

## Today's plan

- Overview of types of synaptic transmission
- Neuromuscular junction as model fast chemical synapse
- Review of key steps

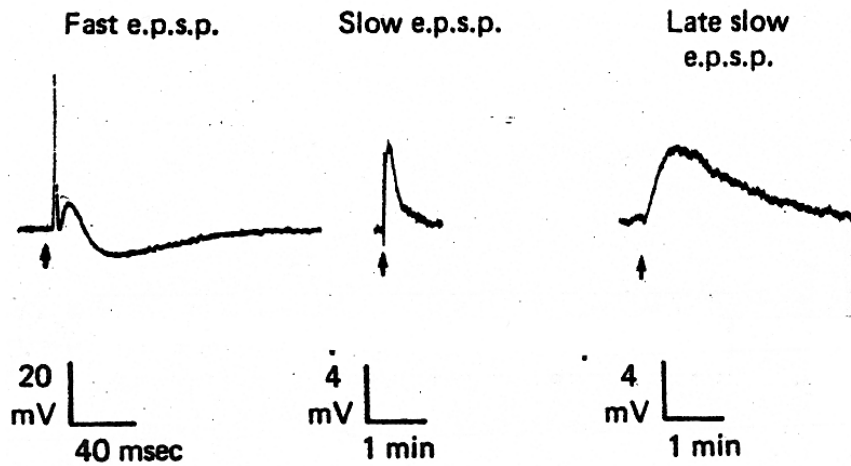
## Types of synaptic transmission

- Electrical
- Chemical
  - Fast
  - Slow
  - Modulatory

## Types of chemical transmission

- Fast – milliseconds
  - Ionotropic
    - Postsynaptic receptor is ion channel
- Slow – 100s of milliseconds – seconds
  - Metabotropic
    - Postsynaptic receptor activates 2<sup>nd</sup> messenger pathway
- Modulatory – seconds – minutes
  - Affects voltage-dependent channels

## Fast and slow EPSPs



Cole & Nicoll 1984



Camillo Golgi  
1852 - 1924



Santiago Ramon y Cajal  
1852 - 1934

## Debate over the neuron doctrine

- Golgi
  - Invented key method using silver salts to stain cells in brain
  - Argued fervently (incorrectly) that the nervous system is a reticulum (network) of connected cells
  - But we now know of extensive electrical synapses
- Cajal
  - Used Golgi method
  - Described many cell types and their subcellular structure
  - Gussed (correctly) the direction of information flow
  - Argued fervently (correctly) that neurons are separate cells

