Synaptic Transmission

Transmission of signals (excitatory or inhibitory) between two nerve cells or nerve to muscle cell. Can be electrical or chemical.

A. Electrical

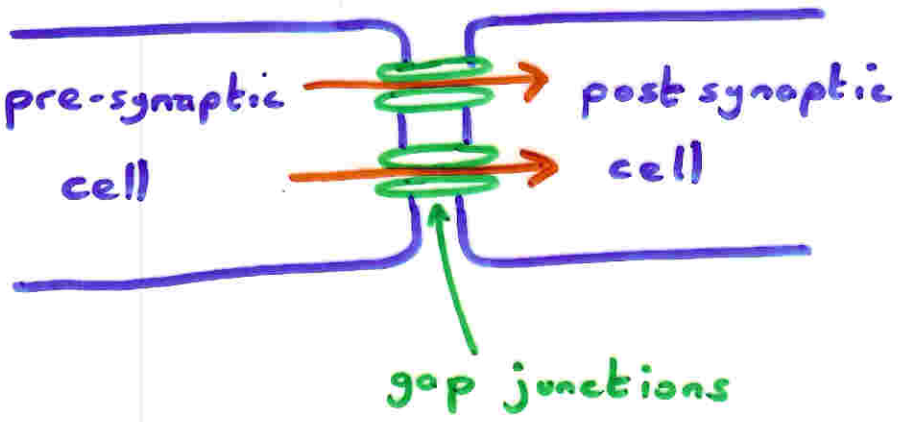


Fig 5.1A

Gap junctions form aqueous pores linking cells. Direct electrical current flow from one cell to the other.

Does not allow for synaptic inhibition.

B) Chemical

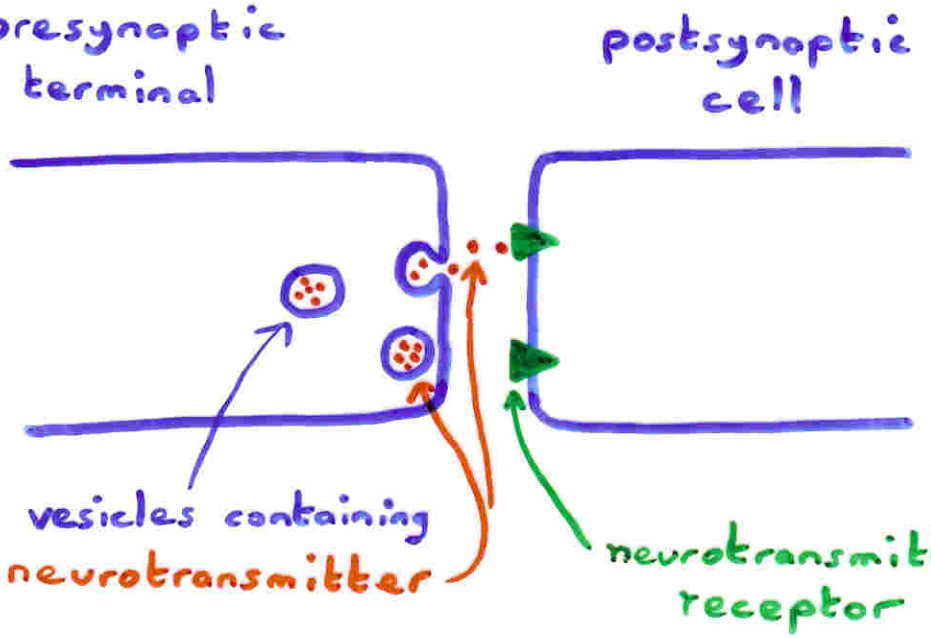


Fig. 5.18

Signaling is via a chemical (neurotransmitter) released by an action potential in the pre-synaptic terminal, which acts on receptors in the postsynaptic cell to produce an electrical response.

i) Pre- and post-synaptic terminals are differentially specialized

ii) Transmission goes only one way

iii) Action of neurotransmitter can be excitatory or inhibitory, depending on nature of transmitter and its receptor.

