# ULTRA STRUCTURE OF CELL AND CELL ORGANELLES AND THEIR FUNCTIONS

In 1665, an Englishman by the name of Robert Hooke examined thin slices of cork and observed that it was composed of numerous little boxes, fitted together like honey comb. Since these boxes resembled the compartment of monastery he named them as cells. The cork cells studied by Hooke were really empty boxes; they had lost their living matter, the protoplasm. After his discovery, the protoplasm in living cells were largely over looked due to its transparency. Today, with the help of special techniques, we are able to see not only the protoplasm but also many bodies inside it.

A general outline of a plant cell is as follows:

I. Cell Wall

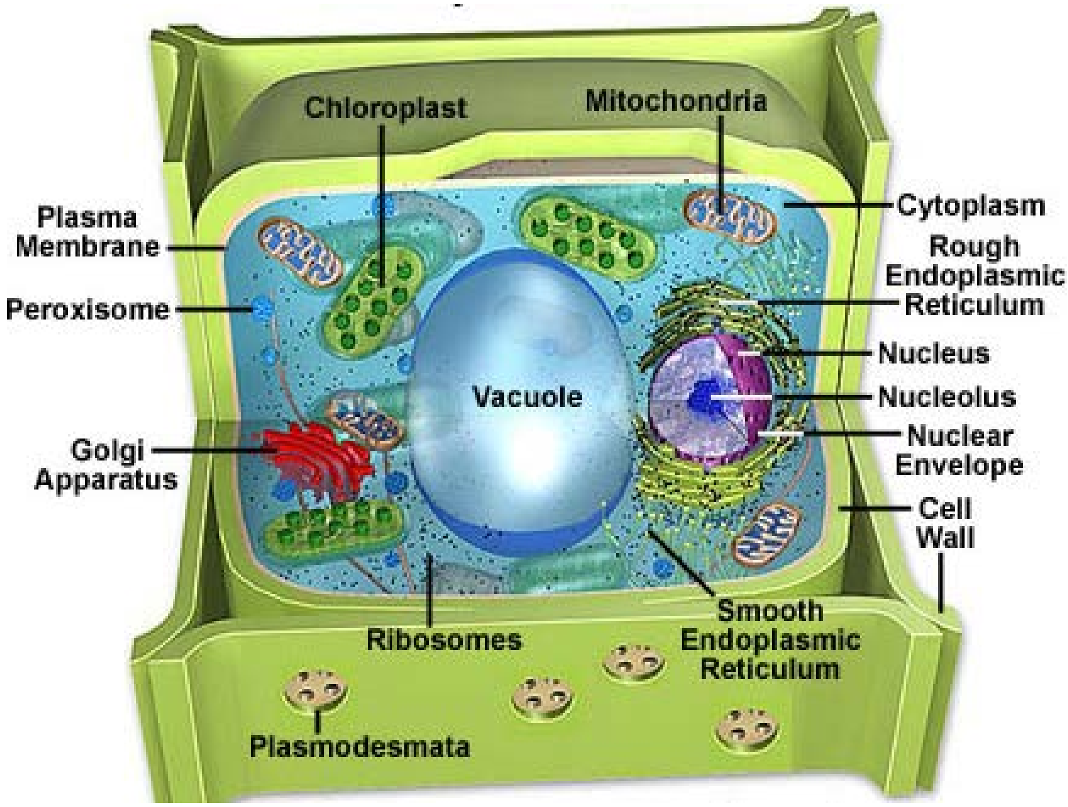
II. Protoplast

  A. Protoplasmic reticulum

    1. Cytoplasm
    2. Endoplasmic reticulum
    3. Ribosomes
    4. Mitochondria
    5. Golgi apparatus
    6. Plastids
    7. Nucleus
    8. Plant cell vacuoles
    9. Peroxisomes
    10. Lysosomes
    11. spherosomes

  B. Non-protoplasmic components

    1. Starch grains




**Cell Wall**

Plant cells are surrounded by a non living and rigid coat called cell wall. Though the cell wall is not a living part of the cell, it is an extra cytoplasmic product. Cell walls are significantly thicker than plasma membranes. It is responsible for the shape of plants and controls the growth rate of plant cells. It is a structural barrier to some molecules and invading insects. Cell walls are also a source of energy, fibre and food.

Walls are a layered structure, having three basic portions: intercellular substance or middle lamella, primary wall and secondary wall. The middle lamella cements together the primary walls of two contiguous cells and the secondary wall is laid over the primary. The middle lamella is mainly composed of a pectic compound which mostly appears to be calcium pectate. The primary wall is largely composed of cellulose and the secondary wall may be of cellulose or cellulose impregnated with other substances.

**Primary cell wall**

The main chemical components of the primary plant cell wall include **cellulose** in the form of organized **microfibrils**, a complex carbohydrate made up of several thousand glucose molecules linked end to end. Cellulose constitutes the bulk of material of cell walls are made. It is soft, elastic, transparent and readily permeable to water. It is a carbohydrate, being composed of three elements – carbon, hydrogen and oxygen. Cotton and linen are nearly pure cellulose. Cellophane, celluloid, paper rayon, synthetic lacquers and varnish are manufactured from cellulose. In addition, the cell wall contains two groups of branched polysaccharides, the **pectins** and **cross-linking glycans**. Pectic compounds are exceedingly gelatinous and viscous. They swell in water. They are found in three forms: insoluble pectose, soluble pectin and insoluble pectic acid. Organized into a network with the cellulose microfibrils, the cross-linking glycans increase the tensile strength of the cellulose, whereas the coextensive network of pectins provides the cell wall with the ability to resist compression. In addition to these networks, a small amount of protein can be found in all plant primary cell walls. Some of this protein is thought to increase mechanical strength and part of it consists of enzymes, which initiate reactions that form, remodel, or breakdown the structural networks of the wall. Such changes in the cell wall directed by enzymes are particularly important for fruit to ripen and leaves to fall in autumn.

Gums and mucilages are complex carbohydrates of the cell wall. They can absorb and retain water, helping in the dispersal of seeds.

One of the most important distinguishing features of plant cells is the presence of a cell wall. The relative rigidity of the cell wall renders plants sedentary, unlike animals, whose lack of this type of structure allows their cells more flexibility, which is necessary for locomotion. The plant cell wall serves a variety of functions. Along with protecting the intracellular contents, the structure bestows rigidity to the plant, provides a porous medium for the circulation and distribution of water, minerals, and other nutrients, and houses specialized molecules that regulate growth and protect the plant from disease.

