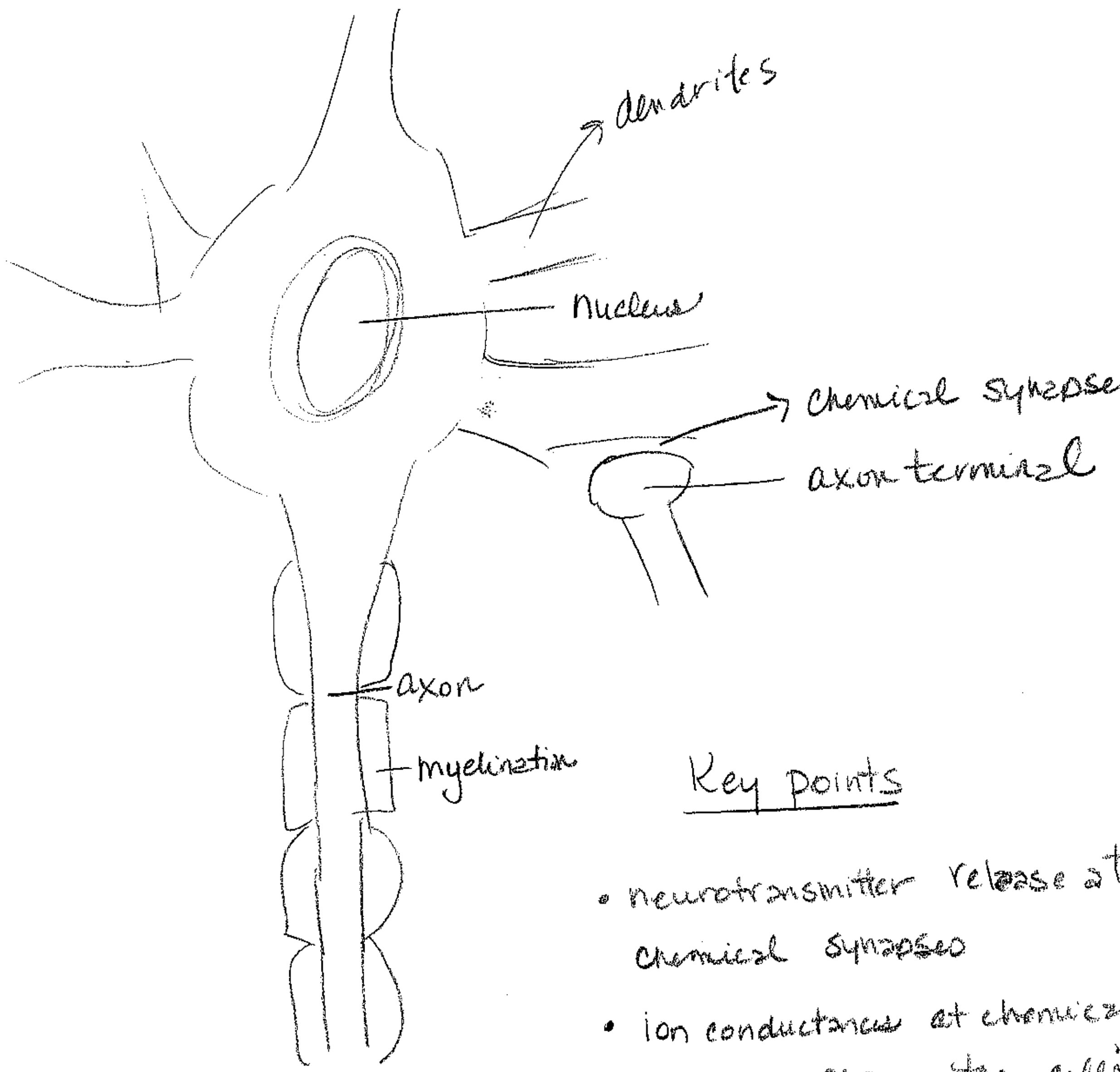
Anatomy of a Neuron

★ Figure 1.1 of Purves, p 2



Key points

- neurotransmitter release at chemical synapses
- ion conductances at chemical synapses change the cell's membrane potential, V_m
- Δ's in V_m <u>may</u> initiate action potentials that propagate through the axon.

