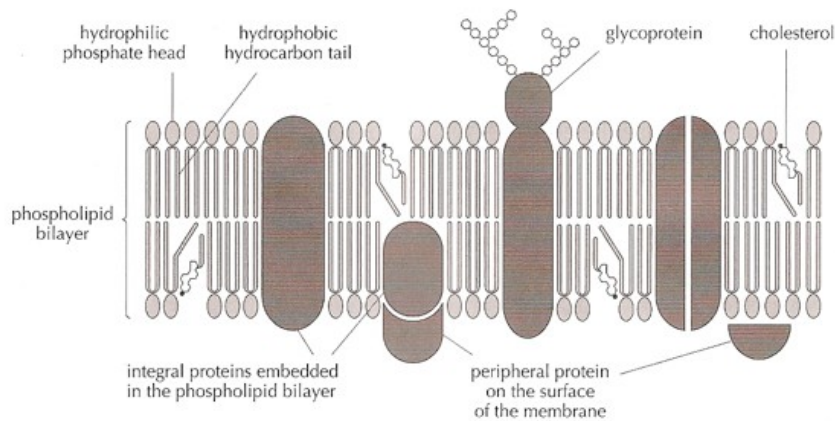


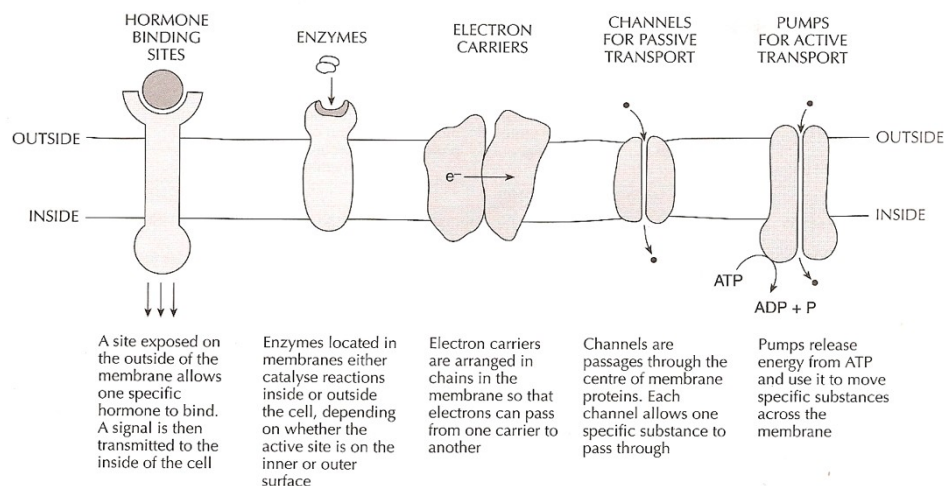
1.3 (B.2.1) Membranes and membrane transport

Fluid mosaic model of a biological membrane

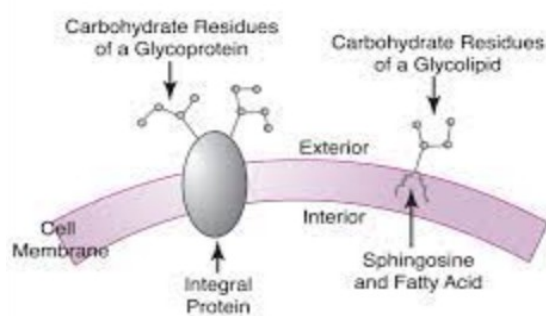


Phospholipids: The attraction between the hydrophobic tails in the centre and between the hydrophilic heads and water, assembles membranes naturally and makes them very stable. Substances with this property (i.e possessing hydrophilic and hydrophobic regions) are called **amphipathic**.

