BMS1052 Learning Objectives

Foundations	
Describe the structure of prototypical neurons	• Neurons consist of three distinct areas – the axon, cell body and dendrite • Neurons contain extensive microtubules to deliver proteins and other molecules down axons and dendrites (no protein synthesis in axons and dendrites) • The membrane of the axon contains specialised proteins – ion channels and ion pumps • The synapse is the connection between two neurons – axons deliver signals to dendrites (often onto dendritic spines)

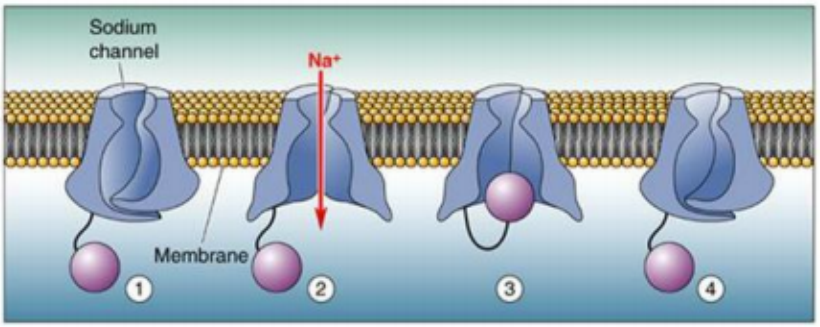
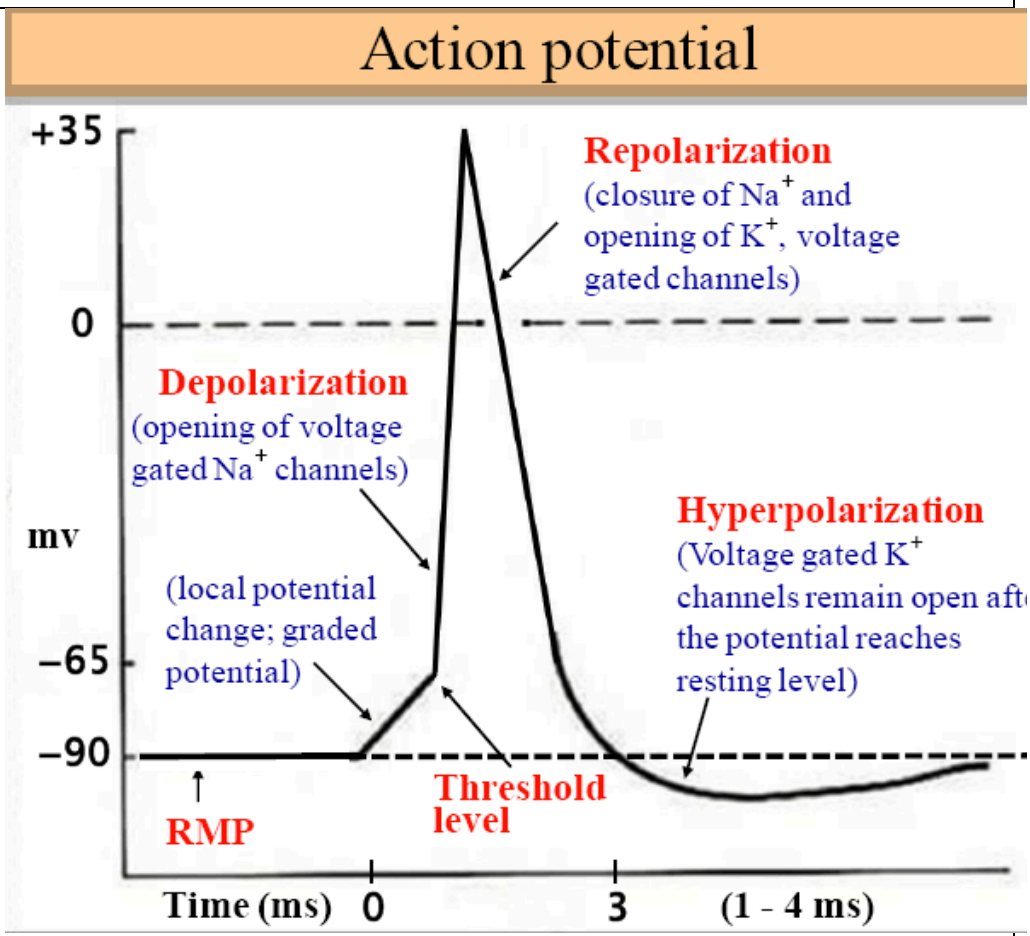
Describe the function of the axon and dendrites	• In general, information is transmitted away from the cell body via axons and towards the cell body via dendrites
	• Transport of materials and information
	  ○ Slow axoplasmic transport – diffusion through cytoplasm or along the membrane
	  ○ Fast axoplasmic transport – active transport via kinesin walking vesicles along the microtubules
	• Transport can be anterograde (towards the synapse) or retrograde (away from the synapse)

