Comprehensive and Easy Course Notes for BIOL1040 Exams and Assessment

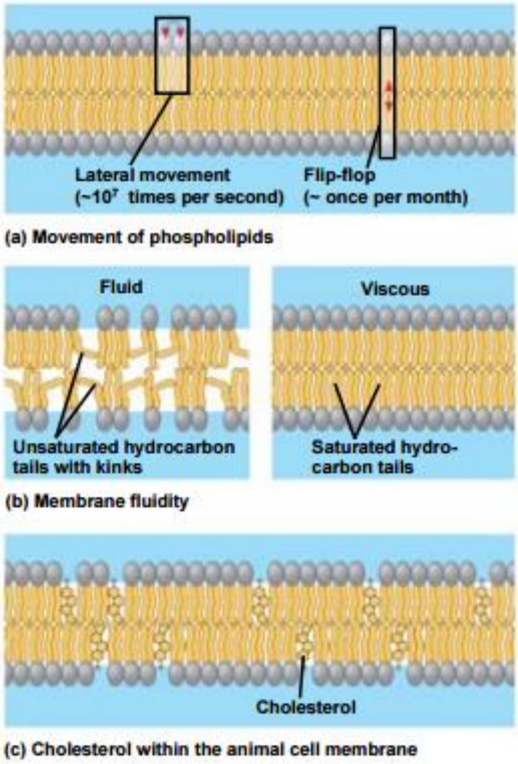
MODULE 1: PRINCIPLES OF CELL FUNCTION

Membrane Structure & Function

Cellular membranes are fluid mosaics of lipids and proteins

Phospholipids are abundant amphipathic molecules which have a phosphate group at the top of a hydrocarbon chain which makes them part hydrophobic (tails) and part hydrophilic (phosphate heads).

The cell membrane is a fluid lipid bilayer membrane with embedded proteins.



(a) Movement of phospholipids

(b) Membrane fluidity

(c) Cholesterol within the animal cell membrane

Why is the membrane fluid?

The fluidity is given by one of the unsaturated fatty acid tails which has kinks in it due to the double bond meaning it doesn't pack as tightly thus allowing fluidity. Phospholipids are very motile – lots of lateral movement and more rare 'flip-flop' movement.

What is the role of cholesterol in ANIMAL CELLS ONLY?

Cholesterol is present in between the phospholipid membrane and acts as a temperature regulator:

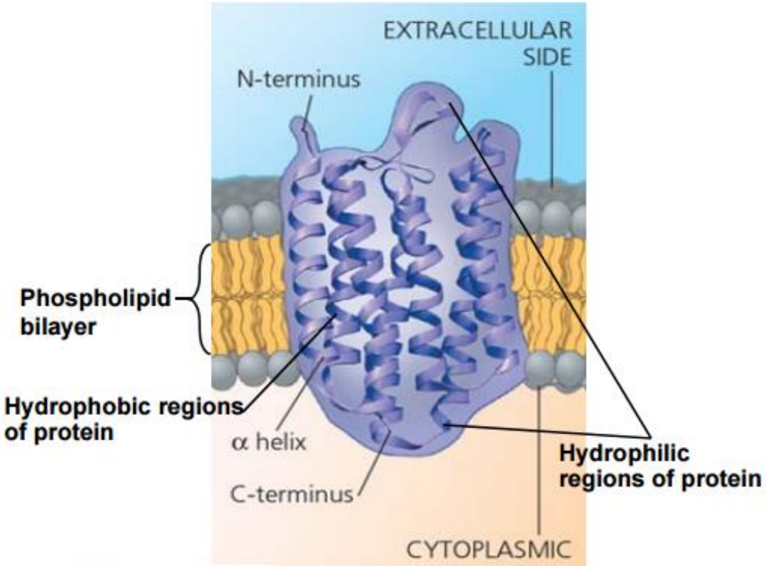
- At low temperatures: it prevents the membrane from getting too viscous
- At high temperatures: it ensures the fluidity of the membrane doesn't get too high

What are the role of proteins in the lipid membrane?