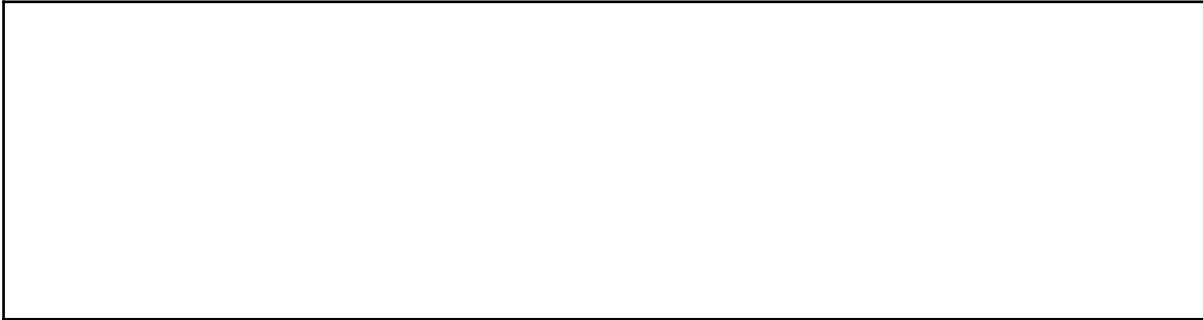
Membrane proteins possess various roles



Glycoproteins and **glycolipids** are used for cell adhesion and cell-to-cell recognition. They distinguish between self and non-self cells, so pathogens and foreign tissues can be recognized and destroyed.



Application: Draw a 2D representation of the fluid mosaic plasma membrane model! Include peripheral, integral proteins, glycoproteins, phospholipids and cholesterol. Indicate hydrophobic and hydrophilic regions.



*hint: Integral proteins are embedded in one or both of the lipid layers of a membrane. Peripheral proteins are attached to one or other surface of the bilayer.

Transport across membranes

Membranes control the composition of cells by mediating *transport* of substances across them.

1) **Passive transport** is the movement of substances across membranes without the use of ATP

1a) **Diffusion** is the movement of **molecules** and **ions** across a partially permeable membrane (phospholipids) from a region of high concentration to a region of low concentration.

- **Simple diffusion** is not selective and depends only on the concentration gradient, particle size and polarity or charge of molecules (e.g. oxygen and carbon dioxide use simple diffusion).
- In cases where selective permeability is required, substances use **channel proteins** to pass in or out the cell. This is called **facilitated diffusion**.

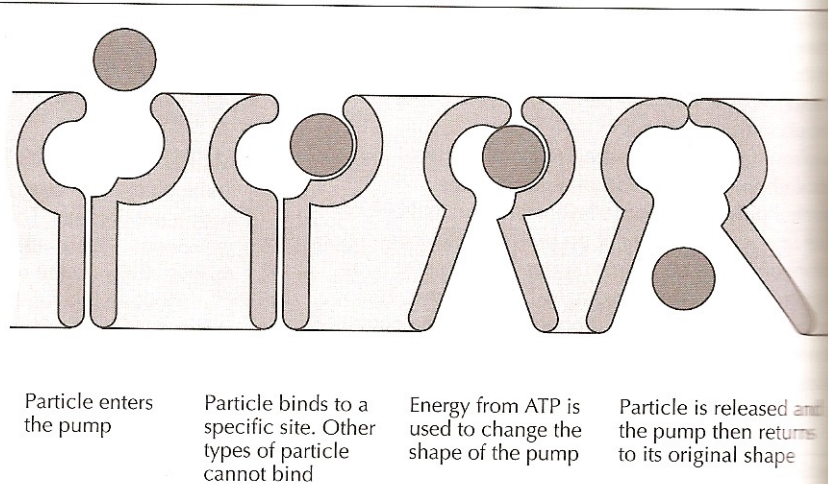
1b) **Osmosis:** The movement of **water** (only!) across a partially permeable membrane from a region of low solute concentration to a region of high solute concentration. **Aquaporins** are channels that increase membrane permeability to water (e.g. found in kidney cells and plant root cells).

2) **Active transport** is the movement of substances across membranes from a region of low concentration to a region of high concentration (meaning against a concentration gradient).

The use of **ATP** and **pump proteins** is essential here.

Figure 1: Mechanism of active transport**ACTIVE TRANSPORT
ACROSS MEMBRANES**

Active transport is the movement of substances across membranes using energy from ATP. Active transport can move substances against the concentration gradient – from a region of lower concentration to a region of higher concentration. Protein pumps in the membrane are used for active transport. Each pump only transports particular substances, so cells can control what is absorbed and what is expelled.

**Some concepts on solution composition**

- **Solute concentration** is the amount of solid or gas dissolved in a set volume of liquid.
A **hypertonic** solution has a higher concentration of solutes than a **hypotonic** solution.
- **Water concentration** is the amount of water molecules present in a space.
Water flows out of areas with low solute (hypotonic) into areas with high solute (hypertonic).