**Secondary cell wall**

The secondary plant cell wall, which is often deposited inside the primary cell wall as a cell matures, sometimes has a composition nearly identical to that of the earlier-developed wall. More commonly, however, additional substances, especially **lignin**, are found in the secondary wall. Lignin is the general name for a group of polymers of aromatic alcohols that are hard and impart considerable strength to the structure of the secondary wall. Lignin is what provides the favorable characteristics of wood to the fiber cells of woody tissues and is also common in the secondary walls of xylem vessels, which are central in providing structural support to plants. Lignin occurs generally in hard mature tissues, such as those straw and wood. It gives sufficient rigidity and strength to the plant body. It is permeable to water and solutes. Lignin also makes plant cell walls less vulnerable to attack by fungi or bacteria, as do **cutin**, **suberin**, and other waxy materials that are sometimes found in plant cell walls.

Cutin is a fatty substance. It forms an external coating, the cuticle on the other cellulose wall of the epidermal cells of leaves and stems. It is not permeable to water. It is effective in protecting the foliage from the leaching effects of rain, in reducing water loss from plant surface and in preventing easy access of the partial parasites. The process of cutin deposition on the cellulose wall is called cutinisation.

Suberin is a fatty substance which resembles cutin in many qualities. It is permeable to water and checks the loss of water from the surface of plants. It is an important constituent of walls of cork cells, but also occur in the internal cells of exodermis and endodermis. The process of suberin deposition on the cellulose wall is termed suberisation.

**Middle lamella**

A specialized region associated with the cell walls of plants, and sometimes considered an additional component of them, is the **middle lamella**. Rich in pectins, the middle lamella is shared by neighboring cells and cements them firmly together. Positioned in such a manner, cells are able to communicate with one another and share their contents through special conduits. Termed **plasmodesmata**, these small passages penetrate the middle lamella as well as the primary and secondary cell walls, providing pathways for transporting cytoplasmic molecules from one cell to another.

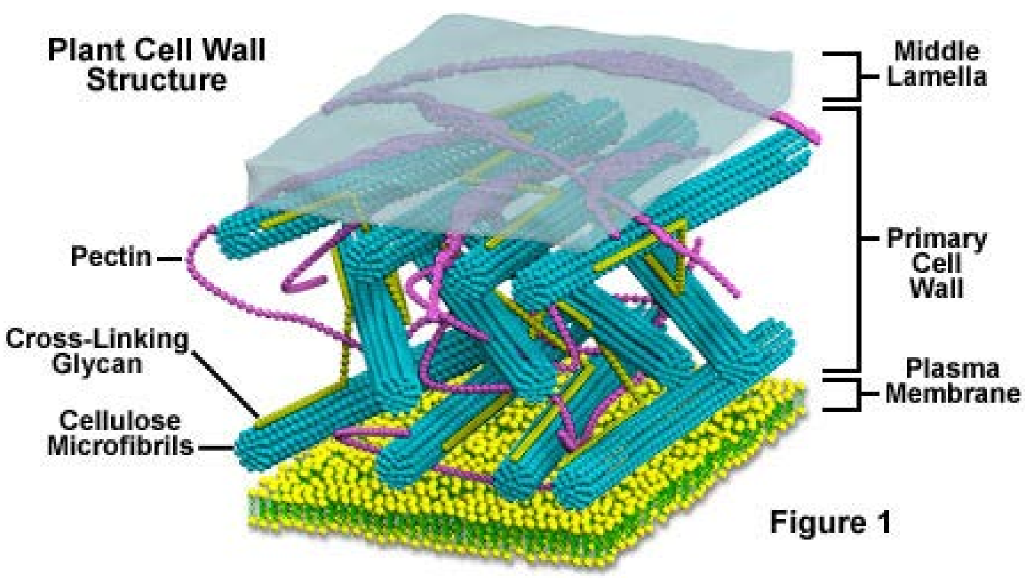
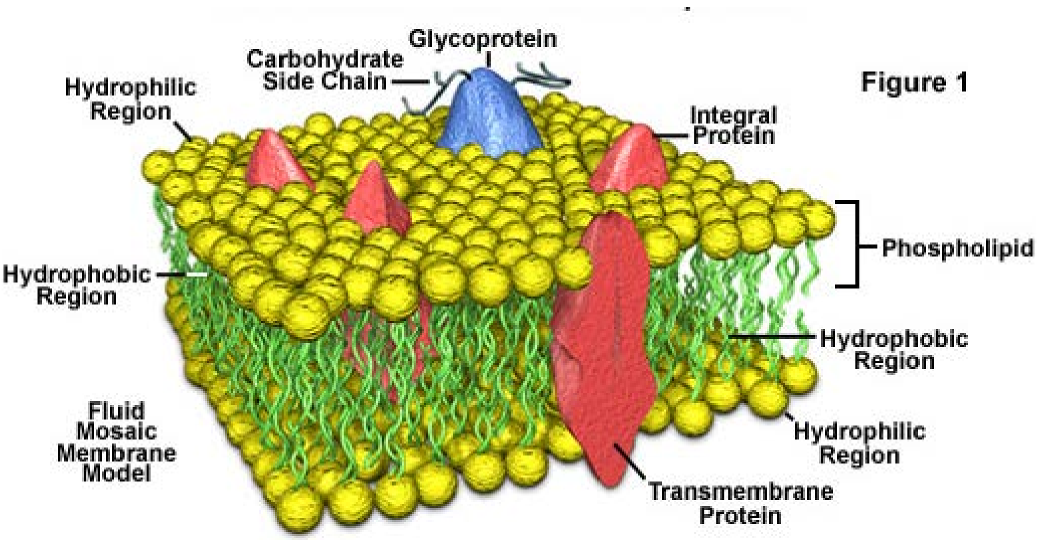


Figure 1

**Plasma Membrane**

All living cells, prokaryotic and eukaryotic, have a plasma membrane that encloses their contents and serves as a semi-porous barrier to the outside environment. The membrane acts as a boundary, holding the cell constituents together and keeping other substances from entering. The plasma membrane is permeable to specific molecules, however, and allows nutrients and other essential elements to enter the cell and waste materials to leave the cell. Small molecules, such as oxygen, carbon dioxide, and water, are able to pass freely across the membrane, but the passage of larger molecules, such as amino acids and sugars, is carefully regulated.




According to the accepted current theory, known as the **fluid mosaic model**, the plasma membrane is composed of a double layer (**bilayer**) of lipids, oily substances found in all cells. Most of the lipids in the bilayer can be more precisely described as **phospholipids**, that is, lipids that feature a phosphate group at one end of each molecule. Phospholipids are characteristically **hydrophilic** ("water-loving") at their phosphate ends and **hydrophobic** ("water-fearing") along their lipid tail regions. In each layer of a plasma membrane, the hydrophobic lipid tails are oriented inwards and the hydrophilic phosphate groups are aligned so they face outwards, either toward the aqueous cytosol of the cell or the outside environment. Phospholipids tend to spontaneously aggregate by this mechanism whenever they are exposed to water.

