**Cell (biology)**

From Wikipedia, the free encyclopedia

|  |
| --- |
| ***Cell*** |
| [Wilson1900Fig2.jpg](http://en.wikipedia.org/wiki/File:Wilson1900Fig2.jpg)  Onion ([Allium](http://en.wikipedia.org/wiki/Allium)) cells in different phases of the cell cycle |
| [Celltypes.svg](http://en.wikipedia.org/wiki/File:Celltypes.svg)  The cells of [eukaryotes](http://en.wikipedia.org/wiki/Eukaryote) (left) and [prokaryotes](http://en.wikipedia.org/wiki/Prokaryote) (right) |

The **cell** (from [Latin](http://en.wikipedia.org/wiki/Latin) *cella*, meaning "small room"[[1]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-1)) is the basic structural, functional and biological unit of all known [living](http://en.wikipedia.org/wiki/Life)[organisms](http://en.wikipedia.org/wiki/Organism). Cells are the smallest unit of life that can [replicate](http://en.wikipedia.org/wiki/Cell_division) independently, and are often called the "building blocks of life". The study of cells is called [cell biology](http://en.wikipedia.org/wiki/Cell_biology).

Cells consist of a [protoplasm](http://en.wikipedia.org/wiki/Protoplasm) enclosed within a [membrane](http://en.wikipedia.org/wiki/Cell_membrane), which contains many biomolecules such as [proteins](http://en.wikipedia.org/wiki/Proteins) and [nucleic acids](http://en.wikipedia.org/wiki/Nucleic_acids).[[2]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Alberts2002-2) Organisms can be classified as [unicellular](http://en.wikipedia.org/wiki/Unicellular) (consisting of a single cell; including most [bacteria](http://en.wikipedia.org/wiki/Bacteria)) or [multicellular](http://en.wikipedia.org/wiki/Multicellular)(including [plants](http://en.wikipedia.org/wiki/Plants) and [animals](http://en.wikipedia.org/wiki/Animals)). While the number of cells in plants and animals varies from species to species, humans contain about 100 [trillion](http://en.wikipedia.org/wiki/Orders_of_magnitude_(numbers)#1012) (1014) cells.[[3]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-3) Most plant and animal cells are visible only under the microscope, with dimensions between 1 and 100 [micrometres](http://en.wikipedia.org/wiki/Micrometre).[[4]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-4)

The cell was discovered by [Robert Hooke](http://en.wikipedia.org/wiki/Robert_Hooke) in 1665. The [cell theory](http://en.wikipedia.org/wiki/Cell_theory), first developed in 1839 by [Matthias Jakob Schleiden](http://en.wikipedia.org/wiki/Matthias_Jakob_Schleiden) and[Theodor Schwann](http://en.wikipedia.org/wiki/Theodor_Schwann), states that all organisms are composed of one or more cells, that all cells come from preexisting cells, that vital [functions](http://en.wikipedia.org/wiki/Biological_process) of an organism occur within cells, and that all cells contain the [hereditary information](http://en.wikipedia.org/wiki/Genetics) necessary for regulating cell functions and for transmitting information to the next generation of cells.[[5]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-5) Cells emerged on Earth at least 3.5 billion years ago.[[6]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Origin1-6)[[7]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Origin2-7)[[8]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-RavenJohnson2002-8)

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**Anatomy**

There are two types of cells, [eukaryotes](http://en.wikipedia.org/wiki/Eukaryote), which contain a [nucleus](http://en.wikipedia.org/wiki/Cell_nucleus), and [prokaryotes](http://en.wikipedia.org/wiki/Prokaryote), which do not. Prokaryotic cells are usually [single-celled organisms](http://en.wikipedia.org/wiki/Unicellular_organism), while eukaryotic cells can be either single-celled or part of [multicellular organisms](http://en.wikipedia.org/wiki/Multicellular_organism).

|  |  |  |
| --- | --- | --- |
| **Table 1: Comparison of features of prokaryotic and eukaryotic cells** | | |
|  | **Prokaryotes** | **Eukaryotes** |
| **Typical organisms** | [bacteria](http://en.wikipedia.org/wiki/Bacterium), [archaea](http://en.wikipedia.org/wiki/Archaea) | [protists](http://en.wikipedia.org/wiki/Protist), [fungi](http://en.wikipedia.org/wiki/Fungus), [plants](http://en.wikipedia.org/wiki/Plant), [animals](http://en.wikipedia.org/wiki/Animal) |
| **Typical size** | ~ 1–5 [µm](http://en.wikipedia.org/wiki/%CE%9Cm)[[9]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-CampbellBiology320-9) | ~ 10–100 [µm](http://en.wikipedia.org/wiki/%CE%9Cm)[[9]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-CampbellBiology320-9) |
| **Type of**[**nucleus**](http://en.wikipedia.org/wiki/Cell_nucleus) | [nucleoid region](http://en.wikipedia.org/wiki/Nucleoid_region); no true nucleus | true nucleus with double membrane |
| **DNA** | circular (usually) | linear molecules ([chromosomes](http://en.wikipedia.org/wiki/Chromosome)) with [histone](http://en.wikipedia.org/wiki/Histone) [proteins](http://en.wikipedia.org/wiki/Protein) |
| **RNA/protein synthesis** | coupled in the [cytoplasm](http://en.wikipedia.org/wiki/Cytoplasm) | [RNA synthesis](http://en.wikipedia.org/wiki/Transcription_(genetics)) in the nucleus [protein synthesis](http://en.wikipedia.org/wiki/Translation_(biology)) in the cytoplasm |
| [**Ribosomes**](http://en.wikipedia.org/wiki/Ribosome) | 50S and 30S | 60S and 40S |
| **Cytoplasmic structure** | very few structures | highly structured by endomembranes and a [cytoskeleton](http://en.wikipedia.org/wiki/Cytoskeleton) |
| [**Cell movement**](http://en.wikipedia.org/wiki/Chemotaxis) | [flagella](http://en.wikipedia.org/wiki/Flagellum) made of [flagellin](http://en.wikipedia.org/wiki/Flagellin) | flagella and [cilia](http://en.wikipedia.org/wiki/Cilium) containing [microtubules](http://en.wikipedia.org/wiki/Microtubule); [lamellipodia](http://en.wikipedia.org/wiki/Lamellipodia) and [filopodia](http://en.wikipedia.org/wiki/Filopodia) containing [actin](http://en.wikipedia.org/wiki/Actin) |
| [**Mitochondria**](http://en.wikipedia.org/wiki/Mitochondrium) | none | one to several thousand (though some lack mitochondria) |
| [**Chloroplasts**](http://en.wikipedia.org/wiki/Chloroplast) | none | in [algae](http://en.wikipedia.org/wiki/Algae) and [plants](http://en.wikipedia.org/wiki/Plant) |
| **Organization** | usually single cells | single cells, colonies, higher multicellular organisms with specialized cells |
| [**Cell division**](http://en.wikipedia.org/wiki/Cell_division) | [Binary fission](http://en.wikipedia.org/wiki/Binary_fission) (simple division) | [Mitosis](http://en.wikipedia.org/wiki/Mitosis) (fission or budding) [Meiosis](http://en.wikipedia.org/wiki/Meiosis) |

**Prokaryotic cells**

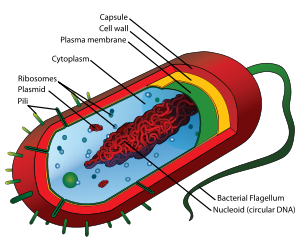
[](http://en.wikipedia.org/wiki/File:Average_prokaryote_cell-_en.svg)

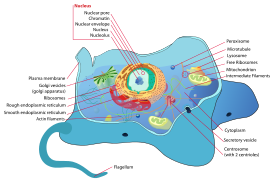
Diagram of a typical [prokaryotic](http://en.wikipedia.org/wiki/Prokaryotic) cell

[Prokaryotic](http://en.wikipedia.org/wiki/Prokaryote) cells were the first form of life on Earth. They are simpler and smaller than eukaryotic cells, and lack membrane-bound organelles such as the [nucleus](http://en.wikipedia.org/wiki/Cell_nucleus). Prokaryotes include two of the [domains of life](http://en.wikipedia.org/wiki/Domain_(biology)), [bacteria](http://en.wikipedia.org/wiki/Bacteria) and [archaea](http://en.wikipedia.org/wiki/Archaea). The DNA of a prokaryotic cell consists of a single chromosome that is in direct contact with the [cytoplasm](http://en.wikipedia.org/wiki/Cytoplasm). The nuclear region in the cytoplasm is called the [nucleoid](http://en.wikipedia.org/wiki/Nucleoid).