1. Transport
2. Enzymatic activity
3. Signal transduction
4. Cell-cell recognition
5. Intercellular joining
6. Attachment to the cytoskeleton and extracellular matrix (ECM)

How is the position of the amino acids in the protein determined?

The amino acids will bend and assume positions relative to the nature of their R groups. That is hydrophobic groups will curl toward the middle of the membrane whereas hydrophilic/charged groups will move toward the outside.



Campbell Biology, 10th ed, Fig 7.6

Membrane Structure results in selective permeability

How are membranes selectively permeable?

Lipid bilayers are impermeable to most essential molecules and ions. It has some permeability to water molecules and a few other small, uncharged molecules like oxygen and carbon dioxide.

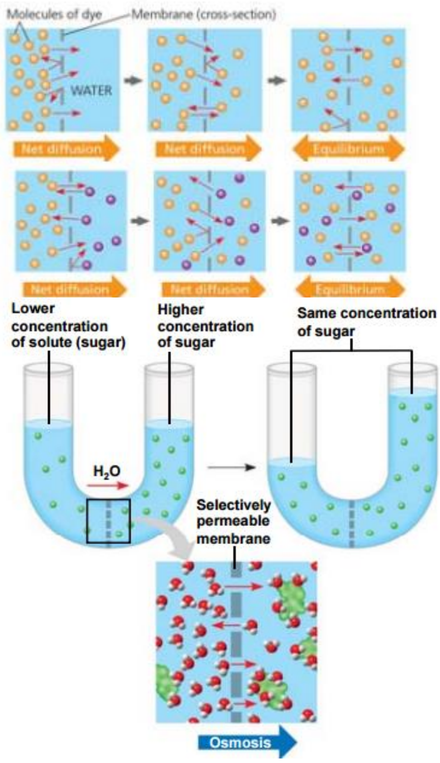
Lipid bilayers are not permeable to:

- Ions such as K+, Na+, Ca2+, Cl-, HCO3-
- Small hydrophilic molecules like glucose
- Macromolecules like proteins and RNA

Passive transport is diffusion of a substance across a membrane with no energy investment

What is diffusion?

With time, due to random motion, molecules will become equally distributed. It occurs to eliminate concentration gradients provided the molecule can cross the membrane.



What is osmosis?

Osmosis is the diffusion of water through a selectively permeable membrane into another aqueous compartment containing solute at a higher concentration. Water moves to reach equilibrium between the ECF and ICF concentrations of a particular solute.

What are osmotica?

- Ions
- Sugars
- Proteins

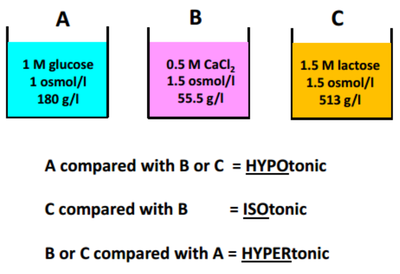
What are some important terms?

- **Tonicity** is the ability of a solution to cause a cell to gain or lose water
- **Isotonic solution**: Solute concentration is the same as that inside the cell; no net water movement across the plasma membrane
- **Hypertonic solution**: Solute concentration is greater than that inside the cell; cell loses water

- **Hypotonic solution**: Solute concentration is less than that inside the cell; cell gains water

What is osmolarity?

This is a term concerned with the number of particles that are produced when in aqueous solution. For instance, whilst glucose dissolves into aqueous glucose and stays as one molecule, CaCl2 will dissociate into 3 ions (Ca2+, Cl-, Cl-) thus meaning that its osmolarity is its concentration multiplied by 3.



What is passive transport?

Passive transport across a cell membrane is facilitated by diffusion by which small, lipid soluble compounds can move through the cell membrane across its concentration gradient.

Passive transport can be facilitated by membrane embedded proteins:

- Transport proteins speed the passive movement of molecules across the plasma membrane
    - Ion channel proteins provide a corridor for a specific molecule/ion to cross the membrane
    - Aquaporins facilitate the diffusion of water
    - Transport proteins allow the passage of hydrophyllic substances to cross membrane

What are the two types of pore forming proteins?

