The Stuff of Life

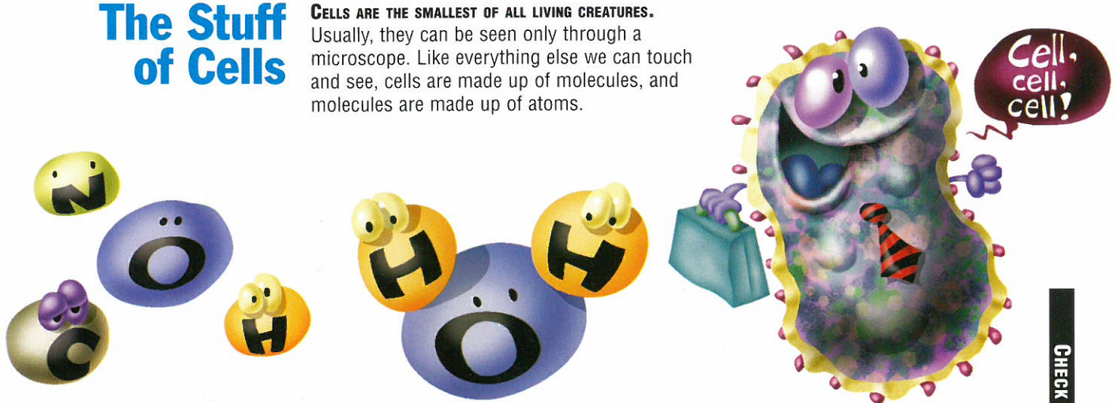
All living things have one thing in common—they are made from cells.

Cells are often described as "building blocks." For instance, you are made of many trillions of cells. Yet cells are not just tiny bricks. Like you, each one gathers fuel, creates energy, grows, reproduces, and even dies.

Every cell also carries a complete set of instructions. In a plant cell, it determines things like leaf size. In a tiger, it tells each cell in a stripe what color to be. In a human cell, it gives us features like height and eye color. It also decides whether an organism turns into a plant, a tiger, or a human. In other words, cells contain the master code that makes all living things what they are.

The Stuff of Cells

CELLS ARE THE SMALLEST OF ALL LIVING CREATURES. Usually, they can be seen only through a microscope. Like everything else we can touch and see, cells are made up of molecules, and molecules are made up of atoms.



1. ATOMS

Atoms are the most basic elements of the universe. Everything living and nonliving is made up of them. The most common atoms are carbon, hydrogen, nitrogen, and oxygen.

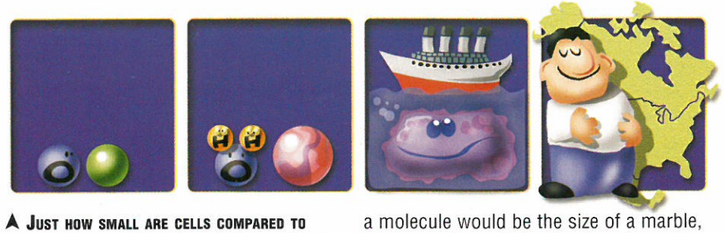
2. MOLECULES

Molecules are atoms that are bonded together. For instance, one water molecule is made up of two hydrogen atoms and one oxygen atom (H_2O).

3. CELLS

Cells are the most basic units of life. They are made up of many atoms and molecules.

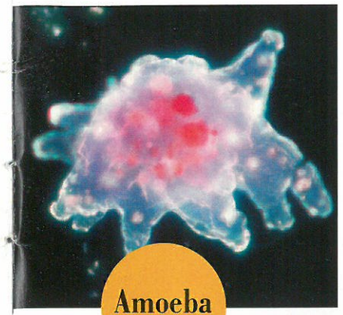
How Small ?



▲ **JUST HOW SMALL ARE CELLS COMPARED TO** other microscopic objects? According to biologist and author Mahlon Hoagland, if an atom were the size of a small pea, a molecule would be the size of a marble, and one cell would be the size of a cruise ship. A human body would be the size of North America.

CHECK IT OUT! What single cell do you eat for breakfast? *(answer on back cover)*

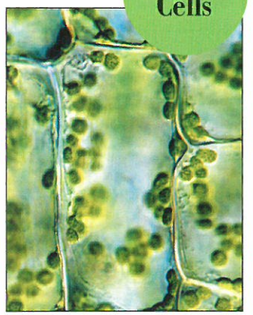
Cells Can Work Alone or Together



Amoeba

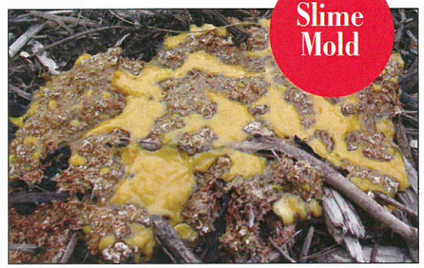
▲ **Single Cells** Creatures made up of one cell are *unicellular.* An amoeba is a single-celled organism that constantly changes shape.

