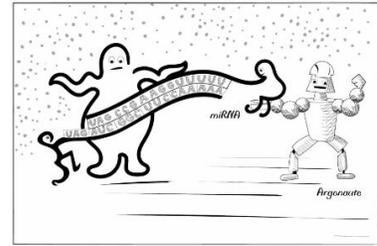


Chapter – 1



Molecular Biology: Introduction and History

Introduction:

Molecular biology is a branch of biology that focuses on the study of biological processes and structures at the molecular level. Molecular biology is to the molecular mechanisms underlying various cellular functions, including DNA replication, transcription, translation, and the regulation of gene expression. Molecular biology also plays a crucial role in advancing our understanding of genetics, genomics, and biotechnology.

History of Molecular Biology:

The field of molecular biology has a rich history that spans several decades and has significantly contributed to our understanding of the fundamental processes of life. Here are some key milestones in the history of molecular biology:

Discovery of DNA as the Genetic Material (1869-1953): The groundwork for molecular biology was laid by scientists such as Friedrich Miescher, who first isolated DNA from cells in the late 19th century. However, it was not until the mid-20th century that James Watson, Francis Crick, Rosalind Franklin, and Maurice Wilkins elucidated the structure of DNA as the double helix in 1953. This discovery marked a turning point in the field.

The Central Dogma (1958): In 1958, Francis Crick proposed that DNA is transcribed into RNA and then RNA is translated into protein. Hence the information flows from DNA to RNA to protein. This is termed as “central dogma” of molecular biology, which describes the flow of genetic information within a biological system.

Discovery of the Genetic Code (1960s): Marshall Nirenberg and Har Gobind Khorana deciphered the genetic code in the early 1960s. They identified the triplet codons in mRNA that specify amino acids during protein synthesis.

Enzyme and Gene Regulation (1960s-1970s): Scientists like Jacob and Monod made significant contributions to understanding how genes are regulated in response to environmental signals. Their work on the lac operon in bacteria provided insights into gene regulation.

Recombinant DNA Technology (1970s): The development of recombinant DNA technology by Paul Berg and others allowed the manipulation and cloning of DNA fragments. This technology revolutionized genetics and biotechnology.

Sequencing the Human Genome (2000s): The Human Genome Project, completed in the early 2000s, involved the sequencing of the entire human genome. This monumental effort has had profound implications for medicine, genetics, and personalized medicine.

Advancements in Molecular Techniques (Ongoing): Molecular biology continues to evolve with advancements in techniques such as PCR (Polymerase Chain Reaction), DNA sequencing, CRISPR-Cas9 gene editing, and various omics technologies (genomics, transcriptomics, proteomics, etc.).

Applications in Medicine and Biotechnology: Molecular biology has led to the development of numerous medical treatments, diagnostic tests, and biotechnological applications, including the production of genetically modified organisms and the study of genetic diseases.

Molecular biology has fundamentally reshaped our understanding of life and has paved the way for groundbreaking discoveries in genetics, genomics, and biotechnology. It remains a dynamic and rapidly evolving field at the forefront of biological research.

William Astbury, a physicist, coined the term "molecular biology" in 1945. In order to ensure that a complex system or advantageous approach would be made in an easy way of understanding, the field of molecular biology only recently developed. By using bacteria and bacteriophages, this organism yields information about fundamental biological processes more quickly than an animal cell.

The Chargaff's Rule

"Chargaff's rule stated that DNA from any species of any organism should have a 1:1 stoichiometric ratio of purine and pyrimidines (*i.e.*, $A+G=T+C$) and, more specifically, that the amount of guanine should be equal to cytosine and the amount of adenine should be equal to thymine. This pattern is found in both strands of the DNA (Fig- 1.1)".