Higher Level

More detail on membrane composition

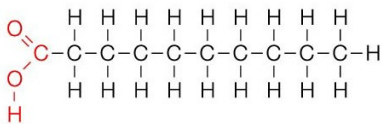
Fatty acid composition and lipid bilayer fluidity

Saturated fatty acids have **no** double bonds between the carbon atoms of the fatty acid chain. That is, the chain of carbon atoms is full of (or "saturated" with) hydrogen atoms.

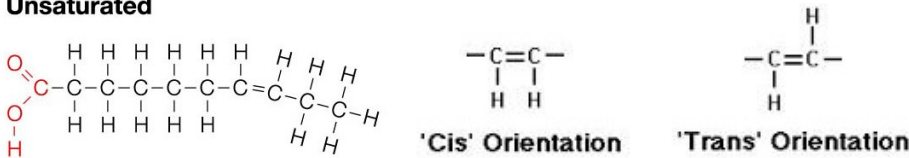
Unsaturated fatty acids have **at least one** double bond within the fatty acid chain. They have **lower** melting points. *Cis* fatty acids have hydrogen atoms on the same side of the two double bonded carbon atoms. *Trans* fatty acids hold hydrogen atoms on opposite sides. A fatty acid chain is:

- Monounsaturated if it contains one double bond.
- Polyunsaturated if it contains more than one double bond.

Saturated



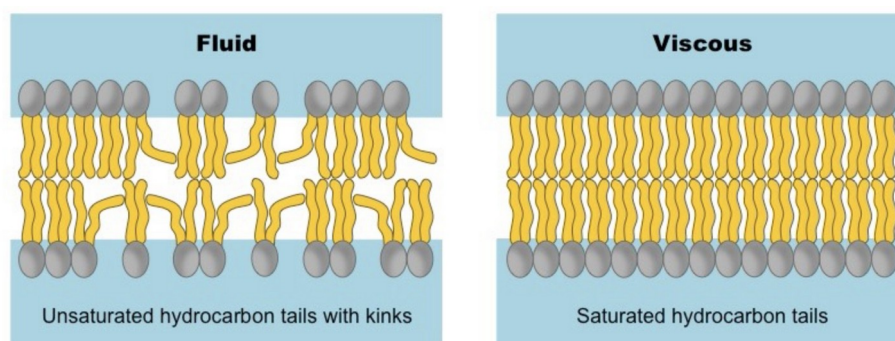
Unsaturated



A membrane containing only *saturated* fatty acids (right) is:

→ thicker, more viscous, has a higher density of phospholipids and a **higher melting point**...

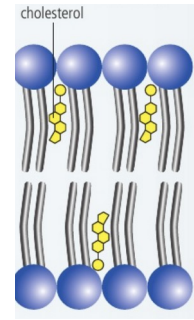
... than a membrane containing both *saturated* and *unsaturated* fatty acids (left). The fluid membrane on the left has a lower melting point. [A melting point defines the minimum temperature required for life.]



Adaptation of membrane composition in relation to habitat: Antarctic Fish have been found to have a higher percentage of unsaturated fatty acids in their membranes than fish from warmer waters. *Why?*

Cholesterol and lipid bilayer fluidity

Cholesterol (a lipid) is a component of *animal* cell membranes (20 - 40%). It acts as a modulator (adjustor) of membrane fluidity. It stabilizes membranes at high temperatures and ensures the membrane will not solidify (freeze) at low ones.

