

David Baltimore (1938–) [1]

By: Zhu, Meilin

David Baltimore studied viruses and the immune system in the US during the twentieth century. In 1975, Baltimore was awarded the Nobel Prize in Physiology or Medicine for discovering reverse transcriptase, the enzyme used to transfer information from RNA to DNA. The discovery of reverse transcriptase contradicted the central dogma of biology at the time, which stated that the transfer of information was unidirectional from DNA, RNA, to protein. Baltimore's research on reverse transcriptase led to the discovery of retroviruses, which accelerated the development of treatments for human immunodeficiency virus or HIV and cancer vaccines. Baltimore also influenced public policy and opinion on genetic engineering. In 1975, he helped organize the Asilomar Conference in Pacific Grove, California, which discussed the [regulation](#) [2] of recombinant DNA or the DNA created using multiple sources of genetic material. Baltimore's research demonstrated how retroviruses replicate and infect cells, and his influence on the Asilomar Conference on Recombinant DNA has guided discussions about regulating biotechnology.

On 7 March 1938, Baltimore was born to Gertrude Baltimore and Richard Baltimore in New York City, New York. His mother received a bachelor's degree in English from [New York University](#) [3] in New York City, New York, and a Master's degree in experimental psychology from the New School in New York City. Baltimore's father did not attend college and worked in the garment business. In the 1940s, Baltimore's mother moved the family to Great Neck, New York so that, according to Baltimore, he and his brother Robert could attend better public schools. In 1952, he attended Great Neck High School in Great Neck and spent a summer learning about biology at the Jackson Memorial Laboratory in Bar Harbor, Maine.

In 1956, Baltimore enrolled at Swarthmore College in Swarthmore, Pennsylvania, where he declared his major in biology. However, he later switched to a chemistry major to complete a research thesis in chemistry. Between his junior and senior year, Baltimore spent his summer at Cold Spring Harbor Laboratories in Cold Spring Harbor, New York, under the supervision of George Streisinger, a molecular biologist. Streisinger was known for being one of the first researchers to clone a zebra [fish](#) [4] (*Danio rerio* [5]). With Streisinger, Baltimore studied the role of protein synthesis in virus replication. In 1960, he graduated with bachelor's degree in chemistry with high honors.

After completing his undergraduate degree, Baltimore began graduate school studying biophysics at Massachusetts Institute of Technology or MIT in Cambridge, Massachusetts. As a graduate student, Baltimore took a 1961 animal virus course at Cold Spring Harbor Laboratories, taught by professors Richard Franklin and Edward Simon. According to Baltimore, he found the course so intriguing that he left MIT to join Franklin's lab at the [Rockefeller University](#) [6] in New York City, where he could pursue a thesis studying enzymes that are made by viruses. In his study of virus enzymes, Baltimore focused on virus replication and its impact on cell metabolism. In 1963, Baltimore and Franklin provided the first description of RNA replicase, an enzyme in viruses that replicates RNA from other RNA strands. In cells, DNA carries the instructions for proteins that carry out cellular functions. RNA is a molecule that copies the DNA instructions and takes them to sites in the cell where proteins are made. Before Baltimore demonstrated the existence of RNA replicase, scientists reported that RNA was only produced from a DNA template. After completing his research with RNA replicase, Baltimore received his PhD from [Rockefeller University](#) [6] in 1964.

In 1965, Baltimore briefly worked as a postdoctoral fellow studying animal viruses under Charles Darnell at the Albert Einstein College of Medicine in the Bronx, New York. However, soon after, researcher Renato Dulbecco recruited Baltimore to work as a research associate at the Salk Institute of Biological Studies in La Jolla, California. Dulbecco studied viruses that caused cancer. With Dulbecco, Baltimore continued his work with RNA replication, studying RNA replication in polio virus. When the polio virus infects a human cell, it makes viral proteins to replicate itself. Baltimore found that the polio virus makes large viral proteins that are later cut or split into individual, smaller proteins. Understanding how proteins are processed in polio virus replication has enabled scientists to manipulate the virus and develop treatments for the disease. In 1967, Baltimore also met Alice Huang at the Salk Institute, who studied viruses at the Salk Institute.

In 1968, Nobel laureate Salvador Luria recruited Baltimore to serve as a professor of microbiology at MIT. Huang moved with Baltimore to continue her research on viruses. In October 1968, Baltimore and Huang married. At MIT, Baltimore and Huang researched a novel RNA replication strategy used by vesicular stomatitis virus, a virus known to infect [horse](#) [7] and cattle. Most cells replicate RNA, a single-stranded nucleic acid essential for gene expression, from DNA. Baltimore and Huang found that some viruses use RNA as a template to replicate other RNA molecules and also DNA. They found that some viruses use the enzyme reverse transcriptase to transcribe DNA from RNA. The class of viruses that use reverse transcriptase, which Baltimore

and Huang discovered in 1970, is called retroviruses. Retroviruses primarily use RNA to make DNA.

Baltimore and Huang's discovery of reverse transcription amended the central dogma of biology at the time. That dogma theorized that genetic information transfers only from DNA, to RNA, to protein. Prior to Baltimore and Huang's discovery, most biologists described the transfer of genetic information only in that order. However, Baltimore and Huang showed that some organisms transferred genetic material in the opposite direction, providing researchers with a better understanding of how retroviruses infect [humans](#)^[8]. When viruses infect a cell, reverse transcriptase copies the RNA of the virus into DNA and uses the human cell for virus replication. Copying the viral RNA into DNA tricks the cells into thinking it is human DNA and makes it easier for replication. Thus, Baltimore's discovery of reverse transcriptase showed how viruses with only RNA can copy its information into DNA to use cells for replication.

