Ionic currents underlying the action potential.

Voltage clamp. (Hodgkin - Huxley, 1952)

Technique that allows voltage across axon membrane to be held at any desired level, while measuring resulting current flow across membrane.

Used with giant (1 mm diameter) squid axon.

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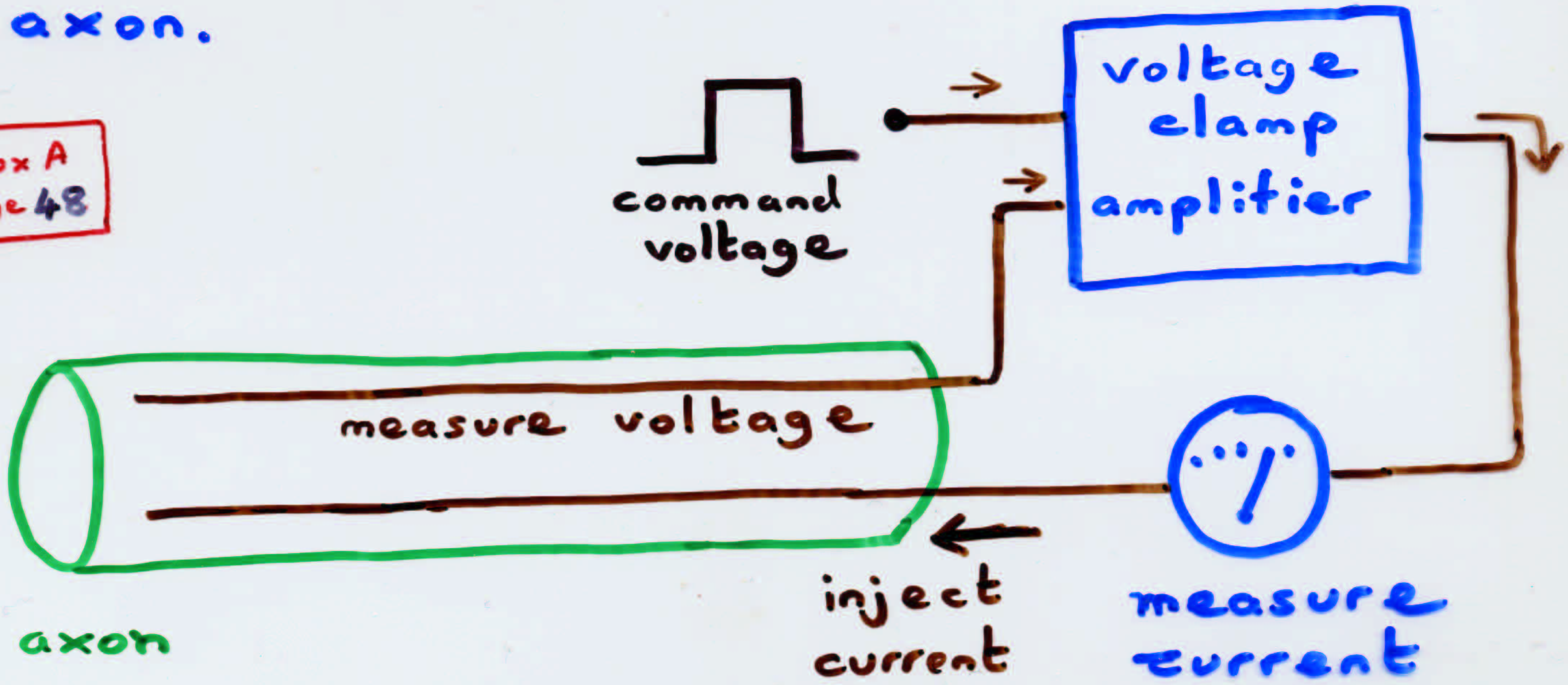