▼ **Cell Groups** Many identical unicellular creatures work so closely with each other that they appear to be one larger creature. Slime molds, for instance, are a colony of cells working together. Individually, they are too small to be seen, but as a colony, they can be seen without a microscope. Scientists have learned that even bacteria can communicate with each other to coordinate their behavior.



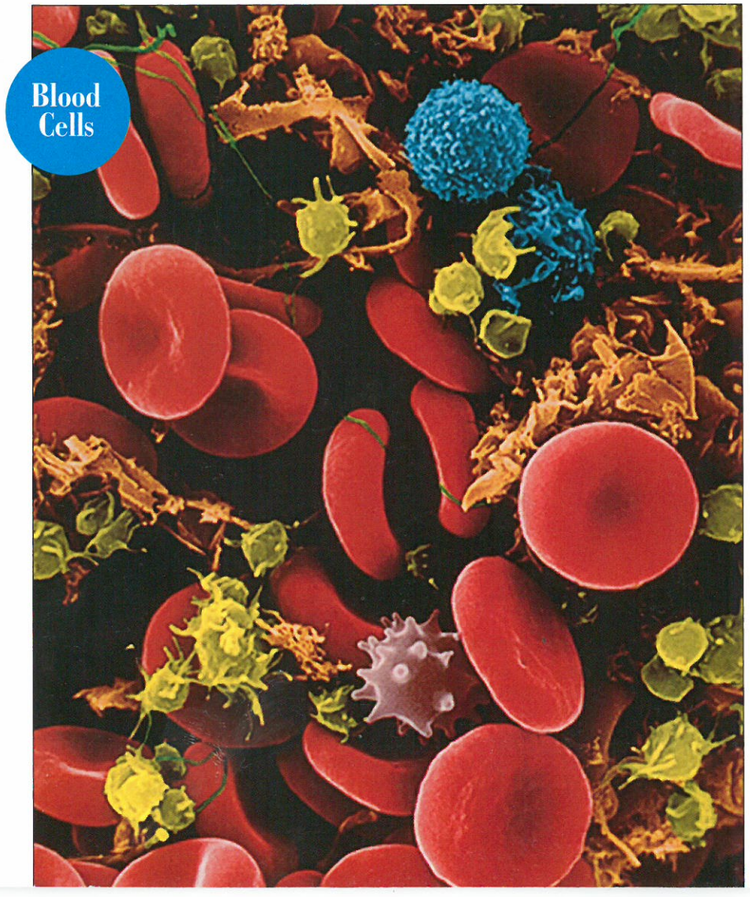
Plant Cells

◄ **Plant Cells** Like people and other animals, plants have specialized cells. These cells might make up the roots and stems or give the stem support. Plants also have specialized cells for transporting food and water.

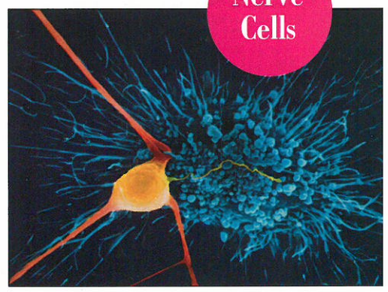


Slime Mold

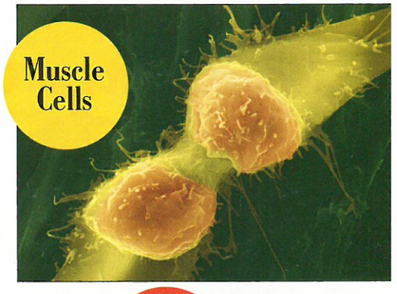
▼ **Animal Cells** Human bodies contain many types of specialized cells, which fall into six categories: blood, nerve, muscle, fat, bone, and skin. (Creatures, including people, which are made up of two or more cells are *multicellular.*) Groups of similar cells form tissue, such as muscle or epidermal (the outer layer of skin), and tissues make up organs, such as the heart and lungs.



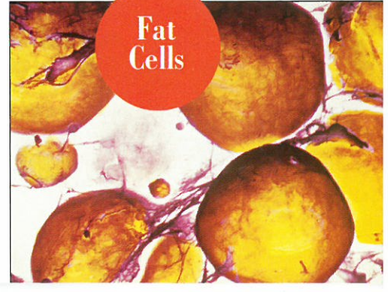
Blood Cells



Nerve Cells



Muscle Cells



Fat Cells

CHECK IT OUT!

