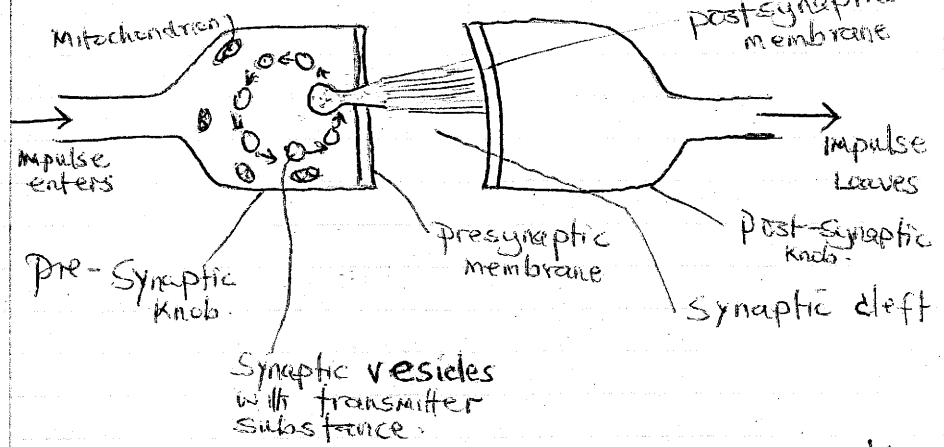
Positively charged outside of polarised membrane, pump extrudes Na^+	Sodium pump ceases. Na^+ enter inside of membrane and outside becomes -ve and inside becomes +ve	Positively charged outside of polarised membrane, pump extrudes Na^+

Synapse / Neurojunction

— A Synapse or neurojunction is the **junction between dendrites of two adjacent neurones**.

— Its function is to allow transmission

of impulses from neurone to neurone.



— In the presynaptic knob there are **vesicles** which contain a transmitter substance which is usually **acetylcholine**. When an **impulse** reaches the synaptic knob, it stimulates the **vesicles** to move towards the pre-synaptic membrane **releasing acetylcholine**. This transmitter substance makes the **membrane permeable**.

— The transmitter substance then **diffuses** across the synaptic cleft to the post-Synaptic membrane which becomes **depolarised**. **Sodium ions** from the cleft then diffuse flow through the post-synaptic membrane into the post-synaptic knob causing an **action potential** at this point. The action potential is then transmitted as **nerve impulse** along the neurone.

— Immediately afterwards Acetylcholine (ACH) liberated in the Synaptic cleft is destroyed by an enzyme **cholinesterase** into inactive products — **choline** and **acetic acid**/ ethanoic acid. These end-products

are reabsorbed by the axon terminals and reconstituted into acetylcholine using energy in form of ATP from the mitochondria.
— The rapid breakdown of acetylcholine is necessary to re-polarise the pre-synaptic membrane for the next nerve impulse propagation so that there is no merging of the successive nerve impulse from neurone to neurone.

Some Revision Questions

1 Describe the structure of a:
(a) sensory neurone
(b) motor neurone
(c) relay neurone (20 MKS)

2. State one structural and one functional difference between a motor and sensory neurone (2MKS)

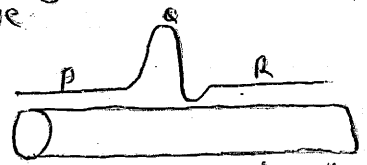
3. Explain how the neurone is adapted to its functions. (20MKS)

4. (a) Name the major parts of the brain (7MKS)
(b) State the functions of each brain part named in (a) above (14 MKS).

5(a) Differentiate between simple and conditioned reflex actions (4 MKS).

(b) Describe the structural basis of a reflex arc. (16 MKS)

6. The diagram below shows distribution of ions in a nerve

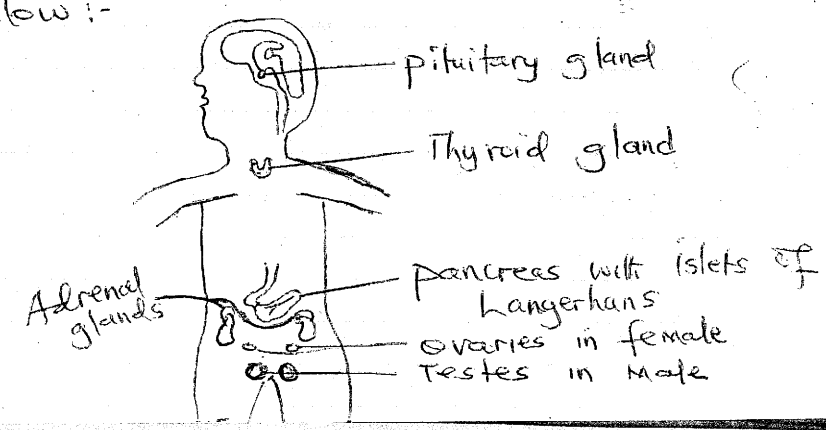


(a) Name the parts labelled P and Q (2MKS)
(b) State the distribution of ions in P and R (4MKS).

The Endocrine system

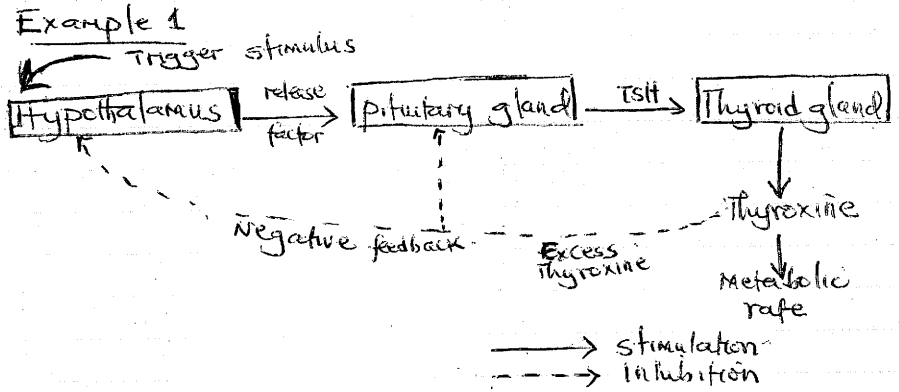
— Consists of **endocrine glands** that are ductless and the **hormones** they secrete. The interaction between these hormones form a network of communication in the body of an animal.
— **Hormones** are organic compounds which are either **protein** or **steroid** in nature produced in minute quantities in cells in one part of the body and **transported in blood** to other parts of the body of the same animal where they produce a **response**.
— The parts of an organism that respond to hormones are called **target organs**.
— Hormones in animals
- regulate growth and development
- control behaviour in animals
- control breeding
- bring about proper functioning of cells.

— The production of hormones in animals is directly or indirectly **influenced by** the **nervous system** (through innervation of the glands by motor end-plates).
— The endocrine glands are located in the various parts of the body as shown below:-

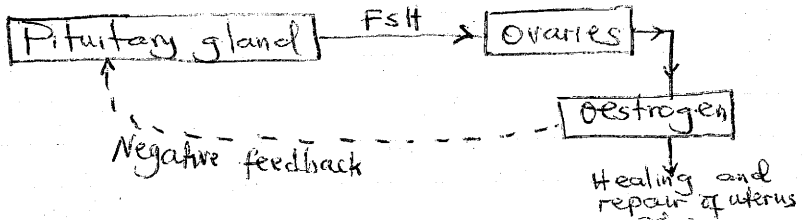


- The pituitary gland is the master gland that controls the activities of other endocrine glands.
- However the action of pituitary gland is also controlled / co-ordinated by the hypothalamus through nervous communication. Thus influences the activities of the pituitary by monitoring the levels of hormones and other chemical substances passing through it; and also influences the secretions of the anterior lobe of the pituitary gland.
- Hormones control their reactions through a feedback mechanism called negative feedback Mechanism. A negative feedback mechanism is one in which products of a process act as a regulater of that process by inhibiting the same gland producing the same product.

