Genetics, Heredity, Evolution and the Lysenko Affair: Part 1

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The organic world has been a source of wonder to mankind since the dawn of civilization. Many questions intrigued the human mind, for example, how did life originate on Earth? What caused the biological diversity that we see in nature? How is heredity to be explained, that is, why does a dog give birth to a dog only and not a cat? A cat is needed to produce a kitten. In different cultures there are mythological stories, stories of creation, to explain these phenomena. In ancient times and throughout the Middle Ages the prevalent idea was that all plants and animals were created by a supreme being, call it God, Allah or Brahmah, and all the varieties were produced as such and did not ever undergo any change.

However, these were all speculative thoughts, unsupported by observation or experiment. Systematic, scientific study of the biological world began in the 17th/18th century. To objectively study biological diversity, Carolus Linnaeus (1707-1778) proposed a scientific hierarchical classification (Kingdom, Phylum, Class, Order, Family, Genus, Species). Subsequently, Jean-Baptiste Lamarck (1744-1829) presented the idea that a particular variety of plant or animal may slowly change its character over generations and may give rise to a new variety. Evolution is a slow transformation within a species to ultimately give rise to a new species. These were revolutionary ideas in those days when the fixity of species was taken for granted, primarily because of religious injunctions. Lamarck's ideas dealt a mortal blow to theological doctrines.

Later, the science of genetics developed and the idea of the gene was combined with natural selection to arrive at the neo-Darwinian concept of evolution. But in Soviet Russia, agro-biologist Trofim Lysenko opposed the idea of gene and presented a new view on heredity and evolution. Lysenko's ideas created a huge controversy not only in the scientific world but also had political overtones. This article attempts to trace the history of development of the modern concepts of heredity and evolution and present an objective critique of Lysenko's ideas.

1. Evolution

1.1 Lamarck

Lamarck stipulated that two principal factors work behind the process of evolution of living forms: the first being an inherent tendency of organisms to move from simple to complex; the second being the modifying role of the environment. According to Lamarck, the first steps towards modification of form are triggered by changes in environmental circumstances; these changes are followed by an organism's subsequent

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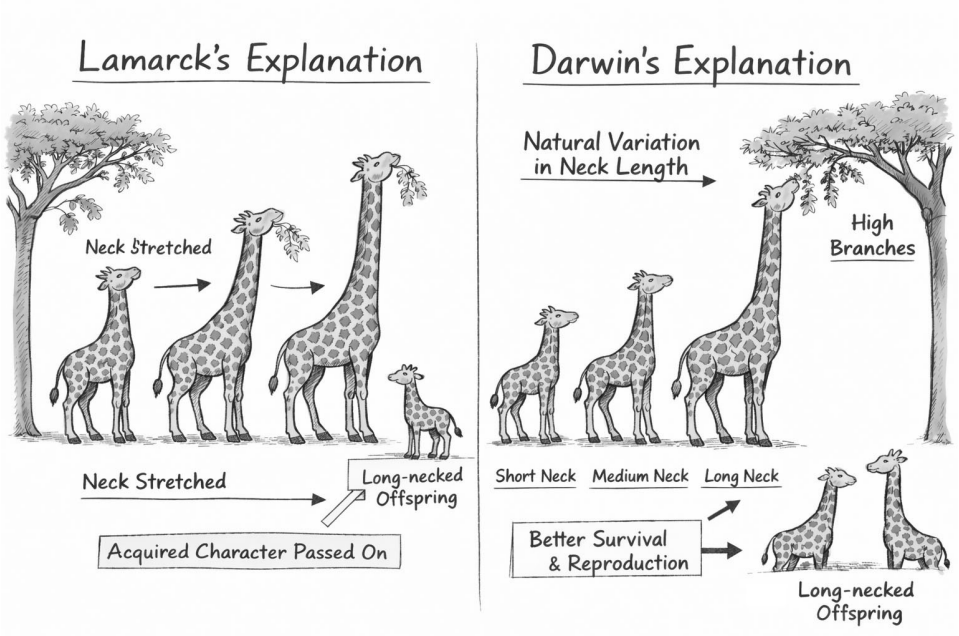


Figure 1: The difference between Lamarckism and Darwinism is schematically portrayed.

attempt to adapt to them by changing its form through the use or disuse of organs. Organs which are used get larger and stronger; organs which are in disuse become smaller and vestigial. And the changes acquired by the organism during its lifetime through such use or disuse are passed on to the progeny.