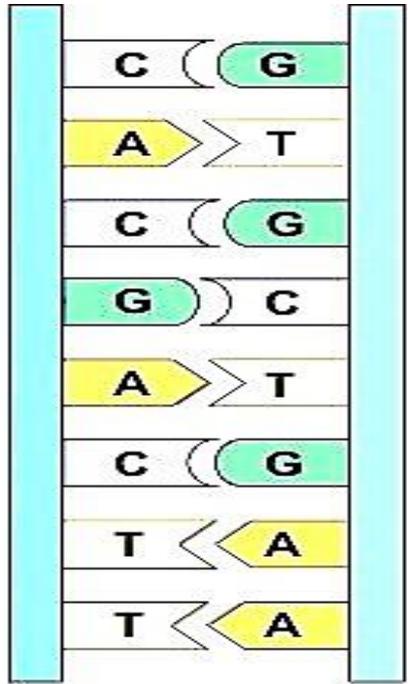


Fig. 1.1: DNA strand shows the pairing of nitrogenous base (no. of purines equal to no. of pyrimidines)

In an effort to comprehend the molecular mechanics of genetic inheritance and the structure of a gene, the science of genetics was developed. The principles of genetic inheritance were first formulated by Gregor Johann Mendel in 1866 as a result of his research on mating crosses in pea plants. The law of segregation, which stipulates that diploid people having two alleles for a single gene will convey one of these alleles to their kids, is one such rule of genetic inheritance. Mendelian genetics is the term used to refer to the study of genetic inheritance because of his influential work.

This work was started in 1869 by Swiss biologist Friedrich Miescher, who initially hypothesised the "nuclein" structure, which we now know to be deoxyribonucleic acid, or DNA. Studying the components of pus-filled bandages and taking note of the special characteristics of the "phosphorus-containing substances" lead him to this unusual material. Phoebus Levene, who suggested the "polynucleotide model" of DNA in 1919 as a result of his biochemical investigations on yeast, was another significant contributor to the DNA model. Erwin Chargaff built on Levene's research and identified a few crucial characteristics of nucleic acids in 1950. The first is that the sequence of nucleic acids differs between species.

Second, the overall concentration of pyrimidines (cysteine and thymine) and purines (adenine and guanine) is always equal. Today, this is referred to as Chargaff's rule. James Watson and Francis Crick used the X-ray crystallography work done by Rosalind Franklin and Maurice Wilkins to disclose the double helical helix of DNA in 1953. In their description of the DNA structure, Watson and Crick speculated about the implications of this particular structure for potential DNA replication mechanisms. For putting forth a model of the structure of DNA, Maurice H.F. Wilkins, J. D. Watson, and F. H. C. Crick shared the 1962 Nobel Prize in Physiology or Medicine.

As time went on, K. A. Marcker and Frederick Sanger found an odd aminoacyl-tRNA in *E. coli* termed N-formyl-methionyl-tRNA and explained that it is involved in a unique process of chain elongation. His discovery of the full 5,400 nucleotide single stranded DNA sequence of the F'174 bacteriophages earned him the second Nobel Prize.

It was established in 1961 that each subsequent amino acid in a protein is specified by three consecutive bases in the DNA of a gene when a gene codes for it. As a result, the genetic code is a triplet code, with each triplet (known as a Codon) designating a certain amino acid.

Furthermore, it was demonstrated that each DNA sequence is read from a set starting point and that the codons in the DNA sequence encoding a protein do not overlap with one another.

Fundamental discoveries about the roles and interactions of the proteins used in the machinery of DNA replication, DNA repair, DNA recombination, and the construction of molecular structures were made between 1962 and 1964 using conditionally lethal mutants of a bacterial virus.

Modern Molecular Biology

The 21st century has seen remarkable advancements in molecular biology, driven by technological breakthroughs and innovative research. These developments have revolutionized our understanding of genetics, genomics, and the molecular mechanisms underlying life processes. Here are some key developments in molecular biology in the 21st century:

Genome Sequencing: The 21st century witnessed a dramatic decrease in the cost of DNA sequencing. This led to the completion of many important genome sequencing projects, including the Human Genome Project and numerous genome sequencing efforts for various organisms. High-throughput sequencing technologies, such as next-generation sequencing (NGS) and third-generation sequencing, have enabled the rapid sequencing of entire genomes, transcriptomes, and epigenomes.

Personalized Medicine: Advances in genomics have paved the way for personalized medicine. By analyzing an individual's genetic makeup, doctors can tailor medical treatments to a patient's unique genetic profile. This approach has been particularly impactful in cancer treatment, where targeted therapies are designed based on genetic mutations.

CRISPR-Cas9 Gene Editing: The discovery and development of the CRISPR-Cas9 gene editing system have been a game-changer in molecular biology. It allows for precise and efficient modification of genes in a wide range of organisms, including humans. CRISPR technology has opened up new avenues for gene therapy, genetic engineering, and disease research.

