EVOLUTION

Evolution means changes over a period of time. Thus evolution is the process by which new species is formed from pre – existing one over a period of time. Evolution is a continuous change from simple to complex organisms. Individuals do not evolve/change; it is a population that evolves.

THEORIES OF THE ORIGIN OF LIFE

Special creation theory: This theory suggests that life was created by a supernatural being with super – natural powers called God at a particular time in the past.

Steady state theory: This asserts that the Earth had no origin, has always been able to support life, has changed remarkably/unusually little if at all and all species had no origin.

Spontaneous generation theory: This suggests that life arose from non – living matter on numerous occasions and it was prevalent in ancient Chinese, Babylonian and Egyptians.

Cosmozoan theory/ the pans Permian theory: This suggests that life could have had an extra – terrestrial origin. It states that life could have arisen once or several times in various parts of the galaxy or the universe and arrived on to Earth by some means.

Biochemical evolution/ biogenesis: This theory states that the origin of the Earth is due to the result of slow and gradual process of chemical evolution that occurred many years ago.
According to this theory, the state of early Earth was different from that of the present earth in that; early earth was too hot and reducing one compared to the present earth which is cold and oxidizing. The main sources of energy earlier were solar and lightening.
As the earth cooled, carbon and less volatile metals condensed and formed the earth's core whose surface was barren and rugged due to volcanic activity and continuous earth movements but contraction on cooling folded and fractured the surface.
It is believed that lighter gases like hydrogen, helium, nitrogen, oxygen and argon would have escaped because the gravitational field of the partially condensed planet would not contain them but however, simple molecules/compounds containing them like water, ammonia, carbon dioxide and methane would have been retained and until the earth had cooled to 70^0C, and the water existed in vapour form.
Through a series of chemical reactions, simple organic molecules e.g. hydrocarbons, formed in the water, due to presence of a reducing atmosphere using solar energy, and from a collection of such chemical substances, through progressive chemical reactions, the first life a arose.
Basing on the above, Stanley Miller successfully synthesized many substances like amino acids, proteins, and nucleotides. On addition, other scientist also produced amino acids, some proteins, nucleotides, ATP, ADP, and other molecules, which are characteristics of living things. The simple molecules are believed to have reacted with themselves to form larger molecules like RNA and proteins.

THE THEORY OF EVOLUTION

Evolution implies an overall gradual development which is both ordered and sequential. In terms of living organisms, it may be defined as the development of differentiated organisms form pre-existing, less-differentiated organisms over the course of time. The following theories were put forward to show the concept of continuity or gradual development of more complex species from pre-existing simpler forms.

1. **Lamarckian evolution;**
   The theory was based on two conditions that is "**the use and disuse of structures and the inheritance of acquired characteristics".**

He explained that in the life of an organism, a change in environment may lead to changed patterns of behavior which can necessitate new or, increased use (or disuse) of certain organs or structures. Extensive use would lead to increased size and or efficiency while traits acquired during the lifetime of the individual were believed to be heritable and thus transmitted to offspring.

For example, according to Lamarck, the present day long-necked giraffes obtained their long necks from their short-necked ancestors through the same process. As the short-necked giraffes stretched to reach leaves on tall trees, it created a small elongation of the neck and that was passed onto the next generation and further stretching of the neck, to feed in tall trees, the neck became longer in the proceeding generations.

Critisms of Lamarckism;
Lamarck's emphasis in the role of the environment in producing phenotypic changes in the individual was correct, e.g. body-building individuals will increase the size of muscles, but these acquired traits, though affecting the phenotype, are non-genetic and having no influence on the genotype cannot be inherited.

2. **Darwin, Wallace theory of evolution by natural selection;**
Charles Darwin visited Galapagos Island and studied the finches which inhabited each of the island while that all had a general resemblances to those of the main land to the equator, they however, differed in certain aspects e.g. the shape of the beaks.
He argued that the finches of Galapagos resemble those of the main land in South America because they descended from a common ancestor. They differed from one another e.g. shape of beaks because each is adapted to its own mode of life and in some instances restricted to its own particular island.
He noted that a few finches had crossed from the main land to those volcanic eruptions. They encountered a range of different foods and each type of finch developed a beak which was adapted to suit its dist.
All along his voyage, Darwin was trying to find out the mechanism by which these changes occurred. Independent to Darwin, Alfred Wallace had drawn his own conclusions on the mechanism of evolution. Wallace sent Darwin a copy of his theory and Darwin realized that they were the same as his. As a result, they joined to present their findings to the scientific society. A year later, Darwin published his book of the origin of species by means of natural selection and the preservation of the favoured races in the struggle for existence.

The essential features of Darwin's theory included;

- Over production of off springs; He believed that all organisms produced a large number of off springs which would lead to an increased size of the population.
- Constancy of numbers, despite the tendency of organisms to increase in number due to over production of species, most population maintained relatively constant numbers. The majority of off springs die before they are able to reproduce.
- Struggle for existence; He concluded on the basis of the above two that members of the species were constantly competing with each other with effort to survive. In this struggle for existence, only few would live for long enough to breed.
- Variation among off springs; they sexually produced off springs of any species to show individual-variation that no two off springs are identical.
- Survival for the fittest by natural selection; among the variety of off springs, some are better adapted to withstand the prevailing conditions than others. I.e. some will be able to survive in the struggle for existence; such types are more likely to survive long enough to breed.
- Like produce like; those survived to breed are likely to produce off springs similar to themselves. The advantageous characteristics which gave them a win in the struggle for existence are likely to be passed on in the next generation.