This is known as the proposition of inheritance of acquired character. As an example, in the Lamarckian scheme, the giraffe is descended from a short-necked ancestor. When environmental changes led to the decline of near-ground food sources, the ancestors had to stretch their necks to reach the leaves higher up on the trees. Over generations, the stretching lengthened their necks, and the acquired trait was inherited by their offspring (Figure 1). Lamarck did not enter into the question of why or how the acquired changes become inheritable.

1.2 Darwin

The idea of Charles Darwin (1809–1882), who came after Lamarck, was different. It was based on the premise that no two organisms in a species are exactly identical. Organisms produce next-generation individuals which occasionally have traits different from the parents, giving rise to variations which are naturally present within every population. Individual organisms with certain anatomical and physiological features are better adapted to any specific natural environment than other variants. They have a larger probability of surviving to maturity and of producing the next generation. Thus, nature selects a particular variant with certain characteristic traits, while other variants with different traits are eliminated. This is the process of natural selection, and Darwin proposed that this is the process which eventually gives rise to new species and hence natural selection is

the driving force for evolution.

Going back to the example of the giraffe, in the Darwinian scheme, within a population of giraffe ancestors, there would be natural variation in neck length: some had short necks, others had long necks. At a time of scarcity of near-ground food sources, individuals with long necks would be at an advantage because they could forage in the leaves of tall trees; they would have a greater chance of survival and reproduction and would be naturally selected (Figure 1).

A striking example of natural selection has been described from England. In pre-industrial England light coloured peppered moths thrived on birch trees; they blended well with the light-coloured, lichen-covered bark and were well camouflaged against the predators. During the Industrial Revolution soot deposition from factory emissions blackened the trees, and the light-coloured moths became easy prey to the predators. The dark-coloured variants were better camouflaged and had an advantage. By the end of the 19th century, through the process of natural selection, the moth population in the industrial belts of England became predominantly dark-coloured. Again, from the middle of the 20th century, as environmental consciousness increased, strict clean-air legislation came into effect, and soot emissions were drastically reduced; the birch trees regained their light-coloured bark, and correspondingly the light-coloured moth started reappearing (Figure 2).

The publication of Darwin's idea created a furore in Great Britain at that time, as it ran counter to the story of creation authorized by Christian theology. The famous zoologist and educator Thomas Huxley came forward to defend Darwin in a combative manner, thereby earning the nickname of "Darwin's Bulldog".



Figure 2: Differently camouflaged white and dark moths on soot-covered and light-coloured barks.

Natural selection operates on the scale of a population, rather than on an individual. For natural selection to operate, two conditions must be satisfied. Firstly, the reproductive process must occasionally produce a variant having a trait different from the parents, for example, black-eyed flies must occasionally give birth to red- or white-eyed flies. In other words, variations must exist within a population. Secondly, the variant must be able to hereditarily transmit its characteristic trait to its offspring – the red- or white-eyed flies must be able to produce more red- or white-eyed flies. If any of these conditions are not met, the process of natural selection and evolution would be clogged and mired in a ditch. Therefore, heredity must encompass both constancy and inconstancy for evolution to proceed.

Darwin was not sure about the cause of variation. But he believed in some form of Lamarckism. In the 1858 paper by Darwin and Wallace it was written, "Selection acts only by the accumulation of slight or greater variations, caused by external conditions, or by the mere fact that in any generation the child is not absolutely similar to its parent." Further, in the 1859 edition of his book Origin of Species he remarked, "I have hitherto sometimes spoken as if the variations—so common and multiform in organic beings