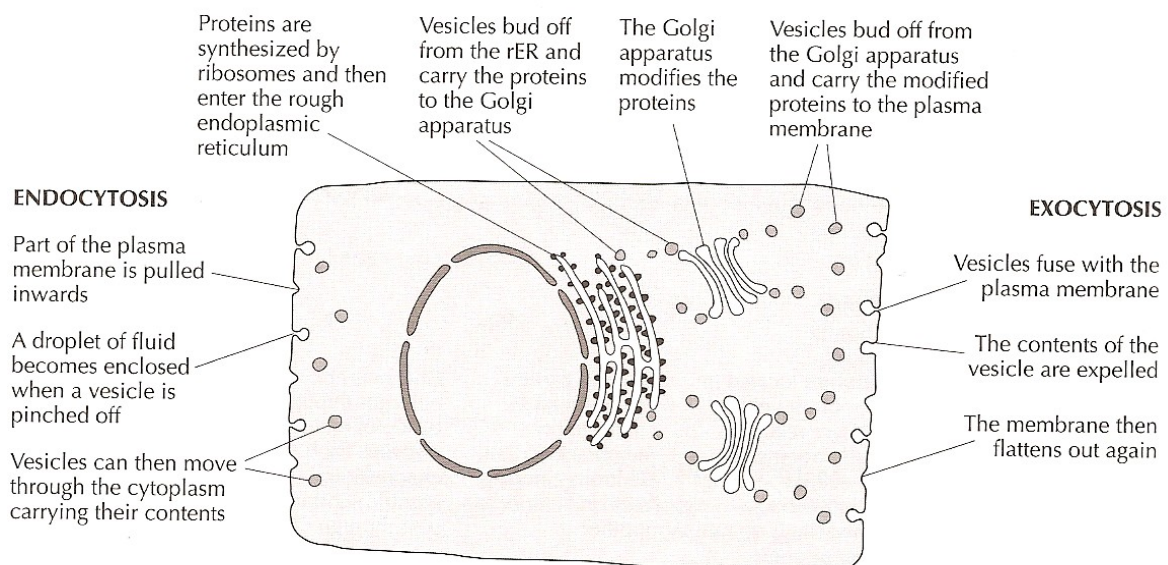


More modes of transport across membranes

Summary of modes of transport in cells:

1. Simple Diffusion
2. Facilitated Diffusion
3. Osmosis
4. Endocytosis
5. Exocytosis
6. Active Transport (direct or indirect)

Vesicles (formation and fusion) are used in the processes of endocytosis and exocytosis.



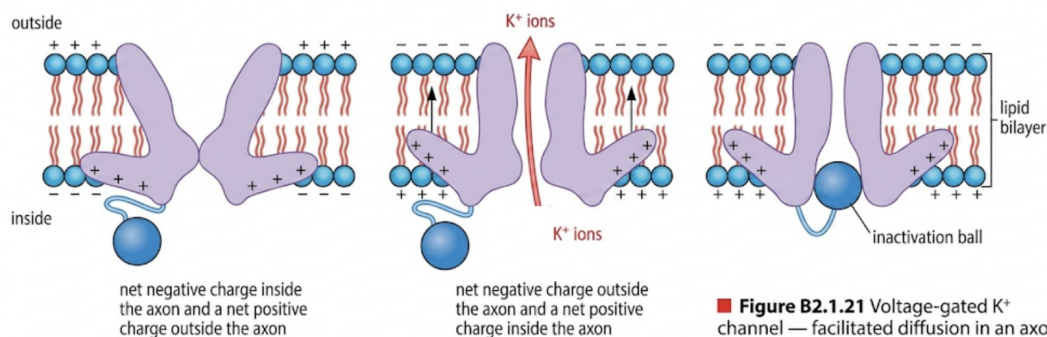
Endocytosis can be either **pinocytosis** (liquid substances) or **phagocytosis** (solid).

Applications of modes on transport in the Nervous System.

Gated Ion Channels are used for *facilitated diffusion* in neurons (they produce nerve impulses).

Gated ion channels are a specialised type of channel protein, said to be gated because they are not permanently open. Instead, they open and close in response to electrical or chemical stimuli, depending on whether it is a voltage-gated or neurotransmitter-gated channel.

Voltage-gated ion channels are activated by reversals in electrical potential (voltage/charge difference across membrane), and are permeable by a specific type of ion. Sodium (Na^+) channels and potassium (K^+) channels embedded in neuron axons are examples of voltage-gated ion channels. Depending on a threshold potential, they may open or close. In the case of potassium (K^+) channels, they open when the inside of the nerve cell becomes more positive than the resting state (see figure), to let positively charged K^+ ions out via *facilitated diffusion* (through a channel, with the concentration gradient).

