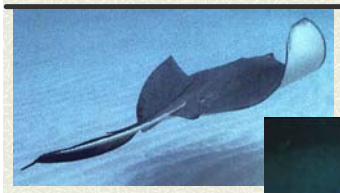
ZOO 332H1S - Lecture 5
(AJE 2003)



FAST SYNAPSES

Torpedo Ray (*Torpedo californica*)

Torpedo Ray - Torpedo rays (*Torpedo californica*) are identifiable by their flat grey bodies and black spots. Interestingly, these animals catch their prey by stunning them with a jolt of electricity! (photo: Daniel Gotshall)

Today

- Electrical synapses - fastest
- Chemical synapses secrete neurotransmitters that modulate post-synaptic ion channels
- Ion channels are related molecularly, but come in many flavours
- Post-synaptic response depends on nature of ion-channel, not transmitter
- Contribution of synapse in determining post-synaptic response depends on position

Electrical and chemical synaptic transmission

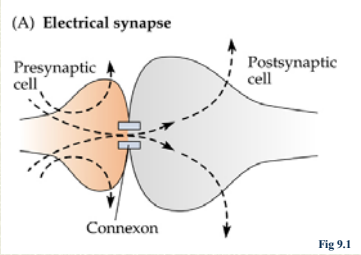


Fig 9.1

cont…Electrical and chemical synaptic transmission

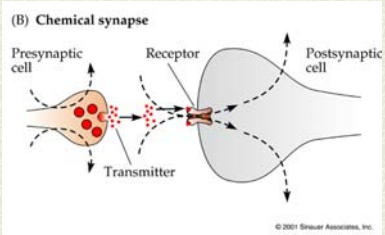
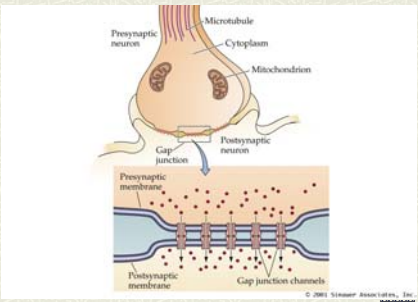


Fig 9.1

cont…Electrical and chemical synapses

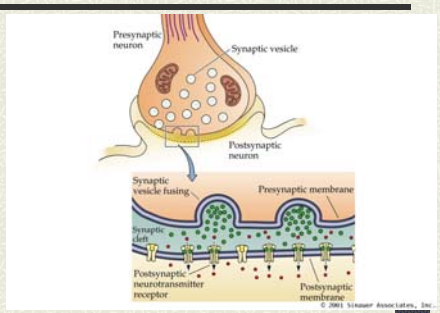
Electrical



Purves *et al.* (2001) - Fig.5-1

cont….Electrical and chemical synapses

Chemical



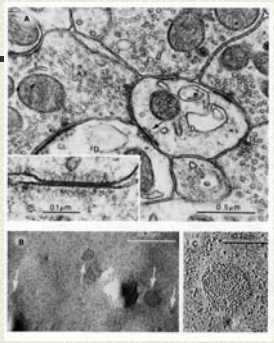
Purves *et al.* (2001) - Fig.5-1

EM of electrical (and chemical) synapses

A - two dendrites in inferior olivary nucleus of the cat

B - freeze-fracture through the presynaptic membrane nerve terminal in ciliary ganglion of a chicken

C - high mag of B (cluster of closely packed particles about 9nm in diameter)

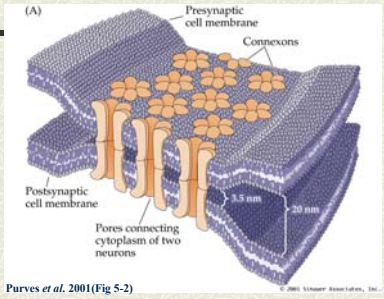


Kuffler, Nicholls, & Martin (1984)

Electrical synapses

Connexons -

- hexameric structure of six conne**xin** proteins (on each side, pre- and post-synaptic)
- Also known as "gap junctions"
- rapid transmission (<0.1ms)



Purves *et al.* 2001(Fig 5-2)

- 1st in crayfish; mammalian example: hormone secreting neurons in hypothalamus (synchronization of secretion into circulation)

cont...Electrical synapses

Modulation:

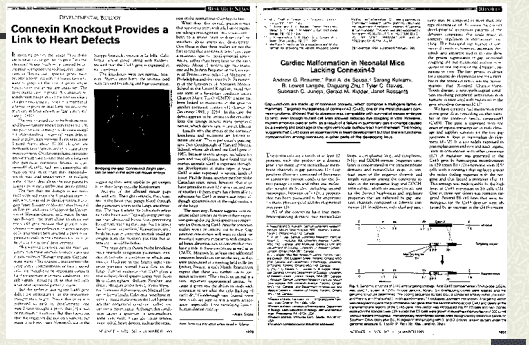
- low pH
- intracellular calcium (Ca^{2+})
- voltage
- 2nd messengers

Pore Size:

- about 1.5nm diameter when open (3.5nm between pre- and post-synaptic cells) – Lucifer Yellow

Connexin proteins in the heart

(don't try to read this here - it will be a handout)



Connexin Knockout Provides a Link to Heart Defects

Cardiac Malformation in Neonatal Mice Lacking Connexin43

Crayfish Giant Axon (GA) to abdominal motor axon

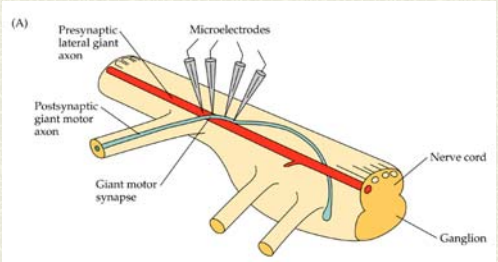
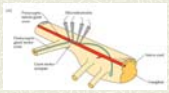


Fig 9.2

cont...Crayfish GA to abdominal motor axon



- the preparation
- intracellular recording presynaptically (GA) and postsynaptically (motor giant)
- rectification (unusual in electrical synapse)

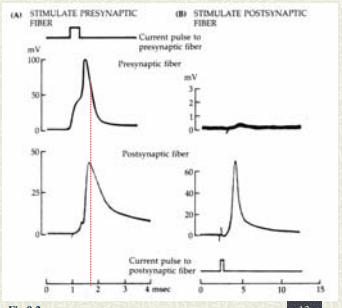
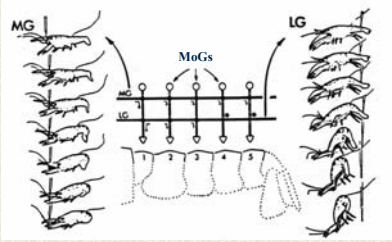


Fig 9.2

Electrical synapses - crayfish giant axon (GA) to abdominal motor axon (MoG)

- the animal
- the giant axons
- excitation
- the behavioural response



From: Krasne & Wine (1984) in Neural Mechanisms of Startle Behavior, RC Eaton (Ed.)

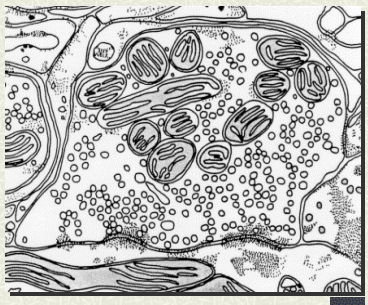
Figure legend from reference for previous slide

Figure 1. Forms of giant-mediated tailflips. When the MGs fire, all segments flex and the abdomen curls and propels the animal backward. When LGs fire, caudal segments remain straight and cause the thrust to be directed mainly down, thus pitching the animal forward. Since MGs respond to rostral inputs and LGs to caudal ones, tailflips always remove the animal from the source of stimulus. Consistent with the difference in form of MG and LG flips, the MGs excite MoGs in every abdominal segment, whereas the LGs excite MoGs only in more rostral segments (circuit of center top) (based on Wine and Krasne, 1972; Mittenthal and Wine, 1973; and taken from Wine and Krasne, 1982).

From: Krasne & Wine (1984) in Neural Mechanisms of Startle Behavior, RC Eaton (Ed.)

