LEC. 1 | INTRODUCTION TO THE CELL

INTRODUCTION

Cells Are the Basic Units of Living Organisms

Trees in a forest, fish in a river, horseflies on a farm, lemurs in the jungle, reeds in a pond, worms in the soil all these plants and animals are made of the building blocks we call cells. Like these examples, many living things consist of vast numbers of cells working in concert with one another. Other forms of life, however, are made of only a single cell, such as the many species of bacteria and protozoa. Cells, whether living on their own or as part of a multicellular organism, are usually too small to be seen without a light microscope. Cells share many common features, yet they can look wildly different. In fact, cells have adapted over billions of years to a wide array of environments and functional roles. Nerve cells, for example, have long, thin extensions that can reach for meters and serve to transmit signals rapidly. Closely fitting, brick-shaped plant cells have a rigid outer layer that helps provide the structural support that trees and other plants require. Long, tapered muscle cells have an intrinsic stretchiness that allows them to change length within contracting and relaxing biceps. Still, as different as these cells are, they all rely on the same basic strategies to keep the outside out, allow necessary substances in and permit others to leave, maintain their health, and replicate themselves. In fact, these traits are precisely what make a cell a cell.

All organisms are composed of structural and functional units of life called **"CELLS"**. The body of some organisms like bacteria, protozoans and some algae is made up of a single cell while the body of fungi, plants and animals are composed of many cells. Human body is built of about one trillion cells. Cells vary in size and structure as they are specialized to perform different functions. But the basic components of the cell are common to all cells. This lesson deals with the structure common to all types of the cell. You will also learn about the kinds of cell division and the processes involved therein.

What Defines a Cell?

Cells are considered the basic units of life in part because they come in discrete and easily recognizable packages. That's because all cells are surrounded by a structure called the **Cell Membrane** which, much like the walls of a house, serves as a clear boundary between the cell's internal and external environments. The cell membrane is sometimes also referred to as the **Plasma Membrane**. Cell membranes are based on a framework of fat-based molecules called **Phospholipids**, which physically prevent water loving, or hydrophilic, substances from entering or escaping the cell. These membranes are also studded with proteins that serve various functions. Some of these proteins act as gatekeepers, determining what substances can and cannot cross the membrane. Others function as markers, identifying the cell as part of the same organism or as foreign. Still others work like fasteners, binding cells together so they can function as a unit.

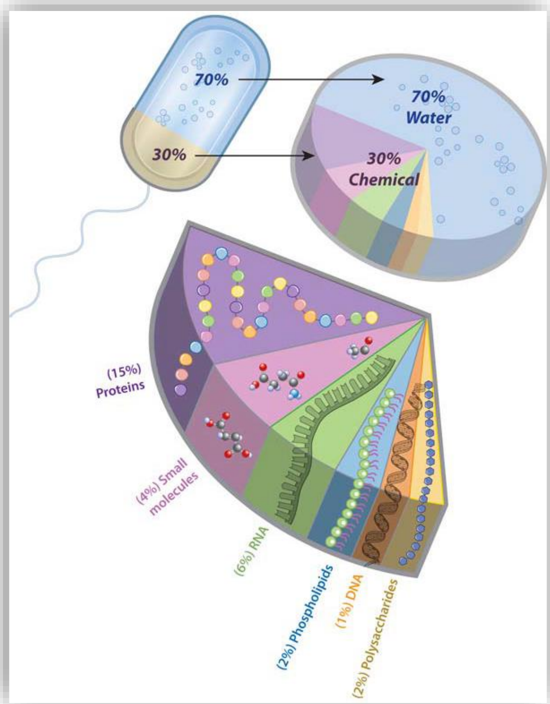

Figure 1: The composition of a bacterial cell Most of a cell is water (70%). The remaining 30% contains varying proportions of structural and functional molecules.

Yet other membrane proteins serve as communicators, sending and receiving signals from neighboring cells and the environment whether friendly or alarming (Fig. 1 in the right). Within this membrane, a cell's interior environment is water based. Called **Cytoplasm**, this liquid environment is packed full of cellular machinery and structural elements. In fact, the concentrations of proteins inside a cell far outnumber those on the outside whether the outside is ocean water (as in the case of a single-celled alga) or blood serum (as in the case of a red blood cell). Although cell membranes form natural barriers in watery environments, a cell must nonetheless expend quite a bit of energy to maintain the high

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concentrations of intracellular constituents necessary for its survival. Indeed, cells may use as much as 30 percent of their energy just to maintain the composition of their cytoplasm.

Some cells also feature orderly arrangements of molecules called **Organelles**. Similar to the rooms in a house, these structures are partitioned off from the rest of a cell's interior by their own intracellular membrane. Organelles contain highly technical equipment required for specific jobs within the cell. One example is the **Mitochondrion** commonly known as the cell's "power plant" which is the organelle that holds and maintains the machinery involved in energy-producing chemical reactions (Fig. 2 Below).

