History and Mechanism of Evolution - Part 5

Objectives

After going through this lesson, the learners will be able to understand the following:

- Population genetics and its role in evolution.
- Hardy Weinberg equilibrium.
- Founder's effect and bottleneck effect.
- The geological time scale
- Brief history of evolution across geological time scale
- Evolution of plants

Content Outline

- Introduction
- Population Genetics & Evolution
- Founders Effect
- Bottleneck Effect
- Geological Time Scale
- Brief History of Evolution
- Evolution of Plants

Introduction

How variations occur and what is the basis of speciation? Initially Mendel had talked of inheritable 'factors' which lead to phenotypic expression. In the first decade of twentieth century, Hugo de Vries based on his work on evening primrose brought forth the idea of mutations-the changing of the structure of a gene, resulting in a variant form, which may be transmitted to subsequent generations, caused by the alteration of single base units in DNA, or the deletion, insertion, or rearrangement of larger sections of genes or chromosomes. He believed that it is mutation which causes evolution and not the minor variations (heritable) that Darwin had talked about initially. Mutations are random and directionless while Darwinian variations are small and directional. Evolution for Darwin was gradual while de Vries believed in single step large mutation. Studies in population genetics, later, brought out some clarity. In this module we try to understand various mechanism through which evolution manifest itself within population genetics i.e. Hardy Weinberg's equation, Bottleneck effect and founders effect, along with that we would also briefly study evolution of various life forms along with the geological time scale.

Population Genetics & Evolution

A population is defined as a group of individuals that belong to the same species and occupy the same area at a particular time. Evolution with the population takes place when the relative frequency of variations changes overtime. For Example there are two forms of proteins in a population, evolution occurs only when there is a change in the number of individuals possessing either of the forms of proteins. The number of individuals can either increase or decrease. The individuals of the population interbreed with each other the study of the properties of genes in the population is known as population genetics. The frequencies of genes in the population are analyzed under the study. The knowledge of Mendelian Genetics is applied to Darwinian natural selection.

Hardy Weinberg Equilibrium or Principal

In 1982 scientist Godfrey Edge Hardy and English mathematician and Wilhelm Weinberg, a German physician independently revealed the mathematical relationship between genotypes in the allele frequency. This formulation was later known as Hardy Weinberg principle; this principle plays the decisive role in understanding population genetics; it gives an idea of the inheritance of gene sequences from one generation to the other under a given set of specific sets of assumptions. They observed that the hereditary conservation of DNA is the characteristic feature of a population.

According to Hardy Weinberg in a large randomly breeding population the allelic frequencies of sexually reproducing organism will remain constant from generation to generation under certain constant conditions. In other words, the frequency of particular genes and alleles tend to remain constant in a population for many generations under certain constant conditions. The population that adopts static conditions and is non evolving at the genetic level. This stability at a genetic level is termed as genetic equilibrium for genetic inertia as the gene pool tends to remain constant for generations together.

According to Hardy Weinberg equilibrium in order to maintain the equilibrium in population when there is no evolution the following conditions have to be met.

- No mutation should occur so that new alleles are not introduced in the population even if the mutation occurs it should not happen at the same rate in both directions.
- No gene flow should occur through the Migration of individuals into or out of the population.
- Random meetings must occur between individuals of the population.
- The population must be large enough so that there is no change in the allele frequency due to genetic drift.
- All the genes have an equal chance to get transmitted to the next generation. No selection should happen, that is genes or alleles should not be selected for or against.

As proportions of genotypes do not change they are known as Hardy-Weinberg equilibrium.

Hardy Weinberg Equation

Hardy Weinberg principle is written in the form of equations in Algebraic terms. Through this law we have been able to explain why the population as a whole with all its variations and genotype frequencies continue to remain unchanged for many generations Mendelian Genetic variations in Hardy Weinberg equation are put together as.

Assuming that a gene has two alleles 'A' and 'a' an if 'p' is the frequency of occurrence of dominant allele 'A' & 'q' is the frequency of occurrence of recessive alleles 'a' in the parental generation then the genotype frequency is expected in the offspring as per Hardy Weinberg equation are represented as:($(p+q)^2 = p^2 + 2pq + q^2 = 1$ = gene frequency of the total population, where p^2 = frequency of occurrence of homozygous dominant alleles(AA), 2 pq=frequency of occurrence of individuals with heterozygous individual (Aa), q^2 frequency of occurrence of individuals with homozygous recessive alleles (aa).

