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Chapter 1

Emergence of Evolutionary Thoughts

The term **evolution** comes from the Latin word *evolvere*, meaning "to unfold or unroll" i.e., to reveal or manifest hidden potentialities. But, today "**evolution**" has come to mean, simply a synonym for "change." Thus, evolution is the change in terms of '**form**' and '**behavior**' of organisms between generations. The term forms of organisms can refer to all levels from DNA sequences to macroscopic morphology while social behavior can be modified from ancestors to successive generation during evolution.

1.1 Biological (Organic) evolution

Biological evolution is **change** in the properties of groups of organisms (population) over the course of generations. Groups of organisms undergo differentiation and subsequent modifications and thus get different from their ancestors. Various changes accumulate in individuals which ultimately result into divergence of it from rest of population. In true sense, **genes mutate, individuals are selected** and **population evolve**. Thus, the unit of evolution is **population**. Some evolutionary changes occur in short time, while some other takes longer time to persist in populations. Good example to this is given by the **short term evolution** occurred in plant and animal breeding experiments by agriculturalists and antibiotic resistance among disease causing microbes. Other changes, such as the appearance of new species and evolutionary lineages, usually take place over much longer time frames. The **fossil record** is the primary source of direct evidence of such **long term** changes.

Evolutionary biology has been of great interests for many philosophers since long time. A number of Greek philosophers had ideas about the gradual evolution of life.

- **Plato** (427-347 B.C.) and his student **Aristotle** (384-322 B.C.) were influenced by western culture, they believed that species are permanently fixed in the form as they are; they remain unchanged and do not evolve. In their **theory of essentialism** they considered that variations that are seen within individual organisms are accidental imperfections.
- **Anaximander** (611-547 BC) proposed the **theory of spontaneous generation** or the **theory of abiogenesis**. The theory said that living organisms could arise from nonliving matter. It was supported by Plato, Aristotle, and Van Helmont.
- **Father Suarez** (1548-1617) was the greatest supporter of the **theory of special creation**. This theory concluded that each species had been created individually by 'God' in the same form as they are at present. Creationism is rejected by evolutionary biologists because it offers no explanation about the origin of adaptation
- **Francesco Redi** (1626-1698) proposed the **theory of biogenesis**. The theory states that living things can only arise from living things and are not spontaneously generated. It was supported by **Spallanzani** and **Louis Pasteur**.
- **Carl Linnaeus (1707-1778)** because of his work in the development the system of binomial nomenclature, the Swedish botanist is known as the "**Father of Taxonomy**". He did not believe in evolution but believed in separate creation and the fixity of species. His systematic methods for classification of organisms are still used to develop phylogenetic trees .
- **George Cuvier (1769-1832)**: He proposed the **theory of Catastrophism** and regarded as "**father of paleontology**". According to Cuvier's theory, Earth's geology and natural history have been shaped by periods of catastrophic extinction and new creations He believed that catastrophes removes most of the populations and remaining organisms repopulate to expand life on earth. This repopulation is the major cause of appearance of changes in organisms. He was a vertebrate zoologist and used **comparative anatomy** to classify animals.
- **James Hutton (1726- 1797)**—according to Hutton's **Uniformation Theory of Geology**, the earth is not static. In 1790s Hutton argued that the earth was transformed not by unimaginable catastrophes but by gradual slow changes. Mountains are eroded by rainfall while molten rocks come out in the form of lava and settle to form rocks after cooling. During rock formation, life forms get deposited in layers which became fossils in the so formed sedimentary rock. Though these changes are tiny, but get accumulated over time that result into divergence.
- **Charles Lyell (1796-1875)**—He put forth the **principles of Geology** which supported the Hutton's theory of uniformation. According to principles of Geology processes that alter the earth are uniform through time

- **Alfred Wegener (1880-1930)** - The German meteorologist and geophysicist proposed the **Theory of Continental Drift** in 1915. His theory proposed that the continents were joined initially and got drifted apart over past 300 million year time. He found the fossils of same species of fresh water reptiles in Africa and South America. It was a major piece of evidence supporting his theory on the continental drift.
- **Thomas Malthus (1766-1834)** - Malthus published an **Essay on the principles of population** in 1798. In his essay he proposed that death and famine were inevitable because the human population tended to increase faster than the supply of food. This essay influenced Darwin greatly and was used in his formulation of the Theory of Natural Selection.