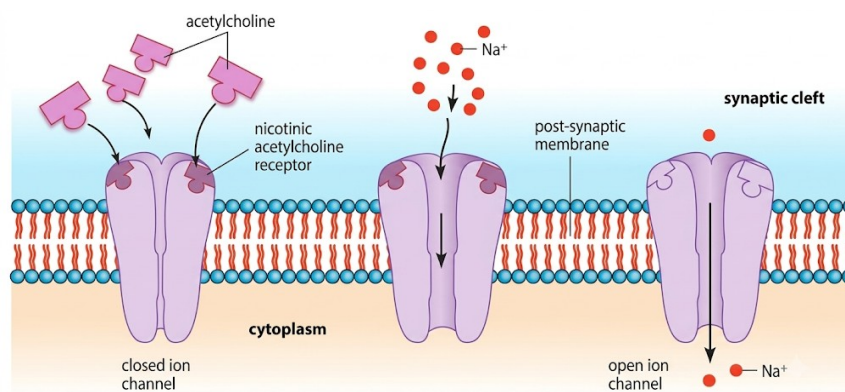


■ **Figure B2.1.21** Voltage-gated K^+ channel — facilitated diffusion in an axon

Neurotransmitter-gated ion channels are activated by binding of chemicals to their surface (they have the property of a receptor), and are also permeable by a specific type of ion. *Nicotinic acetylcholine receptors are an example of a neurotransmitter-gated (or chemically gated) ion channel. They are found at neural synapses. A *synapse* is a small gap between two neurons, across which small chemicals called *neurotransmitters* must 'jump' to pass on a *nerve impulse* (the 'messages' of the nervous system).

Binding of the neurotransmitter *acetylcholine* on the receptor causes a conformational change and the channel opens, allowing sodium ions (Na^+) to pass via *facilitated diffusion*. The binding of acetylcholine is said to be 'reversible'. When removed, the conformational change is reversed and the pore closes.

*Both acetylcholine and nicotine molecules may bind to these receptors, hence the name nicotinic acetylcholine receptors. You may investigate effects of nicotine binding to the ion channel. Relate it to addiction.



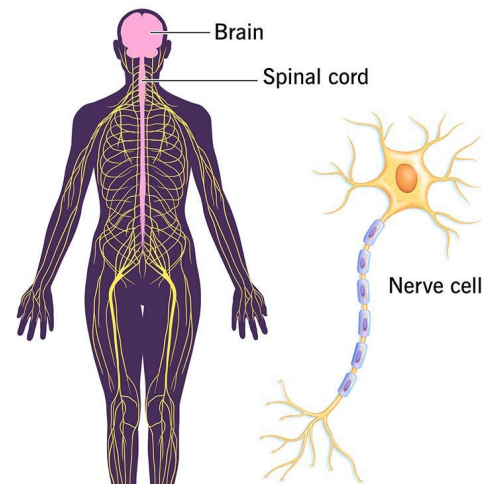
■ **Figure B2.1.20** Nicotinic acetylcholine receptors are an example of a neurotransmitter-gated ion channel

Exchange transporter (proteins) are used for **active transport** in axons (neurons).

Example: The Sodium–potassium pumps set concentration gradients in preparation for a nerve impulse.

An axon is part of a nerve cell that conveys messages rapidly within the body in the form of a nerve impulse.

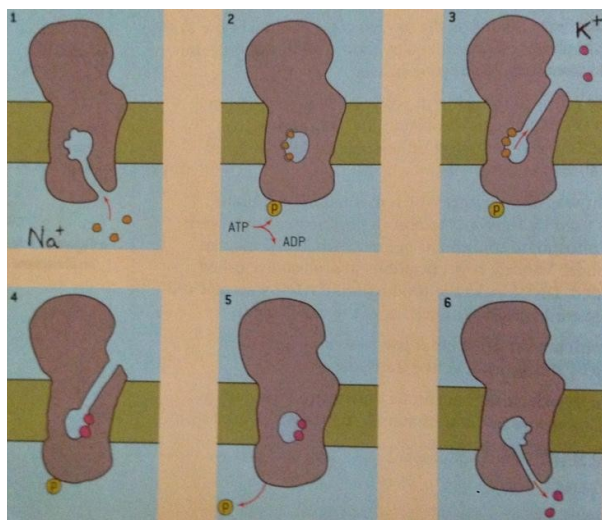
A nerve impulse involves rapid movements of sodium and potassium across the axon's membrane. Two types of transport, and thus two kinds of membrane protein, set up the conditions for the process. Concentration gradients between the inside and outside of the axon are built up through **active transport**, carried out by the *sodium-potassium pump*. The nerve impulse itself is manifested in the form of **facilitated diffusion** through *sodium and potassium channels*, utilising the already generated concentration gradients.



