

Inside the Living Cell

Study Guide for Instructors and Students
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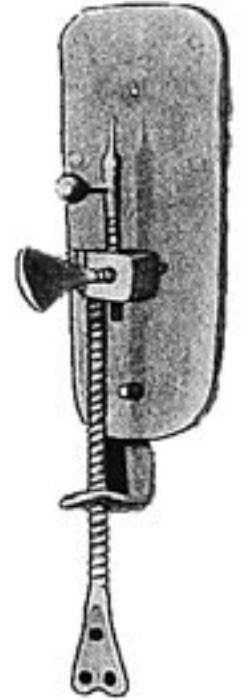
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The Cell - Unit of Life

THE DISCOVERY OF CELLS

Antony Van Leeuwenhoek built this simple microscope over three hundred years ago. He used it to discover single celled organisms swimming around in pond water.

What Leeuwenhoek imagined, was that the tiny organisms he observed were actually little animals. He called them his “cavorting wee beasties.” He even recorded their means of reproducing. They duplicated their structures and then pulled apart to create two identical individuals.



This kind of reproduction is quite different than having babies or growing a new plant from a seed. In these microscopic organisms one individual duplicates itself becoming identical twin sisters.

Around the same time Leeuwenhoek was observing his “wee beasties,” a British scientist, Robert Hook, was turning his more elaborate microscope onto a shaving of cork, just to see if it had a hidden structure of some kind.

He saw that the cork was made up of thousands of little compartments. They reminded him of the prison cells where prisoners were held. Thus the term – cell.

Hook and Leeuwenhoek went on to observe that many kinds of living materials were similarly constructed.

Leaves were made of blocks of cells filled with green particles. The thin skin of an onion was revealed as a latticework of cells. Blood was a floating mass of tiny round cells. Even bone was made of cells.

And it was eventually apparent that those cavorting wee beasties seen in ponds, roadside ditches, and living on people’s teeth were themselves single cells.

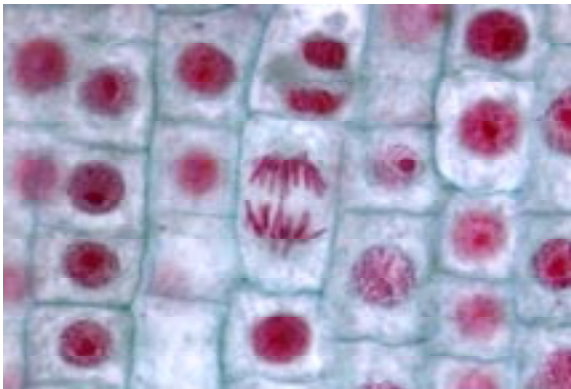
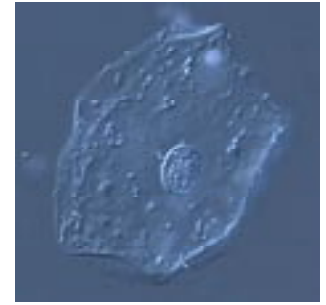
Over the next hundred years, using improved microscopes, scientists found that all things alive were composed of cells, including the tissues of the human body. This was a major step in understanding life. It led to one of the foundation theories of biology. All living things are made of cells, and that all cells come from preexisting cells; there were no exceptions.



CELL STRUCTURES

Around a hundred years ago microscopes showed that all cells have a common structure. All have an outer membrane that holds the cell together, a membrane that allows some substances to pass, but excludes others.

The cells of plants, animals and “protists” as Leeuwenhoek’s wee beasties came to be called, all contain a nucleus. It was soon realized that this structure somehow controlled the cell’s activities.



The nucleus was seen to duplicate just before cell division, suggesting that it carried hereditary information from one generation of cells to the next.

In cells undergoing division the nucleus broke down and its internal structures became visible -- chromosomes.

