

he **cell** is the basic structural and functional unit of all [forms of life](#). Every cell consists of [cytoplasm](#) enclosed within a [membrane](#), and contains many [macromolecules](#) such as [proteins](#), [DNA](#) and [RNA](#), as well as many [small molecules](#) of nutrients and [metabolites](#).^[1] The term comes from the [Latin](#) word *cellula* meaning 'small room'.^[2]

Cells can acquire specified function and carry out various tasks within the cell such as replication, [DNA repair](#), protein synthesis, and motility. Cells are capable of specialization and mobility within the cell.

Most plant and animal cells are only visible under a [light microscope](#), with dimensions between 1 and 100 [micrometres](#).^[3] [Electron microscopy](#) gives a much higher resolution showing greatly detailed cell structure. Organisms can be classified as [unicellular](#) (consisting of a single cell such as [bacteria](#)) or [multicellular](#) (including plants and animals).^[4] Most [unicellular organisms](#) are classed as [microorganisms](#). The number of cells in plants and animals varies from species to species; it has been estimated that the [human body](#) contains around 37 trillion (3.72×10^{13}) cells.^[5] The [human brain](#) accounts for around 80 billion of these cells.^[6]

The study of cells and how they work has led to many other studies in related areas of biology, including: [discovery of DNA](#), [cancer systems biology](#), [aging](#) and [developmental biology](#).

[Cell biology](#) is the study of cells, which were discovered by [Robert Hooke](#) in 1665, who named them for their resemblance to [cells](#) inhabited by [Christian monks](#) in a monastery.^{[7][8]} [Cell theory](#), first developed in 1839 by [Matthias Jakob Schleiden](#) and [Theodor Schwann](#), states that all organisms are composed of one or more cells, that cells are the fundamental unit of structure and function in all living organisms, and that all cells come from pre-existing cells.^[9] Cells emerged on Earth about 4 billion years ago.^{[10][11][12][13]}

Discovery

Main article: [Cell theory](#)

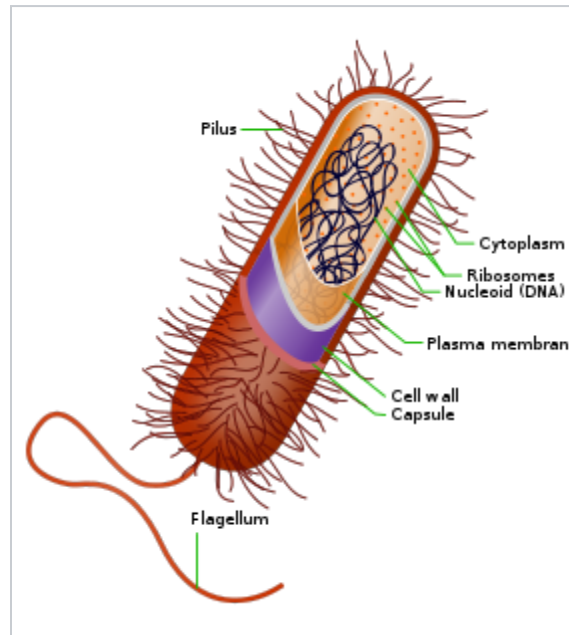
With continual improvements made to [microscopes](#) over time, magnification technology became advanced enough to discover cells. This discovery is largely attributed to [Robert Hooke](#), and began the scientific study of cells, known as [cell biology](#). When observing a piece of cork under the scope, he was able to see pores. This was shocking at the time as it was believed no one else had seen these. To further support his theory, [Matthias Schleiden](#) and [Theodor Schwann](#) both also studied cells of both animal and plants. What they discovered were significant differences between the two types of cells. This put forth the idea that cells were not only fundamental to plants, but animals as well.

Cell types

Cells are broadly categorized into two types: [eukaryotic cells](#), which possesses a [nucleus](#), and [prokaryotic cells](#), which lack a nucleus but still has a nucleoid region. Prokaryotes are [single-celled organisms](#), whereas eukaryotes can be either single-celled or [multicellular](#).^[14]

Prokaryotic cells

Main article: [Prokaryote](#)



Structure of a typical [prokaryotic](#) cell

[Prokaryotes](#) include [bacteria](#) and [archaea](#), two of the [three domains of life](#). Prokaryotic cells were the first form of [life](#) on Earth, characterized by having vital [biological processes](#) including [cell signaling](#). They are simpler and smaller than eukaryotic cells, and lack a [nucleus](#), and other membrane-bound [organelles](#). The [DNA](#) of a prokaryotic cell consists of a single [circular chromosome](#) that is in direct contact with the [cytoplasm](#). The nuclear region in the cytoplasm is called the [nucleoid](#). Most prokaryotes are the smallest of all organisms ranging from 0.5 to 2.0 μm in diameter.^[15]