like cruise control on a car

Ionic currents of squid axon

a) Passive response to hyperpolarizing step

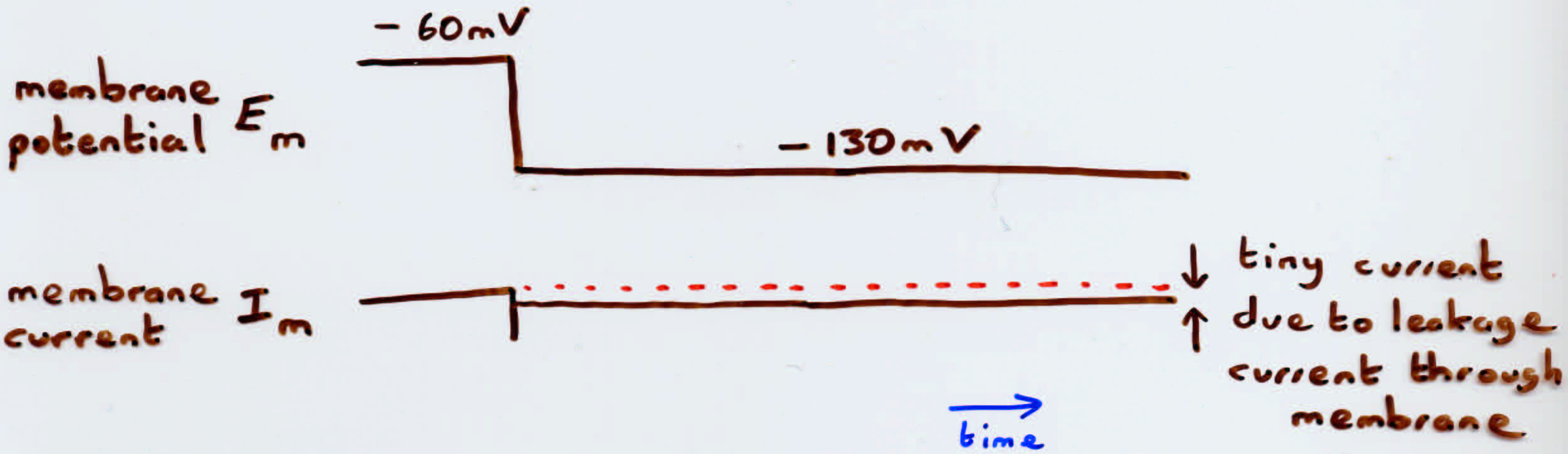
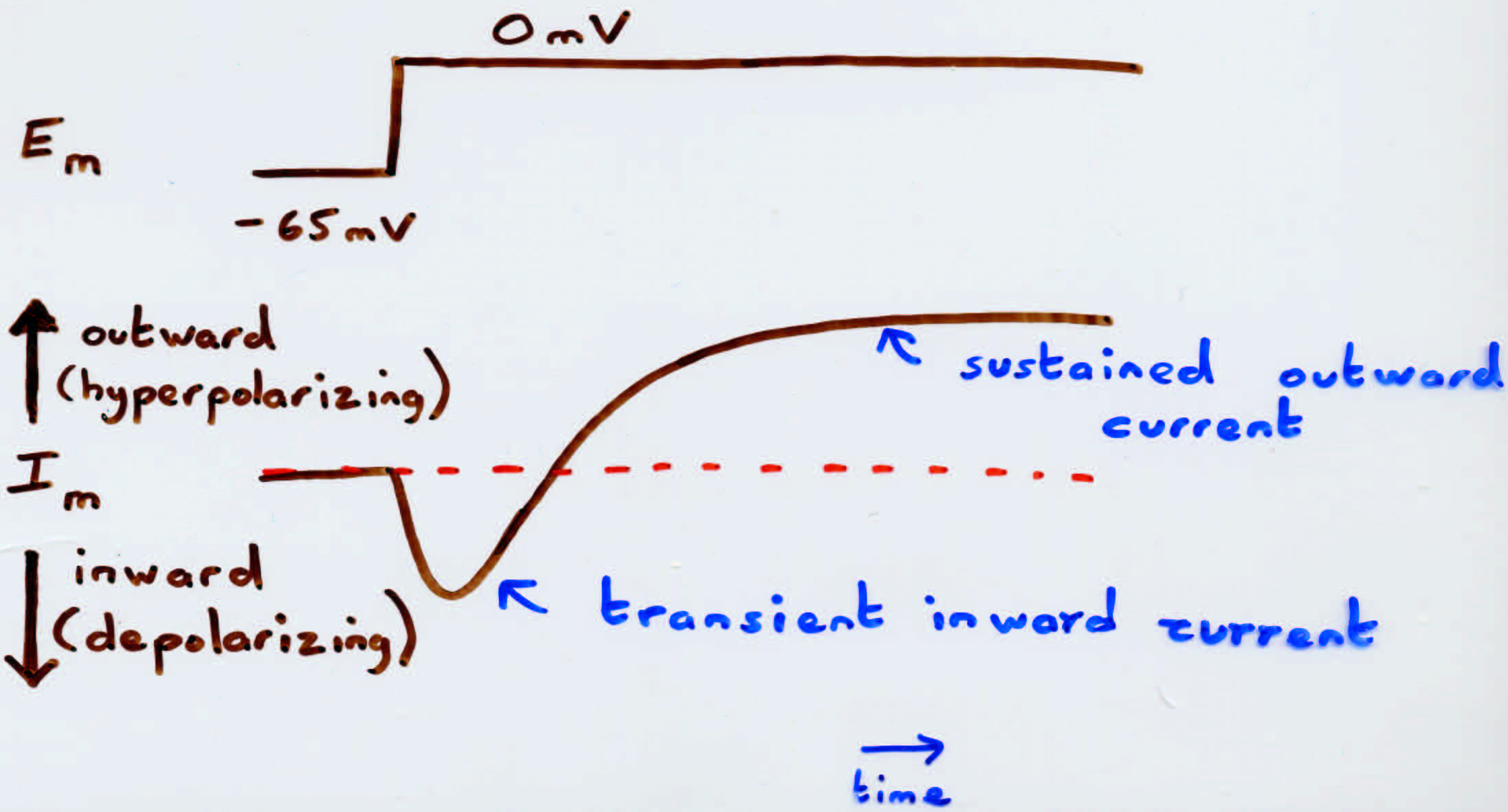