Before 18th century the species concept stated that species appear in the form as they are, even at time of their origin. With the emergence of 18th century, theories of Lamarck and Darwin changed the concept of fixity of species. A comprehensive model was given by both that explains how does the transformation of species occurs i.e., how one species evolves into another.

1.2 Lamarckism

Jean-Baptiste Lamarck (1744- 1829), a French naturalist was incharge of the invertebrate collection at the Natural History Museum in Paris. In 1809 (the year Darwin was born), in his now famous *Philosophie zoologique*, Lamarck set out this idea more systematically and his ideas are referred by the word “**transformism**”.

1.2.1 Main postulates of Lamarckism:

1. **Internal vital forces:** Lamarck believed that every organism has some internal vital forces (will power) and he can develop new structures/organs according voluntarily.
2. **Environment fluctuation and new needs:** The nature of environment is dynamic and changes over time. Whenever it changes, it becomes adverse for the existing life forms and thus desires new needs. To fulfill new demands, an organism develops new organs or appendages by using its internal vital forces to curse the environmental changes.
3. **Use and Disuse of organs:** In every animal that has not reached the end of its development, the more frequent and sustained use of any organ will strengthen this organ little by little, develop it, enlarge it, and give to it a **power** proportionate to the duration of its **use**; while the constant **disuse** of such an organ will insensibly

weaken it, deteriorate it, progressively diminish its faculties, and finally cause it to disappear. Thus, according to Lamarck, an organ gets well developed if being constantly used. Those organs that are not used often undergo degeneration over time.

4. **Inheritance of acquired characters (Soft Inheritance):** Organisms developed certain characters during the life time due to internal vital forces, environment changes and use and disuse of an organ, organism acquires new organs/characters. Such acquired characters are inherited to next generation and after inheritance of such characters through successive generation give rise to generation of new species. He called this property as **inheritance of acquired characters**.

Lamarck came to a conclusion that, because of their different needs, species differ from each other. Organs or appendages needed to perform the specialized functions of the species are used more frequently and thus get well developed than the others. More of the so called “**nervous fluid**” is attracted to these organs and direct the growth and development of those, resulting in their enlargement.

Differences between Lamarckian conception of evolution, and Darwinian (and the modern concept) are represented diagrammatically in **figure 1**.

According to Lamarck, lineages of species persisted indefinitely, changing from one form into another; lineages in his system did not branch and did not go extinct. Lamarck believes that evolution is **goal directed** and **moves toward perfections**.

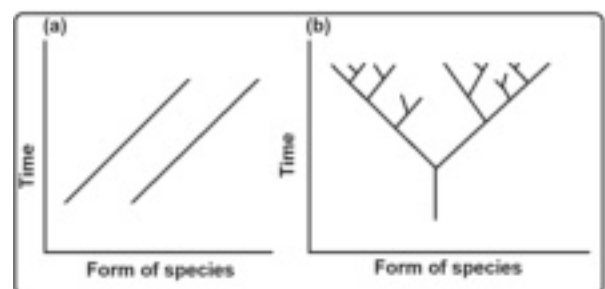


Figure 1: (a) Lamarckian “transformism”. (b) Darwinian evolution is tree-like where lineage split, and it allows extinction.

1.2.2 Examples in support of Lamarckism:

1. **Giraffe:** Initially giraffes used to feed on surface vegetation, and had a small neck and fore-limbs similar to horses. At times when surface vegetation became limited, they had to stretch their neck and fore-limbs to take the leaves for food, which resulted in the slight elongation of these parts. Whatever they acquired in

one generation was transmitted to the next generation with the result that a race of long necked and long fore-limbed animals was developed.

