PAPER 2 Unit I: Genetics: I

1) Contributions of Mendel- Gregor Mendel was an Augustinian monk from Moravia. His contribution to science is in the field of heredity. Although DNA, chromosomes and genetics were unknown concepts at the time, Mendel's experiments focused on the outward effects of the genetic programming (the phenotype). He established the laws of heredity—that's to say the *how* of evolution. So, essentially, he founded the science of genetics, although he didn't use the term *gene*himself (or genetics). Unfortunately, his work on heredity was pretty much ignored during his lifetime so he would probably be surprised to find his name so well known now.

While Darwin explained in broad terms how *evolution* (or, to use his words—natural selection) worked, he didn't know the mechanism that made it work beyond the fairly vague notion of "inheritance". Even though Darwin and Mendel were alive at the same time, they didn't know of each others' work.

Mendel has become best known for his pea plant experiments, conducted over the course of a decade. He was particularly interested in the difficulty in hybrid plant reproduction. With some regularity, hybrids would produce plants which looked dissimilar to themselves.

Mendel chose to study various characteristics of pea plants. One trait which he analyzed was the height of the plant. Some were tall and others were short. He spent the first few years of his botany studies breeding pure forms of tall (TT) and of dwarf (dd) pea plants. These he called the parent generation. Then he cross-pollinated these. The results were a Filial 1 (sibling) generation of tall plants (Td). In today's terms, he had produced plants which carried both the dominant (T) gene and a recessive (d) gene. Because a dominant gene was present, the plant displayed the dominant tall (T) characteristic, even though it carried a recessive (d) gene for shortness. All plants therefore in this generation showed only the characteristics of one parent plant (the tall one).

However, the next generation of plants (Filial 2) produced quite a startling departure from their predecessors. This second generation was allowed to self-pollinate. These mixed (Td) plants generated a characteristic proportion of tall and short plants. In this generation, some received a dominant gene from each parent plant and were pure talls (TT). Others received a recessive gene from each parent and were pure dwarfs (dd). And others received both a dominant and a recessive gene, giving them a tall appearance with a genotype of Td. Therefore by mixing and matching the T and d, Mendel observed that 3 out of every 4 plants in this generation would be tall (TT, Td, dT) and 1 out of 4 would be a dwarf plant (dd). This F2 generation displayed characteristics which reflected the traits of both contributing parental plants.

Although Mendel showed his results to a botanist at the University of Munich and even published a paper on his findings, there was neither interest nor follow-up on his research at that time. It was not until the beginning of the 1900s, when three independent teams of scientists discovered his writings and produced the same results in their experiments, that they affirmed Mendel's conclusions. The scientists credited Mendel with the discovery.

Today, Mendel is known as the father of modern genetics, although unfortunately he never lived to see the widespread acclaim for his work or the fame that attended it. He continued to live out his life as abbot of the monastery, where he taught and held fast to his Christian faith.

2) William Bateson - William Bateson studied organismal variation and heredity of traits within the framework of evolutionary theory in England. Bateson applied Gregor Mendel's work to Charles Darwin's theory of evolution and coined the term genetics for a new biological discipline. By studying variation and advocating Mendelian genetics, Bateson furthered the field of genetics, encouraged the use of experimental methodology to study heredity, and contributed to later theories of genetic inheritance.

In 1894 Bateson published the findings in his first book, *Materials for the Study of Variation Treated with Especial Regard to Discontinuity in the Origin of Species*. Bateson's book outlined discontinuities in variation that he had observed between species. For example, he explains that the male Lamellicorn beetle, *Xylotrupes gideon*, is found in two forms, long-horned or short-horned. The absence of males with horns of medium length meant that variation within that species was not continuous. In *Materials for the Study of Variation*, Bateson also debuted terms such as meristic to describe variation in the number of body parts, and homeotic to describe variation in the arrangement of body parts, after which scientists later named homeotic genes. Bateson's book also challenged Charles Darwin's theory of natural selection. Bateson argued that natural selection could not fully explain the origin of species. According to Darwin, natural selection caused species to evolve from other species via the gradual accumulation of small advantageous characters within the organisms of the evolving species. However, Bateson noted instances of discontinuous variation within species, an observation that strengthened his support of saltationism, as he argued that evolution may sometimes occur in large jumps, rather than through the gradual accumulation of differences.