Synthetic Biology: Synthetic biology combines principles from biology and engineering to design and create artificial biological systems or modify existing ones. This field has led to the development of synthetic organisms, biologically based materials, and innovative biotechnological applications.

Single-Cell Analysis: Advances in single-cell genomics have enabled researchers to study individual cells' genetic and molecular characteristics. This has provided insights into cell diversity, tissue development, and disease mechanisms at an unprecedented level of resolution.

Omics Technologies: Various omics technologies, including genomics, transcriptomics, proteomics, and metabolomics, have become essential tools in molecular biology. These approaches allow for the comprehensive analysis of biological molecules and their interactions.

Epigenetics: Research in epigenetics has expanded our understanding of how chemical modifications to DNA and histones can influence gene expression and cellular function. Epigenetic modifications play a crucial role in development, aging, and disease.

RNA Biology: The study of RNA molecules has gained prominence in the 21st century. This includes research on non-coding RNAs (e.g., microRNAs and long non-coding RNAs), RNA interference (RNAi), and RNA-based therapies.

Functional Genomics: Functional genomics approaches, such as CRISPR-based screens and RNA interference, have been used to identify the functions of individual genes and their roles in cellular processes.

Environmental Genomics: Genomic technologies have been applied to study microbial communities in various environments, contributing to our understanding of ecosystems, biogeochemical cycles, and microbial diversity.

These developments in molecular biology have not only deepened our understanding of fundamental biological processes but have also had profound implications in medicine, agriculture, biotechnology, and environmental science. As technology continues to advance, the 21st century is likely to see even more exciting breakthroughs in the field of molecular biology.

Connection molecular biology to other fields of Biological Sciences

Molecular biology is a subfield of biology that focuses on the study of biological molecules, particularly at the molecular and genetic level. It examines the structure and function of important biomolecules like DNA, RNA, proteins, and various small molecules, and how they interact to carry out the processes of life. Molecular biology has significant relationships and overlaps with several other biological sciences:

1. **Genetics:** Molecular biology and genetics are closely related disciplines. Genetics deals with the inheritance of traits and the study of genes. Molecular biology helps understand

the molecular basis of genetic inheritance by studying how DNA, the genetic material, is replicated, transcribed into RNA, and translated into proteins.

2. **Cell Biology:** Molecular biology is intertwined with cell biology, as it explores the molecular mechanisms that govern cell functions. Understanding cellular processes, such as cell division, signaling pathways, and protein trafficking, involves molecular biology techniques.
3. **Biochemistry:** Biochemistry and molecular biology share a strong connection. Biochemistry focuses on the chemical reactions and processes that occur within living organisms. Molecular biology delves into the molecular components and mechanisms that drive these reactions, such as enzyme function and metabolic pathways.
4. **Genomics:** Genomics is a field that involves the sequencing and analysis of entire genomes. Molecular biology techniques play a fundamental role in genomics by helping to decode and understand the function of genes within the genome.
5. **Biotechnology:** Molecular biology is foundational to biotechnology, where it is used to manipulate DNA and produce genetically modified organisms, develop vaccines, and create recombinant proteins, among other applications.
6. **Microbiology:** In the study of microorganisms, molecular biology helps uncover the genetic and molecular aspects of bacteria, viruses, and other microorganisms. This is essential for understanding pathogenicity and developing treatments.
7. **Evolutionary Biology:** Molecular biology techniques, such as DNA sequencing and molecular phylogenetics, are used to trace the evolutionary relationships between species and understand how life has evolved over time.
8. **Ecology:** Molecular biology can be applied to ecological studies to examine genetic diversity within populations, track species migration, and investigate how environmental factors affect gene expression and adaptation.
9. **Neurobiology:** Molecular biology has greatly contributed to the field of neurobiology by helping to unravel the molecular basis of neural function, including the mechanisms of neurotransmission, neuronal development, and the study of genes related to neurological disorders.

10. Immunology: Molecular biology techniques are used in immunology to understand the genetic basis of the immune response, the production of antibodies, and the molecular recognition of antigens.

In summary, molecular biology serves as a foundational discipline with strong connections to various other biological sciences, enabling researchers to gain a deeper understanding of the molecular mechanisms underpinning life processes and facilitating advances in various fields of biology and medicine.