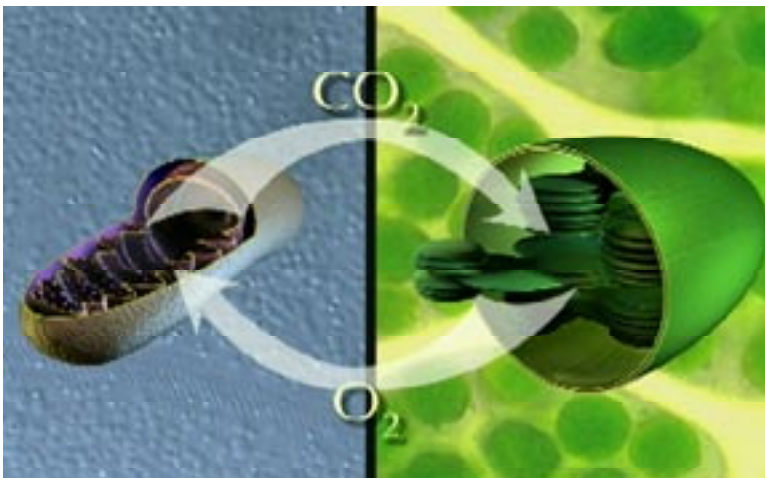
Each species has a characteristic chromosome number. Humans have 23 pairs of chromosomes in each of their body cells.

Outside of the nucleus is a soupy fluid containing many small bodies, a cell’s organs, and appropriately called organelles.

In a cell that has been squeezed by the cover glass to the point of rupture, a bubble forms. In this bubble you can clearly see the tiny cell organelles called mitochondria.

Similar organelles were eventually found in all cells, both plant, animal and protist.

Mitochondria were eventually isolated and their function was discovered. They are the bodies where sugars and other food molecules are metabolized, with the help of oxygen, to supply energy for cell use – the process of cellular respiration.



Plants and green protists have an additional cell organelle clearly visible: rounded green bodies called chloroplasts.

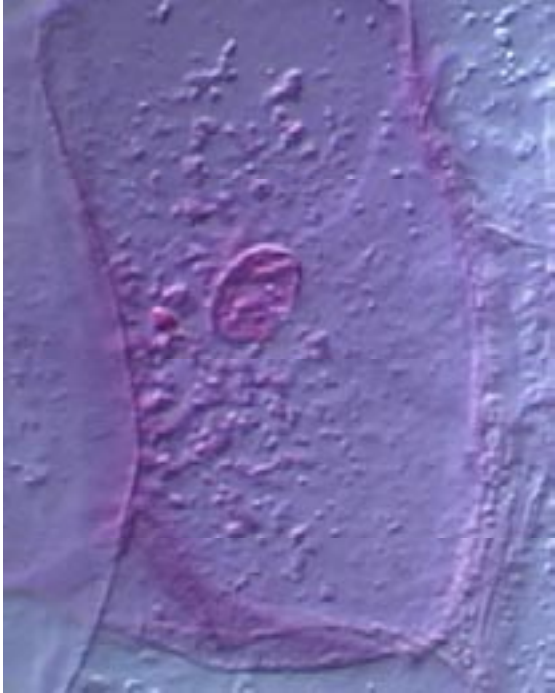
These green bodies are where photosynthesis occurs.

In the process of photosynthesis chloroplasts use the energy in light to convert carbon dioxide from the air into sugars and other organic compounds needed by the plant.

To recap the importance of these two cell organelles: mitochondria carry out cellular respiration and chloroplasts perform photosynthesis. The raw materials for each of these reactions are provided by the other. Chloroplasts liberate oxygen as a by-product. Mitochondria take in oxygen and give off carbon dioxide, the raw material chloroplasts use to make sugar and starch.

DNA DIRECTS CELL ACTIVITIES

In the 1950s biologists knew that the cell nucleus carried some kind of chemical information that was responsible for directing cell activities and for passing the information on to the next generation.



But these researchers wondered what was in the cell nucleus that spelled out the structure of a human, or a mushroom, or an oak tree?