Within the phospholipid bilayer of the plasma membrane, many diverse proteins are embedded, while other proteins simply adhere to the surfaces of the bilayer. Some of these proteins, primarily those that are at least partially exposed on the external side of the membrane, have carbohydrates attached to their outer surfaces and are, therefore, referred to as **glycoproteins**. The positioning of proteins along the plasma membrane is related in part to the organization of the filaments that comprise the cytoskeleton, which help anchor them in place. The arrangement of proteins also involves the hydrophobic and hydrophilic regions found on the surfaces of the proteins: hydrophobic regions associate with the hydrophobic interior of the plasma membrane and hydrophilic regions extend past the surface of the membrane into either the inside of the cell or the outer environment.

Plasma membrane proteins function in several different ways. Many of the proteins play a role in the selective transport of certain substances across the phospholipid bilayer, either acting as channels or active transport molecules. Others function as receptors, which bind information-providing molecules, such as hormones, and transmit corresponding signals based on the obtained information to the interior of the cell. Membrane proteins may also exhibit enzymatic activity, catalyzing various reactions related to the plasma membrane.

**Plasmodesmata**

Plasmodesmata (singular, plasmodesma) are small channels that directly connect the cytoplasm of neighboring plant cells to each other, establishing living bridges between cells. The plasmodesmata, which penetrate both the primary and secondary cell walls allow certain molecules to pass directly from one cell to another and are important in cellular communication.

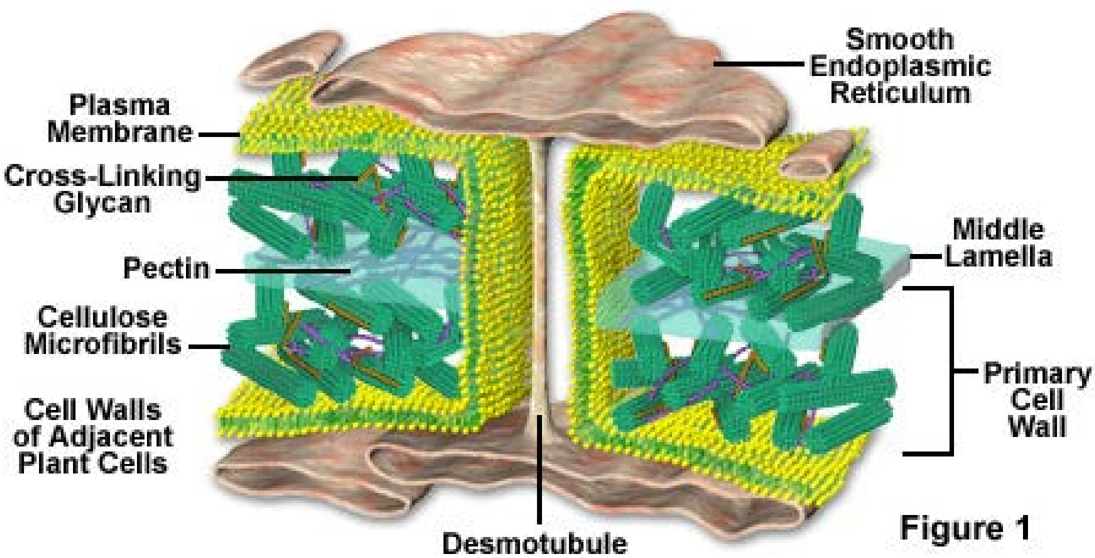


Figure 1

Due to the presence of plasmodesmata, plant cells can be considered to form a **synctium**, or multinucleate mass with cytoplasmic continuity. Somewhat cylindrical in shape, plasmodesmata are lined with the plasma membrane so all connected cells are united through essentially one continuous cell membrane. A majority of plasmodesmata also contain a narrow tube-like structure called the **desmotubule**, which is derived from the smooth endoplasmic reticulum of the connected cells. The desmotubule does not completely fill the plasmodesma and, consequently, a ring of shared cytoplasm is located between it and the inner surface of the membrane-lined channel. Plasmodesmata typically form during cell division when parts of the endoplasmic reticulum of the parent cell get trapped in the new cell wall that is produced to create daughter cells. Thousands of plasmodesmata may be formed that connect the daughter cells to one another.

It is widely thought that by constricting and dilating the openings at the ends of the plasmodesmata, plants cells regulate the passage of small molecules, such as sugars, salts, and amino acids, though this mechanism is not yet well understood. Yet, it is known that in some cases the size restrictions on molecule passage between cells can be overcome. By binding to parts of the plasmodesmata, special proteins and some viruses are able to increase the diameter of the channels enough for unusually large molecules to pass through.

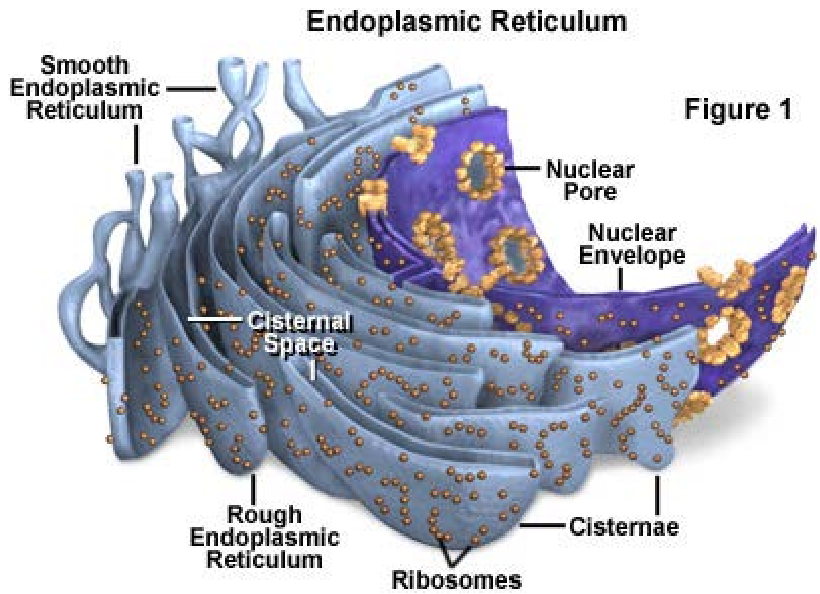
**Cytoplasm**

Part of plant cells outside the nucleus (and outside the large vacuole of plant cells) is called cytoplasm. Strictly speaking, this includes all the organelles (mitochondria, chloroplasts, and so on) and is the area in which most cell activities take place. However, cytoplasm is often used to refer to the jellylike matter in which the organelles are embedded (correctly termed the cytosol). Most of the activities in the cytoplasm are chemical reactions (metabolism), for example, protein synthesis.