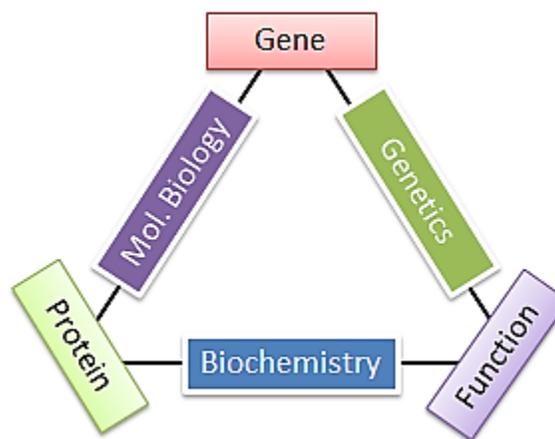
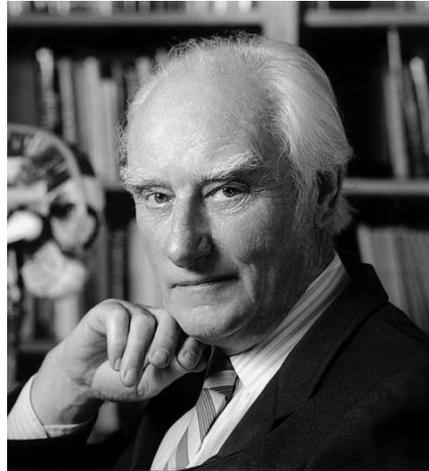


Fig. 1.2: Schematic Diagram of Relation between Molecular Biology, Biochemistry and Genetics

F.H.C. Crick:

Francis Harry Compton Crick, often known as Francis Crick, was a British molecular biologist and neuroscientist. He made significant contributions to the field of molecular biology, including one of the most famous scientific discoveries of the 20th century. Here is a detailed introduction and an overview of his major contributions:

Francis Crick was born on June 8, 1916, in Northampton, England. He had a diverse scientific background, with education in physics, followed by research in molecular biology and neuroscience. His interdisciplinary approach and creative thinking were critical to his groundbreaking work in understanding the structure of DNA.



Francis Harry Compton Crick

Contributions:

1. **Discovery of the DNA Double Helix:** Crick is most renowned for his collaboration with James D. Watson in the discovery of the structure of DNA. In 1953, they proposed the double-helix model of DNA, which explained how genetic information is stored and transmitted. This discovery was a watershed moment in biology and laid the foundation for our understanding of genetics. The structure of DNA allowed scientists to comprehend how genes were copied and passed on to subsequent generations.
2. **Molecular Basis of Genetic Information Flow:** Following the discovery of the DNA structure, Crick focused on elucidating the "central dogma" of molecular biology. He proposed that genetic information flows in a one-way direction from DNA to RNA to proteins, and this concept has been fundamental to our understanding of molecular biology and genetics.
3. **Codon and the Genetic Code:** Crick was involved in deciphering the genetic code, particularly the relationship between the sequence of nucleotides in DNA and the sequence of amino acids in proteins. He, along with Sydney Brenner, played a vital role in deducing the genetic code, which governs how the information in DNA is translated into the synthesis of proteins. This work paved the way for advances in molecular genetics and biotechnology.

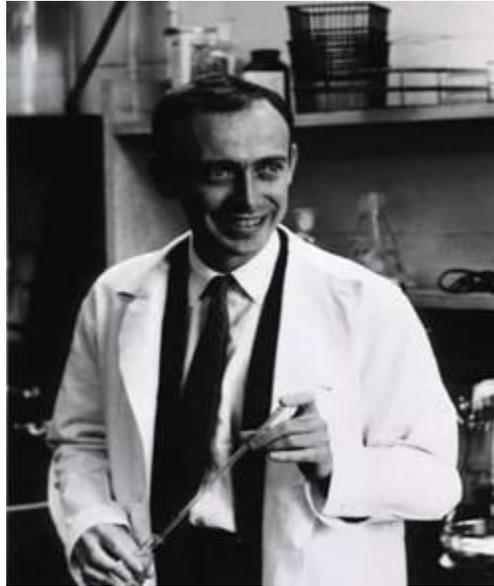
4. Neuroscience: Later in his career, Crick shifted his focus to neuroscience. He contributed to our understanding of the brain's structure and function, particularly in the context of consciousness. He proposed theories about the neural basis of consciousness, which continue to influence the field of neuroscience.
5. Awards and Recognition: In 1962, Crick, along with James Watson and Maurice Wilkins, received the Nobel Prize in Physiology or Medicine for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material.

