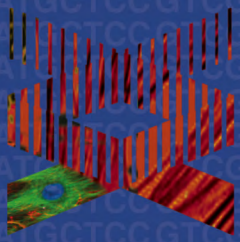
A GUIDE TO YOUR GENOME



NATIONAL
HUMAN GENOME
RESEARCH INSTITUTE

There are more than 6 billion people on our planet — each a massive collection of about 100 trillion cells.

How do these cells know what to do? What tells them to work together to keep your heart pumping, brain thinking and bones growing? The answer lies in a long, winding molecule called deoxyribonucleic acid, or DNA.

The DNA contained within each of your cells carries the instructions needed to build and maintain the many different types of cells that make you, you. Researchers call this complete set of DNA instructions a "genome."

Is my genome unique?

Humans come in many shapes and sizes, but we're all very similar at the DNA level. In fact, the genomes of any two people are more than 99% the same.

Still, the tiny fraction of the genome that varies among humans is very important. DNA variations are part of what makes each of us unique. They affect the color of your eyes, hair and skin. What's more, they influence your risk of disease and your response to drugs.

So, is everything determined by my genome?

No, your DNA is just one part of the amazing puzzle of who you are.

When it comes to your health, other pieces of the puzzle include lifestyle and environmental factors, such as the food you eat and the air you breathe. Once we learn more about how the human genome interacts with these factors to cause disease, we may be able to change our habits and adapt our environment to improve our health.

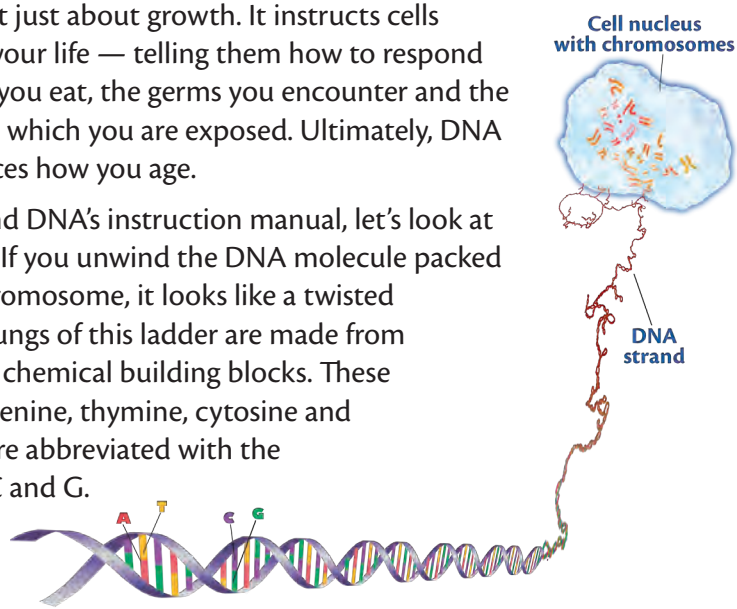
Our genomes also are likely to contribute to some of the ways we feel, think and act. But keep in mind that many other things, such as how you were raised and your access to medical care, can influence your behaviors and your health.

What does my genome do?

If you could peer inside your cells, you'd see your genome contained in 46 tightly packed bundles of DNA — 23 came from your mother and 23 from your father. These DNA bundles, called chromosomes, provide the instructions that enable a one-cell embryo to develop into a 100 trillion-cell adult.

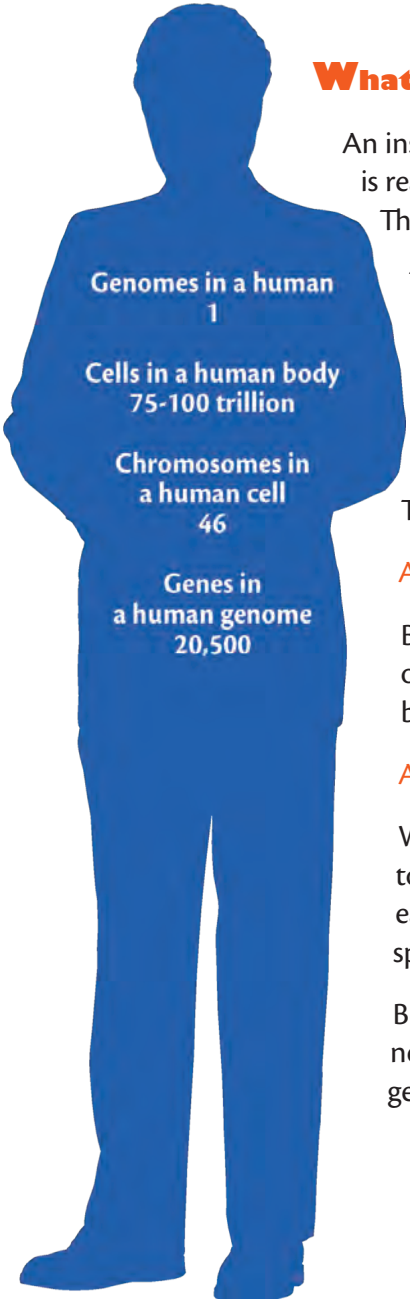
But DNA isn't just about growth. It instructs cells throughout your life — telling them how to respond to the foods you eat, the germs you encounter and the pollutants to which you are exposed. Ultimately, DNA even influences how you age.

