1.4 Membrane transport

Essential idea: Membranes control the composition of cells by active and passive transport.

The background image is a piece of artwork inspired by the complexity of an *E. Coli*. Complexity in cell structure is much greater still in Eukaryotes and this only possible through the compartmentalisation and the selective transport membranes allow.

By Chris Paine

https://bioknowledgy.weebly.com/

http://onlinelibrary.wiley.com/doi/10.1002/bmb.20345/full#fig2

Understandings, Applications and Skills

	Statement	Guidance
1.4.U1	Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.	
1.4.U2	The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis.	
1.4.U3	Vesicles move materials within cells.	
1.4.A1	Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons.	
1.4.A2	Tissues or organs to be used in medical procedures must be bathed in a solution with the same osmolarity as the cytoplasm to prevent osmosis.	
1.4.S1	Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)	Osmosis experiments are a useful opportunity to stress the need for accurate mass and volume measurements in scientific experiments.

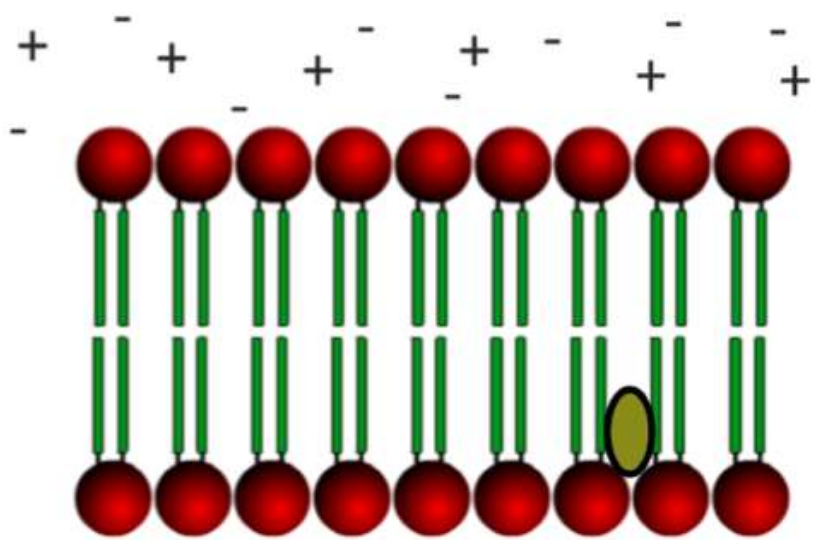
The phospholipid bilayer is selectively permeable

controlled — entry/ exit of molecules

Some molecules pass through easily (diffusion), or go through a 'tunnel' (facilitated diffusion)
Others need energy to get them through (active transport)
Large molecules use their own membrane to get them through (endo-/exo-cytosis)

polar heads:
attracted to other polar (charged) molecules

non-polar tails:
will repel any charged molecule, therefore preventing passage of ions through the membrane.



1.4.U1 Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.

Diffusion is the passive net movement of particles from areas of high concentration to low concentration. This is often through a partially permeable membrane.

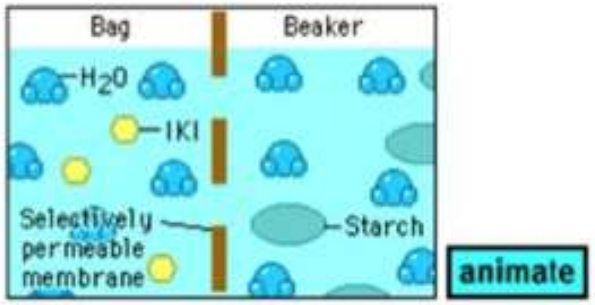
http://highered.mheducation.com/sites/0072495855/student_view0/chapter2/animation__how_diffusion_works.html

passive: does not require energy

net movement: overall movement (all particles are moving all the time)

concentration gradient: the difference in concentration of a substance between two locations

Try the tutorials here:



http://www.phschool.com/science/biology_place/labbench/lab1/concepts.html

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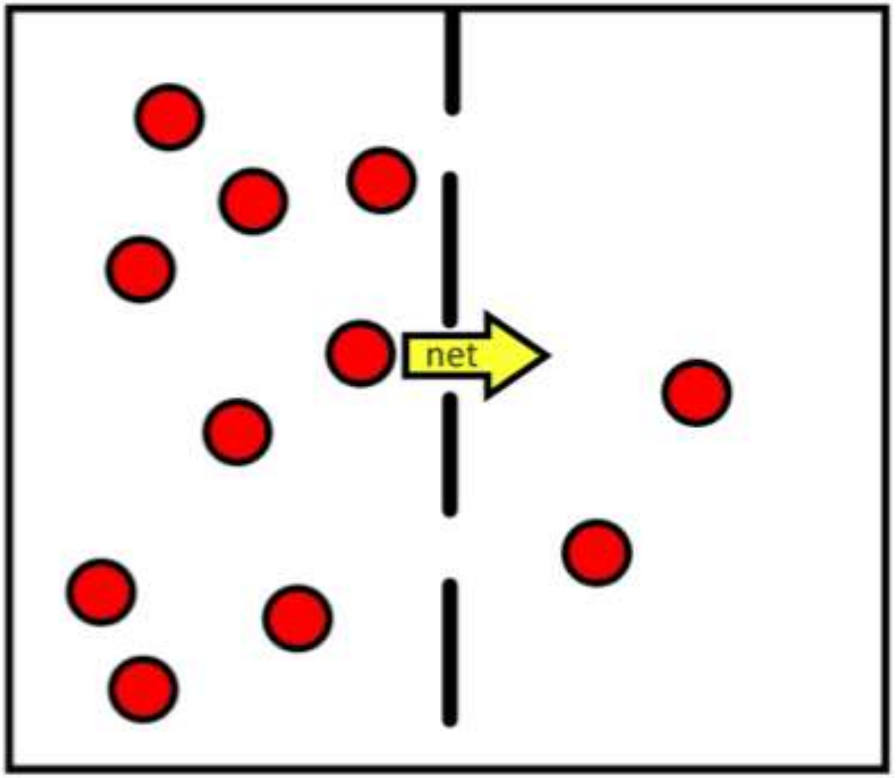
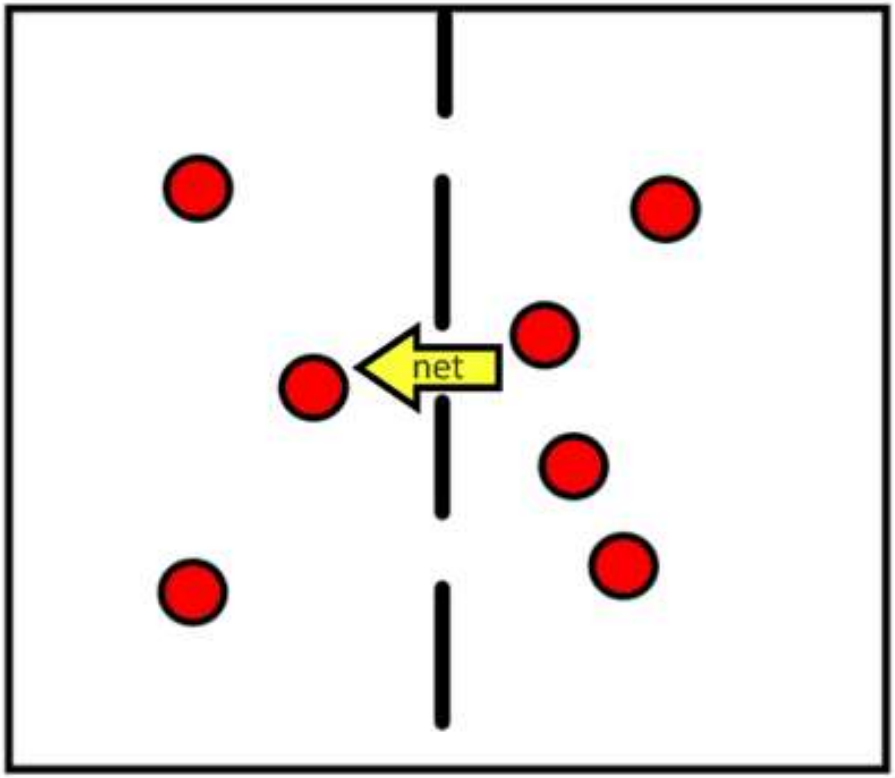


high concentration gradient

∴ faster diffusion



low concentration gradient

∴ slower diffusion

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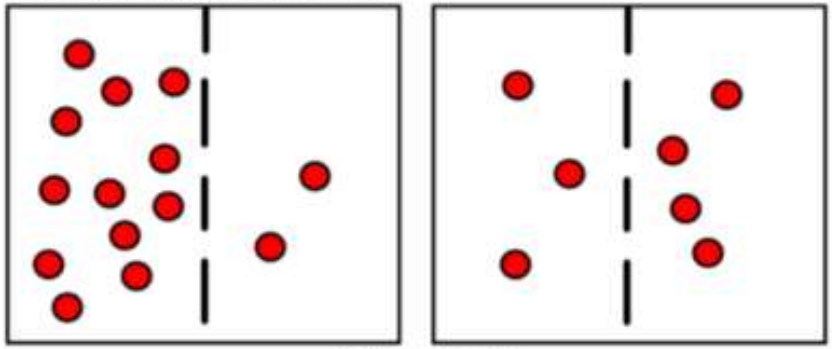
1.4.U1 Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.

Factors affecting the rate of diffusion through a partially permeable membrane:

CONCENTRATION GRADIENT

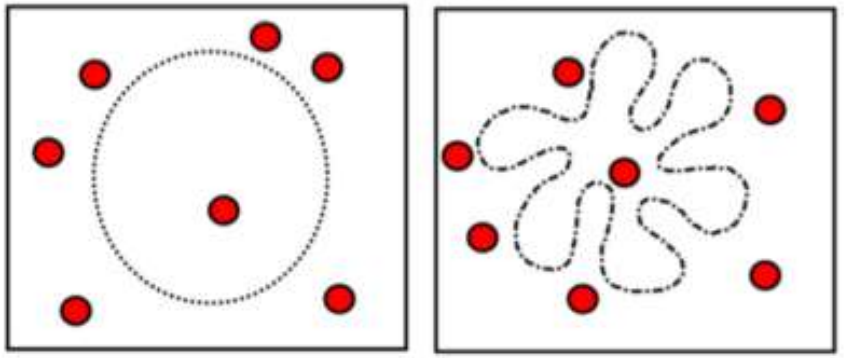


net movement

concentration gradient

rate of diffusion

SURFACE AREA

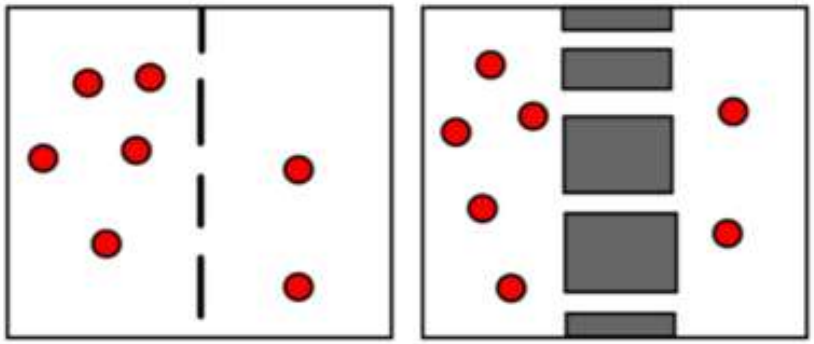


net movement

surface area

rate of diffusion

LENGTH OF DIFFUSION PATH



net movement

diffusion path

rate of diffusion

Which way are the molecules diffusing in each diagram?

How does each factor affect the rate of diffusion?

How does nature maximise the rate of diffusion?