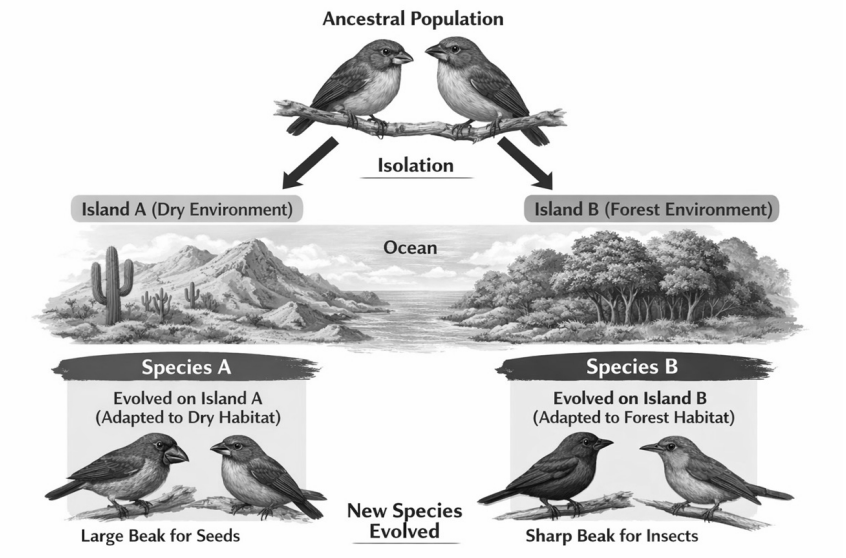


Figure 3: Geographic isolation leading to differentiation into species

under domestication, and to a lesser degree in those in a state of nature—had been due to chance. This, of course, is a wholly incorrect expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation. ··· deviations of structure are in some way due to the nature of the conditions of life, to which the parents and their more remote ancestors have been exposed during several generations." He also said, "I think there can be little doubt that use in our domestic animals strengthens and enlarges certain parts, and disuse diminishes them; and that such modifications are inherited. Under free nature, we can have no standard of comparison, by which to judge the effects of long-continued use or disuse, for we know not the parent-forms; but many animals have structures which can be explained by the effects of disuse."

It may be noted that, though Darwin acknowledged the possibility of the Lamarckian mechanism of change, it was not a necessary component of the process of evolution that he proposed, which required only variation and natural selection.

About inheritance of the changed trait, that is heredity, Darwin presented the 'provisional hypothesis' of pangenesis, which stipulates that every tissue, cell and living part of an organism produces minute particles (gemmules) which carry inheritable characteristics and are transmitted to the offspring via the reproductive process. Thus, pangenesis implies that the whole of parental organisms participates in heredity. However, soon, with the progress of science and the accumulation of evidence, this hypothesis was discarded.

Another important point to note is that the mechanism described by Darwin—variation and natural selection—offers a cogent explanation of evolution within a species, but this does not explain the appearance of a new species (speciation). For a new species to arise, it must lose the ability to viably mate with the other variants. Dobzhansky showed that this can happen through geographic isolation. Geographic

isolation leads to genetic isolation and eventual reproductive isolation. Consider the scenario where a flock of birds from an island is blown by a storm to distant islands and cannot fly back to the island of origin. Let us assume that the environments on two islands, say, food sources, are different. The two populations would now evolve independently on the two islands, and after many generations, the two variants would be selected to fit the different environments at the two sites (Figure 3). The two variants become biologically incompatible and would not interbreed even if they were to reunite. Several other mechanisms for speciation have been described by scientists. We shall not go into the details.

2. Heredity

2.1 Mendel

Gregor Mendel (1822-1864), a clergyman contemporary of Darwin, carried out extensive experiments with pea plants in the monastery gardens and established many of the rules of heredity now known as Laws of Mendelian Inheritance. Mendel noticed that pea plants show many variations in character. An individual character shows two different forms, called traits. He considered seven characters of pea plants, and two traits of each, as shown in Figure 4.

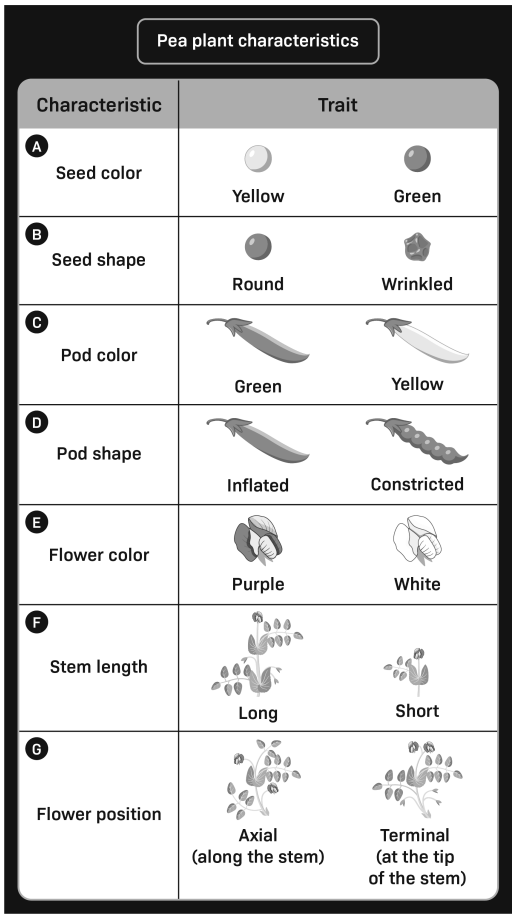


Figure 4: Characters and traits in Mendel's pea plants.