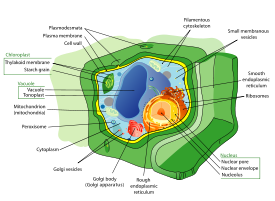
A prokaryotic cell has three architectural regions:

* On the outside, [flagella](http://en.wikipedia.org/wiki/Flagella) and [pili](http://en.wikipedia.org/wiki/Pilus) project from the cell's surface. These are structures (not present in all prokaryotes) made of proteins that facilitate movement and communication between cells.
* Enclosing the cell is the [cell envelope](http://en.wikipedia.org/wiki/Cell_envelope) – generally consisting of a [cell wall](http://en.wikipedia.org/wiki/Cell_wall) covering a [plasma membrane](http://en.wikipedia.org/wiki/Plasma_membrane) though some bacteria also have a further covering layer called a [capsule](http://en.wikipedia.org/wiki/Bacterial_capsule). The envelope gives rigidity to the cell and separates the interior of the cell from its environment, serving as a protective filter. Though most prokaryotes have a cell wall, there are exceptions such as [*Mycoplasma*](http://en.wikipedia.org/wiki/Mycoplasma) (bacteria) and [*Thermoplasma*](http://en.wikipedia.org/wiki/Thermoplasma) (archaea). The cell wall consists of [peptidoglycan](http://en.wikipedia.org/wiki/Peptidoglycan) in bacteria, and acts as an additional barrier against exterior forces. It also prevents the cell from expanding and bursting ([cytolysis](http://en.wikipedia.org/wiki/Cytolysis)) from [osmotic pressure](http://en.wikipedia.org/wiki/Osmotic_pressure) due to a [hypotonic](http://en.wikipedia.org/wiki/Tonicity#Hypotonicity) environment. Some eukaryotic cells ([plant cells](http://en.wikipedia.org/wiki/Plant_cell) and [fungal](http://en.wikipedia.org/wiki/Fungus) cells) also have a cell wall.
* Inside the cell is the [cytoplasmic region](http://en.wikipedia.org/wiki/Cytoplasm) that contains the [genome](http://en.wikipedia.org/wiki/Genome) (DNA), ribosomes and various sorts of inclusions. The [prokaryotic chromosome](http://en.wikipedia.org/wiki/Chromosome#Chromosomes_in_prokaryotes) is usually a circular molecule (an exception is that of the bacterium [*Borrelia burgdorferi*](http://en.wikipedia.org/wiki/Borrelia_burgdorferi), which causes Lyme disease).[[10]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-10) Though not forming a *nucleus*, the [DNA](http://en.wikipedia.org/wiki/DNA) is condensed in a*nucleoid*. Prokaryotes can carry [extrachromosomal DNA](http://en.wikipedia.org/wiki/Extrachromosomal_DNA) elements called [plasmids](http://en.wikipedia.org/wiki/Plasmid), which are usually circular. Plasmids encode additional genes, such as [antibiotic resistance](http://en.wikipedia.org/wiki/Antibiotic_resistance) genes.

**Eukaryotic cells**

[](http://en.wikipedia.org/wiki/File:Animal_cell_structure_en.svg)

Structure of a typical animal cell

[](http://en.wikipedia.org/wiki/File:Plant_cell_structure_svg.svg)

Structure of a typical [plant cell](http://en.wikipedia.org/wiki/Plant_cell)

Plants, animals, fungi, slime moulds, protozoa, and algae are all [eukaryotic](http://en.wikipedia.org/wiki/Eukaryote). These cells are about fifteen times wider than a typical prokaryote and can be as much as a thousand times greater in volume. The main distinguishing feature of eukaryotes as compared to prokaryotes is [compartmentalization:](http://en.wikipedia.org/wiki/Cellular_compartment) the presence of membrane-bound compartments in which specific metabolic activities take place. Most important among these is a [cell nucleus](http://en.wikipedia.org/wiki/Cell_nucleus), a membrane-delineated compartment that houses the eukaryotic cell's DNA. This nucleus gives the eukaryote its name, which means "true nucleus." Other differences include:

* The plasma membrane resembles that of prokaryotes in function, with minor differences in the setup. Cell walls may or may not be present.
* The eukaryotic DNA is organized in one or more linear molecules, called [chromosomes](http://en.wikipedia.org/wiki/Chromosome), which are associated with [histone](http://en.wikipedia.org/wiki/Histone)proteins. All chromosomal DNA is stored in the [*cell nucleus*](http://en.wikipedia.org/wiki/Cell_nucleus), separated from the cytoplasm by a membrane. Some eukaryotic [organelles](http://en.wikipedia.org/wiki/Organelle) such as [mitochondria](http://en.wikipedia.org/wiki/Mitochondria) also contain some DNA.
* Many eukaryotic cells are [ciliated](http://en.wikipedia.org/wiki/Cilium) with *primary cilia*. Primary cilia play important roles in chemosensation,[mechanosensation](http://en.wikipedia.org/wiki/Mechanosensation), and thermosensation. Cilia may thus be "viewed as a sensory cellular [antennae](http://en.wikipedia.org/wiki/Antenna_(biology)) that coordinates a large number of cellular signaling pathways, sometimes coupling the signaling to ciliary motility or alternatively to cell division and differentiation."[[11]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Christenson2008-11)
* Eukaryotes can move using *motile*[*cilia*](http://en.wikipedia.org/wiki/Cilia) or *flagella*. Eukaryotic flagella are less complex than those of prokaryotes.

**Subcellular components**

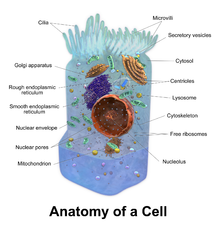
[](http://en.wikipedia.org/wiki/File:Blausen_0208_CellAnatomy.png)

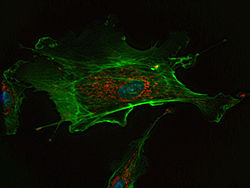
Illustration depicting major structures inside a eukaryotic animal cell

All cells, whether [prokaryotic](http://en.wikipedia.org/wiki/Prokaryotic) or [eukaryotic](http://en.wikipedia.org/wiki/Eukaryotic), have a [membrane](http://en.wikipedia.org/wiki/Cell_membrane) that envelops the cell, regulates what moves in and out (selectively permeable), and maintains the [electric potential of the cell](http://en.wikipedia.org/wiki/Membrane_potential). Inside the membrane, a [salty](http://en.wikipedia.org/wiki/Salt) [cytoplasm](http://en.wikipedia.org/wiki/Cytoplasm) takes up most of the cell volume. All cells (except [red blood cells](http://en.wikipedia.org/wiki/Red_blood_cell) which lack a cell nucleus and most organelles to accommodate maximum space for [hemoglobin](http://en.wikipedia.org/wiki/Hemoglobin)) possess [DNA](http://en.wikipedia.org/wiki/DNA), the hereditary material of [genes](http://en.wikipedia.org/wiki/Gene), and [RNA](http://en.wikipedia.org/wiki/RNA), containing the information necessary to [build](http://en.wikipedia.org/wiki/Gene_expression) various [proteins](http://en.wikipedia.org/wiki/Protein)such as [enzymes](http://en.wikipedia.org/wiki/Enzyme), the cell's primary machinery. There are also other kinds of [biomolecules](http://en.wikipedia.org/wiki/Biomolecule) in cells. This article lists these primary components of the cell, then briefly describes their function.

**Membrane**

The cell membrane, or plasma membrane, surrounds the cytoplasm of a cell. In animals, the plasma membrane is the outer boundary of the cell, while in plants and prokaryotes it is usually covered by a [cell wall](http://en.wikipedia.org/wiki/Cell_wall). This membrane serves to separate and protect a cell from its surrounding environment and is made mostly from a [double layer of phospholipids](http://en.wikipedia.org/wiki/Lipid_bilayer), which are [amphiphilic](http://en.wikipedia.org/wiki/Amphiphilic) (partly [hydrophobic](http://en.wikipedia.org/wiki/Hydrophobic) and partly[hydrophilic](http://en.wikipedia.org/wiki/Hydrophilic)). Hence, the layer is called a [phospholipid bilayer](http://en.wikipedia.org/wiki/Phospholipid_bilayer), or sometimes a fluid mosaic membrane. Embedded within this membrane is a variety of [protein](http://en.wikipedia.org/wiki/Protein) molecules that act as channels and pumps that move different molecules into and out of the cell. The membrane is said to be 'semi-permeable', in that it can either let a substance ([molecule](http://en.wikipedia.org/wiki/Molecule) or [ion](http://en.wikipedia.org/wiki/Ion)) pass through freely, pass through to a limited extent or not pass through at all. Cell surface membranes also contain [receptor](http://en.wikipedia.org/wiki/Receptor_(biochemistry)#Transmembrane_receptors) proteins that allow cells to detect external signaling molecules such as [hormones](http://en.wikipedia.org/wiki/Hormone).