Example 1



Example 2



Roles of Some Hormones in a Mammal

(a) Thyroxine

- The hormone thyroxine is produced by the thyroid gland, found at the neck region. Thyroxine is a compound of iodine. Secreted as in Example 1 illustrated above.

Functions of thyroxine

- Controls basal metabolic activity. This is done by increasing glucose oxidation.
- It also enhances the effect of growth hormone (somatotrophin). Thus ensures normal growth and mental development.
- Works in conjunction with adrenaline to enhance involuntary activities such as increased circulatory rates. In this role it also enhances action of sympathetic nervous system.

Effects of under-secretion of thyroxine / hypothyroidism. Undersecretion of thyroxine leads to :-

- Insufficient iodine in diet or defective enzymatic reactions concerned with formation of thyroxine (hence insufficient availability of thyroxine)
- Cretinism in children and myxoedema in adults. Cretin children have deformed legs, dry leathery skin, large tongue, pot belly and general body sluggishness, poor mental development and low intelligence (IQ). Myxoedema in adults is characterised by swelling of the neck (simple goitre) due to overworking of thyroid gland to synthesise enough thyroxine; low Metabolic rate as shown by reduced heart beat and breathing rate and low body temperature; mental and physical sluggishness. The low physical activity

results in weight gain (obesity), retention of excess tissue fluid (oedema) hence swollen feet and puffy face.

Control of Hypothyroidism

- Balanced diet supplemented by iodised table salt
- Administration of iodine tablets.

Effects of oversecretion of Thyroxine (Hyperthyroidism)

- oversecretion of thyroxine is often due to presence of plasma proteins that stimulate thyroid activity ie defective enzymatic reactions. This leads to :-
- Increased metabolic rate resulting in increased heartbeat, breathing rate and high temperature.
- Nervousness, restlessness and easily irritable.
- Extreme hyperthyroidism can lead to heart failure, a condition called thyrotoxicosis.
- Swelling of front part of neck (exophthalmic goitre).
- Emaciation due to high rate of metabolism.

Control of hyperthyroidism

- Treatment with radioactive iodine.
- Surgical removal of part of thyroid gland.

(b) Adrenaline

- Also referred to as the **fight-or-flight** hormone. It is secreted by the **medulla of adrenal glands**.

NB- The adrenal gland has two regions the outer - adrenal cortex and the inner - adrenal Medella.

- The adrenal medulla receives impulses from

the brain to produce the hormone adrenaline. The adrenal cortex produces **corticosteroid** hormones.

- Adrenaline prepares the body for emergency - fight or flight; by increasing the rate of circulation & metabolic rate. It causes arterioles of the skin and digestive system to constrict, glycogen in liver to be converted to glucose, contraction and relaxation of skeletal muscles at a higher rate, increased breathing rate, fats are broken down to fatty acids and made available in the blood for muscle contraction.
- oversecretion of adrenaline can be brought about by growth of a tumour in the medulla of adrenal glands. Symptoms include high blood pressure, severe headache, racing heart, sweating and faintness. This results in aging of major body organs such as kidney, heart and liver.

Review of some endocrine glands and their secretions.

	Secretory gland	Hormone	Target organ	Function(s)
(a)	PITUITARY i,	Adreno-Cortic trophic hormone (ACTH)	Adrenal Cortex of Adrenal gland.	stimulates adrenal cortex to secrete adrenal-cortico hormones which regulate ions, and protein-Carbohydrate balance/metabolism.
	ii,	Growth hormone (Somatotrophin)	- Bones and other growing regions - Liver	-Stimulates growth by promoting protein synthesis. -Increases metabolic rate.

Secretory gland	Hormone	Target organ	Function(s)
			-Stimulates action of glucagon -Inhibits action of insulin
	iii) Thyroid-stimulating Hormone (TSH) or Thyrotrophin	Thyroid gland	-Stimulates thyroid gland to secrete the hormone thyroxine, which controls basal metabolic rate.
	iv) Anti-diuretic hormone (ADH) or vasopressin	Kidney	-Brings about reabsorption of water by the kidney nephron.
	v) Follicle Stimulating Hormone (FSH)	-Ovaries in females -Testes in males	-Stimulates devt of Graafian follicles. -Stimulates ovarian tissue to secrete the hormone oestrogen -Stimulates spermatogenesis in males.
	vi) -Luteinising hormone (LH) -Interstitial cell stimulating hormone (ICSH)	-Testes in males -Ovaries in females.	-Stimulates secretion of androgens by testes and adrenals. -Causes ovulation and development of Corpus Luteum in females
	vii) Oxytocin	-Uterine wall -Mammary glands	-Stimulates contraction of uterus at birth -Brings about milk expulsion by mammary glands
	viii) Prolactin	Mammary glands	-Stimulates mammary glands to secrete milk.
(b) Parathyroid gland	Parathyroid hormone (Parathormone)	General	-Controls exchange of Ca^{2+} and PO_4^{3-} ions between blood and bones.

Secretory gland	Hormone	Target organ	Function(s)
(c) Ovaries in females	i) Oestrogen	General	-Brings about development of reproductive organs and secondary sexual characteristics -Causes repair of uterine wall after menestruation -Makes uterine muscles more sensitive to oxytocin
	ii) Progesterone	Uterine wall	-Causes proliferation and thickening of lining of uterus after menestruation -Causes uterine wall to be less sensitive to oxytocin (thus maintain pregnancy). -Inhibits ovulation.
(d) Testes in Males	Androgens eg Testosterone	General	-Brings about devt of reproductive organs and secondary sexual characteristics.
		Local (Testes)	-Stimulates spermatogenesis
(e) Adrenal gland	i) Androgens	Male gonads	-Control devt of gonads and secondary sexual characteristics
	ii) Adrenaline & noradrenaline	Muscles	-Increase breathing, circulatory and metabolic rates as well as muscle contraction and relaxation during an emergency.
	iii) Glucocorticoids (Anti-stress hormones)	Liver	-Stimulate conversion of glycogen to glucose, raising blood sugar level -Inhibits respiration thereby reducing use of glucose.

Secretory gland	Hormone	Target organ	function(s)
(e)	Adrenal Cortical hormones (steroids) or Mineral Corticoids	Kidney nephrons	- Regulate balance of Na+ and K+ ions
(f) Gastric glands in wall of stomach	Gastrin	Other gastric glands in wall of stomach	- Stimulates gastric glands to secrete gastric juice for digestion in stomach.
(g) Glands in wall of Duodenum	cholecystokinin	Gall bladder	- stimulates gall bladder to secrete bile.
(h) Pancreas • Pancreatic tissue	Secretin	Islets of Langerhans	- Stimulates islets of Langerhans to secrete Pancreatic juice which is taken through pancreatic duct to duodenum for digestion.
• Islets of Langerhans	Insulin	Liver	Causes liver cells to convert glucose to glycogen or fat thereby reducing blood sugar level.
	Glucagon	Liver	- Causes liver cells to convert glycogen to glucose, thus raising blood sugar level.
(i) Thyroid	Thyroxine	General	- Controls basal metabolic rate - Promotes action of adrenaline and Sympathetic nervous system. - Promotes action of growth hormone.

