**DESCENT WITH MODIFICATION**

***Evolution*** refers to the gradual change in the structure of organisms from simple to complex over a long period of time.

This is a branch of science that attempts to describe the various theories concerning the origin of the earth as well as the origin of life on earth and possible ways in which species have originated. Much of the evidences on which these theories are based, be it scientific or theological (religious) are largely metaphysical; i.e., it’s impossible to repeat the exact events discussed in such theories.

**Theories for the origin of the earth**

Currently two main theories have been put forward to account for the origin of the earth onto which life exists.

***The big bang theory,*** according to this theory, the earth originated from a ball of neutrons that exploded into smaller particles that remained in their orbits around the centre of reaction. The centre of reaction is the sun around which the various planets the earth inclusive orbit.

The main limitation of this theory is how nothing can explode into something.

***Special creation theory,*** according to this theory, the earth was created from nothing by a super-natural being with divine powers and known as God/Allah.

The main limitation to this theory is that it cannot be proved experimental

**Origin of life on earth**

In the same way, several theories have been put forward to describe the origin of life on earth.

***Special creation theory,*** Life on earth was created by a super-natural being with divine powers and called God/Allah.

*ExclArchbishop Ussher of Armagh(1650 AD) – October 4004BC from 1st – 23rdwth man @ 0900*

***Spontaneous generation,*** Life arose from non living matter on a number of occasions by spontaneous generation

Such non living matter was said to contain an active principle that could give rise to living organisms when conditions were favorable. **For example**, *lice from sweat, aphids arise from the dew which falls on plants, fleas from decaying matter, mice from dirty hay, crocodiles from rotting logs at the bottom of bodies of water, maggots from rotting meat and so on*.

In support of his experiment, ***Van Helmot***described an experiment that gave rise to mice in three weeks. He placed a dirty shirt and a handful of wheat grains into a dark cup board, with the sweat in the shirt being the active principle. His set up lacked a control experiment.

The first solid evidence against spontaneous generation came in 1668 from ***Francesco Redi***, who proved that no maggots appeared in meat when flies were prevented from laying eggs.

In this experiment he put a snake, fish, eels and a slice of calf meat in four wide-mouthed flasks; closed and sealed them. He filled four other flasks in the same way and left these open **(control).**

It was **observed** soon that the contents of the open flasks became wormy and flies were seen to enter and leave at random. The closed flasks did not become wormy even after manydays.

He therefore **concluded that** life comes from pre-existing life (biogenesis);non living matter cannot give rise to life.

In 1768, ***SpallanzaniLazzaro*** demonstrated that microbes were present in the air, and could be killed by boiling. He boiled animal and vegetable broths for several hours and immediately sealed them. He took them from heat and set them aside for several days. On examination none of the broths showed any sign of life. He concluded that heat destroyed all forms of living organisms and no life could appear. Some biologists argued that the seal deprived organisms of oxygen for respiration and life could not start.

In the same line, ***Louis Pasteur*** demonstrated the **ubiquitous occurrence** of bacteria (all environments) and that non-living matter could easily become contaminated by living matter if materials were not adequately sterilized.

**All the above described experiments disproved the theory of spontaneous generation in support of biogenesis. The validation of biogenesis however implied that a living organism is required to produce another living organism; where did the first organism come from?**

***Steady state theory,*** this theory asserts that the earth **has no origin** but it has always been there and able to support life. It has changed little if at all any. **Life too** has no origin. Species have always been in existence and the only alternative is variation in number or become extinct but they have always existed. Improved scientific dating methods have always given increasing ages for the earth and extrapolating this trend provides evidence that the earth has no origin.

***Cosmozoan theory (the theory of panspermia),*** this extends the origin of life to an **extra-terrestrial** source elsewhere in the universe. Life could have arose from somewhere else and arrived on to the earth by some means. According to this theory, life is distributed throughout the universe in form of spores that can germinate in the right environments.

Repeated sighting of **UFOs and aliens** provide evidence for this theory. In addition, research on comets and meteorites has revealed presence of many organic compounds like hydrocyanic acid which might have acted as seeds.

***Theory of biochemical evolution (Chemical evolution/abiogenesis)***

This is the scientific theory that was put forward to account for the origin of life on earth according to purely physical and biochemical means.

***Alexander Oparin*** on purely theoretical grounds described the original state of the earth’s atmosphere as a highly reducing one consisting of a mixture of gasses circulating under very high temperatures. The reducing nature of the original earth is illustrated by the occurrence of reduced forms of metals in older rocks, while those in younger rocks are oxidized.

Such gases as **water vapour, ammonia, carbon dioxide, methane and many others**, formed a primordial/organic soup from which life could have arose. In this soup, complex organic compounds mainly hydrocarbons could have been formed with energy from ultra-violet radiation from the sun before formation of the ozone layer.

Some of these hydrocarbons **acquired properties** like membranes to separate them from the organic soup and exchange materials with the soup and capable of self-replication forming the earliest heterotrophic organisms feeding on the organic soup. Soon the organic soup became depleted of nutrients and some acquired abilities to **synthesize their own organic compounds**. These were the first autotrophs, starting with cyclic and later non-cyclic photophosphorylation. This came with release of oxygen gas (evolutionary product) which formed the ozone layer that cut off most of the solar radiations leading to a decrease in surface temperatures.

Non volatile gases condensed down that vapour formed water in the current water bodies. The primitive organisms have undergone a series of modifications to produce the current organisms.

**THEORIES OF EVOLUTION**

Currently there are two theories which have been put forward to account for the mechanisms through which evolution is taking place, these are Lamarckism and Darwinism

***Lamarck’s theory of evolution***

This was put forward by a French biologist called Jean Baptist De Lamarck.

According to Lamarckism, the evolutionary process is based on the **use and disuse** of body structures **and inheritance of acquired** characteristics.

***Explanation;***

Any change in environment dictates **change in behavior** of organisms which leads to increased use or disuse of different body structures/organs. Increased use results into increase in size and efficiency while increased disuse results into decrease in size or degeneracy of body structures. Such acquired xticsare then transmitted to off springs in subsequent generations.

In support of his theory, Lamarck pointed out that the **long necks and legs of modern giraffes** were a result of their short-necked ancestors feeding on leaves at progressively higher levels of trees. Slightly longer necks and legs produced at each generation were passed on to subsequent generations till the size of the present day giraffe was reached.

Similarly, the **webbed feet** of aquatic birds were acquired due to them constantly spreading out their toes in search for food and escape from predators. The **flat shape** of fish was a result of fish lying on their sides in shallow waters.

