VARIATION AND EVOLUTION

1. (a). Define the term variation. (02 marks)

- Variation refers to the observable (phenotypic) differences between individuals of the same species**;** due to interaction between genes and the environment**;**

(b). Distinguish between continuous and discontinuous variation. (05 marks)

Continuous variation	Discontinuous variation
• There is no clear-cut difference between the forms of a character	• there is a clear-cut difference between the forms of a character;
• there are intermediates between the extremes of the character	• there are no intermediates between the different forms of the character;
• Characters are controlled by many genes	• Characters are controlled by one or two (a few) major genes;
• Characters are greatly influenced by the environment	• Characters not much affected by the environment;
• Example; skin colour. height in humans	• Example; sex, blood group in humans

(c). Explain the effect of the environment on genetic variation. (13 marks)

- Organisms of the same genetic constitution can show differences in their phenotype**;** due to the difference in the environment they inhabit**;**
- The environment affects the expression of some genes on the phenotype**;** especially those that control characters that show continuous variation**;** such as height/skin colour/intelligence**;**
- In the presence of suitable environmental factors**;** like light/temperature/food**;** the effects of a gene are fully expressed**;** while in the absence of these factors**;** full gene expression is prevented**;**
- The environment however cannot increase the extent of the phenotype**;** beyond that determined by the genotype**;**
- The characteristics that show discontinuous variation are not greatly affected by the environment**;**

2. (a). What is meant by the term gene reshuffling? (03 marks)

- Is the exchange of genetic material between two organisms**;** during sexual reproduction**;** which leads to production of offspring with combinations of traits that differ from those of the parents**;**

(b). Outline the different forms of gene reshuffling. (03 marks)

- Crossing over between homologous chromosomes**;**
- Independent assortment of homologous chromosomes**;**
- Random fertilization**;**

(c). Explain how each of the above mentioned forms of gene reshuffling leads variation in populations. (14 marks)

- **Crossing over**. This leads to exchange of genetic material**;** between homologous chromosomes**;** which results in separation of linked genes**;** forming new linkage groups/ gene combinations**;**. The further apart the genes are on homologous chromosomes**;** the higher are their chances of crossing over**;**
- **Independent assortment**. The lining of the bivalents on the spindle equator; in metaphase I of meiosis I**;** and their subsequent separation**;** in anaphase I**;** is random and independent of other bivalents**;** thus each gamete formed by meiosis in an individual contains a different gene combination**;**
- **Random fertilization.** The fusion of different gametes**;** during sexual reproduction is random**;** this increases the genetic mixing and variation with the population**;**

3. (a). Explain what is meant by the term mutation. (05 marks)

- This is a spontaneous change**;** in the structure**;** or amount of genetic material in a cell**;**
- The change can affect a single gene (point mutation)**;** or an entire chromosome (chromosomal mutation)**;**
- Mutations produce changes in the genotype and hence appearance of a characteristic in a population;

(b). State the main features of mutations. (05 marks)

- Mutations arise spontaneously (by chance or through mutagens);
- Mutations are not directed by the environment;
- Mutations are relatively persistent;
- Many mutations are disadvantageous;
- They are rare in nature;
- Most gene mutations are recessive;

(c). Explain how mutation contributes to variation. (10 marks)

- Mutations may lead to formation of new alleles**;** that leads to formation of new phenotypic features**;**
- Chromosomal mutations**;** may bring different genes sequences together**;** by deletion or insertion**;** and the combined effect may produce new (beneficial) characteristics**;**
- Gene mutations**;** may lead to several alleles occupying a specific locus**;** this increases both heterozygosity**;** and size of the gene pool of the population**;** hence increase in variation within a population

4. (a). What is meant by the term

(i) Ploidy. (01 mark)

- Is the number of complete sets of chromosomes in a cell**;**

(ii) polyploidy? (01 mark)

- A condition in which a cell has more than two complete sets of chromosomes**;**

(b). Describe the different forms of polyploidy. (08 marks)

- Autopolyploidy**;** refers to possession of more than two complete sets of chromosomes**;** all derived from the same species**;**. Occurs when DNA replicates but cytoplasm fails to cleave**;**
- Allopolyploidy**;** possession of more than two complete sets of chromosomes**;** derived from different species**;** The first generation of hybrids produced from different species are sterile**;** because homologous pairs of chromosomes cannot form during meiosis**;** However, the chromosome number in the sterile hybrid can double**;** producing a fertile hybrid**;**

(c). Explain why polyploidy is

(i). More common in plants than animals. (06 marks)

- Most of them reproduce sexually**;** Polyploidy increases the number of chromosomes in a cell**;** which makes gamete formation during meiosis prone to errors**;** hence normal gametes do not form and animals cannot propagate themselves**;**
- Most plants are capable of asexual reproduction**;** hence can still propagate despite being polyploids**;**

(ii). Associated with increased size of the organism. (05 marks)

- Polyploidy increases the number of chromosomes in the nucleus of a cell**;** hence the size of the nucleus also increases**;** the volume of the cytoplasm increases**;** to preserve/ maintain the nucleus to cytoplasm volume ratio**;** which leads to an overall increase in the size of the organism possessing such cells**;**

5. (a). Trisomy is an example of aneuploidy. What is;

(i). Aneuploidy. (01 mark)

- A condition which a cell has more or less copies of a particular chromosome than the normal cell.