Comparison / similarities between The Nervous and the Endocrine system.

① Both provide means of communication within the body of an animal.
② Both involve transmission of a message triggered by a stimulus and a response.
③ The target organs of hormones are like the effector organs.
④ Both involve chemical transmission
⑤ Both bring about survival response

Differences between endocrine and Nervous systems.

Endocrine system	Nervous system
i, Chemical substance to evoke a response ie chemical	i. Nervous impulse to evoke a response ie electrochemical.
ii, chemical transmitted through blood.	ii, Impulse transmitted through nerve fibre
iii, Response slow but affect several parts of the body.	iii, Response quick, specific and localised.
iv, Effects are long-lasting	iv, Effects rapid and short lived.
v, Response takes place involuntarily	v, Response takes place voluntarily and involuntarily.
vi, Mostly involved in growth responses and some muscle activity	vi, Mostly involved in muscle contractions and stimulation of hormone secretion

Revision quiz

1 What is an endocrine system?
2(a) State the glands that are involved in the production of i, Thyroxine ii, adrenaline.
(b) State the effects of oversecretion and undersecretion of :-

i. Thyroxine ii. adrenaline.

3. (a) State the roles of adrenaline in the body.

(b) What would happen if adrenaline level is increased in the body?

4. State five similarities between the nervous and the endocrine system. (5MKS)

5. State five differences between the nervous and the endocrine system. (5MKS)

Effects of drug abuse on human health

- A drug is a chemical substance which when taken into the body has psychological and physiological effects. Some drugs are used to restore good health as a result of illness. Such are medicinal drugs. Other drugs include cocaine, heroine, madras, tar and nictonne in cigarettes, Khat (Miraa), Cannabis sativa (bhang), glue and alcohol.

- Indiscriminate use of drugs with no regard to side effects is called drug abuse. Prolonged drug abuse leads to addiction (drug dependence).

- The following are some effects of drug abuse

① Depressed appetite and poor eating habits leading to emaciation eg alcohol

② Interference with absorption of vital vitamins such as vitamin K and E which may lead to sterility and blindness.

③ Lowers nervous co-ordination leading to loss of posture and balance eg alcohol.

④ Irritation of lungs and the respiratory tract leading to frequent cough and infections eg nicotine, tobacco, bhang

⑤ May lead to cancer of lungs, throat and urinary bladder eg nicotine and tar in cigarettes. The cigarettes also produce CO.

⑥ May cause stomach ulcers eg alcohols.

⑦ Damage many tissues of the heart and liver leading to heart attacks and liver cirrhosis respectively eg alcohol and cocaine.

⑧ Interference with temperature regulation leading to excessive heat loss.

⑨ Damages the brain leading to insomnia (sleeplessness), amnesia (memory loss), deliriums, hallucinations and mental illness (madness). Other drugs eg cocaine causes shivers, convulsions, nervousness.

⑩ In women, drug abuse may lead to poor foetal development and pregnancy complications.

⑪ Irreversible damage to vital body organs may eventually lead to death eg heroine, cocaine etc

⑫ Addicted persons have impaired judgement which may predispose them to accidents and infections such as HIV/AIDS.

⑬ Overdose on poison the body causing death.

⑭ Underdose of medicines may result in inability of the body to respond to the drug hence no healing.

⑮ Misuse of antibiotics leads to resistance.

⑯ May lead to weakening of immune system as the body is not given chance to produce antibodies.

Classes of drugs

(a) Pain killers eg paracetamol, Acetylsalcylic acid Asprin, etc. Suppress brain pain centres.

(b) Stimulants eg Caffeine. Increase activity of CNS

(c) Depressants. These are also called sedatives/tranquillizers / barbiturates eg chlorphenaramine (piriton). slow down activity of CNS.

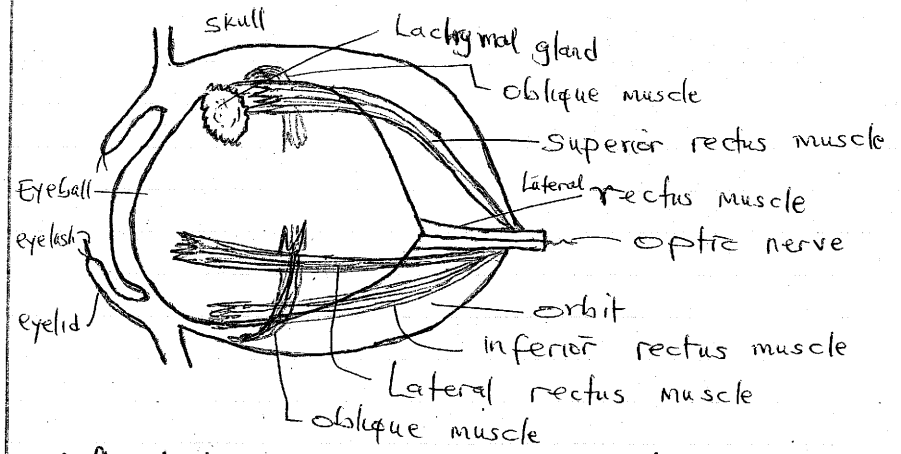
(d) Hallucinogens eg valium. Treat hallucinations.

(e) Antibiotics. (f) Antihistamines etc.

Sense organs

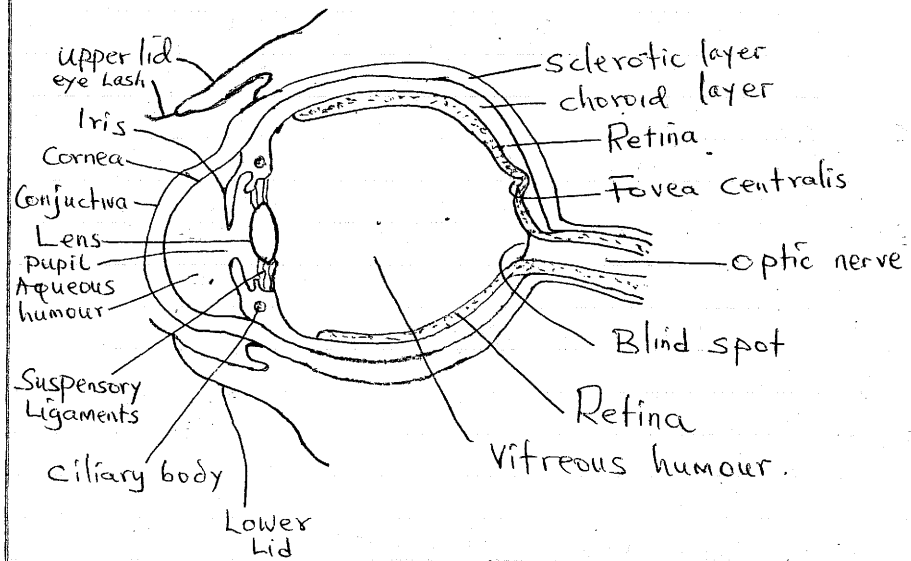
1. The Mammalian Eye

- The eye is a complex organ whose function is to receive light by which an animal perceives and distinguishes objects in its environment.
- The eye is located in the skull socket called orbit which offers protection against physical damage. Within the orbit is a fatty layer which also acts as a shock absorber.
- Within the socket the eye is suspended by sets of muscles :-
  i. Superior and inferior rectus muscles - move the eye up and down respectively
  ii. Lateral rectus muscle - moves the eye outwards
  iii. Medial rectus muscle - moves the eye inwards
  iv. Inferior and superior oblique muscles - move the eye sideways (left and right).
- Eye lids protect the front part of the eye, they have eyelashes (hairy structures) which prevent particles from entering the eye.
- The upper part of the orbit is raised into eyebrows which are hairy to prevent sweat and dust particles from entering the eye.
- Underneath the upper eyelid is the lachrymal gland which secretes a fluid called tears which moistens/lubricates the cornea and washes foreign particles from the eye. It opens into the eye through lachrymal duct below upper eyelid.
- In other mammals eg cat there is a transparent membrane called nictating membrane which is drawn across the eye to clean it, acting as the third eye lid.