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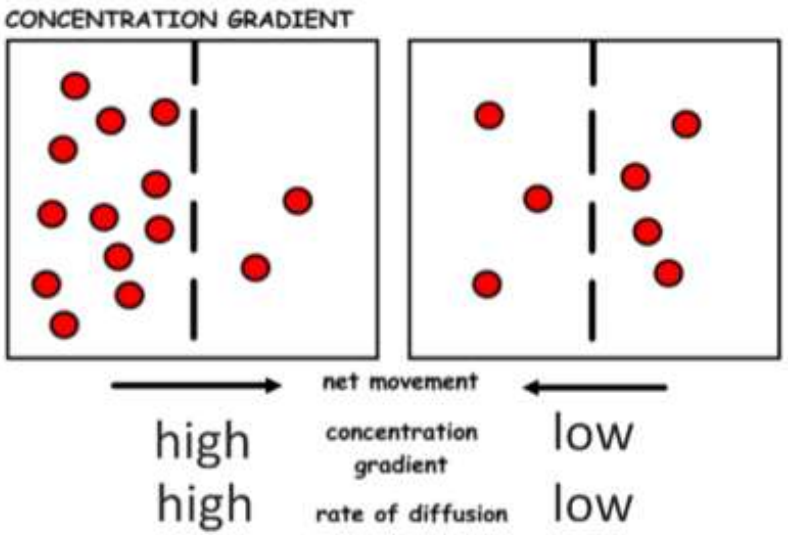
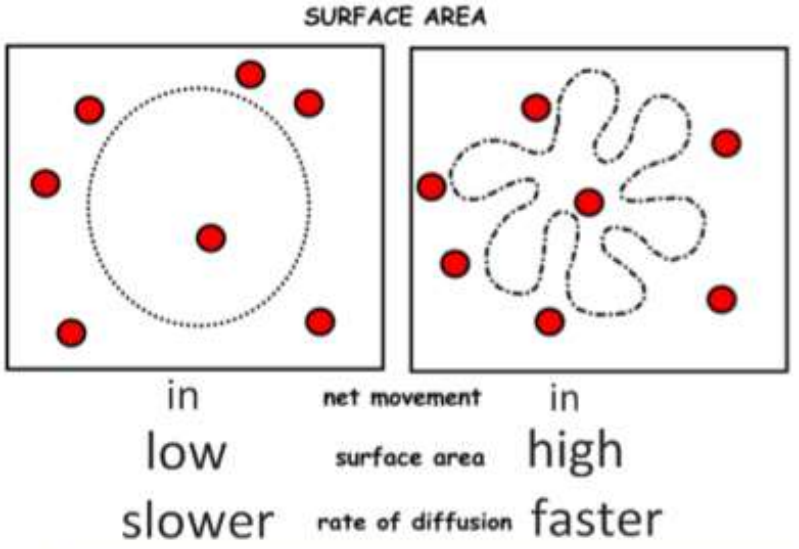
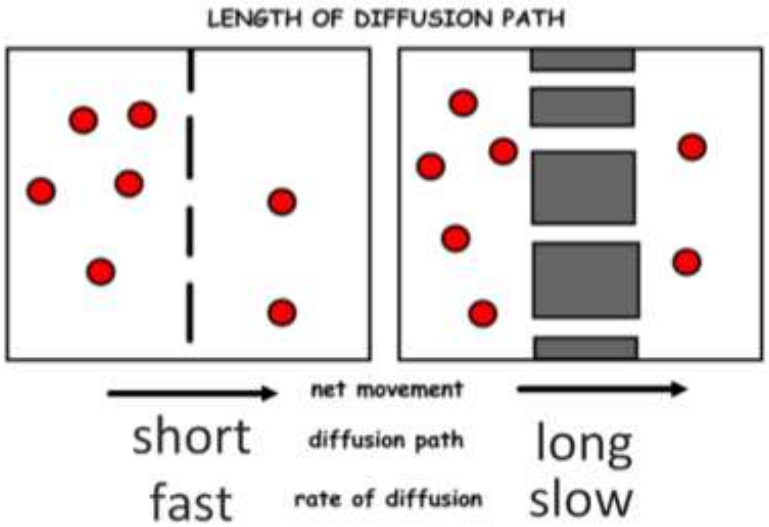
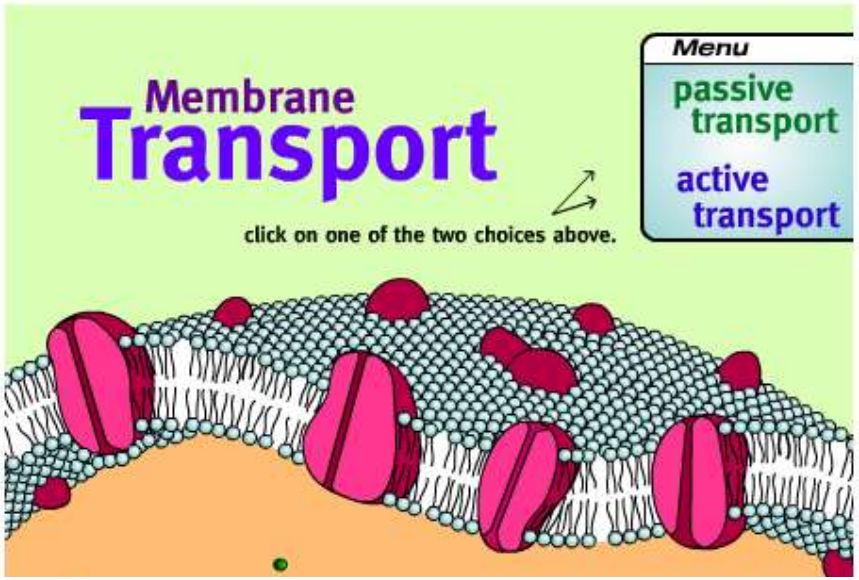
1.4.U1 Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.

Factors affecting the rate of diffusion through a partially permeable membrane:









http://www.northland.cc.mn.us/biology/Biology1111/animations/transport1.html

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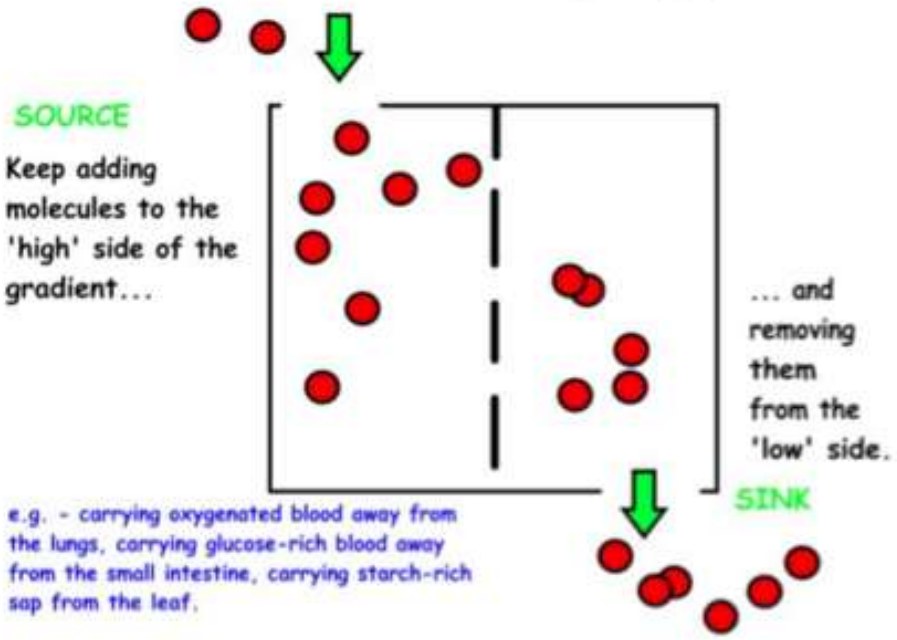
1.4.U1 Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.

ADAPTATIONS IN BIOLOGY: maintaining a large gradient.



Maximising surface area for absorption:

1. Alveoli in lungs
2. Membrane folds in mitochondria and in cristae in the chloroplasts
3. Root hais for water and mineral ion uptake
4. Villi for absorption of digested food molecules.

cristae:

http://porpax.bio.miami.edu/~cmallery/150/cells/mitoSEM2.jpg

alveoli:

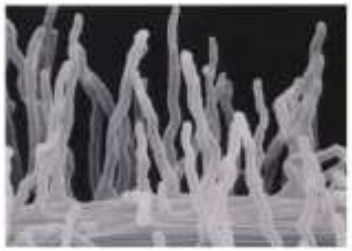
http://www.3dscience.com/img/Products/3D_Models/Human_Anatomy/Alveoli/supporting_images/3D_Model_Anat_Alveoli2_web.jpg

Reducing the length of diffusion path:

1. Membranes are incredibly thin (7-10nm)
2. Folded membranes increase the SA:VOL ratio
3. More membrane in a smaller volume means shorter distances across which molecules must diffuse.

root hairs:

(villi look very similar)



http://quorumsensing.ifas.ufl.edu/HCS200/images/leghiz/rootha2.jpg

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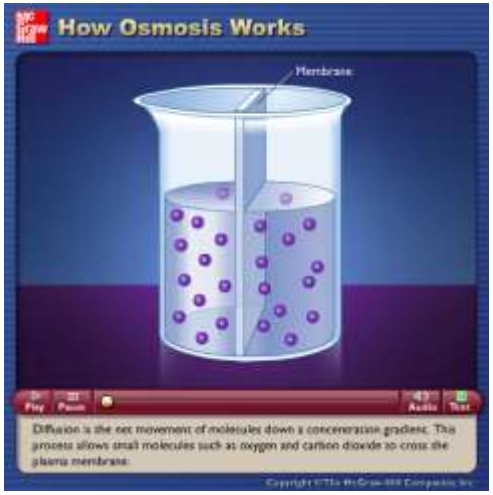
1.4.U1 Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.

What is osmosis?

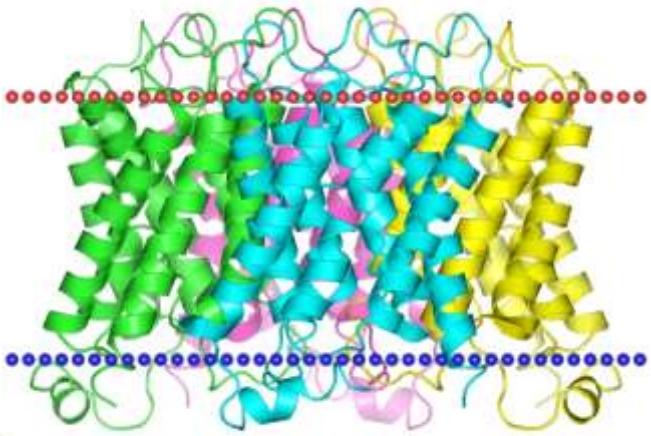
http://www.flickr.com/photos/luchilu/399970490/

Osmosis may occur when there is a partially permeable membrane, such as a cell membrane.