Shared Nobel Prize in 1906

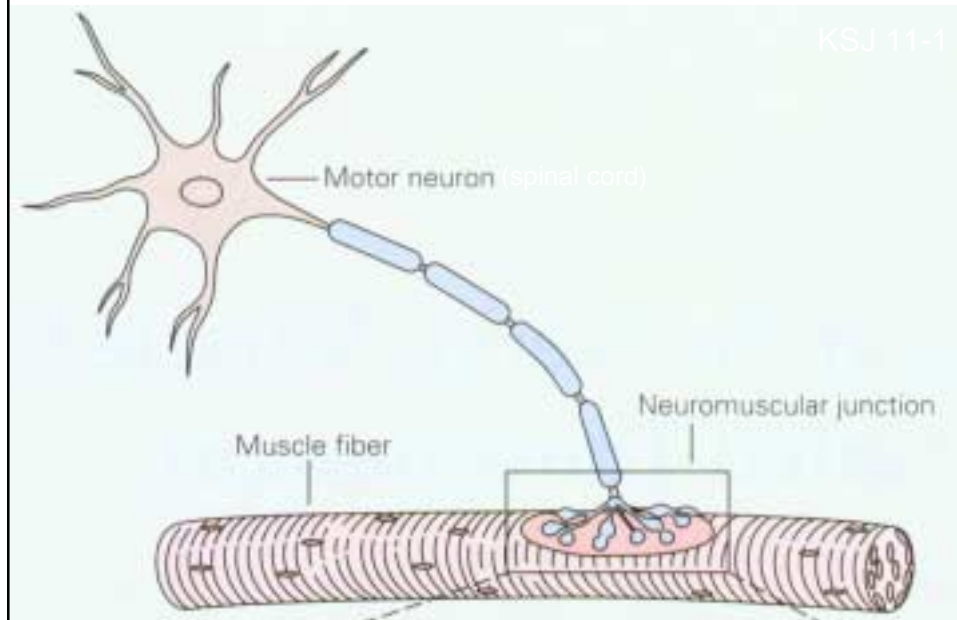
## Golgi-stained neurons



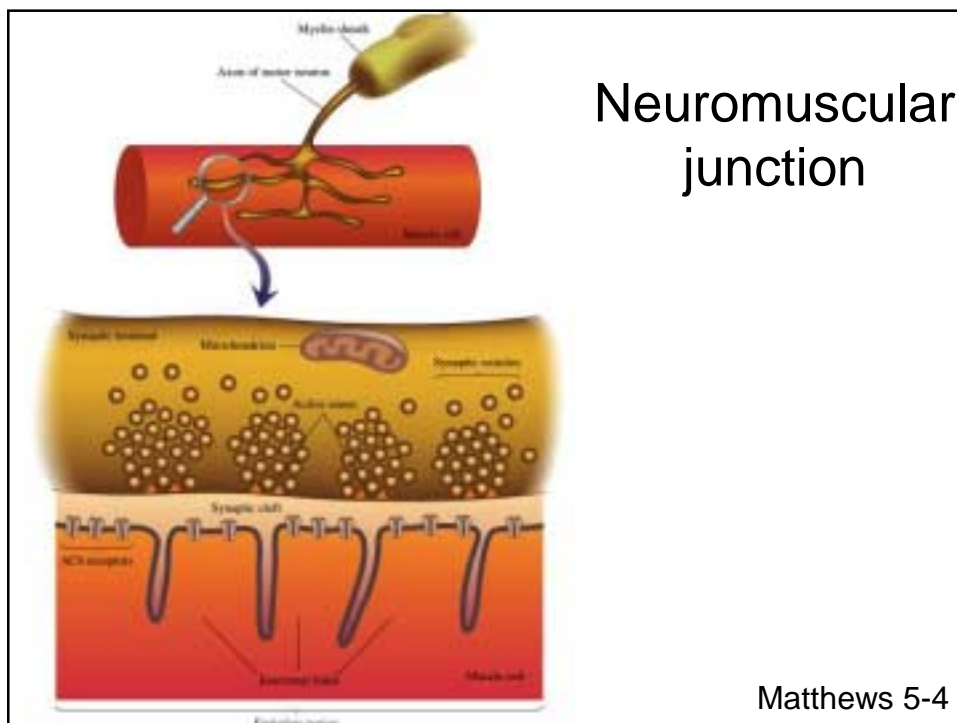
## Electrical synapses

- Mediated by gap junctions
- Connexin proteins
- Channels from cytoplasm to cytoplasm
- Carry information fast
- Conserve sign
- Important for synchronizing neuron populations