A prokaryotic cell has three regions:

- Enclosing the cell is the [cell envelope](#), generally consisting of a [plasma membrane](#) covered by a [cell wall](#) which, for some bacteria, may be further covered by a third layer called a [capsule](#). Though most prokaryotes have both a cell membrane and a cell wall, there are exceptions such as [Mycoplasma](#) (bacteria) and [Thermoplasma](#) (archaea) which only possess the cell membrane layer. The envelope gives rigidity to the cell and separates the interior of the cell from its environment, serving as a protective filter. The cell wall consists of [peptidoglycan](#) in bacteria and acts as an additional barrier against exterior forces. It also prevents the cell from expanding and bursting ([cytolysis](#)) from [osmotic pressure](#) due to a [hypotonic](#) environment. Some eukaryotic cells ([plant cells](#) and [fungal cells](#)) also have a cell wall.
- Inside the cell is the [cytoplasmic region](#) that contains the [genome](#) (DNA), ribosomes and various sorts of inclusions.^[4] The genetic material is freely found in the cytoplasm.

Prokaryotes can carry [extrachromosomal DNA](#) elements called [plasmids](#), which are usually circular. Linear bacterial plasmids have been identified in several species of [spirochete](#) bacteria, including members of the genus [Borrelia](#) notably [Borrelia burgdorferi](#), which causes Lyme disease.^[16] Though not forming a nucleus, the [DNA](#) is condensed in a [nucleoid](#). Plasmids encode additional genes, such as [antibiotic resistance](#) genes.

- On the outside, [flagella](#) and [pili](#) project from the cell's surface. These are structures (not present in all prokaryotes) made of proteins that facilitate movement and communication between cells.

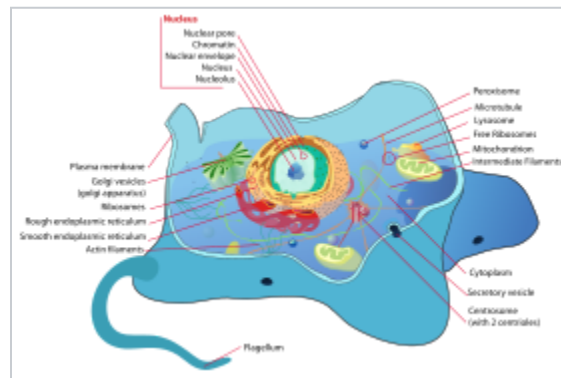
Bacterial shapes

Main article: [Bacteria § Morphology](#)

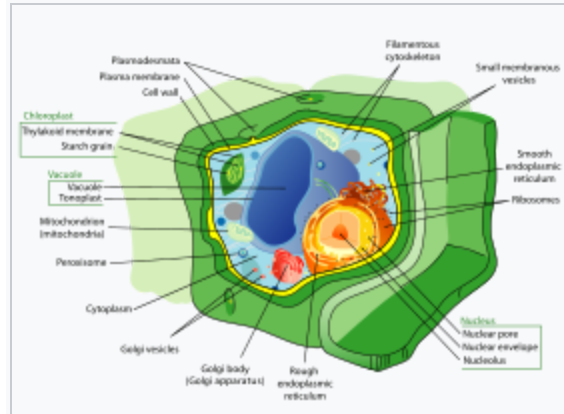
Cell shape, also called cell morphology, has been hypothesized to form from the arrangement and movement of the cytoskeleton.^[17] Many advancements in the study of cell morphology come from studying simple bacteria such as [Staphylococcus aureus](#), [E. coli](#), and [B. subtilis](#).^[18] Different cell shapes have been found and described, but how and why cells form different shapes is still widely unknown.^[18] Some cell shapes that have been identified include rods, cocci and spirochaetes. Cocci have a circular shape, bacilli have an elongated rod-like shape, and spirochaetes have a spiral shape. Many other shapes have also been determined.