Membrane Potential

- V_m is the electrical potential difference across the cell membrane. The sign reflects the inside absolute potential relative to the outside of the cell
- The cells lipid membrane → insulator
- Resting V_m : in absence of input V_m = negative often ~ −50 or −60 mV but varies by cell type
- V_m is set up by charged molecules

Na^+, K^+, Cl^-, Ca^{++}

Na^+ ≈140mM K^+ Cl^- Ca^{++}

Na^+ ~140 mM
K^+ ~ 5 mM
Cl^- ~ 110 mM
Ca^{++} ~ 1 mM

Na^+ ~10mM K^+ ~ Cl^- Ca^{++}

other Proteins − | other anions −

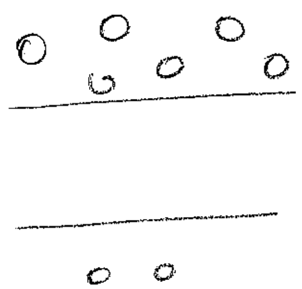
net − charge

Na^+ ~ 5
K^+ ~ 140mM
Cl^- ~ 5
Ca^{++} ~ 0.1μM

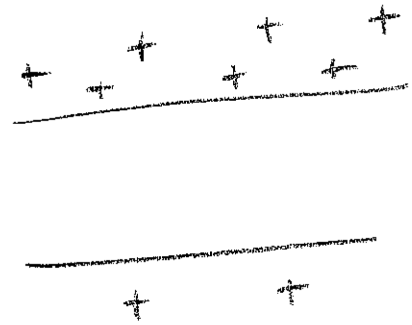
- **Electrochemical Gradients** are stored energy.
  are maintained by active ion pumps (cells must do work to create these)

- **Equilibrium Potential** of an ion.