1. Channels – facilitated diffusion
2. Transporters – facilitated diffusion or active transport using ATP

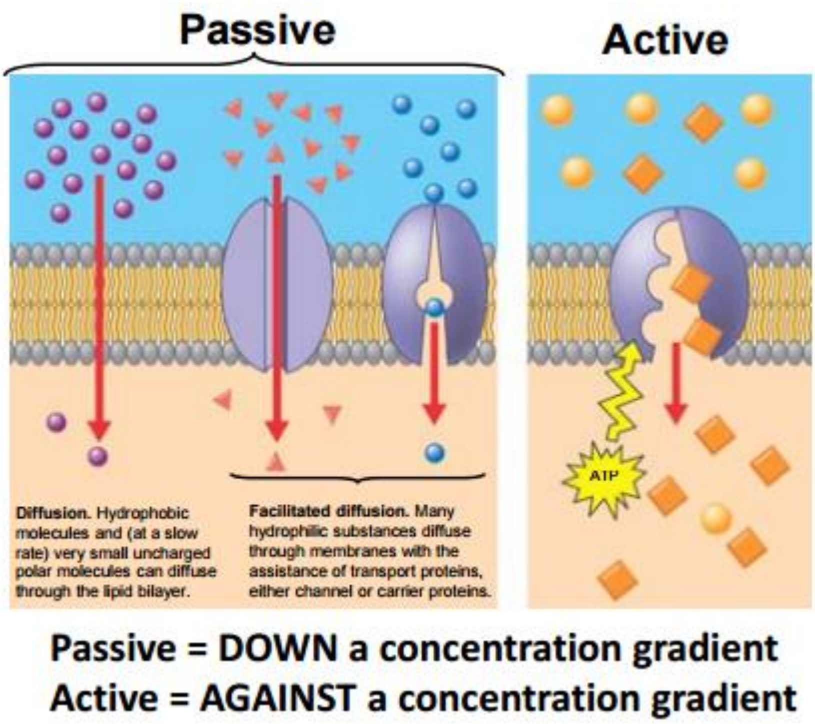
What is active transport?

Active transport is the transport of molecules against their concentration gradient by using the energy from ATP break down.

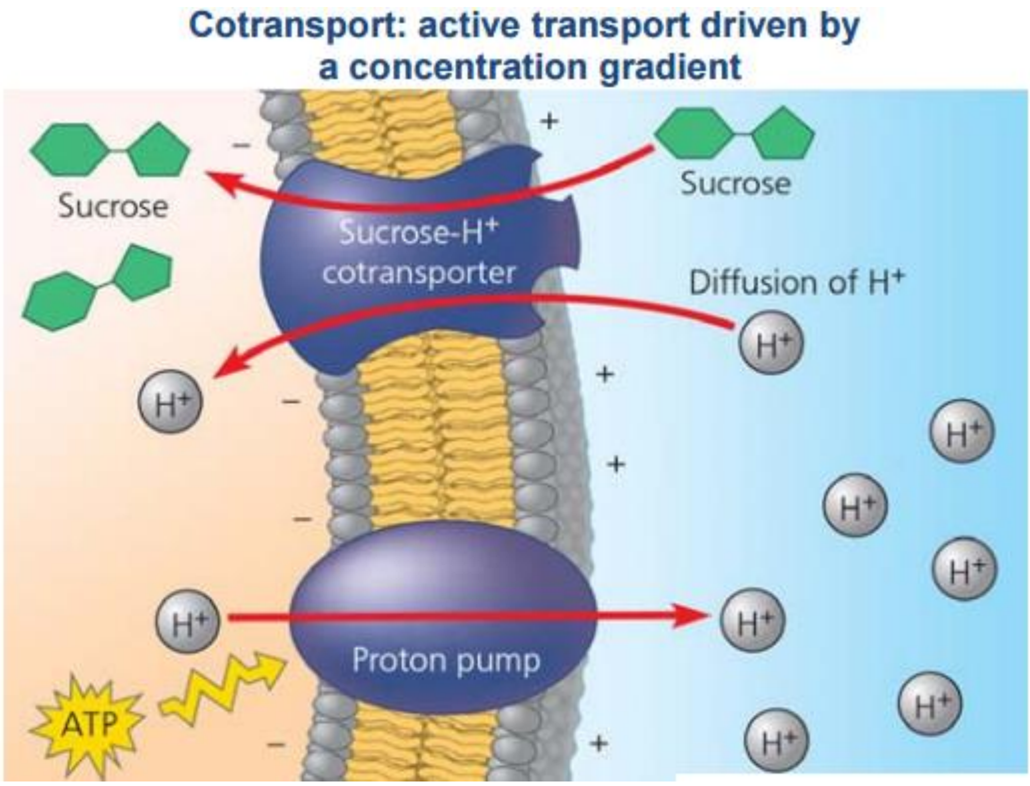
Electrogenic pump – a transport protein that generates a voltage across a membrane.