Stages in chemical synaptic transmission

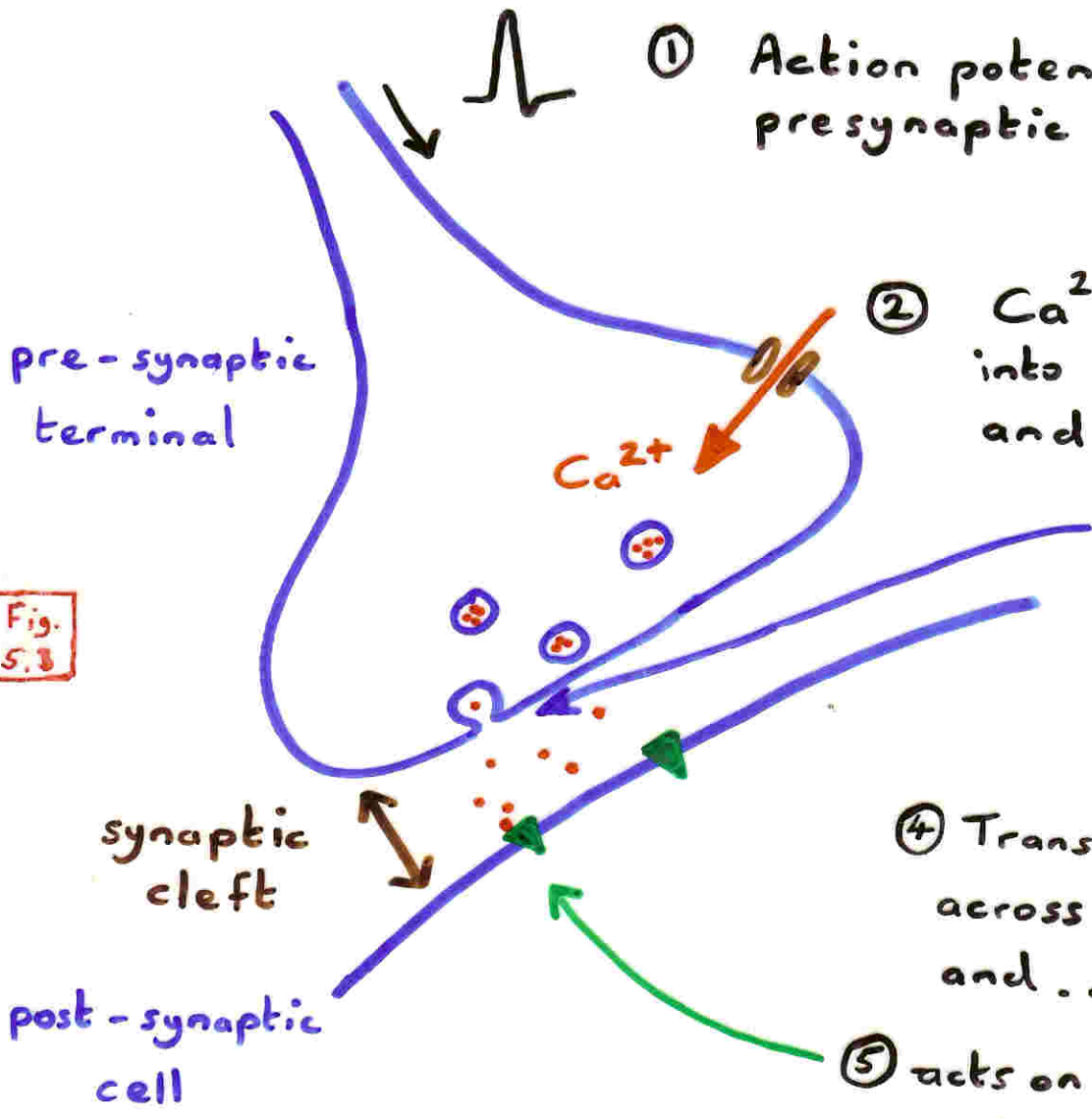


Fig. 5.3

① Action potential in presynaptic nerve

② Ca^{2+} ions flow into neve terminal and ... .

③ trigger release of neurotransmitter

④ Transmitter diffuses across synaptic cleft and .... .