**Cytoskeleton**

[](http://en.wikipedia.org/wiki/File:DAPIMitoTrackerRedAlexaFluor488BPAE.jpg)

A fluorescent image of an endothelial cell. Nuclei are stained blue, [mitochondria](http://en.wikipedia.org/wiki/Mitochondria) are stained red, and microfilaments are stained green.

The cytoskeleton acts to organize and maintain the cell's shape; anchors organelles in place; helps during [endocytosis](http://en.wikipedia.org/wiki/Endocytosis), the uptake of external materials by a cell, and [cytokinesis](http://en.wikipedia.org/wiki/Cytokinesis), the separation of daughter cells after [cell division](http://en.wikipedia.org/wiki/Cell_division); and moves parts of the cell in processes of growth and mobility. The eukaryotic cytoskeleton is composed of [microfilaments](http://en.wikipedia.org/wiki/Microfilament), [intermediate filaments](http://en.wikipedia.org/wiki/Intermediate_filament) and[microtubules](http://en.wikipedia.org/wiki/Microtubule). There are a great number of proteins associated with them, each controlling a cell's structure by directing, bundling, and aligning filaments. The prokaryotic cytoskeleton is less well-studied but is involved in the maintenance of cell shape, polarity and cytokinesis.[[12]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-12)

**Genetic material**

Two different kinds of genetic material exist: [deoxyribonucleic acid](http://en.wikipedia.org/wiki/DNA) (DNA) and [ribonucleic acid](http://en.wikipedia.org/wiki/RNA) (RNA). Cells use DNA for their long-term information storage. The biological information contained in an organism is [encoded](http://en.wikipedia.org/wiki/Genetic_code) in its DNA sequence. RNA is used for information transport (e.g., [mRNA](http://en.wikipedia.org/wiki/MRNA)) and [enzymatic](http://en.wikipedia.org/wiki/Enzyme) functions (e.g., [ribosomal](http://en.wikipedia.org/wiki/Ribosome) RNA). [Transfer RNA](http://en.wikipedia.org/wiki/Transfer_RNA) (tRNA) molecules are used to add amino acids during protein [translation](http://en.wikipedia.org/wiki/Translation_(biology)).

Prokaryotic genetic material is organized in a simple circular DNA molecule (the bacterial [chromosome](http://en.wikipedia.org/wiki/Chromosome)) in the [nucleoid region](http://en.wikipedia.org/wiki/Nucleoid_region) of the cytoplasm. Eukaryotic genetic material is divided into different, linear molecules called [chromosomes](http://en.wikipedia.org/wiki/Chromosome) inside a discrete nucleus, usually with additional genetic material in some organelles like [mitochondria](http://en.wikipedia.org/wiki/Mitochondria) and [chloroplasts](http://en.wikipedia.org/wiki/Chloroplasts) (see [endosymbiotic theory](http://en.wikipedia.org/wiki/Endosymbiotic_theory)).

A human cell has genetic material contained in the [cell nucleus](http://en.wikipedia.org/wiki/Cell_nucleus) (the [nuclear genome](http://en.wikipedia.org/wiki/Genome)) and in the mitochondria (the [mitochondrial genome](http://en.wikipedia.org/wiki/Mitochondrial_genome)). In humans the nuclear genome is divided into 46 linear DNA molecules called [chromosomes](http://en.wikipedia.org/wiki/Chromosome), including 22 [homologous](http://en.wikipedia.org/wiki/Homologous_chromosome) chromosome pairs and a pair of [sex chromosomes](http://en.wikipedia.org/wiki/Sex_chromosomes). The mitochondrial genome is a circular DNA molecule distinct from the nuclear DNA. Although the [mitochondrial DNA](http://en.wikipedia.org/wiki/Mitochondrial_DNA) is very small compared to nuclear chromosomes, it codes for 13 proteins involved in mitochondrial energy production and specific tRNAs.

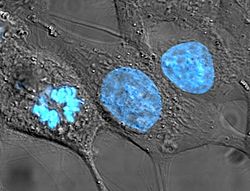
Foreign genetic material (most commonly DNA) can also be artificially introduced into the cell by a process called [transfection](http://en.wikipedia.org/wiki/Transfection). This can be transient, if the DNA is not inserted into the cell's [genome](http://en.wikipedia.org/wiki/Genome), or stable, if it is. Certain [viruses](http://en.wikipedia.org/wiki/Virus) also insert their genetic material into the genome.

**Organelles**

Organelles are parts of the cell which are adapted and/or specialized for carrying out one or more vital functions, analogous to the [organs](http://en.wikipedia.org/wiki/Organ_(anatomy)) of the human body (such as the heart, lung, and kidney, with each organ performing a different function). Both eukaryotic and prokaryotic cells have organelles, but prokaryotic organelles are generally simpler and are not membrane-bound.

There are several types of organelles in a cell. Some (such as the [nucleus](http://en.wikipedia.org/wiki/Cell_nucleus) and [golgi apparatus](http://en.wikipedia.org/wiki/Golgi_apparatus)) are typically solitary, while others (such as [mitochondria](http://en.wikipedia.org/wiki/Mitochondria), [chloroplasts](http://en.wikipedia.org/wiki/Chloroplasts),[peroxisomes](http://en.wikipedia.org/wiki/Peroxisomes) and [lysosomes](http://en.wikipedia.org/wiki/Lysosomes)) can be numerous (hundreds to thousands). The [cytosol](http://en.wikipedia.org/wiki/Cytosol) is the gelatinous fluid that fills the cell and surrounds the organelles.

**Eukaryotic**

[](http://en.wikipedia.org/wiki/File:HeLa_cells_stained_with_Hoechst_33258.jpg)

Human cancer cells with nuclei (specifically the DNA) stained blue. The central and rightmost cell are in [interphase](http://en.wikipedia.org/wiki/Interphase), so the entire nuclei are labeled. The cell on the left is going through [mitosis](http://en.wikipedia.org/wiki/Mitosis) and its DNA has condensed.

* **Cell nucleus**: A cell's information center, the [cell nucleus](http://en.wikipedia.org/wiki/Cell_nucleus) is the most conspicuous organelle found in a [eukaryotic](http://en.wikipedia.org/wiki/Eukaryotic) cell. It houses the cell's [chromosomes](http://en.wikipedia.org/wiki/Chromosomes), and is the place where almost all [DNA](http://en.wikipedia.org/wiki/DNA) replication and [RNA](http://en.wikipedia.org/wiki/RNA) synthesis ([transcription](http://en.wikipedia.org/wiki/Transcription_(genetics))) occur. The nucleus is spherical and separated from the cytoplasm by a double membrane called the [nuclear envelope](http://en.wikipedia.org/wiki/Nuclear_envelope). The nuclear envelope isolates and protects a cell's DNA from various molecules that could accidentally damage its structure or interfere with its processing. During processing, [DNA](http://en.wikipedia.org/wiki/DNA) is [transcribed](http://en.wikipedia.org/wiki/Transcription_(genetics)), or copied into a special [RNA](http://en.wikipedia.org/wiki/RNA), called [messenger RNA](http://en.wikipedia.org/wiki/Messenger_RNA) (mRNA). This mRNA is then transported out of the nucleus, where it is translated into a specific protein molecule. The [nucleolus](http://en.wikipedia.org/wiki/Nucleolus) is a specialized region within the nucleus where ribosome subunits are assembled. In prokaryotes, DNA processing takes place in the [cytoplasm](http://en.wikipedia.org/wiki/Cytoplasm).
* **Mitochondria and Chloroplasts**: the power generators: [Mitochondria](http://en.wikipedia.org/wiki/Mitochondrion) are self-replicating organelles that occur in various numbers, shapes, and sizes in the cytoplasm of all eukaryotic cells. Mitochondria play a critical role in generating energy in the eukaryotic cell. [Respiration](http://en.wikipedia.org/wiki/Cellular_respiration) occurs in the cell mitochondria, which generate the cell's energy by [oxidative phosphorylation](http://en.wikipedia.org/wiki/Oxidative_phosphorylation), using [oxygen](http://en.wikipedia.org/wiki/Oxygen) to release energy stored in cellular nutrients (typically pertaining to [glucose](http://en.wikipedia.org/wiki/Glucose)) to generate [ATP](http://en.wikipedia.org/wiki/Adenosine_triphosphate). Mitochondria multiply by [binary fission](http://en.wikipedia.org/wiki/Binary_fission), like prokaryotes. Chloroplasts can only be found in plants and algae, and they capture the sun's energy to make ATP through [photosynthesis](http://en.wikipedia.org/wiki/Photosynthesis).