The breakthrough came with the first accurate description of the substance found inside the cell nucleus, the DNA molecule, a twisted ladder with interchangeable rungs.

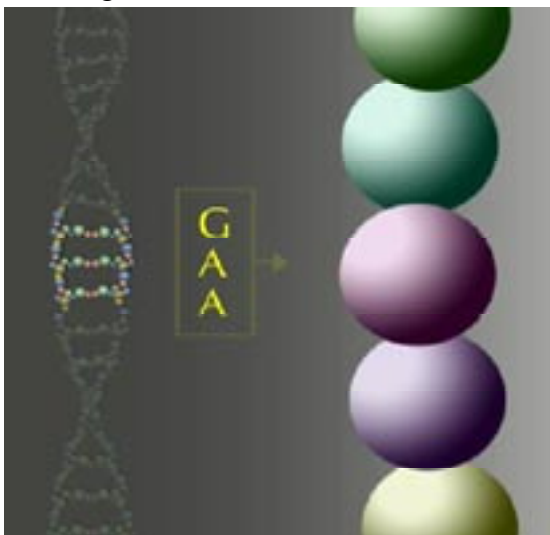
These incredibly long molecules spell out instructions in a three-letter code. Each code word represents a particular amino acid in the chain of amino acids that creates a protein.

Proteins are the large molecules that make up hair, skin, muscles, and organs. And there is something else made of protein -- enzymes.

Enzymes are proteins that act as catalysts or helpers that promote a specific kind of chemical reaction. Each of the thousands of biochemical processes going on in our cells is directed by a specific enzyme or enzymes.

DNA contains the instructions for the order of amino acids that make up a specific enzymatic protein. This string of code words is the gene for that protein.

The gene is copied onto a close chemical relative, RNA, messenger RNA to be exact.



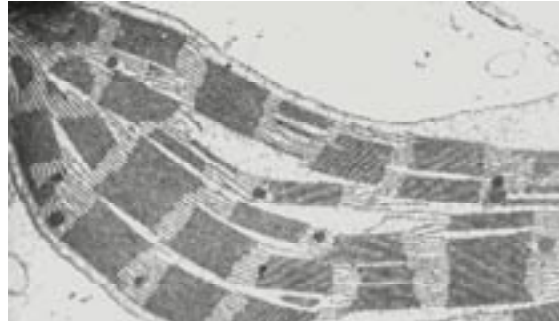
And that messenger RNA transcript is used as the building instruction in a protein assembly line found in the cytoplasm.

The completed enzyme protein moves through the cytoplasm to do its specific job. These enzyme-assisted chemical reactions are what make the processes of life occur.

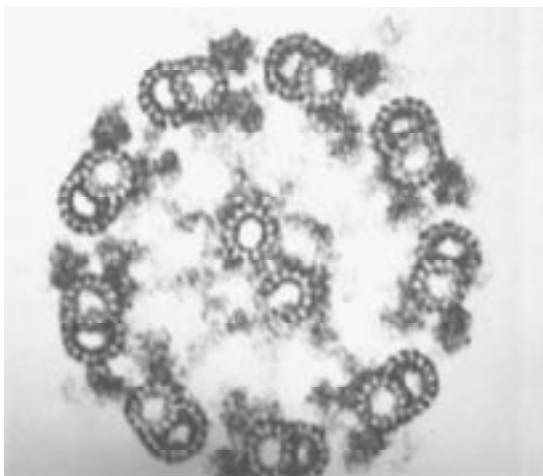
ELECTRON MICROSCOPES MAKE NEW DISCOVERIES

Another developing technology, the electron microscope, let biologists visualize just how complex the cell structures seen with light microscopes actually were.

A tightly focused beam of electrons has a very short wave length, therefore can resolve structures far beyond the light microscope, because light has much longer wavelengths.



In very thin sections of cells, early electron microscopes showed that particles such as mitochondria have an inner structure. Chloroplasts do, too.