⑤ acts on postsynaptic receptors to allow current flow through ion channels

⑥ Transmitter is destroyed or removed

Quantal Nature of Transmitter Release

Fatt & Katz - early 1950's

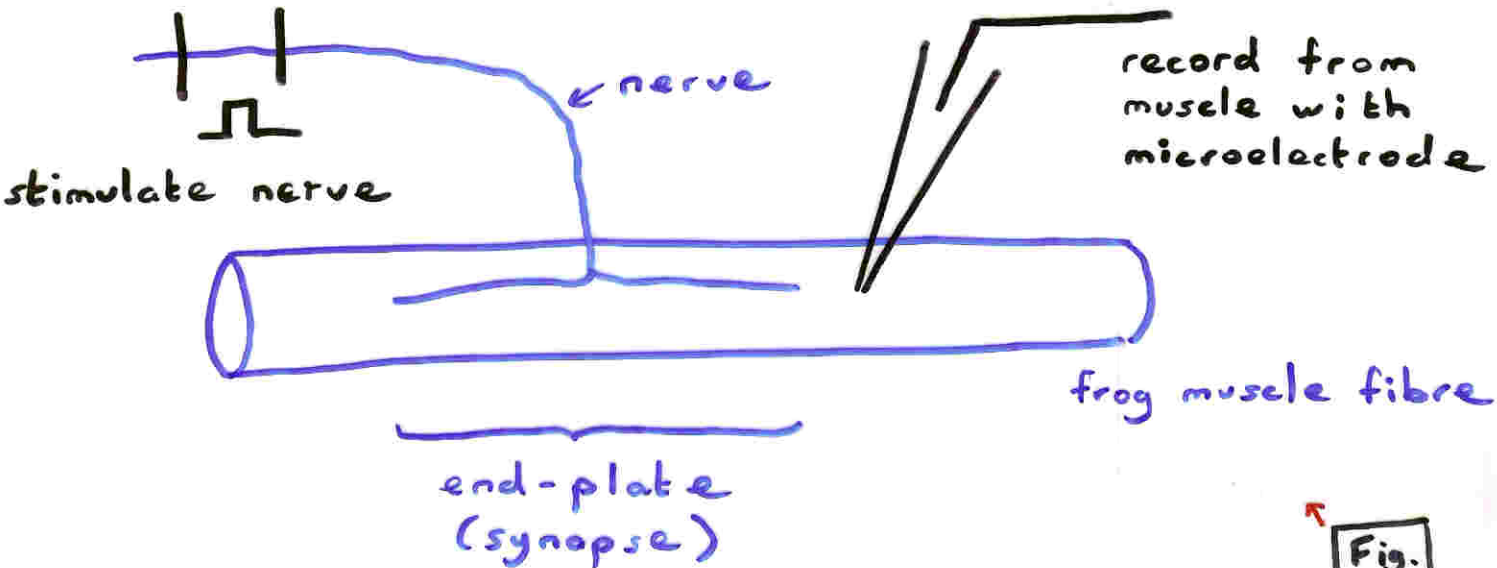
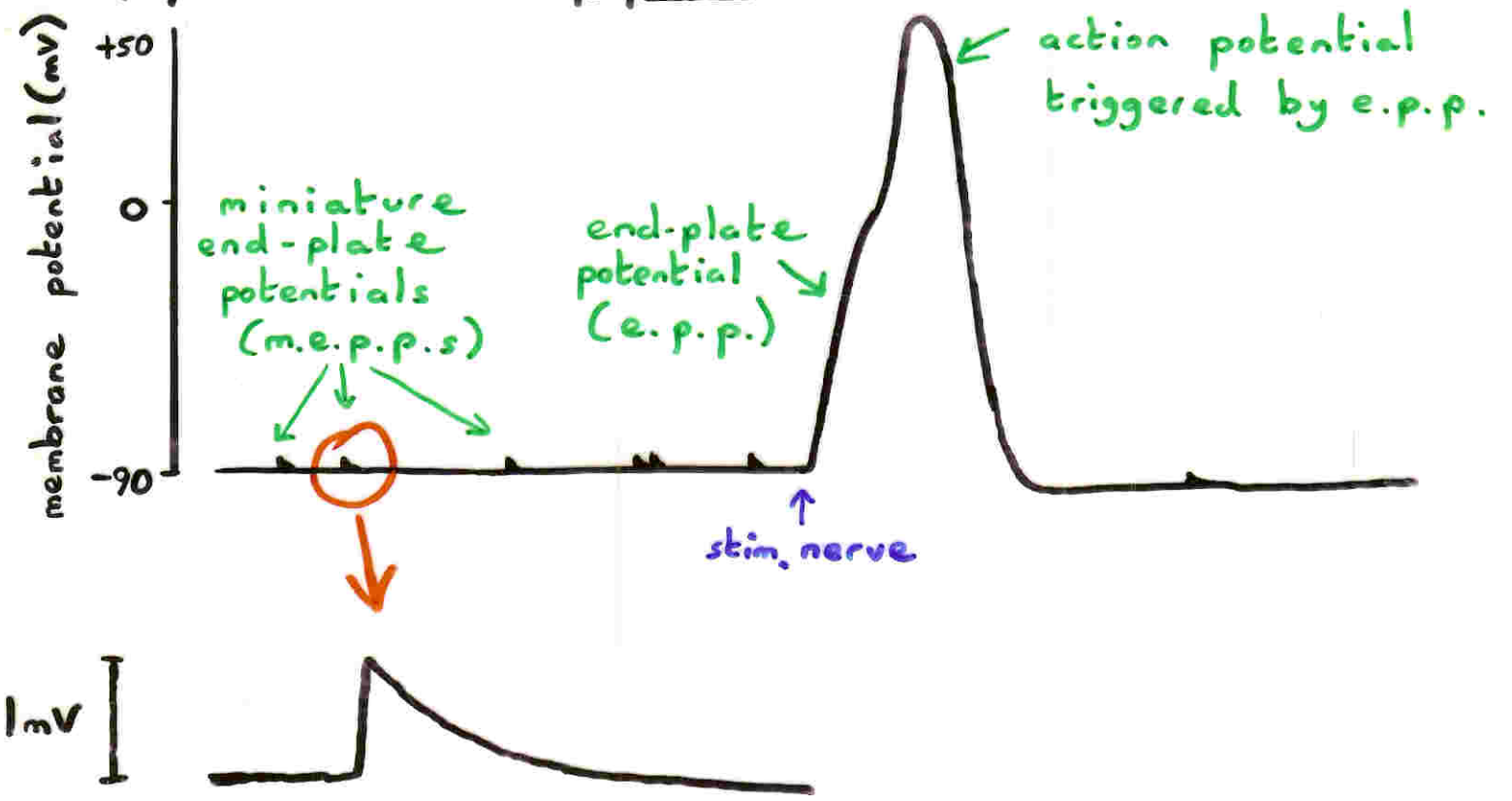
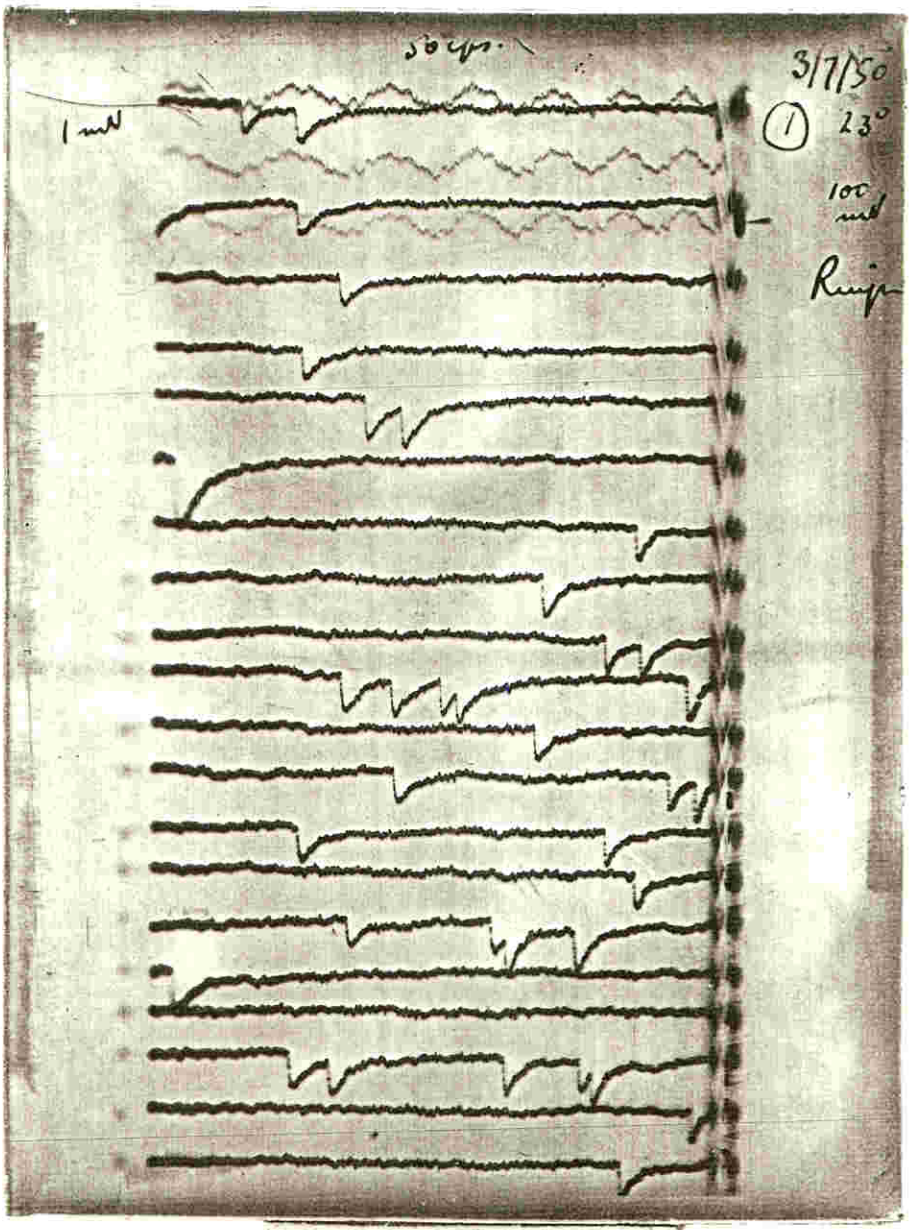