To understand DNA's instruction manual, let's look at its structure. If you unwind the DNA molecule packed into each chromosome, it looks like a twisted ladder. The rungs of this ladder are made from four types of chemical building blocks. These blocks — adenine, thymine, cytosine and guanine — are abbreviated with the letters A, T, C and G.



Depending on how many of these building blocks are stacked together and the order in which they are arranged, DNA can produce many different types of organisms.

It takes about 3 billion pairs of A's, T's, C's and G's to write the instructions needed to build a human. So, every time the human body produces a sperm or an egg, 3 billion DNA letters must be copied and packaged so they can be passed along to future offspring.



What's a gene?

An instruction manual isn't worth much until it is read and actually used to make something. The same goes for your genome.

The DNA building blocks, or letters, in your genome combine in different ways to spell out specific instructions. Still, the language of the genome doesn't make much sense at first glance.

Try reading this sequence of DNA letters:

ATTCAGGGTCTAATGATCGTG

But if you know how to decode the string of letters — and every cell does — you can begin to see three-letter "words."

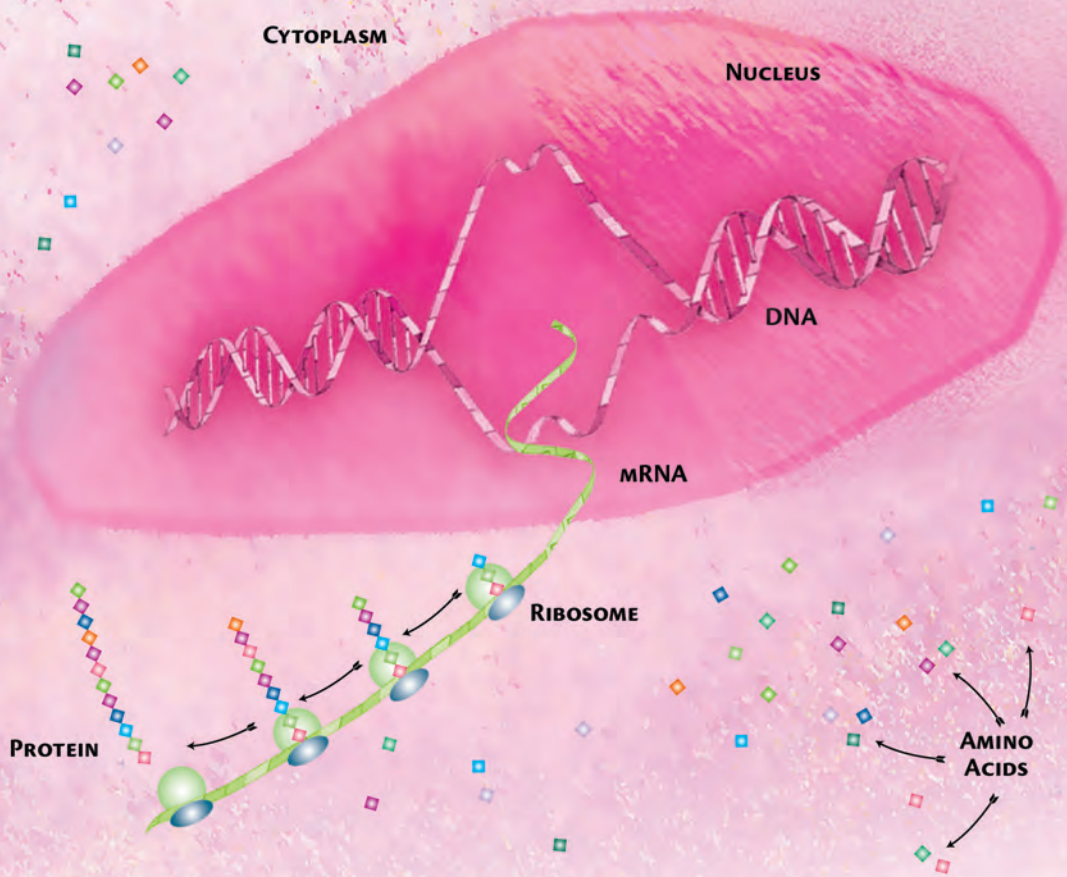
ATT CAG GGT CTA ATG ATC GTG

What's more, these words are strung together to make sentences, or genes, each of which tells the cell how to make a specific protein.