He tried to determine the nature and cause of variation in the population. To understand Mendel's experiments and results, let us take the height of the plant as an example. Mendel first obtained true-breeding tall and dwarf plants, that is, seeds of such plants will always produce tall and dwarf plants, respectively, for many generations. He cross-bred tall and dwarf plants and observed that the first-generation (F1) offspring were all tall; the dwarf variety had disappeared. He then cross-bred the individuals of the first generation and observed that in the second generation (F2) the dwarf variety had reappeared, and the ratio of the number of tall and dwarf plants in the progeny is 3:1. This is, of course, a statistical result obtained by counting many individuals in the progeny. Since some dwarf plants appeared in the second generation, he concluded that the dwarfness trait must have been present within the first generation tall plants, though it was not expressed because tall is dominant over dwarf.

From the observations of the two generations, Mendel deduced that hereditary

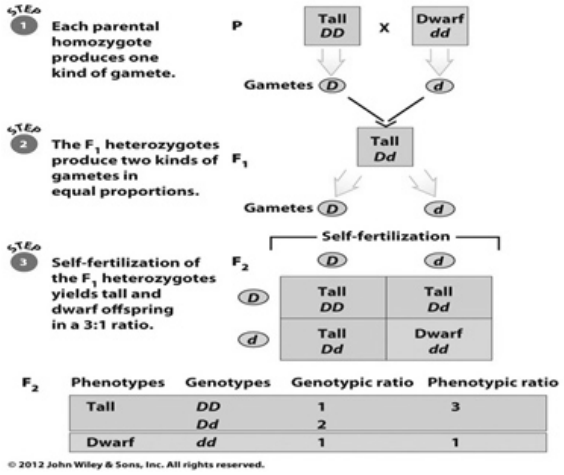


Figure 5: Mendel's model of inheritance

information is passed from the parents to the offspring through discrete units which he called factors. Each particular character of the plant is controlled by two 'factors', one from each parent; the factors separate during gamete formation and recombine in the progeny. A 'factor' is an indivisible, discrete object in the plant which is passed from parents to offspring and which controls the heredity. What Mendel called 'factor' is now called gene. Thus, there is a gene for height, a gene for seed colour, a gene for flower colour and so on. Each gene has two or more alternative forms, called alleles, corresponding to the two different traits of a character. Thus, there is a tallness allele and a dwarfness allele. One of these alleles is dominant, the other recessive (Law of Dominance). Two alleles pair together in a plant.

The Mendelian scheme of inheritance is illustrated in Figure 5. The allele for the tall trait is designated as D, and that for the dwarf trait as d. The allele pairs for the true-breeding tall and dwarf plants are DD and dd, respectively. In the reproductive process, during gamete formation, the alleles in each pair separate and then recombine in the next generation, one from each parent. Therefore, all four allele pairs in the F1 progeny would be Dd, and the corresponding plant would be tall because D is the dominant allele. Following the same principles, self-pollination of this hybrid (Dd) would produce the next generation with the following four combinations DD (tall), Dd (tall), Dd (tall), and dd (short), leading to a 3:1 ratio of long and short plants.

Experiments carried out on hybridization of two traits together, for example, hybridization of tall plants with violet flowers and dwarf plants with white flowers, produced only tall plants with violet flowers in the first generation progeny, and in the second generation after self-pollination progeny plants with different combinations of traits, like tall plants with violet flower, tall plants with white flower, dwarf plants with violet flower and dwarf plants with white flower are produced, but the number of these four types occur in the definite ratio of 9:3:3:1 as predicted by Mendel's model.

Between 1856 and 1863, Mendel carried out numerous breeding experiments involving many different traits, planting thousands of seeds and counting the variants in successive generations. From these, he arrived at a model of how traits are passed on from parents to offspring—the Mendelian laws of heredity are based on this model.

