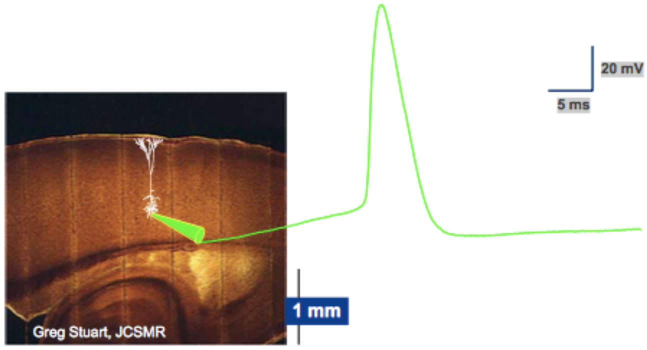
PHSL2101 – Cell physiology

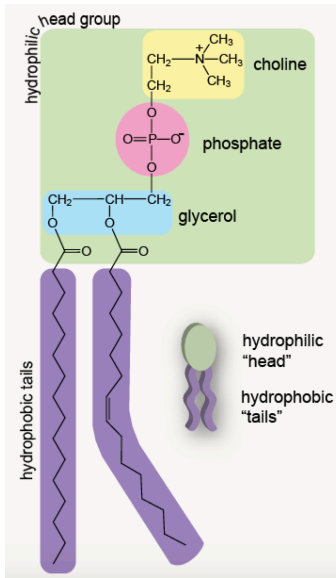
Lecture 1
Human body systems – circulatory, nervous, respiratory, digestive, skeletal, muscular



Cells: the basic functional unit
- Transfer oxygen to tissues
- Nerve cells take in inputs, integrate them and fire electrical signals (action potential)

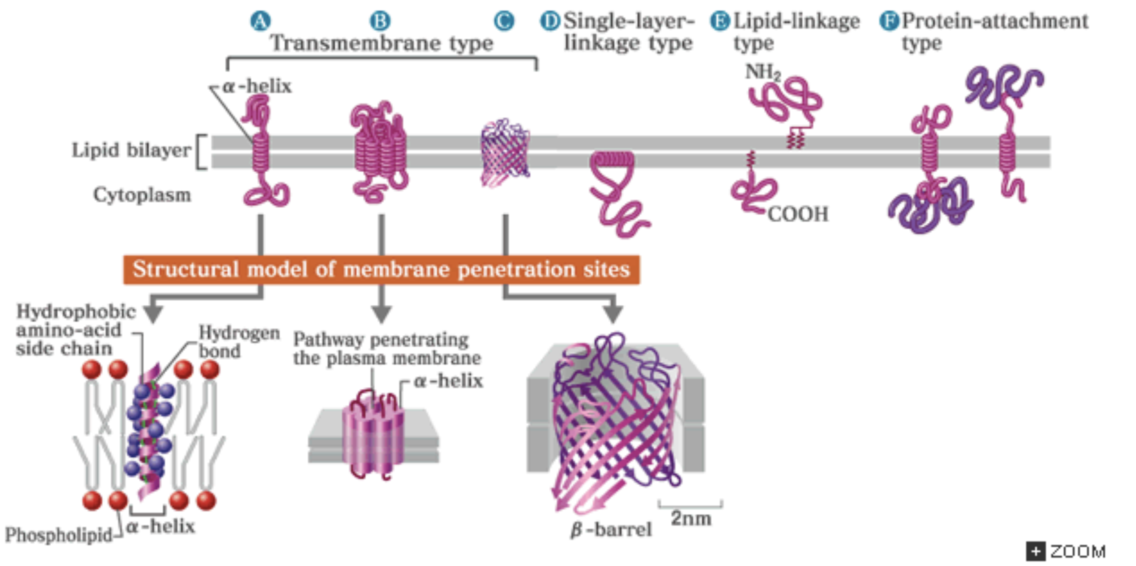
Single cells
- E.g. ear cells vibrate to musical sounds, outer cochlear hair cells move to amplify sound
- E.g. brain cells signaling wake-up, thalamocortical cells have two firing modes, stimuli to wake up causes cells to fire at a different rate
- E.g. muscle cells contracting for movement (skeletal), heart pumping (cardiac), digestion (smooth)

'Excitable cells'
- Have a potential difference or voltage across their membrane e.g. neurons in the brain, muscle cells, epithelial cells
- They use electrical and/or chemical signaling
- Move substances across their membranes
- This affects diseases like epilepsy and anxiety
- Effects of sedatives, alcohol and other drugs



Cell membrane
- Phospholipid bilayer
- Polar (hydrophilic) heads
- Nonpolar (hydrophobic) tails

Membrane potentials
- Membrane proteins span lipid bilayer
- Lipid anchored and peripheral membrane proteins



Cell membrane properties
- Water and solute impermeant
- Hydrophobic/non-polar substances can cross
- Excellent electrical insulator, 10^-5 V/cm
- Behaves as capacitor which effects the voltage response of the cell to stimulation
- Capacitor is combination of two conductors or charged plates (internal and external solutions) separated by an insulating material (lipid), C=Q/V (farads)

Epithelial cells
- Move substances across an cell layer (secrete or absorb substances)
- E.g. H20 movement across lung epithelia
- Cystic fibrosis involves deformity in epithelial cells, they cannot secrete properly leading to thickened mucous