Adaptations of the various parts of the eye to their function

- The mammalian eye is a spherical, fluid-filled structure whose wall consists of three distinct layers
  1. sclerotic layer / scleroid / sclera - The outer layer.
  2. Choroid - Middle layer.
  3. Retina - inner layer.



① **The sclera / sclerotic layer** - Outermost layer of the eye.

It is white-opaque, tough and fibrous to protect the eye and maintain the spherical shape of the eye ball (towards the front). It forms a transparent part towards the anterior part called cornea.

(1) **Cornea** - Front part of the sclera which is transparent to allow light into the retina eye. It is also curved to refract light towards the retina.

(3) **Conjuctiva** - Is a thin transparent layer of tissue / epithelium which covers and protects part of the cornea. It is continuous with the epithelium of the eyelid.

(4) **The choroid layer**

- Is a thin lining of tissue on inner side of the sclera - It contains numerous blood vessels which supply the retina and the rest of the eye with oxygen and nutrients and remove carbon(iv) oxide and other metabolic wastes. It also contains pigmented cells that contain melanin which gives a dark colour to absorb stray light rays to prevent internal reflections.

(5) **Ciliary body**

- ciliary body is a ring of thickened tissue.
- Found at the junction of the sclera and cornea. It contains blood vessels and ciliary muscles.

(a) **Ciliary muscles**

- These are a ring of muscles which on contraction and relaxation changes the thickness of the lens; enabling the eye to focus light on the fovea.

(b) **Suspensory ligaments**

- Fibrous ligaments attached to ciliary body; to hold lens in position and also alter the thickness of the lens during focussing.

(6) **Lens**

- circular, transparent, elastic and biconvex - disc which refracts light on the retina. Also seperates the aqueous from the vitreous humour. It is also involved in accomodation by its change in thickness.

(7) **The vitreous humour** - A clear, transparent jelly which fills the posterior chamber of the eye. Exerts pressure outwards thus supporting and maintaining the shape of the eyeball. It also refracts light onto the retina.

(8) **The aqueous humour**

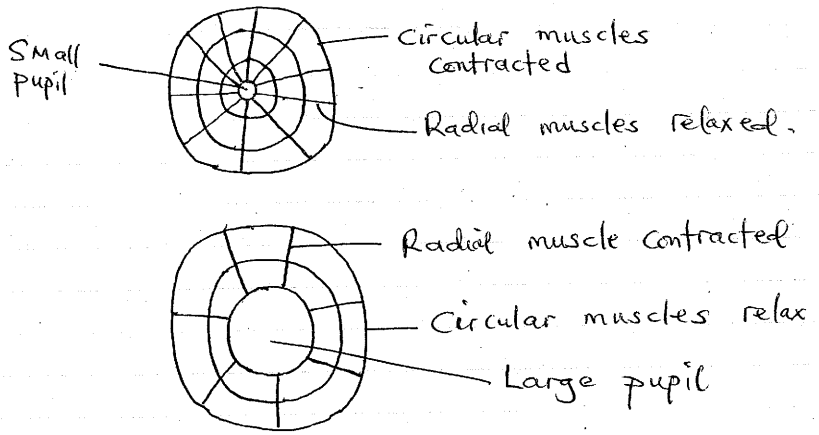
- A clear watery solution / fluid and also transparent which fills the anterior chamber of the eye. Contains blood vessels which nourish the eye parts (lens and cornea) and remove waste products. (These parts lack blood supply). Also maintains the shape of the eyeball by its external outward pressure. Also refracts light slightly to the retina.

(9) **Iris**

- A sheet of circular and radial muscles and is circular in shape. The antagonistic contractions and relaxations of these muscles of the iris control the diameter of the pupil thus controlling amount of light entering the retina eye
- It is also pigmented (with melanin giving the eye its colour - black, brown or blue) to absorb stray light rays); to absorb stray light rays.

(10) **The pupil**

- Hole at the centre of the iris which allows light to enter the retina eye. May be round or narrow slit-like as in cats. Size of the pupil is controlled by the iris; as shown below:-



(11) **The Retina**

- Is the innermost transparent layer of the eye. It is made up of light sensitive cells and sensory neurones. The sensory neurones join to form the optic nerve.
- The light sensitive cells are called **photoreceptor** cells. They are the **rods** and **cones** for perception of light of low intensity and light of high intensity / colour respectively.

(12) **The Fovea Centralis;**

- Also called the yellow spot / fovea centralis. Is part of the retina that contains cones only. Is part of retina that is sensitive to colour.

(13) **The optic Nerve**

- Consists of numerous nerve fibres carrying impulses from the retina to the brain.

(14) **The blind spot**

- Is the point where the optic nerve leaves the eye. It is not sensitive to light because there are no photoreceptor cells / rods

and cones. Blood vessels also enter / leave through the blind spot.

(15) **Tear glands** – Secrete tears which wash away irritating materials that get into the eye. Also keeps the eye moist.

(16) **Eye lids** – Have eye lashes and protects the eye / Cornea from mechanical and chemical injury and from foreign particles. also protects retina from bright light by closing up; either voluntarily or involuntarily;

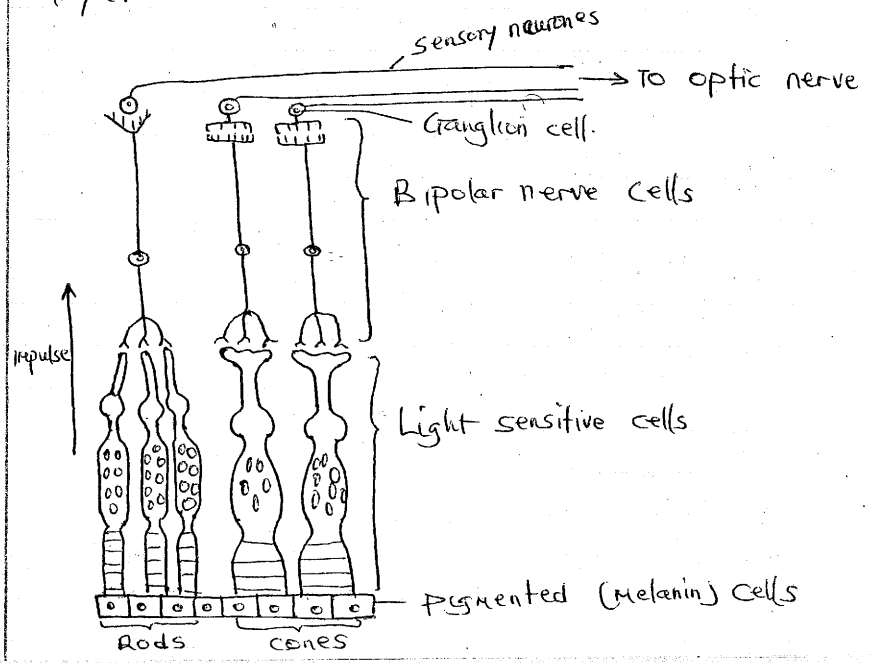
Structure of the Retina

- Composed of three regions :-

(a) An outer pigmented region in contact with the choroid.