2. **Aquatic birds** had terrestrial ancestors which used to live and feed on land. After some time their terrestrial food became limiting and they had to go to water bodies in search of food. They acquired some characters which enabled them to float and survive in water and the organs that are not used become degenerating. For example, wings were no longer needed for aquatic lifestyle, they got reduced in size. On the otherhand, some web like structures were formed between the toes, so that they could live in water easily.
3. **Flat fishes** used to live at the very bottom surface of deep seas. At the bottom of sea sunlight could hardly reach making life there inactive. Fishes living at the bottom lay on one side of the body, so that the eye on that side (lying towards bottom) shifted towards upper side and, thus such fishes have both eyes on one side of the body.
4. **The wading birds** (e.g., Jacana) these birds had to keep their body above the water levels while, standing in water for search of food. Therefore these birds eventually developed long legs through generations of sustained stretching to keep the body above the water level.

1.2.3. Criticism of Lamarck

1. The first proposition of the theory does not have any ground because there is no vital force in organisms, which can increase their body parts.
2. The second Lamarckian principle that new organs result from new needs, is totally wrong. He believed that the environment acted through the nervous systems; in other words, the desire of the animal leads to the formation of new structures.
3. The third Lamarckian principle that organs will develop due to use and degenerate due to disuse, may be correct within the lifetime of an individual is concerned. However, this principle is meaningful only when it is studied in relation to the following fourth principle.
4. The fourth proposition of Lamarck was that the inheritance of characters was acquired during the life time of the individual. This principle has been experimentally found incorrect.

1.2.4. Examples against Lamarckism:

Germplasm Theory: August Weismann (1834–1914), gave the *theory of germplasm*. Lamarckian principles were mainly criticized by his work. He took some mice and cut

their tails and allowed them to reproduce among themselves. He continued to cut their tails for 22 successive generations. He found that every upcoming generation had tailed mice. If Lamarckian principles were true, tails must be absent in progeny mice since, lack of tail was the acquired character. Weismann concluded that there are two types of matter present in organism, one that is present in somatic cells that is the **somatoplasm** and the other one is found in germ cells referred as **germplasm**. Alterations that occur in somatoplasm are not transmitted to next generation while the changes in germplasm lead to inheritance to all following generations. For example, Indian women followed the practice of boring of ear and nose (changes in somatoplasm) from ancient times; but their offspring's never shows this character.

1.2.5 Neo-Lamarckism

Modified form of Lamarckism is called Neo-Lamarckism (neo = new). Neo-Lamarckism proposes that

1. Environment does influence an organism and change its heredity.
2. At least some of the variations acquired by an individual can be passed on to the offspring.
3. Internal vital force and appetency do not play any role in evolution.
4. Only those variations are passed on to the offspring which also affect germ cells or where somatic cells give rise to germ cells.

1.2.6 Evidences in favour of Neo-Lamarckism

1. **Formation of Germ Cells from Somatic Cells:** Vegetative propagation in plants and regeneration in animals
2. **Effect of Environment directly on Germ Cells:** Tower's observations indicate direct effect of environment on germ cells. He exposed the young developing Potato Beetles to extremes of temperature and humidity at the time of the development of their reproductive organs
3. **Effect of Radiation:** Auerbach et al obtained a number of mutations and chromosome aberrations in *Drosophila* with the help of mustard gas
4. **Effect of Change of Environment:** Radish is a two-year crop in cold countries but completes its growth in one year in tropical areas

1.3 Darwinism (Natural Selection)

Charles Darwin (1809-1882) was born in Shrewsbury in Western England. His father sent him to study medicine at the University of Edinburgh. But since Darwin had keen interests in nature; he found the medical studies boring and distasteful. Therefore, he left Edinburgh without the degree

and shortly thereafter enrolled at Christ College at Cambridge University, where he received his B.A. degree in 1831.