Fig. 3.1

b) Voltage-activated currents in response to depolarizing step.



Voltage-dependence of currents

Record currents in squid axon while depolarize to different potentials

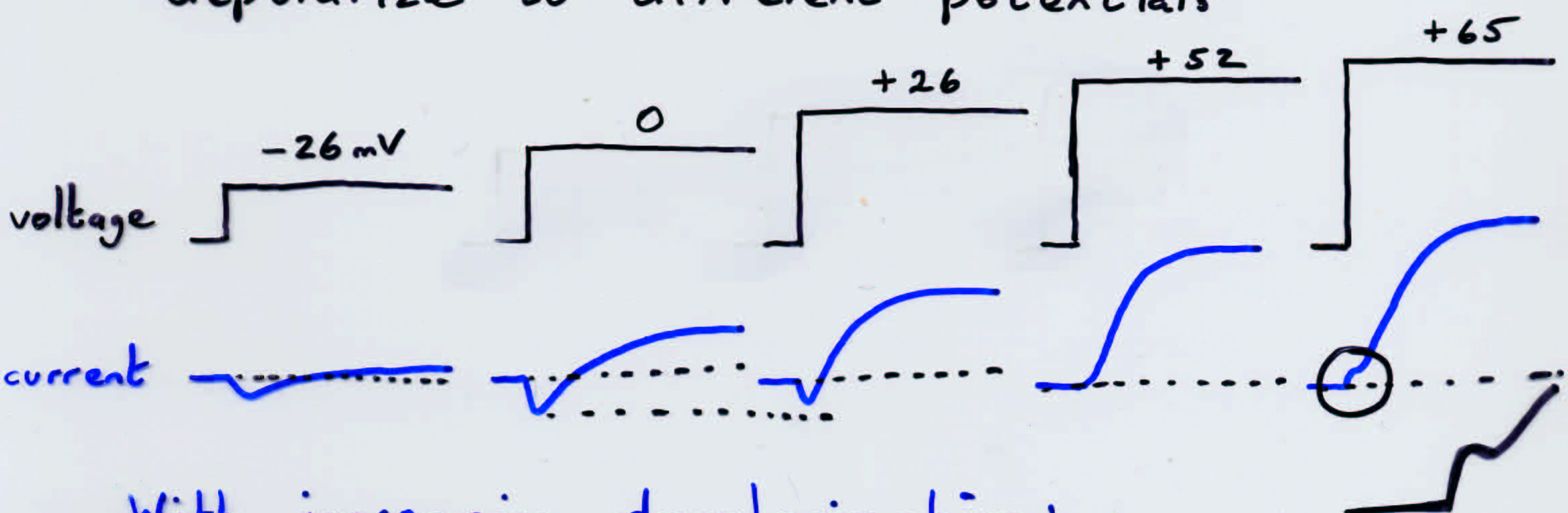


Fig 3.2

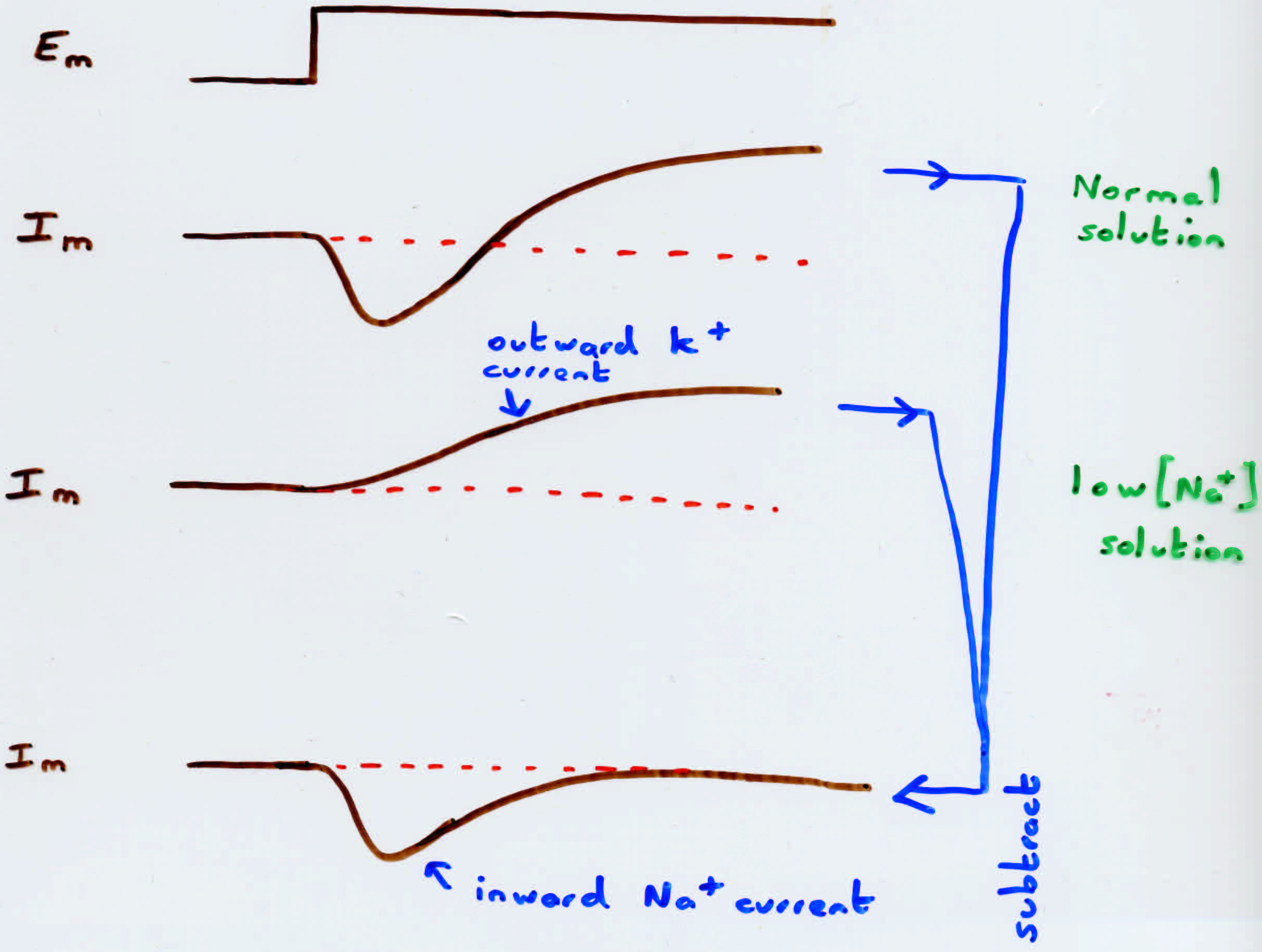
With increasing depolarization:
Early (inward) current first gets larger, then becomes smaller and finally inverts direction.

Late (outward) current becomes progressively larger.

Dissection of current components

Replace most extracellular Na^+ by an impermeant ion (choline)

Fig. 3.4



Can also use tetrodotoxin (TTX) to selectively block Na^+ current.

Current and conductance

current is proportional to number of channels open (conductance g) times voltage making current flow