Biological electricity – electrochemical potential provides driving force, ion channel is the 'switch' and current carried by ions to result in response (depolarization)

Lecture 2
Cell membrane functions – separates internal and external solutions, electrical insulation, transports substances in and out

How do substances move across the cell membrane?
1. Diffusion
- Passive (no energy)
- Arises from Brownian (random thermal) motions
- Movement from high to low concentrations
- Rapid across small distances (single cell), but too slow for signaling long distances (e.g. brain to muscle)
- D = 'diffusion coefficient'
- Water (D approx. 10^-5 cm^2/s) to diffuse across cell membrane (0.1s)
- Ion (D approx. 10^-5cm^2/s) to diffuse from one end of small cell to another (0.1s), protein (D approx. 10^-7cm^2/s) (10s)
- Protein along a 1 metre motor axon (spinal cord to foot) (>1000yrs)

Fick's general law of Diffusion

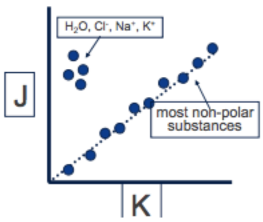
diffusion rate or flux J = DA (dC/dx)

where: A = the area of the interface
dC/dx = solute concentration gradient across the interface (width = x) D
= the diffusion coefficient
= a proportionality constant that varies directly with the speed of random motion (depends on molecule properties such as size)

NB The above D is derived from diffusion in aqueous solution. For **membrane diffusion** an additional constant, the partition co-efficient (K; a measure of lipid solubility), is added to the equation so that:

J = DKA (dC/dx)

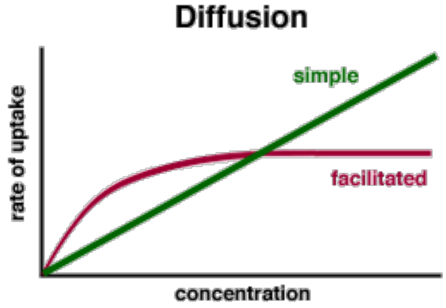
NB: Stanfield gives J = PA ΔC; where P is permeability)



Simple diffusion: lipid soluble/ hydrophobic substances, through membrane e.g. gases, steroids

Facilitated diffusion: water soluble/ hydrophilic substances, via a protein carrier e.g. ions, glucose, amino acids

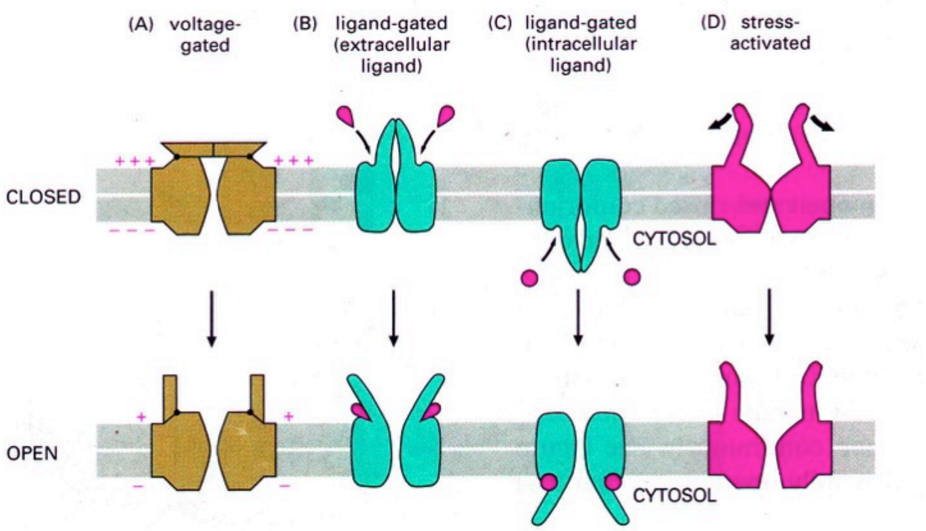
Facilitated diffusion – carrier method



Max flux when all carrier proteins occupied

Glucose facilitated diffusion
- Transporter molecule, binding point, conformational change, release binding (GLUT1)
- Cells need glucose to produce ATP
- Insulin increases diffusion of glucose into cells
- Insulin increases the number of transporters in muscle and fat cells so transport doesn't saturate

Facilitated diffusion – ion channel mediated
- Trans membrane proteins with aqueous pores
- Downhill ion flux (passive), selective
- Can be always open or gated



Lecture 3

Specificity can distinguish simple and facilitated diffusion e.g. GLUT1 transporters favour the D-glucose structure compared to L-glucose structure. Competition can also distinguish e.g. L-glucose 'competes' with D-glucose lowering its uptake; this is how certain drugs can work. Finally, saturation can distinguish the two as transporters can be all 'taken up' but this does not happen with simple diffusion.

Osmosis is water diffusion through aquaporin's
- Typical osmolarity in physiological solutions is approximately 300mOsm
- Isotonic (same)
- Hypertonic (more solute, less water outside), cell will shrink
- Hypotonic (less solute, more water outside), cell will expand

If a swelling cell does not release osmolytes (particles) e.g. via stretch-activated channels or via the Na+ pump, it may burst