Unit 1:

Prokaryotic cell

Introduction

Image of cyanobacterial cells forming a filament composed of dissimilar cell types. Most of the cells are small, but one is round and different in morphology. This larger cell is a nitrogen-fixing cell.

Components of prokaryotic cells

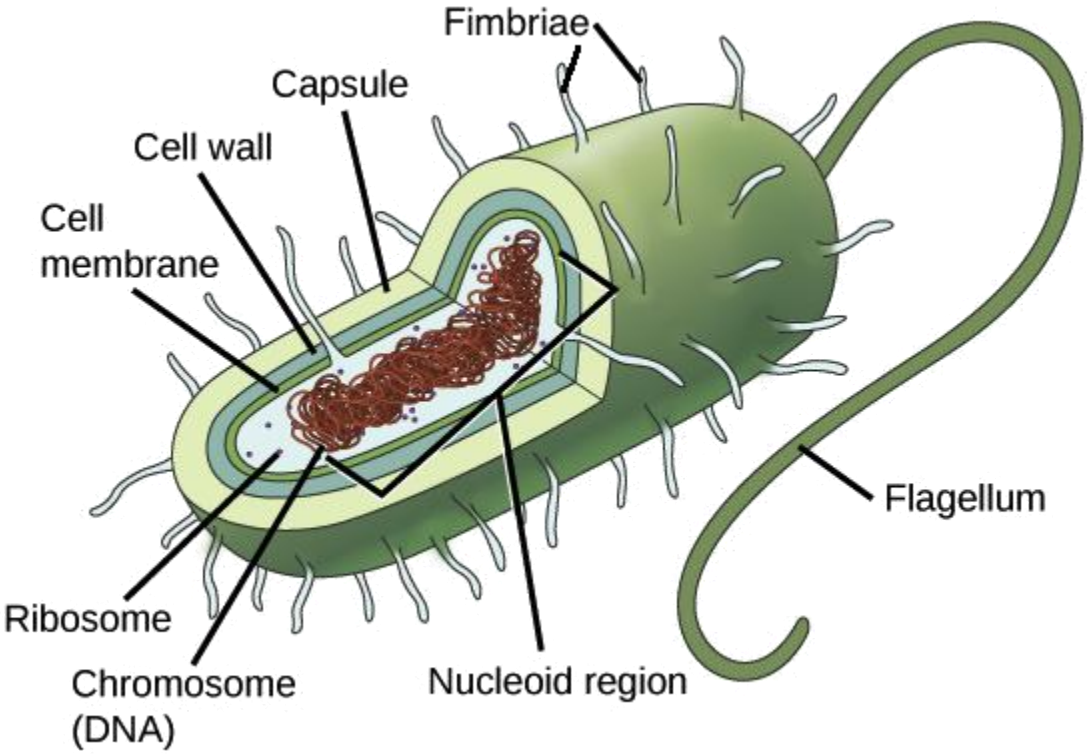
There are some key ingredients that a cell needs in order to be a cell, regardless of whether it is prokaryotic or eukaryotic. All cells share four key components:

1. The **plasma membrane** is an outer covering that separates the cell's interior from its surrounding environment.

2. **Cytoplasm** consists of the jelly-like cytosol inside the cell, plus the cellular structures suspended in it. In eukaryotes, cytoplasm specifically means the region outside the nucleus but inside the plasma membrane.
3. **DNA** is the genetic material of the cell.
4. **Ribosomes** are molecular machines that synthesize proteins.

A **prokaryote** is a simple, single-celled organism that lacks a nucleus and membrane-bound organelles. prokaryotic cells are not divided up on the inside by membrane walls, but consist instead of a single open space.

The majority of prokaryotic D, N, A is found in a central region of the cell called the **nucleoid**, and it typically consists of a single large loop called a circular chromosome. The nucleoid and some other frequently seen features of prokaryotes are shown in the diagram below of a cut-away of a rod-shaped bacterium.



Most bacteria are, however, surrounded by a rigid cell wall made out of **peptidoglycan**, a polymer composed of linked carbohydrates and small proteins. The **cell wall** provides an extra layer of protection, helps the cell maintain its shape, and prevents dehydration. Many bacteria also have an outermost layer of carbohydrates called the capsule. The **capsule** is sticky and helps the cell attach to surfaces in its environment.

Some bacteria also have specialized structures found on the cell surface, which may help them move, stick to surfaces, or even exchange genetic material with other bacteria. For instance, **flagella** are whip-like structures that act as rotary motors to help bacteria move.

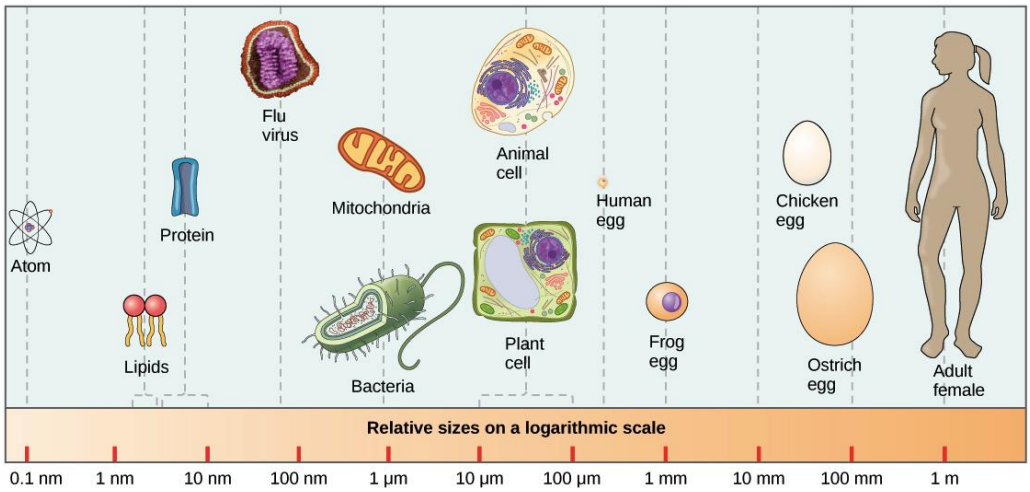
Fimbriae are numerous, hair-like structures that are used for attachment to host cells and other surfaces. Bacteria may also have rod-like structures known as **pili**, which come in different varieties. For instance, some types of pili allow a bacterium to transfer DNA molecules to other bacteria, while others are involved in bacterial locomotion—helping the bacterium move. [Are fimbriae considered pili?]

Archaea may also have most of these cell surface features, but their versions of a particular feature are typically different from those of bacteria. For instance, although archaea also have a cell wall, it's not made out of peptidoglycan—although it does contain carbohydrates and proteins.

Cell size

Typical prokaryotic cells range from 0.1 to 5.0 micrometers (μm) in diameter and are significantly smaller than eukaryotic cells, which usually have diameters ranging from 10 to 100 μm.

The figure below shows the sizes of prokaryotic, bacterial, and eukaryotic, plant and animal, cells as well as other molecules and organisms on a logarithmic scale. Each unit of increase in a logarithmic scale represents a 10-fold increase in the quantity being measured, so these are big size differences we're talking about!