Though Lamarck’s observation on the role of environment in modifying phenotypes was right, such modifications **have no effect on genotype** and cannot be inherited. In illustration of this, ***August Weismann*** cut off the tails of mice for 45 consecutive generations, expecting the enforced disuse of the tails to result into progeny with smaller tails. The mice continued to bear normal sized tails and he concluded that body acquired (somatic)xtics do not affect germ cells and cannot be inherited.

**Darwin’s theory of evolution**

*Charles Darwin was an English naturalist who made several studies on variation in plants and animals. His work was published almost simultaneously with that of Alfred Wallace.*

According to Darwinism, new organisms are formed from the pre-existing ones over a long period of time by natural selection. His theory was based on the following observations and deductions.

***Obsvn I;*** All organisms have got a high reproductive potential that they produce much more off springs than would be necessary to replace them.

***Obsvn II;*** All populations remain fairly constant from generation to generation.

***Dedn I;*** Darwin deduced on the basis of 1 and 2 that there occurs a struggle for existence among organisms of the same species hence many organisms fail to survive or reproduce. Populations therefore tend to remain constant.

***Obsn III;*** Variation occurs in all populations

***Dedn II;*** In the struggle for existence, those variants which are better well adapted to the environment are selected for, survive and reproduce to pass their traits to subsequent generations. Those that are less adapted to the environment fail to survive or reproduce hence ***survival for the fittest.***

***Scientific explanation of Darwin’s theory***

The theory has on several occasions been backed up by a number of scientific observations which provide evidence for the occurrence of N/S in natural populations.

***ObsnI;*** Reproduction is basic to all living organisms and is the fundamental drive that ensures survival. Thomas Malthus was able to highlight the high reproductive potential of humans and that human population, and all other populations are capable of increasing exponentially as a result.

***ObsvnII;*** All population sizes are limited naturally by a combination of environmental factors like food availability, space etc that constitute the environmental resistance. Population size tends to increase until the environment can support no further increase and then remain more or less constant over time.

***DednI;*** Continuous competition (intra- or inter-specific) among individuals for such limited resources creates a struggle for existence which results into failure of some organisms to survive or reproduce.

***ObsnIII;*** Variation has been observed to occur in all populations. No two or more organisms even of the same species are exactly the same in terms of body morphology or even behavior.

***Dedn II;*** During the struggle for existence, individuals that are physically, physiologically or behaviorally better adapted to the environment are said to have ***a selective advantage*** and are selected for by the environment. These reproduce and pass their traits to the next generations, and their numbers increase over time. Those that are less adapted are said to have a ***selective disadvantage*** and are selected against, fail to reproduce or survive and their numbers decline significantly. With time the two groups may evolve into different species.

***Limitations of Darwin’s theory (N/S)***

* Darwin made no attempt to describe how life originated on earth. He only explains how new species arise from pre-existing one
* The theory is coined with many misfortunate terms like survival for the fittest, struggle
* A misconception that human beings descended from apes which was perceived as offensive by both religious and secular communities.
* Contradiction with the Genesis six-day creation
* The theory fails to account for the extinction of dinosaurs and the giant ferns

***Exl.***

*Bshp Samuel Wilberforce Vs prof Thomas H Huxley; if he traced his decencyfrm a monkey through his grandies. “I would rather have a monkey for an ancestor than being connected wth man who uses expensive gifts to obscure the truth*

***Natural selection***

This refers to the process by which those individuals that are**physically, physiologically and behaviorally** better well adapted to the environment are favored and reproduce more to pass their traits to subsequent generations while those that are less adapted fail to survive or reproduce.

***How n/s occurs***

During periods of population increase, some resources become limiting and competition sets in for such resources. This creates a struggle for existence in which individuals that are physically, physiologically or behaviorally better adapted to the environment (have ***a selective advantage)*** and are selected for by the environment. These reproduce and pass their traits to the next generations, and their numbers increase over time. Those that are less adapted are said to have a ***selective disadvantage*** and are selected against, fail to reproduce or survive and their numbers decline significantly. Gradual accumulation of the favorable traits in one direction over a long period of time may result into the two groups evolving into different species.

NB: variation among organisms forms the basis by which n/s; the mechanism of evolnacts. Selection acts by weeding out those individual whose characteristics confer a selective disadvantage (unfit) in favor of the fit individuals.

*S.q Explain how n/s can lead to speciation*

*The modern view of n/s (****Neo-Darwinism)***

With the contemporary evidence from research in genetics and molecular biology, the theory of evolution as stared by Darwin and Wallace was modified into what currently is known as **Neo-Darwinism.** This is the theory of organic evolution by n/s of genetically acquired characteristics.

This should not be confused with chemical evolution which describes the process of formation of organic molecules from simple inorganic molecules which gave rise to the first life forms in the primitive earth. Organic evolution focuses on the gradual modification of organisms from the first primitive forms of the time to the current forms.

**EXAMPLES OF N/S**

The most obvious example of the origin of species by n/s is provided by the distribution of organisms on oceanic islands.

An ***Oceanic island*** is an island that was formed by volcanic activity and has never had direct physical link to the main landmass. For example the Galapagos and Hawaiian islands which were visited by Darwin and Wallace, both of whom were greatly struck by the amazing diversity of species that existed on such islands

The most common of these were

* Darwin’s finches
* The giant tortoises
* Nature of vegetation and the
* Giant Iguana lizards.

According to Darwin’s observations; the island species shared **similar basic characteristics** with those on the nearest main land only that the former were much **larger and more diverse** than the latter. Vegetation too was more lush. The above observations can be explained by the fact that all island species had their origin from the main land and arrived on to the islands by some means. **Plants** could have been taken by means of **dispersal** like wind as seeds and spores or by water as floating seeds and masses of vegetation. **Aquatic and semi-aquatic animals** by ocean currents and terrestrial animals may have been carried by clinging on logs or floating masses of vegetation. Birds, bats and flying insects arrived easily **through flight**

On arrival onto the competition-free islands with plentiful of food, favourable climate and a variety of unexploited niches, the organisms fed and reproduced faster, their body size increased gradually and numbers increased rapidly. As a result, some resources like food and space became limiting and competition set in. This inevitably resulted into resource partitioning and adaptive radiation of the organisms to occupy/exploit vacant niches and reduce competition. Competition therefore exerted a selection pressure acting in favour of individuals with ability to occupy competition-free niches which gradually evolved into different species, hence greater diversity.

***The Darwin’s Finches***

On the main land of Ecuador occurs only one form of finch called the ground finch which feeds upon seeds, this is believed to have given rise to the finch variety that’s exists on the Galapagos. These are though of different species, they are closely related to the ground forms though they differ in body size, feather colour and shape of beaks. Even where several species of the same type of finch occur, they differ in their ecological preferences.