Francis Crick's contributions to the fields of molecular biology, genetics, and neuroscience were groundbreaking and have left an enduring legacy. His work not only provided fundamental insights into the nature of genetic information but also helped shape the direction of biological and medical research for decades to come.

J. D. Watson:

James Dewey Watson, commonly known as James D. Watson, is an American molecular biologist, geneticist, and science writer who is renowned for his groundbreaking contributions to the field of molecular biology, particularly for his work on the structure of DNA. Here's a more detailed introduction and an overview of his significant contributions:

James D. Watson was born on April 6, 1928, in Chicago, Illinois, and grew up with a strong interest in birds and bird-watching. He attended the University of Chicago and, at the young age of 23, he began working at the Cavendish Laboratory at the University of Cambridge, where he would make his most significant discovery.



James Dewey Watson

Contributions:

1. **Discovery of the DNA Double Helix:** Watson is best known for his collaboration with Francis Crick in elucidating the structure of DNA, one of the most important discoveries in the history of science. In 1953, they proposed the double-helix structure of DNA, which explained how genetic information is stored and replicated. This discovery not only revolutionized biology but also provided the basis for understanding the mechanisms of inheritance and evolution.
2. **Nobel Prize:** For their groundbreaking work on DNA, Watson, Crick, and Maurice Wilkins were jointly awarded the Nobel Prize in Physiology or Medicine in 1962. The Nobel Committee recognized their "discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material."
3. **Authorship:** Watson is also known for his writing. His 1968 memoir, "The Double Helix," provides a personal account of the race to discover the structure of DNA and the scientific community's competitive nature at the time. This book is not only an important scientific document but also a bestseller and a widely-read work in the field of science writing.
4. **Leadership and Administration:** Watson held various leadership positions in the scientific community. He served as the director of Cold Spring Harbor Laboratory and

played a significant role in its development as a major center for research in molecular biology and genetics.

5. **Human Genome Project:** While not directly involved in the Human Genome Project, Watson's contributions to the field of molecular biology laid the groundwork for this ambitious endeavor to sequence the entire human genome. His work helped inspire and shape the direction of genomics research.

James D. Watson's contributions to science, particularly his role in discovering the structure of DNA, have had a profound and lasting impact on our understanding of genetics and molecular biology. His work continues to be celebrated and studied as a cornerstone of modern biology.

Har Gobind Khorana

Har Gobind Khorana was an Indian-American biochemist and a pioneer in the field of genetics and molecular biology. Here is a detailed introduction and an overview of his major contributions:

Introduction: Har Gobind Khorana was born on January 9, 1922, in Raipur, British India (now in Pakistan). He displayed an early aptitude for science and went on to become one of the most influential figures in the field of biochemistry and genetics. He made significant contributions to our understanding of the genetic code, particularly in deciphering the role of nucleotides in coding for amino acids in protein synthesis.



Hargobind Khurana

Contributions:

Interpretation of the Genetic Code: Khorana's most groundbreaking work was his interpretation of the genetic code. He was the first scientist to synthesize a functional gene, demonstrating that the order of nucleotides in DNA determines the order of amino acids in proteins. His research paved the way for a deeper understanding of how genetic information is translated into proteins. Two repeating units of ribonucleic acid (RNA) called UCUCUCUCUCUC created two alternate amino acids. This together with the Nirenberg and Leder experiment demonstrated that Serine is coded by UCU and Leucine is coded by CUC.