Graph showing the relative sizes of items from, in order, atoms to proteins to viruses to bacteria to animal cells to chicken eggs to humans.

Suppose, for the sake of keeping things simple, that we have a cell that's shaped like a cube. Some plant cells are, in fact, cube-shaped. If the length of one of the cube's sides is l*l*l, the surface area of the cube will be 6l^26*l*26, l, start superscript, 2, end superscript, and the volume of the cube will be l^3*l*3l, start superscript, 3, end superscript. This means that as l*l*l gets bigger, the surface area will increase quickly since it changes with the square of l*l*l. The volume, however, will increase even faster since it changes with the cube of l*l*l.

Thus, as a cell gets bigger, its surface-area-to-volume ratio drops. For example, the cube-shaped cell on the left has a volume of 1 mm^33start superscript, 3, end superscript and a surface area of 6 mm^22start superscript,

2, end superscript with a surface-area-to-volume ratio of six to one, whereas the cube-shaped cell on the right has a volume of 8 mm^33start superscript, 3, end superscript and a surface area of 24 mm^22start superscript, 2, end superscriptwith a surface area-to-volume ratio of three to one.

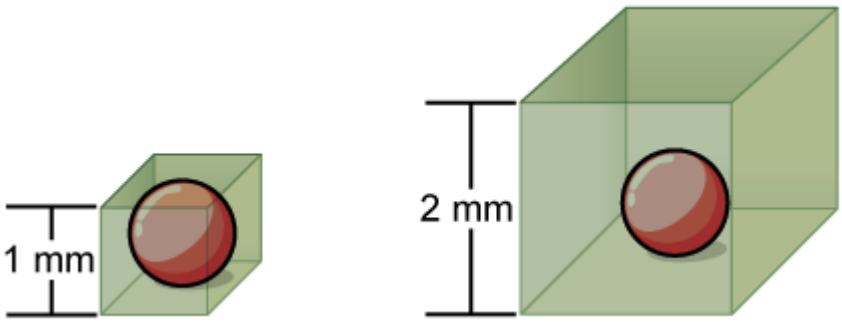


Image of two cubes of different sizes. The cube on the left has 1 mm sides, while the cube on the right has 2 mm sides.

Surface-area-to-volume ratio is important because the plasma membrane is the cell's interface with the environment. If the cell needs to take up nutrients, it must do so across the membrane, and if it needs to eliminate wastes, the membrane is again its only route.

Each patch of membrane can exchange only so much of a given substance in a given period of time – for instance, because it contains a limited number of channels. If the cell grows too large, its membrane will not have enough exchange capacity (surface area, square function) to support the rate of exchange required for its increased metabolic activity (volume, cube function).

The surface-area-to-volume problem is just one of a related set of difficulties posed by large cell size. As cells get larger, it also takes longer to transport materials inside of them. These considerations place a general upper limit on cell size, with eukaryotic cells being able to exceed prokaryotic cells thanks

to their structural and metabolic features—which we'll explore in the next section.

Some cells also use geometric tricks to get around the surface-area-to-volume problem. For instance, some cells are long and thin or have many protrusions from their surface, features that increase surface area relative to volume^2

Cell cycle regulation:

We will discuss two main families of proteins involved in this process—cyclin-dependent protein kinases (Cdks) and cyclins…

Cyclin-Dependent Protein Kinase (Cdks)

A Cdks is an enzyme that adds negatively charged phosphate groups to other molecules in a process called phosphorylation. Through phosphorylation, Cdks signal the cell that it is ready to pass into the next stage of the cell cycle. As their name suggests, Cyclin-Dependent Protein Kinases are dependent on cyclins, another class of regulatory proteins. Cyclins bind to Cdks, activating the Cdks to phosphorylate other molecules.

Cyclins

Cyclins are named such because they undergo a constant cycle of synthesis and degradation during cell division. When cyclins are synthesized, they act as an activating protein and bind to Cdks forming a cyclin-Cdk complex. This complex then acts as a signal to the cell to pass to the next cell cycle phase. Eventually, the cyclin degrades, deactivating the Cdk, thus signaling exit from a particular phase. There are two classes of cyclins: mitotic cyclins and G1 cyclins.

1 cyclins

G1 cyclins bind to Cdk proteins during G1. Once bound and activated, the Cdk signals the cell's exit from G1 and entry into S phase. When the cell reaches an appropriate size and the cellular environment is correct for DNA replication, the cyclins begin to degrade. G1 cyclin degradation deactivates the Cdk and leads to entry into S phase.

Mitotic Cyclins

Mitotic cyclins accumulate gradually during G2. Once they reach a high enough concentration, they can bind to Cdks. When mitotic cyclins bind to Cdks in G2, the resulting complex is known as Mitosis-promoting factor (MPF). This complex acts as the signal for the G2 cell to enter mitosis. Once the mitotic cyclin degrades, MPF is inactivated and the cell exits mitosis by dividing and re- entering G1. The cellular signals (cell size, completion of DNA replication, and cellular environment) provide the signals that regulate the synthesis and degradation of cyclins.

Aptosis:

The cells between your embryonic fingers died in a process called **apoptosis**, a common form of programmed cell death. In **programmed cell death**, cells undergo “cellular suicide” when they receive certain cues. Apoptosis involves the death of a cell, but it benefits the organism as a whole (for instance, by letting fingers develop or eliminating potential cancer cells). They are triggered to undergo programmed cell death. The best-understood form of programmed cell death is **apoptosis**.

Why do cells undergo apoptosis?

Many cells in the human body have the built-in ability to undergo apoptosis (in the same way that they have the built-in ability to copy their DNA or break down fuels). Basically, apoptosis is a general and convenient way to remove cells that should no longer be part of the organism.

- Some cells need to be "deleted" during development – for instance, to whittle an intricate structure like a hand out of a larger block of tissue.
- Some cells are abnormal and could hurt the rest of the organism if they survive, such as cells with viral infections or DNA damage.
- Cells in an adult organism may be eliminated to maintain balance – to make way for new cells or remove cells needed only for temporary tasks.