Eukaryotic cells

Main article: [Eukaryote](#)



Structure of a typical animal cell



Structure of a typical [plant cell](#)

[Plants](#), [animals](#), [fungi](#), [slime moulds](#), [protozoa](#), and [algae](#) are all [eukaryotic](#). 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](#): the presence of membrane-bound [organelles](#) (compartments) in which specific activities take place. Most important among these is a [cell nucleus](#),^[4] an organelle that houses the cell's [DNA](#). This nucleus gives the eukaryote its name, which means "true kernel (nucleus)". Some of the other differences are:

- 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](#), which are associated with [histone](#) proteins. All chromosomal DNA is stored in the [cell nucleus](#), separated from the cytoplasm by a membrane.^[4] Some eukaryotic organelles such as [mitochondria](#) also contain some DNA.
- Many eukaryotic cells are [ciliated](#) with [primary cilia](#). Primary cilia play important roles in chemosensation, [mechanosensation](#), and [thermosensation](#). Each cilium may thus be "viewed as a sensory cellular [antennae](#) that coordinates a large number of cellular signaling pathways, sometimes coupling the signaling to ciliary motility or alternatively to cell division and differentiation."^[19]
- Motile eukaryotes can move using [motile cilia](#) or [flagella](#). Motile cells are absent in [conifers](#) and [flowering plants](#).^[20] Eukaryotic flagella are more complex than those of prokaryotes.^[21]

	Prokaryotes	Eukaryotes
Typical organisms	bacteria , archaea	protists , fungi , plants , animals

Typical size	~ 1–5 μm ^[22]	~ 10–100 μm ^[22]
Type of nucleus	nucleoid region; no true nucleus	true nucleus with double membrane
DNA	circular (usually)	linear molecules (chromosomes) with histone proteins
RNA/protein synthesis	coupled in the cytoplasm	RNA synthesis in the nucleus protein synthesis in the cytoplasm
Ribosomes	50S and 30S	60S and 40S
Cytoplasmic structure	very few structures	highly structured by endomembranes and a cytoskeleton
Cell movement	flagella made of flagellin	flagella and cilia containing microtubules; lamellipodia and filopodia containing actin
Mitochondria	none	one to several thousand
Chloroplasts	none	in algae and plants
Organization	usually single cells	single cells, colonies, higher multicellular organisms with specialized cells
Cell division	binary fission (simple division)	mitosis (fission or budding) meiosis

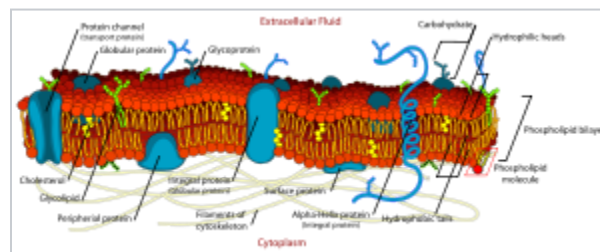
Chromosomes	single chromosome	more than one chromosome
Membranes	cell membrane	

Subcellular components

All cells, whether [prokaryotic](#) or [eukaryotic](#), have a [membrane](#) that envelops the cell, regulates what moves in and out (selectively permeable), and maintains the [electric potential of the cell](#). Inside the membrane, the [cytoplasm](#) takes up most of the cell's volume. Except [red blood cells](#), which lack a cell nucleus and most organelles to accommodate maximum space for [hemoglobin](#), all cells possess [DNA](#), the hereditary material of [genes](#), and [RNA](#), containing the information necessary to [build](#) various [proteins](#) such as [enzymes](#), the cell's primary machinery. There are also other kinds of [biomolecules](#) in cells. This article lists these primary [cellular components](#), then briefly describes their function.

Cell membrane

Main article: [Cell membrane](#)



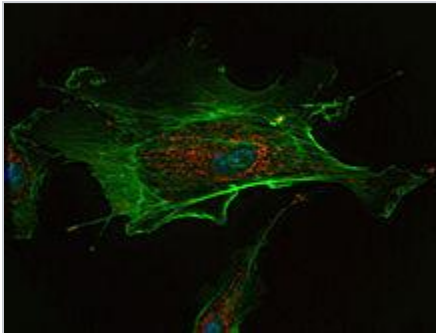
Detailed diagram of lipid bilayer of cell membrane

The [cell membrane](#), or plasma membrane, is a selectively permeable^[23] [biological membrane](#) that 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](#). This membrane serves to separate and protect a cell from its surrounding environment and is made mostly from a [double layer of phospholipids](#), which are [amphiphilic](#) (partly [hydrophobic](#) and partly [hydrophilic](#)). Hence, the layer is called a [phospholipid bilayer](#), or sometimes a fluid mosaic membrane. Embedded within this membrane is a macromolecular structure called the [porosome](#) the universal secretory portal in cells and a variety of [protein](#) molecules that act as channels and pumps that move different molecules into and out of the cell.^[4] The membrane is semi-permeable, and selectively permeable, in that it can either let a substance ([molecule](#) or [ion](#)) pass through freely, pass through to a limited extent or not pass through at all. Cell surface membranes also contain [receptor](#) proteins that allow cells to detect external signaling molecules such as [hormones](#).