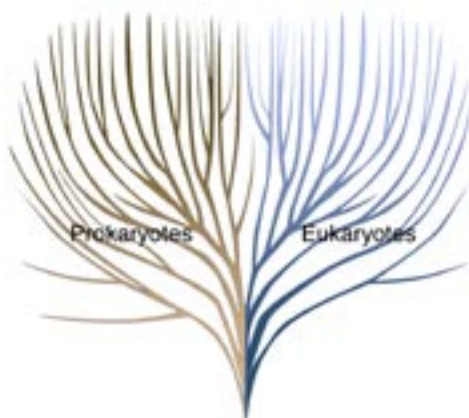


A slice through a cilium (the little hairs that propel many kinds of protists) showed an amazing arrangement of tubes. These molecular tubes became known as microtubules. The bending of these tubes creates the ciliary beat seen in ciliated microorganisms.



The electron microscope also showed that bacteria cells were quite different from the cells of plants, animals and protists. Mainly, a bacterial cell does not have a nucleus. In the

more complex cells of plants animals and protists, the DNA is surrounded by a nucleus, which has a double membrane. In bacteria, however, the DNA forms a loosely distributed mass, not surrounded with membranes. Also, bacteria do not have any of the complex organelles found in nucleated cells.



These findings divided life into two lines: the Prokaryotes (cells without nuclei) and the Eukaryotes (cells with nuclei and organelles built from membranes).

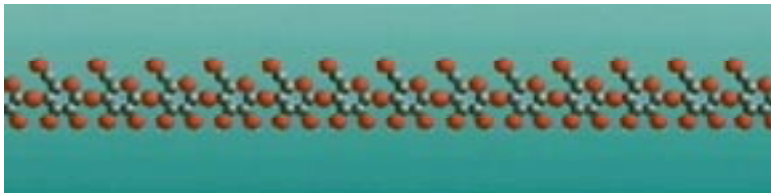
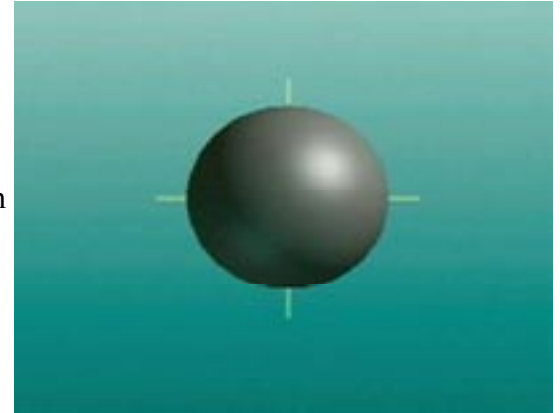
We are Eukaryotes, so are plants, and so are protists and fungi.

The CHEMISTRY OF LIFE is a MACROMOLECULE SHUFFLE

When you burn a living thing, a tree for example, you are left with its most basic chemical component -- carbon. Organisms, from the simplest bacterium to protists, plants and animals are all made from molecules based on the element carbon .

A carbon atom has four bonding sites. For example, it can bond with hydrogen atoms to make CH₄, methane gas -- and with other carbon atoms to form long chains, in which the carbon atoms fill in their other bonding sites with hydrogen and oxygen.

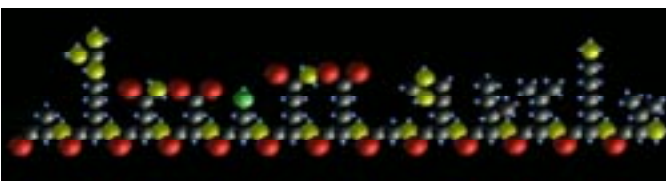
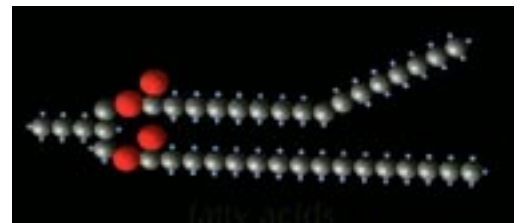
This may come as a surprise, but all living things, from the simplest bacterium on up the tree of life, are composed of just four types of carbon molecules. These four kinds of carbon molecules are:



Carbohydrates, the simplest one being glucose sugar, a six carbon compound. Inside a living cell, aided by an enzyme, sugars are bonded together by simply losing a hydrogen atom from one, and a hydrogen/oxygen pair from the other to make H₂O. Because water is produced during the process, this kind of bonding reaction is called a condensation reaction.