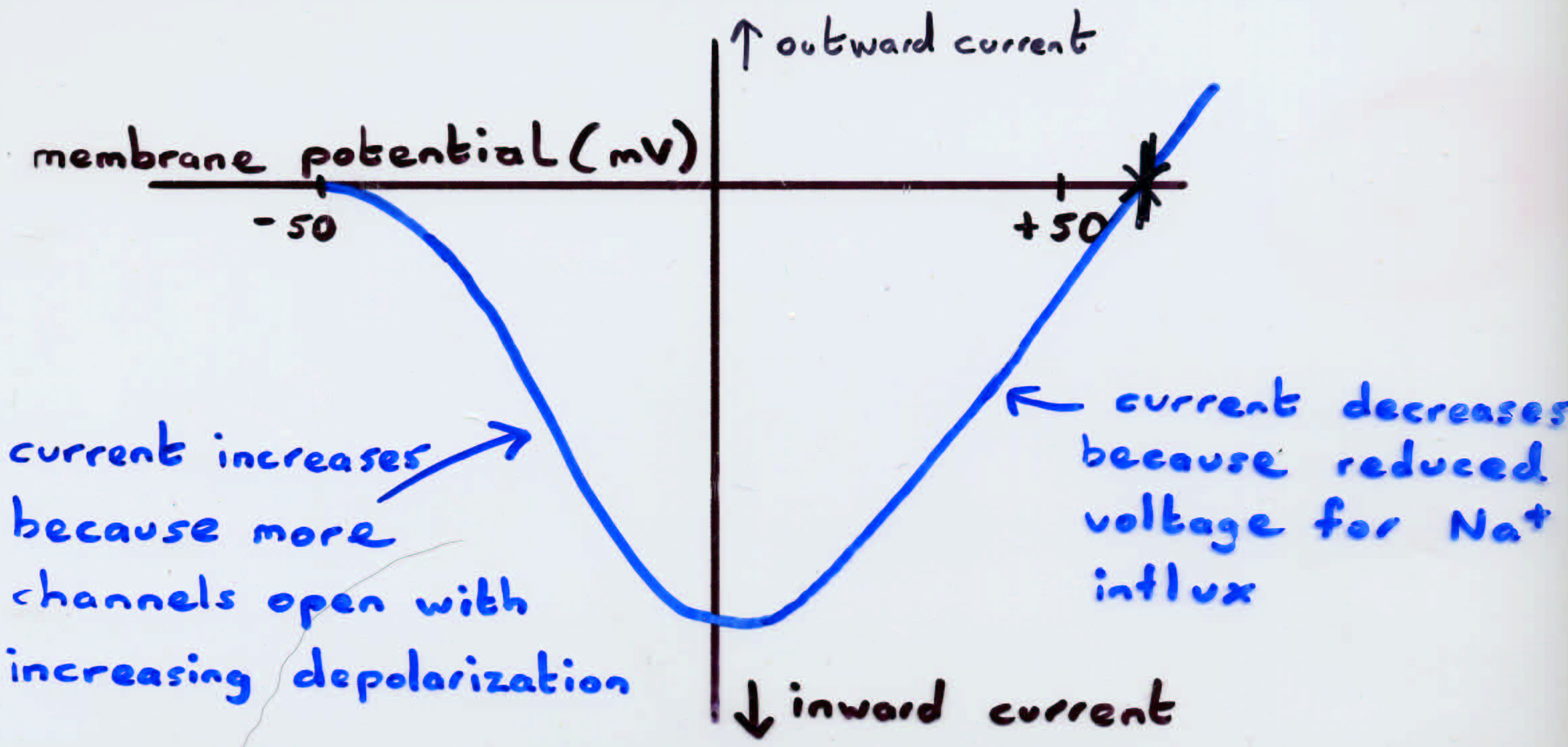
$$g = \frac{I}{V - V_{eq}}$$

- g — conductance
- I — current
- V — membrane potential
- V_{eq} — equilibrium potential for particular ion