How big is an average cell? *(answer on back cover)*

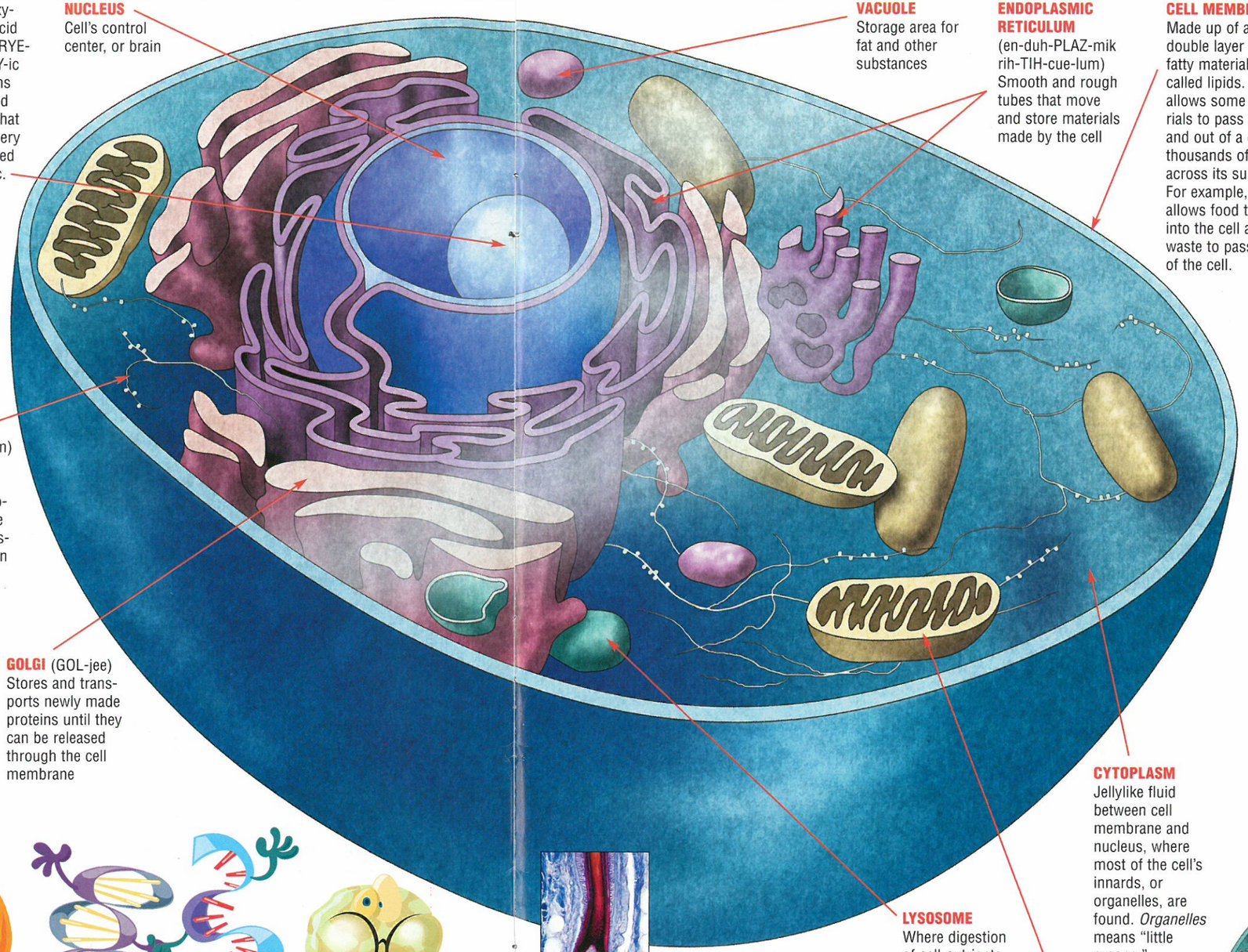
Zooming In

In 1664, English scientist Robert Hooke viewed a thin slice of cork through an early microscope. Cork looked to him as if it were constructed of dozens of tiny rectangular compartments. He called them *cells*, from the Latin *cella*, meaning small room.

At first, scientists couldn't see much within a cell and thought it was just filled with jelly. They called that jelly *protoplasm*. But improved microscopes slowly changed that view. We know now that each cell is really a complex part of life.

What's in a Cell?

Each cell is different, but all cells have features similar to this HUMAN CELL



DNA, or deoxyribonucleic acid (dee-ox-see-RYE-bo-new-CLAY-ic acid), contains cleverly coded information that passes on every single inherited characteristic.

