## Genetic Timeline

### 1859
**Discovery: Natural Selection**

Charles Darwin wrote “On the Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life.”

### 1865
**Discovery: Heredity Transmitted in Units**

Gregor Mendel’s experiments on peas demonstrate that heredity is transmitted in discrete units. The understanding that genes remain distinct entities even if the characteristics of parents appear to blend in their children explains how natural selection could work and provides support for Darwin’s proposal.

### 1869
**Discovery: DNA Isolated**

Frederick Miescher isolates DNA from cells for the first time and calls it “nuclein”.

### 1879
**Discovery: Mitosis Described**

Walter Flemming describes chromosome behavior during animal cell division. He stains chromosomes to observe them clearly and describes the whole process of mitosis in 1882.
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1900

*Discovery: Rediscovery of Mendel’s work*

Botanists DeVries, Correns, and von Tschermak independently rediscover Mendel’s work while doing their own work on the laws of inheritance. The increased understanding of cells and chromosomes at this time allowed the placement of Mendel’s abstract ideas into a physical context.

1902

*Discovery: Chromosome Theory of Inheritance*

Walter Sutton observes that the segregation of chromosomes during meiosis matched the segregation pattern of Mendel’s.

1902

*Discovery: Orderly Inheritance of Disease*

A British physician, Archibald Garrod, observes that the disease alkaptonuria is inherited according to Mendelian rules. This disease involves a recessive mutation, and was among the first conditions ascribed to a genetic cause.

1909

*Discovery: The Word Gene is Coined*

Wilhelm Johannsen coins the word “gene” to describe the Mendelian unit of heredity. He also uses the terms genotype and phenotype to differentiate between the genetic traits of an individual and its outward appearance.
<table>
<thead>
<tr>
<th>Year</th>
<th>Discovery: [Title]</th>
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| 1911 | Discovery: Chromosomes Carry Genes  
Thomas Hunt Morgan and his students study fruit fly chromosomes. They show that chromosomes carry genes, and also discover genetic linkage. |
| 1941 | Discovery: One Gene, One Enzyme Hypothesis  
George Beadle and Edward Tatum’s experiments on the red bread mold, *Neurospora crassa*, show that genes act by regulating distinct chemical events. They propose that each gene directs the formation of one enzyme |
| 1943 | Discovery: DNA Has a Regular Periodic Structure  
William Astbury, a British scientist, obtains the first X-ray diffraction pattern of DNA, which reveals that DNA must have a regular periodic structure. He suggests that nucleotide bases are stacked on top of each other. |
| 1944 | Discovery: DNA Transforms Cells  
Oswald Avery, Colin MacLeod, and Maclyn McCarty show that DNA (not proteins) can transform the properties of cells -- thus clarifying the chemical nature of genes. |
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1944
*Discovery: Jumping Genes*
Barbara McClintock, using corn as the model organism, discovers that genes can move around on chromosomes. This shows that the genome is more dynamic than previously thought. These mobile gene units are called transposons and are found in many species.

1952
*Discovery: Genes Are Made of DNA*
Alfred Hershey & Martha Chase show that only the DNA of a virus needs to enter a bacterium to infect it, providing strong support for the idea that genes are made of DNA.

1953
*Discovery: DNA Double Helix*
Francis H. Crick and James D. Watson described the double helix structure of DNA. They receive the Nobel Prize for their work in 1962.

1955
*Discovery: 46 Human Chromosomes*
Joe Hin Tjio defines 46 as the exact number of chromosomes in human cells.

1955
*Discovery: DNA copying enzyme*
Arthur Kornberg and colleagues isolated DNA polymerase, an enzyme that would later be used for DNA sequencing.
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1956
*Discovery: Cause of Disease Traced to Alteration*

Vernon Ingram discovers that a specific chemical alteration in a hemoglobin protein is the cause of sickle cell disease.

1958
*Discovery: Semiconservative Replication of DNA*

Matthew Meselson and Franklin Stahl demonstrate that DNA replicates semiconservatively: each strand from the parent DNA molecule ends up paired with a new strand from the daughter generation.

1959
*Discovery: Chromosome Abnormalities Identified*

Jerome Lejeune and his colleagues discover that Down Syndrome is caused by trisomy 21. There are three copies, rather than two, of chromosome 21, and this extra chromosomal material interferes with normal development.

1961
*Discovery: First Screen for Metabolic Defect in Newborns*

Robert Guthrie develops a method to test newborns for the metabolic defect, phenylketonuria (PKU).

1961
*Discovery: mRNA Ferries Information*

Sydney Brenner, François Jacob and Matthew Meselson discover that mRNA takes information from DNA in the nucleus to the protein-making machinery in the cytoplasm.
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### 1966
**Discovery: Genetic Code Cracked**
Marshall Nirenberg and others figure out the genetic code that allows nucleic acids with their 4 letter alphabet to determine the order of 20 kinds of amino acids in proteins.

### 1968
**Discovery: First Restriction Enzyme Described**
Scientists describe restriction nucleases, enzymes that recognize and cut specific short sequences of DNA. The resulting fragments can be used to analyze DNA, and these enzymes later became an important tool for mapping genomes.

### 1972
**Discovery: First recombinant DNA**
Scientists produce recombinant DNA molecules by joining DNA from different species and subsequently inserting the hybrid DNA into a host cell, often a bacterium.