ihibitorsS

- Two families of genes, the *cip/kip* (*CDK interacting protein/Kinase inhibitory protein*) family and the INK4a/ARF (*In*hibitor of *K*inase 4/*A*lternative *R*eading *F*rame) family, prevent the progression of the cell cycle. Because these genes are instrumental in prevention of tumor formation, they are known as tumor suppressors.
- The ***cip/kip* family** includes the genes p21, p27 and p57. They halt cell cycle in G_1phase, by binding to, and inactivating, cyclin-CDK complexes. p21 is activated by p53 . p27 is activated by Transforming Growth Factor of β (TGF β), a growth inhibitor.
- The **INK4a/ARF family** includes $p16^{INK4a}$, which binds to CDK4 and arrests the cell cycle in G_1 phase, and $p14^{ARF}$ which prevents p53 degradation.
- Synthetic inhibitors of Cdc25 could also be useful for the arrest of cell cycle and therefore be useful as antineoplastic and anticancer agents
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Animal Cell Structure
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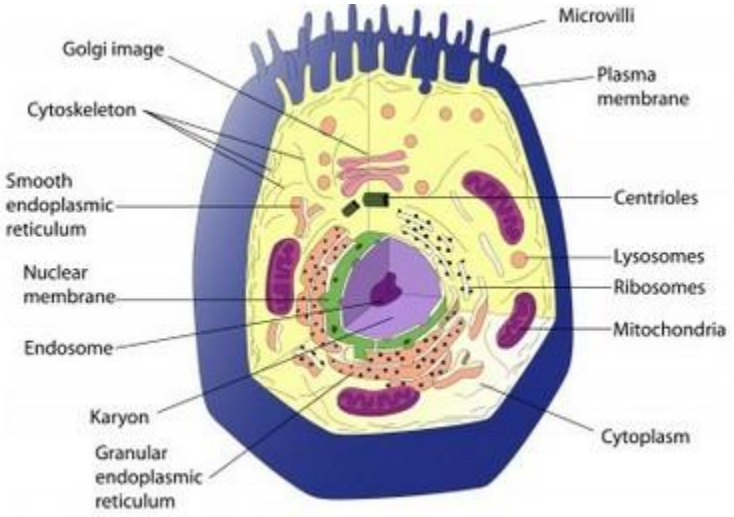
Animal cells are eukaryotic cells, the nucleus and other organelles of the cell are bound by membrane.



Cell membrane

- It is a semi-permeable barrier, allowing only a few molecules to move across it.
- Electron microscopic studies of cell membrane shows the lipid bi-layer model of the plasma membrane, it also known as the fluid mosaic model.
- The cell membrane is made up of phospholipids which has polar(hydrophillic) heads and non-polar (hydrophobic) tails.

Cytoplasm

- The fluid matrix that fills the cell is the cytoplasm.
- The cellular organelles are suspended in this matrix of the cytoplasm.

- This matrix maintains the pressure of the cell, ensures the cell doesn't shrink or burst.

Nucleus

- Nucleus is the house for most of the cells genetic material- the DNA and RNA.
- The nucleus is surrounded by a porous membrane known as the nuclear membrane.
- The RNA moves in/out of the nucleus through these pores.
- Proteins needed by the nucleus enter through the nuclear pores.
- The RNA helps in protein synthesis through transcription process.
- The nucleus controls the activity of the cell and is known as the control center.
- The nucleolus is the dark spot in the nucleus, and it is the location for ribosome formation.

Ribosomes

- Ribosomes is the site for protein synthesis where the translation of the RNA takes place.
- As protein synthesis is very important to the cell, ribosomes are found in large number in all cells.
- Ribosomes are found freely suspended in the cytoplasm and also are attached to the endoplasmic reticulum.

Endoplasmic reticulum

- ER is the transport system of the cell. It transports molecules that need certain changes and also molecules to their destination.
- ER is of two types, rough and smooth.
- ER bound to the ribosomes appear rough and is the rough endoplasmic reticulum; while the smooth ER do not have the ribosomes.

Lysosomes

- It is the digestive system of the cell.
- They have digestive enzymes helps in breakdown the waste moelcules and also help in detoxification of the cell.

- If the lysosomes were not membrane bound the cell could not have used the destructive enzymes.

Centrosomes

- It is located near the nucleus of the cell and is known as the 'microtubule organizing center' of the cell.
- Microtubules are made in the centrosome.
- During mitosis the centrosome aids in dividing of the cell and moving of the chromosome to the opposite sides of the cell.

Vacuoles

- They are bound by single membrane and small organelles.
- In many organisms vacuoles are storage organelles.

Vesicles are smaller vacuoles which function for transport in/out of the cell.

Golgi bodies

- Golgi bodies are the packaging center of the cell.
- The Golgi bodies modify the molecules from the rough ER by dividing them into smaller units with membrane known as vesicles.
- They are flattened stacks of membrane-bound sacs.

Mitochondria

- Mitochondria is the main energy source of the cell.
- They are called the power house of the cell because energy(ATP) is created here.
- Mitochondria consists of inner and outer membrane.
- It is spherical or rod shaped organelle.
- It is an organelle which is independent as it has its own hereditary material.

Peroxisomes

- Peroxisomes are single membrane bound organelle that contain oxidative enzymes that are digestive in function.

- They help in digesting long chains of fatty acids and amino acids and help in synthesis of cholesterol.

Cytoskeleton

- It is the network of microtubules and microfilament fibres.
- They give structural support and maintain the shape of the cell.

Cilia and Flagella

- Cilia and flagella are structurally identical structures.
- They are different based on the function they perform and their length.
- Cilia are short and are in large number per cell while flagella are longer and are fewer in number.
- They are organelles of movement.
- The flagellar motion is undulating and wave-like whereas the ciliary movement is power stroke and recovery stroke.

1) Phases of cell cycle

Interphase

Let's enter the cell cycle just as a cell forms, by division of its mother cell. What must this newborn cell do next if it wants to go on and divide itself? Preparation for division happens in three steps:

- **G_1 phase.** During G_1 phase, also called the first gap phase, the cell grows physically larger, copies organelles, and makes the molecular building blocks it will need in later steps.

- **S phase.** In S phase, the cell synthesizes a complete copy of the DNA in its nucleus. It also duplicates a microtubule-organizing structure called the centrosome. The centrosomes help separate DNA during M phase.

- **G_2.** During the second gap phase, or G_2 phase, the cell grows more, makes proteins and organelles, and begins to reorganize its contents in preparation for mitosis. G_2The G_11t, S, and G_ phases together are known as **interphase**. The prefix *inter-* means between, reflecting that interphase takes place between one mitotic (M) phase and the next.