At the age of 22 he got an interesting job to travel the world as a naturalist as board of HMS Beagle (1832-1837). He used to spend most of the time of his voyage on the sea shores, observing a wide variety of flora and fauna.

- He observed thousands of animals and plants and collected their specimens in South America.
- He carefully studied various adaptations of plants and animals of the Brazilian jungles.
- He observed animals and plants of grasslands of the Argentine pampas, the desolate lands of Tierra del Fuego near Antarctica and the Andes Mountains.

Darwin amazed to see that, the plants and animals of temperate region of South America were more closely related to species of tropical region of South America than to species in temperate region of Europe. He collected several types of finches with varying shapes of beaks. Shapes of the beaks were related to the feeding habits of the finches from the different islands of Galapagos. Initially, Darwin considered that all of the Galapagos finches were the members of same species, but it now became clear that each island had its own distinct species.

To find out why species change and explaining it theoretically was an important step further. Darwin went through the theory given by Lamarck and other philosophers who worked in the same concern, but his observations rejected all the theories including Lamarckian postulates as well. All the people working in this field before Darwin failed to explain a crucial fact of adaptation. Darwin came to a conclusion that beak shapes of each species changed in response to different seed types and these changes were inherited by subsequent generations. Darwin recalled and reassessed all the observations he made during the voyage of Beagle, soon after returning to Great Britain in 1836. Darwin could figure out the major features of his theory of natural selection as the mechanism of evolution, by the early 1840s, and wrote a long essay on the origin of species and natural selection in 1844. But he did not publish his ideas at that time and neither had he presented them publically, as it would be of controversy at that time.

A young British naturalist, **Alfred Russell Wallace** (1823-1913) working in East Indies, sent a letter to Charles Darwin in 1858. Coincidentally, Wallace also studied in the same way independently of Darwin and developed a theory of natural selection essentially identical to Darwin's theory. He attached the manuscript of his theory to the letter for Darwin.

Due to this coincidence of findings, Darwin's friends Charles Lyell and Joseph Hooker arranged a simultaneous announcement of Darwin and Wallace's ideas of natural selection at the Linnaean society in London in 1858. After that, Darwin quickly finished the book with title "**On the Origin of Species**" and published it the next year (1859). Records in Darwin's notebook prove that Darwin's theory of natural selection was formulated 15 years before reading Wallace's manuscript. Thus, Darwin was given more credit as he developed and supported the theory of natural selection, more extensively than Wallace, although Wallace wrote up his ideas for publication first. According to Darwin, a species is originated due to divergence from a preexisting species. The **Origin of Species** mainly emphasizes two main points: the occurrence of evolution and natural selection.

1.3.1 Theory of Natural Selection:

The main features of the Darwin's theory can be explained as follows:

1. **Over-Production:** Organisms tend to multiply in geometric ratio, for example plants produce thousands of seeds, insect lays hundreds of egg and if all the offspring's survive and grow than it will lead to over production. In other words, all organisms have natural tendency to produce more and more offspring.
2. **Struggle for Existence:** There is a competition for basic needs like space, shelter, food and mating partners between the individuals of a species and also from the other species. Every organism is under pressure for survival and continuation of its own species, this is called struggle for existence and it continues for the whole life from zygote stage to its natural death.

When members of a species compete with the members of its own species, then the struggle is intraspecific. This may occur for food, shelter, mating partner etc. On the other hand, when competition occurs for food and shelter between members of different species, it is known as interspecific struggle or competition. Members of all species have to cope with the environmental changes such as, cold, heat, wind, rain, drought, flood, and epidemics, such kind of struggle is called, environmental struggle.

3. **Variations:** There are differences among the individuals of a species and individuals of different species. No two individuals are similar and their requirements are also not same, except the identical twins. Variations occur continuously, but those that increase fitness of an organism persist; while, those that lead to decrease in fitness of an organism, are eventually eliminated.