Fig. 5.6

e.p.p.s and m.e.p.p.s




50 cps.
3/7/50
1 mV
(1)
23°
100 mV
Resp

Stimulating nerve evokes large depolarizatio of muscle end-plate (e.p.p.) which normally triggers action potential, causing muscle to contract. e.p.p. due to massive release of transmitter (acetylcholine : ACh) from nerve terminal.

Also see tiny (1mV) spontaneous depolarizatio even without stimulating nerve - miniature e.p.p.s.

These are due to spontaneous release of ACh from nerve — m.e.p.p.s get bigger if apply drug that stops breakdown of ACh.

e.p.p. evoked by release of ~ 100 quanta of transmitter

In normal solution (2mM Ca^{2+}) e.p.p. is about 100x bigger than m.e.p.p.

But - if $[Ca^{2+}]$ lowered, size of epp gets smaller and epps occur as multiples of size of m.e.p.p.

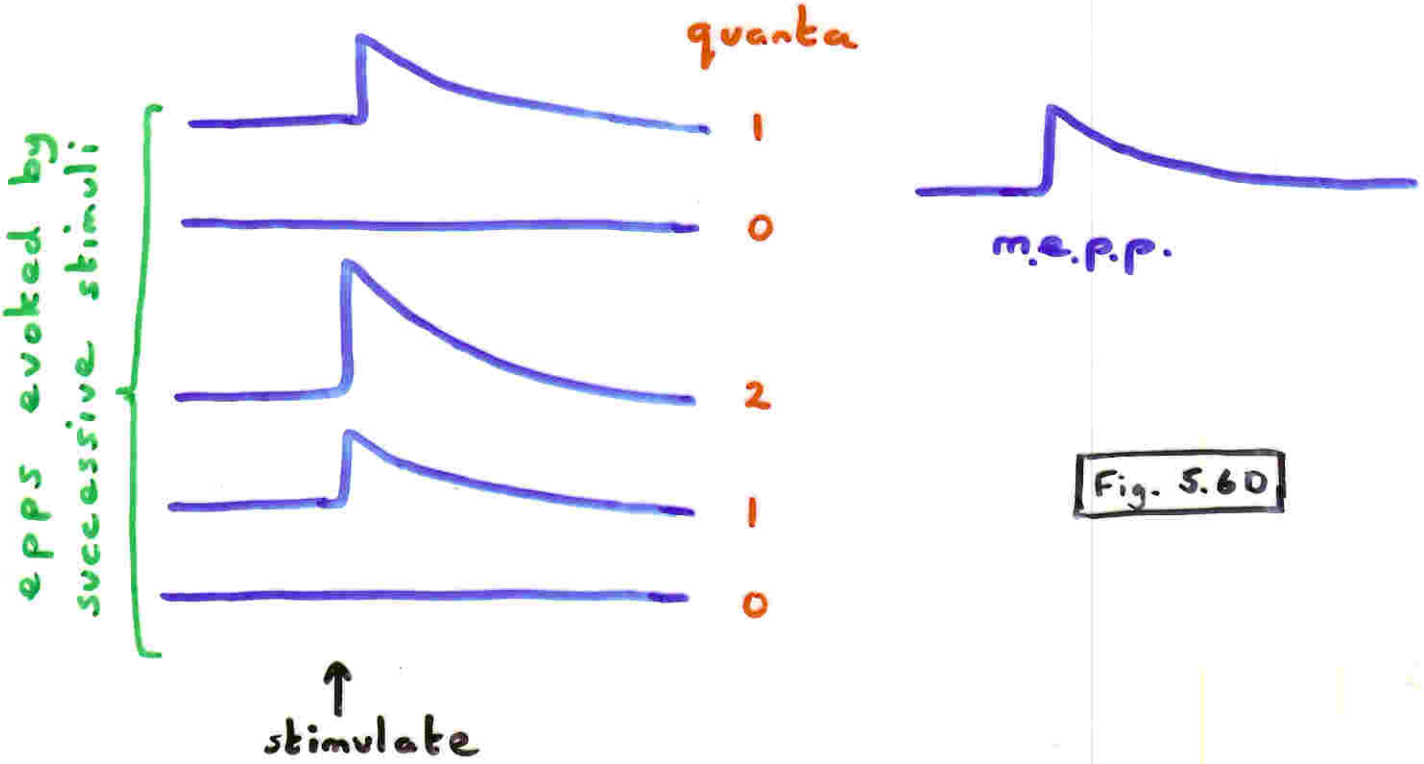


Fig. 5.6D

size distributions of m.e.p.p.s and e.p.p.s.

