

# EMG Signal Activation Pattern Recognition

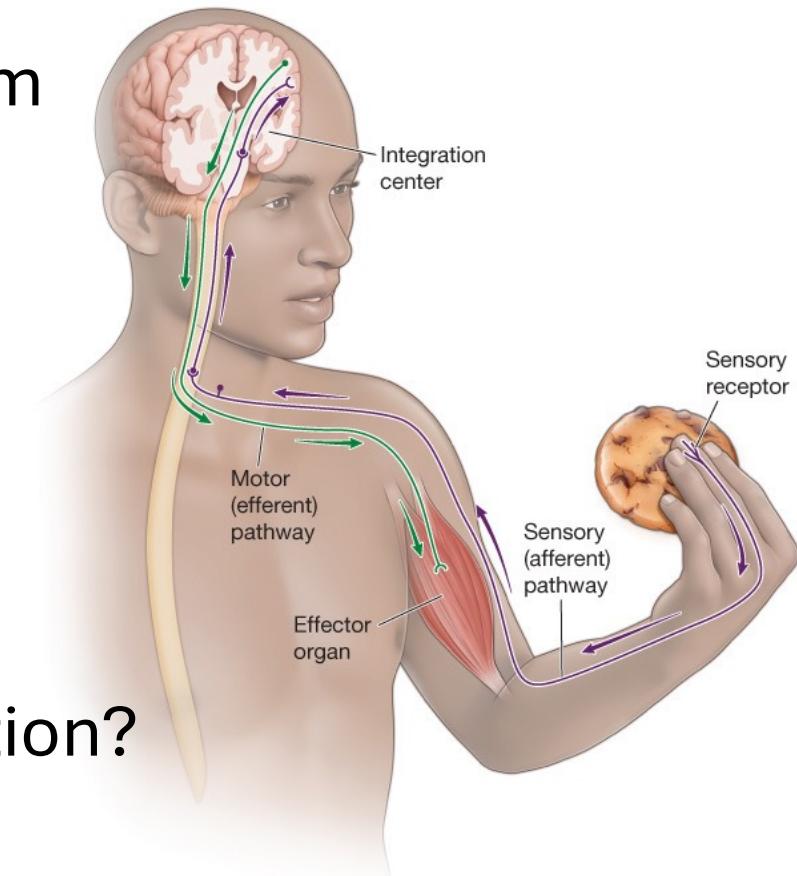
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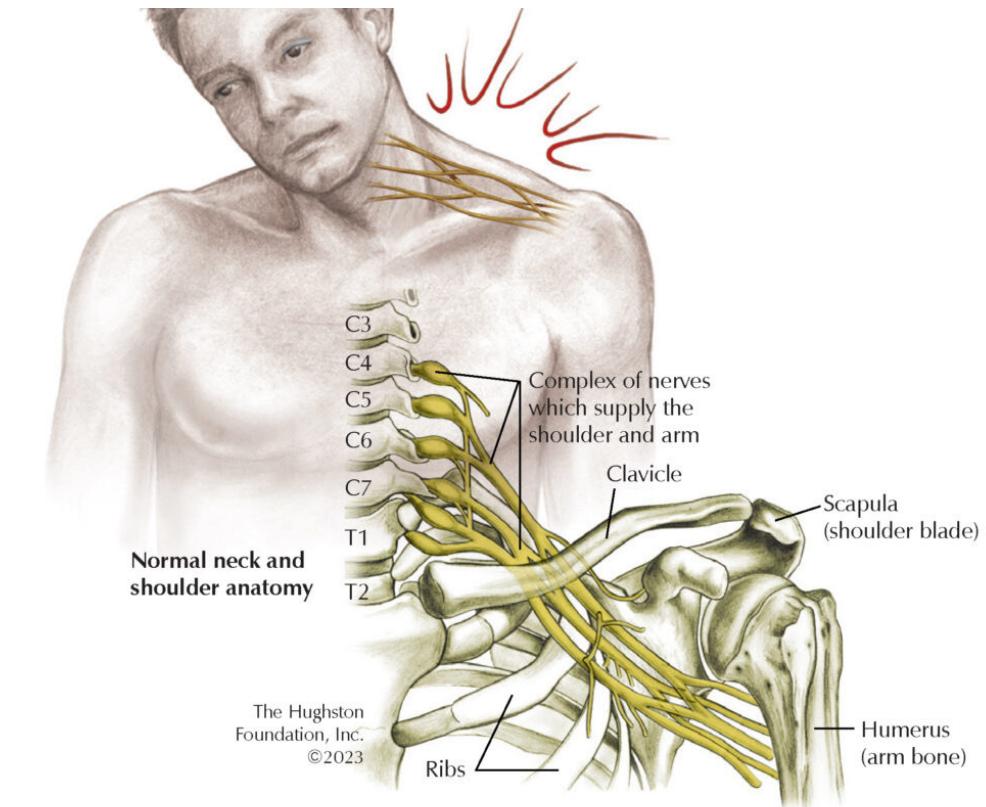
# Background