Variations in some individuals may lead to the better adjustment of that organism to the environmental change. The variations that are helpful for the organism are passed to next generation.

4. **Natural Selection:** Variations lead to generation of organisms with varying fitness levels. The individuals that are most fit for a type of environment are more successful in that environment than the others. Thus, the fit individuals are successful in the struggle of existence.



Figure 2: The Voyage of the Beagle

Fitness of an organism reflects into a longer life and ability to get mating partner over the others. Individuals bearing the best variations for a particular environment are selected by nature. This is called natural selection and it is operated by differential survival, and differential reproduction.

5. **Origin of New Species:** Darwin observed that, variations that increase the fitness of an organism, in environmental changes are passed to next generation. Therefore offspring's become different from ancestors. Natural selection occurs continuously each time giving progenies different from their parent, eventually after many generations, the individuals are very much different than the original ancestors, and thus formation of new species occurs.

1.3.2. Evidence In Favor of Natural Selection:

Industrial Melanism is an evolutionary effect prominent in several arthropods, where dark pigmentation (melanism) has evolved in an environment affected by industrial pollution, including sulphur dioxide gas and dark soot deposits. Sulphur dioxide kills lichens, leaving tree bark bare where in clean areas it is boldly patterned, while soot darkens bark and other surfaces. Darker pigmented individuals have a higher fitness in those areas as their camouflage matches the polluted background better; they are thus favoured by natural selection. This change, extensively studied by **Bernard Kettlewell**, is a popular teaching example in Darwinian evolution, providing

evidence for natural selection. In pre-industrial period in England, peppered moths had light coloration which effectively camouflaged them against light coloured trees and lichens.

During industrial revolution, many lichens died out and trees became blackened by soot from factories and interestingly, dark coloured moths were predominantly seen. This can be explained as a result of natural selection of dark coloured moths which were initially present in fewer numbers.

It is not necessary that in all cases, wing or body coloration would be beneficial for protection from predator. let's consider a scenario in which a moth species occurs as two distinct morphs based on wing colour – pale and dark. In same forest there are trees with dark coloured trunks as well as those with light coloured trunks and the moths can rest on either tree. Birds capture the resting moths and eat. In a field experiment, the proportion (%) of dark and pale morphs captured from dark and light trunk trees was recorded.

	Moth Morph	
Tree Trunk Colour	Dark	Pale
Dark	49	51
Light	48	52

The most probable conclusion can be drawn from the above experimental results is that here predator (birds) capture the moths based on some other character than wing color because having dark or pale wings donot permit any selective advantage to moths in camouflaging.

Antibiotic resistance appearance among bacteria and spread have been classically considered the result of a process of natural selection, directed by the use of antibiotics. In 1952, **Esther and Joshua Lederberg** performed an experiment that helped to show that many mutations are random, not directed. They experimentally proved that antibiotic resistant strains of bacteria surviving an application of antibiotics had the resistance before their exposure to the antibiotics, not as a result of the exposure. Bacteria, that have to face the antibiotic challenge, evolve to acquire resistance and, under this strong selective pressure, only the fittest survive, leading to the spread of resistance mechanisms and resistant clones. Horizontal transference of resistance mechanisms seems to be the main way of antibiotic resistance acquisition.

1.3.3. Darwin's Work Other Than Natural Selection

In addition to natural selection Darwin also wrote about artificial selection, sexual selection and presented theory of pangenesis to explain inheritance.

1. Artificial Selection: Using examples of artificial selection, Darwin explained that the power of selection is a principle driving force of evolution. To improve the qualities of domesticated plants and animals, man has used genetic variants. The process of selection of variants with desired characters and their isolation from those without such characters is called as artificial selection and it is essentially a man-made process. Artificial selection can produce a new breed with desired characters if repeated for many generations.