Sodium-Potassium pump – major electrogenic pump for animal cells that pumps sodium out of the cell and potassium into the cell against their concentration gradients to produce a resting voltage of -70mV in the cell.

Proton pump – the major electrogenic pump for plants



What is cotransport?



The active transport of one solute indirectly drives the transport of another solute. Usually one solute is travelling against their concentration gradient. The solute going to the outside of the cell, against its concentration gradient facilitates the passive transport of another compound. One solute is pumped out against its concentration gradient. This solute binds to another solute such as sucrose and then travels through a cotransporter back inside the cell. Proton pump in this case creates a hydrogen ion gradient that is a form of potential energy that is harness to do work of driving the transport of solutes back into the cell.

How can the Na+/K+-ATPase work together with the Na+-glucose cotransporter to drive glucose uptake?

Another important task of the Na+-K+ pump is to provide a Na+ gradient that is used by certain carrier processes. In the gut, for example, sodium is transported out of the reabsorbing cell on the blood (interstitial fluid) side via the Na+-K+ pump, whereas, on the reabsorbing (lumenal) side, the Na+-glucose cotransporter uses the created Na+ gradient as a source of energy to import both Na+ and glucose, which is far more efficient than simple diffusion.

- Na+ pumped out against conc. Gradient and binds to glucose and flows back in with its conc. Gradient to facilitate glucose intake

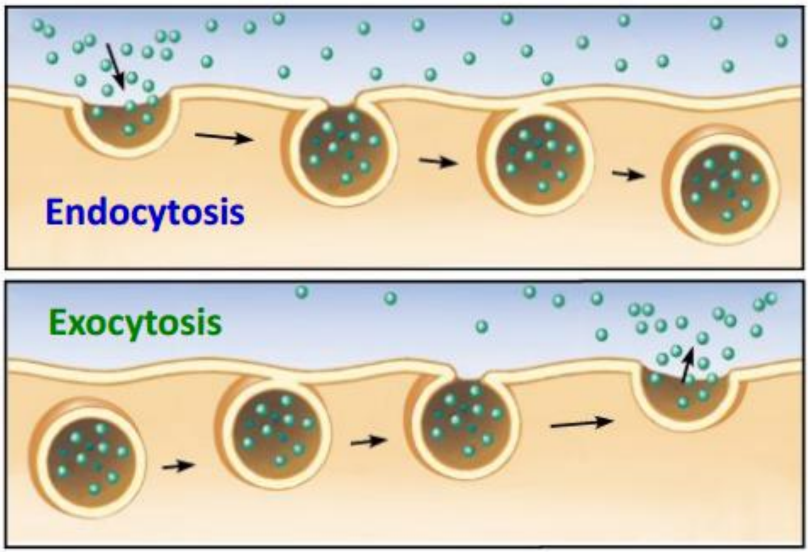
Bulk Transport

What is endocytosis and exocytosis?

Exocytosis and endocytosis result in bulk transport across the plasma membrane.

Endocytosis: the membrane from the cell membrane forms around a pocket of particles. The particles are essentially packaged up.

Exocytosis: the loss of the membrane and exit of the cell.