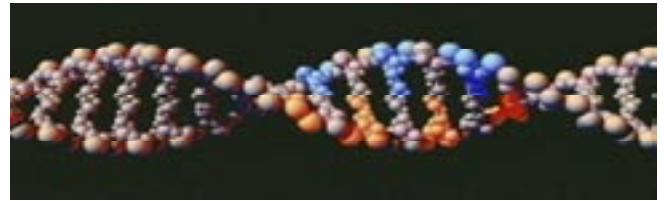
This coupling reaction creates long chains of building block sugars to form a macromolecule, in this case, a starch. Potatoes, rice, pasta, and bread are typical foods made up of starch.

Fats are another one of the four carbon-based molecules, and it's something all cells need. Cell membranes, cell organelles, and hormones are made from fat molecules. And fat molecules, lipids, are made up of fatty acid building blocks. Just as in carbohydrates, fatty acids go together by pulling out water molecules.



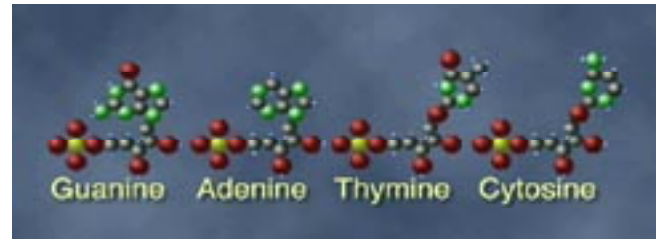
Proteins are another of the four carbon-based molecules. Of the many kinds of proteins, all are made from a selection of only 20 kinds of amino acid building blocks. Different proteins are made bonding the right kinds of amino acids in the right order. If bonded in the wrong order, or insert the wrong amino acid building block, and the resulting protein will probably not function.

Unlike fats and carbohydrates, proteins are almost never straight lines of building blocks. Instead they are twisted into every imaginable shape, shapes that do specific jobs.



The CHEMISTRY OF LIFE - continued

The last of the big four carbon-based macromolecules are the nucleic acids, DNA and RNA. Only four kinds of building blocks make up the sides of the twisted DNA ladder. But those four create an alphabet of coded instructions that can produce every living thing from a bacterium to a baby.



To make your body function you need all four carbon-based macromolecules: carbohydrates, fats, proteins and nucleic acids, and you get them from the food you eat.

In your intestine the real beauty of being an animal shows up. Your enzymes, (which you may recall are, themselves, proteins) converge on each type of macromolecule and render it back to its building blocks:

Carbohydrates go back to the simple sugars from which they were originally made, and these are picked up by the blood and used for quick energy.

Fats are dissembled, yielding up their fatty acid building blocks – your body burns fatty acids for energy or you can use fatty acids to make your own fat -- good insulation should you need it, and a very efficient way to store energy in case of shortages.

Proteins are quickly broken up and their amino acids head straight for the cells of your body where they can be reassembled to build human proteins.

The four DNA building blocks, enzymatically released from the plant and animal cells you eat can now be pressed into service each time one of your cells makes up a duplicate set of DNA instructions and divides.

So eat macromolecules, digest macromolecules, make new macromolecules, and keep your cells happy.

ASSEMBLING A SIMPLE MICROSCOPE

Make a bead lens: With instructor supervision you can heat a glass thread over a low flame. The molten glass balls up and forms a clear bead.