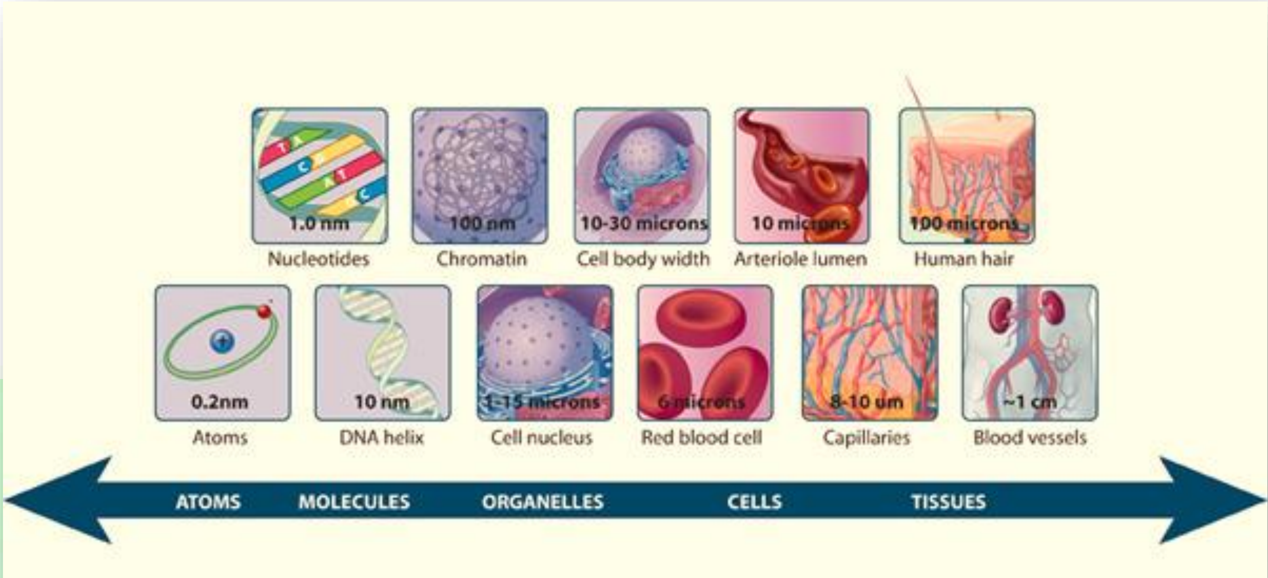

Figure 2: The relative scale of biological molecules and structures Cells can vary between 1 micrometer (µm) and hundreds of micrometers in diameter. Within a cell, a DNA double helix is approximately 10 nanometers (nm) wide, whereas the cellular organelle called a nucleus that encloses this DNA can be approximately 1000 times bigger (about 10 µm). See how cells compare along a relative scale axis with other molecules, tissues, and biological structures (blue arrow at bottom). Note that a micrometer (µm) is also known as a micron.

WHAT OTHER COMPONENTS DO CELLS HAVE ?

Living cells are formed from a small number of the different types of molecules that make up the earth. Most biomolecules contain carbon and many contain nitrogen. Both carbon and nitrogen are very scarce in non-living entities. While cells may not always utilize the most abundant molecules, they do use molecules whose unique chemistry is capable of carrying out the reactions necessary for life.

There are three levels of organization to describe the molecules that make up living organisms (table. 1, 2).

1. The simplest level is the individual elements such as carbon, nitrogen, or oxygen.
2. The basic elements can be arranged into a series of small molecules known as **Building Blocks**. Building blocks include compounds such as amino acids and nucleic acids.

Table 1: Elements, ions, and trace minerals that make up living systems

Elements	Ions	Trace minerals
Oxygen Carbon Nitrogen Hydrogen Phosphorus Sulfur	Sodium Potassium Magnesium Calcium Chloride	Manganese, Iron, Cobalt, Copper, Zinc, Aluminum, Iodine, Nickel, Chromium, Selenium, Boron, Vanadium, Molybdenum, Silicon, Tin and Fluorine

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3. The building blocks are organized into larger compounds, known as **Macromolecules**. Macromolecules comprise the different structures that are found in cells. Four different types of macromolecules are used to construct a cell:

- **Nucleic acids**
- **Proteins**
- **Lipids**
- **Carbohydrates**

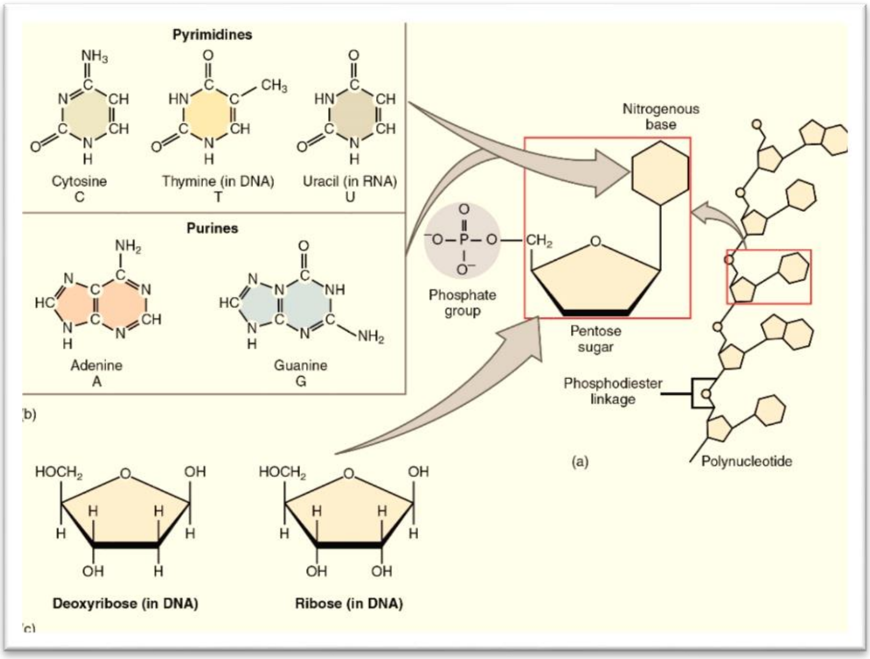
Each type of macromolecule is used for a specific purpose in the cell. There are many examples of macromolecules being combined in different configurations to form larger cell structures.

Table. 2: Three levels of organization describe the compounds that make up living organisms.

I	**Elements**			
II	Phosphate Pyrimidines Purines Ribose Deoxyribose	Amino acids	Fatty acids Glycerol Other components	Sugars
III	Nucleic acids	Proteins	Lipids	Carbohydrates or Polysaccharides

Nucleic acids (Fig.3)

It can be subdivided into **DNA** and **RNA**. DNA is composed of two kinds of building blocks, the bases (adenine, guanine, cytosine, and thymine) and a sugar phosphate backbone. DNA is used by the cell as a repository for all of the information necessary to direct synthesis of the macromolecules and to produce energy for this synthesis. DNA is also used to transmit information from one generation to the next. RNA has a very similar composition to DNA. The two major differences between DNA and RNA are in the sugar used in the sugar phosphate backbone (ribose for RNA and deoxyribose for DNA) and in one of the bases (uracil for RNA and thymine for DNA). In *Escherichia coli*, DNA exists as a double-stranded molecule.



The RNA in the cell has at least four different functions:

A. **Messenger RNA** (mRNA) is used to direct the synthesis of specific proteins.

B. **Transfer RNA** (tRNA) is used as an adapter molecule between the mRNA and the amino acids in the process of making the proteins.

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C. **Ribosomal RNA** (rRNA) is a structural component of a large complex of proteins and RNA known as the ribosome. The ribosome is responsible for binding to the mRNA and directing the synthesis of proteins.

D. The fourth class of RNA is a catch-all class. There are small, stable RNAs whose functions remain a mystery. Some small, stable RNAs have been shown to be involved in regulating expression of specific regions of the DNA. Other small, stable RNAs have been shown to be part of large complexes that play a specific role in the cell. In general, RNA is used to convey information from the DNA into proteins.

Proteins

Proteins are composed of amino acids. Most proteins are made from a unique combination of 20 different amino acids (Fig. 4). The order in which amino acids appear in a protein are specified by the mRNA used to direct synthesis of the protein. All amino acids have a common core of repeating amino–carbon–carboxyl groups, with varying side chains on the central carbon. Proteins, therefore, have a repeating backbone with an amino terminus and carboxyl terminus. The amino acids can be grouped together and described by physical properties such as charge (acid or basic), size, interactions with water (hydrophobic water "hating" or hydrophilic water "loving"), a specific element (sulfur containing) or structure they contain (aromatic rings). The types of amino acids used to make up a protein specify what the protein is capable of. Proteins perform many duties in the cell, including functioning as structural and motor components, enzymes, signaling molecules, and regulatory molecules. Some proteins perform only one function while others are multifunctional.