- Electromyogram (EMG) is used to observe and record the physiological function of skeletal muscle, and by extension, the function of the nervous system
- EMG signals reflect the activity of muscle fibers (muscle cells)
  - Single-unit recording
  - Surface recording
- Muscle activity occurs differentially over time
  - Time series
- How can we quantify and analyze muscle function?

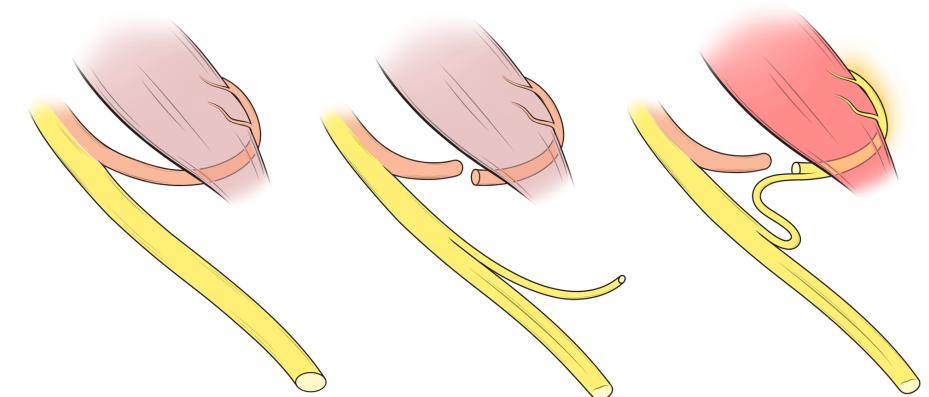


# Motivation

- Peripheral motor nerves power muscles
- Injury or disease of nerves is permanently paralyzing
- Nerve (mostly) cannot be simply repaired, but other redundant nerves may be surgically moved to power the paralyzed muscle
- Nerve transfers—a type of microsurgery to “re-wire” the muscles
- Re-innervation of the healthy nerve into the muscle is a slow process with uncertain results