The most significant conclusion from Mendel's work is that the hereditary information is transmitted from the parent to the offspring through discrete objects, now termed genes. Genes are the discrete units of heredity. There was no blending of traits during inheritance. Thus, the hybridisation of tall and dwarf plants did not produce plants with intermediate heights, but only short and tall plants in different numbers. However, Mendel's analysis cannot be ap-

plied to characters which show continuous variation, like the height of a human being. For such traits, inheritance involves blending parental characters, producing an intermediate physical appearance in the offspring. Modern genetics has shown that such continuous variation arises when a particular character is determined by the action of many genes. Mendel's laws apply when the traits show distinct classes, like tall and dwarf, violet and white, smooth and wrinkled, etc., that is, they show discontinuous variation.

Mendel had no idea about the nature of what he called a factor, or about how it exists within a plant, except that it exists in the reproductive organ. To Mendel, it was a hypothetical entity whose functioning alone was his subject of research. We discuss below how our knowledge of the material existence of the gene, its nature, and its function has advanced.

2.2 Morgan

Mendel's work went unnoticed; it was not even known to Darwin, his contemporary. It was rediscovered independently by Hugo de Vries from the Netherlands and Carl Correns from Germany in 1900. De Vries made another important discovery. He planted the seeds of a particular type of wild primroses; over the years, these multiplied, but De Vries noted that many new variants had spontaneously arisen. He proposed that such variation is caused by spontaneous changes in genes, called mutations, which occur through a random process. The variant qualities are hereditary—carried as discrete instructions by the changed genes. Spontaneous mutation coupled with natural selection sets in motion the engine of Darwinian evolution.

William Bateson, from England, became a convert to Mendel's ideas about heredity in 1900. He himself carried out many experiments at Cambridge, confirmed Mendel's work and took it as his mission to spread Mendel's ideas. He travelled to Germany, France, Italy and the United States to give talks on heredity that highlighted Mendel's discovery. He coined the term 'genetics' for the study of heredity and variation.

Thomas Morgan in the USA carried out extensive experiments during 1905-25 with the fruit fly Drosophila and supported Mendel's theory of heredity. Even before Morgan's work, Boveri, Sutton and Stevens suggested that genes are carried on chromosomes. Morgan elaborated on this idea and brought to light much new information on genes. Morgan and his students showed that genes are not only strung along the chromosome, but some genes are also linked together. Thus, the gene responsible for creating white eyes was inescapably linked to the maleness gene, and the gene for sable colour was linked to the gene that specified wing shape. Genes which have no linkage were inferred to be on different chromosomes. Rarely, a gene could unlink itself from its partner genes and swap places from the paternal chromosome to the maternal chromosome. This is known as "crossing over". It was also shown that some genes are closer together, and are difficult to split, and some are further apart, that is, are positioned further apart on the chromosome. A genetic map of the genes could be prepared. All these suggested that genes had a material existence, but their exact nature was still unknown. Because of Morgan's pioneering and extensive work, the names of Mendel and Morgan are often uttered together while discussing the science of genes.

In the early days of the development of the science of genes (genetics), many ideas and theories associated with genes were proposed, which were later discarded as the science developed. One such early

theory was August Weismann's germ plasm theory. Weismann proposed that hereditary information was contained exclusively in the germ cells (sperm and egg cells), which were not influenced by environmental factors, learning, or morphological changes that occur during an organism's lifetime. The somatic cells carry out the ordinary bodily functions, and no hereditary information passes from the somatic cells to the germ cells. Weismann and his followers propagated the idea of an "immortal" germ plasm that could neither be created nor destroyed; it merely passed from the parents to the progeny. However, Weismann's idea on the immutability of genes has been discarded by the later developments of genetics. Science has now shown that all cells contain genetic information, though the reproductive cells are responsible for the inheritance of genetic information. Moreover, it is accepted that genes do undergo heritable changes or mutations, which are responsible for evolution.

A somatic cell is a cell that exists in the body tissues of multicellular organisms and does not have the ability to transfer genetic information to offspring. Mutations that occur in these types of cells may cause diseases and deformities in an individual, but these will not be passed to the next generation. A germ cell is a cell that is involved in the reproduction of multicellular organisms. A germ cell is primarily responsible for transmitting genetic information to the next generation. Because it carries genetic information, mutations of germ cells can be transferred from parent to offspring.