When a cell is submerged in water, the water molecules pass through the cell membrane from an area of low solute concentration (outside the cell) to one of high solute concentration (inside the cell) (Wikipedia)



http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

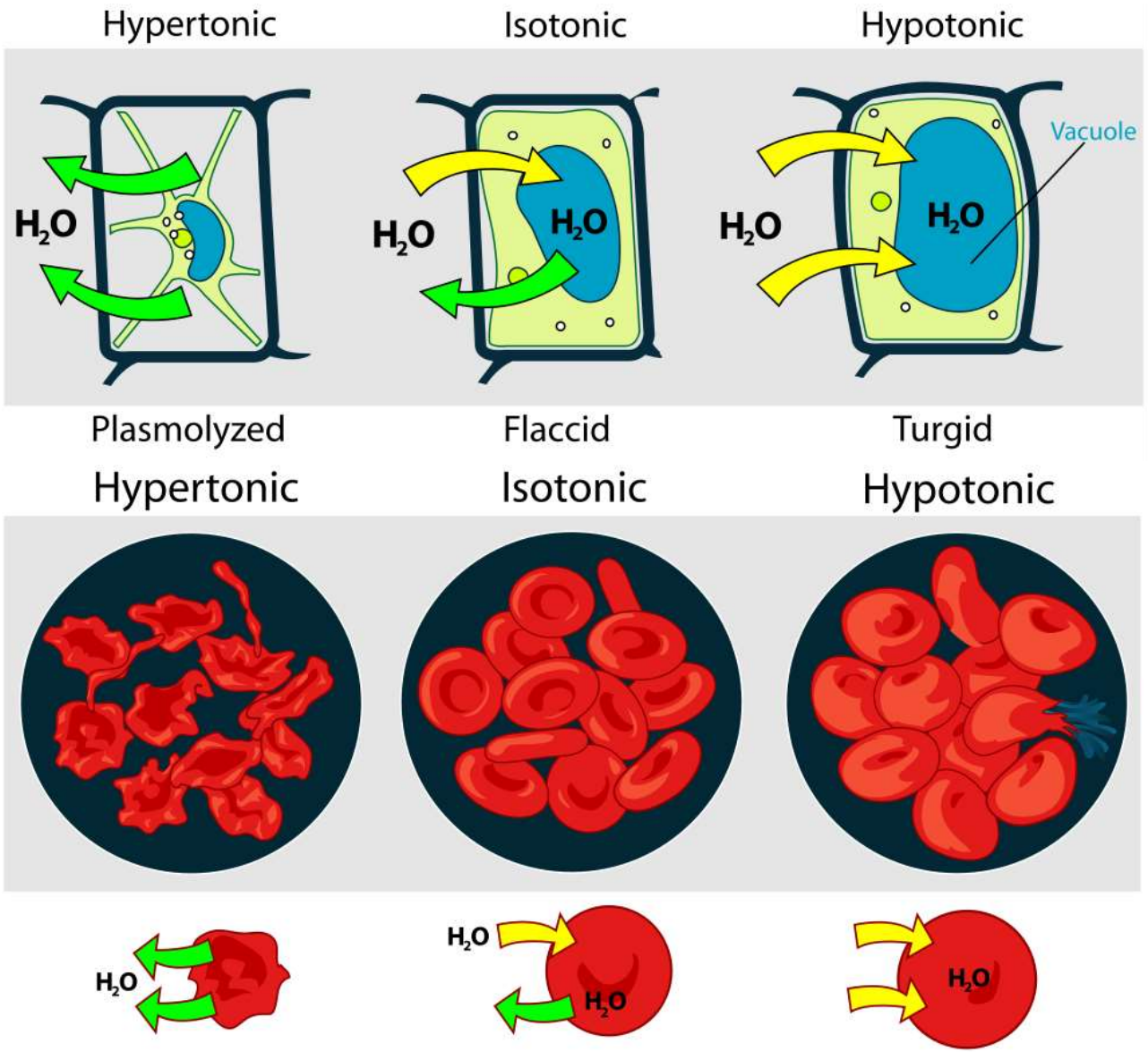


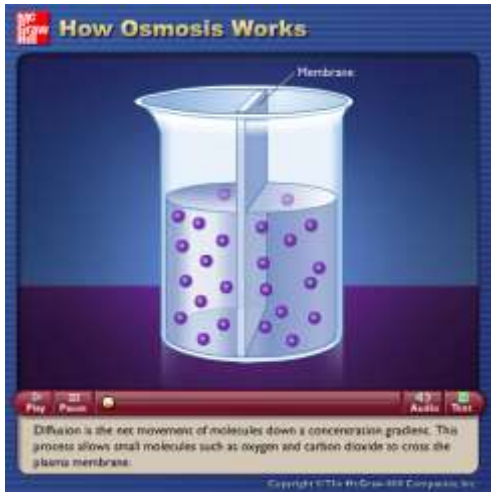
Aquaporin is an integral protein that, as it's name suggests, acts as a pore in the membrane that speeds the movement of water molecules

http://opm.phar.umich.edu/protein.php?pdbid=1sor

1.4.A2 Tissues or organs to be used in medical procedures must be bathed in a solution with the same osmolarity as the cytoplasm to prevent osmosis.

The importance of osmotic control





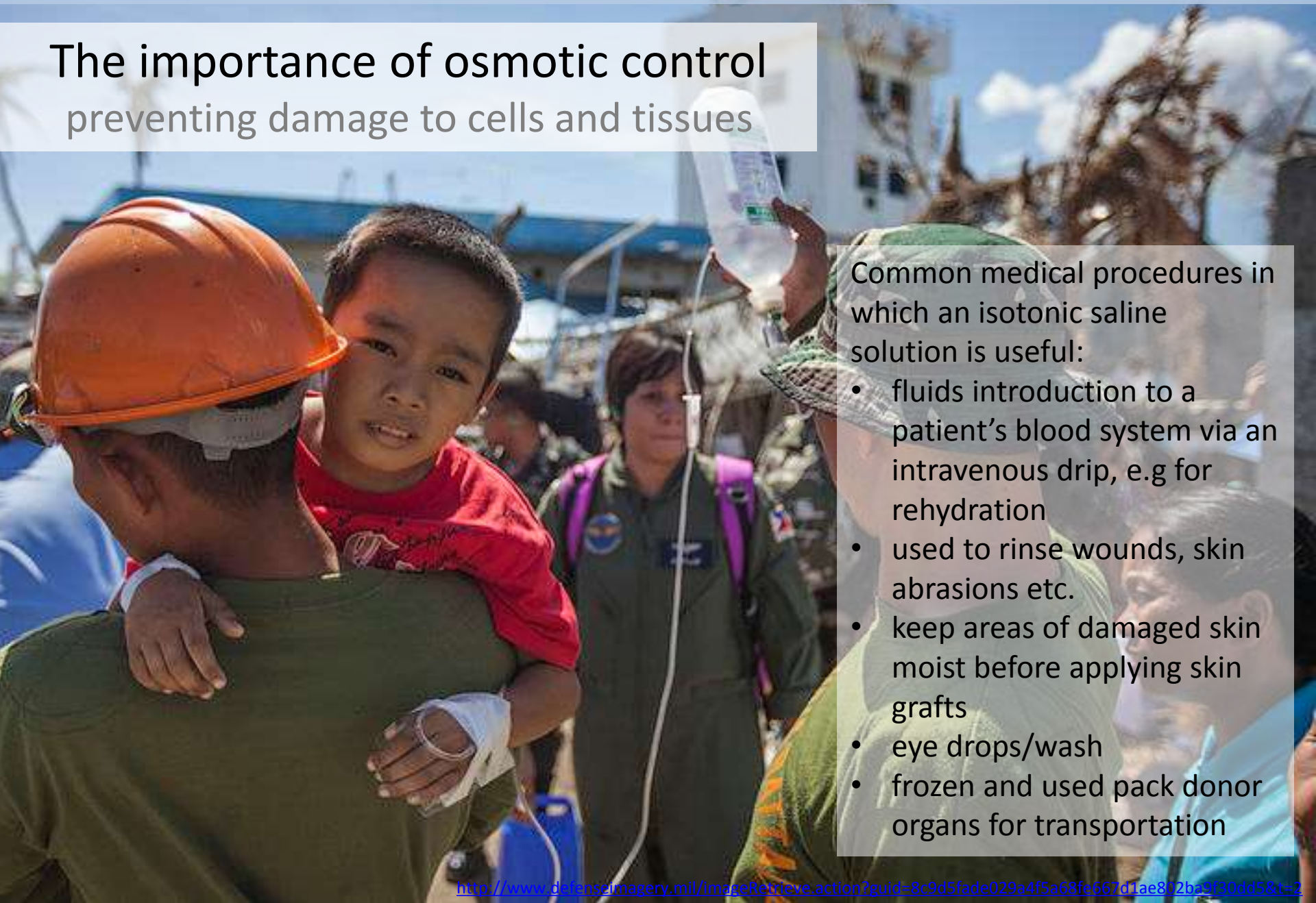
http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

http://commons.wikimedia.org/wiki/File:Osmotic_pressure_on_blood_cells_diagram.svg
http://commons.wikimedia.org/wiki/File:Turgor_pressure_on_plant_cells_diagram.svg

1.4.A2 Tissues or organs to be used in medical procedures must be bathed in a solution with the same osmolarity as the cytoplasm to prevent osmosis.

The importance of osmotic control

preventing damage to cells and tissues

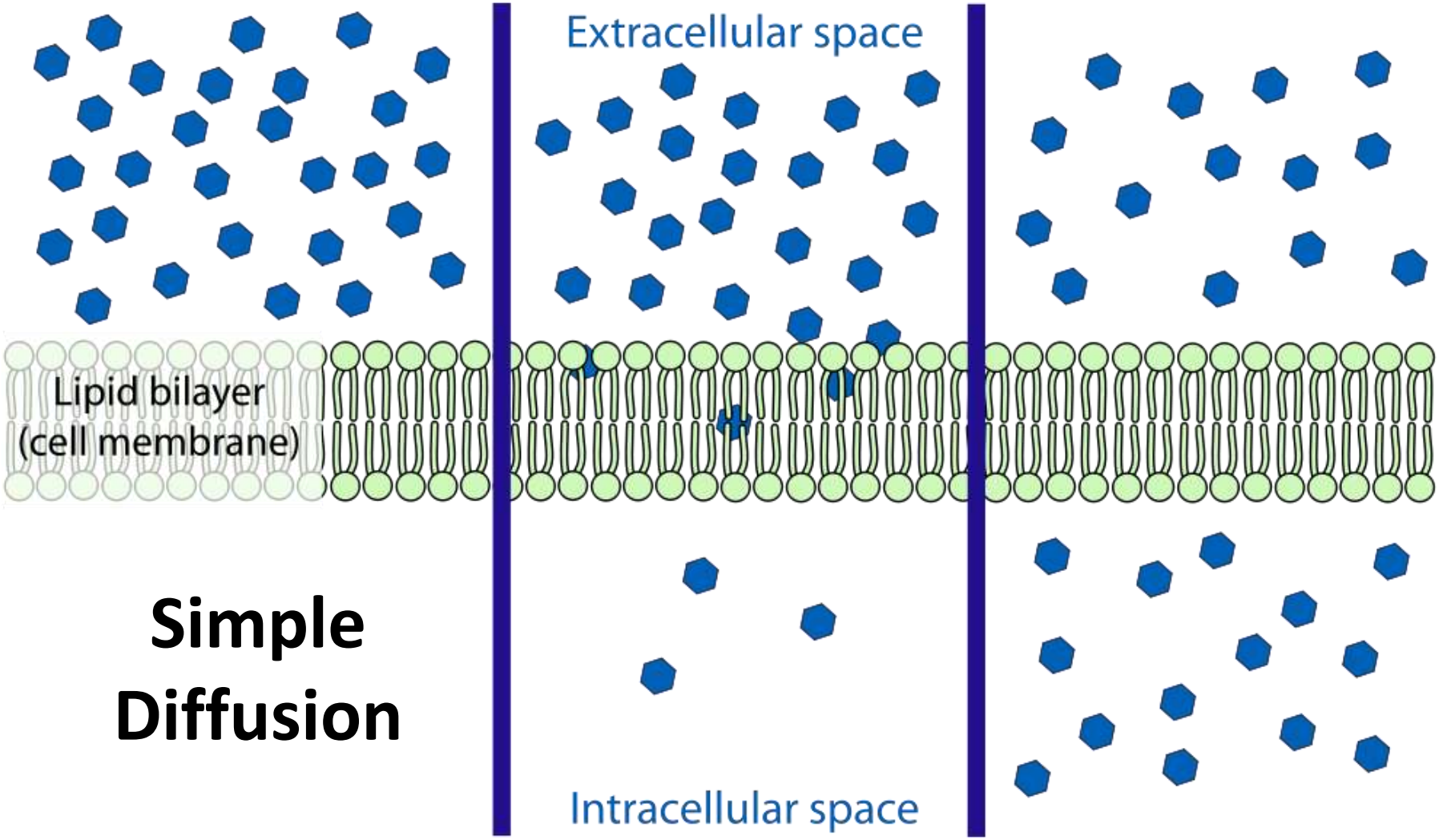


Common medical procedures in which an isotonic saline solution is useful:

- fluids introduction to a patient's blood system via an intravenous drip, e.g for rehydration
- used to rinse wounds, skin abrasions etc.
- keep areas of damaged skin moist before applying skin grafts
- eye drops/wash
- frozen and used pack donor organs for transportation

http://www.defenseimagery.mil/imageRetrieve.action?guid=8c9d5fade029a4f5a68fe667d1ae802ba9f30dd5&t=2

1.4.U1 Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.