Cytoskeleton

Main article: [Cytoskeleton](#)

Further information: [Morphogenesis](#)



A fluorescent image of an endothelial cell. Nuclei are stained blue, [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](#), the uptake of external materials by a cell, and [cytokinesis](#), the separation of daughter cells after [cell division](#); and moves parts of the cell in processes of growth and mobility. The eukaryotic cytoskeleton is composed of [microtubules](#), [intermediate filaments](#) and [microfilaments](#). In the cytoskeleton of a [neuron](#) the intermediate filaments are known as [neurofilaments](#). There are a great number of proteins associated with them, each controlling a cell's structure by directing, bundling, and aligning filaments.^[4] The prokaryotic cytoskeleton is less well-studied but is involved in the maintenance of cell shape, [polarity](#) and cytokinesis.^[24] The subunit protein of microfilaments is a small, monomeric protein called [actin](#). The subunit of microtubules is a dimeric molecule called [tubulin](#). Intermediate filaments are heteropolymers whose subunits vary among the cell types in different tissues. Some of the subunit proteins of intermediate filaments include [vimentin](#), [desmin](#), [lamin](#) (lamins A, B and C), [keratin](#) (multiple acidic and basic keratins), and [neurofilament proteins](#) (NF-L, NF-M).

Genetic material

Main articles: [DNA](#) and [RNA](#)



Deoxyribonucleic acid (DNA)

Two different kinds of genetic material exist: [deoxyribonucleic acid](#) (DNA) and [ribonucleic acid](#) (RNA). Cells use DNA for their long-term information storage. The biological information contained in an organism is [encoded](#) in its DNA sequence.^[4] RNA is used for information transport (e.g., [mRNA](#)) and [enzymatic](#) functions (e.g., [ribosomal](#) RNA). [Transfer RNA](#) (tRNA) molecules are used to add amino acids during protein [translation](#).

Prokaryotic genetic material is organized in a simple [circular bacterial chromosome](#) in the [nucleoid region](#) of the cytoplasm. Eukaryotic genetic material is divided into different,^[4] linear molecules called [chromosomes](#) inside a discrete nucleus, usually with additional genetic material in some organelles like [mitochondria](#) and [chloroplasts](#) (see [endosymbiotic theory](#)).

A [human cell](#) has genetic material contained in the [cell nucleus](#) (the [nuclear genome](#)) and in the mitochondria (the [mitochondrial genome](#)). In humans, the nuclear genome is divided into 46 linear DNA molecules called [chromosomes](#), including 22 [homologous chromosome](#) pairs and a pair of [sex chromosomes](#). The mitochondrial genome is a circular DNA molecule distinct from nuclear DNA.

Although the [mitochondrial DNA](#) is very small compared to nuclear chromosomes,^[4] 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](#). This can be transient, if the DNA is not inserted into the cell's [genome](#), or stable, if it is. Certain [viruses](#) also insert their genetic material into the genome.

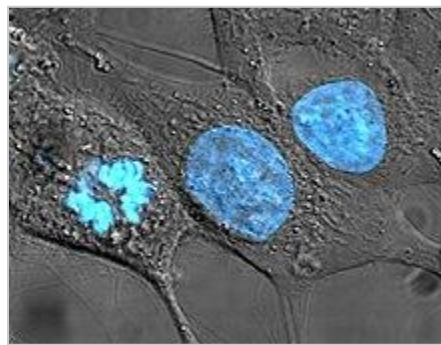
Organelles

Main article: [Organelle](#)

Organelles are parts of the cell that are adapted and/or specialized for carrying out one or more vital functions, analogous to the [organs](#) of the human body (such as the heart, lung, and kidney, with each organ performing a different function).^[4] 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](#) and [Golgi apparatus](#)) are typically solitary, while others (such as [mitochondria](#), [chloroplasts](#), [peroxisomes](#) and [lysosomes](#)) can be numerous (hundreds to thousands). The [cytosol](#) is the gelatinous fluid that fills the cell and surrounds the organelles.

Eukaryotic



Human cancer cells, specifically [HeLa cells](#), with DNA stained blue. The central and rightmost cell are in [interphase](#), so their DNA is diffuse and the entire nuclei are labelled. The cell on the left is going through [mitosis](#) and its chromosomes have condensed.