In many cells, the cytoplasm is made up of two parts: the **ectoplasm** (or plasmagel), a dense gelatinous outer layer concerned with cell movement, and the **endoplasm** (or plasmasol), a more fluid inner part where most of the organelles are found. The semifluid medium between the nucleus and the plasma membrane is called **cytosol**.

**The Endoplasmic Reticulum**

The endoplasmic reticulum (**ER**) is a network of flattened sacs and branching tubules that extends throughout the cytoplasm in plant and animal cells. These sacs and tubules are all interconnected by a single continuous membrane so that the organelle has only one large, highly convoluted and complexly arranged **lumen** (internal space). Usually referred to as the endoplasmic reticulum cisternal space, the lumen of the organelle often takes up more than 10 percent of the total volume of a cell. The endoplasmic reticulum membrane allows molecules to be selectively transferred between the lumen and the cytoplasm, and since it is connected to the double-layered nuclear envelope, it further provides a pipeline between the nucleus and the cytoplasm.




The endoplasmic reticulum manufactures, processes, and transports a wide variety of biochemical compounds for use inside and outside of the cell. Consequently, many of the proteins found in the cisternal space of the endoplasmic reticulum lumen are there only transiently as they pass on their way to other locations. Other proteins, however, are targeted to constantly remain in the lumen and are known as endoplasmic reticulum **resident proteins**. These special proteins, which are necessary for the endoplasmic reticulum to carry out its normal functions, contain a specialized retention signal consisting of a specific sequence of amino acids that enables them to be retained by the organelle. An example of an important endoplasmic reticulum resident protein is the chaperone protein known as **BiP** (formally: the chaperone immunoglobulin-binding protein), which identifies other proteins that have been improperly built or processed and keeps them from being sent to their final destinations.

There are two basic kinds of endoplasmic reticulum morphologies: rough and smooth. The surface of rough endoplasmic reticulum is covered with ribosomes, giving it a bumpy appearance when viewed through the microscope. This type of endoplasmic reticulum is involved mainly with the production and processing of proteins that will be exported, or secreted, from the cell.

The smooth endoplasmic reticulum in most cells is much less extensive than the rough endoplasmic reticulum and is sometimes alternatively termed **transitional**. Smooth endoplasmic reticulum is chiefly involved, however, with the production of lipids (fats), building blocks for carbohydrate metabolism, and the detoxification of drugs and poisons. Therefore, in some specialized cells, such as those that are occupied chiefly in lipid and carbohydrate metabolism (brain and muscle) or detoxification (liver), the smooth endoplasmic reticulum is much more extensive and is crucial to cellular function. Smooth endoplasmic reticulum also plays a role in various cellular activities through its storage of calcium and involvement in calcium metabolism.

**Ribosomes**

All living cells contain ribosomes, tiny organelles composed of approximately 60 percent ribosomal RNA (**rRNA**) and 40 percent protein. However, though they are generally described as organelles, it is important to note that ribosomes are not bound by a membrane and are much smaller than other organelles.

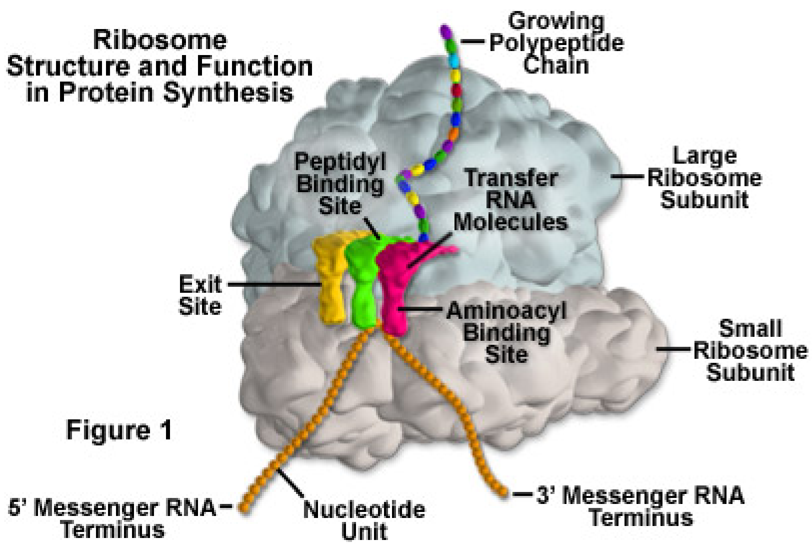


Figure 1

Ribosomes are mainly found bound to the endoplasmic reticulum and the nuclear envelope, as well as freely scattered throughout the cytoplasm, depending upon whether the cell is plant, animal, or bacteria.

In 2000, the complete three-dimensional structure of the large and small subunits of a ribosome was established. Evidence based on this structure suggests, as had long been assumed, that it is the rRNA that provides the ribosome with its basic formation and functionality, not proteins. Apparently the proteins in a ribosome help fill in structural gaps and enhance protein synthesis, although the process can take place in their absence, albeit at a much slower rate.

The units of a ribosome are often described by their Svedberg (**s**) values, which are based upon their rate of sedimentation in a centrifuge. The ribosomes in a eukaryotic cell generally have a Svedberg value of 80S and are comprised of 40s and 60s subunits.

Prokaryotic cells, on the other hand, contain 70S ribosomes, each of which consists of a 30s and a 50s subunit. As demonstrated by these values, Svedberg units are not additive, so the values of the two subunits of a ribosome do not add up to the Svedberg value of the entire organelle. This is because the rate of sedimentation of a molecule depends upon its size and shape, rather than simply its molecular weight.