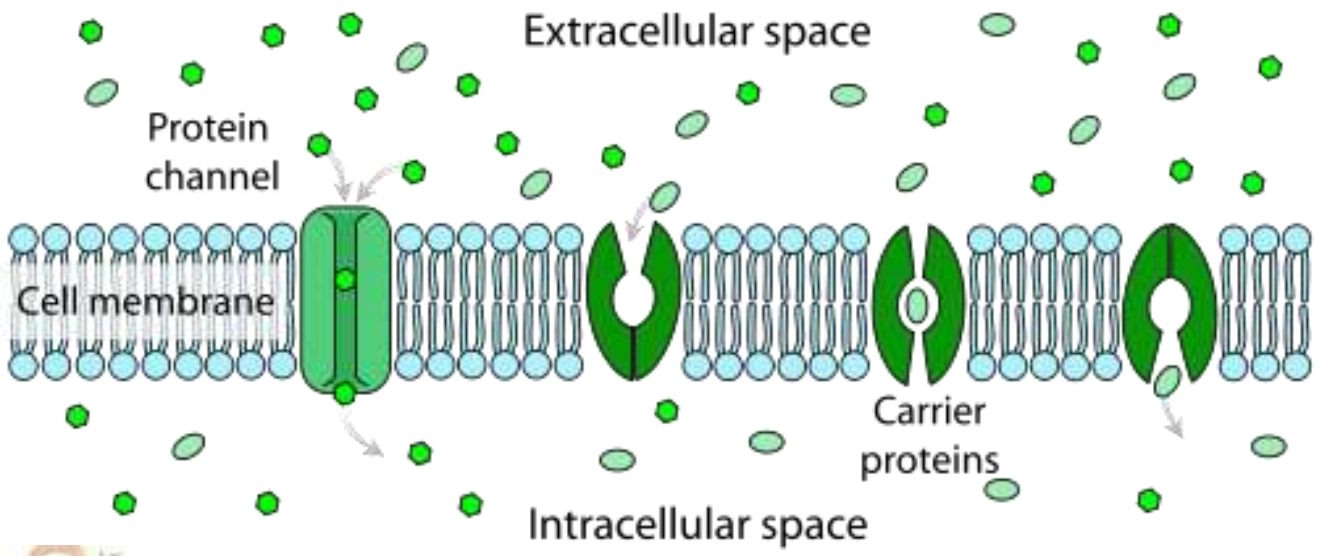


http://commons.wikimedia.org/wiki/File:Scheme_simple_diffusion_in_cell_membrane-en.svg

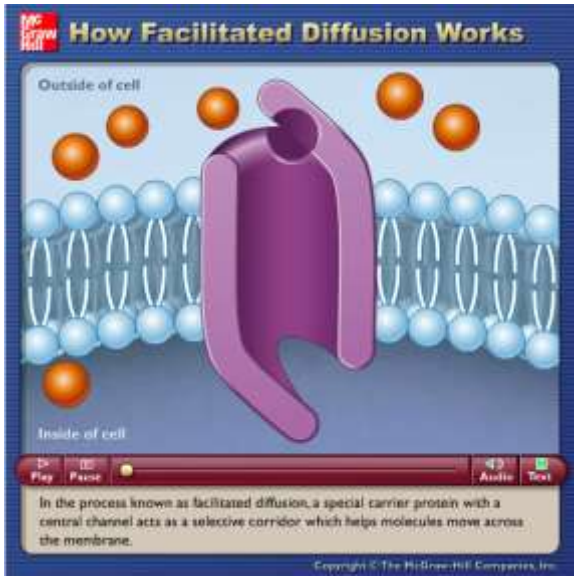
Facilitated Diffusion:

Large and polar molecules can't get across the membrane via simple diffusion

Transmembrane (polytopic) proteins recognise a particular molecule and help it to move across the membrane. The direction it moves is dependent on the concentration gradient.



Watch the animation



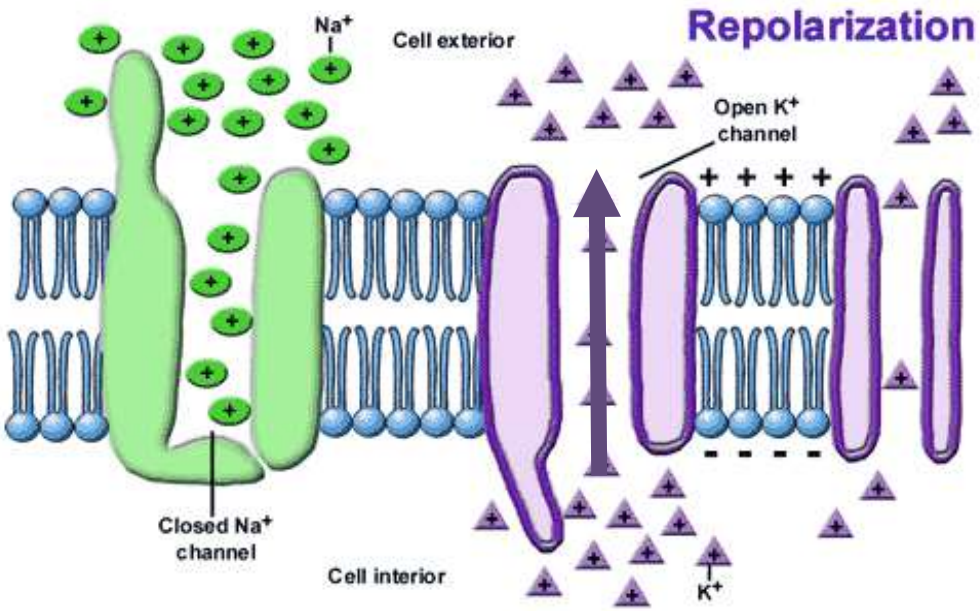
http://commons.wikimedia.org/wiki/File:Scheme_facilitated_diffusion_in_cell_membrane-en.svg

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_facilitated_diffusion_works.html

1.4.A1 Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons.

Potassium channels in **axons** are voltage gated. They enable the facilitated diffusion of potassium out of the axon

1. At one stage during a nerve impulse there are relatively more positive charges inside.
2. This voltage change causes potassium channels to open, allowing potassium ions to diffuse out of the axon.
3. Once the voltage conditions change the channel rapidly closes again.



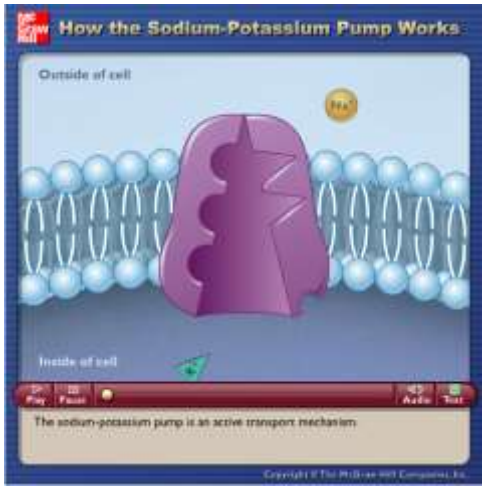
n.b. other positively charged ions that we might expect to pass through the pore are either too large to fit through or are too small to form bonds with the amino acids in the narrowest part of the pore - this explains the specificity of the channel.

http://bioserv.fiu.edu/~walterm/human_online/nervous/nervous_system_files/image012.gif

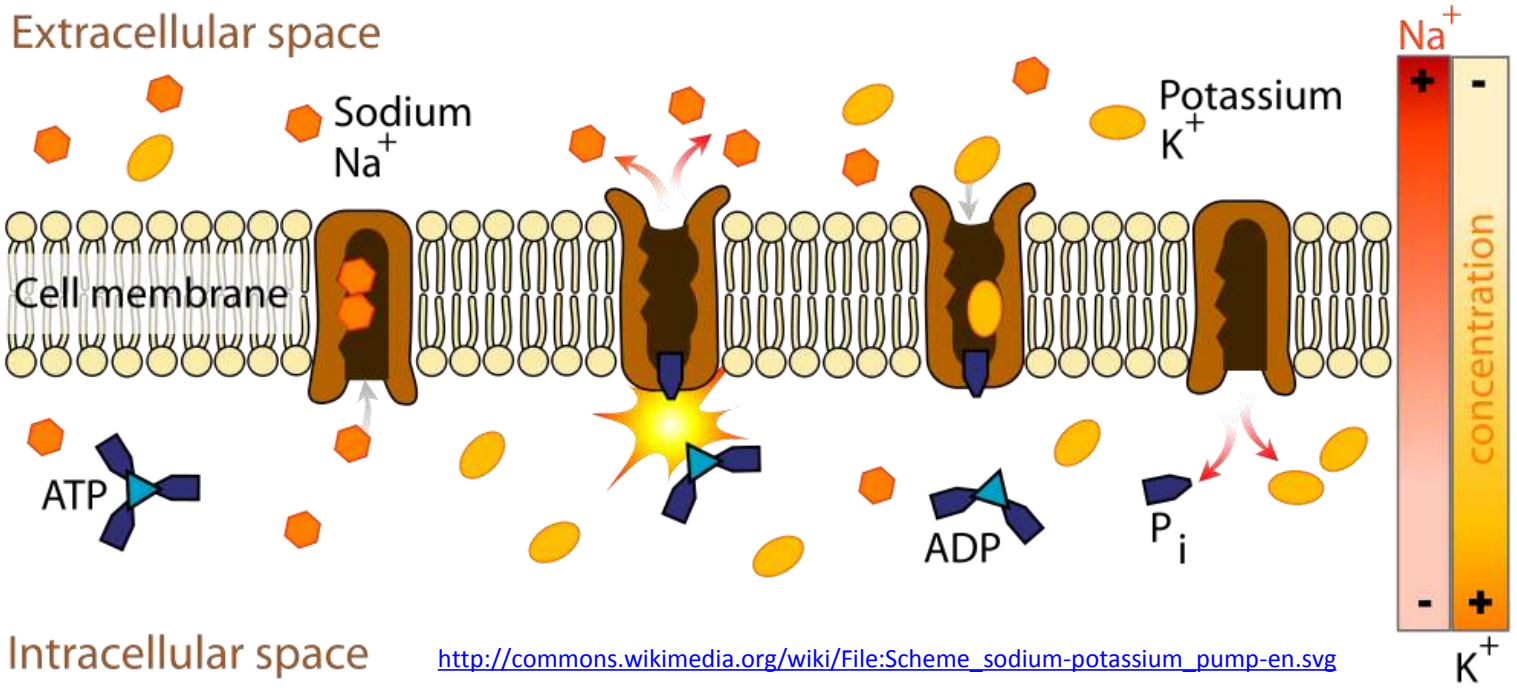
Primary active transport requires **ATP.**

Integral protein pumps use the energy from the hydrolysis of ATP to move ions or large molecules across the cell membrane.