(ii). Trisomy. (01 mark)

- Refers to the presence of three copies of a particular chromosome, instead of the normal two, in a cell;

(b). Give

(i). One other example of aneuploidy apart from trisomy. (01 mark)

- Monosomy**;**

(ii). Three examples of trisomy in humans. (03 marks)

- Down's syndrome (trisomy 21)**;**
- Klinefelter's syndrome (XXY males)**;**
- Turner's syndrome (XO females)**;**

(c). Briefly describe how trisomy in humans arises. (06 marks)

- Trisomy arises when a normal haploid gamete fuses with a gamete with two copies of a given chromosome**;**
- A gamete with two copies a chromosome is formed due non-disjunction**;** of homologous chromosomes in meiosis I**;** or sister chromatids in meiosis II**;**

- Down's syndrome is due to non-disjunction of chromosome 21**;**
- Klinefelter's is due to non-disjunction of sex chromosomes**;**

(d). Explain how polyploidy may arise in a population. (13 marks)

- Polyploidy can occur naturally**;** when chromosomes undergo replication**;** during interphase**;** and chromatids separate during anaphase**;** but cytoplasm fails to cleave**;** during cytokinesis**;** this is called endomitosis**;**
- Artificially**;** polyploidy can be induced by application of chemicals**;** like colchicine**;** that prevents spindle formation**;** so that chromatids fail to separate**;** during anaphase**;**

6. (a). What is meant by the term chiasma? (03 marks)

- A point of physical contact**;** between two non-sister chromatids of homologous chromosomes**;** at which crossing over between the chromosomes occurs**;**

(b). Explain the significance of the chiasma? (09 marks)

- Homologous chromosomes together**;** so that they (bivalents) can behave as a unit**;** during the first meiotic division**;** for proper chromosomal segregation**;**
- At the chiasma, crossing over occurs**;** between non-sister chromatids of the homologous chromosomes**;** which allows genetic mixing**;** by separating linked genes**;** hence introducing variation in the population**;**

(c). Explain the significance of variation in populations. (14 marks)

- Variation allows populations to evolve**;** and adapt to different environmental conditions**;**
- It's the basis of natural selection**;** where the best adapted individuals are selected for**;** survive longer**;** and reproduce**;** and pass on their favorable characteristics to the next generation**;** while individuals with unfavorable characteristics are selected against**;** they either die off**;** or fail to reproduce**;** and become extinct**;**
- Variation allows organisms of a population to utilize different resources in the environment**;** this reduces interspecific competition**;** hence survival of a species**;**

7. (a). With examples, explain the term discontinuous variation. (06 marks)

- Variation in phenotypic characters in which there is a clear-cut difference between the forms of the character**;** and there are no intermediates**;**
- Such characters are not affected by the environment**;** they are controlled by few genes**;** that may have many alleles**;**
- Examples include sex and blood groups in humans**;**

(b). Explain how sexual reproduction causes variation. (14 marks)

- Cross fertilization**;** mixes genes**;** from different individuals**;** giving different gene combinations**;**
- During prophase I of meiosis**;** there is chiasmata formation**;** between homologous chromosomes**;** that allows crossing over**;** separating linked genes**;** while creating new linkage groups**;**

- The lining up of the bivalents at the spindle equator**;** in metaphase I**;** and their subsequent segregation**;** in anaphase I of meiosis**;** is random**;** and independent of other bivalents; also increases gene mixing**;**
- The fusion of gametes is random**;** giving rise to many possible gene combinations**;**

8. (a). Distinguish between crossing over and crossover value. (07 marks)

- Crossing over is the exchange of genetic material**;** between non-sister chromatids of homologous chromosomes**;** during prophase I of meiosis**;** at the chiasmata**;** which results in new allelic combinations in the daughter cells**;**
- Crossover value is the number of offspring showing recombination**;** expressed as a percentage of the total offspring of a given cross**;**

(b). Explain the significance of

(i). Crossing over. (07 marks)

- Crossing over increases the genetic variability of a population**;** and prevents the accumulation of undesired allele combinations**;** by separating linked genes while creating new linkage groups**;**
- Variations increases the chances of the species to adapt to different environmental conditions**;** evolve and hence survive**;**
- Variation also reduces interspecific competition**;** as different members of a species can utilize different resources in the environment**;**

(ii). Crossover values. (08 marks)

- Show relative position of genes on the chromosomes**;** as genes that are so close to each other on the chromosome**;** have less chances of crossing over**;** hence low crossover values**;** while genes that are further apart on the chromosome**;** are likely to cross over**;** hence higher number of recombinants and crossover values**;**
- This is important in production of genetic maps**;**

9. (a). Explain the term meiosis. (05 marks)

- This is a type of cell /nuclear division**;** that results in the formation of four new daughter cells /nuclei**;** each with half the genetic material as the parent cell /nuclei**;**
- It is involved in the formation of gametes**;** in sexually reproducing organisms**;**

(b). Explain the role of meiosis in variation. (09 marks)

- Crossing over**;** between homologous chromosomes**;** during prophase I of meiosis (pachytene)**;** leads to exchange of genetic material between these chromosomes**;** creating new gene combinations/ linkage groups (separating linked genes)**;**
- Independent assortment (random distribution) of chromosomes**;** during meiosis I**;** (**or** the lining up of the bivalents on the spindle**:** in metaphase I**;** and their subsequent movement to the opposite poles**;** in anaphase I**;** is random and independent of other bivalents**;**) results in formation of new gene combinations in the gametes**;**

(c). Describe the role of variation in evolution. (14 marks)

- Variation provides a basis upon which selection works**;**

- Some variations in populations are advantageous**;** and they give a selective advantage to the organisms possessing them**;** and they survive longer**;** reproduce**;** and pass on their favorable characteristics to the next generation**;**
- Other variations are disadvantageous**;** conferring a selective disadvantage to the individuals possessing such traits**;** so that they easily die**;** or fail to reproduce**;** and are eliminated from the population**;**
- If this selection continues for several generations over a long time**;** it leads to creation of a population with advantageous traits**;** that is better adapted to the environment**;**

10. (a). What do you understand by the term evolution? (02 marks)

- This is a gradual process by which more differentiated organisms are formed from the less differentiated organisms**;** over a period of time**;**

(b). Explain how the following provide evidence for evolution

(i). Fossils. (10 marks)