In 1895 Bateson began a series of cross-breeding and hybridization experiments with botanist Edith Rebecca Saunders. Bateson and Saunders's crosses of the flowering plant *Biscutella laevigata* exhibited discontinuous variation in the smoothness of leaves, so they expanded their work to include four other flowering plant species from genera *Matthiola*, *Lychnis*, *Atropa*, and *Datura*. Despite their extensive experiments, they could not distinguish any consistent pattern or mechanism of inheritance. Bateson expanded his work to include butterflies and poultry, but still could not fathom a mechanism until 1900, when Bateson and Saunders learned of Mendel's 1866 pea inheritance paper, which Mendel had written while in Austria.

Bateson adopted Mendel's work, and he advocated for others to do so. The majority of Bateson and Saunders's results from flowering plant crosses fit Mendel's laws of inheritance. In 1902 Bateson published *Mendel's Principles of Heredity: A Defence*, and Bateson's support of Mendelism rather than of biometry started an argument between Bateson and Weldon. This argument culminated in a debate in 1904, known as the biometric-Mendelian controversy, at the British Association for the Advancement of Science meeting at Cambridge. The debate involved Bateson and Karl Pearson, a colleague of Weldon's. Even though many scientists supported biometry rather than Mendelism, Bateson advocated for Mendel's theories, and he sought to expand upon Mendel's work through his own research.

3) **Hardy-Weinberg** **- Hardy-Weinberg law**, an algebraic equation that describes the genetic equilibrium within a population. It was discovered independently in 1908 by Wilhelm Weinberg, a German physician, and Godfrey Harold Hardy, a British mathematician.

The science of population genetics is based on this principle, which may be stated as follows: in a large, random-mating population, the proportion of dominant and recessive genes present tends to remain constant from generation to generation unless outside forces act to change it. In such a way even the rarest forms of genes, which one would assume would disappear, are preserved. The outside forces that can disrupt this natural equilibrium are selection, mutation, and migration. The discovery of this law was especially significant in affirming natural selectionas the primary mechanism of evolution. If the proportions of gene forms in a population do not change, the rate of evolution will be zero. Individual variations occur because of the various genetic combinations that result from random mating of individuals, but nonrandom, or selective, mating must occur for natural selection to take place. Certain gene-controlled traits are selected for or selected against by the partners involved. Over a long period of time, this selective pressure will change the frequency of appearance of certain gene forms, and the traits they control will become commoner or rarer in the population.

Medical geneticists can use the Hardy-Weinberg law to calculate the probability of human matings that may result in defective offspring. The law is also useful in determining whether the number of harmful mutations in a population is increasing as a result of radiation from industrial processes, medical techniques, and fallout.

4) Garrod - In 1896, Archibald E. Garrod became interested in patients with a rare but rather harmless disorder known as alkaptonuria. When exposed to air, patients' urine turns distinctively dark. Garrod soon concluded that alkaptonuria is a congenital disorder, not the result of a bacterial infection as was commonly thought. Rare in the general population but frequent in children of first-cousin marriages, the incidence of alkaptonuria conformed to the pattern of recessive inheritance described by Gregor Mendel in
his experiments with peas.
Garrod, a prominent physician at St. Bartholomew's Hospital in London, understood both the new science of biochemistry and the emerging discipline of genetics. He suspected that, due to a genetic defect, patients with alkaptonuria lacked an enzyme involved in the chemical breakdown of protein, one of many chemical pathways collectively called metabolism. The result: the accumulation of a chemical that darkens urine. Fifty years would pass before biochemists understood all of the steps in the pathway Garrod described.

Garrod immediately grasped the larger implications of his work on alkaptonuria in terms of genetics and serious disease.

• While the signs of alkaptonuria are highly visible, many more disorders of metabolism undoubtedly exist with more subtle manifestations. Garrod called such disorders "inborn errors of metabolism."

• Both normal variation and abnormal differences in chemical makeup are determined by genetics. "I believe that no two individuals," wrote Garrod, "are exactly alike chemically any more than structurally."