### 1973
**Discovery: First animal gene cloned**
Researchers fuse a segment of DNA containing a gene from the African clawed frog Xenopus with DNA from the bacterium E. coli and placed the resulting DNA back into an E. coli cell. There, the frog DNA was copied and the gene it contained directed the production of a specific frog protein.
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1975
*Discovery: DNA Sequencing*

Two groups, Frederick Sanger and colleagues, and Alan Maxam and Walter Gilbert, both develop rapid DNA sequencing methods. The Sanger method is most commonly employed in the lab today, with colored dyes used to identify each of the four nucleic acids that make up DNA.

1976
*Discovery: First Genetic Engineering Company*

Herbert Boyer founds Genentech. The company produces the first human protein in a bacterium, and by 1982 markets the first recombinant DNA drug, human insulin.

1977
*Discovery: Introns Discovered*

Richard Roberts’ and Phil Sharp’s labs show that eukaryotic genes contain many interruptions called introns. These non-coding regions do not directly specify the amino acids that make protein products.

1981
*Discovery: First Transgenic Mice and Fruit Flies*

Scientists successfully add stably inherited genes to laboratory animals. The resulting transgenic animals provide a new way to test the functions of genes.
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### 1982

**Discovery: GenBank Database Formed**

Scientists begin submitting DNA sequence data to a National Institutes of Health (NIH) database that is open to the public.

### 1983

**Discovery: First Disease Gene Mapped**

A genetic marker for Huntington’s disease is found on chromosome 4.

**Discovery: PCR Invented**

The polymerase chain reaction, or PCR, is used to amplify DNA. This method allows researchers to quickly make billions of copies of a specific segment of DNA, enabling them to study it more easily.

### 1986

**Discovery: First Time a Disease Gene is Positionally Cloned**

A method for finding a gene without the knowledge of the protein it encodes is developed. So called, positional cloning can help in understanding inherited disease, such as muscular dystrophy.
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1987

Discovery: First Human Genetic Map

The first comprehensive genetic map is based on variations in DNA sequence that can be observed by digesting DNA with restriction enzymes. Such a map can be used to help locate genes responsible for diseases.

1987

Discovery: Yeast Artificial Chromosomes

Scientists discover that artificial chromosomes made from yeast can reliably carry large fragments of human DNA containing millions of base-pair pieces. Earlier methods used plasmids and viruses, which can carry only a few thousand base-pair pieces. The ability to deal with much larger pieces of DNA makes mapping the human genome easier.

1989

Discovery: Microsatellites Are New Genetic Markers

Repetitive DNA sequences called microsatellites are used as genetic landmarks to distinguish between people. Another type of marker, sequence–tagged sites, are unique stretches of DNA that can be used to make physical maps of human chromosomes.

1990

Discovery: Launch of the Human Genome Project

The Department of Energy and the National Institutes of Health announce a plan for a 15-year project to sequence the human genome. This will eventually result in sequencing all 3.2 billion letters of the human genome.
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1991

**Discovery: ESTs, Fragments of Genes**

An expressed-sequence tag (EST) an identified piece of a gene, is made by copying a portion of a messenger RNA (mRNA) molecule. As such, ESTs provide a way to focus on the “expressed” portion of the genome, which is less than one-tenth

1992

**Discovery: Second-Generation Genetic Map of Human Genome**

A French team builds a low-resolution, microsatellite genetic map of the entire human genome. Each generation of the map helps geneticists more quickly locate disease genes on chromosomes.

1994

**Discovery: FLAVR SAVR Tomato**

The Food And Drug Administration approves the sale of the first genetically modified food.

1995

**Discovery: Ban on Genetic Discrimination in the Workplace**

Protection under the American with Disabilities Act is extended to cover discrimination based on genetic information.
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1996
*Discovery: Mouse Genetic Map Completed*

The lab mouse is valuable for genetics research because humans and mice share almost all of their genes, and the genes on average are 85% identical. The mouse genetic map increases the utility of mice as animal models for genetic disease in humans.

1997
*Discovery: E. coli Genome Sequenced*

The complete sequence of the *E. coli* genome will help scientists learn even more about this extensively studied bacterium.

1998
*Discovery: M. tuberculosis Bacterium Sequenced*

*Mycobacterium tuberculosis* causes the chronic infectious disease tuberculosis. The sequencing of this bacterium is expected to help scientists develop new therapies to treat the disease.

1998
*Discovery: Roundworm C. elegans Sequenced*

The first genome sequence of a multicellular organism, the round worm, *Caenorhabditis elegans*, is completed.
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1999

*Discovery: Chromosome 22 Sequenced*

The first finished, full-length sequence of a human chromosome is produced. Chromosome 22 was chosen to be first because it is relatively small and had a highly detailed map already available. Such a map is necessary for the clone by clone sequencing approach.

2000

*Discovery: Human Genome Working Draft Completed*

By the end of Spring 2000, HGP researchers sequence 90 percent of the human genome with 4-fold redundancy. This working draft sequence is estimated to be 99.9% accurate.

2002

*Discovery: Mouse Genome Working Draft Assembled and Analyzed*

The Mouse Genome Sequencing Consortium publishes an assembled draft and comparative analysis of the mouse genome. This milestone was originally planned for 2003.

2002

*Discovery: Rat Genome Working Draft Completed*

By Fall 2002, researchers sequence over 90% of the rat genome with over 5-fold redundancy.
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2003

*Discovery: Completion of the Human Genome Sequencing*

The finished human genome sequence will be at least 99.99% accurate.

The Future

It will take decades of research for scientists to understand all of the information that is contained within the human genome. In time, more human diseases will be understood at the level of the molecules that are involved, which could dramatically change the practice of medicine by leading to the development of new drugs, as well as to genetic testing to improve and individualize treatments.