Darwin explained the observations in such a way that a group of finches from the mainland colonized the competition-free islands, flourished and their numbers increased rapidly. Sooner than later, the resulting competition resulted into adaptive radiation of the birds to occupy different ecological niches and reduce competition. This with time resulted into formation of a wide variety of finch species on the islands.

In the same way, the lizards on the main land were strictly terrestrial but due to the same reasons, those groups which colonized the islands gradually evolved into terrestrial and aquatic species by n/s. The aquatic lizards mainly fed on marine algae and showed structural adaptations for locomotion in water for example webbed feet and laterally flattened tails

*Examples of Darwin’s finches*

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of finch** | **Beak shape** | **Food** | **Habitat** |
| Large ground finches (ancestral ) | Short & straight | Seeds | Coastal |
| Cactus ground finches | Long slender & slightly curved with a split tongue | Nectar of cactus | Low lands |
| Insectivorous tree finches | Parrot-like | Seeds/insects | Forest |
| Vegetarian tree finch | Curved, parrot-like | Fruits and buds | Forest |
| Warbler | Slender | Insects in flight | Forest |
| Wood pecker | Large straight, use cactus spines to poke insects from holes intrees | Insect larvae | Forest |

**EVIDENCES FOR EVOLUTION**

According to evolutionary studies, it is largely acceptable that each species existing today arose from a certain pre-existing species by n/s and all species have evolved from a single ancestral type. Having looked at the possible mechanisms responsible for evolutionary change among organisms, it is important to switch our focus onto the evidences to prove that indeed evolution occurs. Several branches of biology have come up with related evidence as discussed below.

**Evidence from palaentology**

Palaentology is the study of fossils. A **fossil** is a preserved remain that is believed to be derived from a living organism. Palaentological studies have revealed that older rock rocks of the earth contain very few fossils with simple structures. Progressively younger rocks on the other hand contain a greater variety of fossils with increasingly complex structures. This indicates that with time, organisms show a **progressive change from simple to more complex** forms hence evolution

The main **limitation/criticism** to evolutionary evidence is lack of continuity of fossil record **(the missing links)**. The missing links in fossil record can be accounted for as follows

* Some organisms have soft bodies and do not fossilize easily e.g. molluscs
* Some of the dead bodies were eaten by scavengers
* Some organisms decompose easily before fossilisation
* Some organisms died in places where conditions did not favourfossilisation
* Only a small fraction of fossils have been discovered
* There is a possibility also that some species arose so suddenly that intermediate forms in the lineage do not exist, this is known as punctuated equilibrium

**Punctuated equilibrium** is the process by which species may remain unchanged for long periods of time before giving rise to new species in a comparatively short period of time. Punctuated equilibrium results into **salutatory evolution**. This refers to the evolution of new species from pre-existing ones in form of large jumps rather than by gradual accumulation of small steps.

**Evidence from geographical distribution**

This has no immediate evidence for evolution. Plant and animal species have been shown to be discontinuously distributed throughout the world; this is when a given group of plants or animals have representatives in widely separated localities.

***Examples of discontinuous distribution include;***

Despite the fact that both Africa and S.America lie approximately along the same latitudes with the same variety of habitats, they support quite different faunas in the following examples;

* Africa has short tailed (old world) monkeys while in S.America there are long tailed (new world) monkeys.
* Distribution of lung fish species (order dipnoi). The three remaining species of lung fishes are found separately in S.america, Africa and Australia
* Members of the family camelidae which are represented by the llama in S.America and by camels in Africa and Asia
* Distribution of Australian fauna. Australia is a home of marsupials (pouched mammals) and monotremes (egg-laying mammals) which are represented by Eutherians (placental mammals) elsewhere in the world

The discontinuous distribution of such organisms can be accounted for by continental drift-the splitting of a large landmass called **pangea** into smaller masses forming the current continents of the world as follows;

* Related species must have originated from a common ancestor in a particular area. This explains why such animals differ in details but share many basic similarities
* The species dispersed outwards from that area before continental drift; the degree of dispersal being dependant on the efficiency of the dispersion mechanism and the nature of geographical barriers.
* Continental drift resulted into geographical isolation of the species which evolved along their own lines to adapt to different environments. This resulted into gradual accumulation of structural differences which resulted into different species. Absence of more advanced forms from a given area indicates prior separation of that area from the place of origin

Fossil record has it that the camelides originated from **N.America** and spread southwards to s.america via the isthmus of panama and northwards to Africa through Asia before changes in sea level separated it from n.america. Throughout this time progressive changes due to due to environmental differences have occurred giving rise to the llama and camels

In the same way; Australia is believed to have broken from the other land masses just after the appearance of primitive mammals which underwent adaptive radiation to occupy the vacant ecological niches which are occupied elsewhere by placental mammals. In this process, organisms in similar but geographically isolated areas evolved independently to occupy similar ecological niches; this is referred to as **parallel evolution.** Parallel evolution refers to the independent evolution of similar traits in related organisms occupying similar but geographically isolated habitats. This should not be confused with **convergent evolution** which refers to the **independent** development of similar structures in phylogenetically unrelated species occupying the same habitat

**Divergent evolution** refers to the gradual development of dissimilar structures among phylogenetically related organisms due to adaptive radiation of organisms to different modes of life. E.g. the Darwin’s finches

**Co-evolution is** the joint change of two or more species in close interaction **Predators** and their **prey** sometimes co evolve; parasites and their hosts; plant-eating animals and the plants upon which they feed also coevolve.

Another example of coevolution is between **plants and the animals that pollinate them**. In tropical regions bats visiting flowers to eat nectar, the fur on the bat's face and neck picks up pollen, which the bat transfers to the next flower it visits. Bats that feed at flowers have a slender muzzle and a long tongue with a brushed tip. These adaptations aid the bat in feeding. Flowers that have coevolved with bats are light in color. Therefore, bats, which are active at night, can easily locate them. The flowers also have a fruity odor attractive to bats.

Though the above discussed evidences show that evolution is taking place, none of them explains the possible mechanism by which species have originated, ***the possible mechanism for the origin of species by n/s has been provided by the distribution of plants and animals on oceanic islands (As discussed earlier).***The organisms found on these islands show marked basic similarities to the mainland species but with noticeable differences. The similarities indicate the possibility of a common ancestry while the differences can be accounted for as a result of modifications by adaptive radiation to occupy different ecological niches

*S.Q; Explain how Darwin’s finches provide evidence for evolution*

*How does the distribution of organisms on oceanic islands provide evidence for evolutionary change?*

*Account for the observed structural differences between organisms found on oceanicislands and their ancestors on the nearby mainland.*

**Evidence from comparative anatomy**

This refers to the study of plant and animal structures. Some of the body structures occurring in different species have been observed to have similar basic structures but modified differently in these species. Such structures are called **homologous structures** and they indicate a common ancestry. The minor differences can be explained as divergent evolutionary trends due to adaptive radiation to perform different functions in different environments.