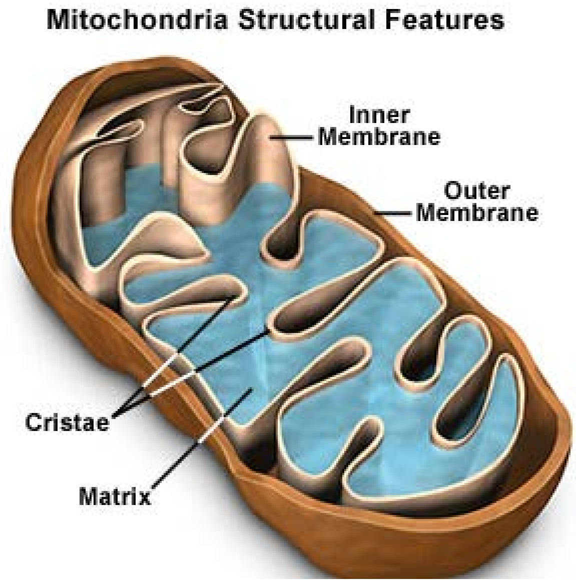
Protein synthesis requires the assistance of two other kinds of RNA molecules in addition to rRNA. Messenger RNA (**mRNA**) provides the template of instructions from the cellular DNA for building a specific protein. Transfer RNA (**tRNA**) brings the protein building blocks, amino acids, to the ribosome. There are three adjacent tRNA binding sites on a ribosome: the **aminoacyl** binding site for a tRNA molecule attached to the next amino acid in the protein, the **peptidyl** binding site for the central tRNA molecule containing the growing peptide chain, and an **exit** binding site to discharge used tRNA molecules from the ribosome.

Once the protein backbone amino acids are polymerized, the ribosome releases the protein and it is transported to the cytoplasm in prokaryotes or to the Golgi apparatus in eukaryotes. There, the proteins are completed and released inside or outside the cell. Ribosomes are very efficient organelles. A single ribosome in a eukaryotic cell can add 2 amino acids to a protein chain every second. In prokaryotes, ribosomes can work even faster, adding about 20 amino acids to a polypeptide every second.

In addition to the most familiar cellular locations of ribosomes, the organelles can also be found inside mitochondria and the chloroplasts of plants. The similarity of mitochondrial and chloroplast ribosomes to prokaryotic ribosomes is generally considered strong supportive evidence that mitochondria and chloroplasts evolved from ancestral prokaryotes.

**Mitochondria**

Mitochondria are rod-shaped organelles that can be considered the power generators of the cell, converting oxygen and nutrients into adenosine triphosphate (**ATP**). ATP is the chemical energy "currency" of the cell that powers the cell's metabolic activities.




The number of mitochondria present in a cell depends upon the metabolic requirements of that cell, and may range from a single large mitochondrion to thousands of the organelles. Mitochondria, which are found in nearly all eukaryotes, including plants, animals, fungi, and protists, are large enough to be observed with a light microscope and were first discovered in the 1800s. The name of the organelles was coined to reflect the way they looked to the first scientists to observe them, stemming from the Greek words for "thread" and "granule." For many years after their discovery, mitochondria were commonly believed to transmit hereditary information. It was not until the mid-1950s when a method for isolating the organelles intact was developed that the modern understanding of mitochondrial function was worked out.

The elaborate structure of a mitochondrion is very important to the functioning of the organelle. Two specialized membranes encircle each mitochondrion present in a cell, dividing the organelle into a narrow **intermembrane space** and a much larger internal **matrix**, each of which contains highly specialized proteins. The outer membrane of a mitochondrion contains many channels formed by the protein **porin** and acts like a sieve, filtering out molecules that are too big. Similarly, the inner membrane, which is highly convoluted so that a large number of infoldings called **cristae** are formed, also allows only certain molecules to pass through it and is much more selective than the outer membrane. To make certain that only those materials essential to the matrix are allowed into it, the inner membrane utilizes a group of transport proteins that will only transport the correct molecules. Together, the various compartments of a mitochondrion are able to work in harmony to generate ATP in a complex multi-step process.

Mitochondria are generally oblong organelles, which range in size between 1 and 10 micrometers in length, and occur in numbers that directly correlate with the cell's level of metabolic activity. The organelles are quite flexible, however, studies have demonstrated that mitochondria change shape rapidly and move about in the cell almost constantly. Movements of the organelles appear to be linked in some way to the microtubules present in the cell, and are probably transported along the network with motor proteins. Consequently, mitochondria may be organized into lengthy traveling chains, packed tightly into relatively stable groups, or appear in many other formations based upon the particular needs of the cell and the characteristics of its microtubular network.

**Golgi apparatus**

The Golgi apparatus (**GA**), also called Golgi body or Golgi complex and found universally in both plant and animal cells, is typically comprised of a series of five to eight cup-shaped, membrane-covered sacs called **cisternae** that look something like a stack of deflated balloons. In some unicellular flagellates, however, as many as 60 cisternae may combine to make up the Golgi apparatus. Similarly, the number of Golgi bodies in a cell varies according to its function. Animal cells generally contain between ten and twenty Golgi stacks per cell, which are linked into a single complex by tubular connections between cisternae. This complex is usually located close to the cell nucleus.

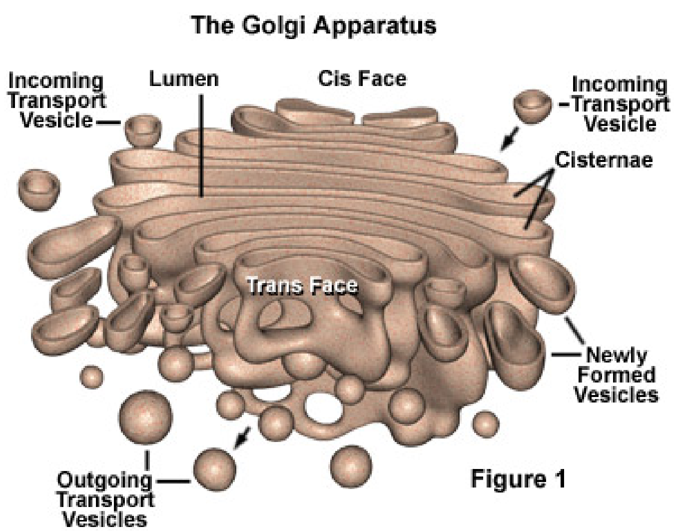


Figure 1

Due to its relatively large size, the Golgi apparatus was one of the first organelles ever observed. In 1897, an Italian physician named Camillo Golgi, who was investigating the nervous system by using a new staining technique he developed (and which is still sometimes used today; known as Golgi staining or Golgi impregnation), observed in a sample under his light microscope a cellular structure that he termed the internal reticular apparatus. Soon after he publicly announced his discovery in 1898, the structure was named after him, becoming universally known as the Golgi apparatus. Yet, many scientists did not believe that what Golgi observed was a real organelle present in the cell and instead argued that the apparent body was a visual distortion caused by staining. The invention of the electron microscope in the twentieth century finally confirmed that the Golgi apparatus is a cellular organelle.