- Formation of new species; Individuals lacking favorable characteristics are less likely to survive long enough to breed and over many generations; their numbers decline. The individuals with favorable characteristics breed with consequent increase in their number. The inheritance of one small variation may not be itself producing new species. However, the development of a number of variations in a particular direction over many generations gradually leads to variation of a new species.

Darwin's law of natural selection;
It stated that, "in a highly reproducing population, there is variation among individuals and some characters are inherited such that those possessing them survive to reproduction stage, while those ones which are not favored by their environment die before they reproduce i.e. favored characters are selected for while the unfavored ones are selected against".

How Darwin explained the development of the long-necked giraffes;
Initially, both short and long-necked giraffe varieties existed. Due to exhaustion of food at the ground level, the short ones could not reach the tree branches and hence starved and died of hunger. The long giraffes survived and produced the long-necked giraffes.

Limitations of Darwin's theory;
- Darwin made no attempt to describe how life originated on earth. He only explains how new species arise from pre-existing ones.
- The theory "struggle for existence" was popularized by the coiling of unfortunate terms such as "survival of the fittest" and "elimination of the unfit".
- A misconception that human beings descended from apes was perceived as offensive by both religious and secular communities.
- Contradiction with the Genesis six-day creation and that of a progressive origin of species.
- The theory fails to account for the extinction of dinosaurs and the giant terms.

3. **Neo-Darwinism-modern theory of evolution;**
   The theory of evolution as proposed by Darwin and Wallace has been modified to light of modern evidence from genetics, molecular biology, ecology, paleontology and ethology, and is known as Neo-Darwinism.
   This is defined as the theory of organic evolution by the natural selection of inherited characteristics for Neo-Darwinism theory to be accepted to be accepted, it necessary to;
   - Establish the fact evolution has taken place in the past (past evolution)
   - Demonstrate a mechanism which result in evolution (natural selection of genes)
   - Observe evolution happening today (evolution in existence)

EVIDENCES OF EVOLUTION
These include; paleontology; geographical distribution; classification, plant and animal breeding, comparative anatomy, adaptive radiation, comparative embryology and comparative biochemistry.

1. **Paleontology;**
   This is the study of fossils. Fossils are any form of preserved remains thought to be derived from a living organism. They include the entire organism, hard skeletal structures, molds and casts, petrifications, impressions, imprints and coprolites.
   The fossil evidence shows the progressive increase in complexity of organisms because in old fossil bearing rocks, there are a few types of simple structured fossilized organisms, while in younger rocks, there is a great variety of complex structured fossilized organisms.
   Throughout the fossil record, many species which appear at an early stratigraphic level (their level in the rock deposits) disappear at a later level, this indicates the times at which species originated and became

extinct. These organisms might have appeared, increased in complexity or have become extinct due to changes in geographical regions and climatic conductions. For example, plants appeared before animals and insects appear before insect pollinated flowers.
The best example of the study of fossil was the horse which underwent various gradual but progressive modifications in feeding and locomotion structures, from the ancient ***hyacotherium*** to the recent advanced feuds horse.

Weakness of paleontology;
The fossil records are less significant if the fossil reward is not continuous, i.e. it has missing links in the fossil record such that ancient organisms can't be linked to the present ones.

Explanation for the gaps or incompetence of fossil record;
- Some dead organisms decompose readily and leave no fossil.
- Some dead organisms might be eaten by scavengers.
- Some organisms are soft bodied therefore not fossilized easily.
- Only a fraction of fossils have been discovered.
- During favourable conditions for fossilization, only a small fraction of living organisms might die.

2. **Classification;**
Before Darwin and Wallace put their theory of evolution, some organisms had led some scientists to propose a system of classification between organisms. Though it is possible to conceive that all species both living and extinct were created separately at a specific time or has no origin, the structural similarity between organisms, which forms the basis of a natural system of phylogenetic classification suggests the existence of an evolutionally process. However, these similarities and differences between organisms may be explained as a result of progressive adaptation by organisms within each taxonomic group to particular environmental conditions over a period of time.
The construction of the phonetic classification system from comparative phenotypic characters i.e. Kingdom, phylum, class, order, family, genes and species was possible because the organisms were related by descent, hence suggest that an evolutionary process has occurred.

3. **Geographical distribution;**
Plant and animal species are discontinuously distributed throughout the world. Some zones have their own characteristic fauna and flora. It is expected that where, identical conditions occur in different parts of the world, the same organisms will be found, but this is not the case, e.g. elephants are found in Africa and India, and lions in Africa and Pampas in S. America but the habitants are different.
However, many related forms of organisms are found in widely, separated regions as shown in the following examples.
- The 3 remaining species of lung fish are found separately in tropical areas of South America (Lepidosiren), Africa (Protopterus) and Australia (Neoceratodus).
- Camels and Ilamas are distributed in North Africa and South America and raccoons widely found in North and South America, and South East Asia.
- Monotremes and marsupials of Australasia.

On addition, Britain and New Zealand gave similar fauna and flora but having different organisms proves that evolution took place.

The discontinuous distribution of species can be explained as follows.
a) A species originates in a particular area
b) Individuals continuously disperse to avoid over-crowding
c) As they encounter new environments as a result of dispersal, they adapt to meet the new conditions which are termed as **adaptive radiation**.

d) Climatic topographical and other changes create barriers between the new varieties and their ancestors causing genetic isolation. These barriers were formed by continental drift.
e) This genetic isolation leads to separate gene production and new species.