**Homologous structures** are body structures of different species with a similar basic plan, body position and embryonic development but modified differently to perform different functions.

**Examples of homologous structures**

* The pentadactyl limb. This is a limb with a similar bone pattern in all tetrapods, terminates in five digits and modified to perform different functions different species. This indicates a common ancestry for all tetrapods which underwent gradual adaptive radiation in adaptation to different ecological niches. This indicates divergent evolutionary trends.

Over time, the limb has undergone structural changes by fussion, enlargement etc to perform different functions in different environments. In humans the fore limb is modified for manipulation, swimming in seals and whales, flight in bats and birds, digging in moles, running in horses etc.

* Branchial arches. These are involved in jaw suspension in fish but appear as ear bones in mammals and are involved in hearing
* Haltares. These are modifications of hind wings in dipterans into small rod-like structures that are involved in maintaining balance during flight
* Pericarps. After fertisation, the ovary wall of different flowering plants becomes modified in a variety of ways to aid in seed dispersal by different agents
* Flower parts. Generally all flowers are comprised of the same basic structures (petals, sepals, ovary, stigma etc) yet they may greatly vary in size, shape, colour and number

Some of the homologous structures have no apparent function and their size has reduced, these are termed as **vestigial organs. Vestigial organs** homologous structures which have greatly reduced in size due to apparent decrease or total loss of function

**Examples include**

* The human appendix is homologous to the functional appendix of herbivores
* The human coccyx represent the remains of tails possessed by our ancestors and embryos
* The human clitoris
* The hip bones of snakes and whale represent the remains of the limb bones of their ancestors

It should be noted however that close similarity does not necessarily indicate close ancestral relationship; somebody structures occurring in phylogenetically distant species may appear superficially similar and perform similar functions, these are called **analogous structures.**

**Analogous structures** are body structures of phylogenetically unrelated species which appear superficially similar and perform similar functions but have different microscopic structures and embryonic development

Two or more forms of unrelated organisms may coexist in the same habitat, competing for the same resources. The selection pressure may act in favour of those organisms possessing a give trait which confers increased survival or reproductive potential to those individuals possessing them. Gradual elimination of the individuals lacking the trait results into its gradual development in organisms of different species. Such structures are called analogous structures and indicate the occurrence of convergent evolutionally trends among unrelated organisms occupying the same habitat

**Examples** of analogous structures include

* Eyes of vertebrates and cephalopod mollusks (like octopuses)
* Wings of insects, birds and bats
* Jointed limbs of insects and vertebrates
* Presence of thorns in plant stems and spines in animals

The wings of insects are thin structures supported by tough veins of cuticle. The wings of birds and bats are feathery and supported by hollow bones. In the same way, the embryonic development of cephalopod and vertebrate eyes are different, the former produces an erect retina with the photoreceptors facing towards incoming light with a blind spot while the latter produces an inverted retina with photoreceptors facing towards incident light and no blind spots are formed. These structures however adopt the same superficial appearance and perform the same functions (analogous structures)

**Evidence from adaptive radiation**

Adaptive radiation refers to the process by which a common ancestor undergoes rapid cumulative change in due to change in environment or increase in competition giving rise to different groups that are better suited to the environment. This indicates the possible mechanism by which evolution occurs by n/s.

When a group of organisms share a homologous structure which is modified to perform different functions, this illustrates the principle of adaptive radiation. Other examples include the adaptive radiation of the Galapagos finches and insect mouth parts. All the mouth parts of insects consist of the same basic structures (Labrum, mandibles, maxillae and the labium). These parts have been modified by enlargement, fussion, reduction or total loss to allow for exploitation of different food sources.

*S.q. Describe the modifications of mouth parts and their functions in different groups of insects using specific examples*

*In their primitive state, insect mouth parts are adapted for* ***biting and chewing herbs****. Such insects as* ***grass hoppers and cockroaches*** *have mandibles with sharp edges for cutting food and well developed maxillae for manipulating food. In adaptation to different food sources, the mouth parts have been modified differently in different insects as follows. In* ***butter flies,*** *the mandibles are lost; labrum and labium are reduced while the maxillae are modified into a long sucking tube for* ***sucking juices.*** *In* ***mosquitoes (for piercing and sucking****), the labrum and maxillae form a sucking tube, mandibles form piercing stylets while the labrum is grooved to hold other mouth parts during feeding. For* ***honey bees,*** *the mouth parts are modified for* ***licking and biting;*** *the labrum is long to lap up honey while the mandibles are modified for chewing pollen and mould wax*

**Evidence form comparative embryology**

Adaptive embryology refers to the study of embryonic stages of organisms. Embryological studies on vertebrates reveal striking structural similarities among embryos of all vertebrate groups especially in early fetal stages of cleavage and gastrulation as well as in early embryonic stages. This has been summarised as the recapitulation principle which states that **“Ontogeny recapitulates phylogeny”***(Haeckel)***.** This literally means that all vertebrates during their embryonic development repeat the evolutionally trends of their proposed ancestors and indicates a common ancestry for all vertebrates.

However the recapitulation principle does not apply universally as no organism shows all the stages of its proposed ancestor

At comparable stages of vertebrates, their embryos possess the following features

* External branchial grooves (gill pouches) in the pharyngeal region. These in fish form the gill slits involved in gaseous exchange while in other vertebrates form the Eustachian tube and the auditory canal involved in hearing
* Segmental myotomes. These are the muscle blocks that are evident in the tail-like structure that is completely retained in certain speciesonly
* A single circulatory system which includes a two-chambered heart. This is fully retained in the fishes only

Embryological studies have also shown that phylogenetic relationships should not only be decided basing purely on adult homologous structures, the echinoderms have been found to be much more related to chordates than to the non chordates despite the fact that adult echinoderms show no structural resemblance to vertebrates. This is so because both echinoderms and chordates show ***a radial cleavage pattern*** and their blastophore becomes the anus of the adult.Such organisms are called the deuterosomes unlike the protosomes (annelids, mollusks and arthropods) which show ***a spiral cleavage pattern*** and the mouth becomes the mouth of the adult. Echinoderms and chordates therefore share a common immediate ancestor

**Evidence from comparative biochemistry**

The theory of biochemical homology among organisms emerges from biochemical studies like serological tests, x-ray analysis and protein sequence analysis. The ubiquitous occurrence of similar biochemical molecules and metabolic process in a wide range of organisms suggests a common ancestry. The slight differences like amino acid sequence in proteins and differences in DNA base sequence reflect changes due to adaptive radiation

**Examples** of biochemical homology include

* Proteins like cytochromes, haemoglobin, myoglobin and nucleic acids occur in almost all living organisms
* The occurrence of similar hormones like prolactine, adrenaline and thyroxine among all vertebrates

Comparative serology has been oftenly used to establish the level of biochemical affinity (closeness) among organisms. When foreign protein molecules present in the serum are injected into the blood stream of an animal, they act as antigens that stimulate its immune system to synthesise anti bodies against them. If after some time the same sample of serum is added, antibody/antigen interaction occurs resulting into a precipitate which settles and can be measured. If for the second time, serum samples from a variety of animals are added to the senstised blood stream, the degree of precipitation reveals the level of biochemical similarity between these animals to the first one. The higher the level of precipitation is the closer the animal is related to the first animal.