(b) A middle region of photoreceptors consisting of rods and cones / photoreceptor layer

(c) Innermost region of neurones / Neural layer



Rods and Cones and light perception

CONES

- Cones contain a photochemical pigment called **iodopsin** which perceives light of high intensity. In the presence of light, iodopsin breaks down to **iodine** and **opsin**. This photochemical reaction brings about depolarisation of the cell membrane of the cones thus generating impulse which is transmitted along the neurones to the optic nerve which carries it to the brain for interpretation.
- **Greater concentration** of cones is in the **fovea** enabling it to perceive details / colour
- Each cone has its own bi-polar neurone which in turns links it with an optic nerve fibre; hence they **lack retinal convergence**. This property of the cones enable them to have high **visual acuity** /ability of eye to distinguish objects clearly.
- In higher vertebrates, there are three types of cone cells which differentiate colours perceived. The three types of cone cells distinguish light of the colours **blue, green** and **red**.
- The **Trichromatic Theory** suggests that simultaneous stimulation of the three types of cones at different degrees bring about colour perception. This explains colour vision. The cones perceive colour at different wavelengths ie
  - blue — 450 nm max.
  - green — 525 nm max.
  - red — 550 nm max.
- If cones for red are stimulated (at 550 nm) one perceives red; stimulation of 525 nm

one sees green and 450 nm one sees blue. Stimulation of red and blue cones makes one to perceive purple / **magenta**; ~~and~~ red and green, one perceives yellow. When the blue, green and red cones are equally stimulated one perceives white etc.

RODS

- Rods contain a photochemical pigment called **rhodopsin** (visual purple) which perceives light of low intensity; but not sensitive to colour. The rods have **retinal convergence** ie several rods form a synaptic contact with one bi-polar neurone. This makes rods to have **low visual acuity** hence can not distinguish fine detail.
- Rhodopsin disintegrates to **opsin** (a complex protein) and **retinine** (derivative of Vit. A) to bring about depolarisation of the cell membrane, thus triggers off an impulse.
- In the **dark** synthesis of **rhodopsin** in the rods is **increased** for continued photochemical reaction in the rods.
- Rods are of greater concentration in the periphery of retina and absent in fovea centralis. Nocturnal animals have more rods than cones.
- The combination of rods and cones enables the eye to be efficient under all light conditions.
- The blind spot lacks both rods and cones.

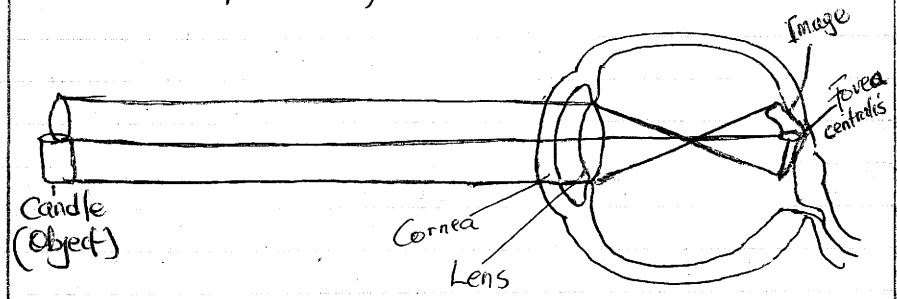
Differences between rods and cones:

Cones	Rods
- Have iodopsin	- Have rhodopsin.
- Lack retinal convergence	- Have retinal convergence
- Have shorter thicker segments	- Have longer thinner segments
- High visual acuity / perceive colour	- Low visual acuity / no colour perception
- Perceive light of high intensity	- Perceive light of low intensity.

Image formation and interpretation

-Light from the object is refracted by the cornea; then to aqueous humour; then to lens. The light rays are further refracted by lens through the vitreous humour and then focused onto the fovea centralis on the retina.

- The image is recorded as **real**, **inverted** and **small** /diminished;



- The photoreceptor cells become stimulated and nerve impulse is generated and transmitted by the optic nerve to the cerebrum of the brain for interpretation.
- In the brain impulses are interpreted and the object appears **real**, **upright** and **normal**
- Images from left eye are interpreted by the right cerebral hemisphere and those from the right eye by the left cerebral hemisphere.

Binocular vision and stereoscopic vision.

- Binocular vision occurs when the visual fields of both eyes overlap so that the fovea of both eyes are focused on the same object. Thus forms the basis of stereoscopic vision.

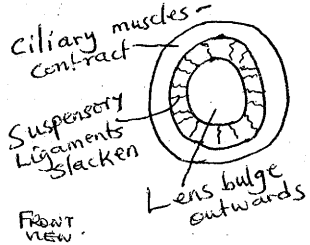
- Stereoscopic vision involves the eyes producing slightly different retinal images simultaneously which the brain resolves as one.
- Binocular vision has the following advantages over monocular vision (as in birds and lizards and chameleons)
  i. Large visual field
  ii. damage to one eye is compensated by the other eg cancels the effects of the blind spot.
  iii. Provides much more accurate assessment of distance, depth, height and width of an object.

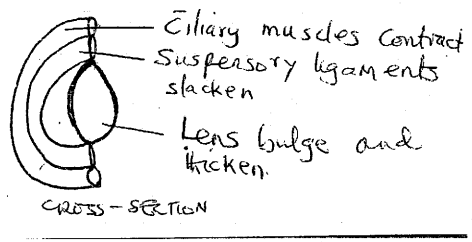
Accomodation of the eye

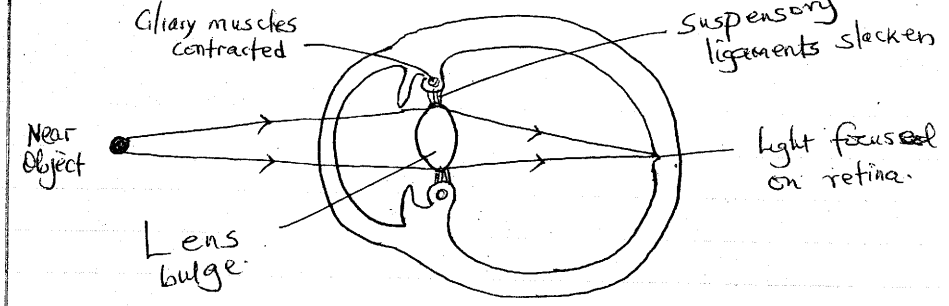
- Accomodation of the eye is the ability of the eye to adjust so as to bring the image of a near or distant object into sharp focus on the retina (fovea centralis).