In 1908, Garrod lectured on inborn errors of metabolism, and his book by that title appeared in 1909. In 1931, he published *Inborn Factors in Disease*. In spite of his prominence in the medical community, Garrod's work did not excite great interest among his contemporaries. Geneticists were busy grappling with the simplest of organisms, biochemistry was still in its infancy and many of the diseases Garrod discussed were rare disorders that physicians seldom saw in clinical practice. But by the 1950s, as the direct role that genes play in producing specific proteins became understood, Garrod began to acquire the reputation he currently enjoys—as the "father of chemical genetics."

5) Morgan - Thomas Hunt Morgan (1866-1945), an American geneticist and Nobel Prize winner of 1933, is considered as "Father of experimental genetics" for his work on and discovery of linkage, crossing over, sex linkage, criss cross inheritance, linkage maps, mutability of genes, etc. He is called fly man of genetics because of selecting fruit fly (Drosophila melanogaster) as research material in experimental genetics. It was largely due to his book, "The Theory of Gene", that genetics was accepted as a distinct branch of biology. In 1910, he discovered linkage and distinguished linked and unlinked genes. Morgan and Castle (1911) proposed "Chromosome Theory of Linkage" showing that genes are located in the chromosomes and arranged in linear order. Morgan and Sturtevant (1911) found that frequency of crossing over (recombination) between two linked genes is directly proportional to the distance between the two. 1% recombination is considered to be equal to 1 centi Morgan (cM) or 1 map unit. He worked on sex linked inheritance and reported a white eyed male Drosophila in a population of red eyed and proved that gene of eye colour is located on X-chromosome. The male passed its genes on X-chromosomes to the daughter while the son gets genes on X-chromosome from the female (mother). It is called criss-cross inheritance.

6) **Griffith** - **Griffith's experiment**, reported in 1928 by Frederick Griffith, was the first experiment suggesting that bacteria are capable of transferring genetic information through a process known as transformation. Griffith's findings were followed by research in the late 1930s and early 40s that isolated DNA as the material that communicated this genetic information. **Griffith's experiment** was an experiment done in 1928 by Frederick Griffith. It was one of the first experiments showing that bacteria can get DNA through a process called transformation.

Griffith used two strains of *Streptococcus pneumoniae*. These bacteria infect mice. He used a type III-S (smooth) and type II-R (rough) strain. The III-S strain covers itself with

a polysaccharide capsule that protects it from the host's immune system. This means that the host will die. The II-R strain does not have that protective shield around it and is killed by the host's immune system.

In this experiment, bacteria from the III-S strain were killed by heat, and their remains were added to II-R strain bacteria. While neither harmed the mice on their own, the blend of the two was able to kill mice.

Griffith was also able to get both live II-R and live III-S strains of *S. pneumoniae* from the blood of these dead mice. He concluded that the type II-R had been "transformed" into the lethal III-S strain by a "transforming principle" that was somehow part of the dead III-S strain bacteria.

Today, we know that the "transforming principle" Griffith saw was the DNA of the III-S strain bacteria. While the bacteria had been killed, the DNA had survived the heating process and was taken up by the II-R strain bacteria. The III-S strain DNA contains the genes that form the shielding polysaccharide part from attack. Armed with this gene, the former II-R strain bacteria were now protected from the host's immune system and could kill the host.

7) Beadle and Tatum - In addition to governing the expression of hereditary characteristics, genes direct the manufacture of proteins that control the basic metabolic functions, which characterize life itself. This insight, with profound consequences for molecular biology, was experimentally confirmed in 1941 by George W. Beadle and Edward L. Tatum.

Beadle, a geneticist, initially worked with the fruit fly*Drosophila* in the laboratory of Thomas Hunt Morgan at Columbia University. By 1935 he had developed suggestive evidence that eye color, known to be inherited, represents a series of genetically determined chemical reactions. His work over the next six years, much of it with Edward L. Tatum, a biochemist, furthered this hypothesis. But the complexity of *Drosophila* proved a drawback to developing experiments that would demonstrate a link between specific genes and their chemical products.

In 1941, Beadle and Tatum turned to a simpler creature, in which specific products of metabolism could be directly studied. A bread mold, *Neurospora crassa*, proved ideal.*Neurospora* can be cultured together with sugar, inorganic salts, and the vitamin biotin. This fungus has a short life cycle, and reproduces sexually and replicates asexually—that is, sexual reproduction gives rise to spores. In addition, *Neurospora* possesses only one set of unpaired chromosomes, so that any mutation is immediately expressed. This much was known, mainly through the work of Bernard O. Dodge, when Beadle and
Tatum began their research.