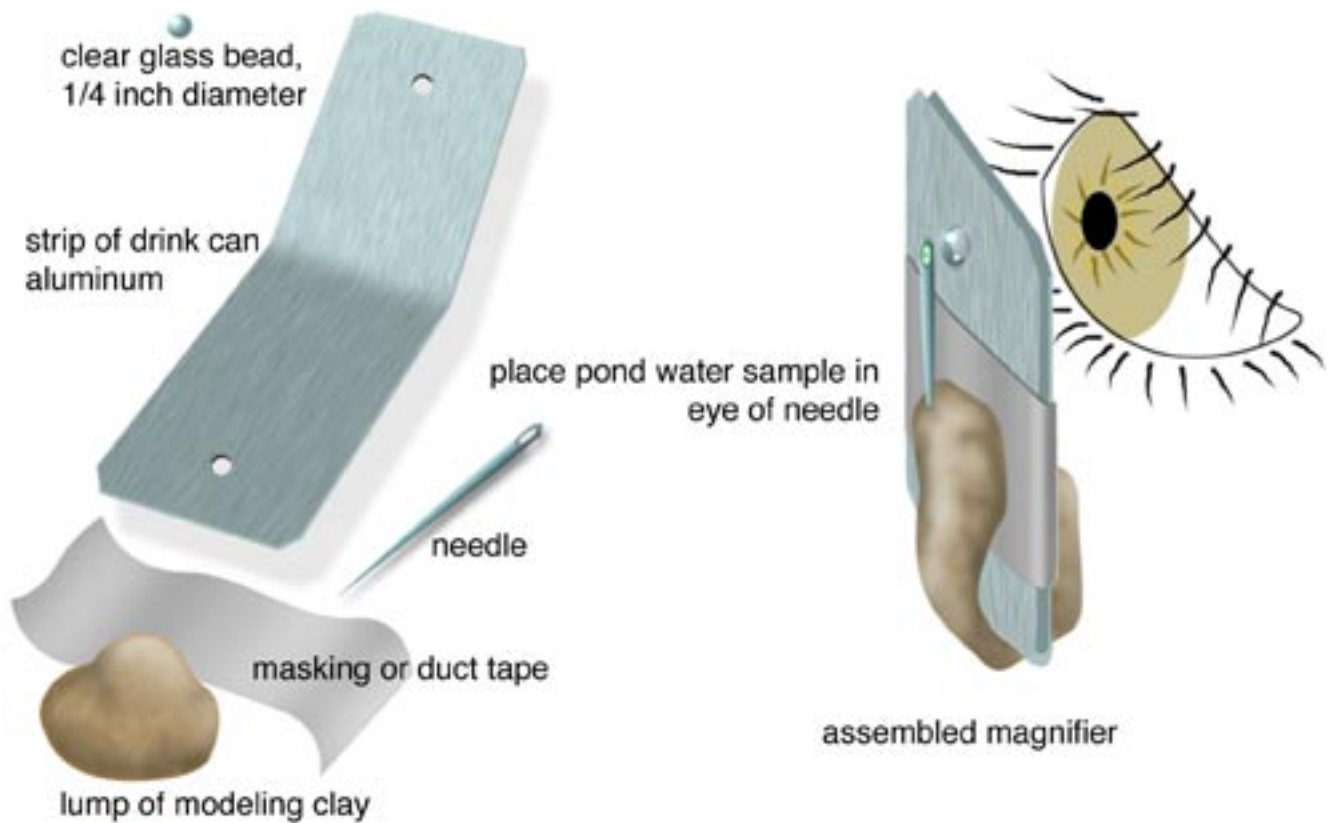
Bend a scrap of aluminum cut from a drink can and punch a tiny hole with an ice pick or awl, about half the diameter of the glass bead.

Position the bead in the hole and hold it all together with a bit of tape.

You now have the optical system for a powerful, hand-held microscope.

A needle can hold a drop of pond water, and with a bit of clay to hold the needle, you have a working Leeuwenhoek microscope.

Focus by moving the needle up to the bead lens. If you hold the microscope very close to your eye, you may be able to see some of the sights seen by Antony Van Leeuwenhoek some 300 years ago.



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