The Golgi apparatus is often considered the distribution and shipping department for the cell's chemical products. It modifies proteins and lipids (fats) that have been built in the endoplasmic reticulum and prepares them for export outside of the cell or for transport to other locations in the cell. Proteins and lipids built in the smooth and rough endoplasmic reticulum bud off in tiny bubble-like vesicles that move through the cytoplasm until they reach the Golgi complex. The vesicles fuse with the Golgi membranes and release their internally stored molecules into the organelle. Once inside, the compounds are further processed by the Golgi apparatus, which adds molecules or chops tiny pieces off the ends. When completed, the product is extruded from the GA in a vesicle and directed to its final destination inside or outside the cell. The exported products are secretions of proteins or glycoproteins that are part of the cell's function in the organism. Other products are returned to the endoplasmic reticulum or may undergo maturation to become lysosomes.

The modifications to molecules that take place in the Golgi apparatus occur in an orderly fashion. Each Golgi stack has two distinct ends, or faces. The **cis** face of a Golgi stack is the end of the organelle where substances enter from the endoplasmic reticulum for processing, while the **trans** face is where they exit in the form of smaller detached vesicles. Consequently, the cis face is found near the endoplasmic reticulum, from whence most of the material it receives comes, and the trans face is positioned near the plasma membrane of the cell, to where many of the substances it modifies are shipped. The chemical make-up of each face is different and the enzymes contained in the lumens (inner open spaces) of the cisternae between the faces are distinctive.

Proteins, carbohydrates, phospholipids, and other molecules formed in the endoplasmic reticulum are transported to the Golgi apparatus to be biochemically modified during their transition from the cis to the trans poles of the complex. Enzymes present in the Golgi lumen modify the carbohydrate (or sugar) portion of glycoproteins by adding or subtracting individual sugar monomers. In addition, the Golgi apparatus manufactures a variety of macromolecules on its own, including a variety of polysaccharides. The Golgi complex in plant cells produces pectins and other polysaccharides specifically needed by for plant structure and metabolism.

The products exported by the Golgi apparatus through the trans face eventually fuse with the plasma membrane of the cell. Among the most important duties of the Golgi apparatus is to sort the wide variety of macromolecules produced by the cell and target them for distribution to their proper location. Specialized molecular identification labels or tags, such as phosphate groups, are added by the Golgi enzymes to aid in this sorting effort.

**Plastids**

In most plant cells structures called plastids are found. They are found in the cytoplasmic matrix of plant cells only. These structures are generally spherical or ovoid in shape and they are clearly visible in living cells. 3 types of plastids found in plant cells:

**Chromoplasts**

Chromoplasts are red, yellow or orange in colour and are found in petals of flowers and in fruit. Their colour is due to two pigments, carotene and xanthophyll.

**Functions**

the primary function in the cells of flowers is to attract agents of pollination,

and in fruit to attract agents of dispersal.

**Leucoplasts**

Leucoplasts are colourless plastids and occur in plant cells not exposed to light, such as roots and seeds. They are colourless due the absent of pigments.

**Functions**

leucoplasts are the centers of starch grain formation;

they are also involved in the synthesis of oils and proteins.

**Chloroplasts**

Chloroplasts are probably the most important among the plastids since they are directly involved in photosynthesis. They are usually situated near the surface of the cell and occur in those parts that receive sufficient light, e.g. the palisade cells of leaves. The green colour of chloroplasts is caused by the green pigment chlorophyll.

One of the most widely recognized and important characteristics of plants is their ability to conduct **photosynthesis**, in effect, to make their own food by converting light energy into chemical energy. This process occurs in almost all plant species and is carried out in specialized organelles known as chloroplasts. All of the green structures in plants, including stems and unripened fruit, contain chloroplasts, but the majority of photosynthesis activity in most plants occurs in the leaves. On the average, the chloroplast density on the surface of a leaf is about one-half million per square millimeter.

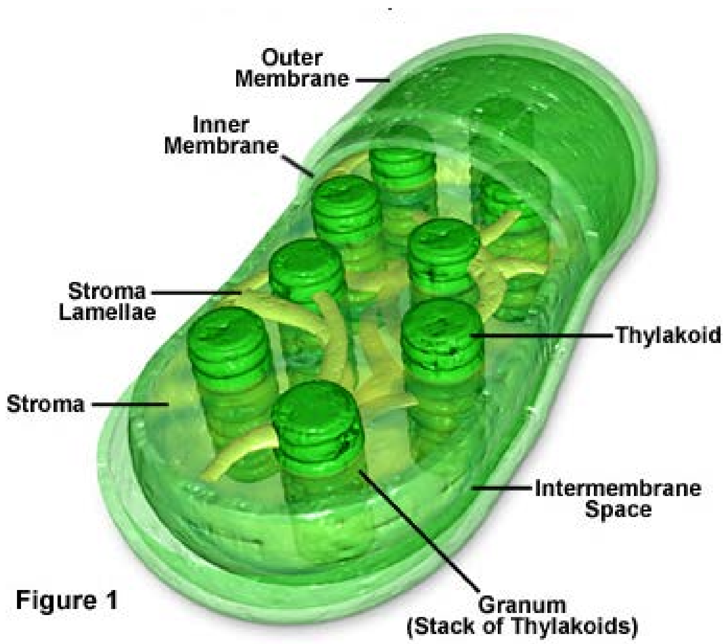



Figure 1

All plastids develop from tiny organelles found in the immature cells of plant meristems (undifferentiated plant tissue) termed **proplastids**, and those of a particular plant species contain copies of the same circular genome. The disparities between the various types of plastids are based upon the needs of the differentiated cells they are contained in, which may be influenced by environmental conditions, such as whether light or darkness surrounds a leaf as it grows.

The ellipsoid-shaped chloroplast is enclosed in a double membrane and the area between the two layers that make up the membrane is called the **intermembrane space**. The outer layer of the double membrane is much more permeable than the inner layer, which features a number of embedded membrane transport proteins. Enclosed by the chloroplast membrane is the **stroma**, a semi-fluid material that contains dissolved enzymes and comprises most of the chloroplast's volume. Since, like mitochondria, chloroplasts possess their own genomes (DNA), the stroma contains chloroplast DNA and special ribosomes and RNAs as well. In higher plants, **lamellae**, internal membranes with stacks (each termed a **granum**) of closed hollow disks called **thylakoids**, are also usually dispersed throughout the stroma. The numerous thylakoids in each stack are thought to be connected via their lumens (internal spaces).