Chemical Synapses

Hallmarks:
- vesicles
- diversity in ligands that activate
- specific structures common to chem sy
- diversity in morph-ology
- *etc.*



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Pre- synaptic events

- AP in presynaptic neuron
- Depolarization opens Ca^{2+} channels
- Increase in $[Ca^{2+}]$ locally
- Increase probability of vesicle fusion
- Increased rate of NT release
- Increased [NT] in synaptic gap

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Post-synaptic events

- NT molecules bind to postsynaptic receptors
- Increased probability of open state of channel
- Increased g_i
- Production of synaptic current, PSP
- NT removed

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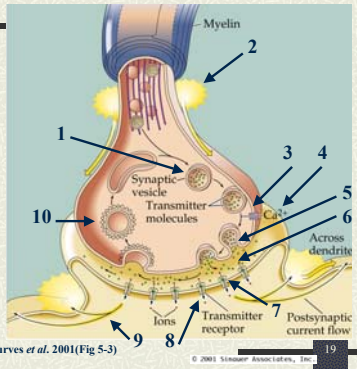
Sequence of events involved in transmission at a typical chemical synapse



Purves *et al.* 2001(Fig 5-3)

Structure of chemical synapse

- "Motor Unit"
- factors which alter number of muscle fibres innervated by a single neuron

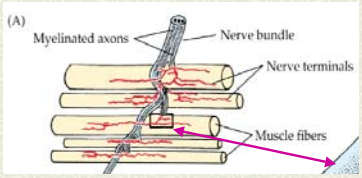


Fig 9.4

cont…Structure of chemical synapse

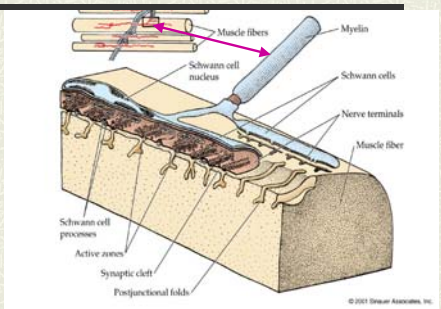


Fig 9.4

Synaptic potentials

nAChR

Safety factor

Effect of curare

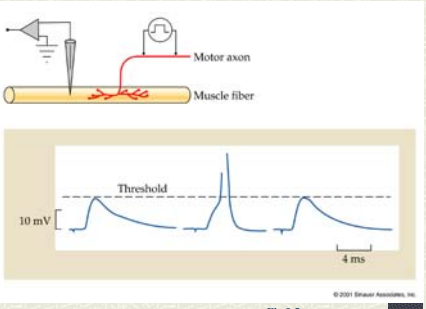


Fig 9.5

Passive spread of synaptic potentials

- Recall passive properties of axon
- Not a good conductor
- Requires regenerative response for depolarization at distance from synapse

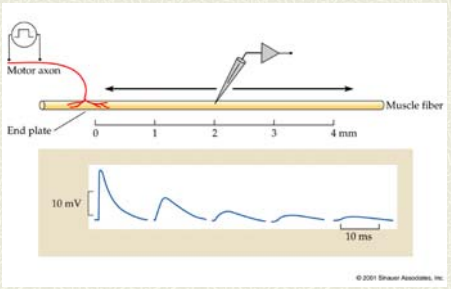


Fig 9.6

Ionophoresis of ACh on muscle fibre

- Region of greatest sensitivity
- Mimic natural event by application of exogenous cmpd
- criteria to establish substance as a NT

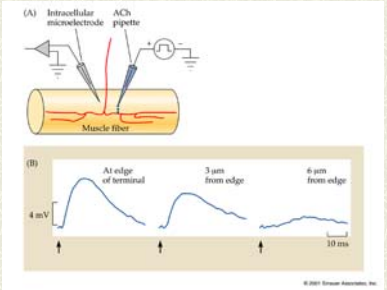
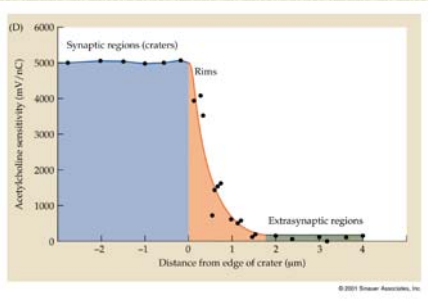


Fig 9.7

Location of ACh receptors



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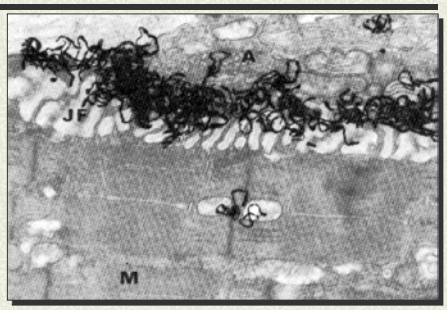
Location of ACh receptors revealed by labelled α-bungarotoxin