Note

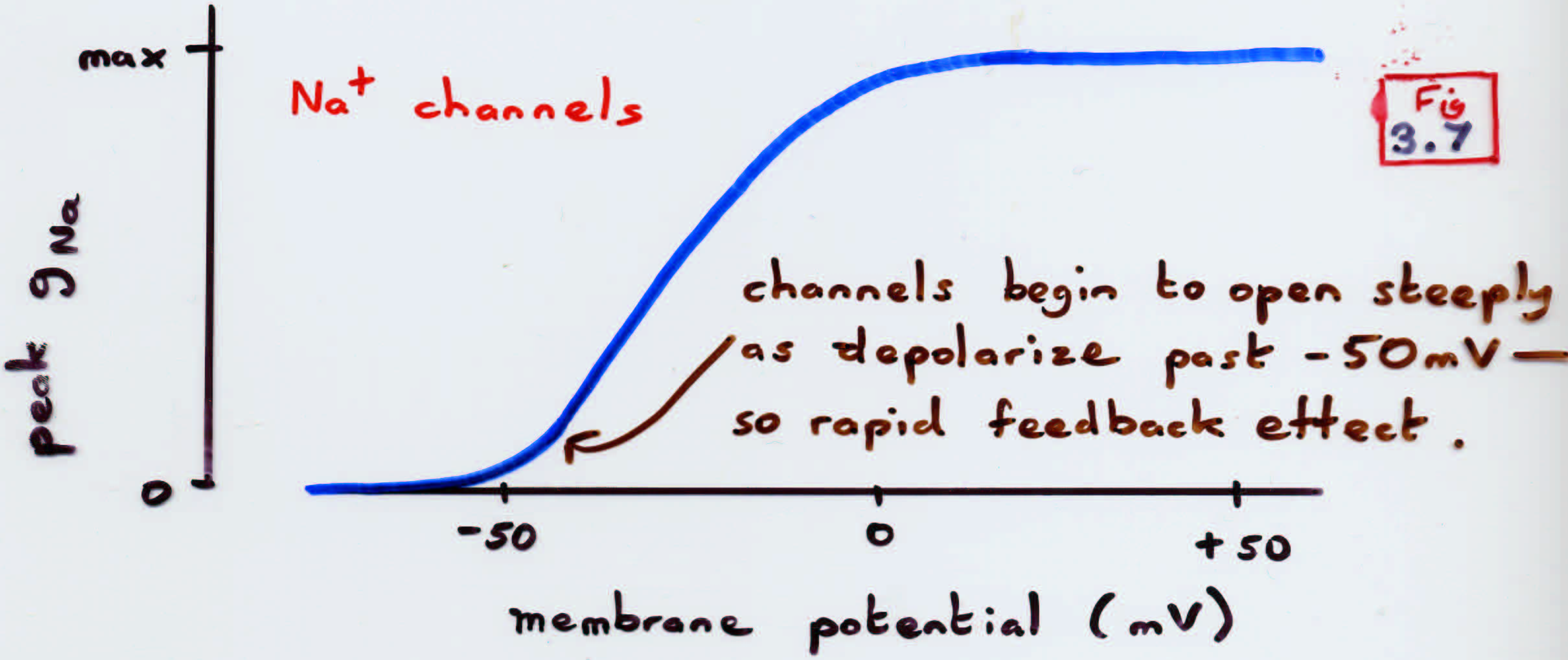
$$\text{conductance} = \frac{1}{\text{resistance}}$$

e.g. current/voltage relationship for Na^+ current



can derive <u>conductance</u> by correcting for passive effect of voltage on current.