Detail and step-by-step **active transport** involved in building neuron concentration gradients.

Three sodium ions are pumped out of the axon and **two potassium** ions are pumped in.

One ATP molecule is used per cycle.



This process creates a buildup of sodium ions outside and potassium ions inside the axon, respectively, preparing for the nerve impulse.

1. The interior of the pump opens. Three sodium ions enter and attach to binding sites.
2. ATP transfers a phosphate group to the pump (energy loaded). This causes the pump to change shape, the inward facing side closes.
3. The pump opens facing the outside of the axon and the three sodium ions are released.
4. Two potassium ions from outside can then enter and attach to their binding sites.
5. Binding of potassium causes release of the phosphate group (energy released).
6. The pump changes shape, it opens to the inside of the axon. Potassium ions are released.

Indirect Active Transport

As we learned, active transport normally involves:

1. movement of materials *against a concentration gradient*
2. expenditure of energy

The energy may be harnessed by one of two means:

- The direct hydrolysis of **ATP** (*primary active transport*)
- By **coupling** with the transport of another molecule (which is moving along its electrochemical gradient). This is known as *indirect active transport*, or *secondary active transport*.

The coupled transport of two distinct molecules is called **co-transport**.

(the movement of a single molecule is called uniport)

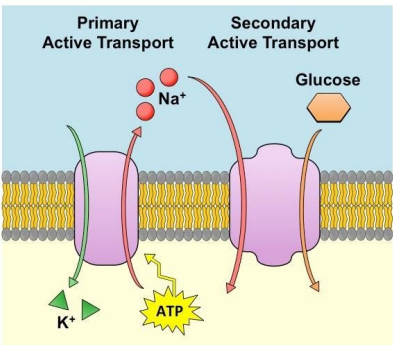
- If the two molecules are transported in the same direction it is called **symport** cotransport.
- If the two molecules are transported in opposite directions it is called **antiport** cotransport.

Sodium-dependent glucose cotransporters are an example of *indirect active transport*.

Found in cells of the small intestine and the kidneys, they play important roles in glucose absorption.

How do they work?

- Active transport of sodium at the base of the cell, using sodium-potassium pumps builds up a concentration gradient of sodium by removing it from the cell. Sodium can enter through the cotransporter protein down its concentration gradient.
- At the same time, glucose is moved into the cell through the same cotransporter as the sodium
- In this way, sodium-dependent glucose cotransporters allow glucose to be transported into cells against its concentration gradient.
- Because glucose is not directly moved into the cell by active transport, but in conjunction with the active transport of sodium ions out from the opposite side of the cell, this process is known as indirect active transport.
- Glucose leaves the cell via facilitated diffusion at the base of the cell, to travel onto where it is needed in the rest of the body.

	The sodium-potassium pump is an example of an antiporter as sodium and potassium are pumped in opposite directions. The glucose cotransporter is a symporter as glucose movement is coupled to the parallel transport of sodium. Step 1 is <u>primary</u> active transport as both molecules are pumped against their gradient and require ATP hydrolysis. Step 2 is secondary active transport, as it is a result of step 1.
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Adhesion of cells to form tissues

Cell adhesion is the **attachment** of cells to other surfaces via specialized membrane proteins called **cell adhesion molecules (CAMs)**.

- Cells can be attached to other cells **or** indirectly anchored to the extracellular matrix (a gel-like framework between cells).
- Cell adhesion molecules play important roles in tissue development and forming complex structures.

Gated ion channels in neurons

Include nicotinic acetylcholine receptors as an example of a neurotransmitter-gated ion channel and sodium and potassium channels as examples of voltage-gated channels.

Sodium–potassium pumps as an example of exchange transporters

Include the importance of these pumps in generating membrane potentials.

Sodium-dependent glucose cotransporters as an example of indirect active transport

Include the importance of these cotransporters in glucose absorption by cells in the small intestine and glucose reabsorption by cells in the nephron.

Adhesion of cells to form tissues

Include the term “cell-adhesion molecules” (CAMs) and the understanding that different forms of CAM are used for different types of cell–cell junction. No detailed knowledge of the different CAMs or junctions is required.