Because tens of thousands of proteins are needed to build an entire human, your genome contains about 20,500 genes.

Genes at Work

So, your genome provides instructions in the form of genes. But exactly how are these instructions used to build proteins?



To make a protein, a gene's DNA sequence is transcribed into a molecule called messenger RNA (mRNA). This molecule leaves the nucleus and enters the outer region of the cell, called the cytoplasm. There the mRNA is read. Tiny machines called ribosomes use the information to assemble building blocks, known as amino acids, into a protein.

What are genetic mutations? And how do they cause disease?

Each of us contains many slight variations in our genomes that make us unique. Most of these variations have little or no impact on our health. But that's not always the case.

Sometimes if a DNA letter is missing or wrong in a gene's instructions, it may produce a damaged protein, extra protein or no protein at all. Such changes in genes are called genetic mutations.

Genetic mutations can cause serious health problems because they affect proteins, which are the workhorses of your body. For example, proteins form special scaffolds that help your cells keep their shapes. They serve as enzymes that help your stomach digest food. The molecule that carries oxygen in your blood is a protein, as are estrogen, testosterone and other hormones.

The transmission of genetic mutations from one generation to the next helps to explain why many diseases run in families. If a certain disease runs in your family, doctors say you have a family history of the condition.

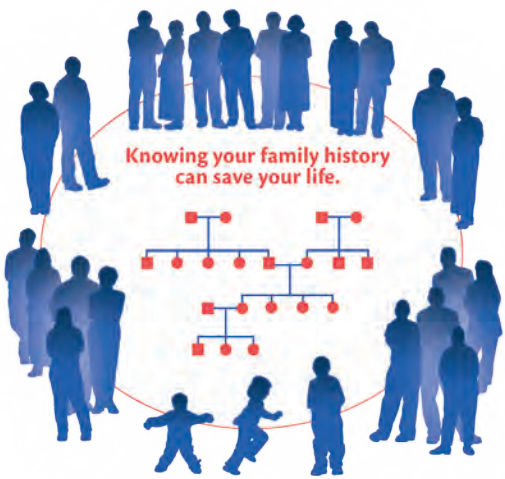
What genetic tests are available for diseases?

Many rare diseases, such as cystic fibrosis and sickle cell anemia, are caused by mutations in a single gene. Single genes also are responsible for some of the rare, inherited types of cancer. Over the past couple of decades, researchers have developed genetic tests to detect mutations for many single-gene disorders. This has led to ways to prevent or reduce symptoms of some of these diseases.

Genetic tests also are available to help couples learn if they carry genetic mutations for rare diseases and if they are likely to have a child affected by the disease. If you are interested in such tests, a good place to start is talking to a genetic counselor or an obstetrician.

Most genetic tests involve taking a small sample of blood or saliva and sending it to a lab. At the lab, technicians purify DNA from the sample and use various technologies to see if it contains a specific genetic mutation. One approach involves placing DNA on tiny chips, called microarrays, that resemble the chips used in computers.

The situation is far more complex for most common diseases, such as cancer, diabetes and heart disease. Researchers are finding that multiple genes — along with lifestyle and environmental factors — interact to determine the risk of these and many other disorders. Another complication is that our genomes also contain genetic variations that protect us against certain diseases.



So, it will take some time before genetic tests are developed to provide a complete picture of your risks for common diseases.

Until then, one important thing you can do for your health — and your family's health — is to collect your family history. Knowing what diseases have affected your blood relatives can help your health care provider gauge your risk for certain diseases and suggest ways to reduce that risk.