4. **Plant and animal breeding;**
One of the earliest features of human civilization was the cultivation of plants and domestic animal from ancestral wild stocks. By selecting those members of the species with favourable variation, such as increased size, improved fertility and artificially breeding them by selecting mating, selecting propagation or selective pollination, the desired characteristics were perpetuated; this has produced the varieties of domestic animals and plants of agricultural importance seen today.
Archaeological remains have shown human to be rearing cattle, pigs and fowl, and cultivating cereal crops and certain vegetables. In terms of genetics, humans are preparing those animals or plant genes which are desirable and eliminating those which are undesirable for their purpose. This selection uses naturally occurring gene variation, together with any fortuitous mutations which occur from time to time.
A recently developed form of artificial selection is the selection resistance to antibiotics, pesticides and herbicides shown by pathogens, pests and weeds respectively. These produce new-strains of organisms which become resistant to the ever-increasing number of chemical substance produced to control them. Darwin used this as evidence for a mechanism by which species might arise naturally. In the case of natural selection, the environment rather than humans was believed to act as the agent of selection.
Artificially selected forms therefore would not have arisen in the wild because they are unable to complete successfully with closely related non-domesticated forms.

5. **Comparative anatomy**;
Comparative study of the anatomy of groups of animals or plants reveals that certain structural features are basically similar.
Organs from different species having a similar basic form, microscopic structure, body position and embryonic development are said to be **homologous**. Examples of homology include; the basic structure of all flowers; the pentadactyl limb of all tetrapod; brachial arches/ear bones as jaw bones in fish and ear bones in mammals; halters in dipteran, pericarp in flowering plants. The existence of these homologies within a group of organisms is an evidence of their descent from a common ancestor and indicates close phylogenetic relationships.
Homologous structures showing adaptations to different environmental conditions and modes of life are examples of adaptive radiation e.g. the mouth parts of insects consist of the same basic structures labium, mandibles, hypopharynx. Maxillae and labium but insect are able to exploit a variety of food materials because some of the above structures are enlarged and modified, others reduced and lost, this produces a variety of feeding structures.
The presence of a structure or physiological process in an ancestral organism, which has become modified in more specialized, apparently related organism indicates a process of descent by modification. The significance of **adaptive radiation** is that it suggests the existence of **divergent evolution** based on modification of homologous structures.
On the other hand, certain homologous structures in some species have no apparent function and are called **vestigial organs** e.g. the human appendix is homologous with the functional appendix of herbivorous animals; non-functional bones in snakes and whales are homologous with the hip bones and hind limbs of for quadruped vertebrates; the vertebrae of the human coccyx are vestigial structures of the tail possessed by our ancestors and embryos.

However, similar structures, physiological processes or modes of life in organisms apparently bearing no close-phylogenetic links but showing adaptations to perform the same function are described **analogous**.

Examples of analogy include; the eyes of vertebrates and cephalopods molluscs (squids and octopuses); the wings of insects and bats; the joined legs of insects and vertebrates; the presence of thorns on plant stems and spines on animals; and the existence of vertebrates neuroendocrine e.g. acetylcholine, 5-hydroxytryptamine and histamine, in nettle stings. These perform the same function though from different organisms.
The existence of analogous structures suggests the occurrence of **convergent evolution**. This is due to the environment acting through the agency of natural selection, favouring those variations which confer increased survival and reproductive potential on that organism possessing them.

6. **Comparative embryology**
A study of the embryonic development of the vertebrate group revealed structural similarities occurring in all the groups i.e. during cleavage, gastrulation and the early stages of differentiation. This has been summarized as the **recapitulation principle** which states the "**ontogeny recapitulates phylogeny**" by Haeckel, that is, the developmental stages through which an organism passes repeat the evolutionary history of the group to which it belongs.
At comparable stages of vertebrates, their embryos possess the following features;
    – External branchial grooves (visceral cleft) in the pharyngeal region and a series of internal paired gill pouches.
    – Segmental myotomes (muscle blocks), which are widest in the tail-like structure. Some species retain while in some they become non – functional and thus lost.
    – A single circulation which includes heart showing no separation into right and left halves, this is fully retained in fish.

These common embryonic structures show that these embryos, and hence the groups to which they belong had a common ancestor.

7. **Comparative biochemistry;**
The occurrence of similar molecules in a complete range of organisms suggests the existence of biochemical homology, in a similar way to the anatomical homology shown by organs and tissues.

Research has shown that water, glucose, proteins, lipids, nuclei and, etc. are common to organism. Cytochromes haemoglobin and ribosomal RNA are also in the search for evolutionally closeness. The theory of biochemical homology among organisms emerges from biochemical studies like serological tests, x-ray analysis, computerized mass spectrometry and protein sequence analysis.

The ubiquitous occurrence of similar biochemical molecules and metabolic process in a wide range of organisms suggest a common ancestry. The slight difference like in amino acid sequence in proteins and different in DNA base sequence are as a result of mutations of ancestral genes.

Examples of biochemical homology include;

- Proteins like cytochromes, haemoglobin, myoglobin and nuclei acids in almost all organisms.
- The occurrence of similar hormones like prolactin, adrenaline and thyroxine among all vertebrates.

MECHANISMS OF SPECIATION: POPULATION GENETICS:

A population is a group of organisms of the same species usually found in a defined geographical area. Population genetics is the branch of biology that deals and provides the mathematical structure for the study of micro evolutionary process.

Terms used in population genetics;

1. **Gene pool;**

This is the total variety of genes and alleles present in a sexually reproducing population. A population whose gene pool shows consistent change from generation to generation is undergoing evolutionary change.
A **static gene pool** represents a situation where genetic variation between members of the species is inadequate to bring about evolutionary change.

2. **Allele frequency;**
This is the number of organisms in a population carrying a particular allele. E.g. in humans the frequency of the dominant allele for the production of pigment in the skin, hair and eyes is 99%. The recessive allele which is responsible for the lack of pigment (albinism) has a frequency of 1%.