A retrogressive idea prevalent during the early days of the development of genetics was that of eugenics, whose early proponent was Galton in Britain, and much later the racist eugenic proponents in the United States (regrettably with support from the judiciary and administration). Galton proposed that every feature in a human being—height, weight, intelligence, beauty—resulted from a conserved pattern of ancestral inheritance; genius was considered to be encrypted in genes. Such ideas led to the reactionary notion that selective breeding of humans with the most desirable character would lead to a superior race (eugenics). However, genetics has scientifically challenged the basis of eugenics and unequivocally rejected it.

Intensive studies in the first half of the 20th Century vastly enriched our knowledge of genes and their behaviour. Mendel's ideas got widespread acceptance. The science of genetics has advanced tremendously. In the subsequent discussion, we shall use the word 'genetics' to denote the science of genes. Please note that Lysenko in Soviet Russia used the word in a different sense, that of the science of heredity.

It came to be generally accepted by the scientific community that genes contain the information for developing organisms' physical characteristics. They control the inheritance of traits from parents to the offspring. Some early geneticists, like Weismann, regarded genes as immutable. But from the very beginning, geneticists talked about changes in genes or mutations, and soon the idea of the immutability of genes was discarded. Most of the geneticists, however, hold that mutations or changes in genes occur by random chance. What is meant by "random" in this context is that mutations may be harmful, beneficial or neutral to the organism, and in their opinion, the consequences of a mutation will have no influence whatsoever on the probability that one particular mutation will or will not occur. In other words, in nature, beneficial mutations will not be more probable than others. However, we shall discuss later that some scientists hold a different view.

3. Darwinism and Neo-Darwinism

We discussed earlier that the basic conceptual framework of Darwinism is based on variation, inheritance of variation, competition, and selection. Modern evolutionary synthesis or Neo-Darwinism adds to it Mendelian genetics—that is, the Mendelian laws of inheritance. According to this modern idea, genetic mutation gives rise to the variants. Neo-Darwinism regards the emergence of variation as a random process. The different variants interbreed to produce a population with variants following Mendel's law. Natural selection acts on the population to favour the survival of the variant best suited to the extant environment. Other factors, such as sexual selection, genetic drift, gene flow, and isolation, also play important roles in the emergence of new species.

Neo-Darwinism has emerged as the generally accepted theory of evolution. But Lamarckian thoughts, with their core concept of inheritance of environment-directed changes in traits acquired during the lifetime of organisms, persist among a section of scientists, particularly paleontologists.

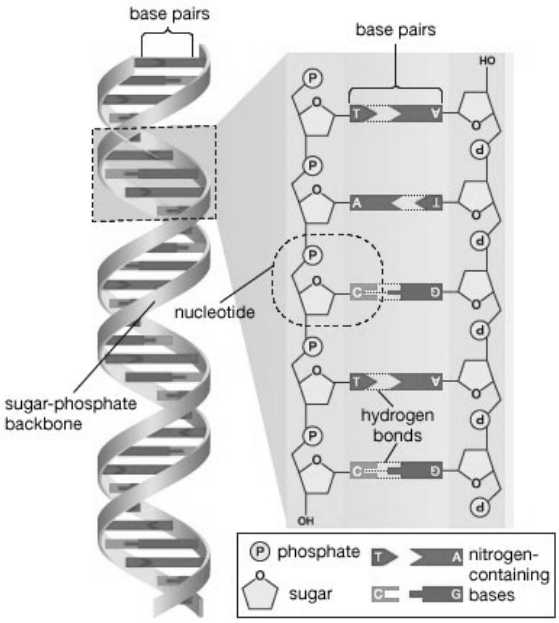


Figure 6: DNA double helix

4. Developments in Genetics and Biology

The work of Morgan and his school brought into focus the existence of genes as a material entity. But in the early days of research, genes were known only by their functions, that is, what they do, and how they work. Scientists were not very sure of what they actually were. But as the science of biology developed and new instruments such as advanced microscopes, X-ray machines, and electron microscopes were introduced, our knowledge of genes became deeper and more precise.

The material nature of genes was confirmed when Hermann Müller artificially induced mutations in Drosophila through X-ray irradiation. Another landmark was the experiment by Frederick Griffith in 1928, which demonstrated that the gene is a chemical molecule and can cross from one organism to another. Soon, it was established that genes reside within the chromosomes in the nucleus of a cell. The principal constituents of chromosomes are DNA and protein. For some time, it was thought that genes reside in the protein, but in 1944, Oswald Avery demonstrated that DNA is the carrier of genes. Finally, in 1953, Francis Crick, James Watson and Rosalind Franklin discovered the "double helix" structure of DNA. This ushered in an explosive development of genetics, and over the next 50 years, many new discoveries were made that have revolutionised our ideas on heredity and related topics.