- A fossil is any form of preserved remains derived from living organisms**;**
- Fossils provide supports evolution by progressive increase in complexity**;**
- The oldest fossil-bearing rocks contain very few fossilized organisms**;** with simple structures**;**
- Younger fossil-bearing rocks contain many fossils**;** which are increasing more complex in structure**;** that appear to be modifications of the older fossilized organisms**;**
- Many species appearing at one early stratigraphic level disappear at a later level**;** showing the times when species originated**;** and went to extinction**;**

(ii). Distribution of camels. (06 marks)

- The distribution of camels throughout the world is discontinuous**;**
- However they all have a common ancestor in north America**;** from where they all migrated to the different parts of the world**;**
- Places lacking camels can be due death and extinction of the camels in such places**;** due to unfavourable condition**;**
- The differences in the camels occurred during their migration as they adapted to their environment**;**

10. Explain how the following provide evidence for evolution

(a). Darwin's finches. (10 marks)

- Darwin's finches provide evidence for adaptive radiation**;** where a single population of finches colonized the Galapagos island**;** with plenty of resources**;** they reproduced rapidly and increased in number**;**. Competition for resources increased**;** and some individuals who had features best suited for the empty niches**;** moved in to fill them**;**
- In isolation from other members of the population**;** each group within its niche developed unique features**;** for example, the songs and feeding habits**;** such that mating between the different groups became impossible**;** and thus, being reproductively isolated**;**

(b). Mammals of Australia. (10 marks)

- Australian mammals provide an example of convergent evolution**;**

- Australia broke off from the mainland**;** before the emergence of eutherian mammals**;**
- When eutherians appeared on the mainland, they outcompeted the primitive monotremes and marsupials**;** making them go to extinction**;**
- Due to long time isolation for the rest of the world**;** Australia native mammals comprise monotremes and marsupials**;**
- However, the monotremes and marsupials evolved such that they fill the ecological niches similar to those filled by the eutherian mammals in the other parts of the world**;**
- This shows that, under similar environmental conditions**;** organisms evolve in the same direction**;**

11. (a). Distinguish between the following pairs of words as used in evolution

(i). Convergent evolution and divergent evolution. (07 marks)

- *Convergent evolution*: this is the independent evolution of similar structures**;** in organisms of different lineages**;** It results in the formation of analogous structures**;**

- *Divergent evolution*: occurs when organisms that share a common ancestor**;** experience different selection pressures**;** to which they adapt differently**;** hence become increasingly different from each other leading to the formation of homologous structures**;**

(ii). Homologous structures and analogous structures. (06 marks)

- *Homologous structures*: these are structures found in different species but have similar basic form**;** body position and embryonic development**;** for example; wing of a bat and hand of human**;**
- *Analogous structures*: these are structures found in different unrelated species of organisms**;** but show adaptations to perform the same function**;** these structures only have a superficial resemblance for example wings of insects and bats**;**

(b). Explain how each of the following provides evidence for evolution

(i). Homologous structures. (06 marks)

- Homologous structures provide evidence for divergent evolution; and illustrate the principle of adaptive radiation; where organisms with a common ancestor; under different environmental conditions; modified a common structure; to suit the environment they inhabited at a time;

(ii). Analogous structures. (06 marks)

- These provide evidence for convergent evolution; where organisms having no close phylogenetic links; have structures that showing superficial resemblances; and thus are adapted to perform the same function;. Natural selection favored the survival of organisms bearing such structures;

12. (a). What is meant by the following terms?

(i). Adaptive radiation. (02 marks)

- This is a process in which organisms having a common ancestor; adapt to different environmental conditions; resulting in a variety of related organisms occupying different environmental conditions; it leads to formation of new species;

(ii). Vestigial structures. (02 mark)

- These are structures in certain organisms that are usually reduced in size; and have no apparent function in these organisms;

(b). Explain how each of the following provides evidence for evolution

(i). Adaptive radiation. (05 marks)

- Provides evidence for divergent evolution; and suggest a common ancestor; from which related groups of organisms evolved due to different adaptations to suit different environmental conditions;
- Such organisms have structures with similar basic plan and embryonic development; which are slightly modified in the adults as a result of evolution and adaptation carry out different activities;

(ii). Vestigial structures. (05 marks)

- These structures provide evidence for evolution through modification by descent; these structures once had a function in the ancestors of the organisms that posses them; however due to evolution, through adaptation to different modes is of life; these structures lost function in the successive generations;
- For example, the human coccyx shows that the organisms from which humans evolved had post anal tails**;**

(iii). Comparative anatomy. (08 marks)

- Compare the structural similarities and differences between organisms.
- Some groups of organisms share homologous structures; which have the same basic plan but is modified to perform different functions in different groups of organisms; for example, the feeding mouth parts of insects; like in butterflies is for sucking nectar; while in mosquitoes it is for piercing and sucking;
- In some organisms the structures are reduces and apparently have no functions in some groups of individuals; these are called vestigial organs;
- Both vestigial organs and homologous structures provide evidence for divergent evolution; from a common ancestor; from which they descended by modification of particular organs;
- Analogous structures have different basic plans; but are modifies to perform the same function; for example, the wings of insects and birds;
- These provide evidence for convergent evolution; when natural selection selected for organisms with that particular adaptation;

13. Explain how each of the following provides evidence for evolution.

(a). Comparative embryology. (07 marks)

- Structural similarity occurring in groups of organisms during the early stages of embryo development suggest an evolutionary process**;**
- As an organism develops, it repeats the evolutionary history of its ancestors;
- Organisms having embryos that show much resemblance during their development**;** suggest that these organisms have a common ancestor**;** and the differences seen later in

their development; is due to the modifications the adults undergo; as they adapt to fit in particular environments;

- This results in groups of organisms that show homologous structures; and the closer the adults are classified on basis of homologous structures the longer their embryological development remain similar;
- For example, the human embryo bears a tail during the early stages of the development suggest a relationship with other mammals bearing post anal tails;

(b). Comparative biochemistry. (12 marks)