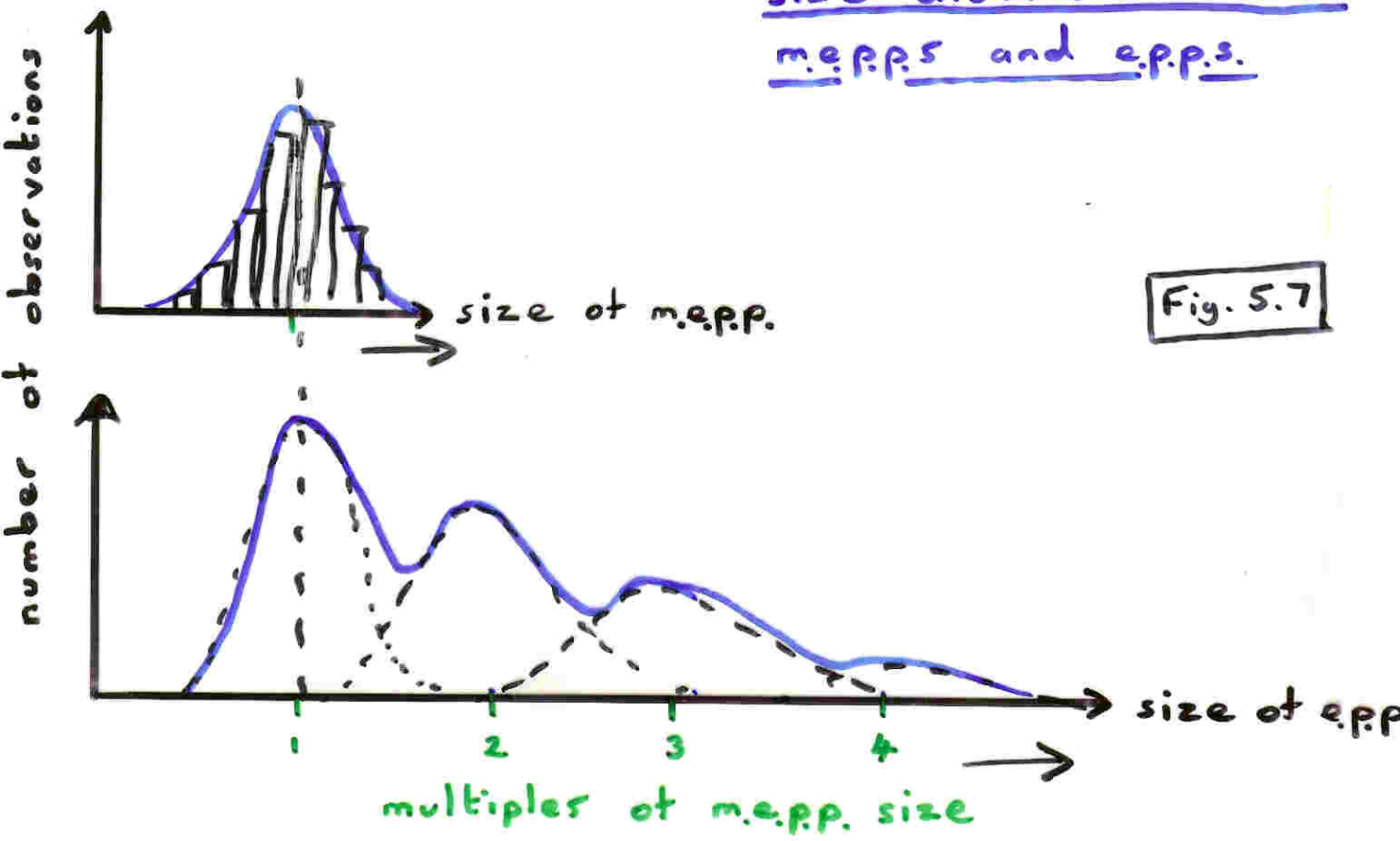


Fig. 5.7

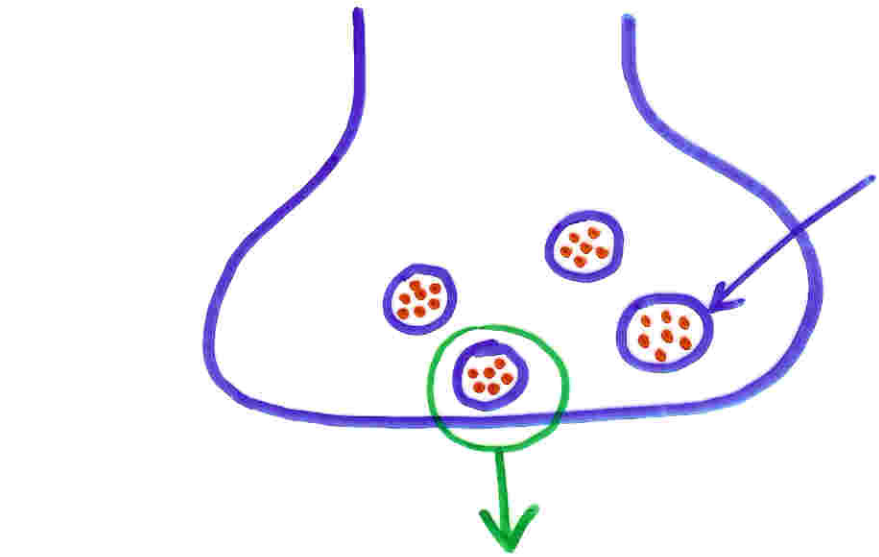
epps are quantized — transmitter is released in 'packets' (quanta) corresponding to the amount of transmitter in a m.e.p.p.

Ca^{2+} entering the nerve terminal increases the probability of release of quanta — the more Ca^{2+} the greater the average number of quanta released.

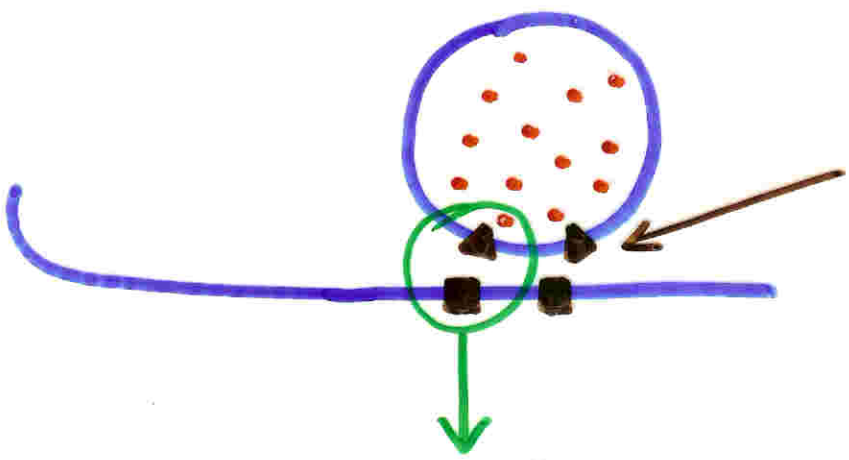
Believed that 1 quantum = 1 vesicle

e.g. drugs (Black Widow spider venom) that cause massive release of transmitter deplete number of vesicles.

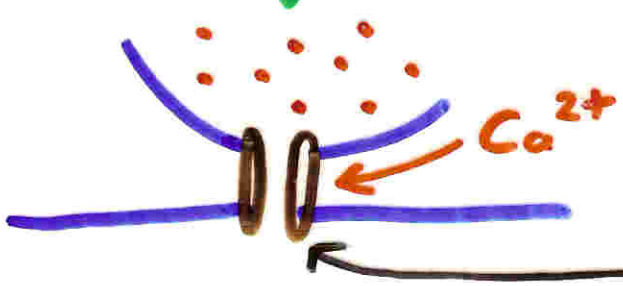
Vesicular nature of transmitter release



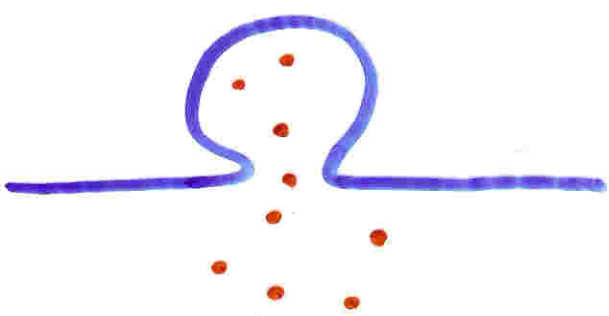
transmitter stored in vesicles – membrane sacks containing a few thousand molecules of transmitter