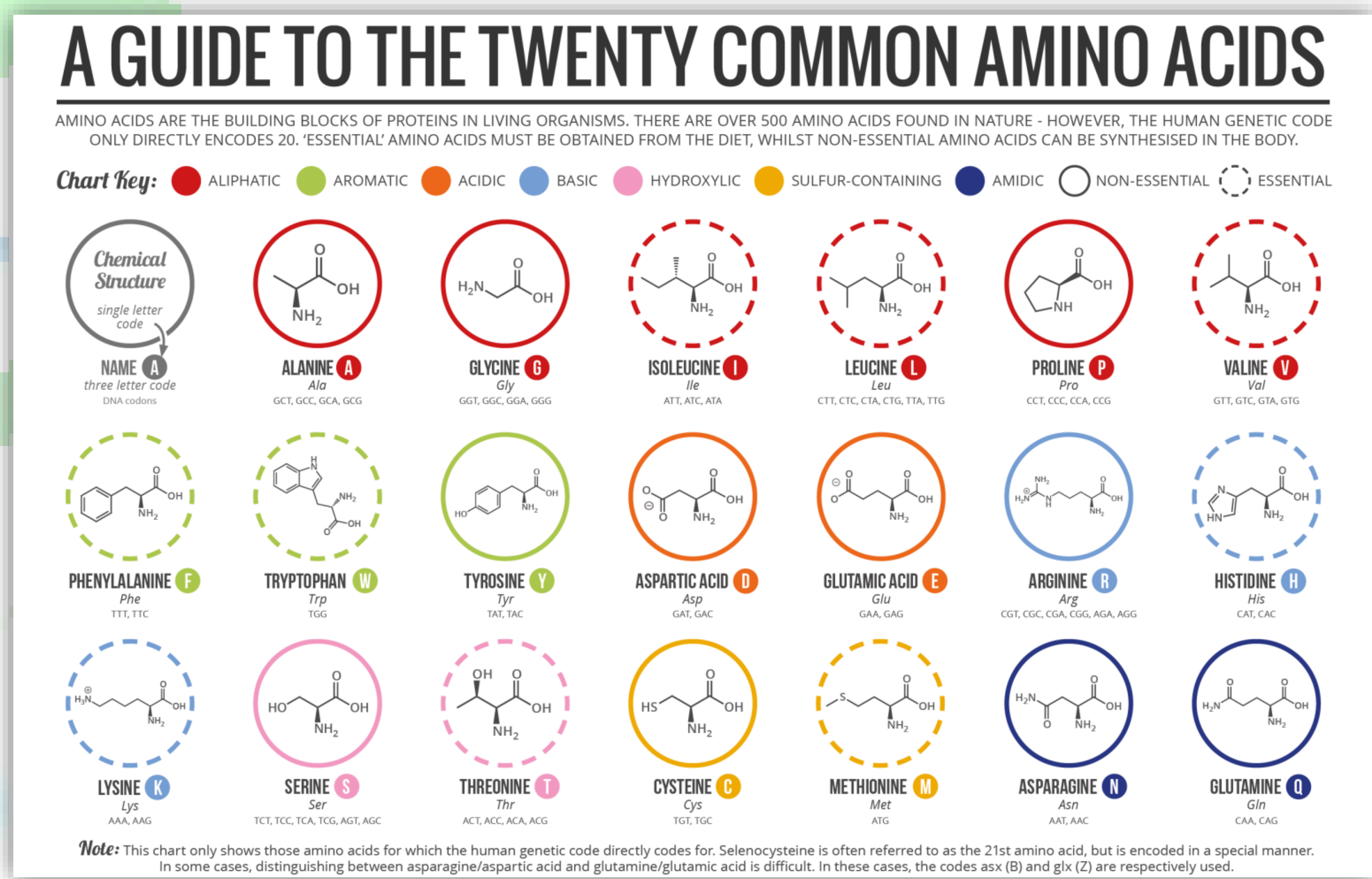

Fig. 4: The 20 common amino acids used to make proteins.

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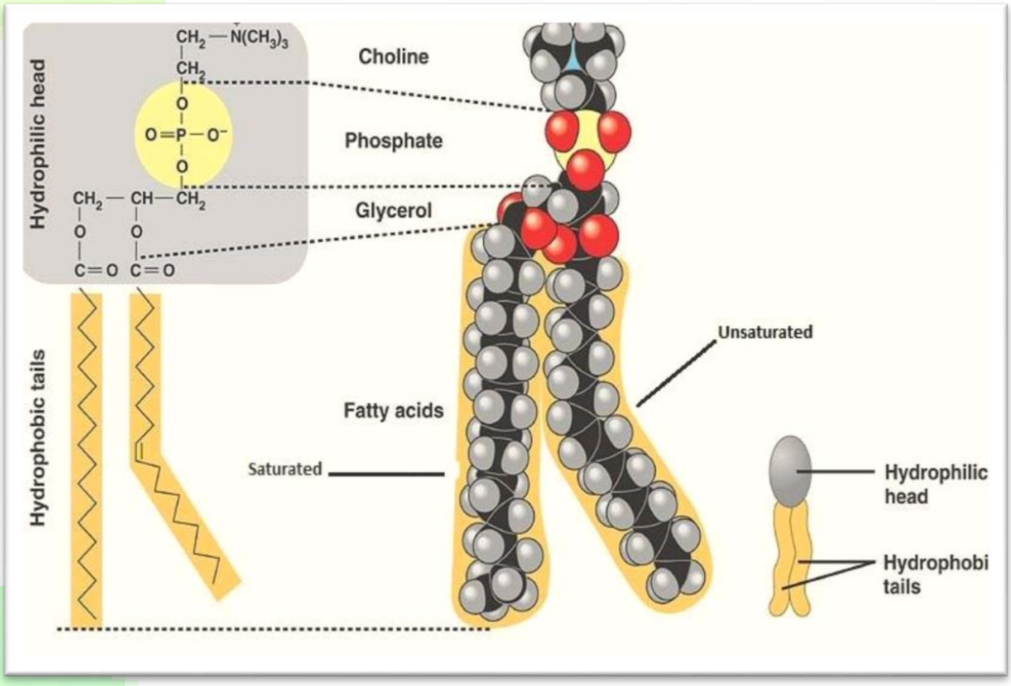

Fig. 5: Lipid molecules. (a) The general structure of a saturated fatty acid. (b) The structure of membranes with two leaflets. (c) The general structure of an