Application of Hardy Weinberg principle

Since in real life conditions like no mutation, no genetic drift is not possible, still Hardy Weinberg principle is very significant as it provides a simple method to analyze whether evolution is taking place. When gene sequences remain constant over several generations it indicates that evolution is not taking place and change in gene frequencies indicate that evolution is in progress thus the Hardy-Weinberg principle helps scientists to determine the degree of evolutionary change.

Factors Affecting Hardy Weinberg Equation

Evolutionary forces like mutation, recombination, gene flow/gene migration can bring about change in gene frequencies such forces can lead to deviations from Hardy Weinberg equilibrium and triggers the process of evolution

- **Mutations-** the changes in the DNA can alter one allele to another, leading to change in particularly alleles in a population.Though mutation rates are very low this still act as a source of genetic variation and is one of the driving force behind evolutionary process.Mutation helps in creation and maintenance of variation in population mutation act as a source of new genes in a gene pool which later leads to speciation

- **Recombination-** Sexual reproduction involves gametogenesis followed by fertilization this leads to recombination of genetic material. Reshuffling of genes provides a new combination of genes and alleles. During sexual reproduction independent assortment of chromosome occurs during crossing over, and random fertilization brings about recombination.

- **Gene Flow/Gene Migration-** The movement of alleles from one population to another population is known as gene flow. This may be due to movement of animals out of the population that is emigration and entry of a new member into a population also called as immigration the characteristics introduced about by the new member brings about changes in the local gene pool.

- **Non–Random breeding-** For Hardy-Weinberg to be true individuals within a population must choose their mate randomly without respect to their phenotype is the phenotype influences made selection then the genotypes and phenotypes of the population will be changed as well if the non random mating selects individual that are similar for mates then the offspring will have increased prevalence of homozygous as Hardy Weinberg would predict self fertilization in plants has just this effect reducing heterozygotes and increasing homozygous

- **Natural selection-** Microbial experiments show that pre-existing advantageous mutations when selected will result in observation of new phenotypes. Over a few generations, this would result in Speciation. Natural selection is a process in which heritable variations enabling better survival are enabled to reproduce and leave a greater number of progeny. A critical analysis makes us believe that variation due to mutation or variation due to recombination during gametogenesis, or due to gene flow or genetic drift results in changed frequency of genes and alleles in future generation. Coupled to enhance reproductive success, natural selection makes it look like a different population. Natural selection can lead to stabilisation (in which more individuals acquire mean character value), directional change (more individuals acquire value other than the mean character value) or disruption (more individuals acquire peripheral character value at both ends of the distribution curve).

The Founder's Effect

In population genetics, the founder effect is the loss of genetic variation that occurs when a new population is established by a very small number of individuals from a larger population. These few individuals disperse and become the founders of new isolated population at some distance away from their native place these individuals are known as pioneers or founders they do not usually carry all the alleles present in the source population some alleles present in the original population might also get lost and others might change drastically in the new population from by the pioneers.The new population as make the organism better adapted to the new environment this phenomena is known as the Founder effect.

Bottleneck Effect

Even if organisms do not move from place to place occasionally the population may be drastically reduced in size this may be due to enamel disturbances like flood and drought epidemic disease another natural forces just you surviving individual in a constitutive and the genetic sample of the original population the resulting alterations and loss of genetic variability has been termed as bottleneck effect.

In a bottleneck a population is reduced to a small number perhaps true disease natural disaster or over hunting the individuals left to reproduce but the following generations reflect the gene pool of the individual that survived the bottleneck not the larger population that existed before as an example if a jar contains a mixture of 1000 black and 200 white marbles representing alleles in a gene pool how to which a person randomly selects 10 marbles the 10 marbles are not likely to represent the exact proportions in the original pool is the choice contains 5 lakh and 5 white marbles then future marble generation's reflect the new allele frequency in the marble.

Northern elephant seals have reduced genetic variation probably because of a population bottleneck humans inflicted on them in the 1890s. Hunting reduced their population size to as few as 20 individuals at the end of the 19th century. Their population has since rebounded to over 30,000 — but their genes still carry the marks of this bottleneck: they have much less genetic variation than a population of southern elephant seals that was not so intensely hunted.