Figure 7: ATGC sequence in a DNA

5. DNA and Inheritance

Understanding the structure of DNA throws light on the process of reproduction. We shall not go into the details, but the mechanism of copying of DNA during reproduction explains why reproduction leads to carrying over of the same traits, and why, at the same time, variation in progeny also occurs—in other words, why a dog gives birth to a dog and not a cat, and why a white dog sometimes gives birth to a brown dog. It provides us with a tool to improve crop quality and impart desired qualities to fruits or cereals.

The DNA is a double-stranded, helical molecule. It consists of two sugar-phosphate backbones on the outside, held together by hydrogen bonds between pairs of nitrogenous bases on the inside. The bases are of four types (Adenine, Cytosine, Guanine, and Thymine: A, C, G, & T). The molecular structure is such that A always pairs with T, and C with G (Figure 6).

The sequence of base pairs in one strand, for example, ATGACGGATCAGCCG $\cdots$, stores the genetic information of any individual. The sequence in one strand automatically fixes the sequence in its companion strand, because A attaches to T in the companion strand, and C to G (Figure 7). It is this DNA sequence that distinguishes one species from another, though the difference in sequence between different species is only a few per cent.

One chromosome may have 10 million to 10 thousand million (10^7 – 10^{10}) base pairs, and one gene may have one thousand to one million base pairs. Drosophila has only 4 pairs of chromosomes; each chromosome has 1.5 to 40 million base pairs; it has a total of nearly 175 million base pairs in the genome and around 14 thousand genes. A human genome has 23 pairs of chromosomes; each chromosome has 50 to 250 million base pairs. The total number of base pairs in 23 chromosomes (a haploid cell) is over 3 billion. The total number of genes exceeds 20,000.

A gene is a section of the DNA strand that carries a definite piece of information. A mutation is a change in the DNA sequence. A mutation in the gene alters the organism's external and internal characteristics. For example, the change from blue colour to red colour of the eye of the fruit fly is due to a change in a particular gene of the fruit fly. Geneticists recognize that mutations can be of various types. Mutations can occur either due to accidental errors during DNA replication or to environmental factors, such as UV radiation or chemical pollutants. Mutation explains the presence of variations in populations.

6. Genetic Code

A basic contention of Mendelian genetics is that traits of organisms are controlled by genes. The question arises: how does a genetic code translate into a physical characteristic? How does the red colour of the eye of a fruit fly Drosophila depend on a particular gene in its DNA? Biologists had discovered that proteins execute diverse functions in the cells. For exam-

ple, a particular protein, myosin, enables muscles to stretch. Some proteins enable chemical reactions. Some proteins bind coloured chemicals, becoming pigments in the eye. Some act as transporters for other molecules (haemoglobin). Others can specify how a nerve cell communicates with other nerve cells. Therefore, scientists directed their study to unravel the relationship between genes and proteins.

Even before the DNA structure was discovered, in 1945, George Beadle and Edward Tatum conducted experiments and proved that a particular gene acts by encoding information to build a particular protein, and the protein actualizes the form or function of the organism. The protein is synthesised according to the genetic code through a two-step process: transcription and translation. For example, a particular sequence of three bases Adenine, Cytosine, Thymine (ACT triplet) in the DNA chain is translated to a particular amino acid Threonine in the protein. The genetic codes (triplets) of all 20 amino acids in protein, as well as the codes to start and stop the process of protein building, are now known. Through the synthesis of protein, the genetic code is expressed as a biological character or trait. This is called gene expression (genotype to phenotype). As an example, a particular genetic code, embodied in a particular sequence in the chain of DNA, say ACT-GGT-CCC, is translated into a chain of amino acids, Threonine-Glycine-Proline (T-G-P), ultimately leading to the construction of a protein with a particular form and function (Figure 8). A mutation in the gene leads to a change in protein synthesis, and thus a change in the trait or character.

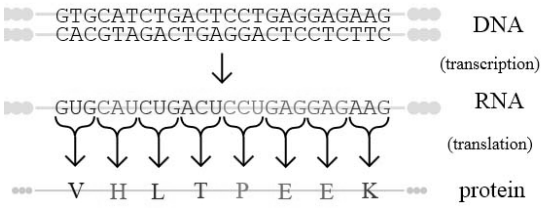


Figure 8: Transcription and Translation. V, H, L, etc. are different amino acids, Valine, Histidine, Leucine, etc.