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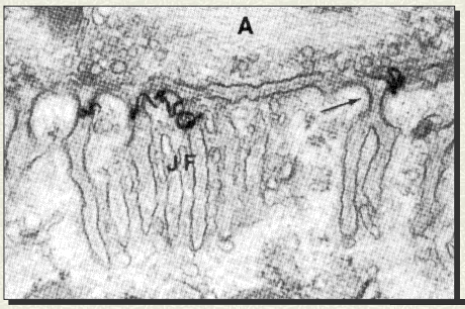
ACh receptors at peak of folds close to presynaptic membrane



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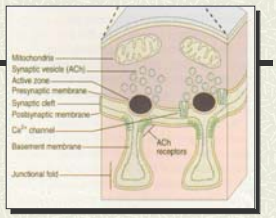
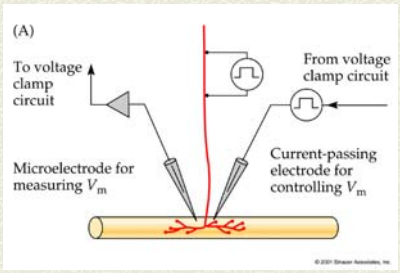
Junctional folds at the end plate

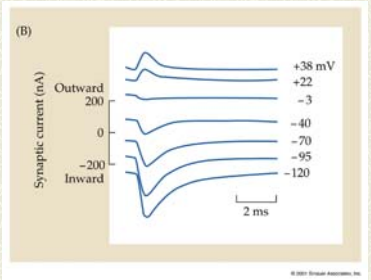


- High conc. of Na^+ channels
- (Ca^{2+} channels?)
- conducting path to T-tubule system/SR

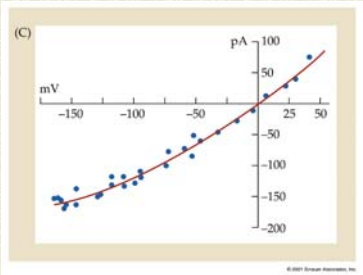
Determining the reversal potential for synaptic response



cont…Determining the reversal potential for synaptic response



cont…Determining the reversal potential for synaptic response



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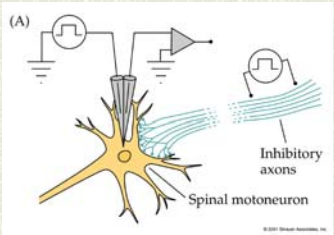
Recording inhibitory synaptic potentials

- Current injection for "current clamp"
- Record membrane potential post synaptic



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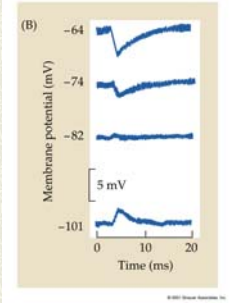
Inhibitory synaptic potentials

- Set membrane potential by injecting current
- Stimulate presynaptic
- Record response in motor neuron cell body
- Reversal potential



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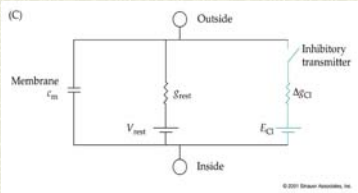
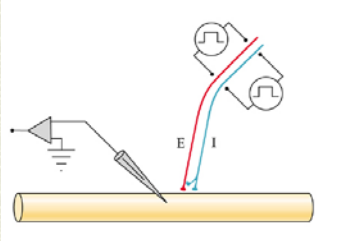
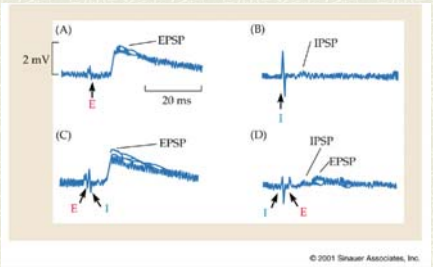
Electrical model



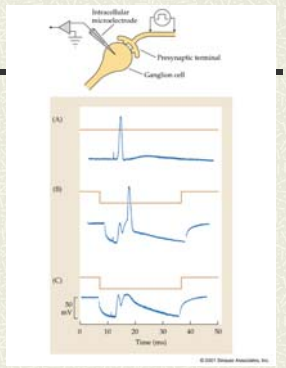
Crayfish NMJ – presynaptic inhibition



Timing of inputs determines efficacy



Discussion Figure



Next…..more on synapses/receptors