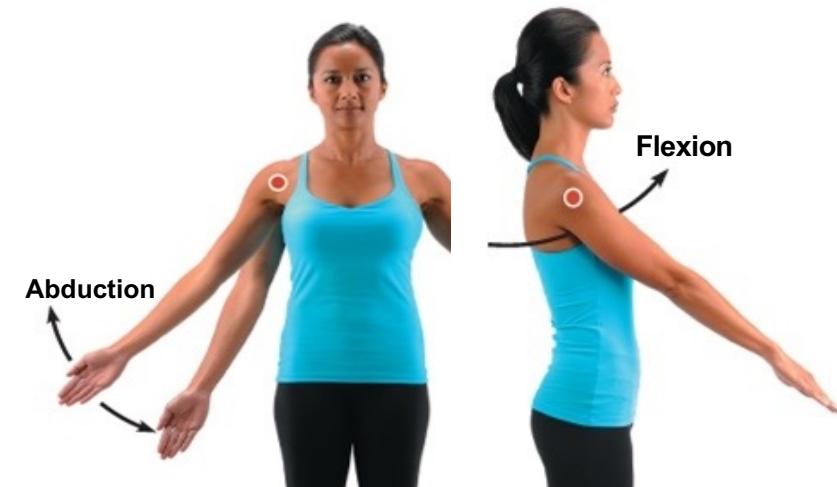
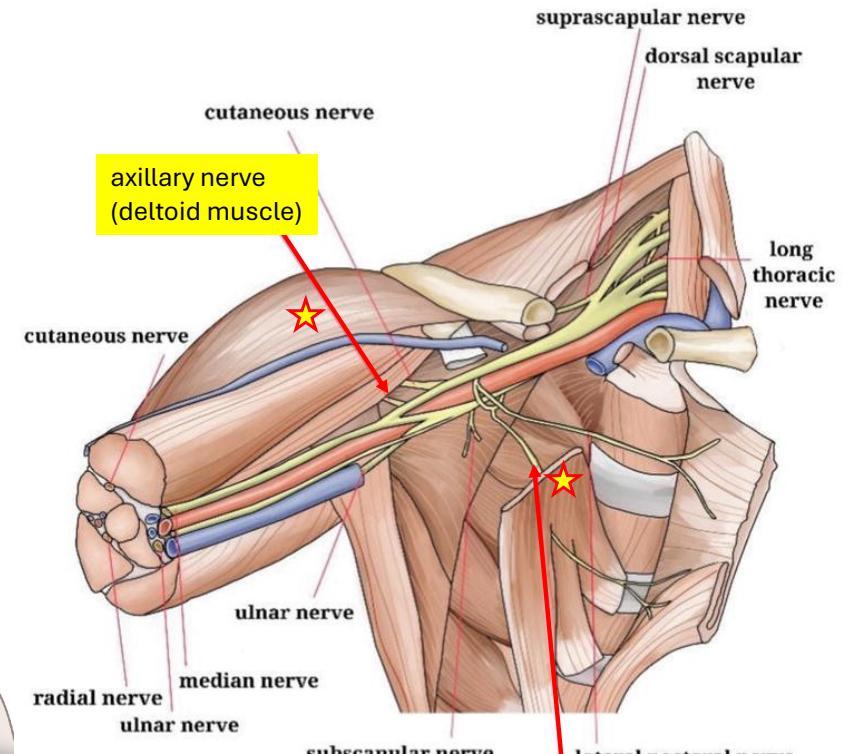
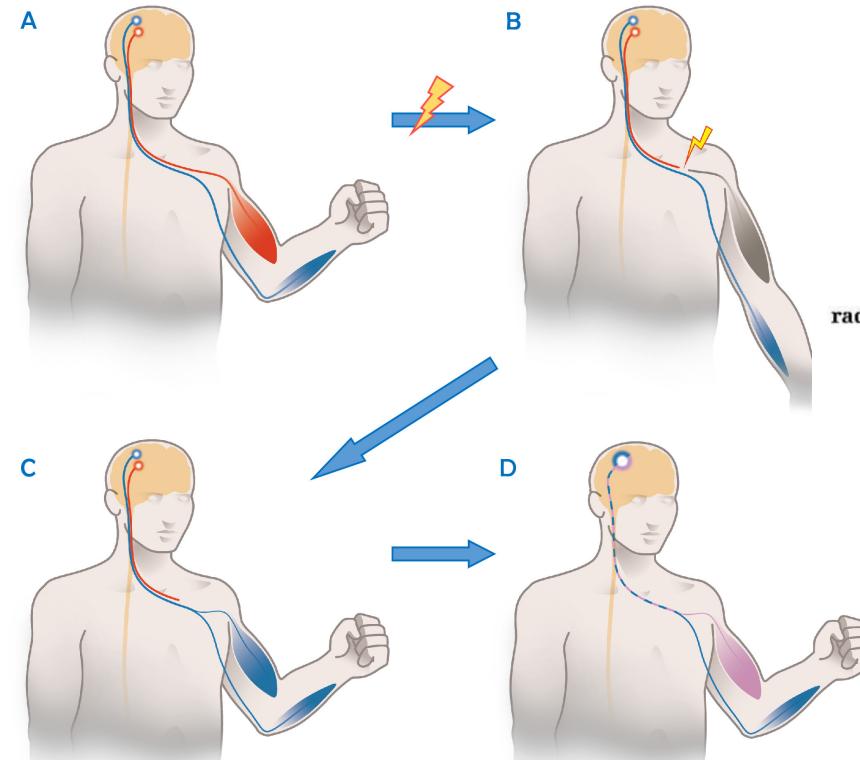
Nerve Transfer Surgery