Light travels as packets of energy called photons and is absorbed in this form by light-absorbing chlorophyll molecules embedded in the thylakoid disks. When these chlorophyll molecules absorb the photons, they emit electrons, which they obtain from water (a process that results in the release of oxygen as a byproduct). The movement of the electrons causes hydrogen ions to be propelled across the membrane surrounding the thylakoid stack, which consequently initiates the formation of an electrochemical gradient that drives the stroma's production of adenosine triphosphate (**ATP**). ATP is the chemical energy "currency" of the cell that powers the cell's metabolic activities. In the stroma, the light-independent reactions of photosynthesis, which involve carbon fixation, occur, and low-energy carbon dioxide is transformed into a high-energy compound like glucose.

**NUCLEUS**

The nucleus is a highly specialized organelle that serves as the information processing and administrative center of the cell. This organelle has two major functions: it stores the cell's hereditary material, or DNA, and it coordinates the cell's activities, which include growth, intermediary metabolism, protein synthesis, and reproduction (cell division).

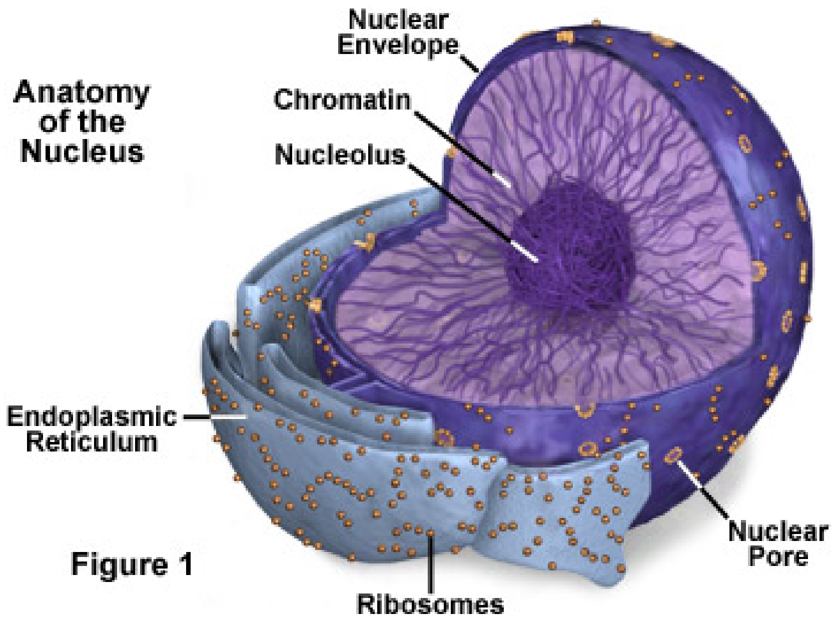



Figure 1

The spherical nucleus typically occupies about 10 percent of a eukaryotic cell's volume, making it one of the cell's most prominent features. A double-layered membrane, the nuclear envelope, separates the contents of the nucleus from the cellular cytoplasm. The envelope is riddled with holes called nuclear pores that allow specific types and sizes of molecules to pass back and forth between the nucleus and the cytoplasm. It is also attached to a network of tubules and sacs, called the endoplasmic reticulum, where protein synthesis occurs, and is usually studded with ribosome.

The semifluid matrix found inside the nucleus is called nucleoplasm. Within the nucleoplasm, most of the nuclear material consists of chromatin, the less condensed form of the cell's DNA that organizes to form chromosomes during mitosis or cell division. The nucleus also contains one or more nucleoli, organelles that synthesize protein-producing macromolecular assemblies called ribosomes, and a variety of other smaller components, such as Cajal bodies, **GEMS** (Gemini of coiled bodies), and interchromatin granule clusters.

**Chromatin and Chromosomes**

Packed inside the nucleus of every human cell is nearly 6 feet of DNA, which is divided into 46 individual molecules, one for each chromosome and each about 1.5 inches long. For DNA to function, it is combined with proteins and organized into a precise, compact structure, a dense string-like fiber called chromatin.

**The Nucleolus**

The nucleolus is a membrane-less organelle within the nucleus that manufactures ribosomes, the cell's protein-producing structures. The nucleolus looks like a large dark spot within the nucleus. A nucleus may contain up to four nucleoli, but within each species the number of nucleoli is fixed. After a cell divides, a nucleolus is formed when chromosomes are brought together into nucleolar organizing regions. During cell division, the nucleolus disappears.

**The Nuclear Envelope**

The nuclear envelope is a double-layered membrane that encloses the contents of the nucleus during most of the cell's lifecycle. The space between the layers is called the perinuclear space and appears to connect with the rough endoplasmic reticulum. The envelope is perforated with tiny holes called nuclear pores. These pores regulate the passage of molecules between the nucleus and cytoplasm, permitting some to pass through the membrane, but not others. The inner surface has a protein lining called the nuclear lamina, which binds to chromatin and other nuclear components. During mitosis, or cell division, the nuclear envelope disintegrates, but reforms as the two cells complete their formation and the chromatin begins to unravel and disperse.

**Nuclear Pores**

The nuclear envelope is perforated with holes called nuclear pores. These pores regulate the passage of molecules between the nucleus and cytoplasm, permitting some to pass through the membrane, but not others. Building blocks for building DNA and RNA are allowed into the nucleus as well as molecules that provide the energy for constructing genetic material.

**Peroxisomes**

Microbodies are a diverse group of organelles that are found in the cytoplasm of almost all cells, roughly spherical, and bound by a single membrane. There are several types of microbodies, including lysosomes, but peroxisomes are the most common. All eukaryotes are comprised of one or more cells that contain peroxisomes. The organelles were first discovered by the Belgian scientist Christian de Duve, who also discovered lysosomes.

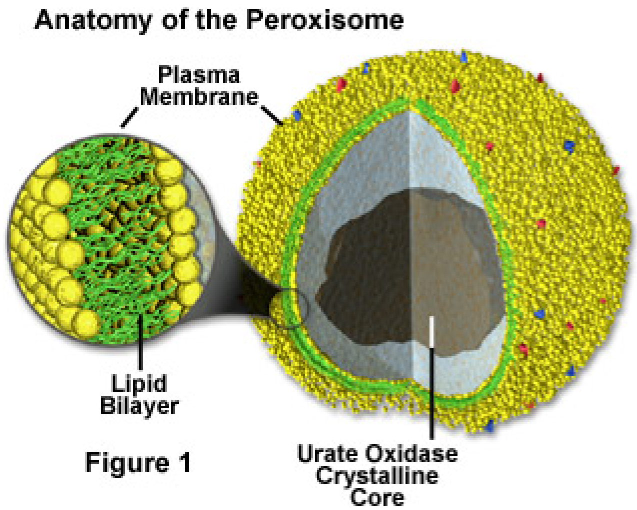


Figure 1

Peroxisomes contain a variety of enzymes, which primarily function together to rid the cell of toxic substances, and in particular, hydrogen peroxide (a common byproduct of cellular metabolism). These organelles contain enzymes that convert the hydrogen peroxide to water, rendering the potentially toxic substance safe for release back into the cell. Some types of peroxisomes, such as those in liver cells, detoxify alcohol and other harmful compounds by transferring hydrogen from the poisons to molecules of oxygen (a process termed **oxidation**). Others are more important for their ability to initiate the production of phospholipids, which are typically used in the formation of membranes.