- Occurrence of similar chemical molecules; like cytochromes and hemoglobin; in phylogenetically related groups of organisms; suggest existence of biochemical homology; with organisms having a common ancestor; under different environment conditions; adapted to fit in them; hence showing divergent evolution; by adaptive radiation;
- In organisms that are phylogenetically unrelated; the presence of such molecules suggests biochemical analogy; where unrelated groups of organisms inhabiting similar environmental conditions; lead to selection of those groups of organisms that possess the molecules; showing convergent evolution;

(c). Comparative serology. (05 marks)

- This shows phylogenetic affinities between animals; depending on the amount of precipitation that occurs; when sensitized serum of one animal is added to the serum of another animal;
- The amount of precipitation is directly proportional to the amount of similar protein molecules present in the serum; and hence the closer are the two organisms phylogenetically related;

14. (a). What is meant by the term selection as used in evolution. (03 marks)

- This a process by which organisms that are best adapted to the environment; survive and reproduce; and pass on their advantageous traits to the next generation; whereas the least suited/ adapted individuals; are selected against; die or fail to reproduce; and hence undergo extinction;

(b). Explain the role of the following selection processes in evolution

(i). Stabilizing election. (10 marks)

- Operates when the phenotypic features coincide with the optimal environmental conditions; and competition is not severe;
- This eliminates the extremes of a given character from a given population; by reducing their reproductive potential; and selects for the intermediates; hence they survive, breed; and transfer their genes to the next generation;
- It reduces variation within the population; and reduces the ability of a given population to evolve and adapt to changing environmental conditions; since many individuals are similar;

(ii). Disruptive selection. (10 marks)

- Occurs when there are fluctuations in the environmental conditions**;** such as seasons and climates**;** so that more than one phenotype within the environment is favored**;** and the population is split into two subpopulations**;**
- If the two populations are isolated**;** so that gene flow is prevented**;** each population can adapt differently**;** each giving rise to new species**;**
- Within the same population**;** variation between individuals increases**;** and hence the ability of the population to adapt to new conditions increases**;**

(iii). Directional selection. (06 marks)

- This operates in response to gradual changes environmental conditions**;**
- The environment provides a pressure that selects for one extreme of the phenotypic range**;** which reproduces and have their allele frequency in the population increase**;** at the expense of the other phenotype at the opposite extreme**;** which is selected against; hence organisms with such characters die before reproducing**;** and become extinct**;**
- It leads to the evolution of better adapted individuals to different environmental conditions**;**

15. (a). State Darwin's theory of natural selection. (09 marks)

- Within a given population in a given environment, organisms that have features that are best suited to the environment**;** are selected for**;** survive**;** and reproduce**;** propagating its advantageous traits to the next generation**;** while those that are less suited**;** are selected against**;** and they either die off**;** or fail to reproduce**;** and they become extinct**;**

(b). State the three observations and two conclusions from which Darwin derived his theory. (09 marks)

- **Observation 1.** Individuals within a population produce on average more individuals than those needed to replace them**;** (populations have high reproductive potentials)
- **Observation 2.** The number of individuals in a given population remains almost constant**;**
- **Deduction 1** Many individuals fail to survive**;** or reproduce**;** hence there is a struggle for existence within a population**;**
- **Observation 3.** Variation exists within a population**;** (offspring within a given population are not exactly alike)
- **Deduction 2.** In the struggle for existence individuals showing variations best adapted to their environment**;** have a selective advantage**;** and produce more offspring than the less adapted individuals**;**

(c). How does the modern view of evolution differ from Darwin's. (05 marks)

- In the modern theory:
- There is natural selection of genetically determined characteristics.
- The genes explain the sources of variation in populations
- It's the population that evolves not an individual organism.
- Evolution can occur by other mechanisms like chance events not only natural selection;
- There is evidence for evolution while Darwin's theory has no evidence;
- Evolution is not always a gradual process; saltatory evolution can also occur;

16. (a). What is natural selection? (03 marks)

- Natural selection is the mechanism of evolution where organisms that possess favorable adaptations to the environment**;** survive**;** and reproduce**;** propagating their genes to the next generation**;** while those with unfavorable ones**;** either die or fail to reproduce**;** and become extinct**;**

(b). How does natural selection occur. (10 marks)

- Natural selection occurs when some organisms within a population possess features (characteristic)**;** that increase their chances of survival**;** and reproduction more than others**;**. Such organisms are selected for**;** breed**;** and pass on their genes to the next generation**;**. Organisms with least adapted (unfavorable) characteristic**;** are selected against**;** they die off**;** or fail to reproduce**;** and become extinct**;**

(c). What is the importance of natural selection? (07 marks)

- Natural selection allows for the organisms of a given population evolve**;** to adapt**;** to the changes in the environmental conditions**;** by allowing individuals that with favorable features**;** to survive**;** and breed**;** and propagate their genes to the next generation**;** while individuals with unfavorable features**;** are selected against**;** and become extinct**;**

17. Explain the role of the following in natural selection.

(a). Environment. (08 marks)

- The environment exerts a selection pressure on organisms;
- A change in environmental conditions**;** causes those organisms that are best adapted to it to the new conditions**;** to be selected for**;** survive; and breed**;** while those that are least adapted die off**;** and become extinct**;**
- If the environmental conditions remain that same for a long period of time; individuals best suited to this condition will be selected for; and those adapted to the extreme conditions; die off and become extinct;
- If the environmental conditions take a number of distinct forms; selection may favor two discrete forms of a species; each one adapted to one set of conditions;

(b). Increased selection pressure. (06 marks)

- Increase in selection pressure may be due to increased competition for resources, predation**;** which results in elimination of those non-adaptive organisms**;** at the extreme of the phenotypic range**;**
- This reduces variation within the population**;** as the remaining organisms become specialized to narrower environmental conditions**;**
- The ability of the population to adapt to the future changes in environment decreases**;** while its chances of extinction increases**;**
- Thus increased selection pressure is a conservative mechanism (prevents evolution)**;** by selecting for the phenotypes best adapted to the prevailing conditions**;**