(a) Accommodation for near objects

- Light rays reflected from a near object tend to **spread out** by the time they reach the eye. Such rays are said to be **diverging**.
- The lens need to increase the **curvature** to be able to refract the rays and focus them on the fovea of retina. To effect this :-
  - The ciliary muscles **contract**;
  - Suspensory ligaments **relax**, releasing tension on the lens.
  - The lens become thicker (more **convex**)

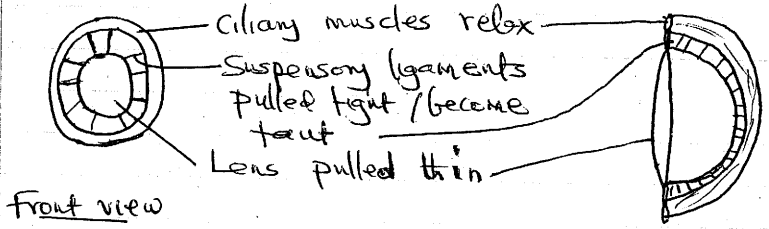


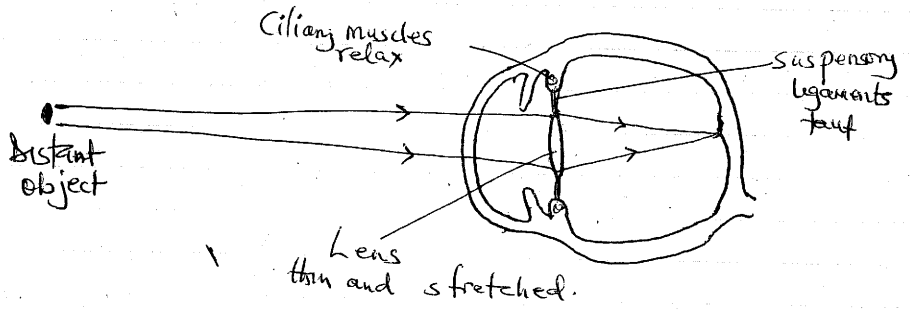




(b) Accommodation for distant objects

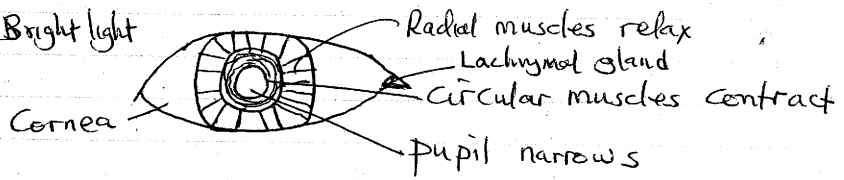
- Light rays from a distant / far object are almost parallel to each other. Hence a thin lens is able to slightly bend them to focus and a small curvature of the lens is required. To focus on a distant object:-
  - Ciliary muscles **relax**
  - Suspensory ligaments become **taut**
  - The tension on the ligaments pulls the lens upwards and downwards decreasing the curvature (making it thinner and stretched) ie lens become less convex.



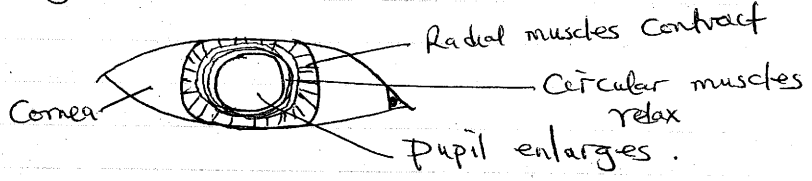


- During accomodation, the iris regulates the amount of light entering the eye.
- In bright light, the circular muscles of the iris contract while the radial muscles relax and the pupil becomes smaller preventing damage of the retina by excessive light.
- In dim light, the circular muscles of the iris relax while the radial muscles contract and the pupil enlarges. This allows enough light to stimulate photoreceptor cells of the retina.

(a) Bright light



(b) Dim light



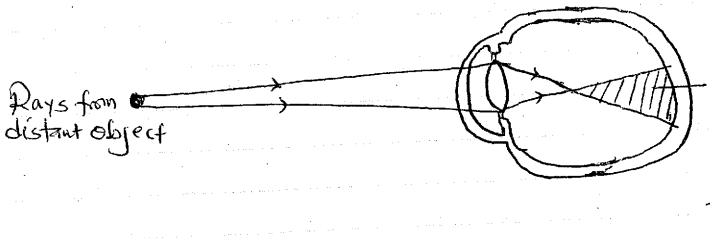
Defects of the Eye

① Short Sightedness / Myopia

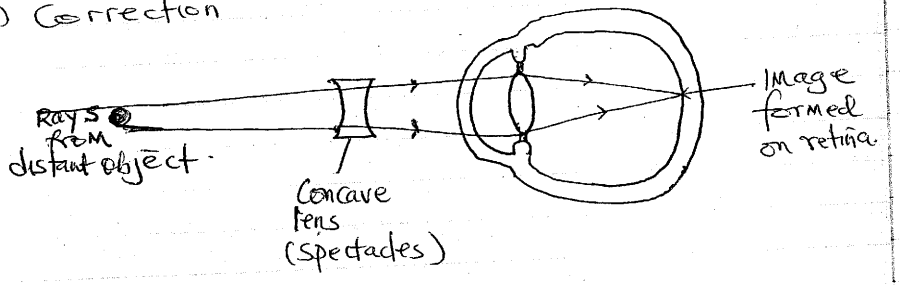
- A condition in which light rays from a distant object are brought to focus in front of the retina while those from near objects are clearly focussed on the retina.
- This is caused by a long eyeball or due to much refractive power of the eye lens.
- The disorder can be corrected by wearing a concave (diverging) lenses. This diverge the light rays before reaching the eye lens thereby enhancing refraction in order to focus rays

sharply on the retina.

(a) Diagram of defective eyeball.



(b) Correction



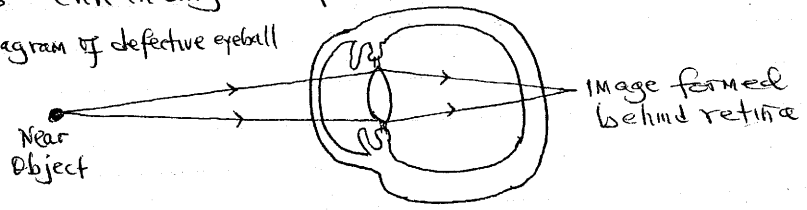
① Long sightedness (Hypermetropia)

— A condition in which light rays from a near object are not brought to focus by time they reach the retina, while those from a **distant object** are sharply **focussed** on the **retina**.

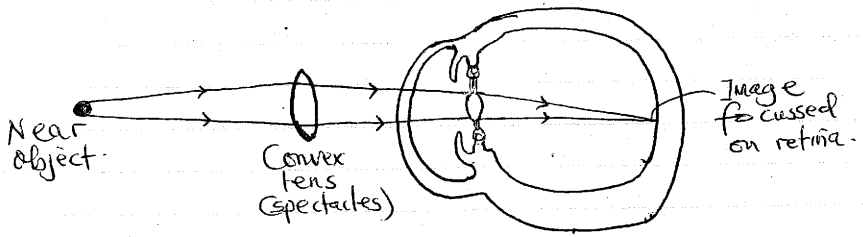
— The disorder is caused by too short an eyeball or a weak lens system.

— The disorder can be corrected by wearing **a convex (converging) lens**. This lens refracts light rays before reaching the eye lens thus enhancing refraction on the retina.