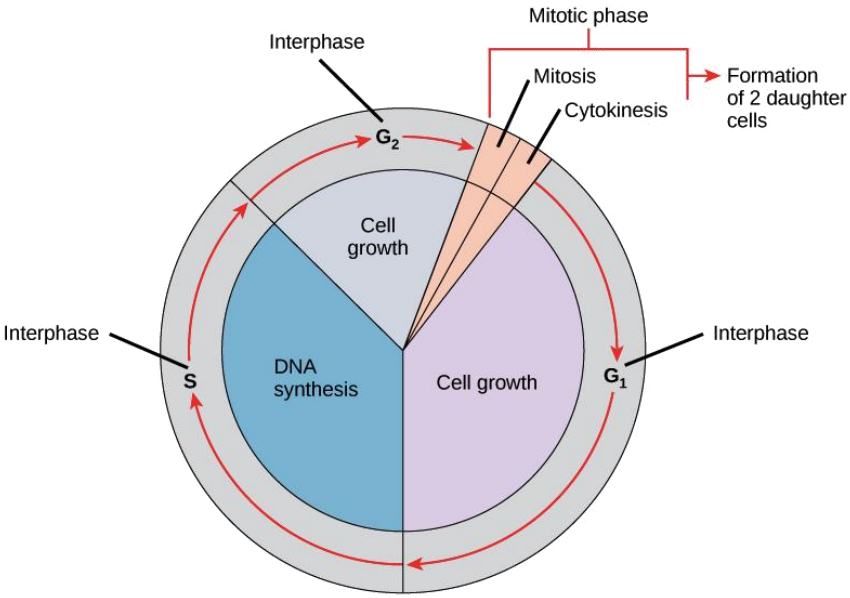
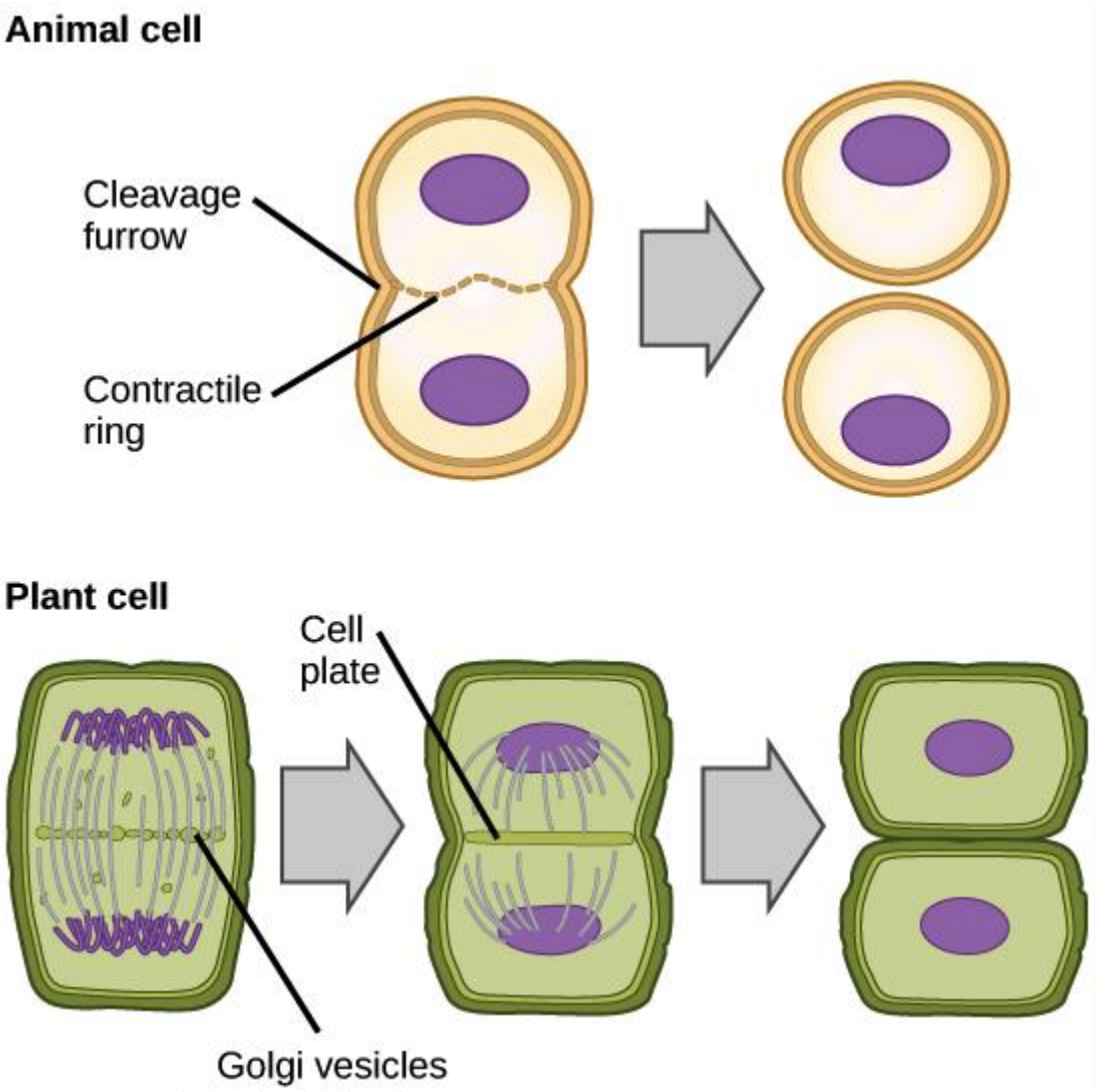


Image of the cell cycle. Interphase is composed of G1 phase (cell growth), followed by S phase (DNA synthesis), followed by G2 phase (cell growth). At the end of interphase comes the mitotic phase, which is made up of mitosis and cytokinesis and leads to the formation of two daughter cells. Mitosis precedes cytokinesis, though the two processes typically overlap somewhat.

M phase

During the mitotic (M) phase, the cell divides its copied DNA and cytoplasm to make two new cells. M phase involves two distinct division-related processes: mitosis and cytokinesis.

In **mitosis**, the nuclear DNA of the cell condenses into visible chromosomes and is pulled apart by the mitotic spindle, a specialized structure made out of microtubules. Mitosis takes place in four stages: prophase (sometimes divided into early prophase and prometaphase), metaphase, anaphase, and telophase. In **cytokinesis**, the cytoplasm of the cell is split in two, making two new cells. Cytokinesis usually begins just as mitosis is ending, with a little overlap. Importantly, cytokinesis takes place differently in animal and plant cells.



Cytokinesis in animal and plant cells.

In an animal cell, a contractile ring of cytoskeletal fibers forms at the middle of the cell and contracts inward, producing an indentation called the cleavage furrow. Eventually, the contractile ring pinches the mother cell in two, producing two daughter cells.

In a plant cell, vesicles derived from the Golgi apparatus move to the middle of the cell, where they fuse to form a structure called the cell plate. The cell plate expands outwards and connects with the side walls of the cell, creating a new cell wall that partitions the mother cell to make two daughter cells.

Image credit: "The cell cycle: FIgure 4" by OpenStax College, Biology (CC BY 3.0).

- In animals, cell division occurs when a band of cytoskeletal fibers called the **contractile ring** contracts inward and pinches the cell in two, a process called contractile cytokinesis. The indentation produced as the ring contracts inward is called the **cleavage furrow**. Animal cells can be pinched in two because they're relatively soft and squishy.
- Plant cells are much stiffer than animal cells; they're surrounded by a rigid cell wall and have high internal pressure. Because of this, plant cells divide in two by building a new structure down the middle of the cell. This structure, known as the **cell plate**, is made up of plasma membrane and cell wall components delivered in vesicles, and it partitions the cell in two.

Cell cycle exit and G_0.

What happens to the two daughter cells produced in one round of the cell cycle? This depends on what type of cells they are. Some types of cells divide rapidly, and in these cases, the daughter cells may immediately undergo another round of cell division. For instance, many cell types in an early embryo divide rapidly, and so do cells in a tumor.

Other types of cells divide slowly or not at all. These cells may exit the G_11 start subscript, 1, end subscriptphase and enter a resting state called **G_0 phase**. In G_0, a cell is not actively preparing to divide, it's just doing its job. For instance, it might conduct signals as a neuron (like the one in the drawing below) or store carbohydrates as a liver cell. G_0 is a permanent state for some cells, while others may re-start division if they get the right signals.

Binding initiates a signaling pathway

When a ligand binds to a cell-surface receptor, the receptor's intracellular domain (part inside the cell) changes in some way. Generally, it takes on a new shape, which may make it active as an enzyme or let it bind other molecules.