In population genetics studies, genes or allele frequencies can be represented in decimals rather than percentages or fractions. Hence this dominant allele frequency is 0.99, and the recessive albino allele frequency is 0.01. Since the total population represent 100% or 1.0, it can be seen that

dominant allele frequency + recessive allele frequency = 1
0.99 + 0.01 = 1

In terms of Mendelian genetic, the dominant allele is represented by a letter say **N** (for normal pigmentation), and the recessive allele would be represented by **n** (the albino condition), thus **N** = 0.99 and **n** = 0.01.

From mathematics of probability, population genetics borrows the symbols **p** and **q** to express the frequency with which a pair of dominant and recessive alleles appears in the gene pool of the population. Therefore, $p + q = 1$; where p = dominant allele frequency and q = recessive allele frequency.
Using pigmentation in humans;
$p = 0.99$ and $q = 0.01$; since $p + q = 1$. Also $0.99 + 0.01 = 1$
Therefore, from the above equation, the frequency of the other may be determined if the frequency of either allele is known.

E.g. if the frequency of the recessive allele is 25%, then $q = 0.25$ or 25%;
Since $p + q = 1$
$p + 0.25 = 1$
Hence, the frequency of the dominant allele is 0.75 or 75%.

3. **Genotype frequencies;**
These refer to the total number of individuals carrying a particular genotype expressed as a percentage of the total population.
In most populations, it is only possible to estimate the frequency of **homozygous recessive** from the two alleles as this is the only genotype that can be identified from its phenotype.

The mathematical relationship between the frequencies of alleles and genotypes in populations is known as the **Hardy-Weinberg equilibrium**. The principle states that;
"**The frequency of dominant and recessive alleles in a population will remain constant from generation to generation provided certain conditions exist**"

This principle holds when the following conditions occur;
- The population is larger i.e. no genetic drift occurs.
- Mating is random, i.e. no sex selection occurs.
- No mutations occur.
- All genotypes are equally fertile, so that no genetic selection occurs

- Generations do not overlap
- There is no emigration or immigration from or into the population, i.e. there is no gene flow between populations.

Introduction of one or more of the conditions above leads to changes in allele or genotype frequency.

4. **The hardy-Weinberg equation;**

This is a mathematical relationship between the allele and genotype frequencies in a population. This can be used to calculate genetic changes in populations.

Starting with two homozygous organisms, one dominant for allele A and one recessive for allele a, all the F_1 off springs will be heterozygous (Aa)

Let: A = dominant allele
a = recessive allele

Parental phenotypes; homozygous dominant x homozygous recessive
Parental genotype (2n) AA x aa
Meiosis
Gametes (n) A x a
Random fertilization
F_1 genotypes (2n) Aa
F_1 phenotype: All heterozygous

If the presence of the dominant allele **A** is represented by **p** and the recessive allele **a** by **q**, the nature and frequency of the genotypes produced by crossing the F1 genotypes above are seen to be;

F1phenotypes: Heterozygous x Heterozygous
F1 genotypes (2n) Aa x Aa
Meiosis
Gametes (n) A a x A a
Random fertilization
F_2 genotypes (2n) AA Aa Aa aa
(p^2) (pq) (pq) (q^2)

F_2 phenotypes Homozygous Hetezygous Homozygous
Dominant recessive

Therefore; p^2 = Homozygous dominant
$2pq$ = Heterozygous
q^2 = Homozygous recessive.

Statistically, the 3 possible genotypes have the following probabilities; AA = ¼; 2Aa = ½ and aa = ¼, the sum of the three genotypes in terms of genotype frequency equal to one.

Hence $p^2 + 2pq + q^2 = 1$.

In summary; since;

p = dominant allele frequency
q = recessive allele frequency
p^2 = homozygous dominant genotype
$2pq$ = heterozygous genotype
q^2 = homozygous recessive genotype.

All allele and genotype frequencies can be calculated from; allele frequency, $p + q = 1$; and genotype frequency; $p^2+2pq + q^2 = 1$

Example;

One person in 10000 is albino, i.e. the albino frequency is 1 in 10000. Since albino condition is recessive that person must possess the homozygous recessive genotype, hence $q^2 - {}^1/_{10000}$.
q = 0.01
:. The Frequency of the albino allele in the population if 0.01 of 1%.
Since p + q = 1
P + 0.01 = 1
P = 0.99
: The frequency of the dominant allele in the population is 0.99 or 99%.

Since; $p = 0.99$
$P^2 = (0.99)^2 = 0.9801$
:. The frequency of the homozygous dominant genotype in the population is 0.9801 or 98%.

Since $p^2 + 2pq + q^2 = 1$
$0.9801 + 2pq + 0.0001 = 1$
$2pq = 0.0198$
or $2pq = 2 \times 0.99 \times 0.01$
$= 0.0198$
:. The frequency of the heterozygous genotype is 0.0198 0r 2%.

Trials;

(a) Cystic fibrosis occurs in the population with a frequency of 1 in 2200. Calculate the frequency of the carrier genotype.
(b) In a population of 200 plants, 128 are homozygous tall, 64 are heterozygous tall and 8 are dwarf.
   (i) Using suitable symbols, state the genotype of all the plants.
   (ii) Calculate the allele frequency of t and T
   (iii) Calculate the genotype frequency.
(c) In a population, the gene responsible for tongue rolling is dominant over the gene for non-tongue rollers. The population of tongue rollers is 84% and non-tongue rollers if 16%. Find the percentage of individuals who are;
   (i) Homozygous for tongue rolling
   (ii) Heterozygous for tongue rolling.