- **Cell nucleus:** A cell's information center, the [cell nucleus](#) is the most conspicuous organelle found in a [eukaryotic](#) cell. It houses the cell's [chromosomes](#), and is the place where almost all [DNA](#) replication and [RNA](#) synthesis ([transcription](#)) occur. The nucleus is spherical and separated from the cytoplasm by a double membrane called the [nuclear envelope](#), space between these two membrane is called perinuclear space. 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](#) is [transcribed](#), or copied into a special [RNA](#), called [messenger RNA](#) (mRNA). This mRNA is then transported out of the nucleus, where it is translated into a specific protein molecule. The [nucleolus](#) is a specialized region within the nucleus where ribosome subunits are assembled. In prokaryotes, DNA processing takes place in the [cytoplasm](#).^[4]
- **Mitochondria and chloroplasts:** generate energy for the cell. [Mitochondria](#) are self-replicating double membrane-bound organelles that occur in various numbers, shapes, and sizes in the cytoplasm of all eukaryotic cells.^[4] [Respiration](#) occurs in the cell mitochondria, which generate the cell's energy by [oxidative phosphorylation](#), using [oxygen](#) to release energy stored in cellular nutrients (typically pertaining to [glucose](#)) to generate [ATP](#) ([aerobic respiration](#)). Mitochondria multiply by [binary fission](#), like prokaryotes. Chloroplasts can only be found in plants and algae, and they capture the sun's energy to make carbohydrates through [photosynthesis](#).

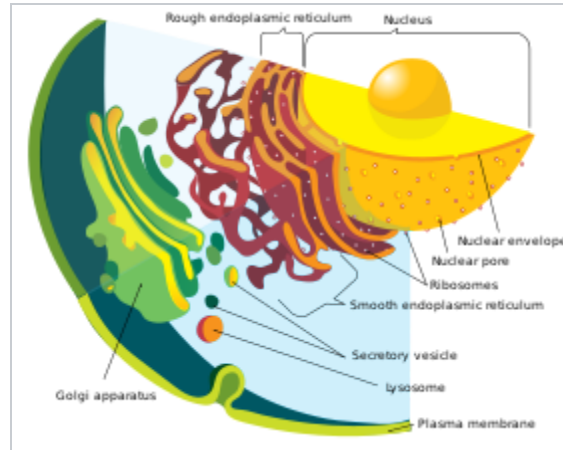


Diagram of the [endomembrane system](#)

- **Endoplasmic reticulum:** The [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.^[4] The smooth ER plays a role in calcium sequestration and release and also helps in synthesis of [lipid](#).
- **Golgi apparatus:** The primary function of the Golgi apparatus is to process and package the [macromolecules](#) such as [proteins](#) and [lipids](#) that are synthesized by the cell.
- **Lysosomes and peroxisomes:** [Lysosomes](#) contain [digestive enzymes](#) (acid [hydrolases](#)). They digest excess or worn-out [organelles](#), food particles, and engulfed [viruses](#) or [bacteria](#). [Peroxisomes](#) have enzymes that rid the cell of toxic [peroxides](#). Lysosomes are optimally active at [acidic pH](#). The cell could not house these destructive enzymes if they were not contained in a membrane-bound system.^[4]
- **Centrosome:** the cytoskeleton organizer: The [centrosome](#) produces the [microtubules](#) of a cell—a key component of the [cytoskeleton](#). It directs the transport through the [ER](#) and the [Golgi apparatus](#). Centrosomes are composed of two [centrioles](#) which lie perpendicular to each other in which each has an organization like a [cartwheel](#), which separate during [cell division](#) and help in the formation of the [mitotic spindle](#). A single centrosome is present in the animal cells. They are also found in some fungi and algae cells.
- **Vacuoles:** [Vacuoles](#) sequester waste products and in plant cells store water. They are often described as liquid filled spaces and are surrounded by a membrane. Some cells, most notably [Amoeba](#), have contractile vacuoles, which can pump water out of the cell if there is too much water. The vacuoles of plant cells and fungal cells are usually larger than those of animal cells. Vacuoles of plant cells are surrounded by [tonoplast](#) which helps in transport of ions and other substances against concentration gradients.

Eukaryotic and prokaryotic

- **Ribosomes:** The [ribosome](#) is a large complex of [RNA](#) and [protein](#) molecules.^[4] 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).^[25]

- **Plastids:** [Plastid](#) are membrane-bound organelle generally found in plant cells and [euglenoids](#) and contain specific *pigments*, thus affecting the colour of the plant and organism. And these pigments also helps in food storage and tapping of light energy. There are three types of plastids based upon the specific pigments. [Chloroplasts](#) contain [chlorophyll](#) and some carotenoid pigments which helps in the tapping of light energy during photosynthesis. [Chromoplasts](#) contain fat-soluble [carotenoid](#) pigments like orange carotene and yellow xanthophylls which helps in synthesis and storage. [Leucoplasts](#) are non-pigmented plastids and helps in storage of nutrients.