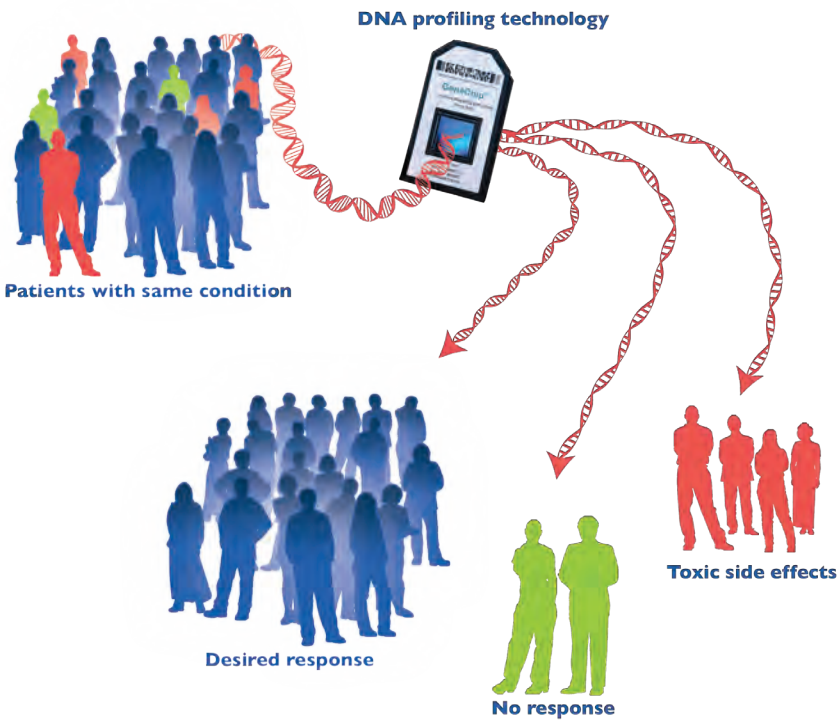
To organize and create your family health history, use the U.S. Surgeon General's free Web tool at: www.surgeongeneral.gov/familyhistory

What will genome research mean for me?

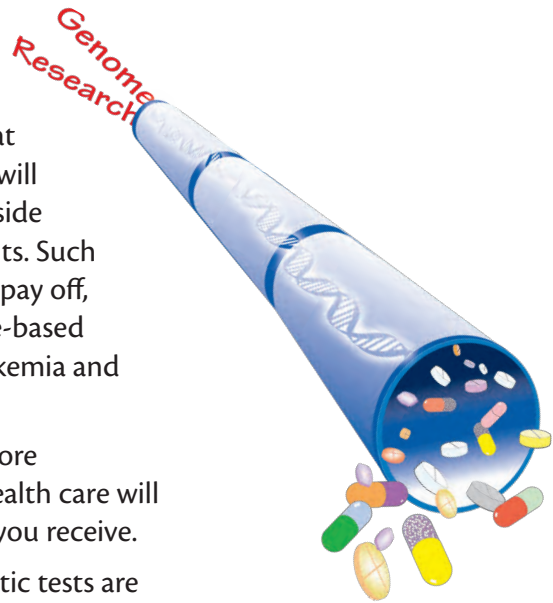
Walk into any drugstore and you'll find drugs developed with the idea that most drugs work pretty much the same way in all people. But genome research has helped to reshape that thinking. Depending on your genetic make-up, some drugs may work faster or slower — or produce more or fewer side effects — in you than they do in others.

Thanks to genome research, doctors soon will be able to use information about your genes to choose those drugs and drug dosages that are most likely to work well in you.

Genetic Testing for Drug Response



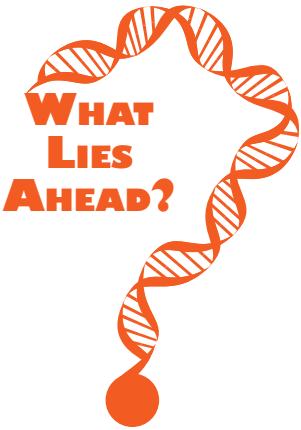
This research will also lead to the development of better drugs. Rather than screening for chemicals with broad action against a disease, researchers are now using genomic information to design drugs targeted at specific pathways involved in the disease. The hope is that this new generation of drugs will work better and cause fewer side effects than current treatments. Such efforts are already starting to pay off, as seen by the success of gene-based drugs in the treatment of leukemia and other cancers.



But that's not all. This new, more individualized approach to health care will extend far beyond the drugs you receive.

Within the next decade, genetic tests are expected to become available to predict your risk for many common conditions. Such tests will signal the end to the current "one-size-fits-all" approach to health care. Based on the information contained in your genome, your health care provider will develop more personalized strategies for detecting, treating and preventing disease.