More explanations;

Imagine that a particular mental defect is one in 25000, the frequency of the allele are; homozygous recessive frequency = 0.00004; recessive frequency is 0.0063; homozygous dominant frequency = 0.9937; and heterozygous frequency = 0.0125 as calculated.
This means that in a population of 25000 individuals, only one individual will suffer the defect but around 313 are carries/heterozygotes. The heterozygotes are acting as a reservoir of the allele; maintain it in the gene pool. As these heterozygotes are phenotypically normal, the frequency of the allele remains unaffected because they are not selected against. This is called heterozygous advantage.
Many recessive alleles are eliminated because they counter disadvantages on the phenotypes, these results from the death of the organism prior to breathing or genetic death, the failure to reproduce.

FACTORS PRODUCING CHANGES IN POPULATIONS

The four major sources of genetic variation with in a gene pool are crossing-over during meiosis; independent segregation during meiosis; random fertilization and mutation.
The first three sources of variation are referred to as **sexual recombination** and cause gene reshuffling. Other sources include natural selection, non-random breeding, genetic drift, genetic load and gene flow.

Natural selection
This tends favour alleles and genotypes that produce environmentally adapted phenotypes, leading to increase in their frequencies while those that are less adapted to the environment are eliminated hence their frequencies decline.

Non-random mating
Mating in most natural populations is non-random. Sexual selection occurs whenever the presence of one or more inherited characteristics increase the likelihood of bringing about successful fertilization of gametes.
Non-random mating is due to structural and behavioral mechanisms in both plants and animals which prevent mating (sexual selection). E.g. flowers with increased size of petals and amount of nectar attract more insects hence increase the chances of pollination; colour patterns in insects, fishes and birds, and behavioural patterns involving nest-building, territory possession and courtship, increase the selective nature of breeding; red-eyed male drosophila are preferred to white-eyed male by the females.
Thus, sexual selection as a mechanism of non-random mating ensures that certain individuals within the population have an increased reproductive potential, so their alleles are more likely to be passed onto the next generation. Organisms with less favourable characteristics have a decreased reproductive potential and the frequency of their alleles being passed onto subsequent generation is reduced.

Genetic drift
Variation is gene frequencies within populations can occur by chance rather than by natural selection. In smaller isolated populations, not all the alleles which are represented of that species may be present. Chance events such as the premature accidental death prior to mating of an organism which is the sole possessor of particular allele would result in the elimination of that allele from the population.
In a small population, as random genetic drift is unpredictable, it can lead to the extinction of the population or result in the population becoming even better adapted to the environment or more widely from the parental population. This may lead to origin of new species by natural selection.
An example of genetic drift is the **Founder principle**. This is when a small population becomes split off from the parent population; it may not be representative in terms of alleles, of the parent population. Some alleles may be absent and others may be represented.
Continuous breeding within the pioneer population will produce a gene pool with allele frequencies different from that of the original parent population. Genetic drift reduces the amount of genetic variation by losing those alleles with low frequency.
Through genetic drift leads to a reduction in variation within population, it can increase variation within a species as a whole. Small isolated populations may develop characteristics a typical of the main population which may have a selective advantage of the environment changes, thus causing speciation.

Genetic load;
This is the existence with the population of disadvantageous alleles in heterozygous genotypes. Some recessive alleles which are disadvantageous in the homozygous genotype may be carried in the heterozygous genotype and confer a selective advantage on the phenotype in certain environment conditions, such as the sickle-cell trait in regions where malaria is endemic. Any increase in recessive alleles in a population as a result of harmful mutations will increase the genetic load of the population.

Gene flow;
This is the continual interchange of alleles between organisms within the gene pool of a given breeding population or the movement of alleles from one population to another as a result of interbreeding between members of the two populations.
This random introduction of new alleles into the population and the removal from the population affects the allele frequency of both populations and leads to increased genetic variation.

However, in case of distributing mutant alleles, throughout all populations, gene flow ensures that all populations of a given species share a common gene pool, hence reducing differences between populations.
The frequency of gene flow between populations depends on their geographical proximity, and the ease with which organisms or gametes can pass between the two populations. i.e. two populations that are situated so close together easily interbreed continuously; flying animals and pollen grains actively or passively disperse into new environment, there, they may interbreed or cross with the resident population, thereby introducing genetic variation into that population.

NATURAL SELECTION

This is the process where those organisms which appear physically, physiologically and behaviorally better adapted to the environment survive and reproduce; those organisms not so well adapted either fail to reproduce of die.
The better adapted organism thus passes on their successful characteristics to the next generation, while those that are poorly adapted do not.

How natural selection occurs

When a population increases in size, certain environmental factors become limiting, such as food availability in animals and light to plants. This produces competition for resources between members of the population. Those organisms exhibiting characteristics which give them a competitive advantage will obtain the resource, survive and reproduce. Organisms without those characteristics are at a selective disadvantage and may die before reproducing. Both the environment and population size operate together to produce selective pressure, that increase or decreases the spread of an allele with in the gene pool.