The Geological Time Scale

In order to represent evolutionary time, evolutionary biologists use the geological time scale. The geological time scale has been made initially by studying the various fossil records found in the earth rocks, however later due to development of radioactive dating technology scientists were able to find the age of rocks and fossils with better precision which helped in dividing the earth's history into Eras and periods. Geologists have divided Earth's fossil history into 4 major eras, i.e., Pre-Cambrian, Paleozoic, Mesozoic and Cenozoic.

- **The Pre-Cambrian Era-** The first prokaryotic cells evolved about 4 billion years ago followed by eukaryotes about 2.5 billion years ago. The Pre-Cambrian era comprises the largest time span in earth's history. During this time simple anaerobic forms of life appeared and were followed by photosynthetic forms which added oxygen to the atmosphere. However, in the pre-Cambrian era which is about 600 million years ago most multicellular organisms were found in the sea like the planktons and some protists who fed on prokaryotes and planktons. Most of the organisms during the pre-Cambrian era had soft bodies. The oldest fossil evidence of complex life comes from the Lantian formation, at least 580 million years ago. A quite diverse collection of soft-bodied forms is known from a variety of locations worldwide between 542 and 600 Ma. These are referred to as Ediacaran or Vendian biota.

- **The Paleozoic Era-** the first period of Paleozoic era was the Cambrian period lasting from (541 million years ago to 485.4 million years ago) due to increased level of oxygen there was a sudden spurt in formation of variety of multicellular lifeforms often termed as Cambrian Explosion. Rich fossil deposits have been discovered in various parts of the world which reveals the first representative of all major groups of organisms that are found on earth today. However most of the forms did not survive but some evolved to form diverse body plans which later got selected under the influence of Natural Selection. The Cambrian period was followed by the Ordovician Period which lasted almost 45 million years, beginning 488.3 million years ago and ending 443.7 million years ago. This period is fossils of trilobites, conodonts. In addition, blastoids, bryozoans, corals, crinoids, as well as many kinds of brachiopods, snails, clams, and cephalopods appeared for the first time in the geologic record in tropical Ordovician environments, also it was the first time when plants colonized land for the first time. This period is also known for the first ever mass extinctions due to glaciation. The Ordovician period is followed by the Silurian period (440-410 Million years ago) some ocean animals survived the mass extinction and first terrestrial animals appeared, arthropods appeared. In the Devonian period fish forms diversified and many life forms evolved on land with the formation of first Gymnosperms and first amphibians, the Devonian period marked another mass extinction. The Devonian period was followed by carboniferous period (360-290 Million years ago) in this period evolved winged insects and reptiles from amphibians. The Permian period (290-245 mya) saw the evolution of many reptile forms.

- **The Mesozoic Era-** The Mesozoic era began about 245 mya and lasted about 180 million years. The Mesozoic era has been divided into three major periods i.e. Triassic, Jurassic and Cretaceous. The reptiles continuously evolved during Triassic period (245-190 mya) with gymnosperms being the dominant plant life on terrestrial environments, the Jurassic era (195-138 mya) it was the age of the dinosaurs however many small mammals and bony fishes evolved during this time. In the Cretaceous period flowering plants or the angiosperms evolved. The Mesozoic era also ended with mass extinction of large land vertebrates including the dinosaurs.

- **The Cenozoic Era-** The earth's most recent era is the Cenozoic era which began about 65 mya and continues to the present. The cenozoic era has been divided into two periods Tertiary period (65-1.8 million years ago) and Quaternary (1.8 million year ago – present) the small mammals that survived the mass extinctions due to meteor impact later evolved into variety of life forms on the land thus this era is also known as the Age of Mammals. It was the time that saw birds and reptiles evolve more into modern forms. The quaternary period began about 2 million years ago till present.