The change in the receptor sets off a series of signaling events. For instance, the receptor may turn on another signaling molecule inside of the cell, which in turn activates its own target. This chain reaction can eventually lead to a change in the cell's behavior or characteristics.

Because of the directional flow of information, the term **upstream** is often used to describe molecules and events that come earlier in the relay chain, while **downstream** may be used to describe those that come later (relative to a particular molecule of interest).

The molecules that relay a signal are often proteins. However, non-protein molecules like ions and phospholipids can also play important roles.

Phosphate groups can’t be attached to just any part of a protein. Instead, they are typically linked to one of the three amino acids that have hydroxyl (-OH) groups in their side chains: tyrosine, threonine, and serine. The transfer of the phosphate group is catalyzed by an enzyme called a **kinase**, and cells contain many different kinases that phosphorylate different targets.

Phosphorylation (marked as a P) is important at many stages of this pathway.

- When growth factor ligands bind to their receptors, the receptors pair up and act as kinases, attaching phosphate groups to one another’s intracellular tails.
- The activated receptors trigger a series of events (skipped here because they don't involve phosphorylation). These events activate the kinase Raf.

- **Second messengers**
- Although proteins are important in signal transduction pathways, other types of molecules can participate as well. Many pathways involve **second messengers**, small, non-protein molecules that pass along a signal initiated by the binding of a ligand (the “first messenger”) to its receptor.

Calcium ions

Calcium ions are a widely used type of second messenger. In most cells, the concentration of calcium ions in the cytosol is very low, as ion pumps in the plasma membrane continually work to remove it. For signaling purposes, may be stored in compartments such as the endoplasmic reticulum.

- Some proteins in the cell have binding sites ions, and the released ions attach to these proteins and change their shape (and thus, their activity). The proteins present and the response produced are different in different types of cells. For instance, signaling in the β-cells of the pancreas leads to the release of insulin, while signaling in muscle cells leads to muscle contraction.
    - Another second messenger used in many different cell types is **cyclic adenosine monophosphate** (**cyclic AMP** or **cAMP**), a small molecule made from ATP. In response to signals, an enzyme called **adenylyl cyclase** converts ATP into cAMP, removing two phosphates and linking the remaining phosphate to the sugar in a ring shape.

Unit 2

Leak channels

Potassium channels function to conduct potassium ions down their electrochemical gradient, doing so both rapidly (up to the diffusion rateof K^+ ions in bulk water) and selectively (excluding, most notably, sodium despite the sub-angstrom difference in ionic radius).[4]Biologically, these channels act to set or reset the resting potential in many cells. In excitable cells, such as neurons, the delayed counterflow of potassium ions shapes the action potential.

By contributing to the regulation of the action potential duration in cardiac muscle, malfunction of potassium channels may cause life-threatening arrhythmias. Potassium channels may also be involved in maintaining vascular tone.

They also regulate cellular processes such as the secretion of hormones (*e.g.*, insulin release from beta-cells in the pancreas) so their malfunction can lead to diseases (such as diabetes)

Potassium channels have a tetrameric structure in which four identical protein subunitsassociate to form a fourfold symmetric (C_4) complex arranged around a central ion conducting pore (i.e., a homotetramer). Alternatively four related but not identical protein subunits may associate to form heterotetrameric complexes with pseudo C_4 symmetry. All potassium channel subunits have a distinctive pore-loop structure that lines the top of the pore and is responsible for potassium selective permeability.

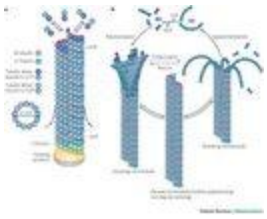
Microtubules and Filaments

The **cytoskeleton** is a structure that helps cells maintain their shape and internal organization, and it also provides mechanical support that enables cells to carry out essential functions like division and movement. There is no single cytoskeletal component. Rather, several different components work together to form the cytoskeleton.

What Is the Cytoskeleton Made Of?

The cytoskeleton of eukaryotic cells is made of filamentous proteins, and it provides mechanical support to the cell and its cytoplasmic constituents. All cytoskeletons consist of three major classes of elements that differ in size and in protein composition. Microtubules are the largest type of filament, with a diameter of about 25 nanometers (nm), and they are composed of a protein called **tubulin**. Actin filaments are the smallest type, with a diameter of only about 6 nm, and they are made of a protein called **actin**. Intermediate filaments, as their name suggests, are mid-sized, with a diameter of about 10 nm. Unlike actin filaments and microtubules, intermediate filaments are constructed from a number of different subunit proteins.

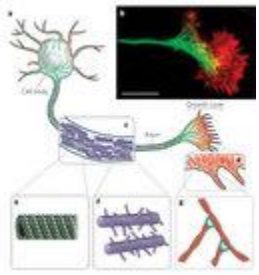
What Do Microtubules Do?



Tubulin contains two polypeptide subunits, and dimers of these subunits string together to make long strands called **protofilaments**. Thirteen protofilaments then come together to form the hollow, straw-shaped filaments of microtubules. Microtubules are ever-changing, with reactions constantly adding and subtracting tubulin dimers at both ends of the filament (Figure 1). The rates of change at either end are not balanced — one end grows more rapidly and is called the **plus end**, whereas the other end is known as the **minus end**. In cells, the minus ends of microtubules are anchored in structures called **microtubule organizing centers** (MTOCs). The primary MTOC in a cell is called the **centrosome**, and it is usually located adjacent to the nucleus.

Microtubules tend to grow out from the centrosome to the plasma membrane. In nondividing cells, microtubule networks radiate out from the centrosome to provide the basic organization of the cytoplasm, including the positioning of organelles.

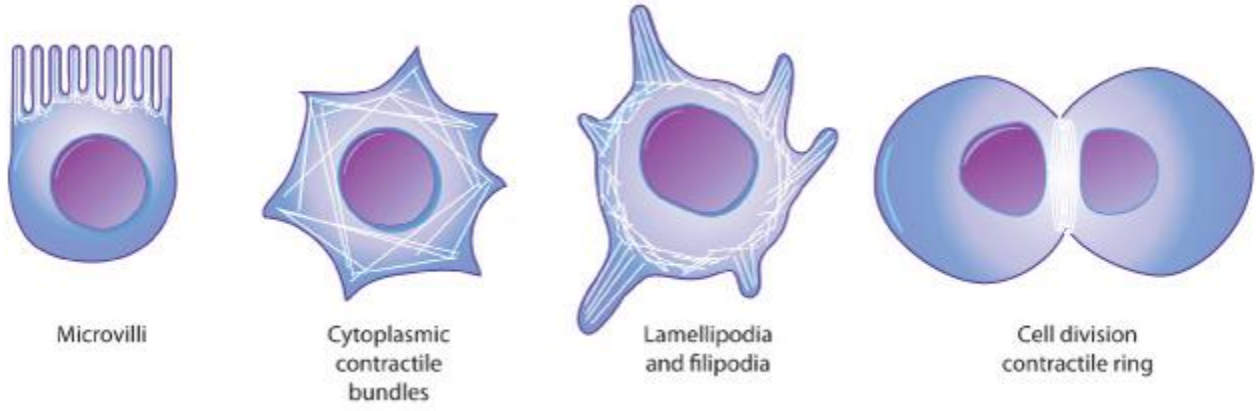
What Do Actin Filaments Do?