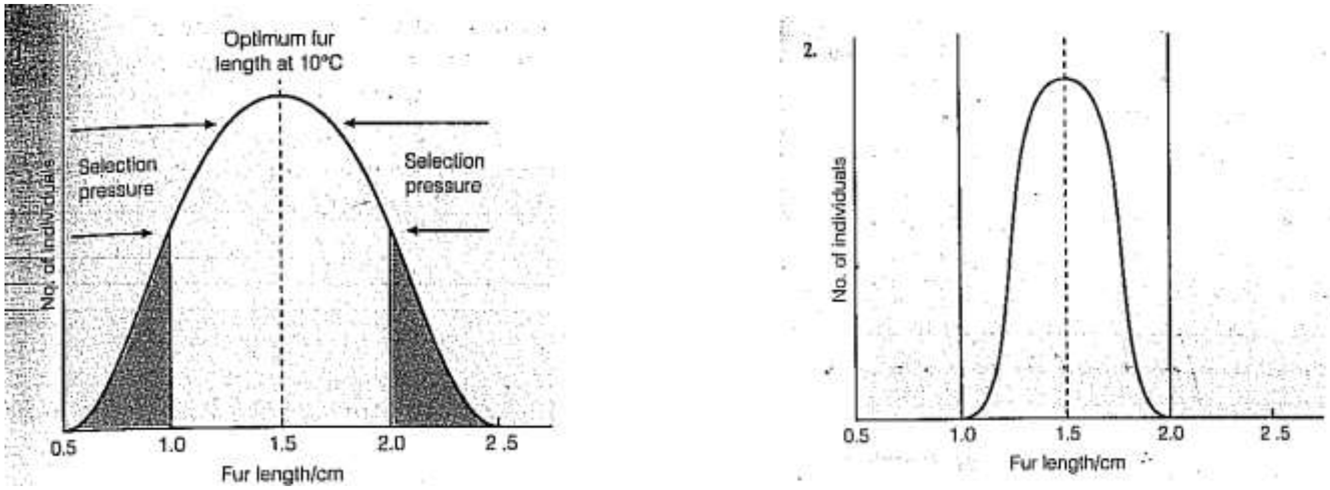
How natural selection causes evolutionally change;

As selection pressure causes the spread of an allele in the gene pool, this changes the allele frequency of a given character. Major changes in genotypes arise from the spread of mutant alleles through the gene pool. The influence of a given mutant allele vary, those mutations affecting alleles controlling important functions are likely to be lethal and removed from the population immediately. However, the gradual appearance of many mutant alleles which exert small progressive changed in phenotypic characteristics brings about an evolutionary change

TYPES OF NATURAL SELECTION;

There are three types of selection process occurring in natural and artificial population i.e. stabilizing, directional and disruptive selection.

1. **Stabilizing selection;**
   This selection favours phenotypic features near the mean or optimal environmental conditions and competition is not severe. It occurs in all populations and eliminates extremes from the population. It brings about constancy in the population and does not favour evolution.

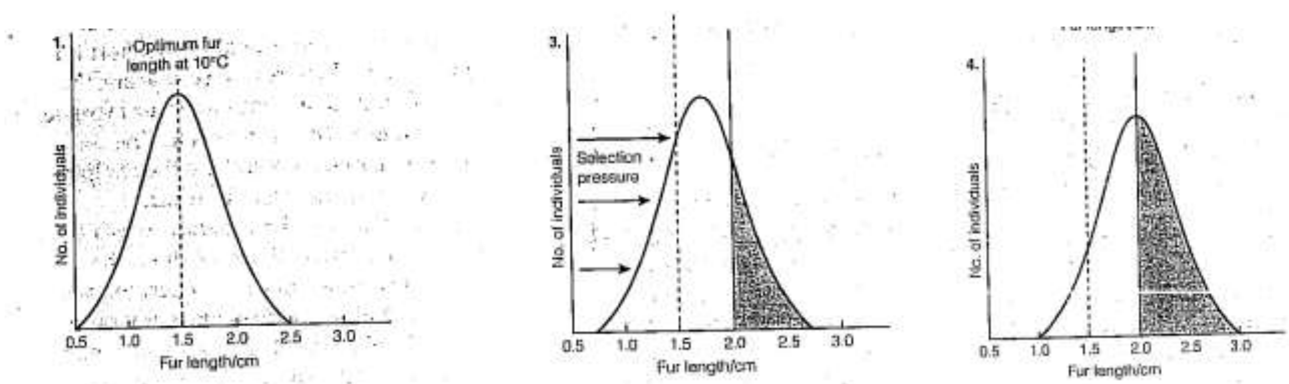


Examples;

- There is an optimum wing length for a hawk of a particular size in a given environment, stabilizing selection operating through differences in breeding potential, will eliminate those hawks with wings spans larger or smaller than this optimum length.
- Death of babies heavier or lighter than the optimum birth weight of 3.6kg
- Elimination of short fur mice in cool years and long fur mice in warm years due to excessive heating up, and maintaining of average fur length of 10cm in both years
- The inheritance of sickle cell anemia, since the extremes die of the sickle cell disease or malaria with the majority of heterozygotes surviving.

2. **Directional selection;**

This form of selection operates in response to gradual changes in environmental conditions. It operates on the range of phenotypes existing within the population and exerts selection pressure which moves the mean phenotype towards one phenotype extreme. This kind of selection brings about evolutionary change by producing a selection pressure which favours the increase in frequency of new alleles within the population. It also forms a basis of artificial selection of plants and animals.