Molecules are moved *against* their concentration gradient

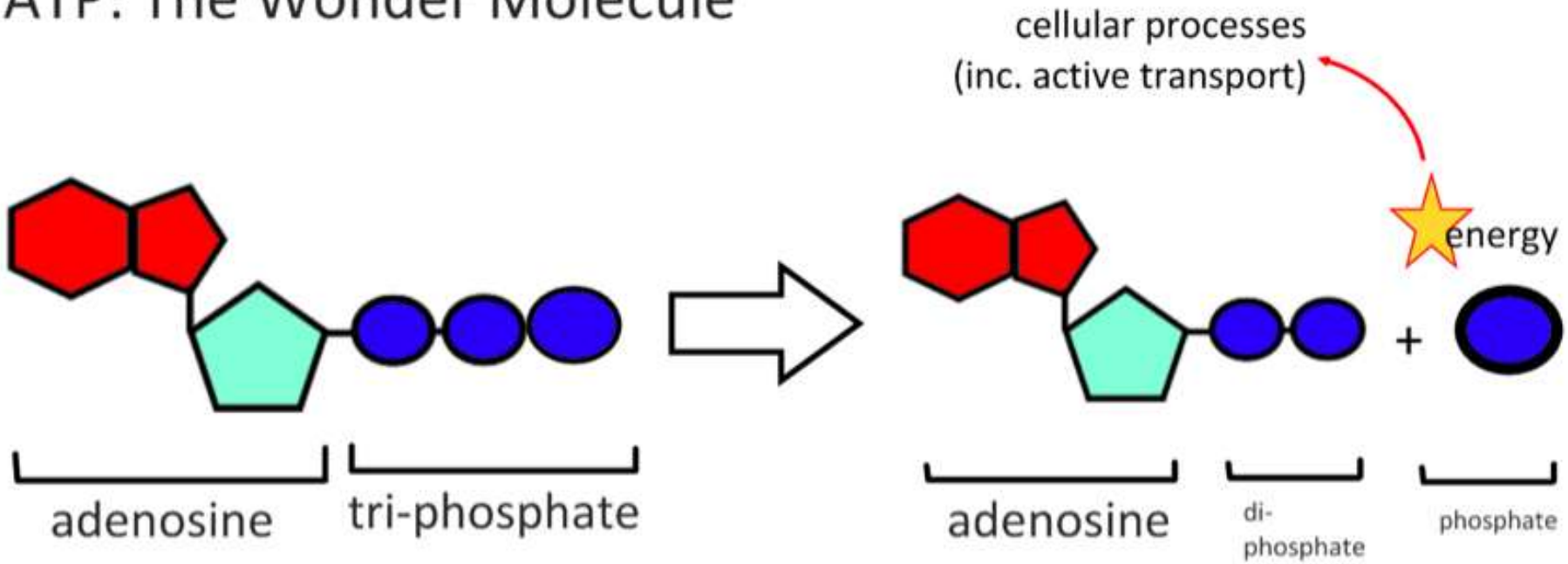


http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_the_sodium_potassium_pump_works.html



http://commons.wikimedia.org/wiki/File:Scheme_sodium-potassium_pump-en.svg

ATP: The Wonder Molecule



Hydrolysis of the bond releases one phosphate and a lot of energy.

use water split

Respiration in the cells recombines ADP with a phosphate ion, to be used for further cellular processes.

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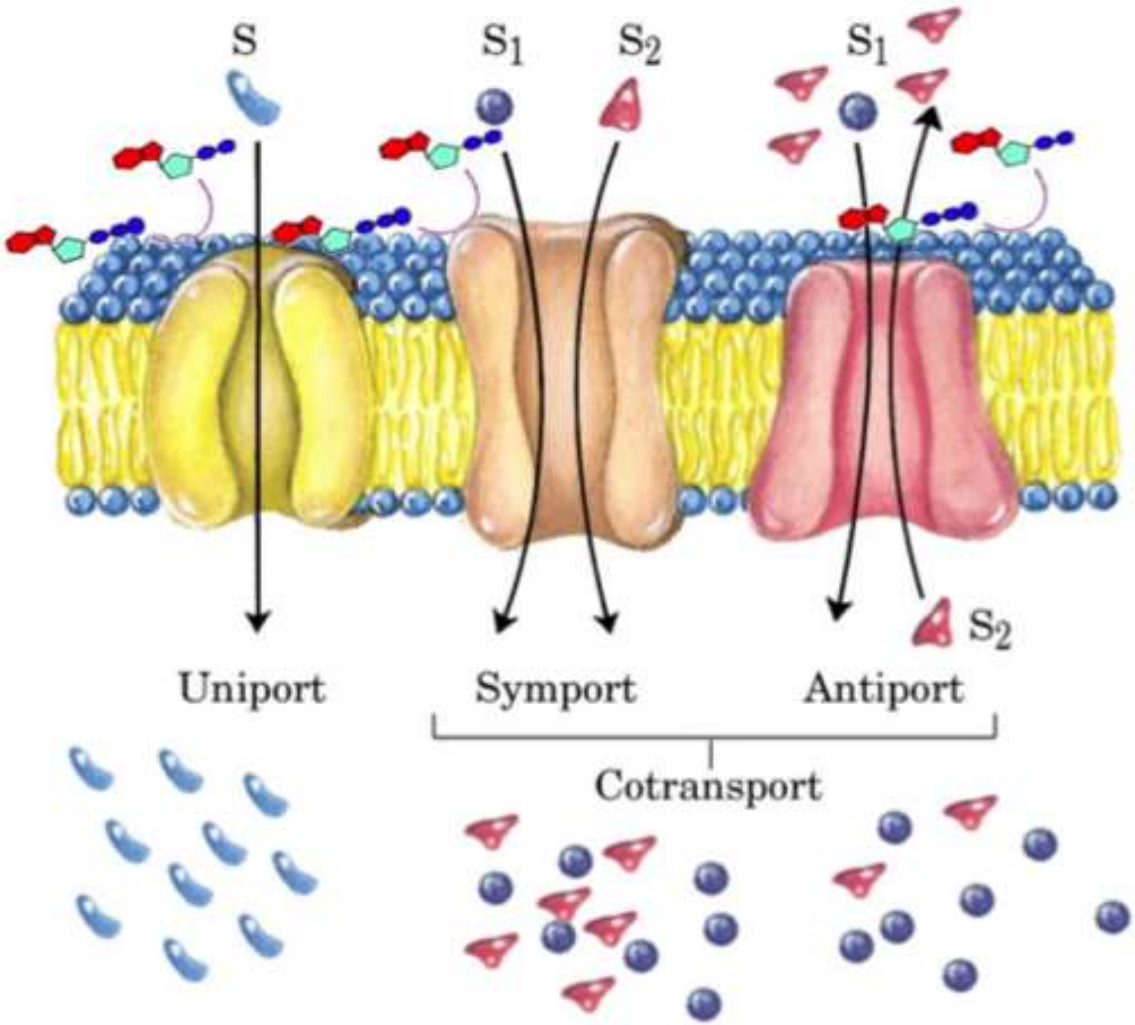
1.4.U1 Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.



Active transport uses energy from the hydrolysis of ATP to pump molecules against the concentration gradient.

Can you deduce the meanings of these terms?

http://www.biochem.arizona.edu/classes/bioc462/462a/NOTES/LIPIDS/Fig12_29UniCotransport.GIF

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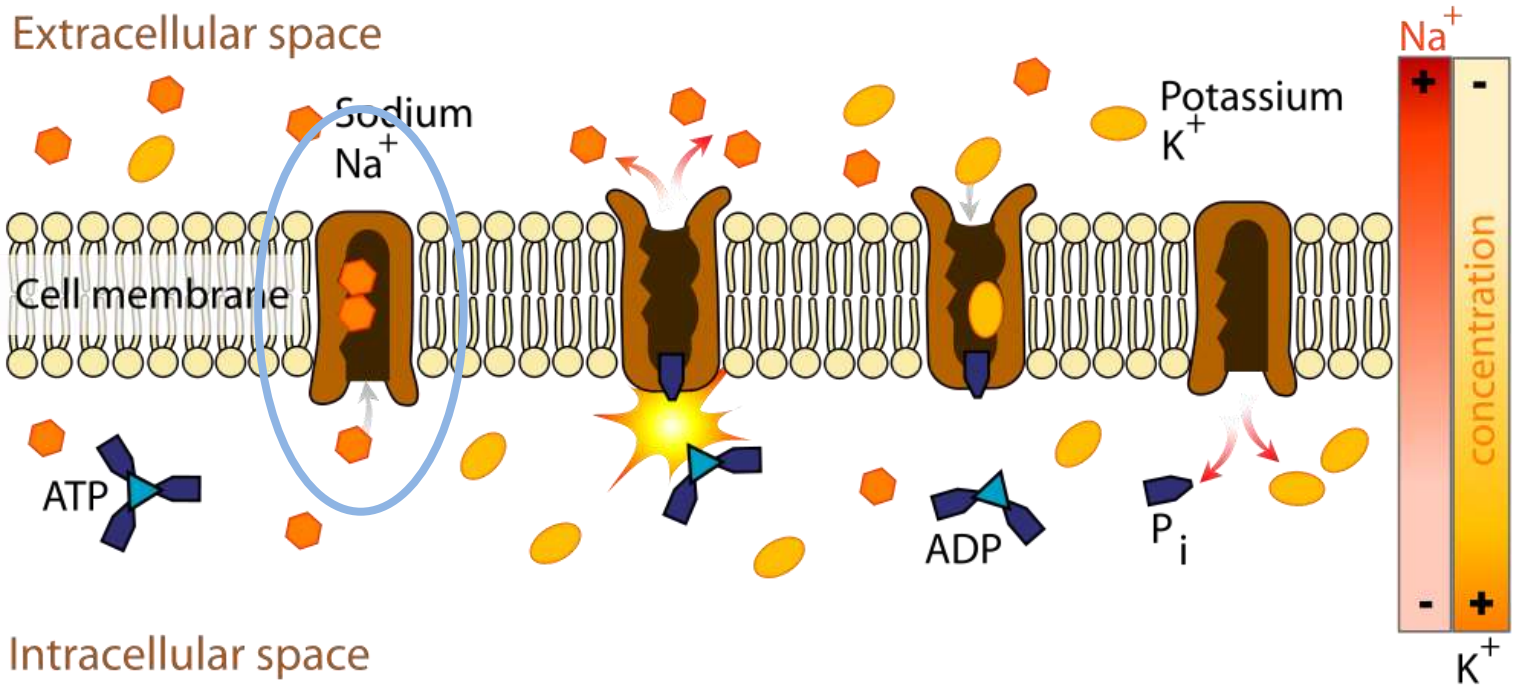
1.4.A1 Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons.