Cell Communication & Receptor Families

What are types of cell signalling?

External signal are converted to responses within cells.

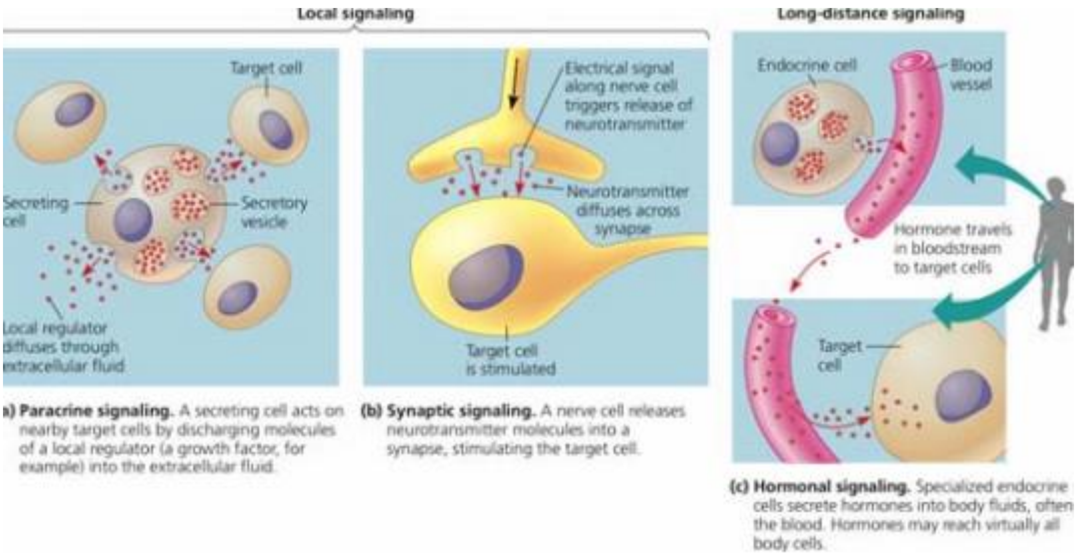
Local signalling

- Pacrine signalling – a secreting cell acts on nearby target cells by discharging molecules of a local regulator into ECF

- Synaptic signalling – nerve cell releases neurotransmitter (by endocytosis) molecules into a synapse, stimulating target cell

Long distance signalling

- Hormonal signalling – specialised endocrine cells secrete hormones into body fluids, often the blood. May reach virtually all cells.



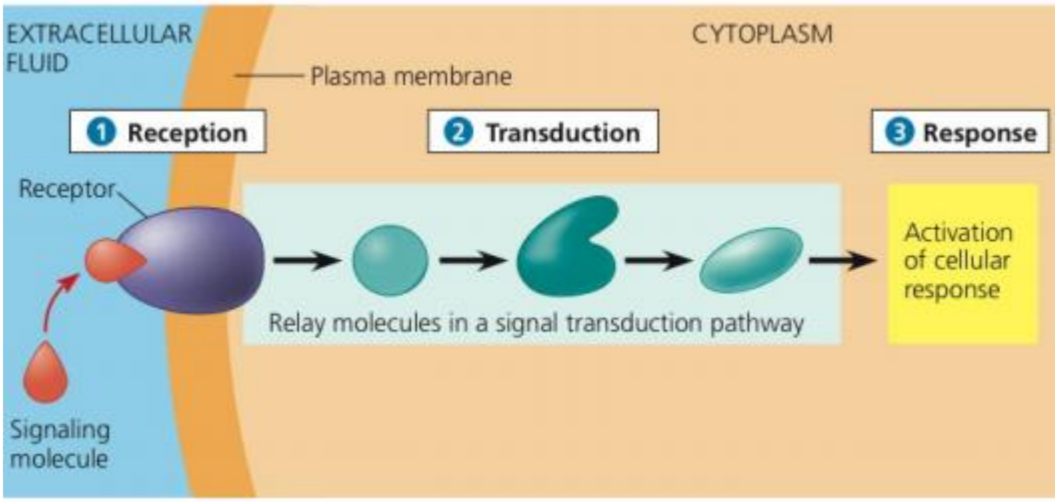
(a) Paracrine signaling. A secreting cell acts on nearby target cells by discharging molecules of a local regulator (a growth factor, for example) into the extracellular fluid.