(a) Diagram of defective eyeball



(b) Diagram of correction.

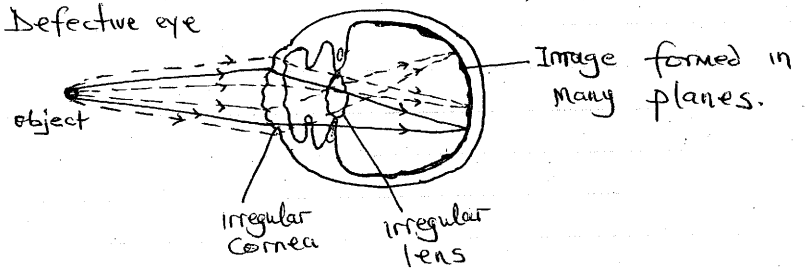


② Astigmatism

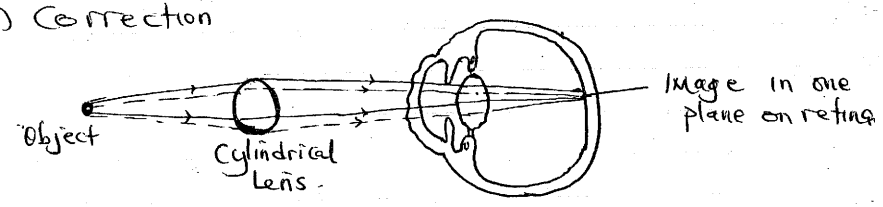
— A condition in which light rays from an object are brought to focuss in different planes. This is caused by **unequal curvature of the Cornea or lens** which produce unequal refraction of light entering the eye.

— Corrected by wearing a special **cylindrical lens** in front of the eyes which corrects the defective planes.

(a) Defective eye



(b) Correction



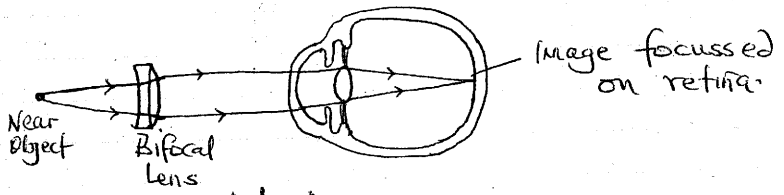
④ Squintedness

— An eye defect in which the **extrinsic muscles** of the eye that control the turning of the eyeball do not co-ordinate accordingly on stimulation.

—The defect affects the paired rectus muscle which turn the eye up and down and the lateral rectus muscles which move the eye left and right. In this condition the eyeballs face different directions hence focussing and accomodation are achieved with difficulty.
—The defect is difficult to correct; may be by surgery.

⑤ old sight (presbyopia)

—This is a condition in which the light rays from a near object are brought to focus behind the retina, while the rays from the distant object are sharply focussed on retina.
—Caused by hardening / loss of elasticity of the lens and weakening of the ciliary muscles due to old age.
—The defect is corrected by wearing a convex or converging lens or a pair of glasses with two different lenses called bifocal lenses.



⑥ Colour-blindness

— A genetic defect in which certain colours cannot be distinguished by the human eye or other animals; eg red-green colour blindness. This is caused by retina lacking cones with pigments that normally respond to these colours.
— Correction possible in future through **gene therapy**/ genetic engineering.

⑦ cataracts

— An eye defect associated with old age

or injury of eye or complications of diabetes mellitus; or damage by ultraviolet rays from the sun.
—In this condition the lens becomes **cloudy** or **opaque** hence blocking transmission of light rays. The transparent protein fibres in the lens are denatured forming the opaqueness due to coagulation.
—Correction can be done by surgery to replace the lens with a good one from a donor or an artificial lens.

Revision Quiz

1(a) Describe how the mammalian eye is adapted to perform its functions (14 Marks)
(b) State six defects of the eye and how they can be corrected (6 MKS).
2. Describe the functions of the various parts of the mammalian eye. (20 MKS).
3(a) Describe how the mammalian eye achieves accomodation of near and distant objects.
(b) Explain how image formation and interpretation occurs in a mammal. (20 MKS)
4(a) Distinguish between rods and cones (4MKS)
(b) What is meant by the terms binocular and stereoscopic visions? (2MKS).
(c) What are the advantages of binocular and stereoscopic visions? (2MKS).

The Human Ear

— The ear is a complex organ for hearing and for posture and balance.
—The ear consists of the following parts:-

Ⓐ outer ear

—The outer or external ear consists of the following :-

i) The pinna - It is funnel-shaped to collect and direct sound waves into the ear canal. It is also made of skin and cartilage (elastic cartilage) to facilitate this function. (N.B: Ear muscles are vestigial)

ii) The Ear canal / external auditory meatus (hence Eustachian)
- This is the ear tube forming a passage between the pinna and the eardrum. It is lined with wax-secreting cells. The wax keeps the eardrum soft and pliable & traps dust. The ear canal is tubular and rigid thus keeping the eardrum pliable.

iii) The Ear drum / Tympanicum / Tympanic membrane
- Is a thin flexible sheet-like membrane. It receives sound waves from air, and vibrates / transforms sound waves into vibrations; to transmit them to ear ossicles (or the malleus).

(B) Middle Ear - It is an air-filled cavity

- Consists of :-

i) Eustachian tube
- A tube connecting the middle ear to the pharynx / throat. It equalises the air pressure in the middle ear to that in the outer ear ie on both sides of tympanium. However may act as a route of infection for the middle ear from the throat.

ii) Ear ossicles.
- Include the Malleus (hammer), incus (anvil) and stapes (stirrup) named according to their shapes.
- These small bones are supported by ligaments and form synovial joints to each other.

- The ossicles transmit / amplify vibrations from the tympanic membrane (ear drum) to the inner ear / oval window.

iii) Oval window / fenestra ovalis
- seperates the perilymph of inner ear from the ear ossicles.
- It transmits vibrations which it receives from the ear ossicles / stapes to the inner ear.

iv) Round window (fenestra rotunda)
- Also separates the perilymph of the inner ear from the ear ossicles.
- It harmonises vibrations between the inner ear and the oval window.

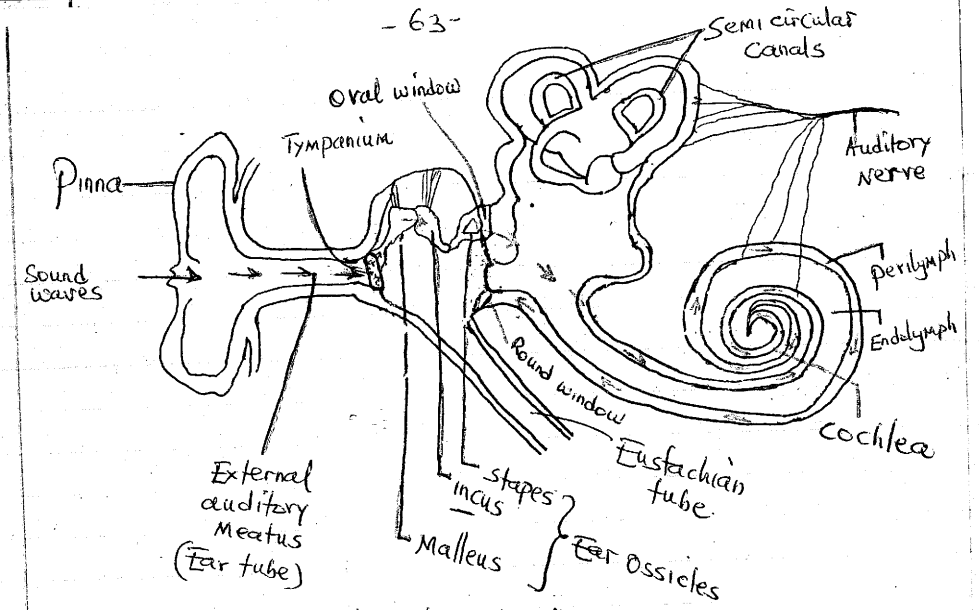
N.B - The muscles attaching the ear ossicles to the wall of ear cavity help to dampen pressure.