The amounts of precipitate produced by adding human serums from several mammals to a rabbit serum which has been sensitized before by human serum are shown as follows. (Human serum is taken as the reference at 100 %)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mammal | Human | Chimp | Gorilla | Gibbon | Baboon | Spi. monkey | Lemur | HedgH | Pig |
| % | 100 | 97 | 92 | 79 | 75 | 58 | 37 | 17 | 08 |

**Evidence from cell biology**

All forms of living organisms are made of cells which comprise typically of the cell membrane which encloses the protoplasm. The protoplasm comprises of the genetic material (nucleic acids), proteins, lipids, carbohydrates, and ATP as the universal energy currency and organelles like Mitochondria, endoplasmic reticulum and ribosomes appear to be of almost universal occurrence. This strongly supports the view that all living things have had a common ancestry. The slight differences In terms of size, shape and composition show adaptive radiation to different modes of life. Plants for example contain chlorophyll needed for photosynthesis.

**Evidence from classification**

Classification refers to the grouping together of organisms showing similarity in morphological feature. Organisms in the same taxonomic group show many basic similarities and are said to share an immediately recent ancestor, while those in different taxonomic groups show many differences. These can be explained as a result of progressive change to adapt to particular environmental conditions

**Evidence from plant and animal breeding**

In this process, man selects those plants and animals showing x-tics of increased usefulness from their ancestral wild stocks; those members with favourable traits like increased size, resistance to disease etc were artificially bred by selective mating, propagation or pollination. Over time, such traits were perpetuated resulting into a general increase in agricultural yield. Species may arise naturally in the same way by n/s. For example several breeds of pigs like the large white known for a high meat yield have been produced by selective breeding of wild pigs over time.

**NATURAL SELECTION**

*This refers to the process by which those individuals that are physically, behaviorally and physiologically better well adapted to the environment are favored and reproduce more to pass their traits to subsequent generations while those that are less adapted fail to survive or reproduce.*

In evolution**, fitness is defined** as the ability of an organism to pass on its alleles to subsequent generations as compared to other individuals of the same species

During n/s, the intensity of the selection pressure depends on the interaction between population size and environmental resistances like disease, competition, predation, lack of enough light, changes in temperature

**Types of n/s**

*To make talking about this easier, we will consider the distribution of traits across a population in graphical form. In we see the normal bell curve of trait distribution. For example, if we were talking about height as a trait, we would see that without any selection pressure on this trait, the heights of individuals in a population would vary, with most individuals being of an average height and fewer being extremely short or extremely tall. However, when selection pressures act on a trait, this distribution can be altered.*

|  |  |
| --- | --- |
|  | There are three types of n/s; namely:   * Stabilising selection * Directional selection * Disruptive selection |

**Stabilising selection**is the type of n/s that operates when favourable phenotypes coincide with optimum environmental conditions and the selection pressure is not severe. It tends to eliminate the members at the extremes in favour of those that conform more to the mean phenotype. In the process it tends to perpetuate a normal distribution curve with the same mean from generation to generation only that it becomes narrower, hence does not allow for evolutionary change as it ensures phenotypic stability over generations.

Stabilising selection occurs in all populations like in the n/s of wing length in hawks and birth weight in humans. There is an optimum wing length for hawks in adaptation to their modes of feeding, stabilising selection operating through differential reproductive potentials will eliminate those hawks with wing spans smaller or larger than this optimum size.

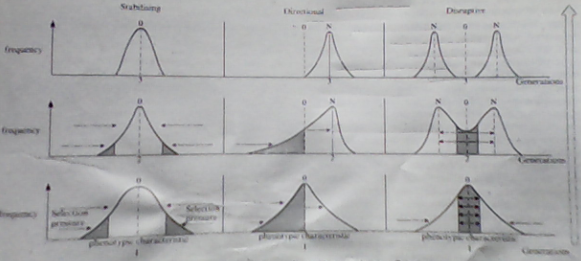
**Directional selection** is the type of selection which acts in response to gradual changes in the environment. It exerts a selection pressure which eliminates the members on one extreme in favour of those at the other extreme, hence pushing the mean phenotype to the other extreme; till the new mean phenotype coincides with the new environmental conditions that stabilising selection tales over to maintain the new mean from generation to generation.

Directional selection favours change in allele frequencies and may lead to evolutionally change and forms the basis for the artificial selection of plants and animals and day to day observations of n/s. Probably when food was in short supply, only the tallest giraffes could reach enough food for survival and only these reproduced to pass their traits, hence gradual development of long necks.

In a series of experiments, D. S. Falconer selectedthe heaviest and the lightest mice at six weeks after birth and let them inbreed separately over several generations. This selective breeding based on mass resulted into two populations with the smallest ones showing a progressive decrease in mass while the heavy ones showed a progressive increase in mass. After termination of the selective breeding, neither of the two groups returned to the mean mass of the original population. This indicates that the artificial selection of phenotypic x-ters led to some genotypic selection that some alleles were lost from each population.

**Disruptive selection** is probably the rarest form of selection but very important in bringing about evolutionary change. It acts in response to fluctuating environmental conditions and severe selection pressure. The selection pressure acts from within the population, eliminating those members closer to the mean phenotype hence pushing the population towards the extremes. This results into splitting the population into two sub-populations and if gene flow is prevented, the two may evolve into different species.

During the evolution of the Galapagos finches, birds with short beaks had an exclusive use of nuts for food while those with long slender beaks had an almost exclusive use of insects. Members with intermediate beaks were probably out competed



**NB:** N/s is important in maintaining fit populations as it ensures survival of fit individuals and eliminates the unfit. However, if the selection pressure is so intense, it tends to reduce genotypic and phenotypic variability of the population making it specialised only to a specific mode of life or environment. This limits the adaptability of the population which increases the likelihood of extinction of such a species in case of environmental change.