Brief History of Evolution

Evolution of major groups of plants about 2000 million years ago (mya) the first cellular forms of life appeared on earth. The mechanism of how non-cellular aggregates of giant macromolecules could evolve into cells with membranous envelopes is not known. Some of these cells had the ability to release O2. The reaction could have been similar to the light reaction in photosynthesis where water is split with the help of solar energy captured and channelised by appropriate light harvesting pigments. Slowly single-celled organisms become multicellular life forms. By the time of 500 mya, invertebrates were formed and active. Jawless fish probably evolved around 350 mya. Sea weeds and few plants existed probably around 320 mya. We are told that the first organisms that invaded land were plants. They were widespread on land when animals invaded land. Fish with stout and strong fins could move on land and go back to water. This was about 350 mya. In1938, a fish caught in South Africa happened to be a Coelacanth which was thought to be extinct. These animals called lobe fins evolved into the first amphibians that lived on both land and water. There are no specimens of these left with us. However, these were ancestors of modern day frogs and salamanders. The amphibians evolved into reptiles. They lay thick shelled eggs which do not dry up in sun unlike those of amphibians. Again we only see their modern day descendents, the turtles, tortoises and crocodiles. In the next 200 million years or so, reptiles of different representative evolutionary history of vertebrates through geological periods shapes and sizes dominated on earth. Giant ferns (pteridophytes) were present but they all fell to form coal deposits slowly. Some of these land reptiles went back into water to evolve into fish like reptiles, probably 200 mya (e.g. *Ichthyosaurs*). The land reptiles were, of course, the dinosaurs. The biggest of them, i.e *Tyrannosaurus rex* was about 20 feet in height and had huge fearsome dagger like teeth. About 65 mya, the dinosaurs suddenly disappeared from the earth. We do not know the true reason. Some say climatic changes killed them. Some say most of them evolved into birds. The truth may live in between. Small sized reptiles of that era still exist today.

The first mammals were like shrews. Their fossils are small sized. Mammals were viviparous and protected their unborn young inside the mother's body. Mammals were more intelligent in sensing and avoiding danger at least. When reptiles came down mammals took over this earth. There were in South America mammals resembling horse, hippopotamus, bear, rabbit, etc. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna. Due to the same continental drift pouched mammals of Australia survived because of lack of competition from any other mammal. Lest we forget, some mammals live wholly in water. Whales, dolphins, seals and sea cows are some examples. Evolution of horse, elephant, dog, etc, are special stories of evolution.

Evolution of Major Groups of Plants

Plants are known to have evolved from a class of freshwater green algae called the charophytes, since they resemble bryophytes in many ways. Plants are classified into two main groups: the bryophytes (nonvascular plants) and the tracheophytes (vascular plants). The first land plant bryophytes evolved during the Devonian period (409-354 million years ago) as stomata first appeared in hornworts and mosses however moses also have food conducting (leptoids) and water-conducting cells (hydroids) that were similar to phloem and xylem of vascular plants thus it is believed that vascular plants most likely evolved from mosses. The first detailed vascular plant fossils appear in rocks from the middle Silurian, about 425 million years ago. The oldest of these, including a plant called *Aglaophyton.* These plants developed mechanisms to synthesize lignin and a better system of transporting food and water allowed them to grow in drier regions. The first appearance of tracheophytes occurred in the Silurian period, the fossil record shows three major evolutionary transitions. The first such transition occurred in the late Devonian, approximately 375 million years ago, this time the most common plants were simple, seedless vascular plants in various phyla, several of which are now extinct. However, one class from this time, the Psilophyta, still has two living genera one being *Psilotum.*From the late Devonian until the end of the

Carboniferous period (290 million years ago) large and complex seedless plants were dominant.

The second major transition was the decline of the lycophytes, sphenophytes, and pterophytes at the end of the Carboniferous and their replacement by gymnosperms in the early Permian period. The evolution of seeds, with their hard protective coats, was certainly an important factor in the success of gymnosperms. Gymnosperms dominated the vegetation on the earth for the next 200 million years until they themselves began to decline and were replaced by better adapted angiosperms in the middle of the Cretaceous period. The primitive known angiosperms were a diverse group of plants called magnoliids. Some of these were herbs with simple flowers; others were woody plants with more complex flowers that were very similar to living magnolias. Magnolias, probably those with small, inconspicuous flowers, gave rise to the two main groups of angiosperms, monocots and eudicots. The presence of vascular tissues, protective seed coat, leaves resistant to desiccation, and being pollinated by insects made angiosperms hugely successful also being pollinated by insects led to coevolution of plants along with their pollinators, which led to increasing specialization of both flowers and insects.

Summary

Thus there are different mechanisms of evolution where knowledge of mendelian genetics is directly applicable, one such principle is the Hardy-Weinberg’s equation which reveals relationship between genotypes in the allele frequency, however there are many factors that may affect Hardy–Weinberg's Equilibrium including Gene flow, Genetic Drift, Natural selection etc. Concepts of population genetics like the Founder’s effect and Bottleneck effect have a lot of applications in evolutionary mechanisms. In order to study evolution, evolutionary biologists use the geological time scale to map the origin of various species and try to create a link between diversified biological life.