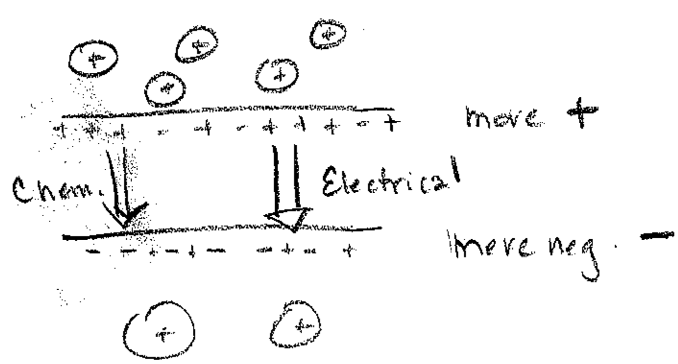
Concentration Gradient

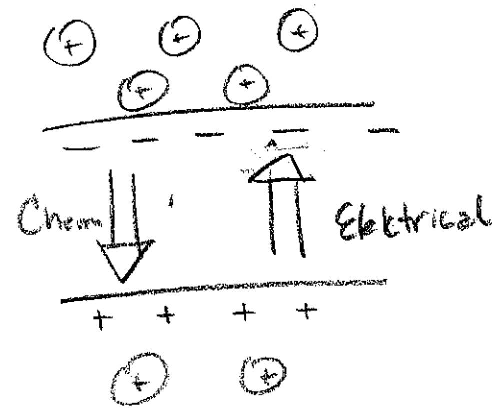


Electrical Gradient



Charged Molecule





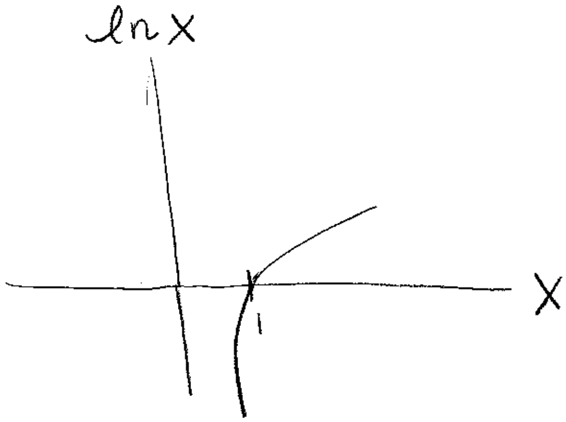
If a channel were to open for that molecule which direction would the charged ion flow?

Equil. Pot: Is the V_m for which the net flow of charged ion is 0. The Chemical gradient is perfectly balanced by the electrical gradient of the membrane potential.

$$E_{ion} = \frac{RT}{zF} \ln \frac{[ion]_{out}}{[ion]_{in}}$$

$$E_{K^+} = \frac{RT}{(+1)F} \ln\left(\frac{5mM}{140mM}\right)$$

↳ < 1 so $E_{K^+} = -$



ln x for $x > 1$ is $+$

for $x < 1$ is $-$

z could be $+$ or $-$

E_{Na^+} is Positive

$(V_m - E_{ion})$ therefore affects the driving force on the ion when a channel for that ion opens

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Ion conductances, g

$g = \frac{1}{R}$ units in Siemens, S.

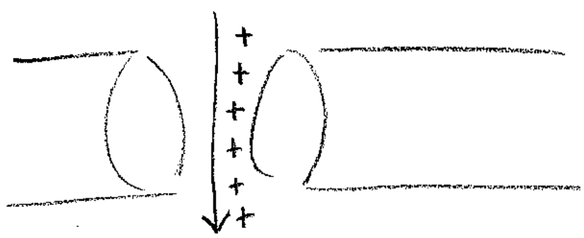
protein channels create selective conductances; ie allow selective flow of ions across the membrane

- direction + magnitude of the flow depends upon $V_m - E_{ion}$.

  if $V_m = E_{ion}$, then no net flow occurs.

- Because ions carry charge, their flow is a **current** and therefore changes V_m.

  note: takes relatively few ions to move to change V_m.

- 

  an inward current : cations in <u>or</u> anions <u>out</u>

- ion channels / conductances may be <u>gated</u> by chemicals or V_m itself.

- probability that the channel is open can be a function of V_m or Conc.

Neurotransmitter Induced Conductances at a Chemical Synapse, figure 5.3 pg 88

Excitatory – Na^+, K^+ / sometimes Ca^{++} flow into the cell depolarize, ie ↑ V_m

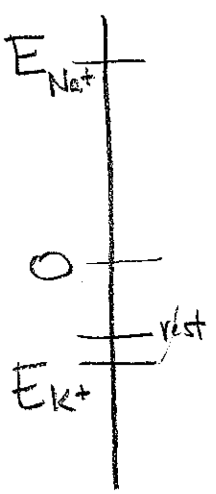
Inhibitory – Cl^- flow into the cell ↓ V_m

– V_m changes due to synaptic currents can generate an action potential via voltage dependent Na^+ + K^+ channels.

Action Potentials

figure 4.3

- at rest Na^+ + K^+ channels are closed.
- depolarization above a threshold induces opening of Na^+ & K^+ channels but Na^+ more quickly
  - Na^+ open 1st, Na^+ flows in, $V_m \rightarrow E_{Na^+}$ which is +



  - the K^+ channels open, K^+ flows out, + starts to oppose Na^+ current
  - Na^+ channels naturally inactivate due to prolonged depolarization
  - K^+ current pulls $V_m \rightarrow E_{K^+}$
  - K^+ channels close b/c V_m has decreased

- cell returns to rest state

- threshold & a long or short path return to a stable state were the 2 features of our 1st neuronal model