(c). Reduced selection pressure. (06 marks)

- This maybe produced in absence of predators, pathogens or increase in optimum environmental conditions**;**

- It leads to more organisms surviving**;** increasing intraspecific variability**;**. These different phenotypes enable the population to increase its geographical range**;** and be able to adapt to changing conditions of the environment**;**
- If such groups of organisms in the different environments become isolated**;** each population will adapt differently to the conditions in its environment**;** and through mutations**;** natural selection**;** and genetic drift**;** such differences are amplified**;** to a point that these two populations may no longer interbreed successfully**;** hence new species are formed**;** through adaptive radiation**;**

18. (a). Explain how natural selection acts an agent of

(i). Constancy within a population. (07 marks)

- Occurs when the environmental conditions to which the organisms must adapt remain constant for a long period of time**;** and coincides with the majority of individuals at the population mean**;** which are best adapted to it**;**. These organisms are selected for; survive; and reproduce**;** while the organisms with traits in the extreme of the population mean; are selected against**;** and die before reproducing**;**.
- By selecting against the individuals at the extremes of the population mean, a single variety of individuals is favored and evolution is prevented**;**

(ii). Change within a population. (10 marks)

- Natural selection promotes emergence of new forms if it the environment changes**;** and many organisms are not well adapted to it**;**
- The selection pressure favors a group of organisms not corresponding to the population mean**;**
- The individuals possessing such advantageous traits**;** will be selected for**;** reproduce**;** and transfer their alleles to the next generation**;** while the less adapted individuals**;** are selected against**;** favoring the emergence/increased number of new forms**;**

(b). Explain the effect of reduced genetic diversity of a given population on the survival of a species. (05 marks)

- Loss of / reduced genetic diversity occurs through increased selection pressure**;**
- This increases the likelihood of a species undergoing extinction**;** because many organisms are genetically similar**;** and the population is unable to adapt**;** to the changing environmental conditions**;**

19. (a). Explain the role of heterozygosis in variation. (07 marks)

- Heterozygosis occurs when an individual has both recessive**;** and dominant alleles in their genotype**;**
- Dominant alleles express their effect on the phenotype while recessive alleles do not**;**
- As a result, the recessive alleles are not exposed to the environment**;** their selection; and possible elimination does not occur**;** this increases the range of possible gene combinations within a population**;** and hence variation**;**

(b). Explain the low frequency of recessive alleles within a population. (07 marks)

- Many recessive alleles confer disadvantages to the phenotype; and in homozygous state**;** they are expressed on the phenotype of the organism**;** and hence environmental selection occurs against them**;** and are eliminated**;** through death of the organisms possessing such alleles**;** before breeding**;** or they may fail to reproduce**;**

(c). Explain the conditions under which the frequency of a recessive allele in a population may increase. (06 marks)

- Occurs when the recessive alleles in the heterozygote**;** confer an advantage to it**;** over the homozygotes**;** in a particular environment**;** In this case, the heterozygotes will be selected for; and hence survive and breed; while the homozygotes are selected against**;** For example, in sickle cell anaemia while heterozygotes are in high proportions compared to the homozygotes in areas where malaria is prevalent**;**
- Occurs when recessive allele occupies a locus on the chromosome**;** very close (a recessive allele very closely linked) to a functionally important dominant allele**;** which is strongly selected for**;**

20. (a). Explain the term polymorphism as used in evolution. (02 marks)

- This is the existence within a population; of two or more distinct forms of individuals;

(b). Distinguish between stable and unstable polymorphism. (04 marks)

- In stable polymorphism, the different forms occur in fairly constant proportions**;** within a population whose members are freely interbreeding**;**
- Unstable(Transient) polymorphism involves on form increasing in number**;** as it spreads through the population**;**

(c). Describe the basis of

(i). Stable polymorphism (06 marks)

- Both forms are selected for**;** at equal intensities; due to the balanced relative advantages and disadvantages the alleles confer to the individuals**;** as each form is favored**;** by natural selection in particular conditions**;** that occur within a varied environment**;** example, blood groups and sex in humans**;**

(ii). Unstable polymorphism (06 marks)

- Occurs during evolution**;** when the population is undergoing a selection process**;** with one form being selected for**;** because it confers advantages to the individuals possessing the trait**;** while the other forms are being selected against**;** due to their disadvantageous traits in this particular environment**;**. The number of individuals with favored traits increase at the expense of those that are have unfavorable traits**;**

21. (a). What is meant by the term genetic equilibrium. (02 marks)

- Genetic equilibrium refers to a state in which the allele frequency of a given population does not change over time (from one generation to the nest);

(b). State the Hardy-Weinberg equilibrium principle. (02 marks)

- It states that, "the allele frequency of a given allele in a population will remain constant from generation to generation in absence of other evolutionary influences;

(c). State the conditions under which the above principle is valid. (02 marks)

- Non-overlap of generations
- Random breeding occurs
- Large population
- No mutations
- No natural selection occurs
- No gene flow
- No genetic death
- No genetic drift
- No migrations occur
- No sexual selection

(b). Explain how each of the conditions mentioned in (c) above may affect genetic equilibrium. (14 marks)

- Mutation**;** is the sudden change in the structure or amount of genes**;** it leads to new alleles that will determine new characteristics in individuals**;** favourable alleles are selected for**;** and mutant alleles spread rapidly in a population**;** while disadvantageous alleles are selected against/are not passed to the next generation/completely eliminated**;**

- Migration (Emigration/ immigration)**;** individuals may leave a population (emigration) decreasing allele frequency**;** individuals may also enter into population (immigration), increasing allele frequency**;**

- Genetic drift**;** this is the loss of alleles in a **small population** by chance other than natural selection**;** due to sudden death of an individual before reproducing**;** decreasing gene frequency/reduce the amount of genetic variation within a population**;**