[](http://en.wikipedia.org/wiki/File:Endomembrane_system_diagram_no_text_nucleus.png)

Diagram of an endomembrane system

* **Endoplasmic reticulum**: The [endoplasmic reticulum](http://en.wikipedia.org/wiki/Endoplasmic_reticulum) (ER) is a transport network for molecules targeted for certain modifications and specific destinations, as compared to molecules that float freely in the cytoplasm. The ER has two forms: the rough ER, which has ribosomes on its surface that secrete proteins into the ER, and the smooth ER, which lacks ribosomes. The smooth ER plays a role in calcium sequestration and release.
* **Golgi apparatus**: The primary function of the Golgi apparatus is to process and package the [macromolecules](http://en.wikipedia.org/wiki/Macromolecule) such as [proteins](http://en.wikipedia.org/wiki/Protein) and[lipids](http://en.wikipedia.org/wiki/Lipid) that are synthesized by the cell.
* **Lysosomes and Peroxisomes**: [Lysosomes](http://en.wikipedia.org/wiki/Lysosome) contain [digestive enzymes](http://en.wikipedia.org/wiki/Digestive_enzyme) (acid [hydrolases](http://en.wikipedia.org/wiki/Hydrolase)). They digest excess or worn-out[organelles](http://en.wikipedia.org/wiki/Organelle), food particles, and engulfed [viruses](http://en.wikipedia.org/wiki/Virus) or [bacteria](http://en.wikipedia.org/wiki/Bacteria). [Peroxisomes](http://en.wikipedia.org/wiki/Peroxisome) have enzymes that rid the cell of toxic [peroxides](http://en.wikipedia.org/wiki/Peroxide). The cell could not house these destructive enzymes if they were not contained in a membrane-bound system.
* **Centrosome** – the cytoskeleton organiser: The [centrosome](http://en.wikipedia.org/wiki/Centrosome) produces the [microtubules](http://en.wikipedia.org/wiki/Microtubules) of a cell – a key component of the[cytoskeleton](http://en.wikipedia.org/wiki/Cytoskeleton). It directs the transport through the [ER](http://en.wikipedia.org/wiki/Endoplasmic_reticulum) and the [Golgi apparatus](http://en.wikipedia.org/wiki/Golgi_apparatus). Centrosomes are composed of two [centrioles](http://en.wikipedia.org/wiki/Centrioles), which separate during [cell division](http://en.wikipedia.org/wiki/Cell_division) and help in the formation of the [mitotic spindle](http://en.wikipedia.org/wiki/Mitotic_spindle). A single centrosome is present in the [animal cells](http://en.wikipedia.org/wiki/Animal_cell). They are also found in some fungi and algae cells.
* **Vacuoles**: [Vacuoles](http://en.wikipedia.org/wiki/Vacuole) store food and waste. Some vacuoles store extra water. They are often described as liquid filled space and are surrounded by a membrane. Some cells, most notably [*Amoeba*](http://en.wikipedia.org/wiki/Amoeba), have contractile vacuoles, which can pump water out of the cell if there is too much water. The vacuoles of eukaryotic cells are usually larger in those of plants than animals.

**Eukaryotic and prokaryotic**

* **Ribosomes**: The [ribosome](http://en.wikipedia.org/wiki/Ribosome) is a large complex of [RNA](http://en.wikipedia.org/wiki/RNA) and [protein](http://en.wikipedia.org/wiki/Protein) molecules. They each consist of two subunits, and act as an assembly line where RNA from the nucleus is used to synthesise proteins from amino acids. Ribosomes can be found either floating freely or bound to a membrane (the rough endoplasmatic reticulum in eukaryotes, or the cell membrane in prokaryotes).[[13]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-13)

**Structures outside the cell membrane**

Many cells also have structures which exist wholly or partially outside the cell membrane. These structures are notable because they are not protected from the external environment by the impermeable cell membrane. In order to assemble these structures, their components must be carried across the cell membrane by export processes.

**Cell wall**

Many types of prokaryotic and eukaryotic cells have a [cell wall](http://en.wikipedia.org/wiki/Cell_wall). The cell wall acts to protect the cell mechanically and chemically from its environment, and is an additional layer of protection to the cell membrane. Different types of cell have cell walls made up of different materials; plant cell walls are primarily made up of pectin, fungi cell walls are made up of chitin and bacteria cell walls are made up of peptidoglycan.

**Prokaryotic**

**Capsule**

A gelatinous capsule is present in some bacteria outside the cell membrane and cell wall. The capsule may be [polysaccharide](http://en.wikipedia.org/wiki/Polysaccharide) as in [pneumococci](http://en.wikipedia.org/wiki/Pneumococci), [meningococci](http://en.wikipedia.org/wiki/Meningococci) or [polypeptide](http://en.wikipedia.org/wiki/Polypeptide)as [*Bacillus anthracis*](http://en.wikipedia.org/wiki/Bacillus_anthracis) or [hyaluronic acid](http://en.wikipedia.org/wiki/Hyaluronic_acid) as in [streptococci](http://en.wikipedia.org/wiki/Streptococci). (See [Bacterial capsule](http://en.wikipedia.org/wiki/Bacterial_capsule).) Capsules are not marked by normal staining protocols and can be detected by [India ink](http://en.wikipedia.org/wiki/India_ink#Uses_other_than_writing) or[methyl blue](http://en.wikipedia.org/wiki/Methyl_blue); which allows for higher contrast between the cells for observation.[[14]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-14):87

**Flagella**

[Flagella](http://en.wikipedia.org/wiki/Flagella) are organelles for cellular mobility. The bacterial flagellum stretches from cytoplasm through the cell membrane(s) and extrudes through the cell wall. They are long and thick thread-like appendages, protein in nature. Are most commonly found in bacteria cells but are found in animal cells as well.

**Fimbriae (pili)**

They are short and thin hair-like filaments, formed of protein called pilin (antigenic). [Fimbriae](http://en.wikipedia.org/wiki/Fimbria_(bacteriology)) are responsible for attachment of bacteria to specific receptors of human cell (adherence). There are special types of pili called (sex pili) involved in conjunction. (See [Pilus](http://en.wikipedia.org/wiki/Pilus).)

**Cellular processes**

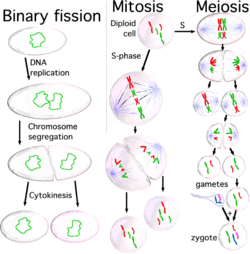
**Growth and metabolism**

Between successive cell divisions, cells grow through the functioning of cellular metabolism. Cell metabolism is the process by which individual cells process nutrient molecules. Metabolism has two distinct divisions: [catabolism](http://en.wikipedia.org/wiki/Catabolism), in which the cell breaks down complex molecules to produce energy and [reducing power](http://en.wikipedia.org/wiki/Reducing_agent), and [anabolism](http://en.wikipedia.org/wiki/Anabolism), in which the cell uses energy and reducing power to construct complex molecules and perform other biological functions. Complex sugars consumed by the organism can be broken down into a less chemically complex sugar molecule called [glucose](http://en.wikipedia.org/wiki/Glucose). Once inside the cell, glucose is broken down to make adenosine triphosphate ([ATP](http://en.wikipedia.org/wiki/Adenosine_triphosphate)), a form of energy, through two different pathways.

The first pathway, [glycolysis](http://en.wikipedia.org/wiki/Glycolysis), requires no oxygen and is referred to as [anaerobic metabolism](http://en.wikipedia.org/wiki/Fermentation_(biochemistry)). Each reaction produces [ATP](http://en.wikipedia.org/wiki/Adenosine_triphosphate) and [NADH](http://en.wikipedia.org/wiki/Nicotinamide_adenine_dinucleotide), which are used in cellular functions, as well as two [pyruvate](http://en.wikipedia.org/wiki/Pyruvate) molecules that derived from the original glucose molecule. In prokaryotes, all energy is produced by glycolysis.