The protein actin is abundant in all eukaryotic cells. It was first discovered in skeletal muscle, where actin filaments slide along filaments of another protein called **myosin** to make the cells contract. (In nonmuscle cells, actin filaments are less organized and myosin is much less prominent.) Actin

filaments are made up of identical actin proteins arranged in a long spiral chain. Like microtubules, actin filaments have plus and minus ends, with more ATP-powered growth occurring at a filament's plus end (Figure 2).

In many types of cells, networks of actin filaments are found beneath the **cell cortex**, which is the meshwork of membrane-associated proteins that supports and strengthens the plasma membrane. Such networks allow cells to hold — and move — specialized shapes, such as the brush border of microvilli. Actin filaments are also involved in cytokinesis and cell movement (Figure 3).



What Do Intermediate Filaments Do?

Intermediate filaments come in several types, but they are generally strong and ropelike. Their functions are primarily mechanical and, as a class, intermediate filaments are less dynamic than actin filaments or microtubules. Intermediate filaments commonly work in tandem with microtubules, providing strength and support for the fragile tubulin structures.

All cells have intermediate filaments, but the protein subunits of these structures vary. Some cells have multiple types of intermediate filaments, and some intermediate filaments are associated with specific cell types. For example, neurofilaments are found specifically in neurons (most prominently in the long axons of these cells), desmin filaments are found specifically in muscle cells, and keratins are found specifically in epithelial cells. Other intermediate filaments are distributed more widely. Note that intermediate filaments are not polar in the way that actin or tubulin are (Figure 4).

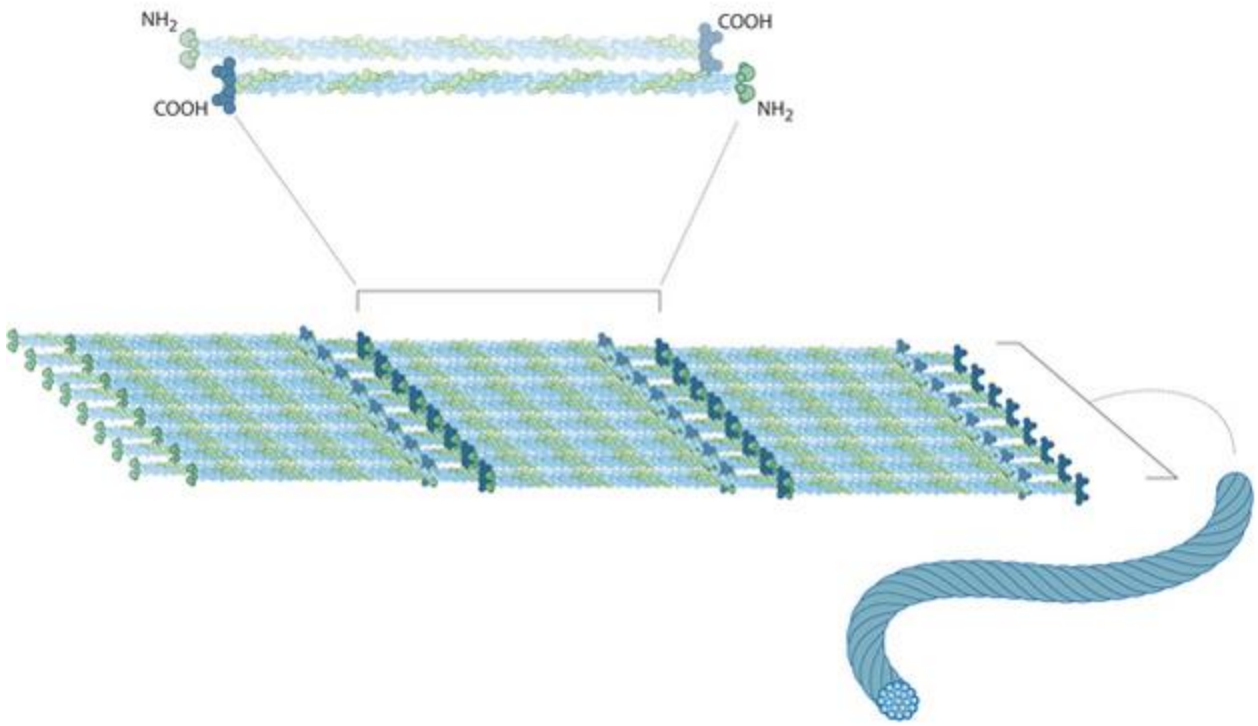


Figure 4: The structure of intermediate filaments

Intermediate filaments are composed of smaller strands in the shape of rods. Eight rods are aligned in a staggered array with another eight rods, and these components all twist together to form the rope-like conformation of an intermediate filament.

How Do Cells Move?

Cytoskeletal filaments provide the basis for cell movement. For instance, **cilia** and (eukaryotic) **flagella** move as a result of microtubules sliding along each other. In fact, cross sections of these tail-like cellular extensions show organized arrays of microtubules.

Other cell movements, such as the pinching off of the cell membrane in the final step of cell division (also known as cytokinesis) are produced by the contractile capacity of actin filament networks. Actin filaments are extremely dynamic and can rapidly form and disassemble. In fact, this dynamic action underlies the crawling behavior of cells such as amoebae. At the leading edge of a moving cell, actin filaments are rapidly polymerizing; at its rear edge,

they are quickly depolymerizing (Figure 5). A large number of other proteins participate in actin assembly and disassembly as well.