Fig 3.7

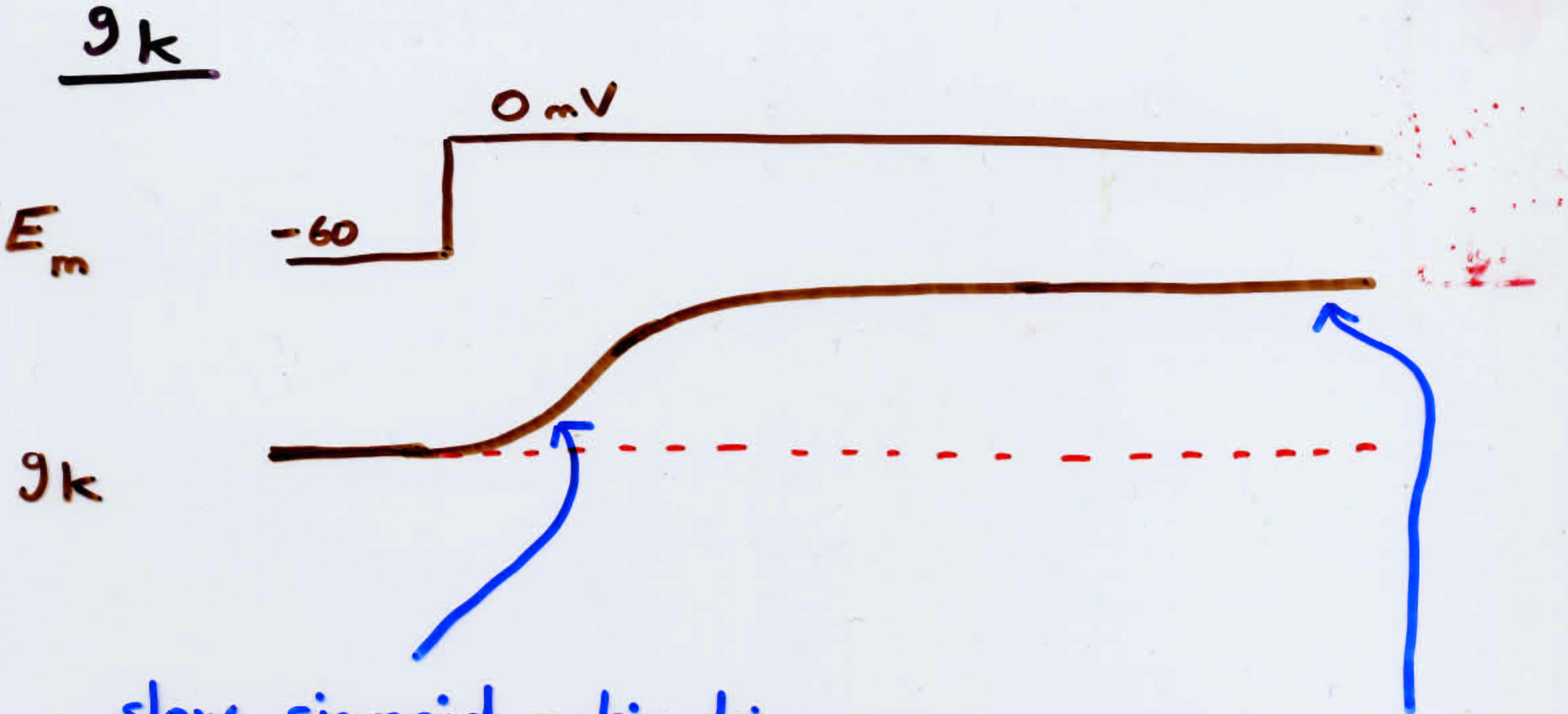


↑
resting potential
(almost no Na^+ channels open)

Curve for K^+ current is similar.

Both Na^+ and K^+ channels open as a steep function of voltage between about -50mV and 0mV.