(b) Synaptic signaling. A nerve cell releases neurotransmitter molecules into a synapse, stimulating the target cell.

(c) Hormonal signaling. Specialized endocrine cells secrete hormones into body fluids, often the blood. Hormones may reach virtually all body cells.

What are the 3 stages of cell to cell communication?

1. Reception
2. Transduction
3. Response



What are the types of receptors and how do they initiate the process of transduction?

Reception occurs when a signalling molecule binds to a receptor protein, causing it to change shape. The signalling molecule is complementary in shape to a specific site on the receptor and attaches there. This molecule acts as a ligand (the term for a molecule that specifically binds to another molecule).

Transduction is the resulting cascades of molecular interactions relaying signals from receptor to target molecules in the cell.

Transmembrane protein Receptor – binds with signalling molecule (which does not need to pass through the cell membrane). Signalling molecule changes the configuration of the receptor in some way, triggering a response.

There are 3 types:

1. Ion channel receptors
- Na+ channel opened by ligand (signalling protein) – causing FAST neurotramission

SEE BELOW FOR MORE

2. G protein coupled receptors
- 7 Transmembrane Domains
- Works with a G protein which is bound to the energy-rich molecule GTP
- Largest family of receptors
    - 1000 members in human genome
- 50% of our drugs target GPCRs
- Activated by a variety of stimuli
    - Light, ions, odorants, neurotransmitters, hormones, proteins'

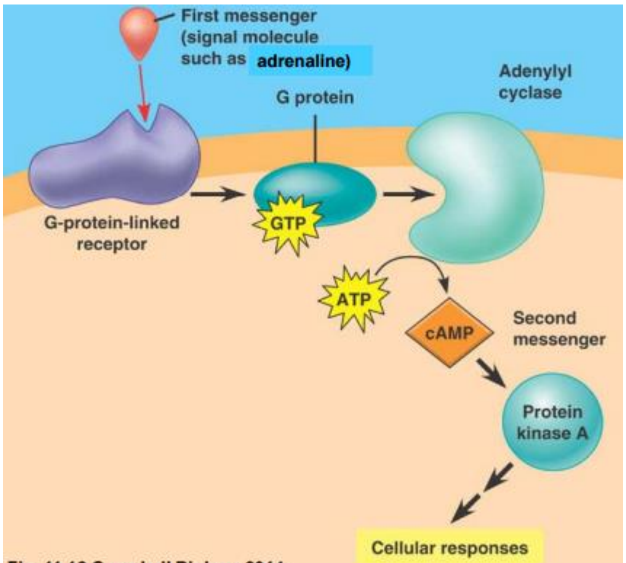


Fig. 11.12 Campbell Biology 2014

Here the first messenger (signalling molecule) comes in to change the configuration of the G-protein linked receptor. This causes the now active receptor to bind with the heterotrimetic (has 3 different peptide chains) G protein which was originally bound to a GDP molecule and this causes a GTP to replace the GDP. This GTP facilitates the activation of another protein (usually an enzyme) which catalyses the conversion of ATP to a second messenger. The second messenger acts by activating another protein leading to cellular responses.