Lipids

They are an unusual group of molecules that, in bacteria, are used to make the membranes that surround a cell. One type of lipid, known as a fatty acid, is composed of long chains of carbon molecules attached to a smaller head group (Fig. 5). The small head group is known as the polar head group. The fatty acid chains are extremely hydrophobic and line up with the long chains of carbons near each other. Because of the properties of the fatty acid chains, membranes are double-sided. One side of a membrane is known as a leaflet. The polar head groups face the outside surfaces of the membranes because the polar head groups are water soluble. Other chemical groups can be added to the head groups of the lipids but, in general, other chemical groups cannot be added to the fatty acids. If the fatty acids contain only single bonds, they are known as saturated fatty acids. Saturated fatty acids are flexible and can be tightly packed. If the fatty acids contain any double bonds they are known as unsaturated fatty acids. Unsaturated fatty acids have a kink in them and cannot be packed as closely. Membranes usually contain a mixture of fatty acids to maintain the right packing density and fluidity.

Monosaccharides	Arabinose Glucose Fructose Galactose Ribose Deoxyribose
Disaccharides	Lactose Maltose
Polysaccharides	Glycogen

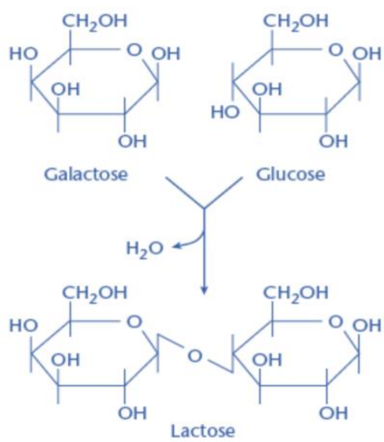

Fig. 6: Types and general structures of carbohydrates. The polymerizing of galactose with glucose results in the formation of lactose upon liberation of one H2O molecule.

Carbohydrates

It was composed of simple sugars (Fig. 6). They can be used as:
1 an immediate source of energy; **2** a stored source of energy; **3** structural components of the cell. In bacteria, carbohydrates that are used as immediate sources of energy are the simple carbohydrates such as glucose, lactose, and galactose. Frequently, the carbohydrates that a bacterium utilizes as energy sources can be used to distinguish one species of bacteria from another. Energy is usually stored in a carbohydrate that is a long polymer of glucose known as glycogen.
Structurally, carbohydrates are used to make a protective covering for the outside of the cell called the **Capsule** or capsular polysaccharide. Carbohydrates are also added to the polar head groups of the fatty acids on the face of the membrane that is exposed to the outside of the cell. The fatty acid attached carbohydrates help protect the cell from detergents and antibiotics. A complex mixture of carbohydrates is used to make the cell wall. Cell walls maintain the shape of the cell.

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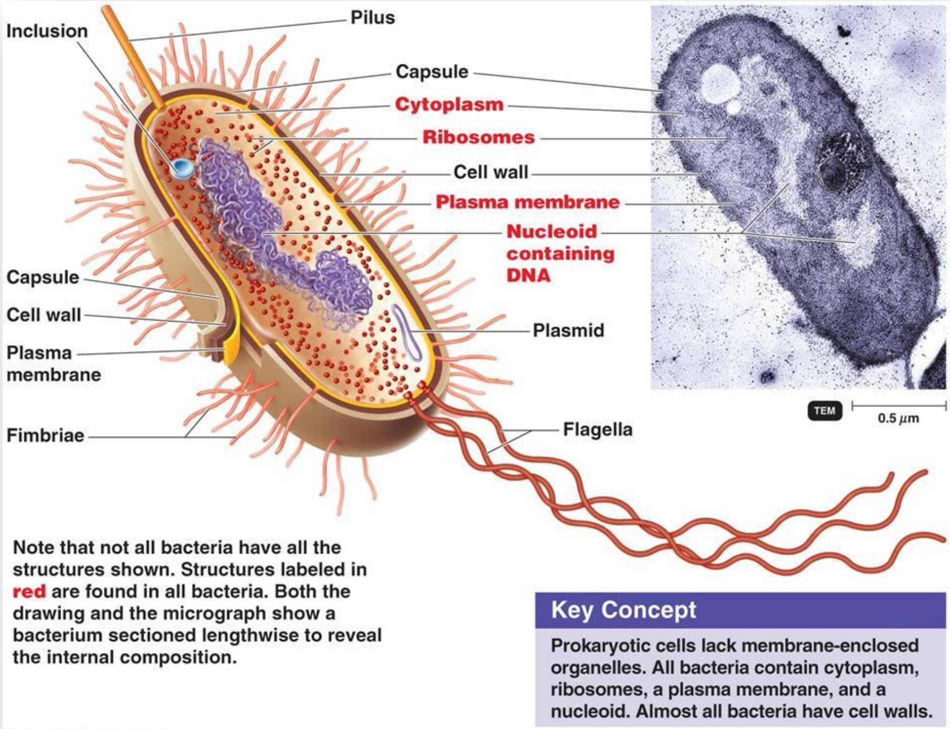
In some species of bacteria, the cell wall is located outside the membrane. In other species, the cell wall is located underneath the outer membrane.