The second pathway, called the Krebs cycle or [citric acid cycle](http://en.wikipedia.org/wiki/Citric_acid_cycle), is performed only by eukaryotes and involves further breakdown of the pyruvate produced in glycolysis. It occurs inside the mitochondria and generates much more energy than glycolysis, mostly through [oxidative phosphorylation](http://en.wikipedia.org/wiki/Oxidative_phosphorylation).

**Replication**

[](http://en.wikipedia.org/wiki/File:Three_cell_growth_types.png)

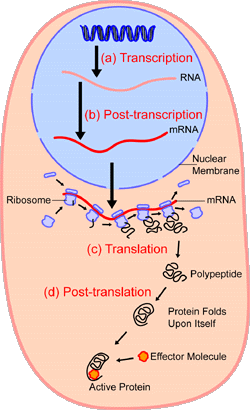
Bacteria divide by [binary fission](http://en.wikipedia.org/wiki/Binary_fission), while eukaryotes divide by [mitosis](http://en.wikipedia.org/wiki/Mitosis) or [meiosis](http://en.wikipedia.org/wiki/Meiosis).

Cell division involves a single cell (called a *mother cell*) dividing into two daughter cells. This leads to growth in [multicellular organisms](http://en.wikipedia.org/wiki/Multicellular_organism) (the growth of [tissue](http://en.wikipedia.org/wiki/Biological_tissue)) and to procreation ([vegetative reproduction](http://en.wikipedia.org/wiki/Vegetative_reproduction)) in [unicellular organisms](http://en.wikipedia.org/wiki/Unicellular_organism). [Prokaryotic](http://en.wikipedia.org/wiki/Prokaryote) cells divide by[binary fission](http://en.wikipedia.org/wiki/Binary_fission), while [eukaryotic](http://en.wikipedia.org/wiki/Eukaryote) cells usually undergo a process of nuclear division, called [mitosis](http://en.wikipedia.org/wiki/Mitosis), followed by division of the cell, called [cytokinesis](http://en.wikipedia.org/wiki/Cytokinesis). A [diploid](http://en.wikipedia.org/wiki/Diploid) cell may also undergo [meiosis](http://en.wikipedia.org/wiki/Meiosis) to produce haploid cells, usually four. [Haploid](http://en.wikipedia.org/wiki/Haploid) cells serve as [gametes](http://en.wikipedia.org/wiki/Gamete) in multicellular organisms, fusing to form new diploid cells.

[DNA replication](http://en.wikipedia.org/wiki/DNA_replication), or the process of duplicating a cell's genome, always happens when a cell divides through mitosis or binary fission. This occurs during the S phase of the [cell cycle](http://en.wikipedia.org/wiki/Cell_cycle).

In meiosis, the DNA is replicated only once, while the cell divides twice. DNA replication only occurs before [meiosis I](http://en.wikipedia.org/wiki/Meiosis_I). DNA replication does not occur when the cells divide the second time, in [meiosis II](http://en.wikipedia.org/wiki/Meiosis_II).[[15]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-15) Replication, like all cellular activities, requires specialized proteins for carrying out the job.

**Protein synthesis**

[](http://en.wikipedia.org/wiki/File:Proteinsynthesis.png)

An overview of protein synthesis.  
Within the [nucleus](http://en.wikipedia.org/wiki/Cell_nucleus) of the cell (*light blue*),[genes](http://en.wikipedia.org/wiki/Gene) (DNA, *dark blue*) are [transcribed](http://en.wikipedia.org/wiki/Transcription_(genetics))into [RNA](http://en.wikipedia.org/wiki/RNA). This RNA is then subject to post-transcriptional modification and control, resulting in a mature [mRNA](http://en.wikipedia.org/wiki/MRNA) (*red*) that is then transported out of the nucleus and into the[cytoplasm](http://en.wikipedia.org/wiki/Cytoplasm) (*peach*), where it undergoes[translation](http://en.wikipedia.org/wiki/Translation_(genetics)) into a protein. mRNA is translated by [ribosomes](http://en.wikipedia.org/wiki/Ribosome) (*purple*) that match the three-base [codons](http://en.wikipedia.org/wiki/Codon) of the mRNA to the three-base anti-codons of the appropriate[tRNA](http://en.wikipedia.org/wiki/Transfer_RNA). Newly synthesized proteins (*black*) are often further modified, such as by binding to an effector molecule (*orange*), to become fully active.

Cells are capable of synthesizing new proteins, which are essential for the modulation and maintenance of cellular activities. This process involves the formation of new protein molecules from [amino acid](http://en.wikipedia.org/wiki/Amino_acid) building blocks based on information encoded in DNA/RNA. Protein synthesis generally consists of two major steps: [transcription](http://en.wikipedia.org/wiki/Transcription_(genetics)) and [translation](http://en.wikipedia.org/wiki/Translation_(genetics)).

Transcription is the process where genetic information in DNA is used to produce a complementary RNA strand. This RNA strand is then processed to give [messenger RNA](http://en.wikipedia.org/wiki/Messenger_RNA) (mRNA), which is free to migrate through the cell. mRNA molecules bind to protein-RNA complexes called [ribosomes](http://en.wikipedia.org/wiki/Ribosome) located in the [cytosol](http://en.wikipedia.org/wiki/Cytosol), where they are translated into polypeptide sequences. The ribosome mediates the formation of a polypeptide sequence based on the mRNA sequence. The mRNA sequence directly relates to the polypeptide sequence by binding to [transfer RNA](http://en.wikipedia.org/wiki/Transfer_RNA) (tRNA) adapter molecules in binding pockets within the ribosome. The new polypeptide then folds into a functional three-dimensional protein molecule.

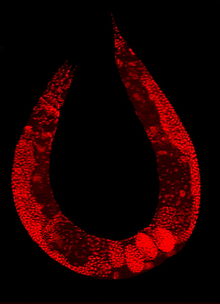
**Movement or motility**

Unicellular organisms can move in order to find food or escape predators. Common mechanisms of motion include [flagella](http://en.wikipedia.org/wiki/Flagella) and [cilia](http://en.wikipedia.org/wiki/Cilia).

In multicellular organisms, cells can move during processes such as wound healing, the immune response and [cancer metastasis](http://en.wikipedia.org/wiki/Cancer_metastasis). For example, in wound healing in animals, white blood cells move to the wound site to kill the microorganisms that cause infection. Cell motility involves many receptors, crosslinking, bundling, binding, adhesion, motor and other proteins.[[16]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-16) The process is divided into three steps – protrusion of the leading edge of the cell, adhesion of the leading edge and de-adhesion at the cell body and rear, and cytoskeletal contraction to pull the cell forward. Each step is driven by physical forces generated by unique segments of the cytoskeleton.[[17]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-AlbertsB-17)[[18]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Ananthakrishnan-18)

**Multicellularity**

**Cell specialization**

[](http://en.wikipedia.org/wiki/File:C_elegans_stained.jpg)

Staining of a [*Caenorhabditis elegans*](http://en.wikipedia.org/wiki/Caenorhabditis_elegans)which highlights the nuclei of its cells.

Multicellular organisms are [organisms](http://en.wikipedia.org/wiki/Organism) that consist of more than one cell, in contrast to [single-celled organisms](http://en.wikipedia.org/wiki/Single-celled_organism).[[19]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-19)

In complex multicellular organisms, cells specialize into different [cell types](http://en.wikipedia.org/wiki/Cell_type) that are adapted to particular functions. In mammals, major cell types include [skin cells](http://en.wikipedia.org/wiki/Skin_cells), [muscle cells](http://en.wikipedia.org/wiki/Muscle_cells), [neurons](http://en.wikipedia.org/wiki/Neuron), [blood cells](http://en.wikipedia.org/wiki/Blood_cell), [fibroblasts](http://en.wikipedia.org/wiki/Fibroblast), [stem cells](http://en.wikipedia.org/wiki/Stem_cells), and others. Cell types differ both in appearance and function, yet are [genetically](http://en.wikipedia.org/wiki/Genetics) identical. Cells are able to be of the same [genotype](http://en.wikipedia.org/wiki/Genotype) but different cell type due to the differential [regulation](http://en.wikipedia.org/wiki/Regulation_of_gene_expression) of the [genes](http://en.wikipedia.org/wiki/Gene) they contain.