NUCLEUS
Cell's control center, or brain

VACUOLE
Storage area for fat and other substances

ENDOPLASMIC RETICULUM
(en-duh-PLAZ-mik rih-TIH-cue-lum)
Smooth and rough tubes that move and store materials made by the cell

CELL MEMBRANE
Made up of a double layer of fatty material called lipids. It allows some materials to pass into and out of a cell at thousands of places across its surface. For example, it allows food to pass into the cell and waste to pass out of the cell.

RIBOSOME
(RI-buh-sohm)
Protein-producing factories. Proteins produce chemical messages that run a cell.

GOLGI (GOL-jee)
Stores and transports newly made proteins until they can be released through the cell membrane

LYSOSOME
Where digestion of cell nutrients takes place

CYTOPLASM
Jellylike fluid between cell membrane and nucleus, where most of the cell's innards, or organelles, are found. *Organelles* means "little organs."

MITOCHONDRION
(mite-uh-CON-dree-on)
Produces energy for cell to use by breaking down substances

Ingredients of Cells

WATER
Water makes up about 90 percent of a cell's weight. Here's what's in the other 10 percent:

PROTEINS
About 5 percent are protein molecules, which in turn are made up of chemicals called amino acids.

CARBOHYDRATES
These are sugars, which are burned for quick energy. They make up about 2.5 percent.

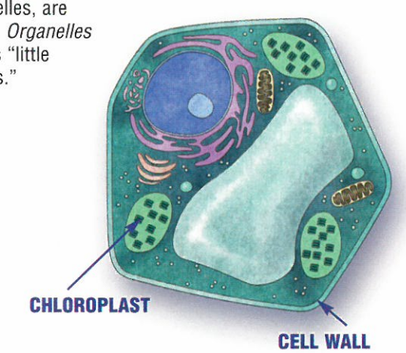
NUCLEIC ACIDS
These go by their initials—DNA and RNA—and make up about 1.5 percent of cells. They control the cells by supplying the codes that decide which chemicals get made and when.

FATS
Fats, oils, and waxes called lipids make up about 1 percent—mostly in the cell's outer membrane.

▲ **HAIR FOLLICLES,** like this one, and nails are made of proteins. About half the stuff in your body is made of protein. Every person has about 500,000 different proteins working at any time. Most serve as switches that turn chemical reactions on and off when needed. Proteins are made by organelles. Organelles perform other jobs as well, such as turning food into energy and moving molecules around.

PLANT CELLS differ greatly from animal cells

THEY HAVE A STIFF outer covering instead of a fatty one. Most plant cells also contain organelles called chloroplasts. Within each chloroplast, the green pigment (color) chlorophyll uses the sun's light energy to combine carbon dioxide and water to make sugar. This process—called photosynthesis—supplies plants with energy. Plants in turn supply energy for all other forms of life.



DNA

DNA dee-ox-see-RYE-bo-new-CLAY-ic acid

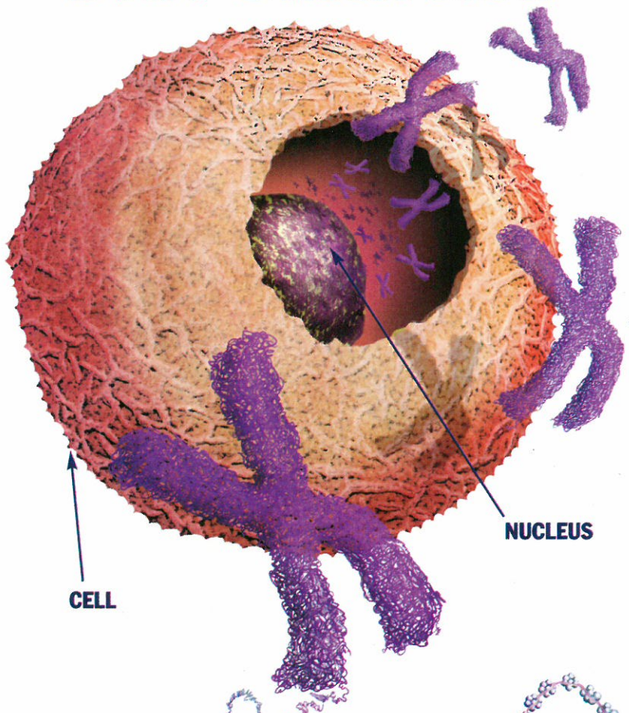
Deoxy no oxygen

Ribo type of sugar

Nucleic in the cell's nucleus, or core

Acid Sour chemical, like vinegar

DNA Unraveled



CHROMOSOME
Chromosomes are made up of tightly wound strands of DNA. Chromosomes are found in the cell's nucleus.

HISTONE
Histones are protein molecules. They act as spools around which DNA winds. Histones play a role in gene regulation.