Improved varieties of domestic animals such as dogs, horses, pigeons, poultry cows, goats, sheep and pigs are produced by animal breeders by using artificial selection from their wild type varieties. Similarly improved and advanced varieties of useful plants like wheat, rice, sugarcane, cotton, pulses, vegetables, and fruit plants are developed by plant breeders using artificial selection. Artificial selection and natural selection are all way similar despite the difference that in artificial selection man controls selection and the characters selected are of human use.

2. Sexual Selection: In case of animals, males and females differ in structure and organization of their reproductive organs, while in some cases, there are certain characters that do not take part in reproduction directly but give the basis of visual differentiation between males and females by their external appearances. These characters are called **secondary sexual characters**. This distinction in appearance is called as **sexual dimorphism**. The dimorphism might be due to difference in size (usually males are larger than females) or appearance of visually differentiable appendages such as colorful plumage of male birds, manes on male lions, antlers on male deer. Sexual selection eventually results into sexual dimorphism. Usually in sexual selection females choose male for mating on the basis of certain traits like horns, antlers, plumage etc.

Today, sexual selection is described as **intrasexual selection** and **intersexual selection**. When individuals of one sex (usually males in vertebrates) directly compete with each other for mates of the opposite sex, then it is called intrasexual selection. To combat with the competitor males, various secondary sexual characters such as antlers are used by males. Aggression and powerful males have well developed secondary sexual characters. This is especially common in species where a single male garners a harem of females. These males may gain their status by defeating smaller, weaker, or less fierce male in combat. In intersexual selection, also called as mate choice, usually females choose mate of its own choice and the traits selected by such mate choice are called ornaments (plumage in male birds). Females choose males having

attractive ornamental organs and fighting abilities, and thus males tend to pass the genes encoding such characters. According to Charles Darwin beards in human males and the relative hairlessness of human compared to nearly all mammals are result of sexual selection.

1.3.4 Critics of Darwinism

Darwin's theory was neither completely accepted nor rejected; there was a mix response. Since Darwin's theory contradicted bible, at that time, thus the idea of evolution became controversial at that time. According to bible, all the living beings are created separately, but professional biologists claimed the new evolutionary view. According to Darwin, variations occur continuously and they eventually lead to generation of new species, but he was **unable to explain the cause and origin of variations**, because he could not give any satisfactory theory for heredity and this became the major objection to Darwin's theory.

Although Darwin tried to explain heredity in a theory called as "**Pangenesis**". Pangenesis says that body cells shed gemmule which collects in the reproductive organs before fertilization. Thus every cell of the body contributes in the constitution of the offspring. Pangenesis itself is now seen as deeply flawed and not supported by any observation.

Darwin's postulate stating about sexual selection was also under criticism as it is applicable to small numbers of population only. Also it fails to explain why males can't select the best fit females for mating and why only females get right to select the best fit male.

1.4 The Modern Synthesis

At the beginning of the 20th century, when the Mendelian laws of inheritance was rediscovered and reassessed, the next step was to narrow the gap between Darwin's theory of evolution and the genetic basis of variations, it leads to the synthesis of Darwin's theory of natural selection with Mendelian theory of heredity to establish what is known as **neo-Darwinism**, or **the Modern synthesis** or the **synthetic theory of evolution**, after the title of a book by Julian Huxley, *Evolution: The Modern synthesis* (1942). It is called synthesis because it integrates discoveries and ideas from many different fields, including paleontology, taxonomy, biogeography and population genetics (**Figure 3**).

The architects of this modern synthesis included geneticists **Theodosius Dobzansky** and **Sewall Wright**, biogeographer and taxonomist **Ernst Mayr**, paleontologist **George Gayward Simpson**, botanist **G. Ledyard Stebbins** and **R. A. Fisher**. The old dispute between Mendelians and Darwinians was ended. Darwin's theory now possessed what it had lacked for a half a century; a well tested theory of heredity.