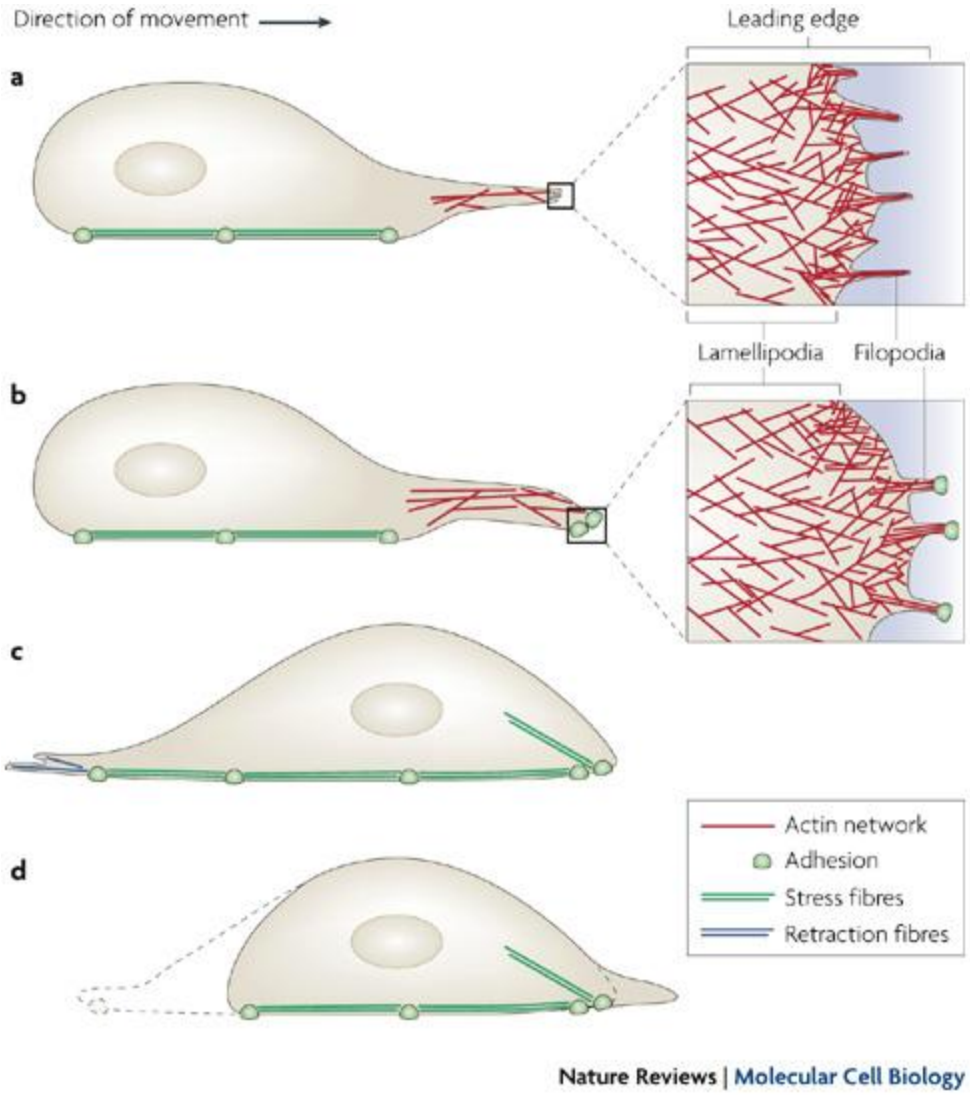


Figure 5: Cell migration is dependent on different actin filament structures.

(A) In a cell, motility is initiated by an actin-dependent protrusion of the cell's leading edge, which is composed of armlike structures called lamellipodia and filopodia. These protrusive structures contain actin filaments, with elongating barbed ends orientated toward the plasma membrane. (B) During cellular arm extension, the plasma membrane sticks to the surface at the leading edge. (C) Next, the nucleus and the cell body are

pushed forward through intracellular contraction forces mediated by stress fibers. (D) Then, retraction fibers pull the rear of the cell forward.

Conclusion

The cytoskeleton of a cell is made up of microtubules, actin filaments, and intermediate filaments. These structures give the cell its shape and help organize the cell's parts. In addition, they provide a basis for movement and cell division.

There are a few different types of cell-cell interactions. Some of these interactions are meant for big molecules that enter and exit the cell called, endocytosis (entering the cell) and exocytosis (exiting the cell). For smaller particles like amino acids, water, ions and other solutes there are different types of direct contact between the cells called gap junctions.

Exocytosis - exiting the cell

Exocytosis is a process used by the cell to take out its trash and to incorporate proteins into the cell membrane. During exocytosis, the phospholipid bilayer of the cell membrane surrounds the waste proteins, creating a bubble-like structure called a vesicle. Vesicles are frequently used in the cell for transportation of molecules across the cell membrane.

Diagram showing vesicle fusing with cell membrane to expel its contents via exocytosis.

Waste proteins

A slightly different process occurs for waste products being ejected out of the cell, instead of proteins being incorporated into the cell membrane. Once the vesicle has enclosed the waste proteins on the inside of the cell, it moves towards the cell membrane. The vesicle merges with the cell membrane, opening the bubble-like structure and ejecting the contents in the environment surrounding the cell.

Proteins destined for the cell membrane

Exocytosis is also used to integrate new proteins into the cell membrane. In this process, the new protein is formed inside the cell, and migrates to phospholipid bilayer of the vesicle. The vesicle, containing the new protein as a part of the phospholipid bilayer, fuses with the cell membrane. This allows the protein to be directly integrated into the cell membrane when the vesicle, in the same way as with waste proteins, fuses and opens with the cell membrane.

Diagram showing a vesicle fusing with cell membrane to incorporate a new membrane protein.

Endocytosis - bringing in the goods

Endocytosis is the opposite process of exocytosis. Endocytosis brings molecules into the cell. These molecules are important for the survival of the cell, such as glucose. There are three different styles of endocytosis: 1) phagocytosis, 2) pinocytosis, and 3) receptor-mediated endocytosis.

Phagocytosis

Phagocytosis is the process similar to eating, where the cell engulfs a molecule in order to move it to the interior of the cell. The process starts by the molecule binding to specific receptors on the surface of the cell membrane, triggering the cell membrane to reshape, surrounding the molecule. The receptors allow this process to be specific, controlling what can enter the cell. Then, the two ends of the cell fuse, creating a vesicle that surrounds the molecule. Eventually the membrane around the molecule will be digested and its contents will be used! For example, white blood cells recognize pathogens, such as viruses or bacterial cells, outside of the cell and will use phagocytosis to bring it in to destroy it!

Diagram showing how a cell takes up a virus via phagocytosis.

Pinocytosis

If phagocytosis is how the cell eats, then pinocytosis is how the cell drinks. Pinocytosis engulfs dissolved ions and other solutes in the liquid medium surrounding the cell. This is different than phagocytosis, which brings full, undissolved or insoluble molecules into the cell. The distortion of the cell membrane to engulf the dissolved solutes is similar to that of phagocytosis. Another important distinction is that pinocytosis is not specific to what is carried into the cell, whereas phagocytosis can be highly specific. The liquid medium outside the cell is always filled with dissolved particles and solutes that are handy for the cell, so the cell doesn't need this process to be specific.

Diagram showing how a cell takes up liquid via pinocytosis.

Receptor-mediated endocytosis

Receptor-mediated endocytosis is very specific with respect to what is imported into the cell. It's actually a bit like a lock-and-key system. There are receptors embedded in the cell membrane that, when bound by molecules with an exact match in shape, size, or other physical attribute, will allow the molecule to enter into the cell through the same engulfment process as phagocytosis or pinocytosis.

Diagram showing how certain substances must bind a cell membrane protein to be taken up by that cell.

Cell junctions

There are many different ways that cells can connect to each other. The three main ways for cells to connect with each other are: gap junctions, tight junctions, and desmosomes. These types of junctions have different purposes, and are found in different places.

Gap Junctions

Gap Junction Definition

Gap junctions are a type of cell junction in which adjacent cells are connected through protein channels. These channels connect the cytoplasm of each cell and allow molecules, ions, and electrical signals to pass between them. Gap junctions are found in between the vast majority of cells within the body because they are found between all cells that are directly touching other cells. Exceptions include cells that move around and do not usually come into close contact with other cells, such as sperm cells and red blood cells. Gap junctions are only found in animal cells; plant cells are connected by channels called plasmodesmata instead.