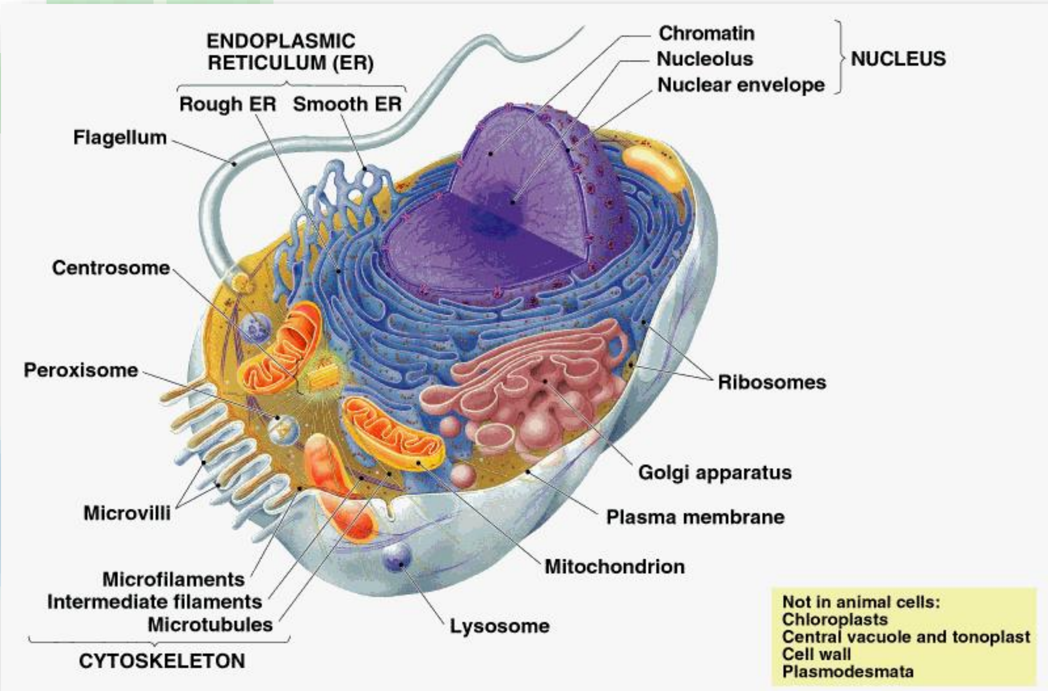
Each of the four types of macromolecules provides unique functions to the cell. For some of the cell's requirements, a single type of macromolecule suffices. In other situations, a mixture of macromolecules is required. It is interesting that beginning with a limited number of elements and ending with only four major classes of large molecules, the 5000–6000 different compounds needed to make a cell can be constructed.

WHAT ARE THE DIFFERENT CATEGORIES OF CELLS?

Rather than grouping cells by their size or shape, scientists typically categorize them by how their genetic material is packaged. If the DNA within a cell is not separated from the cytoplasm, then that cell is a prokaryote. All known prokaryotes, such as bacteria and archaea, are single cells. In contrast, if the DNA is partitioned off in its own membrane bound room called the nucleus, then that cell is a eukaryote.



Some eukaryotes, like amoebae, are free-living, single-celled entities. Other eukaryotic cells are part of multicellular organisms. For instance, all plants and animals are made of eukaryotic cells sometimes even trillions of them (Figure 7).



Eukaryotic cell (left) has membrane-

enclosed DNA, which forms a structure called the nucleus (located at center of the eukaryotic cell; note the purple DNA enclosed in the pink nucleus). A typical eukaryotic cell also has additional membrane-bound organelles of varying shapes and sizes. In contrast, a prokaryotic cell does not have membrane-bound DNA and also lacks other membrane bound organelles as well.

HOW DID CELLS ORIGINATE?

Researchers hypothesize that all organisms on Earth today originated from a single cell that existed some 3.5 to 3.8 billion years ago. This original cell was likely little more than a sack of small organic molecules and RNA-like material that had both informational and catalytic functions. Over time, the more stable DNA molecule evolved to take over the information storage function, whereas proteins, with a greater variety of structures than nucleic acids, took over the catalytic functions. As described in the previous section, the absence or presence of a nucleus and indeed, of all membrane-bound organelles is important enough to be a defining feature by which cells are categorized as either prokaryotes or eukaryotes. Scientists believe that the appearance of self-contained nuclei and other organelles represents a major advance in the evolution of cells. But where did these structures come from? More than one billion years ago, some cells "ate" by engulfing objects that floated in the liquid environment in which they existed. Then, according to some theories of cellular evolution, one of the early eukaryotic cells engulfed a prokaryote, and together the two cells formed a symbiotic relationship. In particular, the engulfed cell began to function as an organelle within the larger eukaryotic cell that consumed it. Both chloroplasts and mitochondria, which exist in modern eukaryotic cells and still retain their own genomes,