## Neuromuscular junction

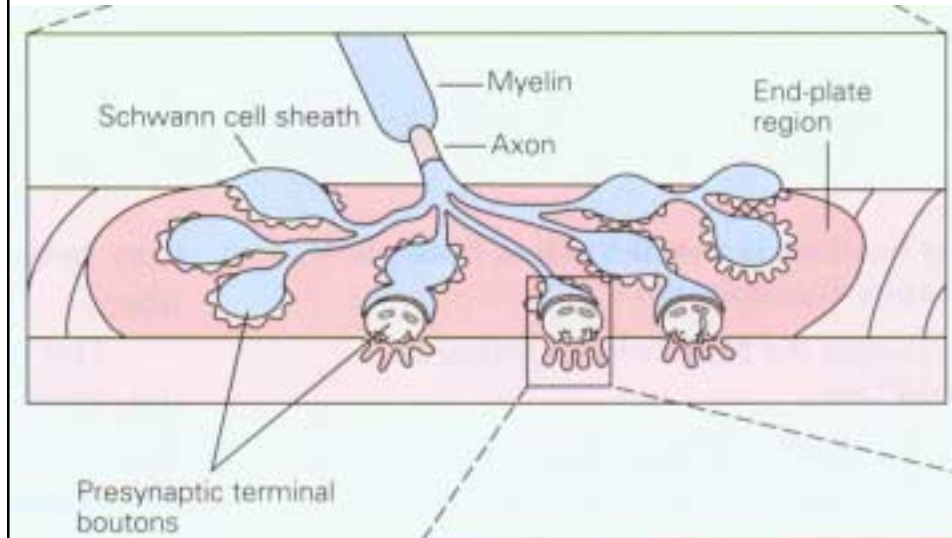


## Neuromuscular junction



## Motor endplate

KSJ 11-1



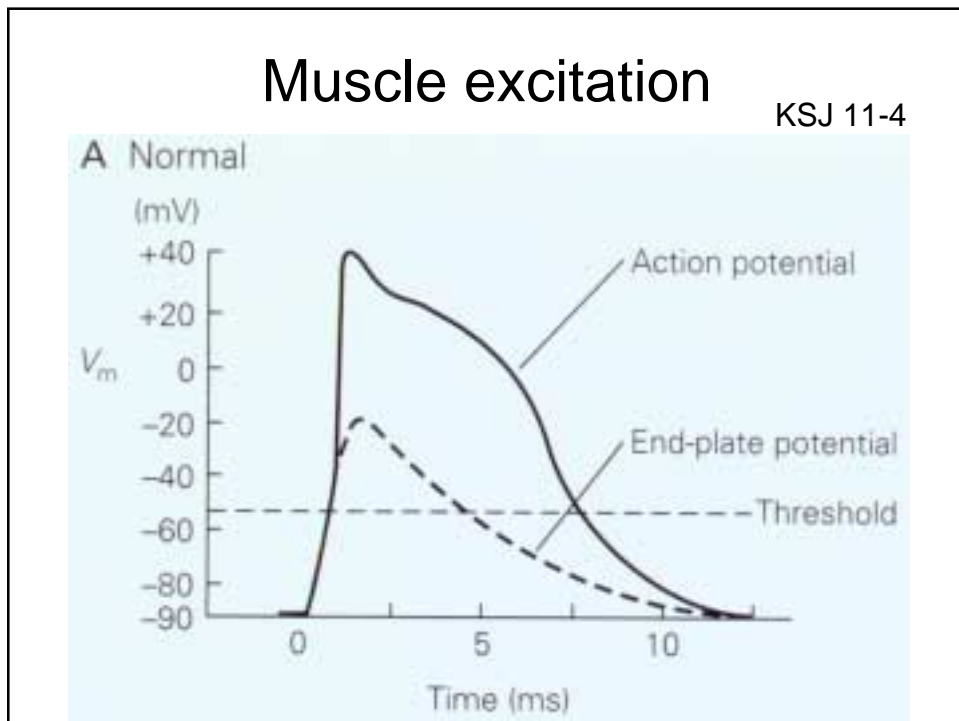
## Anatomical terms

- Presynaptic terminal
  - Synaptic vesicle
  - Active zone
- Synaptic cleft
- Postsynaptic element
  - Postsynaptic density
    - Receptors
    - Enzymes
  - Dendritic spine (sometimes)

## Acetylcholine receptor

- Ligand-gated ion channel
- Permeable to  $\text{Na}^+$  and  $\text{K}^+$
- Reversal potential  $\sim 0$  mV