Function of Gap Junctions

The main function of gap junctions is to connect cells together so that molecules may pass from one cell to the other. This allows for cell-to-cell communication, and makes it so that molecules can directly enter neighboring cells without having to go through the extracellular fluidsurrounding the cells. Gap junctions are especially important during embryonic development, a time when neighboring cells must communicate with each other in order for them to develop in the right place at the right time. If gap junctions are blocked, embryos cannot develop normally.

Tight Junctions

Tight Junctions Definition

Tight junctions are areas where the membranes of two adjacent cells join together to form a barrier. The cell membranes are connected by strands of transmembrane proteins such as claudins and occludins. Tight junctions bind cells together, prevent molecules from passing in between the cells, and also help to maintain the polarity of cells. They are only found in vertebrates, animals with a backbone and skeleton; invertebrates have septate junctions instead.

Function of Tight Junctions

Tight junctions have several different functions. Their most important functions are to help cells form a barrier that prevents molecules from getting through, and to stop proteins in the cell membrane from moving around. Tight junctions are often found at epithelial cells, which are cells that line the surface of the body and line body cavities. Not only do epithelial cells separate the body from the surrounding environment, they also separate surfaces within the body. Therefore, it is very important that the permeability of molecules through layers of epithelial cells is tightly controlled.
Claudins and occludins are the two main types of proteins present at tight junctions, and they are both transmembrane proteins. Claudins are important in forming tight junctions, while occludins play more of a role in keeping the tight junction stable and maintaining the barrier between cells that keeps unwanted molecules out.

Tight junctions are a branching network of protein strands on the surface of a cell that link with each other throughout the surface of the membrane. The strands are

formed by transmembrane proteins on the surfaces of the cell membranes that are adjacent to each other.

Desmosomes

Finally, desmosomes are quite different from gap junctions and tight junctions. With desmosomes, cell membranes are connected by thread like substances that connect the cells across the space in between cells. Much like tight junctions, desmosomes physically hold the cells together, but do not allow fluids or materials to pass from the inside of one cell to the next. These connections are also attached to the scaffolding of the cell, called the cytoskeleton, to help with structural support. The space in between the cells allows for water and solutes to flow freely between each cell without compromising the connection. This is convenient for areas of our body that experience high stress like in our skin or our intestines because the space in between the cells offer flexibility that the other junctions can't.

Plasmodesmata (singular: **plasmodesma**) are microscopic channels which traverse the cell wallsof plant cells[2] and some algal cells, enabling transport and communication between them. Plasmodesmata evolved independently in several lineages,[3] and species that have these structures include members of the Charophyceae, Charales, Coleochaetales and Phaeophyceae (which are all algae), as well as all embryophytes, better known as land plants.[4] Unlike animal cells, almost every plant cell is surrounded by a polysaccharide cell wall. Neighbouring plant cells are therefore separated by a pair of cell walls and the intervening middle lamella, forming an extracellular domain known as the apoplast. Although cell walls are permeable to small soluble proteins and other solutes, plasmodesmata enable direct, regulated, symplastic transport of substances between cells. There are two forms of plasmodesmata: primary plasmodesmata, which are formed

during cell division, and secondary plasmodesmata, which can form between mature cells.

Unit 3

An **interrupted gene** (also called a **split gene**) is a gene that contains sections of DNA called exons, which are expressed as RNA and protein, interrupted by sections of DNA called introns, which are not expressed.

The DNA sequence in the exon provides instructions for coding proteins. The function of the intron was not understood at first, and they were called noncoding or junk DNA. Split genes were independently discovered by Richard J. Roberts and Phillip A. Sharp in 1977, for which they shared the 1993 Nobel Prize in Physiology or Medicine [1] Their discovery implied the existence of then-unknown machinery for splicing out introns and assembling genes; namely, the spliceosome. It was soon accepted that 94% of human genes were interrupted, and perhaps 50% of hereditary diseases involved errors in splicing introns out of interrupted genes.[2] The best-known example of a disease caused by a splicing error is Beta-thalassemia, in which extra intronic material is erroneously spliced into the gene for making hemoglobin.

Lower eukaryotes, including yeast, have many *uninterrupted* regions, as they contain long stretches of exons that create the mRNAnecessary for the synthesis of proteins. This does not mean, however, that these sections are fully uninterrupted, as tRNA synthesis requires excision of a nucleotide sequence, followed by ligation. Nevertheless, gene interruption is the rule.

ifferences between Exons and Introns :
1) exons are the coding areas, whereas introns are the non coding areas of the gene.
2) exons code for the proteins but the introns are not implicated with the protein coding.
3) introns are less conserved as their sequences change very frequently over time. However exons are very much conserved and their sequence does not

change rapidly over time or in between species.
4) exons are DNA sequences represented in the final RNA molecule, but introns are removed through RNA splicing for generating a mature RNA molecule.

n **overlapping gene** is a gene whose expressible nucleotide sequence partially overlaps with the expressible nucleotide sequence of another gene.[1] In this way, a nucleotide sequence may make a contribution to the function of one or more gene products. **Overprinting**refers to a type of overlap in which all or part of the sequence of one gene is read in an alternate reading frame from another gene at the same locus. Overprinting has been hypothesized as a mechanism for *de novo* emergence of new genes from existing sequences, either older genes or previously non-coding regions of the genome.[2] Overprinted genes are particularly common features of the genomicorganization of viruses, likely to greatly increase the number of potential expressible genes from a small set of viral genetic information.

Genes may overlap in a variety of ways and can be classified by their positions relative to each other.

- *Unidirectional* or *tandem* overlap: the 3' end of one gene overlaps with the 5'end of another gene on the same strand. This arrangement can be symbolized with the notation → → where arrows indicate the reading frame from start to end.
- *Convergent* or *end-on* overlap: the 3' ends of the two genes overlap on opposite strands. This can be written as → ←.
- *Divergent* or *tail-on* overlap: the 5' ends of the two genes overlap on opposite strands. This can be written as ← →.

Overlapping genes can also be classified by *phases*, which describe their relative reading frames

- *In-phase overlap* occurs when the shared sequences use the same reading frame. This is also known as "phase 0". Unidirectional genes with phase 0 overlap are not considered distinct genes, but rather as alternative start sites of the same gene.
- *Out-of-phase overlaps* occurs when the shared sequences use different reading frames. This can occur in "phase 1" or "phase 2", depending on

whether the reading frames are offset by 1 or 2 nucleotides. Because a codon is three nucleotides long, an offset of three nucleotides is an in-phase, phase 0 frame.

INTRONS
VERSUS
EXONS

INTRONS	EXONS
Introns are the DNA segments which do not encode any amino acid sequence in the coding region	Exons are the DNA segments which encode a part of an amino acid sequence of a complete protein
Belong to the non-coding DNA	Belong to the coding DNA
Considered as the bases located between two exons	Considered as the bases which encode an amino acid sequence of a protein
Found in eukaryotes	Found in both prokaryotes and eukaryotes
Stay in the nucleus by splicing out from the mRNA primary transcript during mRNA processing inside nucleus	Leave the nucleus to the cytoplasm after the production of the mature mRNA
Found in DNA and mRNA primary transcript	Found in both DNA and mRNA
The sequences are less conserved	The sequences are highly conserved