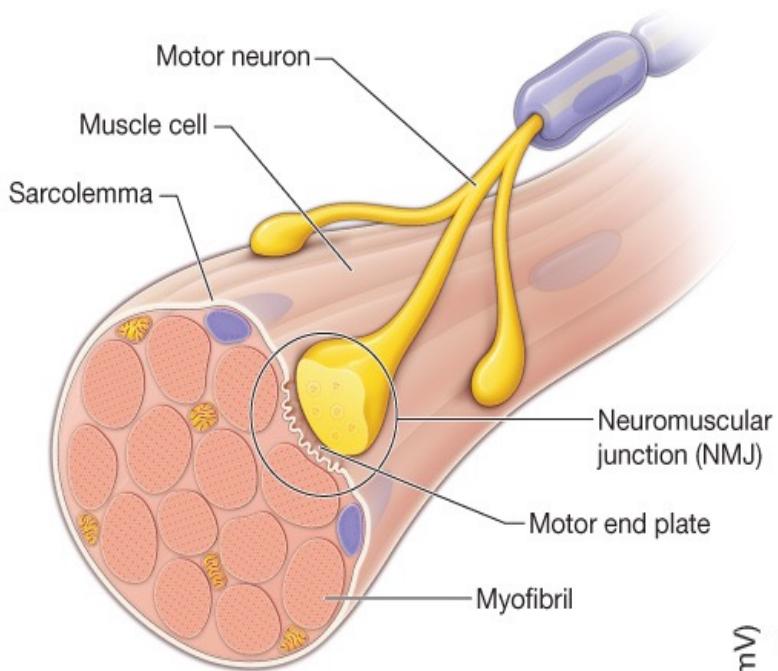
Damaged nerve is cut and a healthy nerve fiber is transferred in its place