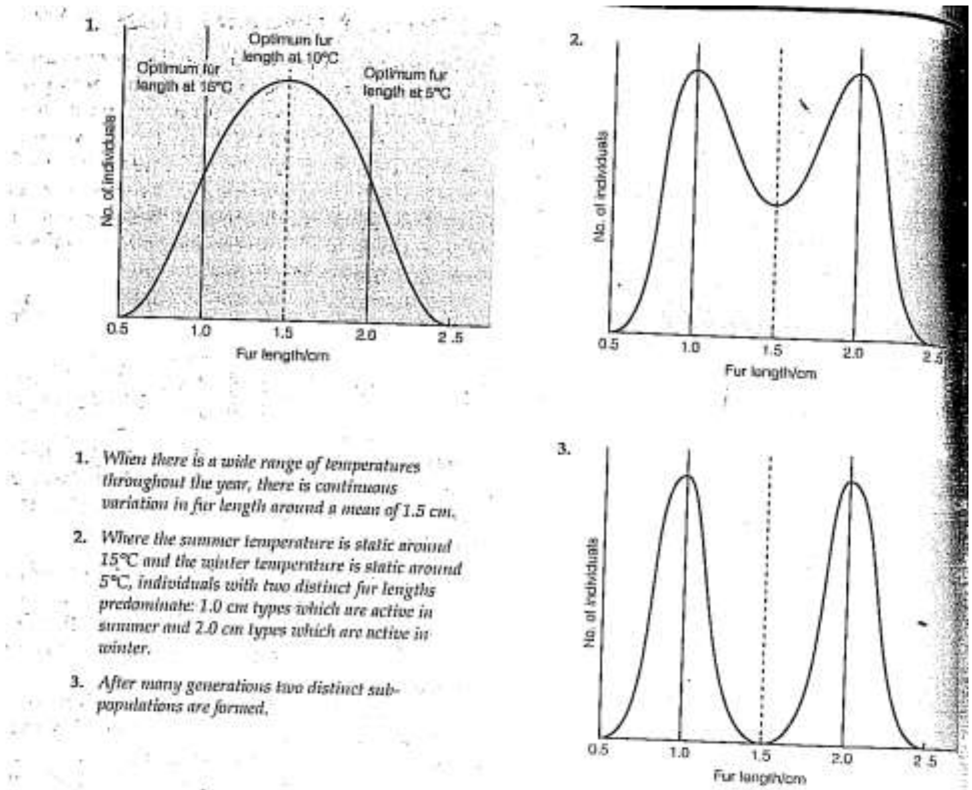


Examples;

- Gradual development of long-necked giraffes.
- Industrial mechanism
- Resistance to anti-biotic
- Selective breeding of organisms.

3. **Disruptive selection;**

This selection favours the presence of more than one phenotype within a population due to fluctuating conditions within an environment. Selection pressures acting from within the population due to increased competition push the phenotypes away from the population mean towards the extremes of the population. This splits a population into two subpopulations. If gene flow between the subpopulations is prevented, each population gives rise to a new species. This selection is very important in bringing about evolutionary changes.



Examples;

- Alternations in environmental temperature between 50c in winter and 150c in summer with no intermediate temperature produce two distinct species with 2 fur lengths.
- Variety of the Galapagos finches
- Polymorphism

NATURAL SELECTION IN ACTION

These include the day to day observations of natural selection. They include the following;

- Insect's resistance to insecticides like flies and mosquitoes to DDT
- Pest's resistance to pesticides
- Heavy meal tolerance in grass and other plants
- Antibiotic resistance by pathogens e.g. bacteria to penicillin
- Resistance to antimalarial drugs
- Industrial mechanism
- Polymorphism
- War farm (an anti-coagulant) resistant by rats

Drugs and pesticides resistance.

Resistance occurs due to continuous exposure of organisms to such chemicals. This induces random mutations. The mutation causes the synthesis of an oxido-reductase enzyme which either reduces or oxidizes the chemical into harmless substances making them resistant.

In such populations, the chemical acts as a directional selection pressure that eliminates the non-resistant forms in favour of the resistant ones. The later have a selective advantage hence a higher reproductive potential, and their numbers increase as resistance is passed to next generation. The non-resistant forms are eliminated and sooner than later, the whole population becomes resistant to the chemical.

Heavy metal tolerance in grass and other plants

Spoil heaps contain the waste material from mines, hence contain high concentrations of certain heavy metals e.g. tin, lead, copper and nickel. In such high concentrations, these metals are toxic to host plants. However, a few plants like the horsetails are found scattered in such soils, which have developed tolerance to such metals.
Because in such plants, mutations occur rendering them ability to trap these metals in to their cell walls, confine them in vacuoles or excrete them. Tolerance is passed to next generations enabling the plants to flourish in polluted areas as their non-tolerant competitors are killed by heavy metals while in unpolluted areas, they have a competitive disadvantage, less competitive and rarely survive.

Industrial melanism

This is the process that led to the appearance of higher frequencies of melanic forms of peppered moths than non-melanic forms as a result of air pollution that followed the industrial revolution.
Peppered moths occur in two phenotypes forms namely; ***Biston betulana typica***, the speckled white in colour and the normal non-melanic forms, and ***Biston betularia carbonaria***, a melanic mutant and appears darker (almost black), though to arise due to spontaneous mutation.
The peppered moths fly at night and during day they rest on tree trunks and walls of buildings. They depend on colouration of these areas to camouflage with their back grounds to prevent predation by birds.

Explanation;

Before the industrial revolution, the tree barks had a pale appearance due to lichen growth because of the low air pollution levels. The light forms could unlike the dark camouflage properly with their back grounds, preventing predation. These had a selective advantage which rendered them a higher reproductive potential, hence increased their number much more than the dark forms which could not camouflage well, hence predated.
Following the industrial revolution, the air pollution resulted into killing the lichens and back grounds were further darkened by smoke. In such conditions the dark forms easily camouflaged then the light forms and could not easily be spotted by predators, these therefore had a higher selective advantage under a directional selection pressure provided by selective predation, which eliminated the light forms in favour of the dark forms.
Overtime, the relative numbers of the dark forms increased gradually while those of the light forms deceased. However, the two forms can still interbreed successfully and are therefore of the same species.

Polymorphism

This is the existence of two or more forms of the same species with in the same population. Such phenotypes are referred to as **morphs**. There are two forms of polymorphism i.e. transient and balanced/stable polymorphism.