In what became a celebrated experiment, Beadle and Tatum first irradiated a large number of *Neurospora*, and thereby produced some organisms with mutant genes. They then crossed these potential mutants with non-irradiated*Neurospora*.

Normal products of this sexual recombination could multiply in a simple growth medium. However, Beadle and Tatum showed that some of the mutant spores would not replicate without addition of a specific amino acid—arginine. They developed four strains of arginine-dependent *Neurospora*—each of which, they showed, had lost use of a specific gene that ordinarily facilitates one particular enzyme necessary to the production of arginine.

Beadle and Tatum's fairly simple experiment was a keystone in the development of molecular biology. In its basic form, the concept that genes produce enzymes had been first put forth as early as 1901 by Archibald Garrod—as Beadle acknowledged when he and Tatum were awarded the Nobel Prize in Physiology or Medicine in 1958. While Garrod's work had been largely ignored, Beadle and Tatum's research, more than three decades later, was immediately recognized.

From Beadle and Tatum's work arose a basic hypothesis: One gene specifies the production of one enzyme. This idea was exceptionally fruitful, but also much debated and eventually modified. Today, it is usually said, more accurately, that each gene specifies the production of a single polypeptide—that is, a protein or protein component. Thus, two or more genes may contribute to the synthesis of a particular enzyme. In addition, some products of genes are not enzymes per se, but structural proteins.

8) Avery, Mac Leod, Mc Carthy - By the 1940s, genes were understood as discrete units of heredity, which also generate the enzymes that control metabolic functions. Contemporary wisdom suggested that genes were proteins. But in 1944, experiments by Oswald T. Avery showed that a nucleic acid, deoxyribonucleic acid (DNA), known to be ubiquitous in organisms, was the chemical basis for specific and apparently heritable transformations in bacteria.

Avery, an immunochemist at the Hospital of the Rockefeller Institute for Medical Research, worked for many years with pneumococcus, a bacterium that causes pneumonia. As early as 1928, he and other scientists were baffled by results of an experiment with these microbes. Mice were injected with a live but harmless form of pneumococcus and also with an inert but lethal form. Although expected to live, the mice in fact soon succumbed to infection and died. Bacteria recovered from the mice remained lethal in subsequent generations.

How did the nonlethal form of the bacteria acquire the virulence of the killed strain? The difference between the two forms lay in their protective casings. The immune system could detect and destroy the "rough" outer coat of the innocuous "R" form of the bacteria. But the lethal "S" form had a smooth capsule that evaded detection, enabling the bacteria to reproduce.

Avery soon discovered that "R" bacteria could become deadly simply when combined with inert lethal "S" form in a test tube—the mice were unnecessary to the equation. Such types of bacteria were at the time thought to be as stable as species. What enabled the "transformation?" As Avery posed it, the question became entirely biochemical: "What is the substance responsible?"

Together with Colin MacLeod and Maclyn McCarty, Avery undertook to purify—from some twenty gallons of bacteria—what he called the "transforming factor." As early as 1936, Avery noted that it did not seem to be a protein or carbohydrate, but a nucleic acid. Further analysis showed that it was DNA.

A cautious scientist, Avery was long reluctant to publically ascribe a genetic role to DNA. (Both he and other scientists suggested as much privately.) But in 1944, Avery and his colleagues

published a paper in the *Journal of Experimental Medicine* in which they set out the nature of the "transforming principle."

• Deoxyribonucleic acid (DNA) plays a central role in determining specific characteristics in the course of reproduction. If experimental results could be confirmed, wrote Avery, "then nucleic acids must be regarded as possessing biological specificity the chemical basis of which is as yet undetermined."

Avery's paper was not initially widely read by geneticists, but it excited commentary and further research into the nature of DNA—including the relative composition of the bases that comprise it and X-ray diffraction studies of its structure. Almost a decade passed before, in 1953 in England, Francis Crick and James Watson discovered that DNA was comprised of paired sequences of complementary bases. DNA, by the order of its bases, encodes the genes.

Avery, meanwhile, had retired from the Rockefeller Institute in 1947. His death, in 1955, came before widespread recognition of his role in discovering the significance of DNA.

9) Hershey & Chase -We know about Griffith's experiment and experiments that followed to discover the hereditary material in organisms. Based on Griffith's experiment, Avery and his team isolated DNA and proved DNA to be the genetic material. But it was not accepted by all until Hershey and Chase published their experimental results.