The sodium–potassium pump follows a repeating cycle of steps that result in three sodium ions being pumped out of the **axon (of neurons)** and two potassium ions being pumped in. Each time the pump goes round this cycle it uses one ATP. The cycle consists of these steps:

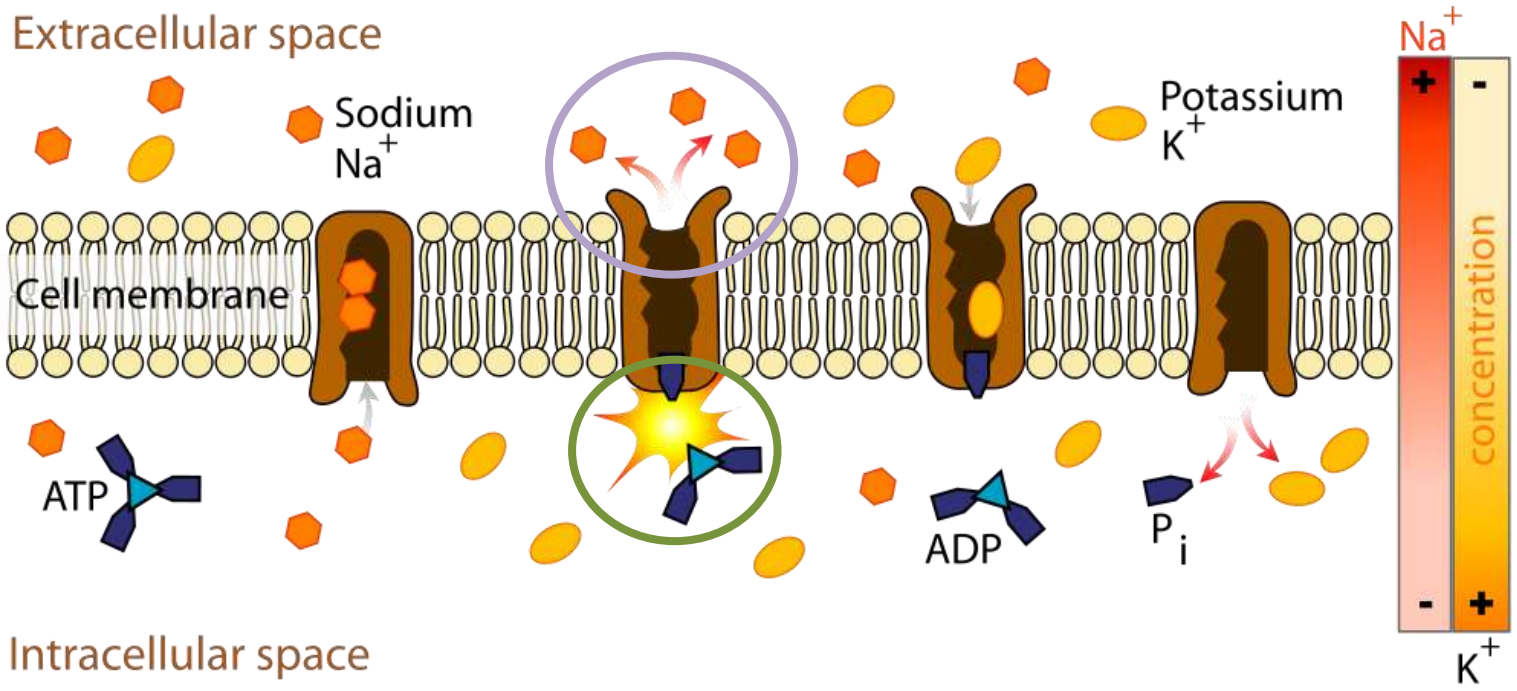


1 *The interior of the pump is open to the inside of the axon; three sodium ions enter the pump and attach to their binding sites.*

http://commons.wikimedia.org/wiki/File:Scheme_sodium-potassium_pump-en.svg

1.4.A1 Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons.

3 *The interior of the pump opens to the outside of the axon and the three sodium ions are released.*

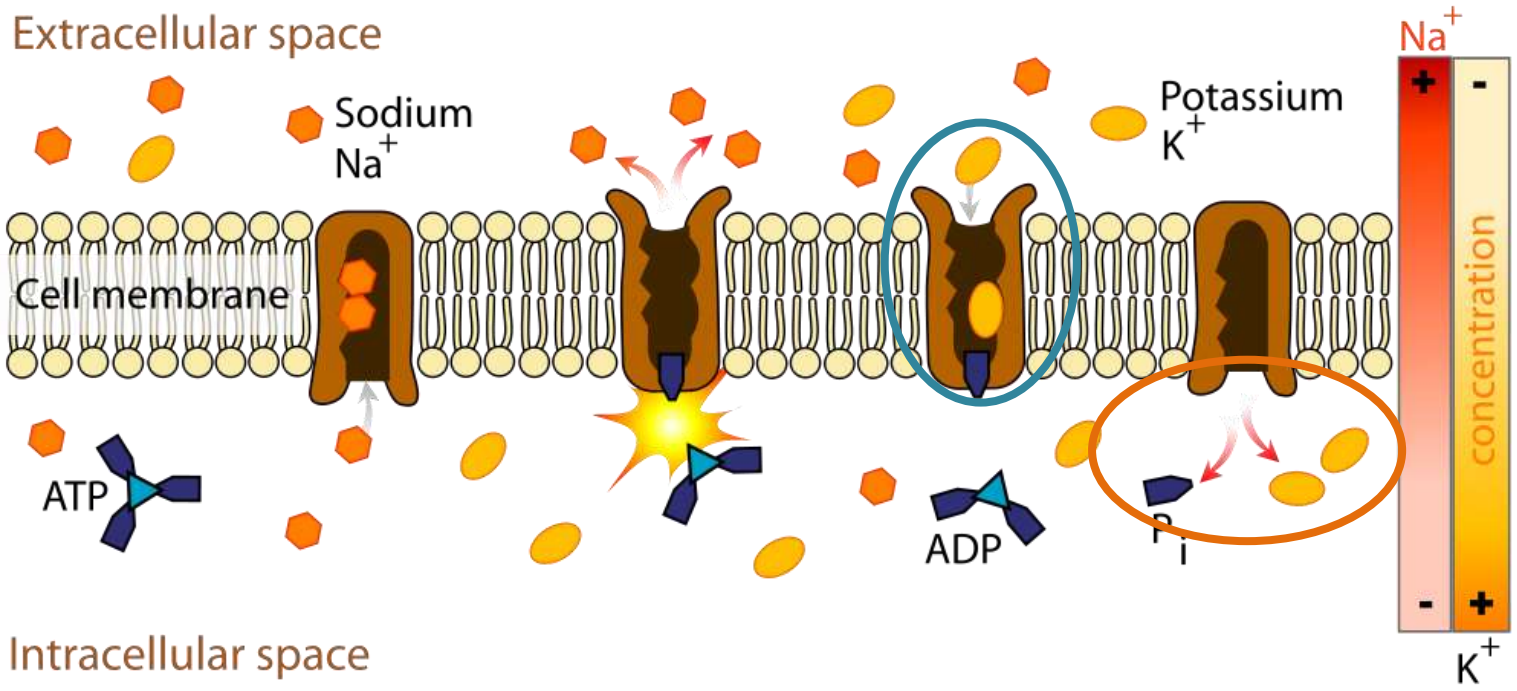


2 *ATP transfers a phosphate group from itself to the pump; this causes the pump to change shape and the interior is then closed.*

http://commons.wikimedia.org/wiki/File:Scheme_sodium-potassium_pump-en.svg

1.4.A1 Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons.

4 *Two potassium ions from outside can then enter and attach to their binding sites.*

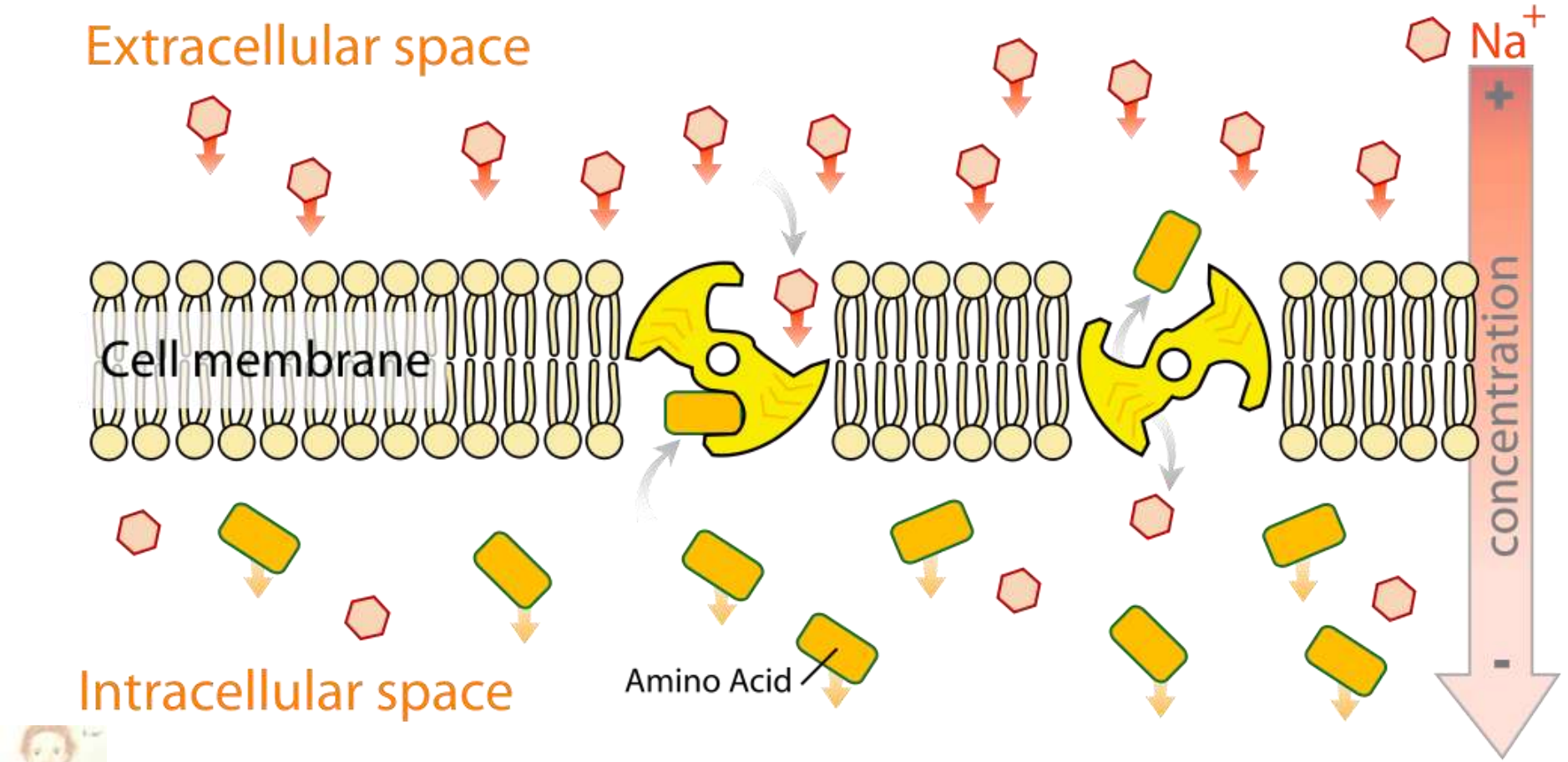


5 *Binding of potassium causes release of the phosphate group; this causes the pump to change shape again so that it is again only open to the inside of the axon.*

6 *The interior of the pump opens to the inside of the axon and the two potassium ions are released. Sodium ions can now enter and bind to the pump again (#1).*

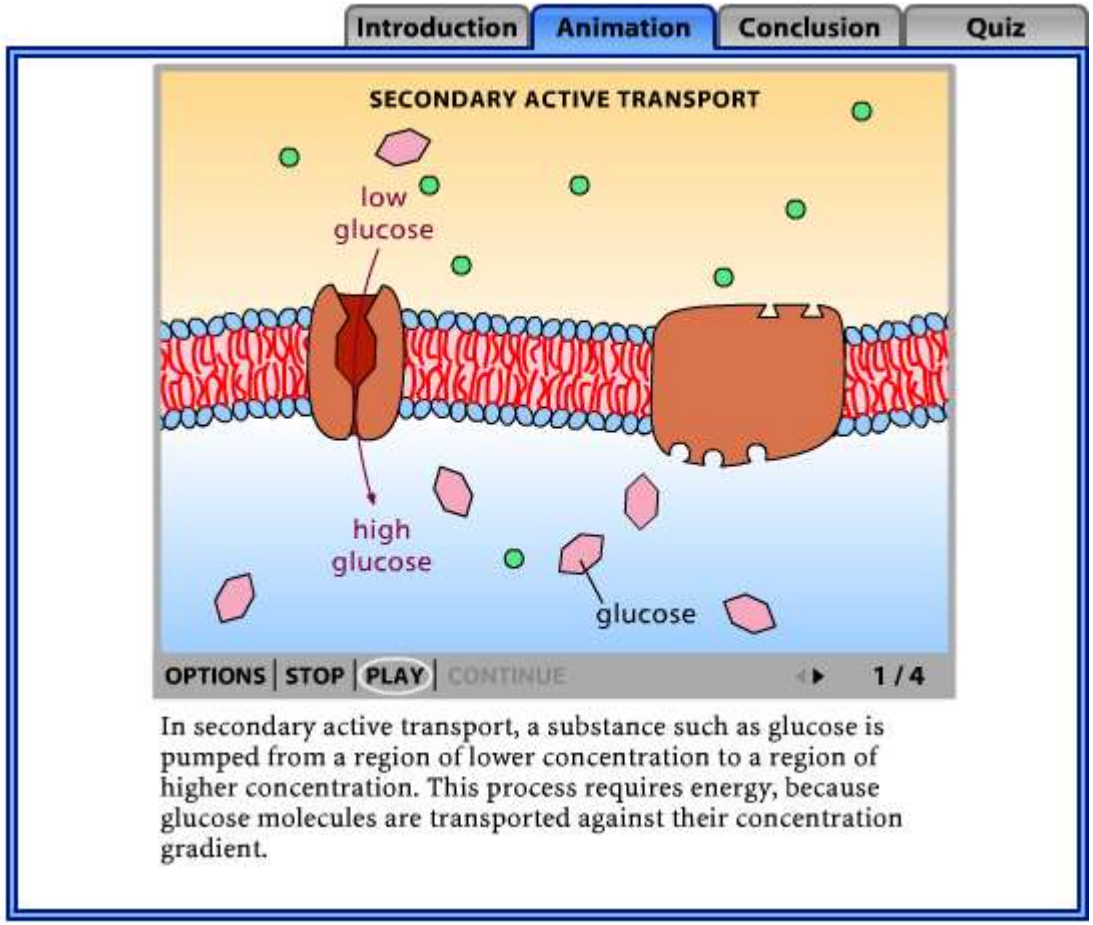
http://commons.wikimedia.org/wiki/File:Scheme_sodium-potassium_pump-en.svg