- Genetic load**;** is where particular disadvantageous alleles exist in a heterozygous condition within a population**;** heterozygous genotypes have a selective advantage over the homozygous individuals**;** in such a case recessive/ dominant alleles will have their frequency increasing a population**;** which may lead to formation of new species**;**

- Non-random breeding/sexual selection/biased mating**;** this is where structural and behavioural mechanisms in organisms prevent mating from being random**;** resulting in sexual selection**;** which will ensure that certain individuals within the population will have increased reproductive potential**;** there alleles are passed to the next generation/there gene frequency become high and more frequent in a population**;**

- Gene flow**;** this is where alleles are transferred from one deme to another**;** due to interbreeding between the two subpopulations**;** mutant alleles are evenly distributed between the two subpopulations/populations**;** altering their gene frequencies/each population creates new alleles separately/variation occurs that will lead to formation of new species**;**

- Selective predation/natural selection**;** is where the genotype frequency of particularly more adapted; individuals increases; while those of less adapted ones**;** decreases as they die off as they are selected against;

- Genotypes are not equally fertile/ genetic death**;** some individuals die without reproducing**;** hence their alleles not transmitted to the next generation**;**

22. Explain the role of the following in evolution

(a). Genetic drift. (11 marks)

- *Genetic drift* is the change in gene frequency**;** in a small population**;** by chance other than natural selection**;** due to death of the individuals carrying particular alleles/failure of the individuals carrying such alleles to reproduce**;**
- Where loss of alleles occurs; it leads to reduction in genetic diversity**;** and the population may fail to adapt to changes in environmental conditions**;**
- When the allele frequency drifts upwards**;** it may lead to a population developing characteristics unique to itself**;** which may have a selective advantage; over other variants of the species**;**. In the presence of isolating mechanisms**;** and gene flow is prevented**;** the small population may develop features that diverge from for the other sub-populations**;**. Through adaptive radiation**;** new species may emerge**;**

(b). Gene flow (09 marks)

- Gene flow is the movement of allele from one population to another**;** as a result of interbreeding between members of the populations**;**
- This leads to increase in genetic diversity of the recipient population**;** which if advantageous**;** may be selected for**;** bringing about evolutionary changes (population to adapt)**;**
- Gene flow reduces differences between populations**;** as genes are exchanged**;** increasing genetic uniformity between the two populations**;** which prevents speciation**;**

23. Explain the role of the following in evolution

(a). Non-random breeding. (11 marks)

- Non-random breeding occurs through sexual selection**;** where individuals with favorable characters**;** increase their chances of breeding/ mating and fertilization of gametes**;** have an increased reproductive potential**;** survive**;** and reproduce**;** transferring their genes to the next generation**;** while organisms with less favorable characters**;** have a decreased reproductive potential**;** and die before reproducing**;** leading to their extinction**;**

(b). Founder effect. (10 marks)

- *Founder effect*. Refer to the loss in genetic variation within a population**;** that occurs as a result of the population being established/ founded by a small number of individuals**;** that do not contain all the alleles of the species**;**

- The continued breeding within such small populations decreases the proportion of heterozygotes**;** and increases that of the homozygotes**;**. This reduces variation within the population**;** increasing its chances of extinction**;**.
- However, these populations may develop features unique to themselves compared to other populations of the species**;** in which case, the differences between the populations of the species increases**;** hence isolation**;** followed by natural selection**;** and random mutations**;** may produce new species of organisms**;**

24. (a). What is meant by the term inbreeding? (02 marks)

- This is the selective mating of closely genetically related organisms**;** in order to propagate some desirable characteristics**;**

(b). Explain the effect of inbreeding in a population. (04 marks)

- Leads to reduction in fertility;
- Reduces variability of the genome; by increasing homozygosity; and hence reduced hybrid vigor;

(c). Describe the mechanisms which limit inbreeding in plants. (10 marks)

- Bearing stamens and carpels on different plants**;**
- Monoecious plants**;** have brightly colored petals and/sepals**;** nectaries they produce nectar**;** and good scent**;** to attract insects that carry pollen from one plant to another**;**
- Stamens and carpels may be located on different flowers of the same plant**;** or mature at different times**;**
- Self-sterility/ incompatibility**;** where the plant's pollen fails to germinate pollen tubes on its own stigmas**;**
- Stamens may hang downwards**;** so that the pollen is scattered far away from the parent plant**;**
- Stigmas are higher than the surrounding stamens**;** making it impossible for the pollen to fall on the stigma of the same flower**;** and the visiting insects brush on the stigma before the stamens**;**

(d). Explain why organisms show features that limit inbreeding in their populations. (04 marks)

- Inbreeding eliminates the possibility of genetic mixing**;** there by leading to the reduction in the fecundity of the species**;** resulting in the reduction of vigor**;** and fertility**;**
- Outbreeding improves the vigor of the hybrids**;** they are more disease resistant**;** have high yields**;**

25. (a). What is meant by the term out breeding? (03 marks)

- Involves mating of individuals from genetically dissimilar populations**;** producing hybrids**;** with increased hybrid vigor**;**

(b). Distinguish between hybrid and hybrid vigor (02 marks)

- Hybrid: is an offspring resulting from mating of two genetically dissimilar parents;

- Hybrid vigor: Refers to the improved characters of the offspring produced by parents that are genetically dissimilar;

(c). Explain how outbreeding leads to increase in vigor (10 marks)

- Increases heterozygosity**;** due to mixing of genes**;** as heterozygotes has more dominant alleles**;**
- There are more allele interactions within a given combination of alleles**;** resulting in a wide range of phenotypes**;**
- Changes in chromosome number may occur**;** due to hybridization**;** like in polyploidy**;** leading to increase in cell volume**;** as the nucleus increases**;**

(d). What is the role of outbreeding in evolution of new species? (05 marks)

- Outbreeding leads to genetic mixing**;** and allows for hybridization**;** and polyploidy**;** which produces new varieties of organisms**;** that maybe more adaptive to environmental changes than their predecessors**;**

