

THE RESEARCH SCIENCE AND THE SHAPING OF MODERN LIFE REVOLUTION



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Session 3 Genetics Could We?

When Austrian monk Gregor Mendel's mid-19th century experiments led to the discovery of the basic mechanisms of heredity, the science of genetics was born. Since then, the focus of scientific inquiry has moved from Mendel to molecules and from genetics—the study of individual genes and the way traits pass between generations—to genomics, the study of an organism's entire complement of DNA (deoxyribonucleic acid). Today the landscape is dominated by the Human Genome Project whose end product—the complete sequence of all 3.1 billion base pairs of DNA contained in almost every human cell—is an encrypted blueprint for human life. No one could have predicted that only a century after Mendel, scientists would begin to master the DNA molecule itself. How did we reach this point? The story is one of persistence, intuition, and just plain luck.

In 1944, a series of ingenious experiments established that genes are made up of DNA and the existence of genes became less and less theoretical. In the 1950s scientists developed X-ray crystallography which made it possible to interpret the three-dimensional structure of a crystallized molecule. It allowed Maurice Wilkins and Rosalind Franklin to take "snapshots" of DNA that were used in 1953 by James Watson and Francis Crick to discover that DNA was shaped like a spiral staircase, or double helix. Their discovery of the actual physical structure of DNA finally created a consensus among geneticists that genes were real. With the basics of heredity now worked out, their successors began to examine and manipulate genetic processes at the molecular level.

The other major players at the molecular level are proteins—structures that are made of amino acids and govern cell function. In the 1950s, chemist Fred Sanger figured out how to determine the order of amino acids in a given protein. That proteins consist of linear arrays of twenty amino acids, and genes consist of linear arrays of four nucleic acids, or bases (DNA) indicated that some kind of code connected the information in the DNA to the production of proteins. In the 1960s, Crick and Sydney Brenner determined that a different triplet of bases in the DNA—called codons—codes for each of the twenty amino acids, chains of which build the various proteins. The code eventually turned out to be the same in all organisms, from ferns to flamingos.

Technologies that enabled scientists to see and manipulate specific DNA sequences also evolved. A crucial breakthrough was the invention of polymerase chain reaction (PCR) by Kary Mullis in 1983, a process that generates trillions of copies of a specified segment of DNA in a matter of hours. PCR transformed molecular biology by making genetic material in quantities large enough to allow experimentation. All these discoveries set the stage for the first sequencing of an entire genome, that of a tiny virus called PhiX0174, in 1977. The sequence unveiled many unknowns about genes and gene structure, a theme that played out over and over as more genomes were sequenced.

Now that the human genome has been sequenced, the emphasis is shifting to proteomics: the study of all the proteins for which genes code. While a genome is relatively fixed, the proteins in any particular cell change dramatically as genes are turned on and off in response to their environment, directing an astonishing range of biological functions with exquisite precision, and producing a multiplicity of outcomes.

But the ability to manipulate DNA makes us capable of doing immense harm to ourselves and our environment including the potential for genetic discrimination and the invasion of genetic privacy, and the environmental consequences of altering the genomes of plants and animals. As our skills and knowledge grow, we need to think hard about dealing with such potential consequences.

There is no doubt, however, that genomic technologies will change our lives for the better. Comparative genomics, which compares whole genome sequences from a range of

organisms, will advance our understanding of the natural world and the role genes play in complex human diseases. Microarray technology, which enables scientists to compare tens of thousands of genes at once, promises to unlock the genetic roots of diseases and to enhance our ability to treat them. The new field of pharmacogenomics will usher in an era of personalized medicine. There may even come a time when geneticists begin to manipulate our genes to increase human life spans. Finally, as we sequence the genomes of more and more species, our understanding of the tree of life and our place in the natural world will deepen.

Further Reading:

- Davies, Kevin. *Cracking the Genome: Inside the Race to Unlock Human DNA*. (Free Press, 2001)
- Roleff, Tamara, ed. *Biomedical Ethics: Opposing Viewpoints*. (Greenhaven Press, 1998)
- Yount, Lisa, ed. *Genetic Engineering*. (Greenhaven Press, 2002)

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