Most distinct cell types arise from a single [totipotent](http://en.wikipedia.org/wiki/Totipotent) cell, called a [zygote](http://en.wikipedia.org/wiki/Zygote), that [differentiates](http://en.wikipedia.org/wiki/Cellular_differentiation) into hundreds of different cell types during the course of [development](http://en.wikipedia.org/wiki/Development_(biology)). Differentiation of cells is driven by different environmental cues (such as cell–cell interaction) and intrinsic differences (such as those caused by the uneven distribution of [molecules](http://en.wikipedia.org/wiki/Molecule) during [division](http://en.wikipedia.org/wiki/Cell_division)).

**Origin of multicellularity**

Multicellularity has evolved independently at least 25 times,[[20]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Grosberg2007-20) including in some prokaryotes, like [cyanobacteria](http://en.wikipedia.org/wiki/Cyanobacteria), [myxobacteria](http://en.wikipedia.org/wiki/Myxobacteria),[actinomycetes](http://en.wikipedia.org/wiki/Actinomycetes), [*Magnetoglobus multicellularis*](http://en.wikipedia.org/wiki/Deltaproteobacteria) or [*Methanosarcina*](http://en.wikipedia.org/wiki/Methanosarcina). However, complex multicellular organisms evolved only in six eukaryotic groups: animals, fungi, brown algae, red algae, green algae, and plants.[[21]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-21) It evolved repeatedly for plants ([Chloroplastida](http://en.wikipedia.org/wiki/Chloroplastida)), once or twice for [animals](http://en.wikipedia.org/wiki/Animal), once for [brown algae](http://en.wikipedia.org/wiki/Brown_algae), and perhaps several times for [fungi](http://en.wikipedia.org/wiki/Fungi), [slime molds](http://en.wikipedia.org/wiki/Mycetozoa), and [red algae](http://en.wikipedia.org/wiki/Red_algae).[[22]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-22) Multicellularity may have evolved from [colonies](http://en.wikipedia.org/wiki/Colony_(biology)) of interdependent organisms, from [cellularization](http://en.wikipedia.org/wiki/Cellularization), or from organisms in [symbiotic relationships](http://en.wikipedia.org/wiki/Symbiosis).

The first evidence of multicellularity is from [cyanobacteria](http://en.wikipedia.org/wiki/Cyanobacteria)-like organisms that lived between 3 and 3.5 billion years ago.[[20]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Grosberg2007-20) Other early fossils of multicellular organisms include the contested [Grypania](http://en.wikipedia.org/wiki/Grypania) spiralis and the fossils of the black shales of the [Palaeoproterozoic](http://en.wikipedia.org/wiki/Palaeoproterozoic)[Francevillian Group Fossil](http://en.wikipedia.org/wiki/Francevillian_Group_Fossil) B Formation in [Gabon](http://en.wikipedia.org/wiki/Gabon).[[23]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-23)

The evolution of multicellularity from unicellular ancestors has been replicated in the laboratory, in [evolution experiments](http://en.wikipedia.org/wiki/Experimental_evolution) using predation as the [selective pressure](http://en.wikipedia.org/wiki/Selective_pressure).[[20]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Grosberg2007-20)

**Origins**

The origin of cells has to do with the [origin of life](http://en.wikipedia.org/wiki/Abiogenesis), which began the [history of life](http://en.wikipedia.org/wiki/Timeline_of_evolution) on Earth.

**Origin of the first cell**

[](http://en.wikipedia.org/wiki/File:Stromatolites.jpg)

[Stromatolites](http://en.wikipedia.org/wiki/Stromatolites) are left behind by[cyanobacteria](http://en.wikipedia.org/wiki/Cyanobacteria), also called blue-green algae. They are the oldest known fossils of life on Earth. This one-billion-year-old fossil is from[Glacier National Park](http://en.wikipedia.org/wiki/Glacier_National_Park_(U.S.)) in the [United States](http://en.wikipedia.org/wiki/United_States).

There are several theories about the origin of small molecules that led to life on the [early Earth](http://en.wikipedia.org/wiki/Early_Earth). They may have been carried to Earth on meteorites (see [Murchison meteorite](http://en.wikipedia.org/wiki/Murchison_meteorite)), created at [deep-sea vents](http://en.wikipedia.org/wiki/Hydrothermal_vent), or synthesized by lightning in a reducing atmosphere (see[Miller–Urey experiment](http://en.wikipedia.org/wiki/Miller%E2%80%93Urey_experiment)). There is little experimental data defining what the first self-replicating forms were. [RNA](http://en.wikipedia.org/wiki/RNA) is thought to be the earliest self-replicating molecule, as it is capable of both storing genetic information and catalyzing chemical reactions (see [RNA world hypothesis](http://en.wikipedia.org/wiki/RNA_world_hypothesis)), but some other entity with the potential to self-replicate could have preceded RNA, such as [clay](http://en.wikipedia.org/wiki/Abiogenesis#Clay_theory) or [peptide nucleic acid](http://en.wikipedia.org/wiki/Peptide_nucleic_acid).[[24]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-OrgelLE-24)

Cells emerged at least 3.5 billion years ago.[[6]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Origin1-6)[[7]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Origin2-7)[[8]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-RavenJohnson2002-8) The current belief is that these cells were [heterotrophs](http://en.wikipedia.org/wiki/Heterotroph). The early cell membranes were probably more simple and permeable than modern ones, with only a single fatty acid chain per lipid. Lipids are known to spontaneously form bilayered [vesicles](http://en.wikipedia.org/wiki/Vesicle_(biology)) in water, and could have preceded RNA, but the first cell membranes could also have been produced by catalytic RNA, or even have required structural proteins before they could form.[[25]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-25)

**Origin of eukaryotic cells**

The eukaryotic cell seems to have evolved from a [symbiotic community](http://en.wikipedia.org/wiki/Symbiosis) of prokaryotic cells. DNA-bearing organelles like the[mitochondria](http://en.wikipedia.org/wiki/Mitochondria) and the [chloroplasts](http://en.wikipedia.org/wiki/Chloroplasts) are descended from ancient symbiotic oxygen-breathing [proteobacteria](http://en.wikipedia.org/wiki/Proteobacteria) and [cyanobacteria](http://en.wikipedia.org/wiki/Cyanobacteria), respectively, which were [endosymbiosed](http://en.wikipedia.org/wiki/Endosymbiotic_theory) by an ancestral [archaean](http://en.wikipedia.org/wiki/Archaea) prokaryote.

There is still considerable debate about whether organelles like the [hydrogenosome](http://en.wikipedia.org/wiki/Hydrogenosome) predated the origin of [mitochondria](http://en.wikipedia.org/wiki/Mitochondria), or vice versa: see the [hydrogen hypothesis](http://en.wikipedia.org/wiki/Hydrogen_hypothesis) for the origin of eukaryotic cells.