SUPERCOIL
A lot of DNA has to fit into a small package, so it is tightly coiled. If you keep twisting a rubber band, it eventually curls up into a small ball, just the way DNA becomes "supercoiled."

◀ **DNA IS FOUND IN** the cell's nucleus. DNA is a big deal because it carries the instructions the body needs in order to function.

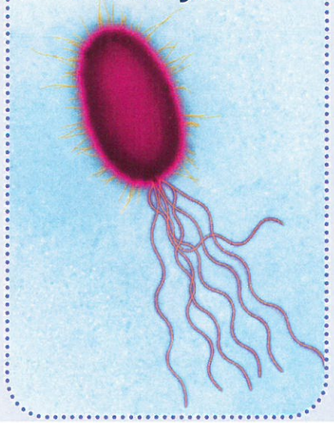
A hush falls over the courtroom. A lawyer points dramatically at a man sitting behind a table and thunders, "DNA evidence proves that this man is the killer."

Moments like that—both on TV and in real courtrooms—have made DNA the rock star of cell science, or cytology. Even many people who are not sure what a cell is have heard of DNA evidence and DNA testing. Police today routinely catch criminals by using DNA tests. Your DNA is as individual as your fingerprint pattern. Just a bit of hair, saliva, or blood can provide enough DNA to solve an otherwise unsolvable mystery.

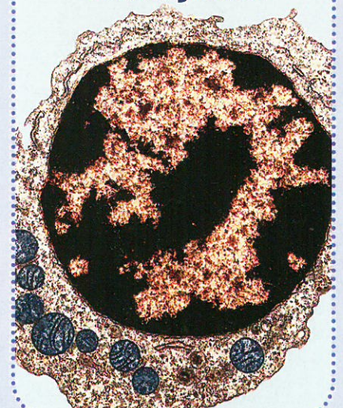
➤ **THE NUCLEUS OF** each human cell has around 25,000 genes. Genes are the most basic unit of heredity. They carry the traits we inherit from Mom and Dad. One gene is just a section of DNA on a chromosome that tells the cells to make a particular protein. Proteins determine such things as hair texture and foot size—and whether we have hair or feet at all. They also ensure that skin grows and blood circulates. One gene might produce a single trait, like being able to roll your tongue. But genes usually work together.

NOT EVERY CELL HAS a nucleus. Fossils show that Earth's first life forms were prokaryotes (pro-KAHR-ee-oats)—cells with no nucleus. They appeared about four billion years ago. Cells with a nucleus—called eukaryotes (you-KAHR-ee-oats)—appeared about 1.6 billion years ago. Scientists now believe that eukaryotes form from prokaryotes fusing together to make new, more complex life forms. A prokaryote might have one small strand of DNA. Eukaryotes can have up to one thousand times that. Today, prokaryotes are mainly one-celled bacteria. Most other types of life are eukaryotes.

Prokaryotes



Eukaryotes

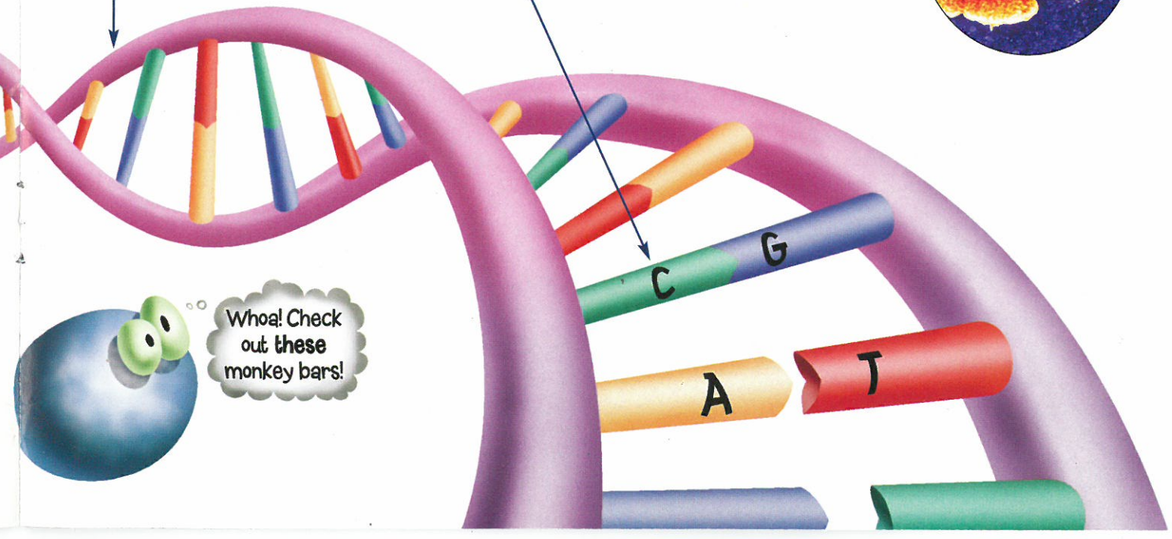


CHECK IT OUT! What type of cell in your body has no nucleus? *(answer on back cover)*

DOUBLE-STRANDED DNA
If you stretched out one DNA strand, it would look like a spiral ladder, a shape scientists call the "double helix." Running down the center of the ladder are steps that hold it together. These rungs are made of pairs of molecules called bases.