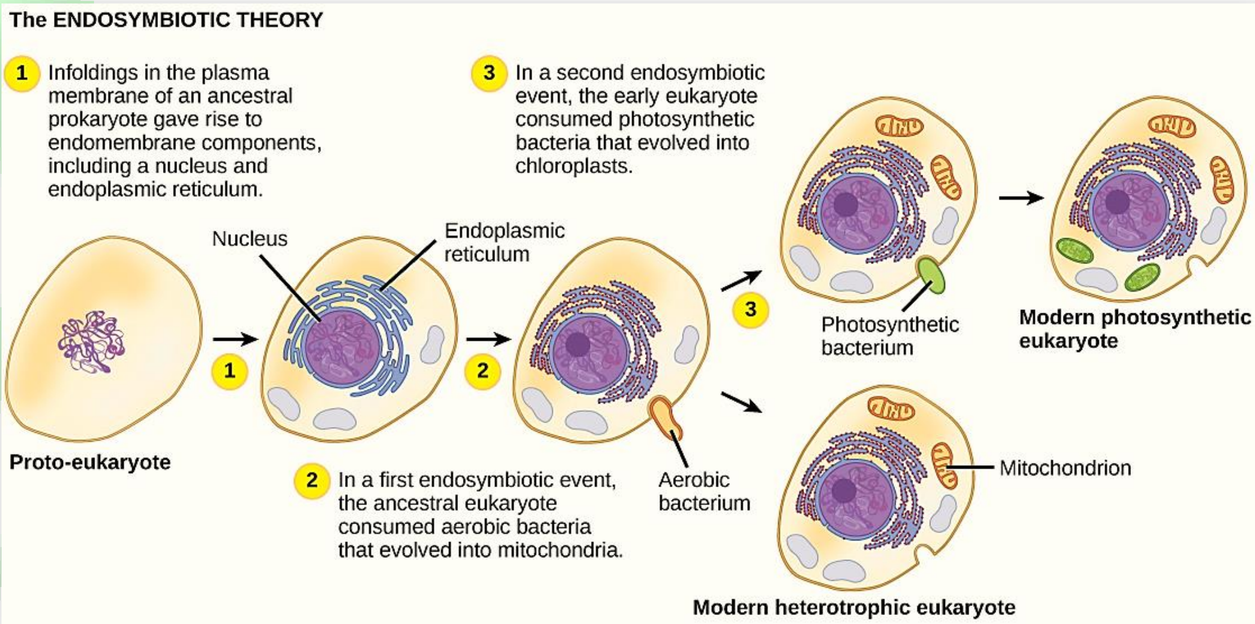


Fig. 8: The origin of mitochondria and chloroplasts

are thought to have arisen in this manner (Figure 8). Of course, prokaryotic cells have continued to evolve as well. Different species of bacteria and archaea have adapted to specific environments, and these prokaryotes not only survive but thrive without having their genetic material in its own compartment. For example, certain bacterial species that live in thermal vents along the ocean floor can withstand higher temperatures than any other organisms on Earth.

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THE CELL AND CELL THEORY

Soon after Anton van Leewenhock invented the microscope, Robert Hooke in 1665 observed a piece of cork under the microscope and found it to be made of small compartments which he called "cells" (Latin cell = small room). In 1672, Leewenhock observed bacteria, sperm and red blood corpuscles, all of which were cells. In 1831, Robert Brown, an Englishman observed that all cells had a centrally positioned body which he termed the nucleus.

The cell theory

In 1838 M.J. Schleiden and Theodore Schwann formulated the **"Cell Theory"**. The cell theory maintains that:

- All organisms are composed of cells.
- Cell is the structural and functional unit of life, and
- Cells arise from pre-existing cells.

The cells vary considerably, in shape and size. Nerve cells of animals have long extensions. They can be several feet in length. Muscle cells are elongated in shape. Egg of the ostrich is the largest cell (75 mm). Some plant cells have thick walls. There is also wide variation in the number of cells in different organisms.

THE CELL

A cell may be defined as a unit of **Protoplasm** bounded by a plasma or cell membrane and possessing a nucleus. Protoplasm is the life giving substance and includes the cytoplasm and the nucleus. The cytoplasm has in it **Organelles** such as **Ribosomes, Mitochondria, Golgi bodies, plastids, Living inclusions like crystals, Pigments** etc. The bacteria have neither organelles nor a well formed nucleus. But every cell has three major components

- Plasma membrane
- Cytoplasm
- DNA (naked in bacteria and covered by a membrane in all other organisms

TWO BASIC TYPES OF CELLS

Cytologists recognize two basic types of cells. Their differences have been tabulated below in table below. Organisms which do not possess a well formed nucleus are **Prokaryotes** such as the bacteria. All others possess a well-defined nucleus, covered by a nuclear membrane. They are **Eukaryotes**.

Table 3: Differences between Eukaryotic and Prokaryotic cells

Eukaryotic "eu = true, karyon = nucleus"	Prokaryotic cell "Pro = early/primitive"
1. Nucleus distinct, with well-formed nuclear membrane.	1. Nucleus not distinct, it is in the form of nuclear zone 'nucleoid'. Nuclear membrane absent.
2. Double-membraned cell organelles (Chloroplasts, mitochondria nucleus) and single membraned (Golgi apparatus, lysosomes vacuole endoplasm reticulum) are present.	2. Single-membraned cell bodies like mesosomes present. Endoplasmic reticulum and Golgi body absent.
3. Ribosomes - 80 S	3. Ribosomes - 70 S
4. Distinct compartments in the cell i.e. the cytoplasm and the nucleus.	4. No compartments.