Balanced polymorphism; This occurs when different forms co-exist in the same population in a stable environment. Examples include; the existence of two sexes in animals and plants; existence of A, B, AB and O blood groups in man, existence of red-green colour blindness, and the existence of workers, drones and queen bee. Here, the genotypic frequencies of the various forms exhibit equilibrium since each form has a selective advantage of equal intensity.

Transient polymorphism; This arises when morphs existing in a population undergo a strong selection pressure. The frequencies of the phenotypic appearance of each form are determined by the intensity of the selection pressure. It applies in situations where one form is gradually being replaced by another example include the melanic and non-melanic forms of the peppered moth.

ARTIFICIAL SELECTION

Humans' carryout artificial selection through domestication of animals and plants since civilization. This causes speciation in that, the isolation of natural populations and the selective breeding of organisms showing characteristics or traits which are useful to humans; this exerts a directional selection pressure which leads to changes in allele and genotype frequencies within the population. This is an evolutionary mechanism which gives rise to new breeds, strains, varieties, races and subspecies.
There are two basic methods of selective breeding i.e. inbreeding and outbreeding.

Outbreeding

This involves crossing individuals from genetically distinct populations. It is useful in plant breeding but also in commercial production of meat, eggs and wool in animals species.
Outbreeding takes place between members of different varieties/ strains and in certain plants between closely related species. The progeny are known as **hybrids**. Hybrids have superior phenotypic characteristics to either of the parent stock, a process called **hybrid vigour** or **heterosis**, such as increased grain yield in maize. Increased vigour results from the increased heterozygosity which arises from gene mixing.
Selective breeding/hybridization can induce changes in chromosome number (chromosomal mutation), a phenomenon called **polyploidy** which can lead to the production of new species.
The ***disadvantage*** with outbreeding is that it makes good consistent qualities harder to achieve. However, it results into healthier and stronger hybrid.

Inbreeding

This involves selective reproduction between closely related organisms e.g. between off springs produced by the same parents, in order to propagate particularly desirable characteristics. It occurs mainly in animals such as cattle, pigs, poultry, cats, sheep and dogs to increase yields of milk, meat, eggs and wool.
However, prolonged inbreeding leads to reduction in fertility, reduces the viability of the genome (the sum of all the alleles of an individual) by increasing the number of homozygous genotypes, than heterozygous genotypes.
These problems are overcome by outbreeding through artificial insemination, or using another bull. This introduces new alleles into the herd, thereby increasing heterozygosity of the breeding population.

SPECIATION

This is the process by which one or more species arise from previously existing species. A single species may give rise to new species i.e. intraspecific speciation or two different species may give rise to a new species i.e. interspecific hybridization.

Types of speciation;

There are **two** types of speciation, i.e. allopatric and sympatric speciation.

1. **Allopatric speciation**
   This is a type of intraspecific speciation which occurs as a result of spatial separation of a population into two subpopulations, usually due to geographical barriers like mountains, seas, rivers, or differences in habitat preference. These physical barriers prevent interbreeding among the individuals of the two subpopulations leading to reproductive isolation and interrupts gene flow.
   Due to continuous natural selection, mutations, and random genetic drift, result into changes in the allele and genotype frequencies of the two populations, making their gene pools to diverge more from that of the original population. This leads to the group on each side adapting to suit its own environment through adaptive radiation.

Prolonged separation results into the populations becoming genetically isolated such that the individuals can no longer interbreed successfully, the two are now different species and speciation is said to have occurred e.g. the Galapagos finches.

2. **Sympatric speciation;**
   This is a type of intraspecific speciation that occurs when organism inhabiting the same area becomes reproductively isolated into two groups for reasons other than geographical barriers. It usually occurs following a short term period of allopatric/geographical isolation which results into reproductive isolation of the two groups coexisting in the same area.
   The overall result is independent change in the allele and genotype frequencies of the two subpopulations due to natural selection, leading to formation of races and subspecies. If genetic isolation persists over a long period of time, these may gradually evolve into different species.

ISOLATING MECHANISMS

These are means of producing and maintain reproductive isolation within a population. They are also called reproductive isolation mechanism. Reproductive isolation refers to the existence of biological factors (barriers) that impede members of the same or different species from interbreeding successfully. These include pre – zygotic mechanism (barriers to the formation of hybrids) and post-zygotic mechanism (barriers affecting hybrids).

Pre – zygotic mechanisms

- Seasonal isolation; this occurs where two species mate ort flower at different times of the year. This prevents breeding if the periods do not coincide.
- Ecological isolation; this occurs where two species inhabit similar regions but have different habitat preferences. Such species can meet only very rarely If not at all.
- Behavioural isolation; this occurs where animals exhibit courtship patterns, mating only results if the courtship display by one sex results in acceptance by the other sex.
- Physiological/reproductive isolation; this is where two groups of individuals cannot breed due to a number of reasons connected to their physiological nature.
- The genitalia of the groups may be incompatible (mechanical isolation).
- The gametes may be prevented from meeting i.e. in animals, the sperms may not survive in the female reproductive parts, or in plants the pollen tube may fail to grow.
- Fusion of gametes may not take place despite the sperm reaching the ovum of the pollen grain tube entering the micropyle, (gametic isolation).
- Development of the embryo may not occur despite fertilization takes place, further development may not occur or fetal abnormalities may arise during early growth (hybrid isolation).
- The hybrid may be sterile (hybrid sterility) e.g. a mule (hybrid isolation).

Post zygotic mechanisms

- Hybrid in-viability; this is when hybrid produced fail to develop to maturity.
- Hybrid sterility; this is when hybrids are viable but fail to functional gametes and are therefore infertile.
- Hybrid breakdown the F_1 hybrids are fertile by F_2 generation and backcrosses between F_1 hybrids and parental stocks fail to develop or are infertile.