BASES (LETTERS) OF THE GENETIC CODE
The code of life—like whether you have blue eyes or brown—depends on which base pairs follow which along the ladder. There are four different possible base pairs, and any number of different patterns can be made with them. These patterns form the codes for an individual, and we call them genes.

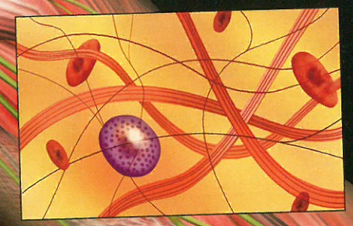
This is what real chromosomes look like.



What Cells Do

Tissue Types

The trillions of cells in our bodies join to create one living being. In animals, similar cells group together to form four types of tissue.

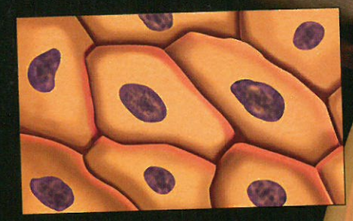


CONNECTIVE

This is the most abundant tissue in the body. It was given its name because its chief function is to connect the other three tissues.

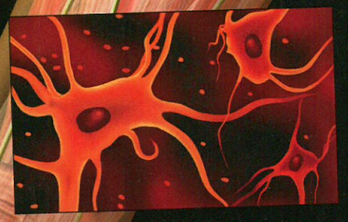
MUSCLE

This tissue is responsible for movement. It makes up voluntary muscles, which carry out movement you can control, such as flexing your fingers, and involuntary muscles, which move on their own, such as your heart beating.



EPITHELIAL

This tissue forms the covering or lining of all of the body's surfaces.



NERVE

This tissue controls and coordinates all the body's functions.

CHECK IT OUT! Can human cells live without each other? *(answer on back cover)*

THE STORY OF CELLS

Around 1590, the Dutch lens makers Hans and Zacharias (above) Janssen hit on an invention that made the discovery of cells inevitable. They put two glass lenses in a tube and created the world's first microscope. About 60 years later, English scientist Robert Hooke used the invention to study cork from a tree. He called the empty compartments he saw *cells*. The name stuck, but our view of them has changed radically.

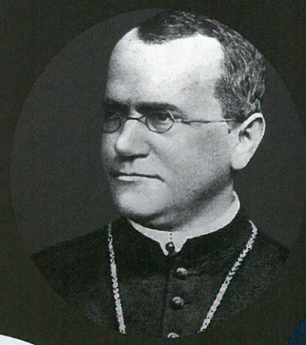
1673

Using a simple, single-lens microscope he made himself, Dutch cloth merchant Anton van Leeuwenhoek (LAY-ven-hook) becomes the first to see living cells. They include bacteria in plaque that he scraped off his teeth.

1859

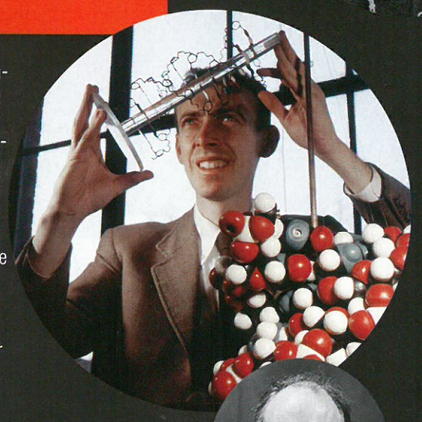
French researcher Louis Pasteur disproves spontaneous generation. He exposes meat broth to air. But he uses an S-shaped container that traps any airborne bacteria before they reach the broth. No life forms appear in the broth. Pasteur's work adds support to the cell theory.

1860s



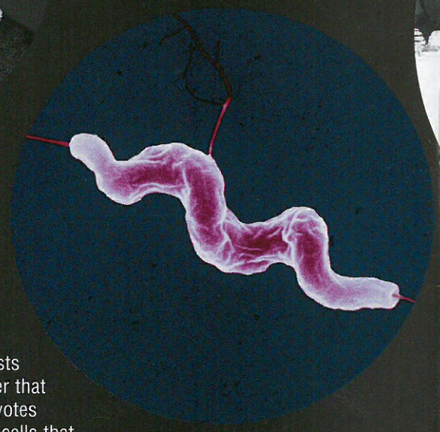
Austrian monk Gregor Mendel uses pea plants to show how genes control heredity. His work is ignored for decades, but by 1900 it becomes the foundation of genetics, the study of genes.