Baltimore was not the only person to show that RNA can be transcribed to DNA. In 1970, Baltimore and Howard Temin, an associate professor at the University of Wisconsin Madison in Madison, Wisconsin, published back-to-back articles in *Nature* about the discovery of reverse transcriptase. Baltimore and Temin both received recognition for their simultaneous discoveries of reverse transcriptase, and the researchers later shared the 1975 [Nobel Prize in Physiology or Medicine](#)^[9].

In 1972, Baltimore received a tenured professorship in the Department of Biology at MIT and helped organize the newly built Koch Institute for Integrative Cancer Research at MIT to study basic science related to cancer. Additionally, Baltimore took part in organizing discussions about the ethics of scientific research. In 1975, Baltimore helped biochemist researchers Paul Berg and Maxine Singer organize the Asilomar Conference on Recombinant DNA in Pacific Grove, California. Baltimore and his colleagues organized the conference to discuss the [regulation](#)^[2] of recombinant DNA and other biotechnology. Scientists in the 1970s used recombinant DNA to incorporate [genes](#)^[10] from one organism into the [genome](#)^[11] of another organism. Baltimore and others noted the risks of recombinant DNA technology, primarily that it could enable dangerous traits from one organism to easily transfer to other organisms. For example, some researchers were concerned that [genes](#)^[10] of a cancer-causing virus could be copied into [Escherichia coli](#)^[12] (*E. coli*), a species of bacteria that inhabits the human intestine. Those researchers argued that if that recombinant *E. coli* was improperly contained, a cancer outbreak could occur. Baltimore, Singer, and Berg organized the Asilomar conference to discuss methods to prevent such an occurrence. Most conference attendees were biologists, along with some lawyers and physicians. Baltimore and the other attendees called for a moratorium on using any recombinant DNA technology until guidelines for conducting research on recombinant DNA technology were established. Ultimately, Baltimore helped lead the one of the earliest discussions about the ethics of using DNA-editing technology.

Later in his life, Baltimore began taking on leadership roles at research institutions. In 1982, Baltimore was selected by philanthropist Edwin C. Whitehead to help establish an independent research institute dedicated to studying basic biomedical science. Baltimore served as founding director of [Whitehead Institute](#)^[13] for Biomedical Research or WBIR in Cambridge, Massachusetts. Whitehead donated 135 million dollars to fund the institution. With Baltimore as its director, the WBIR conducted research in many fields of biology, including genomics, cancer, and immunology.

During the early 1990s, the WBIR partnered with the [National Institutes of Health](#)^[14] in Bethesda, Maryland, to complete the Human Genome Project, which aimed to map out the entire human [genome](#)^[11]. Baltimore aided with that project while supporting labs at both WBIR and MIT. At WBIR and MIT, Baltimore led researchers to discover that a mutated protein called BCR-ABL alone could cause leukemia, a type of cancer that affects the bone marrow and the blood cells produced there. Because BCR-ABL is mutated, the protein causes uncontrolled cell growth in the bone marrow, leading to cancer. The discovery of the BCR-ABL protein has led to the development of an anti-cancer drug for types of leukemia called Imatinib.

Through Baltimore's research of retroviruses, he also became involved in combatting HIV. HIV is a [retrovirus](#)^[15] that leads to AIDS, a disease that prevents the immune system from working properly. In 1986, Baltimore co-authored a report, "Confronting AIDS," with Sheldon Wolff, a research scientist working at Tufts University in Boston, Massachusetts. In the report, Baltimore and Wolff called for a one-billion-dollar research program on HIV/AIDS. Baltimore also served as the head of the National Institutes of Health AIDS Vaccine Research Committee in the 1990s. He directed research and government funds for HIV/AIDS vaccine development.

Throughout his career, Baltimore served as president of several academic institutions. In 1990, he briefly served as president at [Rockefeller University](#)^[6]. He resigned one year later but stayed on as faculty for research. As research faculty, Baltimore led a research group to discover NF- κ B, a protein that helps regulate immune responses to infection in the cell. Improper expression of NF- κ B has been linked to many diseases, including cancer. In 1997, Baltimore was appointed president again of [California Institute of Technology](#)^[16] or Caltech in Pasadena, California. He served as president for eight years, retiring in 2005. In 2006, he served as president of the American Association for the Advancement of Science for three terms, which ended in 2009.

Baltimore was honored many times throughout his career for his contributions to the study of viruses and immune systems. Baltimore and Temin, among four other scientists, were awarded the Canada Gairdner International Award for their contributions

to science in 1974. The award is often considered a precursor to receiving the Nobel Prize in Physiology or Medicine. Baltimore, Temin, and Dulbecco were awarded the [Nobel Prize in Physiology or Medicine](#)^[9] in 1975 for their discovery of reverse transcription. Baltimore was honored as the American Cancer Society Professor of Microbiology in 1973 and as a fellow of the American Academy of the Arts and Sciences in 1974. In 1987, he was elected a foreign member of the Royal Society and French Academy of Science. While at [California Institute of Technology](#)^[16], Baltimore received the National Medal of Science from US President Bill Clinton in 1999 and the Warren Alpert Foundation Prize in 2000. As of 2017, Baltimore is a member of the [National Academy of Sciences](#)^[17], the American Academy of Arts and Sciences, and the American Association of Immunologists.

As of 2017, Baltimore continues to serve as Millikan Professor of Biology at Caltech. His research focuses on the function of microRNA, a subtype of nucleic acid involved in regulating mRNA expression.

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