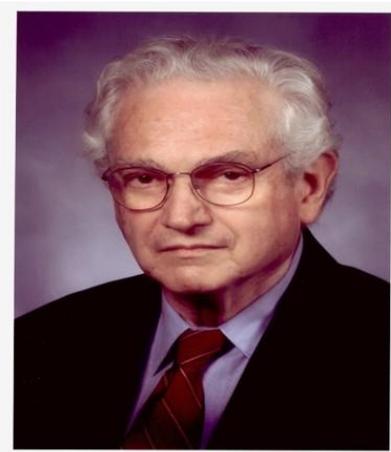
1. **Total Synthesis of a Gene:** In 1972, Khorana and his team successfully synthesized a gene in the laboratory. This achievement was a landmark in the field of molecular biology and gene synthesis, and it had far-reaching implications for genetic engineering and biotechnology.
2. **Nobel Prize:** In recognition of his pioneering work in deciphering the genetic code and synthesizing genes, Har Gobind Khorana was awarded the Nobel Prize in Physiology or Medicine in 1968, along with Robert Holley and Marshall Nirenberg. They were honored for their discoveries concerning the interpretation of the genetic code and its function in protein synthesis.
3. **Advancements in DNA and RNA Chemistry:** Khorana made significant contributions to the chemical synthesis of DNA and RNA molecules. His work was instrumental in advancing our understanding of the molecular structure and function of these key genetic materials.
4. **Genetic Engineering and Biotechnology:** Khorana's work laid the foundation for the field of genetic engineering and biotechnology. His pioneering research in gene synthesis provided the essential tools and knowledge that allowed for the manipulation and engineering of DNA, which is integral to modern biotechnology and medicine.
5. **Educator and Mentor:** In addition to his research contributions, Khorana was known for his dedication to education and mentorship. He trained numerous scientists and inspired generations of researchers in the field of genetics and molecular biology.

Har Gobind Khorana's work revolutionized the field of genetics and molecular biology and had a profound impact on our understanding of the genetic code and its role in protein synthesis. His research laid the foundation for the development of genetic engineering, biotechnology, and modern medicine. Khorana's legacy continues to influence the scientific community and remains an integral part of the history of molecular biology and genetics.

Marshall Warren Nirenberg

Marshall Warren Nirenberg was an American biochemist and geneticist who made significant contributions to the field of molecular biology, particularly in deciphering the genetic code. Here is an introduction to his life and an overview of his major contributions:

Marshall Warren Nirenberg was born on April 10, 1927, in New York City, USA. He displayed an early interest in science and went on to become one of the key figures in understanding how genetic information is translated into proteins, a fundamental process in biology.



Marshall Warren Nirenberg

Contributions:

1. **Cracking the Genetic Code:** Nirenberg is best known for his groundbreaking experiments in the early 1960s, which helped decipher the genetic code.

Along with his research partner, Heinrich J. Matthaei, he conducted experiments in which they synthesized RNA molecules of known sequences and introduced them into cell-free systems. They discovered that specific sequences of RNA, known as codons, corresponded to specific amino acids in protein synthesis. This work was crucial in understanding how the sequence of nucleotides in DNA determines the sequence of amino acids in proteins.

2. Nobel Prize: In recognition of his pioneering work in deciphering the genetic code, Marshall Nirenberg was awarded the Nobel Prize in Physiology or Medicine in 1968. He shared the prize with Robert Holley and Har Gobind Khorana, and they were honored for their discoveries concerning the interpretation of the genetic code and its function in protein synthesis.
3. RNA and DNA Research: Nirenberg made other contributions to the fields of RNA and DNA research, including the study of tRNA (transfer RNA) and its role in protein synthesis. His work on RNA and its interactions with ribosomes and amino acids significantly advanced our understanding of the molecular processes underlying protein synthesis.
4. Scientific Leadership and Mentorship: Nirenberg played a prominent role in scientific leadership and mentorship. He was involved in various research institutions and universities, where he mentored and influenced numerous scientists and researchers in the fields of molecular biology and genetics.

Marshall Warren Nirenberg's groundbreaking work in deciphering the genetic code fundamentally changed our understanding of genetics and molecular biology. His contributions were pivotal in unraveling the complex process of protein synthesis and laid the groundwork for advancements in genetic engineering, biotechnology, and our comprehension of the central dogma of molecular biology.

Venkatraman "Venki" Ramakrishnan is an Indian-born American structural biologist who has made significant contributions to the field of molecular biology.

Here is an introduction to his life and an overview of his major contributions:

Introduction: Venkatraman Ramakrishnan was born on March 5, 1952, in Chidambaram, India. He pursued his education in India and the United States and became a prominent figure in structural biology and molecular genetics. He holds dual citizenship in the United States and the United Kingdom.