1953



American scientist James Watson (right) and English scientist Francis Crick (below) show that the structure of DNA is a double helix. This discovery paves the way for dozens of other breakthroughs in genetics. It also opens up the field of genetic engineering in which people can change the DNA of a plant or animal.

1977

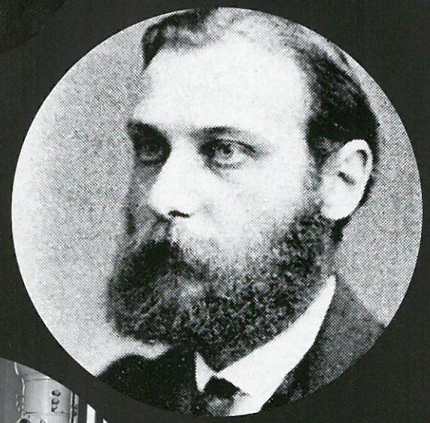


Scientists discover that prokaryotes (single cells that lack a nucleus) are really made up of two distinct groups: bacteria and a group called archaea (ar-KEE-uh). Cells in the archaea group look like bacteria, but their DNA is different, and they often live in extreme environments, such as the hot springs in Yellowstone National Park.

1831

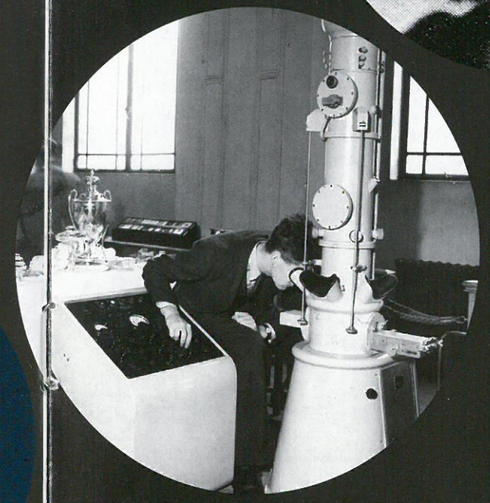
Scottish biologist Robert Brown shows that the nucleus is a key part of each cell. Others had noticed the nucleus before, but none thought it very important.

1860s



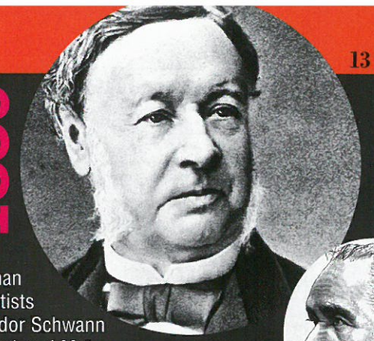
German scientist Walther Flemming stains cells with dye to make them easier to see under a microscope. It works so well that he is able to discover how they reproduce.

1931



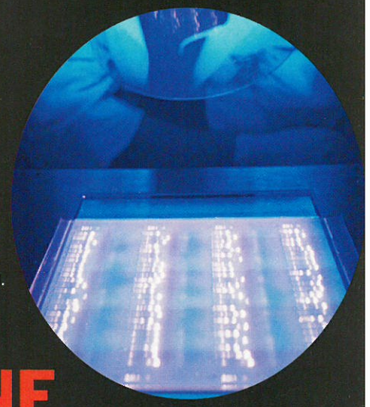
The invention of the electron microscope makes it possible for scientists to magnify objects up to a million times, making it possible to see even atoms. This gives scientists much greater insight on the inner workings of cells.

1839



German scientists Theodor Schwann (above) and Matthias Schleiden (right) advance the "cell theory of life." It states that all life on Earth is composed of cells. Two decades later, German Rudolph Virchow provides a second part to the theory. He states that all cells come from existing live cells. This theory conflicts with the belief that life can "spontaneously generate." For instance, people believed that maggots spontaneously grew out of rotten meat.

2000

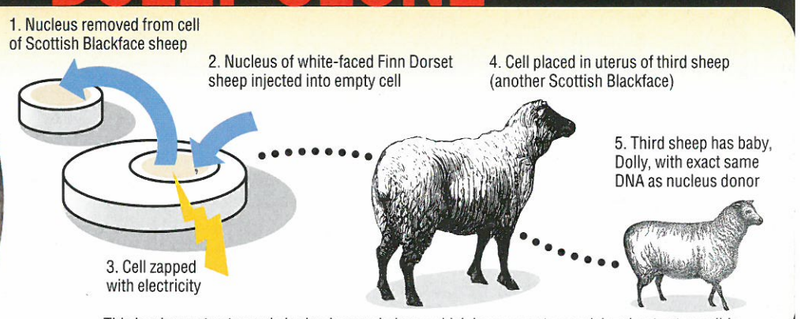


The Human Genome Project finishes a map of the entire human genome (the set of all genes). Before, scientists only knew bits and pieces of it. Among other things, this is expected to allow doctors to prevent, diagnose, and treat illnesses at the cellular level, where they begin.