(C) The Inner Ear

- Consists of membraneous labyrinth, filled into bony labyrinth. It is made up of :-

i) the vestibular apparatus which consists of • Semi-circular canals, the utricule / utriculus and succule / succulus which are fluid filled. The fluid is known as endolymph. The semi-circular canals are placed at right angles to each other and have sensory receptors in a swelling called ampulla for maintenance of posture and balance.

ii) the cochlea
- Is partly coiled to increase surface area. It consists of canals, membranes and fluid (endolymph and perilymph); sensory hairs and nerves. Concerned with hearing.

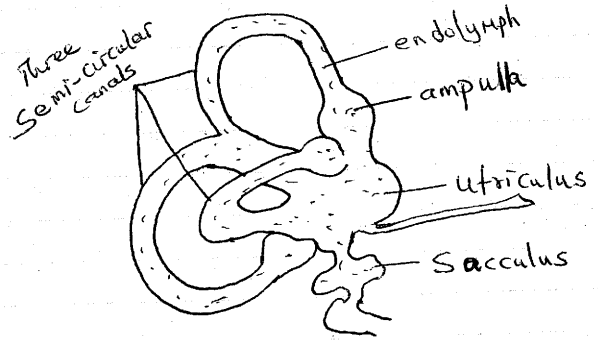


* Longitudinal Section through the ear.

Maintenance of posture and balance:

(a) by semi-circular canals

- There are three semi-circular canals; arranged in planes; at right angles; to each other.



- At the end of each canal is a swelling called **ampulla**, which contains sensory receptors.
- The movements of the head cause movement of a fluid (**endolymph**); in atleast one canal.
- The fluid movement displaces / deflects the ampulla. This stimulates the sensory hairs / receptors. In this way sensory impulses are generated and transmitted to the brain / Cerebellum; by auditory nerve for interpretation In the brain information is relayed **via** motor nerves to the muscles which maintain body balance. Eg when one spins and suddenly stops, one feels dizzy. This is because the endolymph is still in motion and impulse is being generated from sensory hairs in ampulla to the brain and hence Motor impulses are being sent to the muscles to restore body balance.

Role - Sensation of motion and restoration of balance

Role - postural maintenance.

(b) by Role of utricule & saccule

- Vestibule consists of **utriculus** and **saccalus** which contain **sensory cells**. They maintain body **balance and posture** in relation to **gravity**.
- When body balance is shifted, the fluid in the vestibule (ie endolymph) deflects sensory hairs. This triggers impulse to the brain via the auditory nerve. The brain interpretes the impulse according to the position of the body in relation to gravity. The brain relays impulses via Motor neurones to muscles of the body to restore the correct posture. (NB = Semi circular Canals + utricule + saccule + ampulla → vestibular apparatus)

cochlea and Hearing

- The cochlea is the structure responsible for **hearing**. It is partly / spirally **coiled** to increase surface area for attachment of sensory cells responsible for hearing.

- It consists of a system of canals, membranes

and sensory cells. The canals are filled with endolymph and perilymph.
— Sound waves are collected by pinna into the external auditory meatus. The sound waves strike the eardrum causing it to vibrate. The vibrations are transmitted to the ear ossicles (Malleus then incus and finally stapes) in middle ear. The stapes pass the vibrations to the oval window from where the vibrations are transmitted to the perilymph of the cochlea
— In the cochlea the vibrations stimulate the sensory hair cells to generate nerve impulses which are transmitted to the brain via the auditory nerve for interpretation. The intensity of the stimulus enables the brain to interprete the impulses as sound of specific pitch and loudness.
— Meanwhile, the vibrations in the fluid of the inner ear are dissipated back into the middle ear through the round window.
— Frequency discrimination is possible because certain frequencies stimulate only specific small parts of the cochlea eg high pitched sounds strike apex of cochlea whereas low pitched sounds strike base of cochlea.
— Detection of direction of sound is possible because both ears function together. When sound comes from front, or back, both ears receive the waves at the same time and intensity of impulse from both ears will be of same strength. But if sound waves are from one side, one ear receives them earlier than the other and

generates impulse faster whereas this is delayed for the other ear, hence direction is recognised; and so is the distance.

Defects of the Ear and their corrections

(1) Deafness

— A condition whereby an individual is unable to hear. Can be;-
(a) Absolute / Nerve deafness
— When nerve impulses are unable to reach the brain due to:- damaged auditory nerve by presence of tumour; damaged cochlea; damaged brain cells responsible for sound perception.
— This can be hereditary or disease-caused.
— Correction involves use of visual signs during speech, learning skills of lip reading since the condition can not be treated.
(b) Partial / Conductive deafness
— A condition whereby a person is partially unable to hear due to problems of relaying sound waves to inner ear. This may be due to:- failure of ossicles to amplify sound waves; failure of ear drum to vibrate due to accumulation of wax in ear canal; damage or rapturing of eardrum by infections or blows or accidents or high pitched / loud sounds; pus production due to infection; use of certain drugs such as chloroquine in some individuals
— Correction can be by:- treatment of ear infections by ear specialists (audiologists) use of hearing aids; learning lip reading skills and visual signs in speech.

② Vertigo

- A condition whereby an individual has problems in balancing and posture.
- Caused by abnormalities or damage of the vestibular apparatus eg by infections, accidents etc, or inner ear receiving many impulses on balance and posture.
- Can be corrected by proper medical care.

③ Absence of outer ear (pinna)

- Hereditary
- Correction by fitting an artificial pinna.

④ Tinnitus

- Defect characterised by ringing or hissing sounds in ear leading to distortion in sound perception.
- Correction is by treating the infections of outer / middle ear or use of hearing aids.

⑤ Hearing loss due to old age (presbycusis)

- Due to old age following wearing out of the cochlea hairs and the ossicles.
- May be corrected by use of hearing aids

NB The deaf and other physically impaired / disabled are integrated in our society eg through special schools, to equip them with compensatory skills and can now participate even in games like Paralympic Games.

Revision quiz

1. Describe how the mammalian ear is adapted to its functions. (20 mks)
2. Describe the functions of the various parts of the mammalian ear (20 mks).

3 (a) State the functions of each of the following parts of the ear
   i, Tympanium (3 mks)
   ii, Ear ossicles (2 mks)
   iii, Eustachian tube (1 mk)
   (b) Explain how the semi-circular canals perform their functions. (14 mks).

4. List four ear disorders and state how they can be corrected (8 mks).

5 (a) Describe the role of the vestibule in posture and balance. (10 mks)
   (b) Describe hearing sensation in a mammal (10 mks).

6. What is the function of semi-circular canals in a mammal (1 mk)