Venkatraman Ramakrishnan

Contributions:

1. Structure of the Ribosome: Ramakrishnan is best known for his pioneering work in solving the structure of the ribosome, a complex molecular machine that plays a crucial role in protein synthesis. In 2000, he and his research team determined the high-resolution structure of the ribosome, a significant achievement that explained how genetic information is translated into proteins. This discovery shed light on the molecular basis of protein synthesis

and had far-reaching implications in fields like microbiology, genetics, and medicine.

2. **Nobel Prize:** In recognition of his groundbreaking research on the ribosome, Venkatraman Ramakrishnan was awarded the Nobel Prize in Chemistry in 2009. He shared the prize with Thomas A. Steitz and Ada E. Yonath for their structural studies of the ribosome, which deepened our understanding of the biological machinery behind protein production.
3. **Structural Biology Advancements:** Ramakrishnan's work goes beyond the ribosome. He has made significant contributions to the field of structural biology, using techniques such as X-ray crystallography to study the structures of various biomolecules. His research has helped elucidate the structures of other critical biological molecules, shedding light on their functions and mechanisms.
4. **Scientific Leadership:** Ramakrishnan has held leadership positions in various scientific organizations and institutions. He has been associated with the Medical Research Council (MRC) Laboratory of Molecular Biology in Cambridge, the University of Utah, and other esteemed institutions, where he has actively mentored and inspired the next generation of scientists.
5. **Science Communication:** In addition to his scientific contributions, Ramakrishnan is an advocate for science education and public understanding of science. He has contributed to science communication, raising awareness about the importance of scientific research and the value of critical thinking.

Venkatraman Ramakrishnan's research on the ribosome and other structural biology advancements has greatly advanced our understanding of fundamental biological processes. His Nobel Prize-winning work on the ribosome continues to influence

various fields, from fundamental biology to the development of antibiotics, making a profound impact on science and medicine.

Katalin Karikó and Drew Weissman

Katalin Karikó and Drew Weissman are biochemists who have made groundbreaking contributions to the development of mRNA (messenger RNA) vaccines, which have played a pivotal role in the fight against infectious diseases, including the COVID-19 pandemic.

Katalin Karikó: Katalin Karikó was born in Hungary and earned her Ph.D. in biochemistry. She conducted her early research on mRNA at the University of Szeged in Hungary. Later, she moved to the United States and joined the University of Pennsylvania. She is a Senior Vice President at BioNTech, a biotechnology company, and her contributions are as follows:

1. **Discovery of Modified mRNA:** Karikó's pioneering work involved the development of modified mRNA to make it more stable and less immunogenic. This was a crucial breakthrough because unmodified mRNA is naturally unstable and can trigger an immune response when introduced into the body. Her work allowed for the use of mRNA as a safe and effective means of delivering genetic information.
2. **mRNA Vaccines:** Karikó and her collaborator, Drew Weissman, developed the technology that underlies mRNA vaccines, such as the Pfizer-BioNTech and Moderna COVID-19 vaccines. These vaccines use synthetic mRNA to instruct cells to produce a spike protein found on the surface of the SARS-CoV-2 virus, training the immune system to recognize and combat the virus. Their work has been instrumental in the rapid development of effective COVID-19 vaccines.



Katalin Karikó and Drew Weissman

Drew Weissman: Drew Weissman is an American immunologist and professor of medicine at the University of Pennsylvania. His contributions to mRNA vaccine technology are as follows:

1. Collaboration with Katalin Karikó: Drew Weissman collaborated closely with Katalin Karikó to develop modified mRNA that could be used in vaccines. They co-authored numerous papers detailing their findings on how to make mRNA more stable and less likely to trigger harmful immune responses.
2. mRNA Vaccine Development: Weissman's work in modifying mRNA, which reduces the risk of immune reactions, was integral to the development of mRNA vaccines for COVID-19 and other diseases. His research laid the foundation for the safety and efficacy of these vaccines.

Katalin Karikó and Drew Weissman's contributions to mRNA vaccine technology have had a profound impact on public health, as mRNA vaccines have proven highly effective in combating infectious diseases. Their work has not only revolutionized vaccine development but also opened up new possibilities in the fields of immunology and genetic medicine.

Nobel Prize: In recognition of his groundbreaking research, 2023 Nobel Prize in Physiology or Medicine has been awarded Katalin Karikó and Drew Weissman for their discoveries of nucleoside base alterations, which allowed for the creation of COVID-19 mRNA vaccines.