vesicle and cell membranes contain special proteins



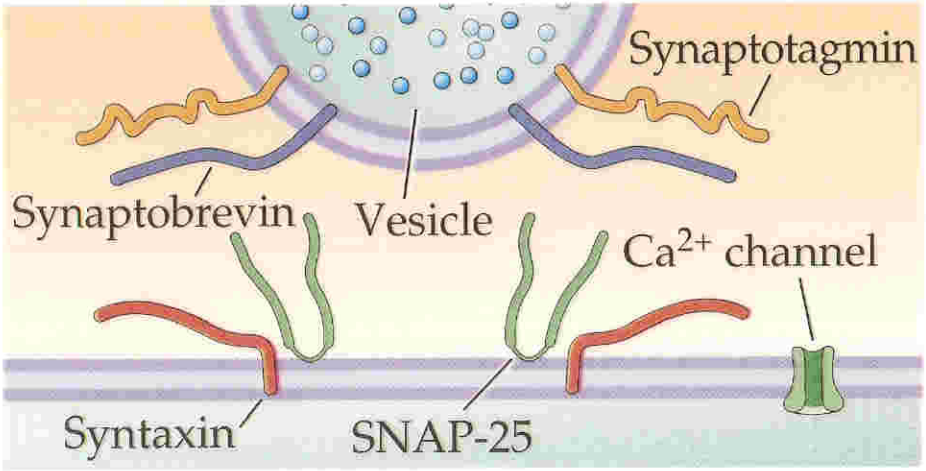
Ca^{2+} causes proteins in vesicle and cell membrane to interact, forming fusion pore



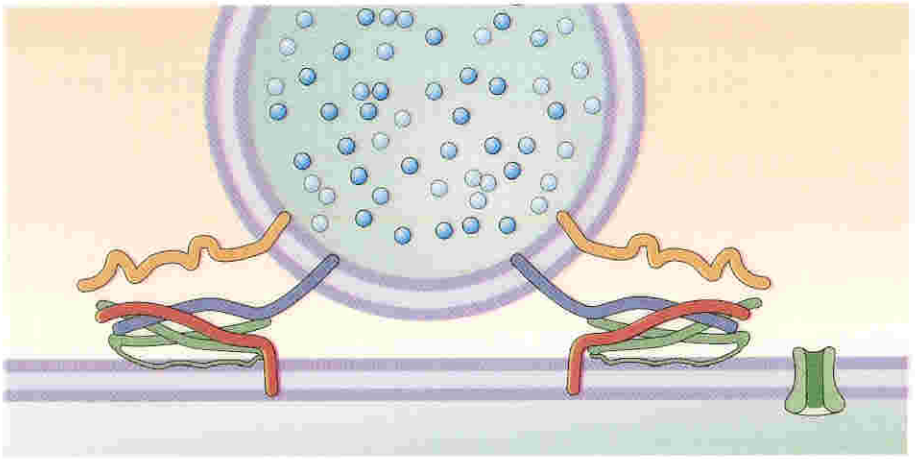
pore enlarges and bursts open, allowing vesicle to fuse with cell membrane.

(B)