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 [semipermeable cell membrane](#). In order to assemble these structures, their components must be carried across the cell membrane by export processes.

Cell wall

Further information: [Cell wall](#)

Many types of prokaryotic and eukaryotic cells have a [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 [cellulose](#), 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](#) as in [pneumococci](#), [meningococci](#) or [polypeptide](#) as [Bacillus anthracis](#) or [hyaluronic acid](#) as in [streptococci](#). Capsules are not marked by normal staining protocols and can be detected by [India ink](#) or [methyl blue](#), which allows for higher contrast between the cells for observation.^{[26]:87}

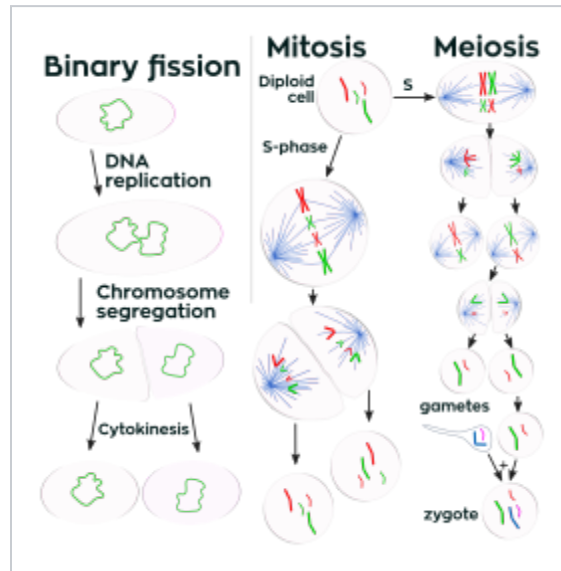
Flagella

[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. A different type of flagellum is found in archaea and a different type is found in eukaryotes.

Fimbriae

A **fimbria** (plural fimbriae also known as a **pilus**, plural pili) is a short, thin, hair-like filament found on the surface of bacteria. Fimbriae are formed of a protein called **pilin** (**antigenic**) and are responsible for the attachment of bacteria to specific receptors on human cells (**cell adhesion**). There are special types of pili involved in **bacterial conjugation**.

Cellular processes



Prokaryotes divide by **binary fission**, while **eukaryotes** divide by **mitosis** or **meiosis**.

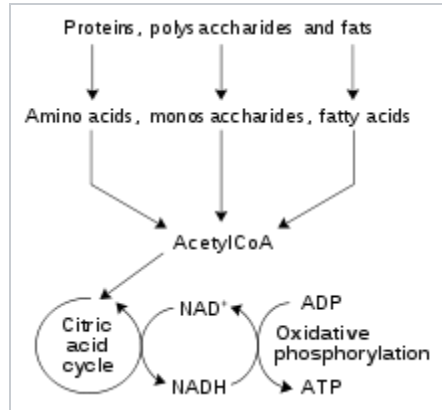
Replication

Main article: [Cell division](#)

Cell division involves a single cell (called a *mother cell*) dividing into two daughter cells. This leads to growth in **multicellular organisms** (the growth of **tissue**) and to procreation (**vegetative reproduction**) in **unicellular organisms**. **Prokaryotic** cells divide by **binary fission**, while **eukaryotic** cells usually undergo a process of nuclear division, called **mitosis**, followed by division of the cell, called **cytokinesis**. A **diploid** cell may also undergo **meiosis** to produce haploid cells, usually four. **Haploid** cells serve as **gametes** in multicellular organisms, fusing to form new diploid cells.

DNA replication, or the process of duplicating a cell's genome,^[4] always happens when a cell divides through mitosis or binary fission. This occurs during the S phase of the **cell cycle**.

In meiosis, the DNA is replicated only once, while the cell divides twice. DNA replication only occurs before **meiosis I**. DNA replication does not occur when the cells divide the second time, in **meiosis II**.^[27] Replication, like all cellular activities, requires specialized proteins for carrying out the job.^[4]



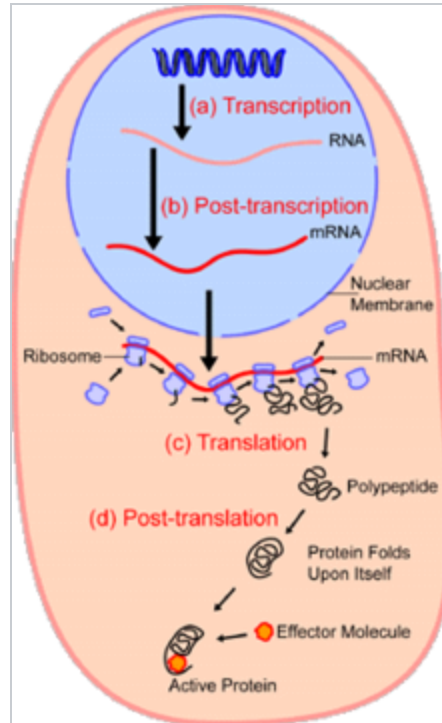
An outline of the [catabolism](#) of [proteins](#), [carbohydrates](#) and [fats](#)