In **secondary active transport**, the required energy is derived from energy stored in the form of concentration differences in a second solute.



http://commons.wikimedia.org/wiki/File:Scheme_secundary_active_transport-en.svg

Typically, the concentration gradient of the second solute was created by primary active transport, and the diffusion of the second solute across the membrane drives secondary active transport.

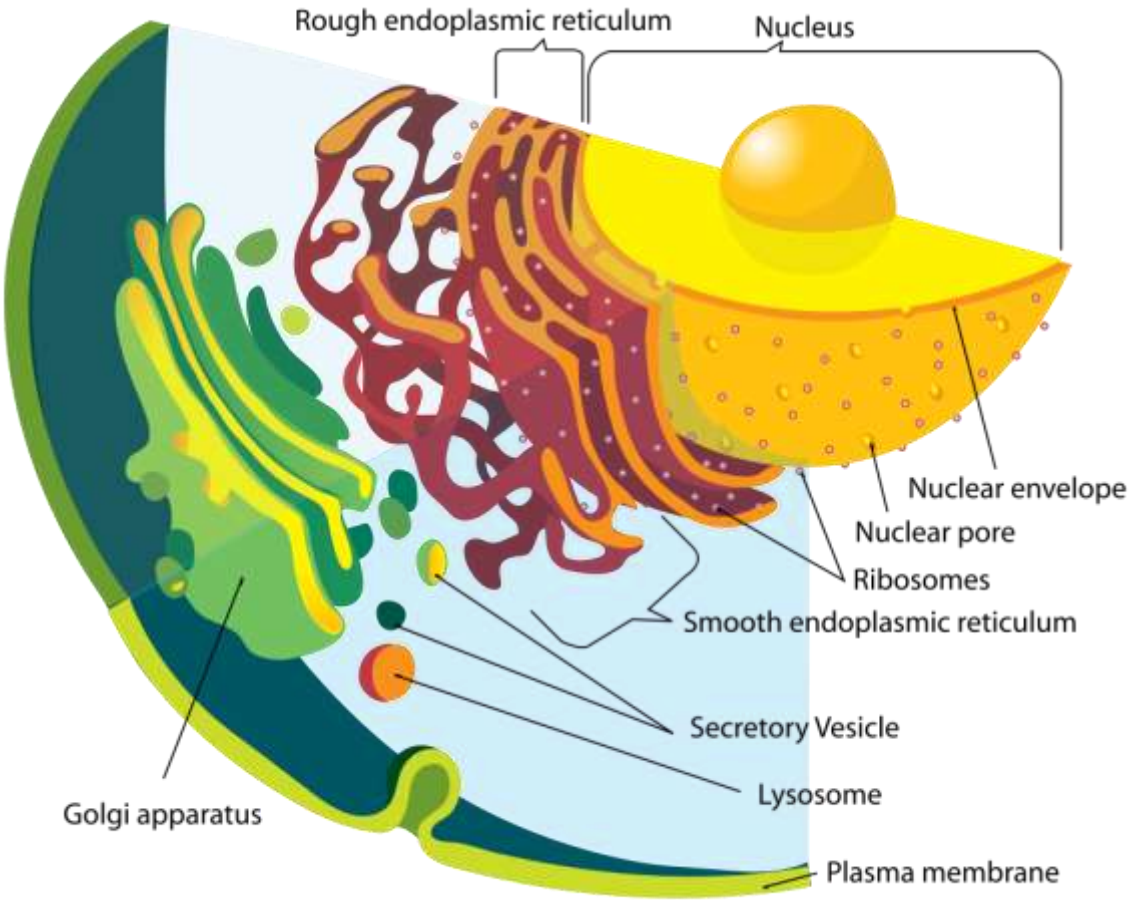


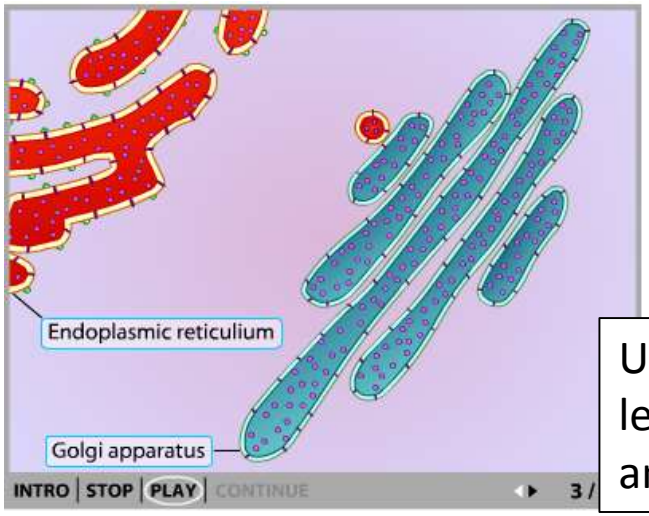
http://bcs.whfreeman.com/thelifewire/content/chp05/0502002.html

1.4.U3 Vesicles move materials within cells.

Vesicles are small spheroidal packages that bud off of the RER and the Golgi apparatus

They carry proteins produced by ribosomes on the RER to the Golgi apparatus, where they are prepared for export from the cell via another vesicle





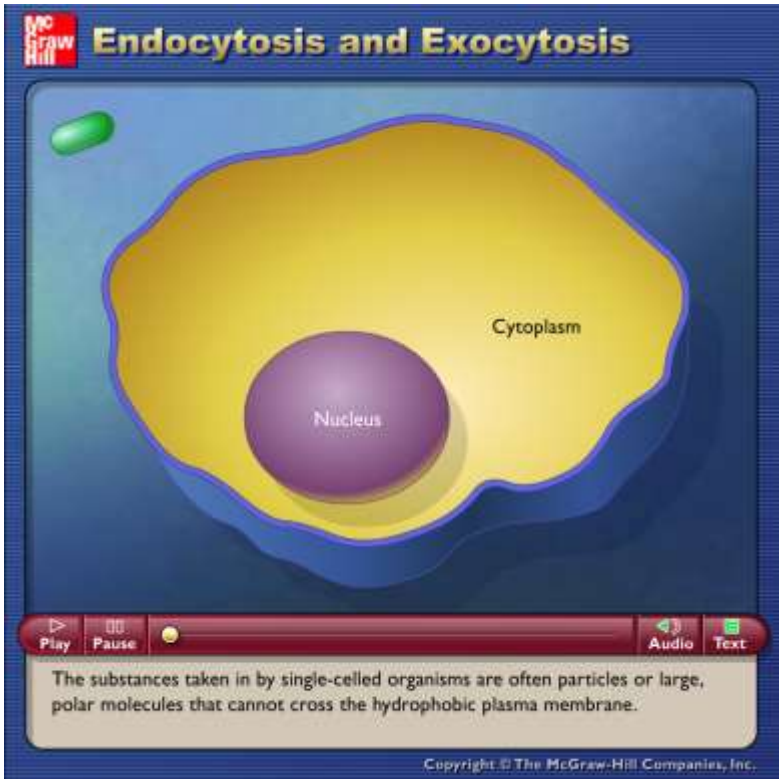
Use the animated tutorial to learn more about the formation and use of vesicles in cells

http://www.sumanasinc.com/webcontent/animations/content/vesiclebudding.html

1.4.U2 The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis.

Endocytosis: The taking in of external substances by an inward pouching of the plasma membrane, forming a **vesicle**

Exocytosis: The release of substances from a cell **(secretion)** when a **vesicle** joins with the cell plasma membrane.

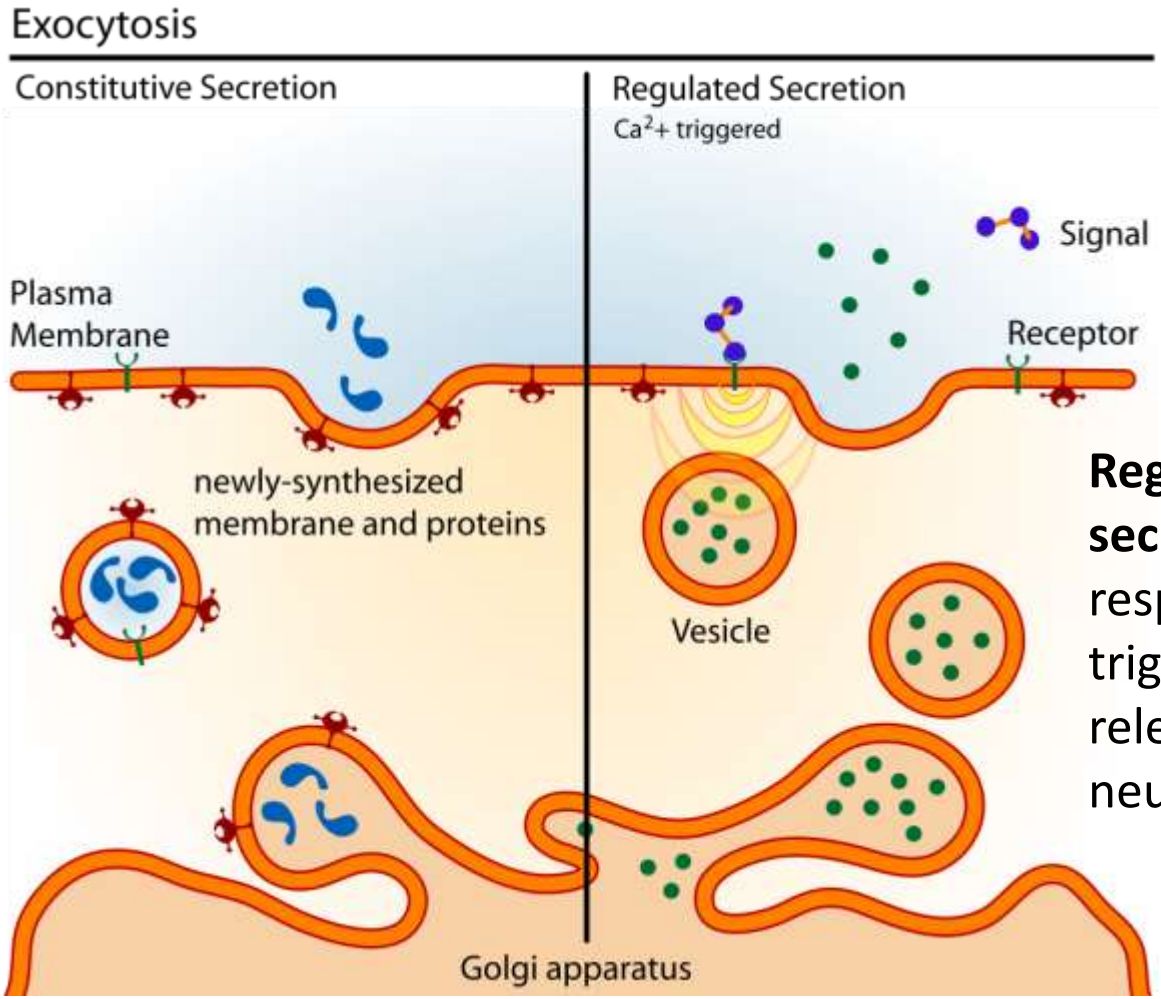


http://highered.mcgraw-hill.com/olc/dl/120068/bio02.swf

Diagrams on following slides

1.4.U2 The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis.