**History of research**

* 1632–1723: [Antonie van Leeuwenhoek](http://en.wikipedia.org/wiki/Antonie_van_Leeuwenhoek) teaches himself to make [lenses](http://en.wikipedia.org/wiki/Lens_(optics)), constructs [simple microscopes](http://en.wikipedia.org/w/index.php?title=Simple_microscopes&action=edit&redlink=1) and draws [protozoa](http://en.wikipedia.org/wiki/Protozoa), such as [*Vorticella*](http://en.wikipedia.org/wiki/Vorticella) from rain water, and[bacteria](http://en.wikipedia.org/wiki/Bacterium) from his own mouth.
* 1665: [Robert Hooke](http://en.wikipedia.org/wiki/Robert_Hooke) discovers cells in [cork](http://en.wikipedia.org/wiki/Cork_(material)), then in living plant tissue using an early compound microscope. He coins the term *cell* (from [Latin](http://en.wikipedia.org/wiki/Latin) *cella*, meaning "small room"[[26]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-26)) in his book [*Micrographia*](http://en.wikipedia.org/wiki/Micrographia) (1665), in which he compared the cork cells he sees through his microscope to the small rooms monks lived in.[[27]](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_note-Hooke-27)
* 1839: [Theodor Schwann](http://en.wikipedia.org/wiki/Theodor_Schwann) and [Matthias Jakob Schleiden](http://en.wikipedia.org/wiki/Matthias_Jakob_Schleiden) elucidate the principle that plants and animals are made of cells, concluding that cells are a common unit of structure and development, and thus founding the cell theory.
* 1855: [Rudolf Virchow](http://en.wikipedia.org/wiki/Rudolf_Virchow) states that new cells come from pre-existing cells by [cell division](http://en.wikipedia.org/wiki/Cell_division) (*omnis cellula ex cellula*).
* 1859: The belief that life forms can occur spontaneously ([*generatio spontanea*](http://en.wikipedia.org/wiki/Abiogenesis)) is contradicted by [Louis Pasteur](http://en.wikipedia.org/wiki/Louis_Pasteur) (1822–1895) (although [Francesco Redi](http://en.wikipedia.org/wiki/Francesco_Redi) had performed an experiment in 1668 that suggested the same conclusion).
* 1931: [Ernst Ruska](http://en.wikipedia.org/wiki/Ernst_Ruska) builds the first [transmission electron microscope](http://en.wikipedia.org/wiki/Transmission_electron_microscope) (TEM) at the [University of Berlin](http://en.wikipedia.org/wiki/University_of_Berlin). By 1935, he has built an EM with twice the resolution of a light microscope, revealing previously unresolvable organelles.
* 1953: [Watson](http://en.wikipedia.org/wiki/James_D._Watson) and [Crick](http://en.wikipedia.org/wiki/Francis_Crick) made their first announcement on the [double helix](http://en.wikipedia.org/wiki/Double_helix) structure of DNA on February 28.
* 1981: [Lynn Margulis](http://en.wikipedia.org/wiki/Lynn_Margulis) published *Symbiosis in Cell Evolution* detailing the [endosymbiotic theory](http://en.wikipedia.org/wiki/Endosymbiotic_theory).

**See also**

* [Cell culture](http://en.wikipedia.org/wiki/Cell_culture)
* [Cellular component](http://en.wikipedia.org/wiki/Cellular_component)
* [Cytorrhysis](http://en.wikipedia.org/wiki/Cytorrhysis)
* [Cytotoxicity](http://en.wikipedia.org/wiki/Cytotoxicity)
* [Plasmolysis](http://en.wikipedia.org/wiki/Plasmolysis)
* [Stem cell](http://en.wikipedia.org/wiki/Stem_cell)
* [Syncytium](http://en.wikipedia.org/wiki/Syncytium)

**References**

* 1. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-1) ["Cell"](http://www.etymonline.com/index.php?term=cell). Online Etymology Dictionary. Retrieved 31 December 2012.
  2. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Alberts2002_2-0) [Cell Movements and the Shaping of the Vertebrate Body](http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Search&db=books&doptcmdl=GenBookHL&term=Cell+Movements+and+the+Shaping+of+the+Vertebrate+Body+AND+mboc4%5Bbook%5D+AND+374635%5Buid%5D&rid=mboc4.section.3919) in Chapter 21 of [*Molecular Biology of the Cell*](http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Search&db=books&doptcmdl=GenBookHL&term=cell+biology+AND+mboc4%5Bbook%5D+AND+373693%5Buid%5D&rid=mboc4) fourth edition, edited by Bruce Alberts (2002) published by Garland Science.  
     The Alberts text discusses how the "cellular building blocks" move to shape developing[embryos](http://en.wikipedia.org/wiki/Embryo). It is also common to describe small molecules such as [amino acids](http://en.wikipedia.org/wiki/Amino_acid) as "[molecular building blocks](http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Search&db=books&doptcmdl=GenBookHL&term=%22all+cells%22+AND+mboc4%5Bbook%5D+AND+372023%5Buid%5D&rid=mboc4.section.4#23)".
  3. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-3) Lodish (2007). *Molecular Cell Biology,6e*. W.H.Freeman and Company. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-7167-7601-4](http://en.wikipedia.org/wiki/Special:BookSources/0-7167-7601-4).
  4. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-4) Campbell, Neil A.; Brad Williamson; Robin J. Heyden (2006). [*Biology: Exploring Life*](http://www.phschool.com/el_marketing.html). Boston, Massachusetts: Pearson Prentice Hall.[ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-13-250882-6](http://en.wikipedia.org/wiki/Special:BookSources/0-13-250882-6).
  5. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-5) Maton, Anthea; Hopkins, Jean Johnson, Susan LaHart, David Quon Warner, Maryanna Wright, Jill D (1997). *Cells Building Blocks of Life*. New Jersey: Prentice Hall. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-13-423476-6](http://en.wikipedia.org/wiki/Special:BookSources/0-13-423476-6).
  6. ^ [Jump up to:***a***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Origin1_6-0) [***b***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Origin1_6-1) Schopf, JW, Kudryavtsev, AB, Czaja, AD, and Tripathi, AB. (2007). *Evidence of Archean life: Stromatolites and microfossils.* Precambrian Research 158:141-155.
  7. ^ [Jump up to:***a***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Origin2_7-0) [***b***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Origin2_7-1) Schopf, JW (2006). *Fossil evidence of Archaean life.* Philos Trans R Soc Lond B Biol Sci 29;361(1470):869-85.
  8. ^ [Jump up to:***a***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-RavenJohnson2002_8-0) [***b***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-RavenJohnson2002_8-1) Peter Hamilton Raven; George Brooks Johnson (2002). [*Biology*](http://books.google.com/books?id=GtlqPwAACAAJ). McGraw-Hill Education. p. 68.[ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [978-0-07-112261-0](http://en.wikipedia.org/wiki/Special:BookSources/978-0-07-112261-0). Retrieved 7 July 2013.
  9. ^ [Jump up to:***a***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-CampbellBiology320_9-0) [***b***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-CampbellBiology320_9-1) *Campbell Biology—Concepts and Connections*. Pearson Education. 2009. p. 320.
  10. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-10) European Bioinformatics Institute, [Karyn's Genomes: Borrelia burgdorferi](http://www.ebi.ac.uk/2can/genomes/bacteria/Borrelia_burgdorferi.html), part of 2can on the EBI-EMBL database. Retrieved 5 August 2012
  11. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Christenson2008_11-0) Satir, Peter; Christensen, ST; Søren T. Christensen (2008-03-26). ["Structure and function of mammalian cilia"](http://www.springerlink.com/content/x5051hq648t3152q/). *Histochemistry and Cell Biology* (Springer Berlin / Heidelberg) **129** (6): 687–693. [doi](http://en.wikipedia.org/wiki/Digital_object_identifier):[10.1007/s00418-008-0416-9](http://dx.doi.org/10.1007%2Fs00418-008-0416-9). [PMC](http://en.wikipedia.org/wiki/PubMed_Central) [2386530](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2386530). [PMID](http://en.wikipedia.org/wiki/PubMed_Identifier) [18365235](http://www.ncbi.nlm.nih.gov/pubmed/18365235). 1432-119X. Retrieved 2009-09-12.
  12. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-12) Michie K, Löwe J (2006). "Dynamic filaments of the bacterial cytoskeleton". *Annu Rev Biochem* **75**: 467–92. [doi](http://en.wikipedia.org/wiki/Digital_object_identifier):[10.1146/annurev.biochem.75.103004.142452](http://dx.doi.org/10.1146%2Fannurev.biochem.75.103004.142452). [PMID](http://en.wikipedia.org/wiki/PubMed_Identifier) [16756499](http://www.ncbi.nlm.nih.gov/pubmed/16756499).
  13. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-13) Ménétret JF, Schaletzky J, Clemons WM, et al., CW; Akey (December 2007). "Ribosome binding of a single copy of the SecY complex: implications for protein translocation". *Mol. Cell***28** (6): 1083–92. [doi](http://en.wikipedia.org/wiki/Digital_object_identifier):[10.1016/j.molcel.2007.10.034](http://dx.doi.org/10.1016%2Fj.molcel.2007.10.034). [PMID](http://en.wikipedia.org/wiki/PubMed_Identifier) [18158904](http://www.ncbi.nlm.nih.gov/pubmed/18158904).
  14. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-14) [*Prokaryotes*](http://books.google.com/?id=N2GU-DYKkk0C&pg=PA87&lpg=PA87&dq=Prokaryotic+india+ink#v=onepage&q=india%20ink&f=false). Newnes. Apr 11, 1996. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [9780080984735](http://en.wikipedia.org/wiki/Special:BookSources/9780080984735).
  15. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-15) *Campbell Biology—Concepts and Connections*. Pearson Education. 2009. p. 138.
  16. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-16) Revathi Ananthakrishnan1 \*, Allen Ehrlicher2 ✉. ["The Forces Behind Cell Movement"](http://www.biolsci.org/v03p0303.htm). Biolsci.org. Retrieved 2009-04-17.
  17. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-AlbertsB_17-0) Alberts B, Johnson A, Lewis J. et al. Molecular Biology of the Cell, 4e. Garland Science. 2002
  18. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Ananthakrishnan_18-0) Ananthakrishnan R, Ehrlicher A. The Forces Behind Cell Movement. Int J Biol Sci 2007; 3:303–317. <http://www.biolsci.org/v03p0303.htm>
  19. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-19) Becker et al., Wayne M. (2009). *The world of the cell*. [Pearson Benjamin Cummings](http://en.wikipedia.org/wiki/Benjamin_Cummings). p. 480. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [978-0-321-55418-5](http://en.wikipedia.org/wiki/Special:BookSources/978-0-321-55418-5).
  20. ^ [Jump up to:***a***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Grosberg2007_20-0) [***b***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Grosberg2007_20-1) [***c***](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Grosberg2007_20-2) Grosberg RK, Strathmann RR. [The evolution of multicellularity: A minor major transition?](http://www-eve.ucdavis.edu/grosberg/Grosberg%20pdf%20papers/2007%20Grosberg%20%26%20Strathmann.AREES.pdf) Annu Rev Ecol Evol Syst. 2007;38:621–654.
  21. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-21) <http://public.wsu.edu/~lange-m/Documnets/Teaching2011/Popper2011.pdf>
  22. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-22) [Bonner, John Tyler](http://en.wikipedia.org/wiki/John_Tyler_Bonner) (1998). ["The Origins of Multicellularity"](https://web.archive.org/web/20120308175112/http:/courses.cit.cornell.edu/biog1101/outlines/Bonner%20-Origin%20of%20Multicellularity.pdf) (PDF, 0.2 MB). [*Integrative Biology: Issues, News, and Reviews*](http://en.wikipedia.org/w/index.php?title=Integrative_Biology:_Issues,_News,_and_Reviews&action=edit&redlink=1) **1** (1): 27–36. [doi](http://en.wikipedia.org/wiki/Digital_object_identifier):[10.1002/(SICI)1520-6602(1998)1:1<27::AID-INBI4>3.0.CO;2-6](http://dx.doi.org/10.1002%2F%28SICI%291520-6602%281998%291%3A1%3C27%3A%3AAID-INBI4%3E3.0.CO%3B2-6). [ISSN](http://en.wikipedia.org/wiki/International_Standard_Serial_Number) [1093-4391](http://www.worldcat.org/issn/1093-4391).
  23. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-23) [El Albani, Abderrazak](http://en.wikipedia.org/wiki/Abderrazak_El_Albani); A, Bengtson S, Canfield DE, Bekker A, Macchiarelli R, Mazurier A, Hammarlund EU, Boulvais P, Dupuy JJ, Fontaine C, Fürsich FT, Gauthier-Lafaye F, Janvier P, Javaux E, Ossa FO, Pierson-Wickmann AC, Riboulleau A, Sardini P, Vachard D, Whitehouse M, Meunier A. (1 July 2010). "Large colonial organisms with coordinated growth in oxygenated environments 2.1 Gyr ago". [*Nature*](http://en.wikipedia.org/wiki/Nature_(journal)) **466** (7302): 100–104. [doi](http://en.wikipedia.org/wiki/Digital_object_identifier):[10.1038/nature09166](http://dx.doi.org/10.1038%2Fnature09166). [ISSN](http://en.wikipedia.org/wiki/International_Standard_Serial_Number) [0028-0836](http://www.worldcat.org/issn/0028-0836). [PMID](http://en.wikipedia.org/wiki/PubMed_Identifier) [20596019](http://www.ncbi.nlm.nih.gov/pubmed/20596019).
  24. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-OrgelLE_24-0) Orgel LE (1998). "The origin of life--a review of facts and speculations". *Trends Biochem Sci***23** (12): 491–5. [doi](http://en.wikipedia.org/wiki/Digital_object_identifier):[10.1016/S0968-0004(98)01300-0](http://dx.doi.org/10.1016%2FS0968-0004%2898%2901300-0). [PMID](http://en.wikipedia.org/wiki/PubMed_Identifier) [9868373](http://www.ncbi.nlm.nih.gov/pubmed/9868373).
  25. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-25) Griffiths G (December 2007). "Cell evolution and the problem of membrane topology".*Nature reviews. Molecular cell biology* **8** (12): 1018–24. [doi](http://en.wikipedia.org/wiki/Digital_object_identifier):[10.1038/nrm2287](http://dx.doi.org/10.1038%2Fnrm2287). [PMID](http://en.wikipedia.org/wiki/PubMed_Identifier) [17971839](http://www.ncbi.nlm.nih.gov/pubmed/17971839).
  26. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-26) ["Cell"](http://www.etymonline.com/index.php?term=cell). Online Etymology Dictionary. Retrieved 31 December 2012.
  27. [**Jump up^**](http://en.wikipedia.org/w/index.php?title=Cell_(biology)&printable=yes#cite_ref-Hooke_27-0) "*... I could exceedingly plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular [..] these pores, or cells, [..] were indeed the first microscopical pores I ever saw, and perhaps, that were ever seen, for I had not met with any Writer or Person, that had made any mention of them before this. . .*" – Hooke describing his observations on a thin slice of cork. [Robert Hooke](http://www.ucmp.berkeley.edu/history/hooke.html)
* http://upload.wikimedia.org/wikipedia/en/thumb/6/62/PD-icon.svg/12px-PD-icon.svg.png This article incorporates [public domain material](http://en.wikipedia.org/wiki/Copyright_status_of_work_by_the_U.S._government) from the [NCBI](http://en.wikipedia.org/wiki/National_Center_for_Biotechnology_Information) document ["Science Primer"](http://www.ncbi.nlm.nih.gov/About/primer/index.html).