DNA repair

Main article: [DNA repair](#)

In general, cells of all organisms contain enzyme systems that scan their DNA for [DNA damage](#) and carry out [repair processes](#) when damage is detected.^[28] Diverse repair processes have evolved in organisms ranging from bacteria to humans. The widespread prevalence of these repair processes indicates the importance of maintaining cellular DNA in an undamaged state in order to avoid cell death or errors of replication due to damage that could lead to [mutation](#). *E. coli* bacteria are a well-studied example of a cellular organism with diverse well-defined [DNA repair](#) processes. These include: (1) [nucleotide excision repair](#), (2) [DNA mismatch repair](#), (3) [non-homologous end joining](#) of double-strand breaks, (4) [recombinational repair](#) and (5) light-dependent repair ([photoreactivation](#)).

Growth and metabolism



An overview of protein synthesis.

Within the **nucleus** of the cell (*light blue*), **genes** (DNA, *dark blue*) are **transcribed** into **RNA**. This RNA is then subject to post-transcriptional modification and control, resulting in a mature **mRNA** (*red*) that is then transported out of the nucleus and into the **cytoplasm** (*peach*), where it undergoes **translation** into a protein. mRNA is translated by **ribosomes** (*purple*) that match the three-base **codons** of the mRNA to the three-base anti-codons of the appropriate **tRNA**. Newly synthesized proteins (*black*) are often further modified, such as by binding to an effector molecule (*orange*), to become fully active.

Main articles: [Cell 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**, in which the cell breaks down complex molecules to produce energy and **reducing power**, and **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 simpler sugar molecules called **monosaccharides** such as **glucose**. Once inside the cell, glucose is broken down to make adenosine triphosphate (ATP),^[4] a molecule that possesses readily available energy, through two different pathways.

Protein synthesis

Main article: [Protein biosynthesis](#)

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](#) building blocks based on information encoded in DNA/RNA. Protein synthesis generally consists of two major steps: [transcription](#) and [translation](#).

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](#) (mRNA), which is free to migrate through the cell. mRNA molecules bind to protein-RNA complexes called [ribosomes](#) located in the [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](#) (tRNA) adapter molecules in binding pockets within the ribosome. The new polypeptide then folds into a functional three-dimensional protein molecule.

Motility

Main article: [Motility](#)

Unicellular organisms can move in order to find food or escape predators. Common mechanisms of motion include [flagella](#) and [cilia](#).

In multicellular organisms, cells can move during processes such as wound healing, the immune response and [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.^[29] 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.^{[30][31]}

Navigation, control and communication

See also: [Cybernetics § In biology](#)

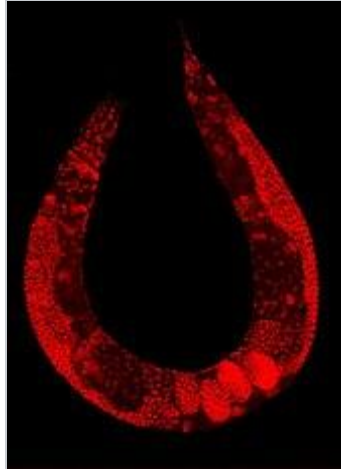
In August 2020, scientists described one way cells—in particular cells of a slime mold and mouse pancreatic cancer-derived cells—are able to [navigate](#) efficiently through a body and identify the best routes through complex mazes: generating gradients after breaking down diffused [chemoattractants](#) which enable them to sense upcoming maze junctions before reaching them, including around corners.^{[32][33][34]}

Multicellularity

Main article: [Multicellular organism](#)

Cell specialization/differentiation

Main article: [Cellular differentiation](#)



Staining of a *Caenorhabditis elegans* highlights the nuclei of its cells.

Multicellular organisms are **organisms** that consist of more than one cell, in contrast to **single-celled organisms**.^[35]

In complex multicellular organisms, cells specialize into different **cell types** that are adapted to particular functions. In mammals, major cell types include **skin cells**, **muscle cells**, **neurons**, **blood cells**, **fibroblasts**, **stem cells**, and others. Cell types differ both in appearance and function, yet are **genetically** identical. Cells are able to be of the same **genotype** but of different cell type due to the differential **expression** of the **genes** they contain.