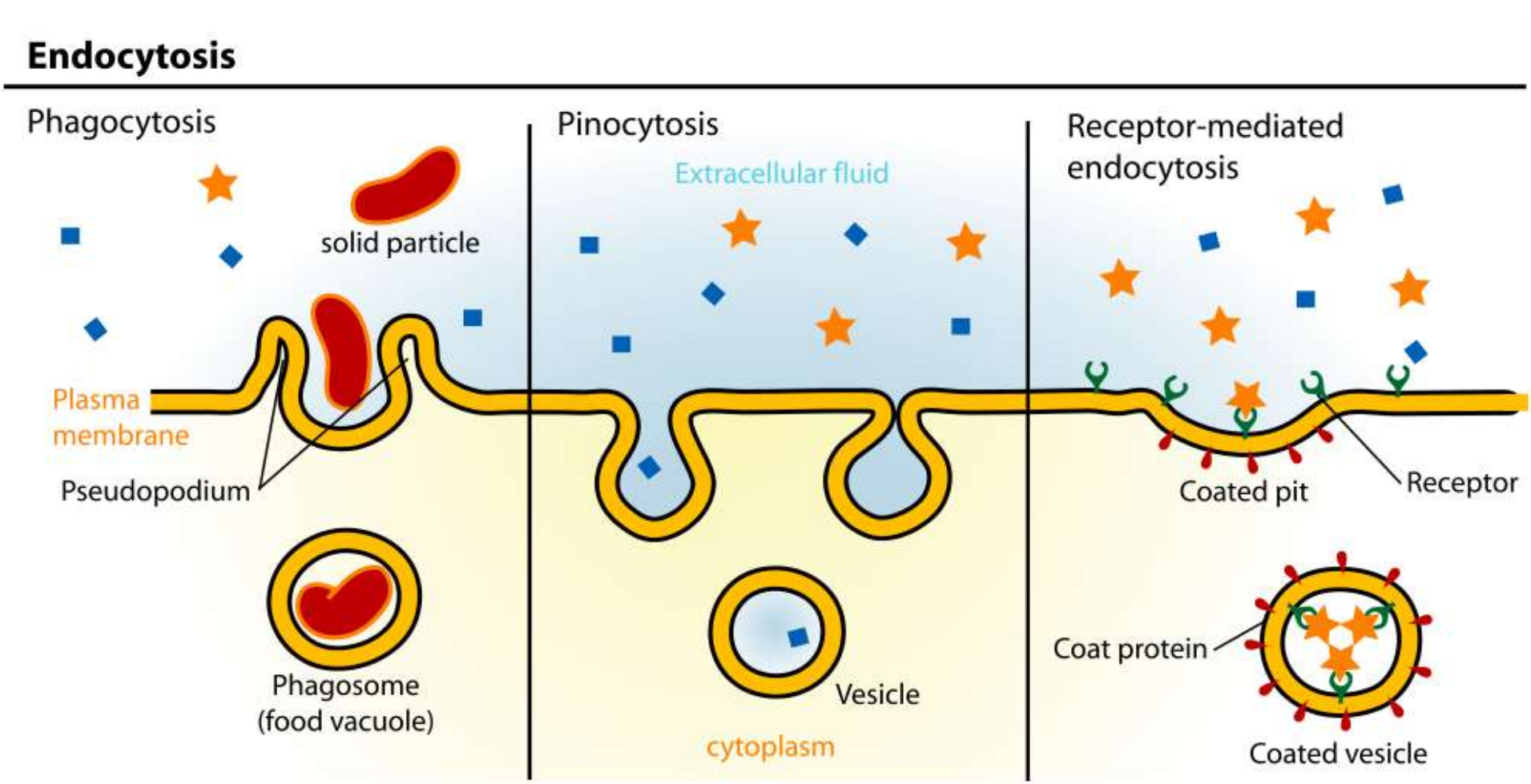
Constitutive secretion occurs continuously in cells, depending on their function



Regulated secretion is in response to a trigger e.g. the release of neurotransmitters

http://commons.wikimedia.org/wiki/File:Exocytosis_types.svg

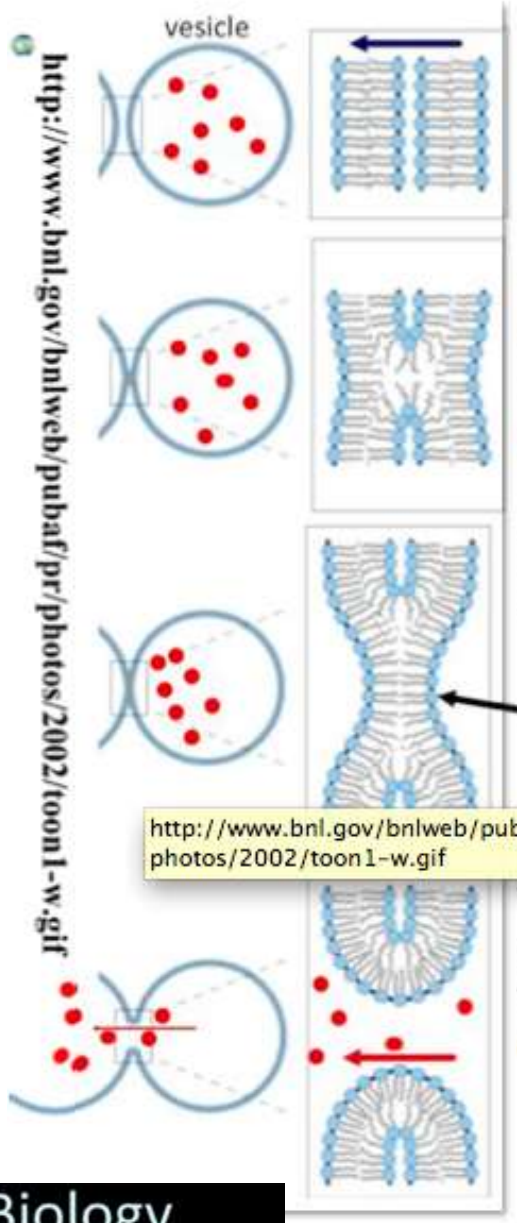
1.4.U2 The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis.



“Cell eating” “Cell drinking”

http://commons.wikimedia.org/wiki/File:Endocytosis_types.svg

1.4.U2 The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis.



The vesicle approaches the plasma membrane. All membranes are made of the phospholipid bilayer, so share the same properties.

The membranes begin to fuse. Remember the fluidity of the plasma membrane - the phospholipids can flow around each other.

For a moment, there is a single phospholipid bilayer at the point of contact.

small single bilayer:
"temporary intermediate structure"

http://www.bnl.gov/bnlweb/pubaf/pr/photos/2002/toon1-w.gif

The membrane pore opens, allowing the contents to pass through. Notice that through the whole process, there is never an unbroken section of the bilayer.

How do membranes fuse?

Lin Yang

It wasn't until 2002 that the method for membrane fusion was discovered - by Yang and Hwang - using X-ray diffraction images.

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1.4.S1 Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)

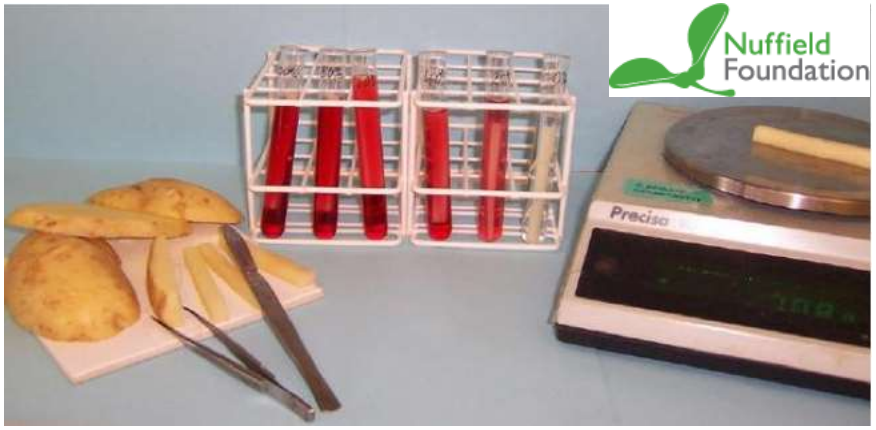
http://www.saps.org.uk/secondary/teaching-resources/286-measuring-the-water-potential-of-a-potato-cell

Estimation of osmolarity is a simple lab with many possible variations.

The two lab protocols shown suggest different ways of measuring the dependent variable.

This is an ideal opportunity to practise and improve your understanding of the following IA criteria:

- Analysis
- Evaluation
- Communication



http://www.nuffieldfoundation.org/practical-biology/investigating-effect-concentration-blackcurrant-squash-osmosis-chipped-potatoes

n.b. estimation of osmolarity should be limited to statements such as "this tissue has an osmolarity equivalent to a 2% sucrose solution". Molar concentrations maybe used in place of % and other solution such as sodium chloride maybe used in place of glucose.

Bibliography / Acknowledgments

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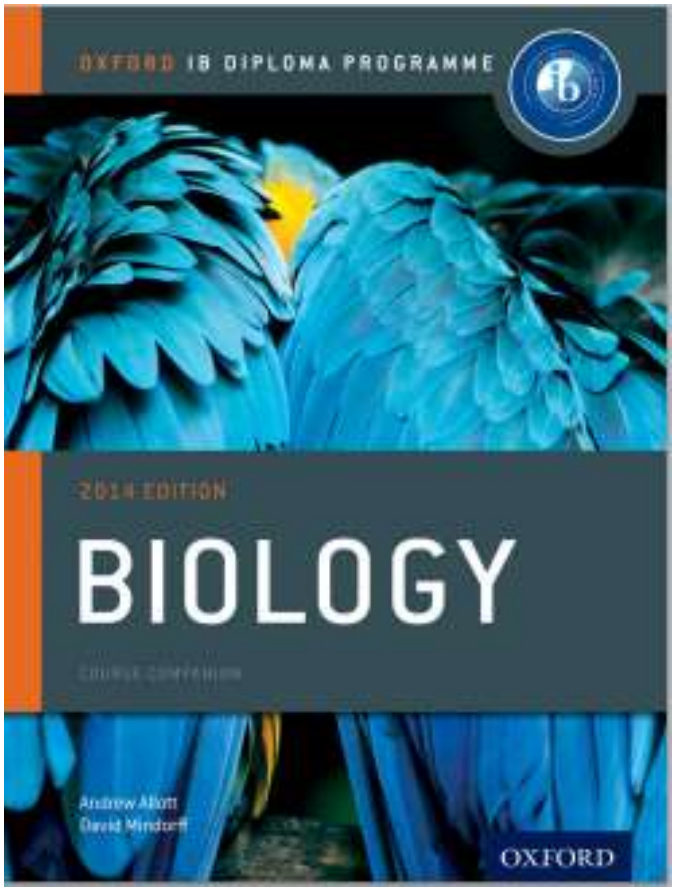

Jason de Nys