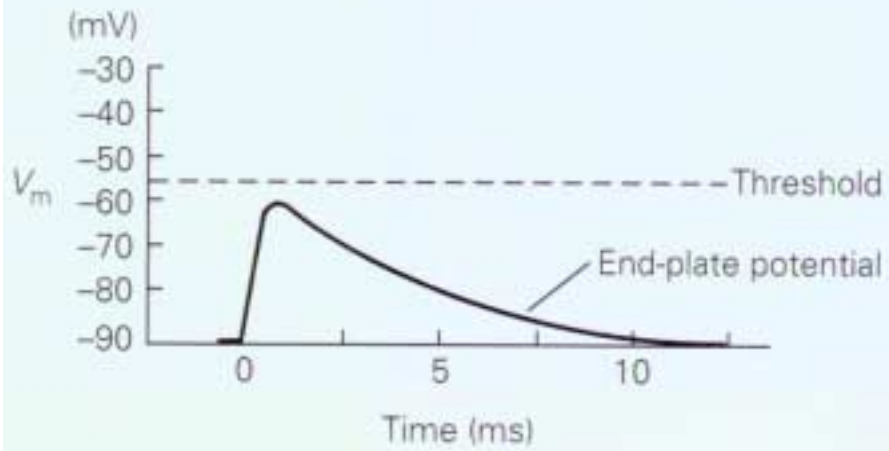
Matthews 5-5



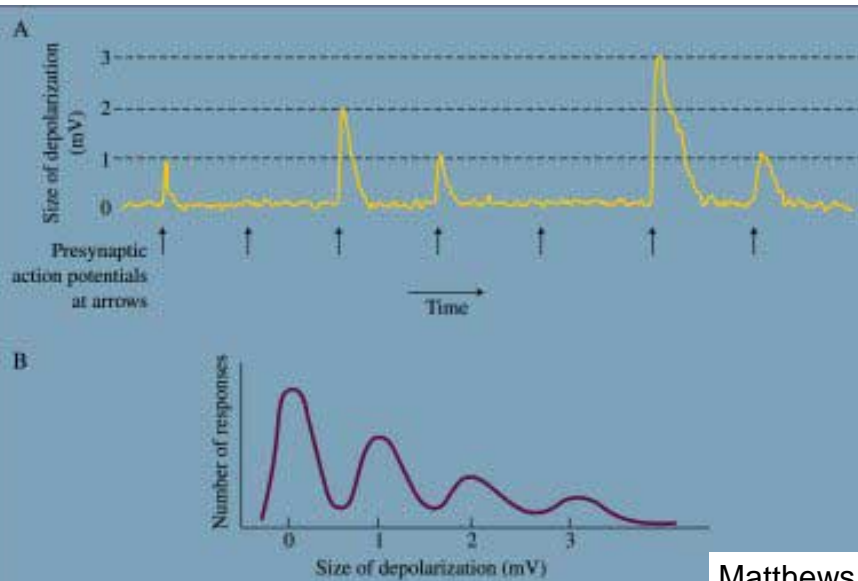
## Endplate potential

KSJ 11-4