**External links**

* [MBInfo - Descriptions on Cellular Functions and Processes](http://www.mechanobio.info/)
* [MBInfo - Cellular Organization](http://www.mechanobio.info/topics/cellular-organization)
* [Inside the Cell](http://publications.nigms.nih.gov/insidethecell/) - a science education booklet by [National Institutes of Health](http://en.wikipedia.org/wiki/National_Institutes_of_Health), in PDF and [ePub](http://en.wikipedia.org/wiki/EPub).
* [Cells Alive!](http://www.cellsalive.com/)
* [Cell Biology](http://www.biology.arizona.edu/cell_bio/cell_bio.html) in "The Biology Project" of [University of Arizona](http://en.wikipedia.org/wiki/University_of_Arizona).
* [Centre of the Cell online](http://www.centreofthecell.org/)
* [The Image & Video Library of The American Society for Cell Biology](http://cellimages.ascb.org/), a collection of peer-reviewed still images, video clips and digital books that illustrate the structure, function and biology of the cell.
* [HighMag Blog](http://highmagblog.blogspot.com/), still images of cells from recent research articles.
* [New Microscope Produces Dazzling 3D Movies of Live Cells](http://www.hhmi.org/news/betzig20110304.html), March 4, 2011 - [Howard Hughes Medical Institute](http://en.wikipedia.org/wiki/Howard_Hughes_Medical_Institute).
* [WormWeb.org: Interactive Visualization of the *C. elegans* Cell lineage](http://wormweb.org/celllineage) - Visualize the entire cell lineage tree of the nematode [*C. elegans*](http://en.wikipedia.org/wiki/Caenorhabditis_elegans)

**Textbooks**

* Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P (2002). [*Molecular Biology of the Cell*](http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=mboc4.TOC&depth=2) (4th ed.). Garland. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-8153-3218-1](http://en.wikipedia.org/wiki/Special:BookSources/0-8153-3218-1).
* Lodish H, Berk A, Matsudaira P, Kaiser CA, Krieger M, Scott MP, Zipurksy SL, Darnell J (2004). [*Molecular Cell Biology*](http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=mcb.TOC) (5th ed.). WH Freeman: New York, NY. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [978-0-7167-4366-8](http://en.wikipedia.org/wiki/Special:BookSources/978-0-7167-4366-8).
* Cooper GM (2000). [*The cell: a molecular approach*](http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=cooper.TOC&depth=2) (2nd ed.). Washington, D.C: ASM Press.[ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-87893-102-3](http://en.wikipedia.org/wiki/Special:BookSources/0-87893-102-3).

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