26. Explain the role played by the following in evolution

(a). Natural selection (08 marks)

- Natural selection is a mechanism of evolution**;**
- Through natural selection, organisms with the best adaptive features to a particular environment**;** survive**;** and reproduce**;** and transfer their genes to the next generation**;** while those with the least adaptive features to that environment**;** die off**;** or fail to reproduce**;** become eliminated from the environment**;**

(b). Mutation (07 marks)

- Mutations leads to emergency of new alleles within the population**;** and hence variation increases**;**
- If the mutant alleles are dominant**;** express their effects on the phenotype of the organisms**;** in which case, the favorable characteristics will be selected for**;** survive**;** and reproduce**;** and pass on their gene to the next generation**;** and those alleles that confer disadvantages to the organism**;** will be selected against**;**. The organism dies**;** or fails to reproduce**;** and hence those alleles are prevented from passing on to the next generation; leading to their extinction**;**
- Recessive mutant alleles are not expressed in heterozygous condition**;** hence do not undergo selection**;**
- Recessive alleles have fewer chances of combining in homozygous state**;** and hence experience less selection**;**

(c). Polyploidy (05 marks)

- Polyploidy results in doubling of the chromosome number of a given cell or organism**;**
- New species can arise through allopolyploidy**;** where sterile hybrids**;** may undergo chromosome doubling**;** forming fertile allotetraploids**;** which can interbreed with themselves**;** but not with either parental stock**;** and hence a new species is formed**;**

27. (a). Describe the role of the following in evolution.

(i) Meiosis (07 marks)

- Meiosis leads to the formation of haploid gametes**;**
- During prophase I**;** crossing over occurs**;** between homologous chromosomes**;** resulting in the new allele combinations**;** which creates the variation**;**
- Organisms with favoured characteristics are selected for**;** survive**;** and reproduce**;** and pass on their favourable characteristics to the next generation**;** while those with unfavored characteristics**;** selected against**;** they die or fail to reproduce**;** and their alleles are eliminated**;**

(ii) Fertilization. (06 marks)

- Fertilization involves the random union**;** of two different parental gametes**;** which leads to gene mixing**;**. The resultant organisms with favorable variations**;** are selected for**;** survive**;** and reproduce**;** and propagate their alleles go the next generation**;** while those unfavorable variations**;** are selected against**;**. They either die or fail to reproduce**;** and their alleles are eliminated from the population**;**

(b). Explain why mutant alleles cannot be completely eliminated from the population. (07 marks)

- Many mutant alleles are recessive to non-mutant alleles**;** and in the heterozygous state**;** they are not expressed on the phenotype**;** hence cannot be eliminate**;** by natural selection**;**
- Some of them confer advantages to the heterozygote**;** increasing its chances of survival**;** and hence passing on these alleles to the next generation**;**
- Some are closely linked; on the chromosomes to functionally important allele; which is selected for; hence, always passes along with it from one generation to the next;

28. (a). What is meant by the term speciation? (02 marks)

- This is the process by which new species are formed**;** from the pre-existing ones**;**

(b). Describe the process of speciation. (18 marks)

- Allopatric speciation occurs when the demes are geographically isolated**;**
- Speciation starts with a single population that splits**;** into two or more separate subpopulations (demes)**;** with its own gene pool**;** and become isolated from each other**;** preventing gene flow between the populations**;**
- Each deme experiences different environmental conditions**;** hence adapts differently through mutations**;** and natural selection**;** occurring independently**;** each group evolves along separate lines**;**. Such organisms become reproductively isolated so that upon mixing them**;** they cannot interbreed**;**
- Sympatric speciation can also occur when organisms are inhabiting the same geographical area**;** where a mutation such as polyploidy**;** creates a new group of organisms with different genetic composition that are reproductively isolated**;** from the other related groups**;**
- The isolating means may be ecological**;** seasonal**;** behavioral**;**

29. (a). What is meant by the term

(i). Isolating mechanism (02 marks)

- A means of preventing gene flow**;** between populations of closely related organisms**;**

Or

- A means of producing and maintaining reproductive isolation**;** within a population**;**

(ii). A deme (02 marks)

- Is a subpopulation produced**;** when a single population is split into two or more groups by an isolating mechanism**;**

(b). Describe the role of isolating mechanisms in speciation. (16 marks)

- Isolating mechanisms can be Geographical**;** or Reproductive**;**
- Speciation occurs if geographical isolation leads to reproductive isolation**;**
- In geographical isolation involves physical barriers**;** splitting a population into demes**;** which may prevent gene flow between them**;**. Adaptation to new conditions**;** random genetic drift in small populations**;** and independent mutations**;** lead to changes in allele frequencies**;** so that the organisms diverge**;** do not breed when populations are brought together**;**
- Reproductive isolation maintains a barrier to gene flow between groups organisms within a population**;**
- These barriers may act before**;** or after mating**;**
- Barriers acting before mating prevent gametes of individuals of two population from meeting**;** and hence cannot produce an offspring**;** for example: Seasonal**;** ecological**;** behavioral**;** and mechanical isolation**;**
- Barriers acting after mating prevent the formation of a viable offspring even when two organism of different populations mate**;** for example: hybrid sterility**;** hybrid inviability and hybrid breakdown**;**

30. (a). Explain the factors that determine the rate of spread of a mutant allele within a population. (12 marks)

- Nature of the allele**;** and its effect on the phenotype of the organism**;**
- Dominant alleles which confer advantages to the organisms**;** will allow the organism to survive**;** and reproduce**;** and hence be spread rapidly**;** while a dominant allele that confers disadvantages on the phenotype will be selected against**;** the organism dies or fails to reproduce**;** and its spread is prevented**;**
- Recessive alleles spread very slowly through populations**;** because their chances of being expressed on the phenotype are low**;**. In heterozygote which are usually the majority**;** the effects of the allele are not expressed**;**
- Recessive alleles that increase the chances of survival of the heterozygote**;** also spread more rapidly than the other recessive alleles that are not expressed at all**;**
- Recessive alleles closely linked to a functionally important dominant allele**;** can spread rapidly as the dominant allele is being selected for;