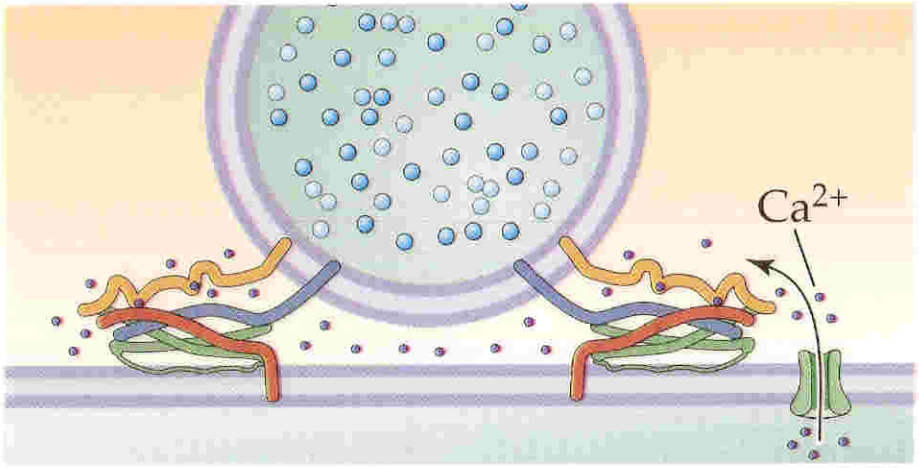
(1) Vesicle docks



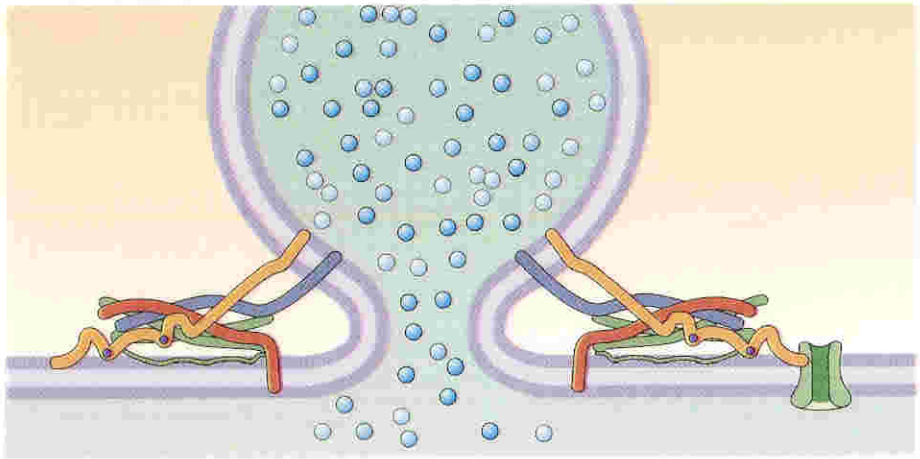
(2) SNARE complexes form to pull membranes together



(3) Entering Ca^{2+} binds to synaptotagmin



(4) Ca^{2+}-bound synaptotagmin catalyzes membrane fusion



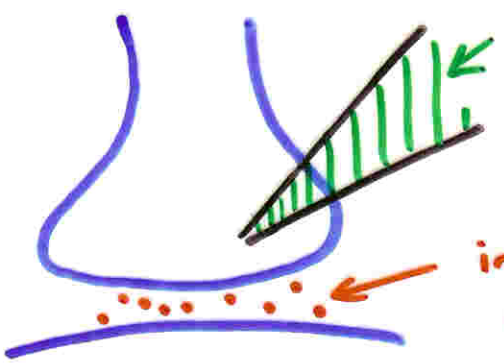
Evidence

① Synaptic transmission stops if extracellular Ca^{2+} removed.

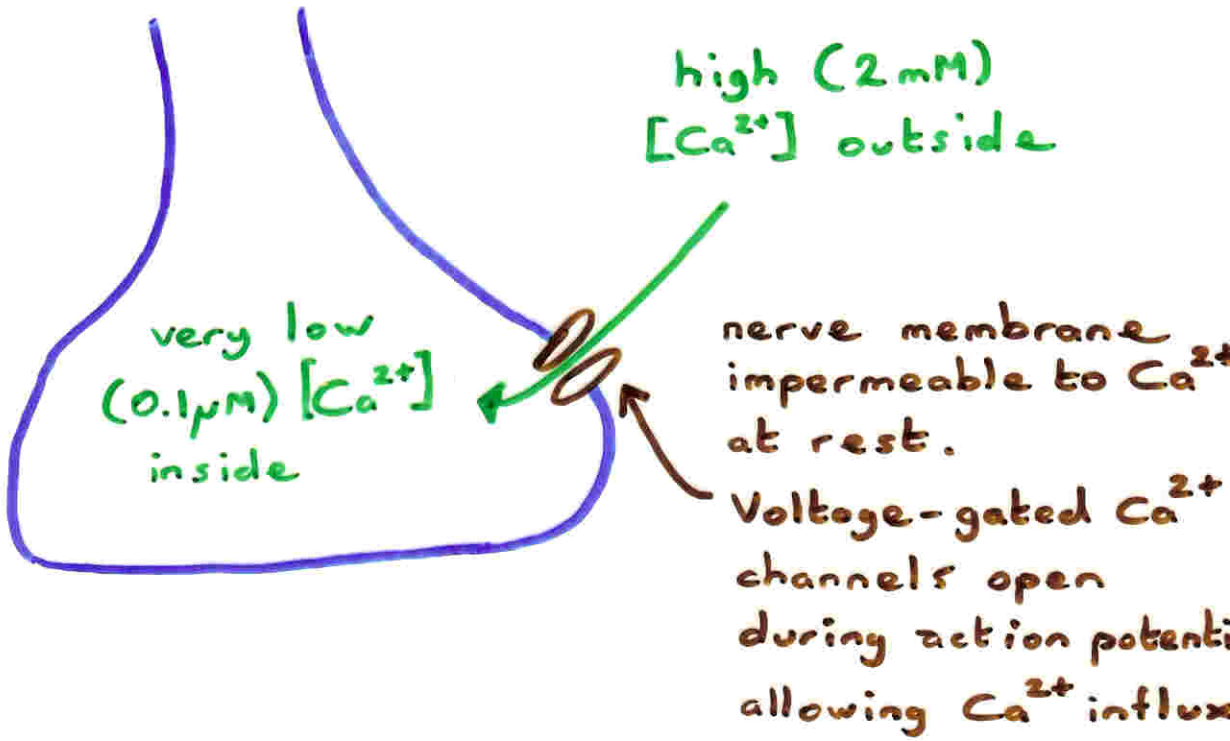
Transmitter release varies very steeply (fourth power) with $[Ca^{2+}]$, so Ca^{2+} in blood and CSF regulated tightly.

② Can mimick synaptic transmission by injecting Ca^{2+} into nerve terminal.

Fig. 5.11B



Ca^{2+} and transmitter release



Ca^{2+} ions entering the terminal carry a 'chemical' message. It is the rise in intracellular $[Ca^{2+}]$ that triggers transmitter release, not the electrical current carried by Ca^{2+} ions