1997

Scottish scientists create Dolly, a clone, or genetic copy, of another sheep. Here's how they did it.

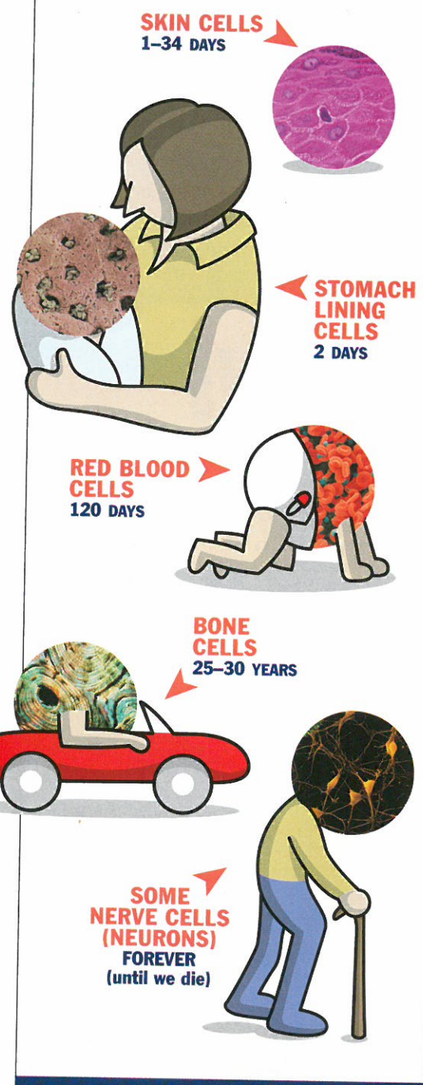
DOLLY CLONE



This is a huge step toward cloning human beings, which is very controversial and not yet possible.

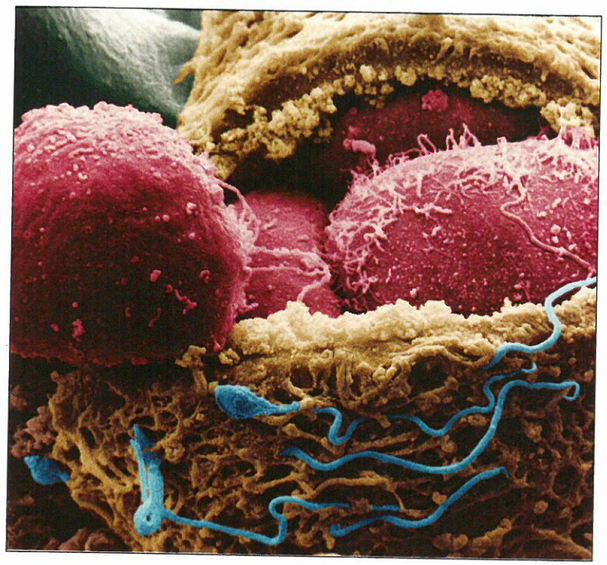
CHECK IT OUT! Why were two different breeds of sheep used? *(answer on back cover)*

Life Span of a Cell



HUMAN CELLS ARE preprogrammed to die through a process called apoptosis. Some cells, such as skin cells, die off every day but are replaced by new ones. Others, such as heart cells, cannot be replaced. Scientists are looking for ways to control cell death. That might allow them to kill off harmful cells, such as cancers.

MOST TYPES OF human cells reproduce only themselves. For instance, muscle cells can only make more muscle cells. But stem cells can change into other types of cells. This ability allows them to act as a repair system for the body, offering potential cures for diseases. For example, adult bone marrow stem cells (left) can form kidney tissue, and thus help some patients with kidney disease.



EMBRYONIC STEM cells can produce all 216 kinds of human cells. An embryo is an organism at any time before full development. The embryos from which human embryonic stem cells are derived are typically four or five days old and are a hollow microscopic ball of cells called a blastocyst (above). Embryonic stem cells may one day help treat people with spinal cord damage or Alzheimer's disease. But many people are against using embryonic stem cells. They argue that using embryos as a stem cell source is murder. Others say that week-old embryos are not yet fully human.

CHECK IT OUT!

What do you get when you cross a spider with a goat? (answer on back cover)