(b). Explain the different post-zygotic mechanisms that isolate organisms of different species (08 marks)

- **Hybrid sterility;** refers to failure of a hybrid (offspring of two genetically unrelated individuals) to produce functional gametes**;** because chromosomes cannot form homologous**;** pairs during meiosis**;**

- **Hybrid inviability;** occurs when a hybrid fails to develop to maturity**;** due to genetic incompatibility of the parents**;**
- **Hybrid breakdown;** occurs when the first filial generation is fertile but the second generation fail to develop**;** or are infertile; due to genetic incompatibility**;**

31. Explain the role of the following in speciation.

(a). Interspecific hybridization. (07 marks)

- Occurs when two different species give rise to a single species**;** and leads to sympatric speciation**;** in which two unrelated species are mated**;** The hybrids are usually infertile**;** but in case of plants, they are propagated by vegetative propagation**;** Fertile hybrids are formed when chromosome mutation occurs**;** to produce alloploids**;** which are cannot breed with either parental populations**;**

(b). Explain why large-sized organisms are more prone to extinction that the small-sized organisms. (12 marks)

- Large organisms are slow to adapt to changes in their environment**;** compared to the small sized organisms**;** which is largely due to the complexity of the genetic makeup**;**. Small organisms like bacteria can undergo rapid mutations**;** which allows it to cope up with the changes in the environment while in large animals such mutations would be disadvantageous; and hence would die off**;**
- Small sized organisms generally have short life cycles**;** and produce many offspring per birth**;** than their large-sized counterparts**;**, thus large organism are slow to reach sexual maturity**;** and death at younger age is generally high**;** hence a few survive to reproduce**;** compared to the smaller ones**;**

32. (a). Describe how sickle cell anaemia arises in an individual. (10 marks)

- Arises due a gene mutation; caused by substitution of base adenine for thymine in the genetic code CTT and CTC; producing CAT and CAC; hence code for amino acid valine; instead of glutamine; at position 6 of the beta polypeptide chain of the haemoglobin molecule;
- Glutamine is polar and hydrophilic; while valine is non-polar and hydrophobic;. In low oxygen tension; valine crystalizes and forms rod-like fibres; which change the shape of the red blood cell from a circular disc shape to sickle-shape;
- In the sickle shape, the red blood cell cannot carry oxygen and clogs small blood vessels like the capillaries causing severe pain;

(b). Explain why sickle cell trait is common in areas where malaria is endemic. (05 marks)

- Sickle cell trait occurs individuals that are heterozygous for sickle cell anaemia**;**
- Half of their red blood cells can become sickle-shaped while the other half is normal**;**
- In areas where malaria is common heterozygotes have an advantage over the homozygotes**;** because the plasmodium which attacks red blood cells does not attack those that contain sickle haemogloin**;** hence the heterozygotes are likely to survive more

than homozygotes**;** which are selected against**;** and pass on this advantageous trait to the next generation**;**

(c). Using sickle cell anaemia, explain the following terms

(i). Genetic load. (03 marks)

- This is the occurrence high frequency of a disadvantageous allele in a population; because it confers an advantage to the heterozygotes; for example: sickle cell trait in malaria endemic region**;**

(ii). Heterozygous advantage. (02 marks)

- Occurs when an allele is disadvantageous in the homozygous state; is advantageous in the heterozygous**;**

33. (a). What is meant by the term reproductive isolation? (02 marks)

- These are mechanisms that prevent organisms of different species from producing an offspring or producing a viable offspring;
- Such mechanisms can occur before or after mating;

(b). Describe the different prezygotic mechanisms that act as isolating barriers between organisms of different species (09 marks)

- Ecological/ habitat isolation**;** occurs between subspecies that live within different habitats in the same area**;** and thus, do not meet to breed**;**
- Season/ temporal isolation**;** occurs between subspecies of organism that mate or flower in different times of the year (season)**;**
- Behavioral isolation**;** occurs when the animal's courtship patterns of behavior do not attract or fail to elicit a matting response**;**
- Mechanical isolation**;** occurs when organisms of different species cannot breed due to the incompatibility of their genetalia**;**

(c). Explain how territorial behavior leads to evolution. (11 marks)

- Organisms fight to establish a territory and defend it from other organisms**;**
- Organisms that succeed, have plenty of food**;** and mates**;** thus survive**;** and breed**;** and pass on their genes to the next generation**;** while the weaker ones are relegated to the edges of the territory**;** where they fail to get food**;** or mates**;** thus die**;** and their genes are eliminated from the population**;**

34. (a). What is meant by the term extinction of species? (03 mark)

- The termination of a species**;** by due death of individuals**;** capable of reproducing**;**

(b). Outline human activities that can lead to species extinction. (05 marks)

- Overexploitation of wildlife like over fishing and hunting; leads to death of the organisms more than they reproduce;
- Destruction of the animals' habitants;
- Introduction of alien species in some areas that outcompete the indigenous ones;
- Use to toxic substances that pollute the organisms' environment leading to their death;

- Selective breeding to propagate certain characters at the expense of another group of organisms
- Extermination of particular organisms that do not have man's desirable characteristics;

(c). Explain how a species may become extinct. (12 marks)

- Extinction of a species starts with the failure of a group of organisms to adapt**;** to the changes in its environment**;** as a result of unfavorable characteristics it has in that particular environment**;** With selection pressures like intensive predation**;** intense competition from closely related species**;** the organisms may fail to compete**;** and hence dies off**;** before reproducing**;** which leads to decline in the specie population**;** until it is completely eliminated**;**
- Extinction of a species can also occur due to chance events**;** by premature death of the individuals of the population**;** due to accidents and natural disasters**;**

THE END; FOR NOW.