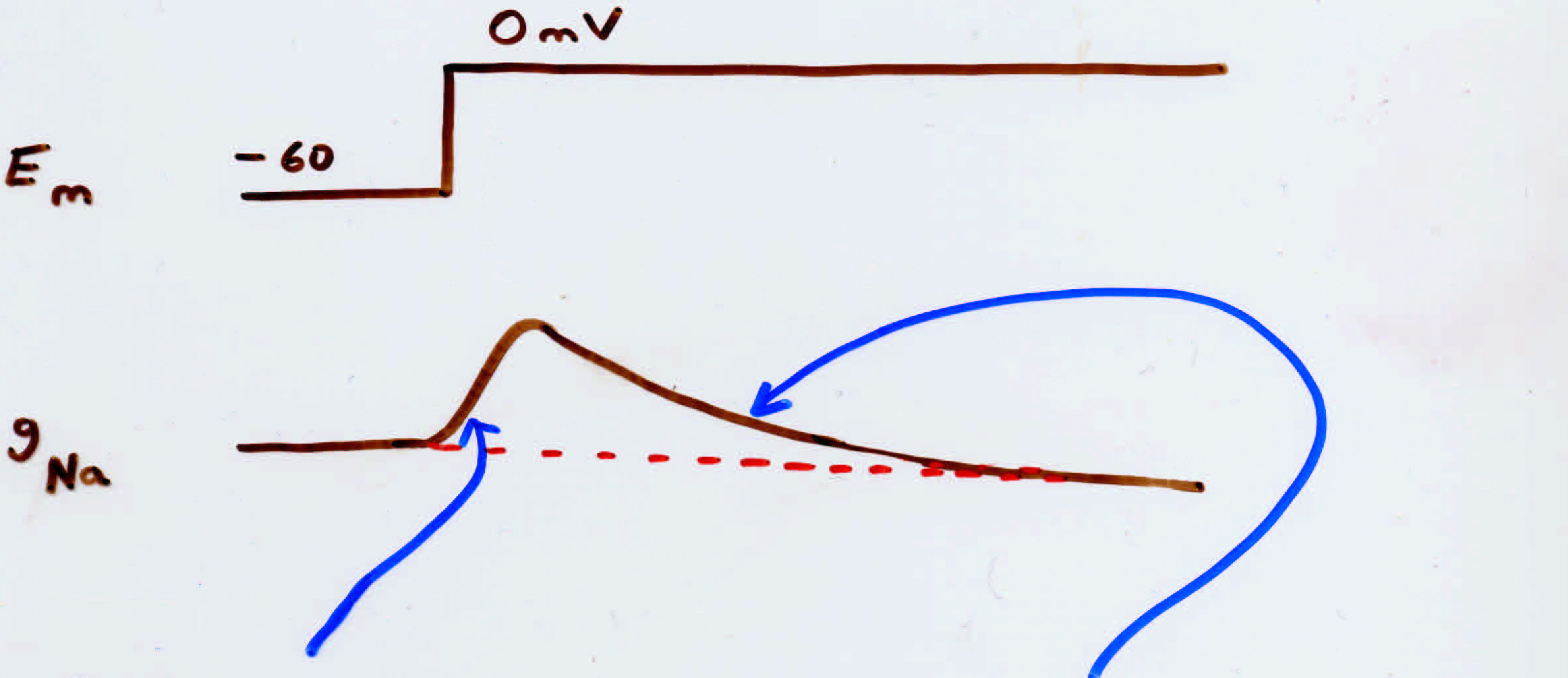
Kinetics of ion conductances



slow sigmoid activation - so that few K+ channels are open during rising phase of action potential