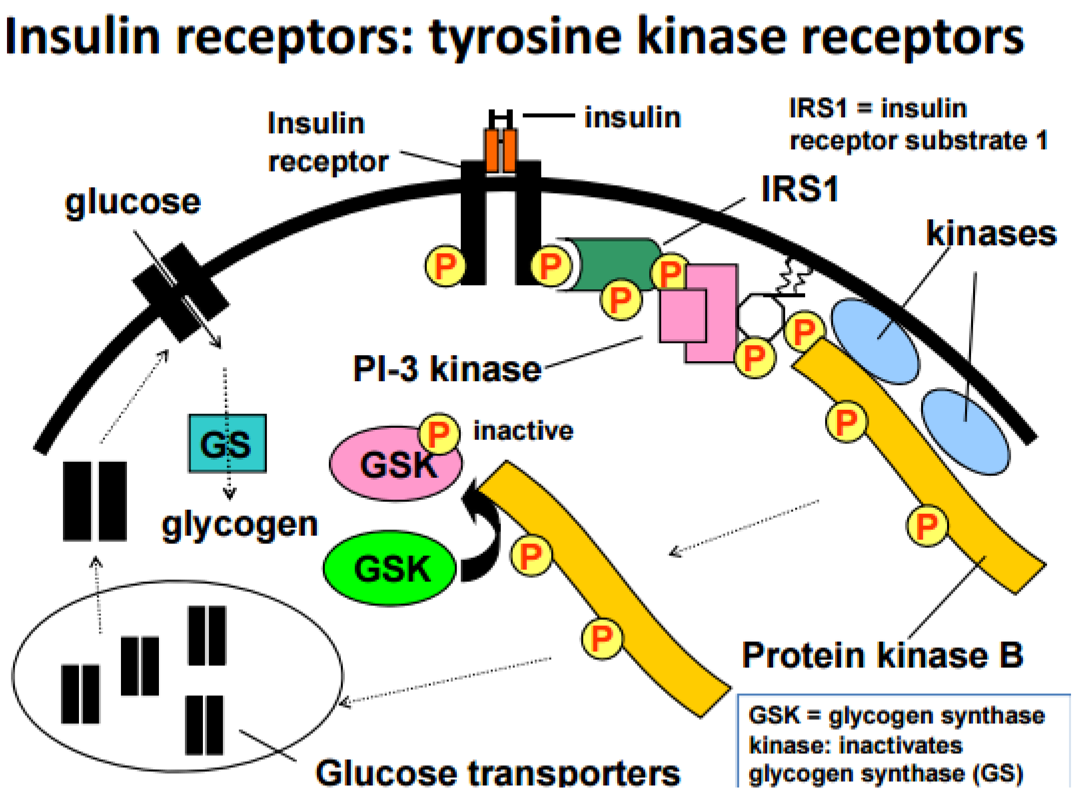
The changes in the enzyme and G protein are only temporary because the G protein also functions as a GTPase enzyme – in other words, it then hydrolyses its bound GTP to GDP and an inorganic phosphate group. Now the G protein is inactive again and is ready for reuse.

EXAMPLE:

Adrenaline works on a G-protein coupled receptor (beta-receptor) which activates the splitting of the subunits of the G-protein and the binding of GTP to produce an enzyme (adenylyl cyclase) which produces the second messenger cAMP and another enzyme protein kinase A that inhibits glycogen synthesis and promotes glycogen breakdown into glucose mainly in the liver for release into the blood stream and use for energy by the body.

Also acts on the beta-receptor of the smooth muscle cells of the vessels that supply blood to the skeletal muscle resulting in vasodilation. Also acts on the alpha-receptor of the smooth muscle cells of the vessels that supply blood to the digestive tract resulting in vasoconstriction.

3. Tyrosine-kinase linked receptors
- 1 TMD
- Receptor acts as a catalyst (once bound to signalling molecule) for the phosphorylation of amino acids in proteins.
    - Phosphorylation = adding a phosphate group to the OH group in the amino acid



The receptor tyrosine kinase receptors look to be individual units referred to as monomers. The binding of a signalling molecule such as a growth factor causes two receptor monomers to associate closely with each other, forming a complex known as a dimer. This activates the tyrosine kinase region of each monomer causing them to phosphorylate the tyrosine on their tails by transferring a phosphate from ATP to the tails of each monomer. This fully activated receptor is recognised by specific relay proteins. Each binds to a phosphorylated tyrosine and undergoes a resulting structural change that triggers a transduction pathway leading to cellular response.

EXAMPLE: The pancreatic beta cells (β cells) are known to be sensitive to the glucose concentration in the blood. They release insulin when blood glucose levels are high to promote the production of glucose transporters in the liver and the storage of glucose as glycogen.