Identify ways of characterising and naming neurons	• Neurons vary in:
	  ○ Number of neurites – unipolar (dendrite extends from axon), bipolar (one axon and one dendrite attached to either side of the soma), or multipolar (lots of dendrites attached to the soma and one axon)
	  ○ Shape and dendrite – stellate (collate info within a brain region) or pyramidal cells (send info to other brain regions)
	  ○ Connections
	  ○ Axon length – Golgi Type I (extend axons from one brain region to another) or Golgi Type II (involved in computations within a brain region)
	  ○ Neurotransmitters

Identify the 4 different classes of glia cells	• Myelinating glia – oligodendroglia (CNS) and Schwann cells (PNS) • Astrocytes • Microglia • Ependymal cells

Describe the role and location of the 4 different classes of glia cells	• Myelinating glia
	  ○ Oligodendroglia (CNS) and Schwann cells (PNS) generate myelin
	  ○ Myelin forms a sheath around axons, providing electrical insulation and increasing speed and efficiency of communication
	  ○ Regular gaps in the myelin are called Nodes of Ranvier and allow signals to travel faster by jumping between gaps
	• Astrocytes
	  ○ Most numerous glia in the brain – fill spaces between neurons and vessels
	  ○ Influence neuron growth and regulate chemical content of extracellular space (can take ions from one region and move them to another)
	  ○ Also maintain blood-brain barrier and provide metabolic support for neurons
	• Microglia
	  ○ Macrophages – remove debris associated with dead/degenerating cells
	  ○ Fight inflammation within the brain
	• Ependymal cells

	○ Epithelium-like cells that line fluid-filled ventricles in the brain and produce CSF
Identify the factors that lead to movement of ions across a membrane	• Concentration gradient ○ Ions diffuse "down" their concentration gradient – from high to low concentration • Electric field ○ Ions move towards opposite charges • At equilibrium there is no net ion flow across the membrane • These movements create tension between the electrical pull and the concentration pull
Describe the factors affecting an ionic equilibrium potential	• Concentration ratio • Electric charge • Not the permeability
Describe the factors affecting a cell's resting membrane potential	• The cell's resting membrane potential is approximately -65mV • Concentration ratio • Electric charge • Permeability of all ions
Apply the Nernst equation and Goldmann equation	• $E_{ion} = 2.303\frac{RT}{zF}\log_{10}\frac{[ion]_{out}}{[ion]_{in}} = \frac{61.5}{z}\log_{10}\frac{[ion]_{out}}{[ion]_{in}}$ in mV z – ionic charge T – temperature R – universal gas **constant** F – Faraday **constant** [ion] – ionic concentration Note that equilibrium potential is independent of *permeability* and *ionic conductance*. • $V_m = 61.5\log_{10}\frac{P_K[K]_{out} + P_{Na}[Na]_{out} + P_{Cl}[Cl]_{in}}{P_K[K]_{in} + P_{Na}[Na]_{in} + P_{Cl}[Cl]_{out}}$ • What matters is the relative ionic permeability (an ion's permeability compared to the permeability of other ions)
Know how to estimate equilibrium and membrane potentials	• Can estimate the membrane potential by knowing which ion is the most permeable
Describe the function of the Na/K-ATPase (Na-K pump)	• The pump actively transports Na and K across the membrane • Requires ATP – pushed Na out of the cell and K into the cell against their concentration gradients • Conformational changes ○ When open intracellularly, the pump binds ATP and 3 intracellular Na ions ○ ATP is hydrolysed, leading to phosphorylation and release of ADP ○ The pump changes conformation, releasing Na into the extracellular space ○ The pump binds 2 extra K ions, causing dephosphorylation and a second conformational change, returning it to its original position ○ ATP binds and K ions are released • 3 Na out, 2 K in
Describe how selectivity and gating occurs in Na and K channels	• Channels are selectively permeable due to physical shape and chemical properties • Pore loop act as physical filter (due to close proximity) • Charged domains on amino acid residues act as a chemical filter

	• Gating in voltage gated sodium channels  ○
Describe why passive ion diffusion is an unreliable way to transfer signals between neurons	• Passive diffusion of ions through the cytosol requires no additional energy • This process is slow and breaks over long distances
Describe the components of an action potential, including what channels are involved and when	 • • Voltage gated Na channels open causing rapid depolarisation • Voltage gated Na channels are only open for approximately 1ms, and thus close and inactivate rapidly (repolarisation) • Voltage gated K channels (delayed rectifier) channels open causing hyperpolarisation • Sodium channels remain inactivated until the membrane potential is hyperpolarised • Closing of potassium channels causes reversion to the resting membrane potential
Describe factors affecting the speed and nature	• Normally the action potential propagates away from the spike initiating zone, towards the axon terminal • Inactivation of voltage gated Na channels prevents backflow