B With curare

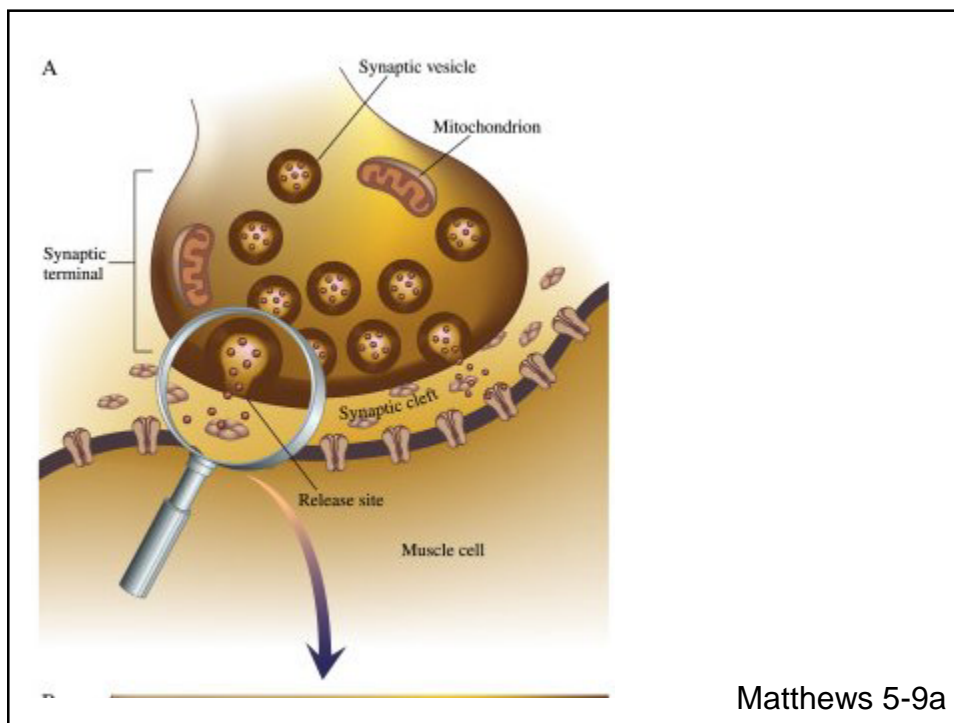
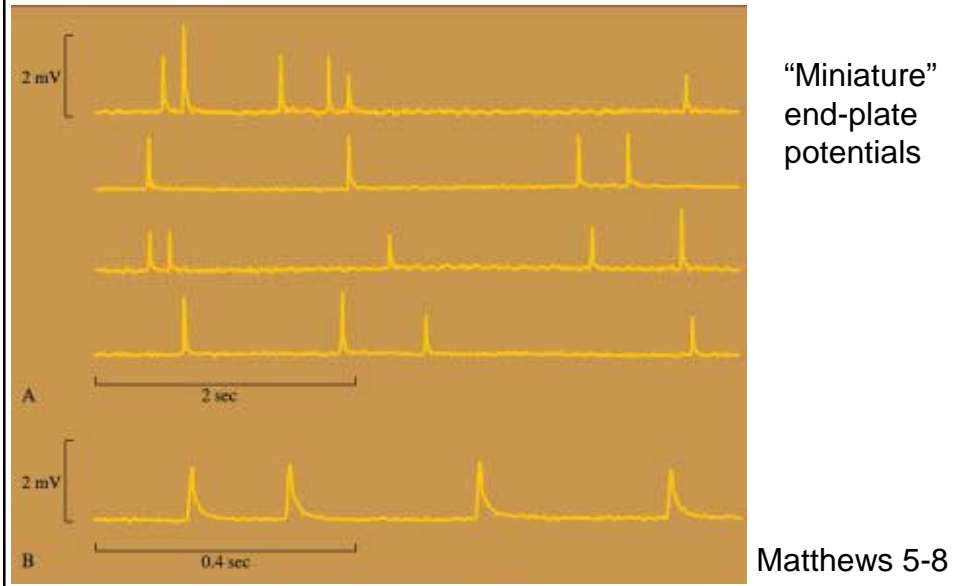