Decrease in the intensity of selection pressure, probably due to absence of predators, parasites and competition under optimum environmental conditions allows for increased variability hence the likelihood of adaptive radiation of organisms to occupy different ecological niches. This may with time lead to speciation in case of interrupted gene flow. This probably accounts for the diversity of the Darwin’s finches.

**NB:** Disruptive selection may result into a population expressing two distinct phenotypes; this is referred to as polymorphism

**Polymorphism** refers to the existence of two or more distinct forms of the same species in the same population. Such phenotypes are referred to as **morphs**

The best example is the existence of two forms of peppered moths, the melanic and the normal forms and the existence of different forms of land snail *Cepaeanenoralis.*

There are two types of polymorphism; balanced/stable and transient polymorphism

**Balanced polymorphism** this occurs when different forms co-exist in the same population in a stable environment. The best example is the existence of two sexes in plants and animals, ABO blood groups in man, red-green colour blindness and the existence of workers, drones and queen bees. In such cases,the genotypic frequencies of the various forms exhibit equilibrium because they have a selective advantage of equal intensity. Whilst the genotypic frequencies may vary within the population, they tend to remain constant from generation to generation.

**Transient polymorphism** this arises when different forms or morphs exist in a population undergoing a strong selection pressure, the frequency of the morphs being dependant on the intensity of the selection pressure. It usually applies in situations where one form is gradually being replaced by another for example in the melanic and non-melanic forms of peppered moths

**ARTIFICIAL SELECTION**

By far we have discussed the process by which nature chooses (select) between who to survive or not; Survival can in the same way be as a result of deliberate decision of man, this is referred to as artificial selection.

**Artificial selection** refers to the isolation of natural populations and selective breeding of organisms showing x-tics/traits of usefulness to man by selective mating, pollination or propagation. In the process, humans exert a directional selection pressure resulting into changes in the allele and genotype frequencies of the population; giving rise to new breeds, strains, varieties or sub populations. In all cases, such groups have isolated gene pools but retain the same basic gene and chromosomal structure x-tic of the same species to which they all belong

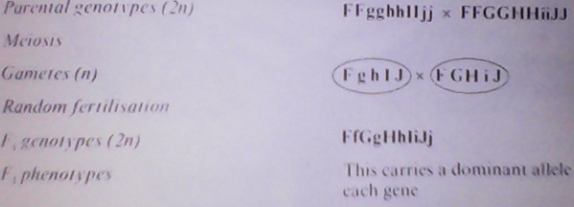
In the process, favourable traits like high meat and milk yield, hardness, disease resistance, fast growth etc are perpetuated. This provides evidence for the occurrence of evln by n/s in the same way.

Artificial selection involves in breeding or out breeding

**In breeding** refers to the selective breeding among closely related organisms, the extreme of which is self fertilization. This is usually aimed at retaining desirable traits in a population. However, prolonged in breeding results into reduction in fertility levels as it tends to increase the extent ofhomozygosity at the expense of heterozygosity hence reducing the variability of the genome (sum/total of all the alleles possessed by an individual). This also reduces the ability of the population to resist diseases and can be solved by resorting to out breeding

**Out breeding** refers to the crossing of unrelated organisms from genetically distinct populations. Out breeding usually result into hybrids with phenotypic x-tics that are superior of either parental stocks; this is referred to as **hybrid vigor (heterosis)**

The increase in hybrid vigor is as a result of increase heterozygosity at the expense of homozygosity due to gene mixing. A given organism may possess some but not all the dominant alleles needed for vigorous growth, the heterozygote produced by out breeding is likely to carry at least a copy of each dominant allele and will be more vigorous than either parents

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**NATURAL SELECTION IN ACTION**

This refers to the day to day observations of n/s.

Examples include the following.

* Insects resistance toinsecticides, like flies and mosquitoes to Dichlorodiphenyltrichloroethane (DDT)
* Pests resistance to pesticides
* Heavy metal tolerance in grass and other plants
* Antibiotic resistance by pathogens e.g. bacteria to penicillin and methycilin

**How does the resistance arise?**

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

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

In the same way; soils near mines are usually devoid of vegetation. This is because such soils contain high concentrations of heavy metals like mercury, lead, zinc and copper which are highly toxic to plant growth. However a few plants like the horsetails are found scattered in such soils which have developed tolerance to such metals. In such plants, mutations occur rendering them ability to trap these metals into 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

**Bacterial populations can easily become resistant because of the same following reasons:**

* They have a haploid DNA such that in case of a mutation, the resistant allele is instantly expressed phenotypically due to absence of the non resistant copy
* They reproduce rapidly by binary fission hence the number of resistant individuals increases so rapidly that soon the whole population becomes resistant.
* Ability of individual bacteria to exchange resistant alleles. This is called **plasmid exchange** leading to a rapid spread of resistance in a population

**NB**: The most important example of n/s in action is illustrated by industrial melanism

**Industrial melanism**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 (*Bistonbetularia)* are known to occur in two phenotypic forms (polymorphic) namely; **Bistonbetulariatypica and Bistonbetulariacarbonaria.** The former are speckled white in colour and are the normal non melanic forms while the latter are melanic mutants and appear darker (almost black). This phenotype is thought to have arisen due to a spontaneous mutation

The peppered moths are known to fly at night and during day they are resting on tree trunks and walls of buildings. They depend on cryptic colouration to camouflage with their backgrounds in effort to prevent predation by birds.

**Explanation**

Originally (before the industrial revolution) due to low pollution levels, the tree barks had a pale appearance due to lichen growth. The light forms could unlike the dark forms camouflage beautifully as their body colour emerged properly with their back grounds, that predators could not easily spot them. These had a selective advantage which rendered them a higher reproductive potential and their numbers increased much more than those of the dark forms which could not emerge well with a pale background. Predators could easily spot them for food which kept their numbers very low.

Following the industrial revolution, the air pollution resulted into killing of the lichens and backgrounds were further darkened by smoke. In such conditions, the dark forms could more easily camouflage than 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 favor of the dark forms. Over time, the relative numbers of the dark forms increased gradually while those of the light forms decreased; this is referred to as **industrial melanism.**

It is also a good illustration of transient polymorphism. The two forms can still interbreed successfully and are therefore of the same species.

**POPULATION GENETICS**

Population genetics is the branch of biology that deals &provides the mathematical structure for the study of microevolutionary process

**Microevolution** refers to the change in the allele frequencies that occur within a population over time. Mainly due to mutations, genetic drift, gene flow, selection (natural and artificial), gene flow for example industrial melanism, microevolution of resistance to antibiotics, pesticides etc.

**Macroevolution** refers to evolutionary changes at a level higher than the species level, resulting into formation of a higher taxonomic group such as class or genus.

