Cells, function and interaction

Get yourself connected

In addition to being important in separating the outside and inside of the cell, the membrane allows the cell to interact and communicate with surrounding cells and the extracellular matrix. These interactions are known as ‘junctions’ and can be separated into three types, determined by their structure and function: tight, anchoring and communicating junctions.

Tight junctions (sometimes called occluding junctions)

Tight junctions create a seal between neighbouring cells at the plasma membranes, preventing small molecules ‘leaking’ from one cell to the next. This creates a ‘sheet’ of cells, which can act as a wall within an organ or tissue, keeping molecules on one side by preventing them from moving between the cells in the wall.

In the human digestive system, these cell sheets are used as a wall between the digestive tract and blood vessels, meaning nutrients have to pass through these cells to reach the blood. They have also been shown to be important in maintaining the blood–brain barrier.

Anchoring junctions

As their name suggests, anchoring junctions act to anchor a cell to the cytoskeleton of a neighbouring cell or to the extracellular matrix, through the use of either actin or intermediate filament proteins in the cytoskeleton.

Between two neighbouring cells, anchoring junctions use cadherin proteins at the cell membranes to link the two cells’ cytoskeletons. Junctions that link actin cytoskeletons together are called adherens, and junctions that link intermediate filaments together are called desmosomes.

Anchoring junctions between a cell and the extracellular matrix use integrin proteins at the cell membrane. Junctions that link actin in the cell’s cytoskeleton to the extracellular matrix are called focal adhesions, and junctions that link intermediate filaments to the matrix are called hemidesmosome.

Communicating junctions

Communicating junctions are different to tight and anchoring junctions, as they not only link cells together but also let them communicate. The main communicating junctions between animal cells are gap junctions. These specialised junctions connect the cytoplasm of neighbouring cells directly to allow molecules, ions and electrical impulses to pass between the cells.

In plant cells, plasmodesmata act in a similar way to gap junctions. They allow cell–cell communication but are themselves lined with plasma membrane and directly connect the endoplasmic reticulum of the two cells.

Cells within cells

Were some organelles originally bacteria?

Some organelles, such as mitochondria and chloroplasts, found inside eukaryotic cells look rather like cells themselves. According to the endosymbiotic theory, eukaryotes originated when symbiotic bacteria (which exist alongside cells in a mutually beneficial relationship) began to live inside larger cells, giving them ready-made compartments. Over time, these bacteria became permanent additions – chloroplasts and mitochondria – to the cells we see today.

This would account for the loop of mitochondrial DNA (mtDNA) found within mitochondria that codes for ribosomal RNA (rRNA) and for components of the electron transport chain, which is involved in oxidative phosphorylation. mtDNA is maternally inherited through the egg and accounts for less than 1 per cent of the cell's total DNA.

Working together

Cellular organelles work together.

After transcription in the nucleus, proteins are synthesised in translation using the genetic code of mRNA by ribosomes. Some ribosomes are attached to the rough endoplasmic reticulum (rER) and allow proteins to be directed into the rER as they are created. Other ribosomes are found 'freely' in the cytoplasm, where they create proteins that are then transported to the rER.

Inside the rER lumen the proteins fold up, helped by special proteins called 'chaperones' that ensure each protein folds correctly into its 3D shape. While they are in the ER, proteins undergo some modifications – usually the addition of sugar chains – that can help the proteins fold correctly and prevent them being broken down.

The next stop on the proteins' journey is the Golgi apparatus. The proteins in the rER are packaged up into membrane-bound vesicles and, with the help of the cytoskeleton, moved along to the Golgi apparatus. The Golgi apparatus is a stack of multiple compartments. As the proteins move through, each compartment modifies the protein in a different way as each has different specialised enzymes. These modifications often include adding or changing sugar chains. After the modifications are complete, the proteins are again packaged up into vesicles, and from the Golgi apparatus they face one of three fates.

First, many proteins are transported to the plasma membrane, where the vesicle membrane and plasma membrane fuse, releasing the contents into the extracellular matrix – a process known as exocytosis.