7. The Role of Environment

Lamarckists assign a directing or controlling role to the environment. According to them, the environment causes a directed change in the organism, making it better adapted to the environment, and such changes may be inherited, that is, passed on to the next generation. Neo-Darwinists accord a different role to the environment. Though they acknowledge that environmental factors in some instances give rise to mutation in genes, according to them, mutation in general is a random phenomenon, and it is not possible to predict which particular gene will be mutated at a point in time due to a given environmental factor, like the presence of X-rays. They hypothesize that spontaneous mutations occur in nature, but they are random, and the environment selects the mutant best adapted to it. The environment plays a causative role in evolution by weeding out the unfit mutants and by allowing the mutants better adapted to a given environment to survive and create progenies.

In the 1930s, Theodosius Dobzhansky, through extensive research on wild populations of Drosophila, showed that a genotype determines a phenotype, that is, a gene determines a trait. But genotypes are not the sole determinants of phenotypes. The environment contributes to the physical attributes of the organism. In other words, whether a particular gene will be expressed as a particular physical characteristic is, to a large extent, dependent on the environment. Certain circumstances in life can

cause genes to be silenced or expressed over time. What we eat, where we live, who we interact with, when we sleep, and how we exercise—all of these can eventually cause chemical modifications around the genes that will turn those genes on or off over time. Thus,

Genotype + environment = Phenotype

However, the capacity of the gene to be expressed as an actual attribute depends not only on the environment but also on chance. In other words, a gene may be activated by external triggers or by random chance. In women, a mutant BRCA1 gene increases the risk for breast cancer, but not all women carrying the BRCA1 mutation develop cancer. One woman with such a mutation might develop an aggressive variant of breast cancer, another with the same mutation might develop an indolent variant, and yet another might not develop breast cancer at all. We still do not know what causes the differences in outcomes between these three women, but the cause is likely a combination of age, other genes, environmental exposures, and many known and unknown factors. Just the genotype, BRCA1 mutation, does not determine the final outcome. So the rule is,

Genotype + environment + triggers
+ some random process = Phenotype

Some new developments in the ideas on the role of the environment will be elaborated later.

In the second part of the article we shall present a critical analysis of the controversy over Lysenko's work in the background of the above discussion on the interplay of genetics and environment in evolution. □

Glossary

Cell – Basic building blocks of all living things

Chromosome – Threadlike structures made up of protein and a single molecule of DNA. Chromosomes reside in the nucleus of the cell.

DNA – Deoxyribonucleic acid, a chemical that forms the filamentous structure of chromosomes and carries genetic information as the sequence of chemical bases, adenine (A), guanine (G), cytosine (C) and thymine. DNA forms a double-stranded helical structure.

Gamete – A mature male or female germ cell that is able to unite with another of the opposite sex.

Genotype – The genetic make-up of an organism, in other words, the organism's complete set of genes.

Hetrozygotic – An individual inheriting different versions (alleles) of a genomic marker from each biological parent.

Homozygotic – An individual inheriting the same version (allele) of the genomic marker from each biological parent.

Phenotype – Refers to the observable traits of an individual. Phenotype is the observable expression of genotype.

Ribosome – It is a cellular structure composed of protein and RNA; it is the site of protein synthesis in the cell. The ribosome reads the mRNA sequence and translates that genetic code into a specified string of amino acids, which grow into long chains that fold to form proteins. (See Translation)

RNA – Ribonucleic acid, that exists as a single strand with four bases A, C, G and U (Uracil). RNA performs several functions in the cell, including transcription and translation. RNA involved in the process of transcription and translation is called messenger RNA (mRNA).

Transcription – It is the process of generating an RNA copy of the DNA gene. In transcription, a genetic code in DNA (e.g., ATG-CAC-GGG) is used to build an RNA copy (AUG-CAC-GGG).

Translation – It is the process by which the genetic message carried by the mRNA is converted into a protein by the ribosome. For example, the mRNA AUG is used to synthesise the amino acid Methionine. A chain of mRNA can thus encode a chain of amino acids in a protein.

Zygote – It is a cell resulting from the union of a female gamete (egg) with a male gamete (sperm); it is a fertilized egg cell.