Some biologists believe that macroevolution results from a build-up of small changes due to microevolution. One common **misconception** about evolution is thatindividual organisms evolve. It is true that naturalselection *acts* on phenotypic x-tics of individuals to determine the fate of genotype. Each organism's combinationof traits affects its survival and reproductive successcompared to other individuals;it’s only those individuals that can reproduce successfully before death that contribute to the future species. But the evolutionaryimpact of natural selection is only apparent in the changesin a *population* of organisms over time, for this reason; **though individual organisms are acted upon by n/s, its populations that evolve but not individuals.The population is the smallest unit of evolution.**

**TERMS USED:**

**A population** is a group of organisms of the same species living together in a given habitat at a given time

**A species** refers to a group of organisms which can interbreed successfully to produce fertile off springs

**Gene pool;** Refers to 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 said to be undergoing evolutionary change.

**NB: A static gene pool** is one where genetic variation is inadequate to bring about evolutionary change

**Gene flow** is the movement of alleles from one population to another as a result of interbreeding among members of the two populations. Alleles are known to flow from a donor population into the recipient population

**Genetic load;**this refers to the existence of disadvantageous alleles in heterozygous genotypes within a population

Very many disadvantageous alleles are able to exist in populations in heterozygous forms as in this form they are rarely expressed phenotypically for possible elimination by environmental selection, for example albinism, colour blindness, sickle-cell anaemiaetc

The maintainance of fairly high frequencies of a recessive allele which may be potentially hazardous in a homozygous recessive state is referred to as the **heterozygous advantage**

The most obvious example is illustrated by the sickle-cell trait.

**Sickle-cell trait** is a condition when an individual has one copy of the normal allele for hemoglobin production and a recessive allele for abnormal hemoglobin. Such heterozygotes/carriers have both normal and sickle-shaped red blood cells and this is referred to as sickle-cell trait.

Sickle-cell carriers have consistently shown a high resistance to malaria much more than both the normal and the sick. This therefore confers a selective advantage to the heterozygotes leading to consistently high frequencies of the sickle cell allele especially in such areas as the tropics where malaria is prevalent.

**Explanation** The carriers have both normal and sickle-shaped red blood cells, the former contain very low levels of oxygen due to abnormal hemoglobin while the latter contain high oxygen levels. This makes it difficult for the plasmodia parasites to survive in the low oxygen environments in sickle cells and to adapt to constantly changing oxygen contents. Some of them die while others are effectively eliminated by the body defence system before establishment of the disease leading to resistance

**Allele frequency** refers to the total number of copies of a given allele expressed as a percentage of the total number of alleles for that gene in a population.

For example in human beings, production of body pigments is determined by a dominant allele while the recessive allele results into no pigment production (albinism). The frequencies of the dominant and recessive alleles are 99% and 01% respectively. Since the total percentage is 100%; 99 + 01 = 100. However, frequencies in population genetics are usually represented as decimals rather than percentages or fractions,

→ 0.99 + 0.01 = 1.00.

Mathematically; if we let **p** and **q** to represent the dominant and recessive allele frequencies respectively, then **p + q = 1…………………………………………………………………… (I)**

From equation (i) above; if the allele frequency of either allele is known, the allele frequency of the other can be determined. E.g. If the allele frequency of the recessive allele is 25%,

Then q = 0.25. Using p + q = 1, p = 0.75.

**Genotype frequency** refers to the total number of individuals carrying a particular genotype expressed as a percentage of the total population.

In most populations, it’s only possible to estimate the frequency of two alleles in a homozygous recessive state as this is the only genotype which can be directly observed phenotypically. E.g. 1 person in 10000 is albino. Albinism is known to be a recessive character, for the person to be an albino, they must be possessing two copies of the defective allele (homozygous recessive).

**Hardy-Weinberg equation** is a mathematical relationship between the frequencies of alleles and genotypes in a population. This can be used to calculate genetic changes in populations.

Considering a population with a certain gene occurring in two allelic forms, one homozygous for a dominant allele **A** and the other for a recessive allele **a**; all the F1 off springs will be heterozygous (**Aa**)

From equation 1 above, the frequency (probability) of A = p while that of a = q. The results from a cross between two F1 organisms would be as follows.

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From the above cross, it becomes obvious that the F2 genotypes can be expressed in terms of p and q such that p2 = homozygous dominant genotype, q2 = homozygous recessive genotype and 2pq = heterozygous genotypes. But since total probability is equal to 1, then p2 + 2pq + q2 = 1.

**In summary (equations and definition of symbols)**

Examples

1. 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

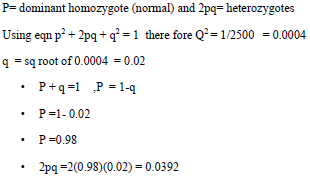
ii) Calculate the allele frequency of t and T

iii) Calculate the genotype frequency

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1. In a Caucasian population, the frequency of individuals affected by cystic fibrosis is **approximately 1 in 2500.** This is a recessive disorder and affected individuals are homozygotes. If q represents allele frequency of the disease, find the frequency of dominant homozygotes and heterozygotes

**Answers**

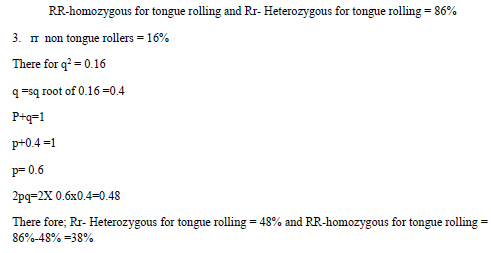
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1. In a human population the gene responsible for tongue rolling is dominant over the gene for non tongue rollers. The population of tongue roller is 84% and non tongue roller is 16%.

Find the percentage of individuals, who are,

1. Homozygous for tongue rolling

2. Heterozygous for tongue rolling



**HARDY-WEINBERG’S PRINCIPLE**

It states that **“The allele and genotype frequency of a large sexually reproducing population remains constant from generation to generation provided that disruptive factors like mutation and selection do not act”**

The gene pool of such a population remains static and the population is said to be in Hardy-Weinberg equilibrium, it cannot undergo evolutionary change.

For this principle to hold, the following factors must be fulfilled:

* Provided the population is sufficiently large that no genetic drift occurs
* Mating should be random such that no sex selection occurs
* There should be no gene flow
* All genotypes should be equally fertile such that there is no genetic load
* No mutations should occur as these tend to increase genetic diversity
* Provided generations do not overlap
* There should be no emigration or immigration
* Natural selection should not act, as this would favour some genotypes over others

NB: In prevalence of the above factors, the frequencies of all alleles and genotypes will remain constant over generations. In case all or at least one of the above factors is reversed, the frequencies are prone to change and the stability of the population is upset. This initiates evolutionary change.