Second, some vesicles will be 'held' at the plasma membrane, only to be released upon a specific signal. Neurotransmitters, for example, are held in vesicles until an action potential causes depolarisation. This depolarisation causes a calcium influx that allows the vesicle to fuse with the plasma membrane and release the neurotransmitter into the synaptic cleft.

The third fate acts as a quality control for the cell: any misfolded proteins will be transported to the lysosome to be degraded. Proteins that don't fold correctly may not be able to do their job properly or might even be harmful for the cell.

One, two or many?

Not all of your cells have a single nucleus

Most cells have a single nucleus, but not all. Some cells in adult heart muscle have two nuclei. This happens because the cells take the normal cell cycle through copying and separation of chromosomes, but do not go the whole way and divide. Why does this happen?

Skeletal muscles, such as your biceps, have very long cells with many nuclei. They form by fusion of cells with one nucleus, and their multiple nuclei may help them produce the many proteins required for muscle contraction. Another idea is that one nucleus lies dormant but triggers further cell division if the muscle gets damaged, acting as a 'back-up' nucleus.

By contrast, red blood cells in mammals have no nucleus. These cells are specialised for carrying oxygen and lose their nucleus during the final stage of their development, to maximise the amount of oxygen they can carry.

Passing on the message

Cells pass on signals via cascades of events

Cells have evolved efficient ways of processing the many signals they receive. To recognise a signal, the cell needs receptor proteins that are specific to the signal. This signal may be chemical, such as a hormone or neurotransmitter, or physical, such as light or pressure, to allow the cell to respond to its changing environment.

Some receptors exist inside the cell and bind to signal molecules that are able to pass through the cell membrane, such as the hormone oestrogen.

Most of these receptors exist on the exterior of the cell membrane, facing out into the extracellular matrix in order to recognise signals (or first messengers) that may not be able to get into the cell. These receptors belong to one of three groups – G-protein coupled receptors (GPCRs), ion channel receptors and enzyme-linked receptors – depending on the mechanism they use to relay the signal into the cell.

Many enzyme-linked receptors activate adenylyl cyclase, an enzyme that transforms ATP into cyclic adenosine monophosphate (cAMP) – which is a common second messenger inside the cell. Multiple molecules of cAMP are made for each bound first messenger, amplifying the message; this is known as a signal transduction cascade. The effects of cAMP depend on both the first messenger (often a hormone) and the target cell.

For example, adrenaline increases heart rate and how strongly the heart beats, as well as promoting glycogen breakdown in muscle. Different hormones whose actions are mediated by cAMP can cause the same response in a given cell – for example, adrenaline, glucagon and other hormones trigger the breakdown of triglycerides in fat cells.

On the move

Proteins keep cells together

Smaller structures inside cells are often made of microtubules (tube-shaped polymers of the protein tubulin). Microtubules are very versatile and have evolved to work in a range of different ways. For example, microtubules form the cytoskeleton, an internal scaffold in cells. Microtubule structures are dynamic and are constantly being built, pulled apart and rebuilt.

Cilia, thin rods that protrude from the surface of cells, are bundles of microtubules. The most basic cilia move in the ebb and flow of fluid outside the cell, sensing changes in the environment. Motile cilia can move fluid themselves instead of just being moved by it. Millions of cilia move to sweep mucus up out of the lungs into the throat, removing inhaled dust and dead cells.

Flagella, which are larger, are also tightly arranged bundles of microtubules. They help cells move and can also be involved in sensing the environment outside the cell. Eukaryotes (cells with nuclei) from any species have microtubule, cilia and flagella proteins with very similar sequences and secondary structures. As such, these proteins are ‘highly conserved’. In prokaryotic cells such as bacteria, which do not have a nuclear membrane, the flagellum is made from a different protein called flagellin.

Motile cilia and flagella are powered by tiny cellular machines, which are also made from proteins. Molecular motors like this move muscles, power cilia, shift cargo along networks of microtubules inside the cell and organise chromosomes for cell division.