In 1952, Alfred Hershey and Martha Chase took an effort to find the genetic material in organisms. Their experiments led to an unequivocal proof to DNA as genetic material. Bacteriophages (viruses that affect bacteria) were the key element for Hershey and Chase experiment.

The virus doesn't have their own mechanism of reproduction but they depend on a host for the same. Once they attach to the host cell, their genetic material is transferred to the host. Here in case of bacteriophages, bacteria are their host. The infected bacteria are manipulated by the bacteriophages such that bacterial cells start to replicate the viral genetic material. Hershey and Chase conducted an experiment to discover whether it was protein or DNA that acted as the genetic material that entered the bacteria.

DNA as Genetic Material

Experiment: The experiment began with the culturing of viruses in two types of medium. One set of viruses (A) was cultured in a medium of radioactive phosphorus whereas another set (B) was cultured in a medium of radioactive sulfur. They observed that the first set of viruses (A) consisted of radioactive DNA but not radioactive proteins. This is because DNA is a phosphorus-based compound while protein is not. The latter set of viruses (B) consisted of radioactive protein but not radioactive DNA.

The host for infection was E.coli bacteria. The viruses were allowed to infect bacteria by removing the viral coats through a number of blending and centrifugation.

Observation: E.coli bacteria which were infected by radioactive DNA viruses (A) were radioactive but the ones that were infected by radioactive protein viruses (B) were non-radioactive.

Conclusion: Resultant radioactive and non-radioactive bacteria infer that the viruses that had radioactive DNA transferred their DNA to the bacteria but viruses that had radioactive protein didn't get transferred to the bacteria. Hence, DNA is the genetic material and not the protein

10) Watson &Crick - Genes, by mid-twentieth century, were located to the chromosomes, known to be composed of protein and deoxyribonucleic acid, or DNA. The discovery of its molecular structure, by Francis Crick and James Watson, immediately suggested that DNA—not a protein, as was widely imagined—was the master molecule that contains the genes, self-replicates and recombines during reproduction.

In 1951 Crick, a graduate student at Cavendish Laboratory in Cambridge, began working informally with the American post-doctorate James Watson. Crick had trained in physics and was engaged in X-ray studies to characterize biological molecules. Watson had studied with Salvador Luria, a pioneer in bacterial genetics. Both Crick and Watson were explicitly motivated to investigate DNA by suspicion of its fundamental significance.

For about two years Crick and Watson worked together without success. Emulating the eminent chemist Linus Pauling, who had made an important but failed effort to describe DNA, they began building three-dimensional models, using cardboard cutouts and sheet metal to represent the molecule's chainlike structure. They were aware that DNA might have the general, winding shape of a helix. But how DNA's four bases (adenine, guanine, thymine, and cytosine) were arranged around a sugar and phosphate backbone remained a mystery.

On February 21, 1953, Watson had the key insight. He recognized how two pairs of complementary bases (adenine-thymine and guanine-cytosine) would have identical shapes if held together by hydrogen bonds. Two long chains of such base pairs would likely form a double helix—roughly, the shape of an enormously long, winding, doubled-railed staircase. The DNA molecule, comprised of long strands of such base pairs in specific and varied sequences, could embed genetic information that, if the strands were separated, could be copied.

Indeed, with Crick and Watson's discovery, together with evidence acquired over the previous decade, the implication that DNA contained the genes was immediately apparent. On April 25, 1953, *Nature*published their brief communication, in which they famously noted that "the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material." Crick and Watson elaborated with a longer paper several weeks later.

Subsequent work made it abundantly clear that DNA, indeed a double helix, was the chemical substance of genes. In 1962 Crick and Watson were awarded the Nobel Prize in Physiology or Medicine, shared with Maurice Wilkins, whose work with Rosalind Franklin on X-ray crystallography had provided crucial evidence.

Discovery of the structure of DNA was the keystone to a half-century of research that initiated a scientific revolution. Biology acquired a molecular and biochemical basis, and research into

DNA brought forth new technologies that illuminated the complex chemistry of protein synthesis and reproduction.