Most distinct cell types arise from a single **totipotent** cell, called a **zygote**, that **differentiates** into hundreds of different cell types during the course of **development**. 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** during **division**).

Origin of multicellularity

Multicellularity has evolved independently at least 25 times,^[36] including in some prokaryotes, like **cyanobacteria**, **myxobacteria**, **actinomycetes**, ***Magnetoglobus multicellularis***, or ***Methanosarcina***. However, complex multicellular organisms evolved only in six eukaryotic groups: animals, fungi, brown algae, red algae, green algae, and plants.^[37] It evolved repeatedly for plants (**Chloroplastida**), once or twice for **animals**, once for **brown algae**, and perhaps several times for **fungi**, **slime molds**, and **red algae**.^[38] Multicellularity may have evolved from **colonies** of interdependent organisms, from **cellularization**, or from organisms in **symbiotic relationships**.

The first evidence of multicellularity is from **cyanobacteria**-like organisms that lived between 3 and 3.5 billion years ago.^[36] Other early fossils of multicellular organisms include the contested **Grypania spiralis** and the fossils of the black shales of the **Palaeoproterozoic Francevillian Group Fossil B** Formation in **Gabon**.^[39]

The evolution of multicellularity from unicellular ancestors has been replicated in the laboratory, in [evolution experiments](#) using predation as the [selective pressure](#).^[36]

Origins

Main article: [Evolutionary history of life](#)

The origin of cells has to do with the [origin of life](#), which began the [history of life](#) on Earth.

Origin of the first cell



[Stromatolites](#) are left behind by [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](#) in the United States.

Further information: [Abiogenesis](#) and [Evolution of cells](#)

There are several theories about the origin of small molecules that led to life on the [early Earth](#). They may have been carried to Earth on meteorites (see [Murchison meteorite](#)), created at [deep-sea vents](#), or synthesized by lightning in a reducing atmosphere (see [Miller–Urey experiment](#)). There is little experimental data defining what the first self-replicating forms were. [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](#)), but some other entity with the potential to self-replicate could have preceded RNA, such as [clay](#) or [peptide nucleic acid](#).^[40]

Cells emerged at least 3.5 billion years ago.^{[41][42][43]} The current belief is that these cells were [heterotrophs](#). 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](#) 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.^[44]

Origin of eukaryotic cells

Further information: [Evolution of sexual reproduction](#)

The eukaryotic cell seems to have evolved from a [symbiotic community](#) of prokaryotic cells. DNA-bearing organelles like the [mitochondria](#) and the [chloroplasts](#) are descended from ancient

symbiotic oxygen-breathing [Alphaproteobacteria](#) and "[Cyanobacteria](#)", respectively, which were [endosymbiosed](#) by an ancestral [archaeon](#) prokaryote.

There is still considerable debate about whether organelles like the [hydrogenosome](#) predated the origin of [mitochondria](#), or vice versa: see the [hydrogen hypothesis](#) for the origin of eukaryotic cells.

History of research

Main article: [Cell theory](#)



Robert Hooke's drawing of cells in [cork](#), 1665

- 1632–1723: [Antonie van Leeuwenhoek](#) taught himself to make [lenses](#), constructed basic [optical microscopes](#) and drew protozoa, such as [Vorticella](#) from rain water, and [bacteria](#) from his own mouth.
- 1665: [Robert Hooke](#) discovered cells in [cork](#), then in living plant tissue using an early compound microscope. He coined the term *cell* (from [Latin](#) *cellula*, meaning "small room"^[2]) in his book *Micrographia* (1665).^[45]
- 1839: [Theodor Schwann](#) and [Matthias Jakob Schleiden](#) elucidated 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](#) stated that new cells come from pre-existing cells by [cell division](#) (*omnis cellula ex cellula*).
- 1859: The belief that life forms can occur spontaneously (*generatio spontanea*) was contradicted by [Louis Pasteur](#) (1822–1895) (although [Francesco Redi](#) had performed an experiment in 1668 that suggested the same conclusion).
- 1931: [Ernst Ruska](#) built the first [transmission electron microscope](#) (TEM) at the [University of Berlin](#). By 1935, he had built an EM with twice the resolution of a light microscope, revealing previously unresolvable organelles.

- 1953: Based on [Rosalind Franklin](#)'s work, [Watson](#) and [Crick](#) made their first announcement on the [double helix](#) structure of DNA.
- 1981: [Lynn Margulis](#) published *Symbiosis in Cell Evolution* detailing the [endosymbiotic theory](#).