If your genetic profile shows that you are at increased risk for colon cancer, you might undergo more frequent colonoscopy screening and reduce the amount of meat in your diet. Or if your genome contains variations that raise your risk of heart disease, you might exercise more and take drugs that lower cholesterol.



There is bright promise on the horizon. As researchers learn more about the human genome, more and more gene-based tools and technologies will appear everywhere — from the doctor's office to the crime lab. Progress is being made faster than anyone ever dreamed possible.

But is our society fully prepared to handle these new tools and technologies?

Since the start of the Human Genome Project, the National Human Genome Research Institute has devoted a significant part of its resources to addressing the ethical, legal and social implications of genome research.

Among the many questions being tackled are: Who should have access to your personal genetic information? What can be done to make sure that genetic information is not used to discriminate against individuals or groups? Will all sectors of society have access to these new technologies?

On a personal level, you likely will face some challenging issues and decisions related to gene-based technologies and information over the course of your lifetime.

By learning more about your genome and what it may mean for your future, you have taken a major step towards preparing yourself for this exciting new era: The Genome Era.

Learn More About Your Genome & Your Health

Genetics and Rare Diseases Information Center
www.genome.gov/Health/GARD
E-mail: gardinfo@nih.gov
Toll-free phone (12 p.m-6 p.m. Eastern, Mon.-Fri.)
1-888-205-2311
TTY: 1-888-205-3223

This free service provides information about genetic and rare diseases. Its Web site offers educational materials and refers people to reliable sources of information. Information specialists are also available to answer questions in English and Spanish.

Health Fact Sheets
www.genome.gov/Health/FactSheets

This series of fact sheets helps health care consumers understand genetic concepts and technologies. Topics include genetic testing, genetic counseling and overviews of specific genetic disorders.

Genetics Home Reference
http://ghr.nlm.nih.gov

This online reference, created by the National Library of Medicine at NIH, provides consumer-friendly information about the effects of genetic variations on human health. It contains information on the genetics of more than 200 conditions.

NHGRI Clinical Studies
www.genome.gov/ClinicalStudies

Learn about clinical studies being conducted by the National Human Genome Research Institute (NHGRI). This online resource lists eligibility criteria and contact information for each study.

Learn More About the Science of Your Genome

Talking Glossary
www.genome.gov/Education/Glossary

This online glossary features written definitions, audio explanations and illustrations. It is designed to help people without scientific backgrounds understand the terms and concepts used in genetic research.

Understanding the Human Genome Project
www.genome.gov/Education/Kit

This multi-media, educational kit covers the basics of genomic science. Interactive modules help high-school students to better understand genetics, molecular biology and the Human Genome Project. It is available online and as a CD-Rom, which can be requested by sending an e-mail to nhgriecib@mail.nih.gov.

Science Fact Sheets
www.genome.gov/Education/FactSheets

NHGRI offers a series of fact sheets that explain complex genetic concepts and research techniques to a non-scientific audience. Topics include cloning, DNA chip technologies and genome-wide association studies.

Comparing Genomes

Every living creature has a genome. These collections of DNA, passed from parents to offspring, contain the specific instructions that make each type of organism unique. By comparing our genome with those of other creatures, we can learn much about the human body and how it functions in health and disease.

Species	Chromosomes	Genes
Human	46	20,500
Chimpanzee	48	20,000 - 23,000
Dog	78	19,300
Mouse	40	22,500 - 30,000
Japanese pufferfish	44	30,000 - 40,000
Fruit fly	8	14,000
Rice	24	46,000 - 55,600

The Human Genome Project

In 1990, researchers from around the world launched the Human Genome Project. Their goal: to determine the sequence of the 3 billion building blocks, or letters, in our DNA instruction manual.

Why? Hidden among these billions of letters is information that will expand our knowledge of the human body and improve human health.

Led in the United States by the National Human Genome Research Institute (NHGRI) and the Department of Energy, the Human Genome Project was completed in April 2003. But exploration of the genome is just beginning.

To really understand how something works, you first need a checklist of all the individual parts and a chart of where they are located. Then, you must figure out how all these parts fit together -- and how they work together.

Researchers face a similar challenge. They now have a pretty good list of parts: the human genome sequence. But they still need to figure out exactly where each part is located, how different parts interact with each other and how the parts work together to contribute to health and disease.

Today, NHGRI supports many research projects that build upon the foundation laid by the Human Genome Project. These include efforts to map human genetic variation, to develop less costly sequencing technologies and to unravel the genetics of cancer and other common diseases.

www.genome.gov

NIH Publication No. 07-6284
October 2007

Graphics: J. Ades for NHGRI