Francis Crick became one of the chief investigators of molecular biology through the mid-1970s, before turning to work in neurobiology. James Watson, an eminent figure in genetics research in the United States, became head of Cold Spring Harbor Laboratory and, for a time during the late 1980s, of the Office of Human Genome Research of the National Institutes of Health.

11) Barbara McClintock -

Barbara McClintock was born in Hartford, Connecticut. Her father was an army doctor and her mother was a piano teacher. McClintock was an active child and enjoyed many sports like volleyball, skating, and swimming. She had a passion for information, and in a time when a woman's career was a successful marriage, McClintock was determined to go to college. In 1918, she enrolled in Cornell University, the College of Agriculture.

Under the social and intellectual background of college, McClintock blossomed into a popular coed. By the time she finished her undergraduate credits, she found herself in graduate school in the new field of cytology. As a paid assistant in her second year of graduate work, she improved on a method that her employer was using and was able to identify maize chromosomes. It was a problem he had been working on for years and she effectively scooped her own boss.

When she finished her Ph.D. in 1927, McClintock knew that her next step was to map corn chromosomes in linkage groups like T. H. Morgan's group was doing for *Drosophila*. To do this work, McClintock stayed at Cornell as an instructor. She met fellow graduate students Marcus Rhoades and George Beadle who became lifetime friends as well as colleagues. McClintock helped Beadle sort out the *Neurospora* chromosomes. Beadle, with Edward Tatum, built on this work and developed the "one gene, one enzyme" theory using *Neurospora*.

In 1929, McClintock met Harriet Creighton, a new graduate student at Cornell. The two of them became friends and worked together to show that chromosomal crossovers occur in corn chromosomes.

In 1931, supported by a fellowship from the National Research Council, McClintock started splitting her time between the University of Missouri and Cornell. She began investigating the effects of X-rays on corn chromosomes, which led to her discovery of translocations, inversions, deletions and ring chromosomes in corn.

After a depressing and disappointing sojourn in Germany in 1933, McClintock returned to Cornell and with some support from the Rockefeller Foundation managed to stay for almost three years. In 1936, she was finally offered a faculty position at the University of Missouri. McClintock was assistant professor at the University for five years until she realized that her independent and "maverick" ways were not in keeping with the University's idea of a "lady" scientist. Knowing that she would never be promoted, McClintock left in 1941.

Marcus Rhoades, who was at Columbia University, and Milislav Demerec, a *Drosophila* scientist at Cold Spring Harbor, invited her to Cold Spring Harbor Laboratory for the summer. Rhoades was growing his corn there, and Demerec knew and respected McClintock as a scientist. McClintock stayed for the summer and late into the fall. When Demerec became the Director of the Department of Genetics of the Carnegie Institution of Washington at Cold Spring Harbor, he offered McClintock a position. Undecided at first, McClintock finally accepted the position in 1942. It was at Cold Spring Harbor that McClintock figured out the process of transposition in corn chromosomes. For this and her other work, McClintock was awarded an unshared Nobel Prize for Physiology or Medicine in 1983.

Although many people recognized McClintock's genius, she herself admitted that sometimes it was difficult for her to express her ideas. Her work on transposition in corn chromosomes was fairly well-known but little understood until the molecular basis for transposition was shown in 1970s. McClintock was frustrated by other people's lack of understanding and acceptance of an idea that was so clear and reasonable to her.

McClintock was a research investigator at Cold Spring Harbor until her death in 1992. She enjoyed playing tennis. Each fall, she was often seen on the Cold Spring Harbor grounds collecting black walnuts for use in baked goods that she gave to a favored few of her colleagues. In addition to her brilliance as a geneticist, many people remember her quick wit and her sense for fun. She was dedicated to, and passionate about, her work, and was happiest in the cornfield or in her laboratory.

12) **Lederberg-** **Joshua Lederberg** (born May 23, 1925, Montclair, N.J., U.S.—died Feb. 2, 2008, New York, N.Y.), American geneticist, pioneer in the field of bacterial genetics, who shared the 1958 Nobel Prizefor Physiology or Medicine (with George W. Beadle and Edward L. Tatum) for discovering the mechanisms of genetic recombination in bacteria.

Lederberg studied under Tatum at Yale (Ph.D., 1948) and taught at the University of Wisconsin(1947–59), where he established a department of medical genetics. In 1959 he joined the faculty of the Stanford Medical School, serving as director of the Kennedy Laboratories of Molecular Medicine there from 1962 to 1978, when he moved to New York City to become president ofRockefeller University. He held that post until 1990.