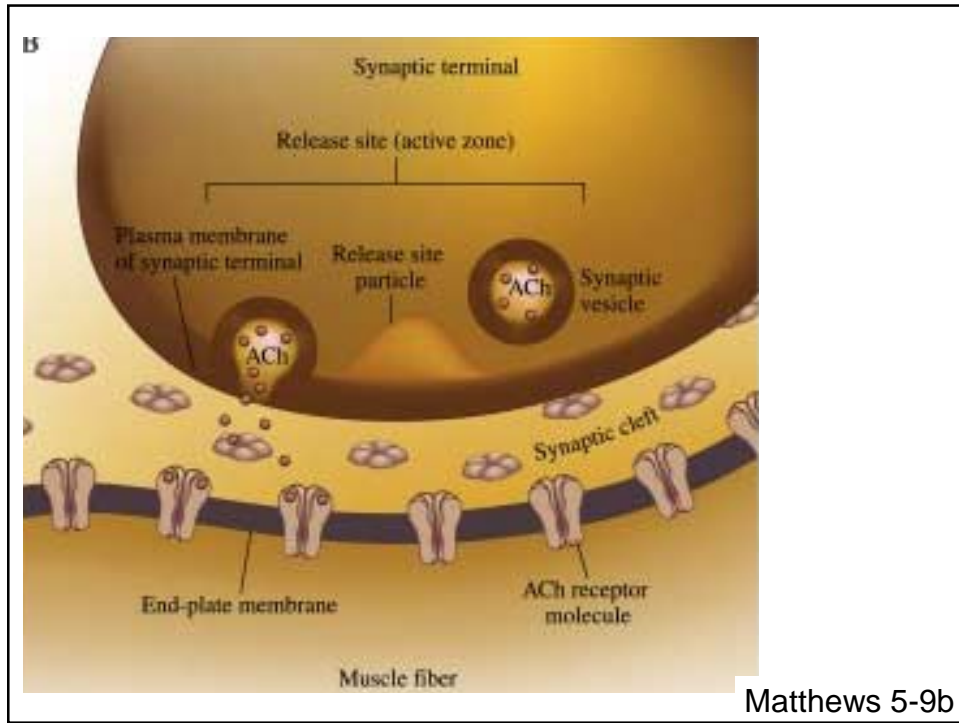
## Quantal nature of synaptic transmission



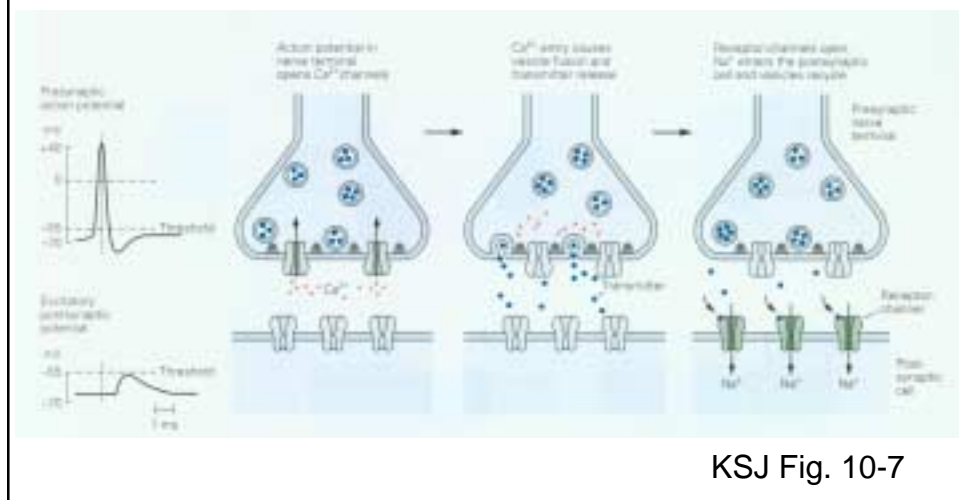
Matthews 5-7

## Spontaneous release of quanta





## Key steps in fast transmission



## Key steps in chemical transmission

- Action potential in presynaptic terminal
- Depolarization activated voltage-dependent calcium channels
- Calcium influx causes vesicle exocytosis
- Transmitter diffuses across synaptic cleft and binds to receptors
- Receptor-channels open, current flows, affecting postsynaptic neuron firing
- Removal/inactivation of transmitter
- Recycling of vesicle membrane

## Some specifics on NMJ

- Transmitter is acetylcholine (ACh)
- Receptors are nicotinic AChRs
- Receptor channels pass cations nonselectively – reversal potential is 0 mV
- Each vesicle causes ~1-2 mV depolarization
- High safety factor – each presynaptic AP causes a postsynaptic AP (and twitch)



## Determinants of the shape of the postsynaptic response 1

- Voltage depends on synaptic current and membrane resistance & capacitance
- Synaptic current depends on synaptic conductance and driving force
  - $I_{\text{syn}} = G_{\text{syn}}(t) * (V_{\text{mem}} - V_{\text{rev}})$
- Driving force on a channel type is the difference between the current potential and that channel's equilibrium potential