Maintained current - no inactivation. K+ current decreases during falling phase of action potential only because membrane repolarizes.

g_{Na}



fast activation - so rapid upstroke of action potential

channels inactivate even though depolarization maintained

Mathematical reconstruction of Action Potential

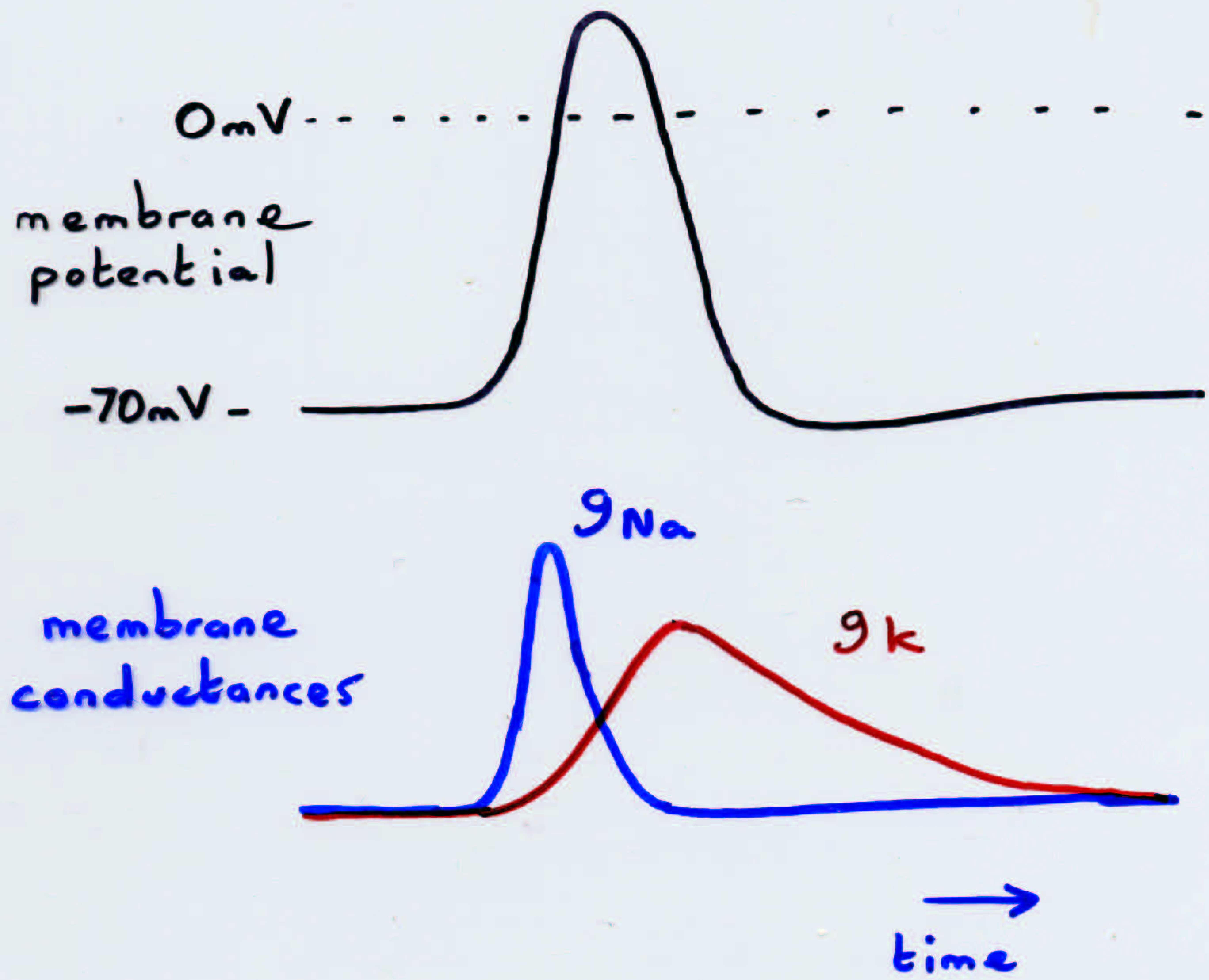


Fig. 3.8

Note that g_{Na} falls because of inactivation

g_K falls (with some delay) because the membrane re-polarizes