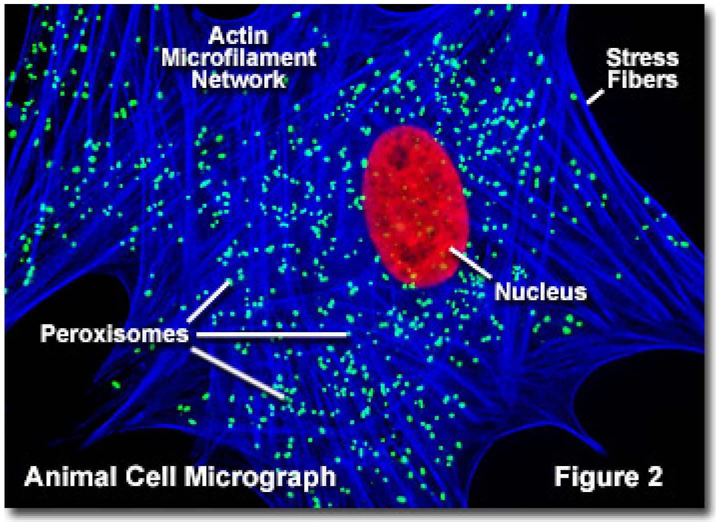
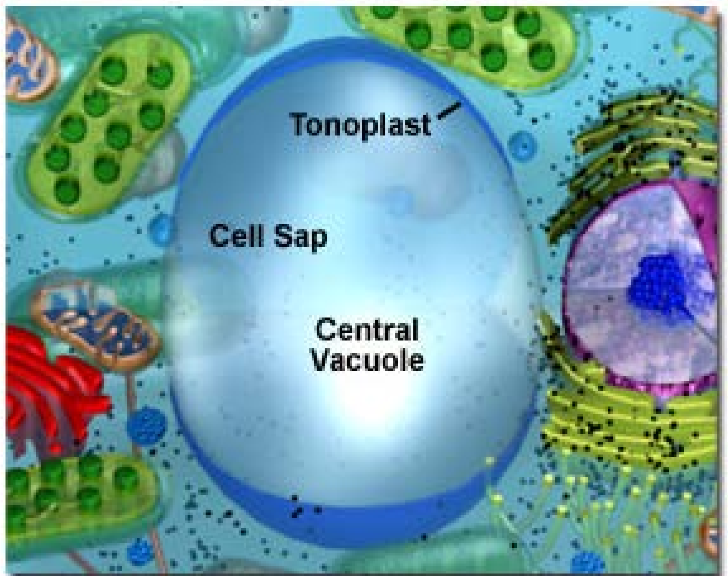


Figure 2

**Plant Cell Vacuoles**

Vacuoles are membrane-bound sacs within the cytoplasm of a cell that function in several different ways. In mature plant cells, vacuoles tend to be very large and are extremely important in providing structural support, as well as serving functions such as storage, waste disposal, protection, and growth. Many plant cells have a large, single **central vacuole** that typically takes up most of the room in the cell (80 percent or more). Vacuoles in animal cells, however, tend to be much smaller, and are more commonly used to temporarily store materials or to transport substances.




The central vacuole in plant cells is enclosed by a membrane termed the **tonoplast**, an important and highly integrated component of the plant internal membrane network (**endomembrane**) system. This large vacuole slowly develops as the cell matures by fusion of smaller vacuoles derived from the endoplasmic reticulum and Golgi apparatus. Because the central vacuole is highly selective in transporting materials through its membrane, the chemical palette of the vacuole solution (termed the **cell sap**) differs markedly from that of the surrounding cytoplasm. For instance, some vacuoles contain pigments that give certain flowers their characteristic colors. The central vacuole also contains plant wastes that taste bitter to insects and animals, while developing seed cells use the central vacuole as a repository for protein storage.

Among its roles in plant cell function, the central vacuole stores salts, minerals, nutrients, proteins, pigments, helps in plant growth, and plays an important structural role for the plant.

Under optimal conditions, the vacuoles are filled with water to the point that they exert a significant pressure against the cell wall. This helps maintain the structural integrity of the plant, along with the support from the cell wall, and enables the plant cell to grow much larger without having to synthesize new cytoplasm. In most cases, the plant cytoplasm is confined to a thin layer positioned between the plasma membrane and the tonoplast, yielding a large ratio of membrane surface to cytoplasm.

The structural importance of the plant vacuole is related to its ability to control **turgor pressure**. Turgor pressure dictates the rigidity of the cell and is associated with the difference between the osmotic pressure inside and outside of the cell. Osmotic pressure is the pressure required to prevent fluid diffusing through a semipermeable membrane separating two solutions containing different concentrations of solute molecules. The response of plant cells to water is a prime example of the significance of turgor pressure. When a plant receives adequate amounts of water, the central vacuoles of its cells swell as the liquid collects within them, creating a high level of turgor pressure, which helps maintain the structural integrity of the plant, along with the support from the cell wall. In the absence of enough water, however, central vacuoles shrink and turgor pressure is reduced, compromising the plant's rigidity so that wilting takes place.

Plant vacuoles are also important for their role in molecular degradation and storage. Sometimes these functions are carried out by different vacuoles in the same cell, one serving as a compartment for breaking down materials (similar to the lysosomes found in animal cells), and another storing nutrients, waste products, or other substances. Several of the materials commonly stored in plant vacuoles have been found to be useful for humans, such as opium, rubber, and garlic flavoring, and are frequently harvested. Vacuoles also often store the pigments that give certain flowers their colors, which aid them in the attraction of bees and other pollinators, but also can release molecules that are poisonous, odoriferous, or unpalatable to various insects and animals, thus discouraging them from consuming the plant.

**Amyloplast (Starch Grain)**

A membrane-bound organelle containing concentric layers of starch (amylopectin). This organelle is commonly found in subterranean storage organs, such as tubers (potatoes), corms (taro & dasheen), and storage roots (sweet potatoes). Amyloplasts are also found in bananas and other fruits.