Svedberg unit "S"

When the cell is fractionated or broken down into its components by rotating in an ultracentrifuge at different speeds the ribosomes of eukaryotic and prokaryotic sediment (settle down) at different speeds. The coefficient of sedimentation is represented in Svedberg unit and depicted as S.

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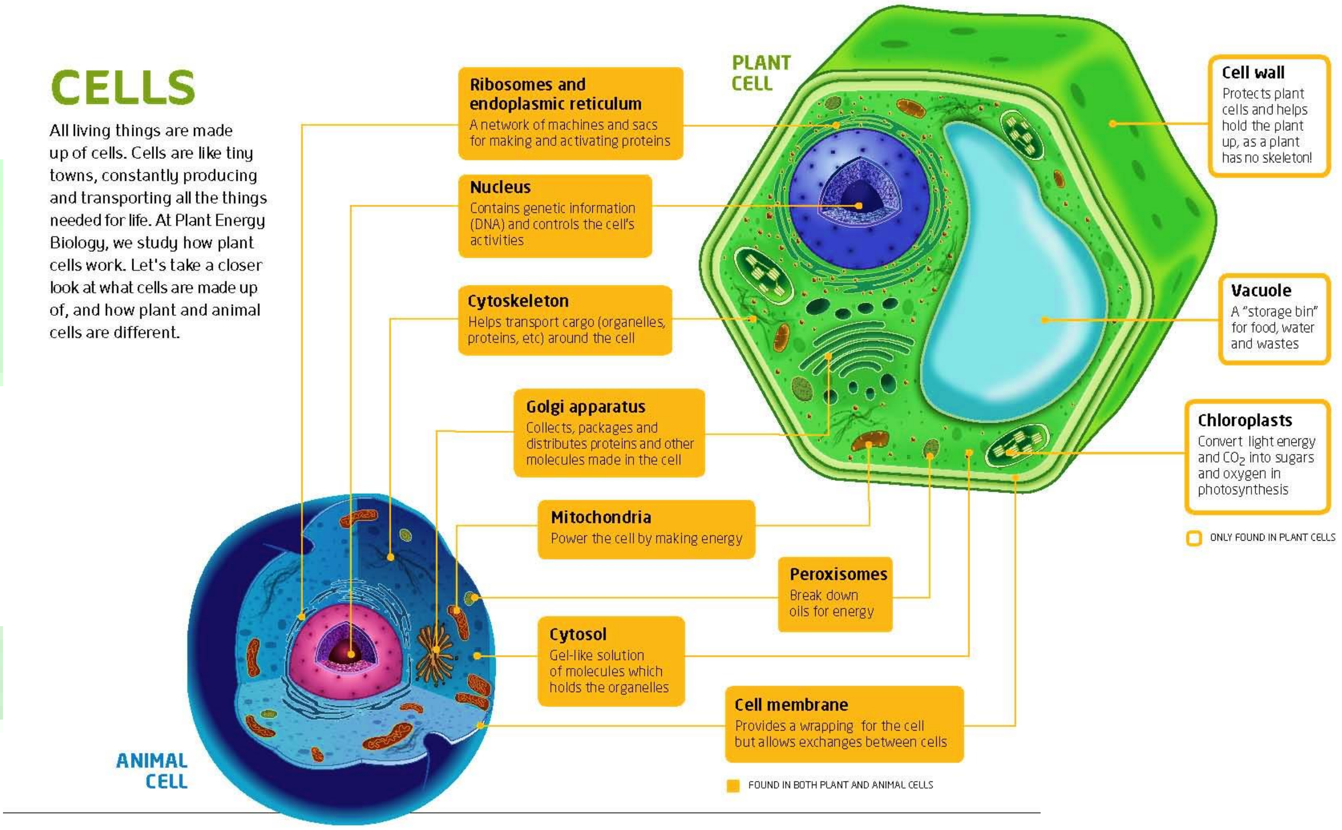
Table 4: Difference between plant cell and animal cell	
Plant Cell	**Animal Cell**
1. Cellulose cell wall present around cell membrane. 2. Vacuoles are usually large. 3. Plastids present. 4. Golgi body present in the form of units known as dictyosomes. 5. Centriole absent.	1. No cell wall. 2. Generally vacuoles are absent and if present, are usually small. 3. Plastids absent. 4. Golgi body well developed. 5. Centriole present.



CONCLUSION

Cells are the smallest common denominator of life. Some cells are organisms unto themselves; others are part of multicellular organisms. All cells are made from the same major classes of organic molecules: nucleic acids, proteins, carbohydrates, and lipids. In addition, cells can be placed in two major categories as a result of ancient evolutionary events: prokaryotes, with their cytoplasmic genomes, and eukaryotes, with their nuclear-encased genomes and other membrane-bound organelles. Though they are small, cells have evolved into a vast variety of shapes and sizes. Together they form tissues that themselves form organs, and eventually entire organisms.