**FACTORS RESPONSIBLE FOR CHANGES IN ALLELE FREQUENCIES OF THE POPULATION**

**N/s,** This tends to favour those 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**.**

**Gene flow,**it refers tothe movement of alleles from one population to another as a result of interbreeding among the members of the two populations. This results into introduction of new alleles hence from other populations leading to change in the allele frequencies of the population. However, gene flow is said to be conservative to evolutionary change in the long run. It tends to ensure uniform distribution of alleles in all populations which reduces genetic variation and increases uniformity among organisms as all populations share a common gene pool, this limits the action of n/s. For this reason, interrupting gene flow is a prerequisite to evolutionary change and speciation.

**Mutations,** *Mutations* are random occurrences which change the genetic constitution of organisms. They greatly increase genetic diversity, where advantageous mutations are favoured by natural selection and disadvantageous ones are phased out.

**Non-Random Mating,** this occurs when there is sexual selection (a mechanism on non-random mating). It occurs when the presence of one or more inherited characteristics increases the likelihood of successful fertilization. In such cases, only organisms having certain characteristics will have high chances of reproducing hence passing on their traits to next generations, while those without such features will have reduced reproductive potentials. Only some alleles will be passed to next generation leading to change in their frequencies

Examples include eye colour in drosophila (females prefer red-eyed males), colour patterns in insects and birds, petal size and colour in flowers etc.

**Genetic drift**

This refers to the change in the gene frequencies within a population as a result of chance rather than by n/s

Although chance events occur in populations of all sizes, they alter allele frequencies substantially only in small populations

A small population may become isolated from a large population and it may not be truly representative of the original population in terms of allele and genotype frequencies, some alleles may be absent while others may be disproportionally represented. Continuous breeding in the small pioneer population results into loss of some alleles, increase or decrease in the frequencies of other alleles just by chance. In the process, a gene pool that is atypical of the parent population will be produced, this is known as the **founder effect (**as it occurs in the founder population).

In the same way, a sudden change in the environment, (such as a fire or flood) may drastically reduce the size of a population, just by chance, certain alleles may be overrepresented among the survivors, others may be underrepresented, and some may be absent altogether. Ongoing genetic drift is likely to bring about changes in the allele frequencies of the population and may result into a gene pool that is different from the original population. This is referred to as the **bottleneck effect,** (named so because the population passed through a restricted path

Random genetic drift may lead to the following;

* Total loss of some alleles from the population, due to death of the few individuals carrying such alleles
* Total extinction of the population
* The population becoming much better adapted to the environment
* Wide divergence of the population from the parent population, and all these occur just by chance rather than n/s.

**SPECIATION**

This is the process by which new species may arise from pre-existing species.

***Intraspecific speciation*** is when a single species gives rise to new species. If this occurs when the whole population is occupying the same geographical area, its referred to as **sympatric** speciation whilst **allopatric speciation** occurs when the populations are occupying geographical isolated habitats In some cases, commonly in flowering plants, two species may give rise to a new species; this is known as ***interspecific hybridisation.***

***ALLOPATRIC SPECIATION***

This is the type of intraspecific speciation which occurs as a result of spatial separation of a population into two subpopulations, usually due to geographical barriers like mountain ranges, seas, rivers or differences in habitat preferences. This prevents interbreeding among the individuals of the two subpopulations leading to reproductive isolation and interrupts gene flow. Due to continuous n/s, 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. 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

***SYMPATRIC SPECIATION***

This is the type of sympatric speciation that occurs when all members of the population are occupying the same geographical area. It usually occurs following a short term period of allopatric/geographical isolation which results into accumulation of reproductively isolating traits among the individuals. This interrupts gene flow leading to genetic 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 n/s; leading to formation of races and subspecies. If genetic isolation persists over a long period of time, these may gradually evolve into different species, this is referred to as sympatric speciation.

**ISOLATING MECHANISMS**

***An isolating mechanism*** is a means of producing and maintaining reproductive isolation within a population. They are often called ***reproductive isolation mechanisms***

***Reproductive isolation*** refers to the existence of biological factors (barriers) that impede members of the same or different species from interbreeding successfully

Isolating mechanisms are classified as **prezygotic** mechanisms (Which are barriers to formation of hybrids) or **postzygotic** mechanisms (barriers that prevent hybrids from reproducing)

***Prezygotic isolating*** mechanisms include the following

Seasonal isolation; Occurs when two species mate or flower at different times of the year. Eg*Pinusradiata*in February and *Pinusattenuata*in April

* ***Ecological isolation***; occur when two species inhabit similar regions but have different habitat preferences within that same area. Such species can meet only very rarely if at all. *Viola arvensis*grows on Calcareous soils and *Viola tricolor* on acidic soil, in the same way one of the species may be more of aquatic yet the other prefers terrestrial habitats
* ***Behavioral isolation***: occurs where animals exhibit courtship patterns, mating only results if the courtship behavior displayed by one sex is accepted or interpreted by another. (colour and marking on members of the opposite sex) E.g.Darwin’s finches.
* ***Mechanical isolation***; occurs in animals where morphological differences prevent successful mating and in plants where related species of flowers are pollinated by different animals

All the 4 above prezygotic isolation mechanisms (prevent mating or fertilization)

* ***Gametes from different*** species may also be prevented from meeting even when mating has taken place. For instance, sperm may not be able to survive in the reproductive tract of females of the other species, or biochemical mechanisms may prevent the sperm from penetrating the membrane surrounding the other species' eggs.

***Post zygotic mechanism*** (barriers that occur after fertilization)

* ***Hybrid inviability***; this is when the produced hybrids are unable to survive to reproductive maturity. The genes of different parent species may interact in ways that impair the hybrid's development or survival in its environment. Sometimes development of embryo may not occur after fertilization
* ***Hybrid sterility***: This is when hybrids are viable but fail to produce functional gametes and are therefore infertile. This is becausethechromosomes of the twoparent species differ in numberor structure, that they cannot allow for complete pairing of chromosomes during meiosis e.g. the mule (2n =63) results from a horse 2n=60 and donkey (2n=66)

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* ***Hybrid breakdown***: The F1 hybrids are fertile but the F2 hybrids and their back crosses are infertile E.g. hybrid formed between sp of cotton

**INTERSPECIFIC HYBRIDISATION**

This is a form of sympatric speciation which occurs when a new species is produced by the crossing of individuals from two unrelated species. It is common in plant breeding and most hybrids are infertile but can reproduce asexually, though allopolyploidy may result into production of fertile off springs due to non-disjunction.