Modern Synthesis differs from Darwinism in three important aspects.

1. It recognizes several mechanisms of evolution in addition to natural selection. One of these, random genetic drift, may be as important as natural selection.
2. It recognizes that characteristics are inherited as discrete entities called genes. Variations within a population are due to the presence of multiple allele of a gene.
3. It postulates that speciation is (usually) due to the gradual accumulation of small genetic changes over long periods of time which leads to large changes i.e. macroevolution is simply a lot of microevolution.

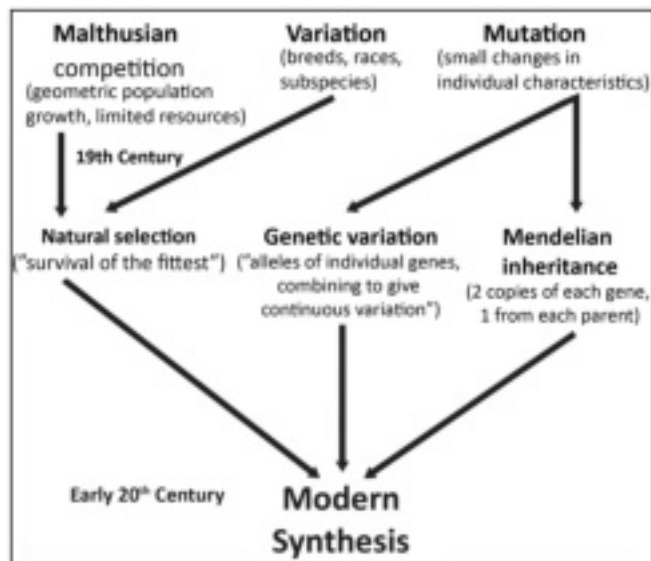


Figure 3: Modern synthesis for theory of evolution.

According to modern synthesis of evolution

1. The **phenotype** (observed characteristic) is different from the **genotype** (the set of genes in an individual's DNA); phenotypic differences among individual organisms may be due partly to genetic differences and partly to direct effects of the environment.
2. Environmental effects on an individual's phenotype do not affect the genes passed on to its offspring. In other words, **acquired characteristics are not inherited**.
3. Hereditary variations are based on particles-genes-that retain their identity as they pass through the generations; they do not blend with other genes. This is true of both discretely varying traits (e.g., brown vs. blue eyes) and continuously varying traits (e.g., body size, intensity of pigmentation). Genetic variation in continuously varying traits is based on several or many discrete, particulate genes, each of which affects the trait slightly ("**polygenic inheritance**").
4. Genes mutate, usually at a fairly low rate, to equally stable alternative forms, known as **alleles**. The phenotypic effect of such mutations can range from undetectable to very great. The variation that arises by mutation is amplified by **recombination** among alleles at different loci.
5. Evolutionary change is a **populational process**: it entails, in its most basic form, a change in the relative abundances (proportions or frequencies) of individual organisms with different genotypes (hence, often, with different phenotypes) within a population. One genotype may gradually replace other genotypes over the course of generations. Replacement may occur within only certain populations, or in all the populations that make up a species.
6. The **rate of mutation is too low** for mutation by itself to shift a population from one genotype to another. Instead, the change in genotype proportions within a population can occur by either of two principal processes: random fluctuations in proportions (**genetic drift**), or nonrandom changes due to the superior survival and/or reproduction of some genotypes compared with others (i.e., natural selection). Natural selection and random genetic drift can operate simultaneously.
7. Even a slight intensity of natural selection can (under certain circumstances) bring about **substantial evolutionary change** in a realistic amount of time. Natural selection can account for both slight and great differences among species, as well as for the earliest stages of evolution of new traits. **Adaptations** are traits that have been shaped by natural selection.
8. Natural selection can alter populations beyond the original range of variation by increasing the **frequency of alleles** that, by recombination with other genes that affect the same trait, give rise to new phenotypes.
9. Natural populations are **genetically variable** and so can often evolve rapidly when environmental conditions change.
10. Populations of a species in different geographic regions differ in characteristics that have a **genetic basis**.
11. The differences between different species, and between different populations of the same species, are often based on differences at several or many genes, many of which have a small **phenotypic effect**. This pattern supports the hypothesis that the differences between species evolve by rather small steps.