With Tatum he published “Gene Recombination in *Escherichia coli*” (1946), in which he reported that the mixing of two different strains of a bacterium resulted in genetic recombination between them and thus to a new, crossbred strain of the bacterium. Scientists had previously thought that bacteria only reproduced asexually—i.e., by cells splitting in two; Lederberg and Tatum showed that they could also reproduce sexually, and that bacterial genetic systems are similar to those of multicellular organisms.

While biologists who had not previously believed that "sex" existed in bacteria such as *E. coli*were still confirming Lederberg's discovery, he and his student Norton D. Zinder reported another and equally surprising finding. In the paper "Genetic Exchange in *Salmonella*" (1952), they revealed that certain bacteriophages (bacteria-infecting viruses) were capable of carrying a bacterial gene from one bacterium to another, a phenomenon they termed transduction.
Lederberg's discoveries greatly increased the utility of bacteria as a tool in genetics research, and it soon became as important as the fruit fly *Drosophila* and the bread mold *Neurospora*. Moreover, his discovery of transduction provided the first hint that genes could be inserted into cells. The realization that the genetic material of living things could be directly manipulated eventually bore fruit in the field of genetic engineering, or recombinant DNA technology.
At the dawn of space exploration, Lederberg coined the term *exobiology* to describe the scientific study of life outside Earth's atmosphere. He later served as a consultant to NASA'sViking mission to Mars.

13) Edward Tatum -Edward Tatum was born in Boulder, Colorado. While Tatum was growing up, his family moved a number of times. His father had different teaching positions at various universities and colleges in the Midwest. Tatum grew up in a science-oriented household as his father had a Ph.D and an M.D.
Tatum obtained a Bachelor's degree from the University of Wisconsin in 1931, and he stayed to do graduate work on nutritional requirements of different bacterial strains. This research had a practical aspect. The bacterial strains Tatum worked on were found in milk. By knowing what bacteria needed for growth, strategies could have been developed to control their growth.
After his Ph.D., Tatum spent a year at the University of Utrecht, Netherlands, doing the same type of research. In 1937, his professors at Wisconsin forwarded him a job ad. George Beadle was looking for a research associate for his new lab at Stanford University. The job was an excellent research opportunity; however, Tatum's professors advised him to go into the dairy industry and do butter research - the money was better.
Tatum chose intellectual challenge over money. He spent the first few years in Beadle's lab isolating and identifying the "substances" involved in *Drosophila* eye color determination - an extension of Beadle's earlier work. They were beaten by another group, but this set into motion the events leading up to the *Neurospora* experiments. The switch to *Neurospora* supposedly came about after one of the biology classes Tatum volunteered to teach. Beadle was sitting in on the lecture and was reminded of the *Neurospora* system; he thought it would be the perfect system to use to study gene action.
The new *Neurospora* project had no guarantee of success. So, Beadle and Tatum had a deal; they would test only 5,000 *Neurospora* cultures. If they couldn't find one nutritional mutant in 5,000, they would abandon the project. The experiment was a success and Edward Tatum shared the 1958 Nobel Prize in Physiology or Medicine.

In 1945, Tatum had a short stint at Washington University in St. Louis, and then moved to Yale. He was using the *Neurospora* strategy to find genetic mutants in bacteria. He used *Escherichia coli* strain K12 from the Stanford collections. At the time, K12 was not the most common *E. coli* strain in use, but this proved to be a fortuitous choice. K12 had the properties that allowed Tatum and his studentJoshua Lederberg to demonstrate bacterial recombination. Lederberg shared the 1958 Nobel Prize in Physiology or Medicine.

In 1948, Tatum returned to Stanford and in 1956 was appointed the head of the new Department of Biochemistry. In 1957, Tatum left to accept a professorship at the Rockefeller Institute and stayed until his death.

Tatum was a very supportive boss. He had his own goals for his lab, but never failed to actively encourage his students in their research interests. He was on the editorial board of science journals such as *Genetics*, *Science*, and the *Journal of Biological Chemistry*. Tatum also served as scientific advisor on many boards and helped set the national policy on training for students and post doctoral fellows. Tatum died in 1975 from heart failure complicated by emphysema from a lifetime of cigarette smoking.