12. Differences among geographic populations of a species are often **adaptive**, and thus are the consequence of natural selection.
13. Phenotypically different genotypes are often found in a single interbreeding population. Species are not defined simply by phenotypic differences. Rather, different species represent distinct "**gene pools**", that is, species are groups of interbreeding or potentially interbreeding individuals that do not exchange genes with other such groups.
14. **Speciation** usually occurs by the genetic differentiation of geographically segregated populations. Because of the geographic segregation, interbreeding does not prevent incipient genetic differences from developing.
15. Evolution is **gradual process** and not goal directed. Evolution need **not** always lead to a better phenotype. Evolution can be **progressive** or **retrogressive**
16. **Prokaryotes evolve faster** than eukaryotes due to small generation time.
17. Mutations are **random** while selection depends on **given conditions**.
18. The fossil record includes **many gaps** among quite different kinds of organisms. Such **gaps** may be explained by the incompleteness of the fossil record. But the fossil record also includes examples of gradations from apparently ancestral organisms to quite different descendants. These data support the hypothesis that the evolution of large differences proceeds incrementally.

The modern synthesis explain that variations which are observed from one generation to next are mainly due to

1. **Mutations:** A mutation is a spontaneous permanent change that occurs in our DNA sequence, either due to mistakes when the DNA is copied or as the result of environmental factors. Mutation can be small (point) or gross (chromosomal). Mutation is creator of variation and random process. In an experimnt
2. **Genetic Drift:** It is chance fluctuation in the gene pool of a small population and was proposed by **Sewall and Wright**. Changes in allele frequency due to genetic drift is random and regardless of adaptive fitness. **Motoo Kimura** introduced the **neutral theory of molecular evolution**. Neutral theory of evolution holds that most evolutionary changes at the molecular level, and most of the variation within and between species, are due to random genetic drift of mutant alleles that are selectively neutral.

3. **Genetic Recombination:** It is continuous source of variation due to crossing over in sexually reproducing organisms.

4. **Independent Assortment:** When cells divide during meiosis, homologous chromosomes are randomly distributed during anaphase I, separating and segregating independently of each other. This is called independent assortment. It results in gametes that have unique combinations of chromosomes. It brings **maximum variations**, for example in human independent assortment alone can form **2^{23} variant types** of gametes in each parent (human has 23 pairs of chromosome).

1.5 Concept Check

1. Charles Darwin discussed all of the following EXCEPT:
 - (1) Natural selection tends to remove those organisms that are poorly adapted to their environments.
 - (2) Individuals in a population compete with one another for limited resources.
 - (3) Gene mutations are the source of variation for evolution
 - (4) Organisms tend to produce more offspring than can survive in each generation.
2. Column A lists names of evolutionary biologists and column B lists descriptions of evolutionary mechanisms proposed by them in random order

	Column-A		Column-B
A.	Jean Bepiste Lamarck	(i)	Variation at the molecular level is selectively neutral
B.	Charles Darwin	(ii)	Inheritance of acquired characters
C.	Motoo kimura	(iii)	Differential reproduction of genotypes
D.	Sewall Wright	(iv)	Changes in allele frequency due to random genetic drift

- (1) A -(i), B -(ii), C -(iv), D -(iii)
- (2) A -(ii), B -(iii), C -(i), D -(iv)
- (3) A -(iii), B- (i), C -(ii), D -(iv)
- (4) A -(ii), B -(iii), C -(iv), D -(i)

3. Given below are names of scientists and phrases describing their work, which may or may not be matched