# EMG Data from a Patient Who Underwent Nerve Transfer

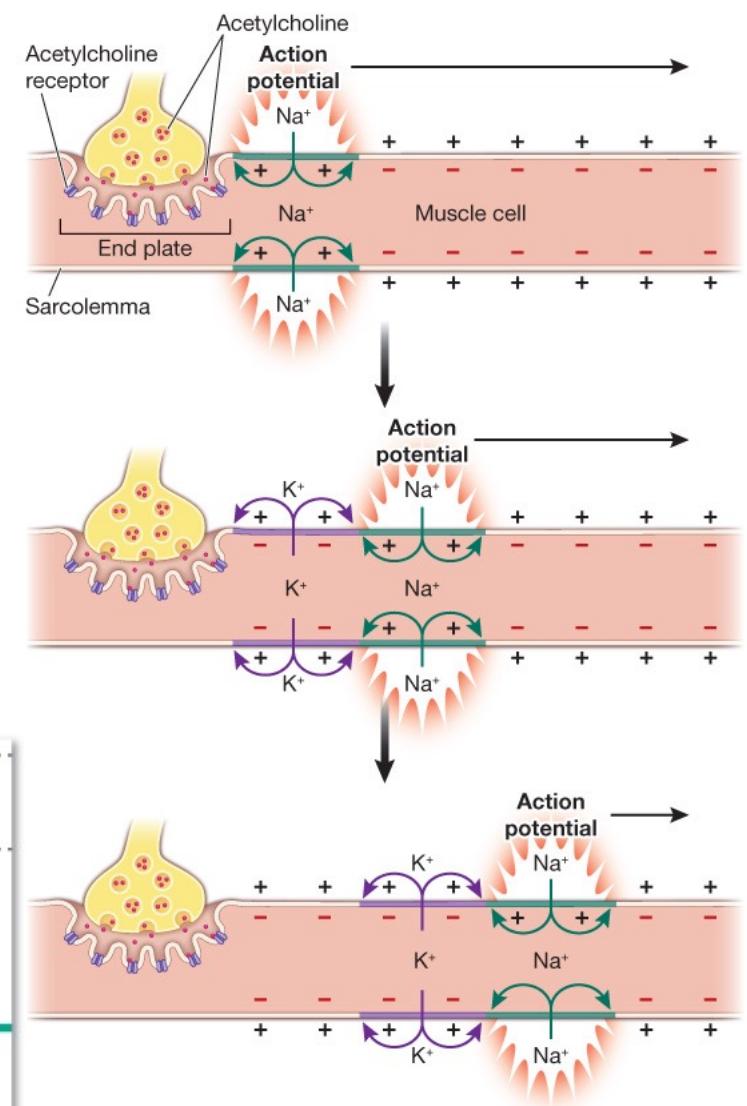
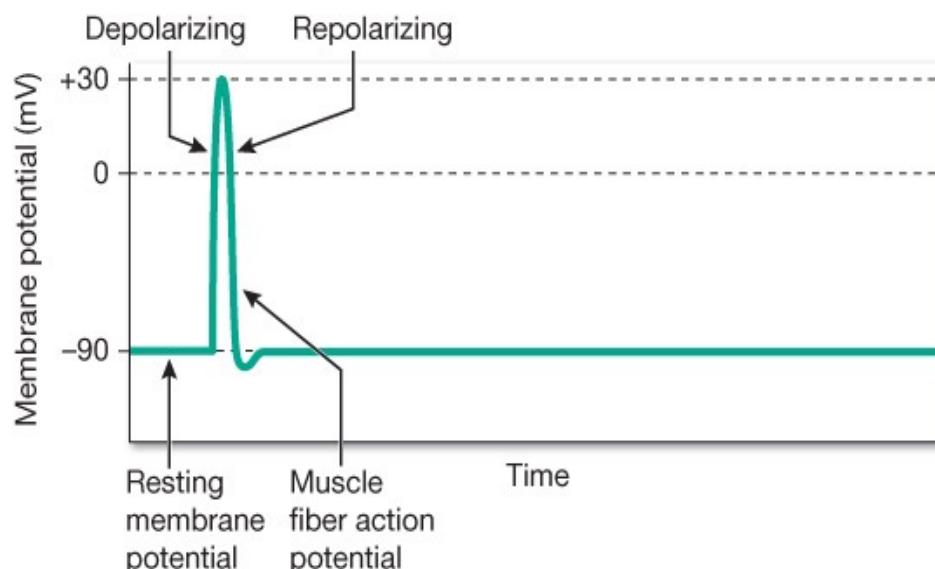
- 6-year-old girl
- Viral paralysis of one shoulder with transfer of medial pectoral nerve to axillary nerve
- Surface EMG recorded from the deltoid (shoulder)
  - At rest (**baseline**)
  - Chest+shoulder (**low**)
  - Resistance added chest+shoulder (**high**)



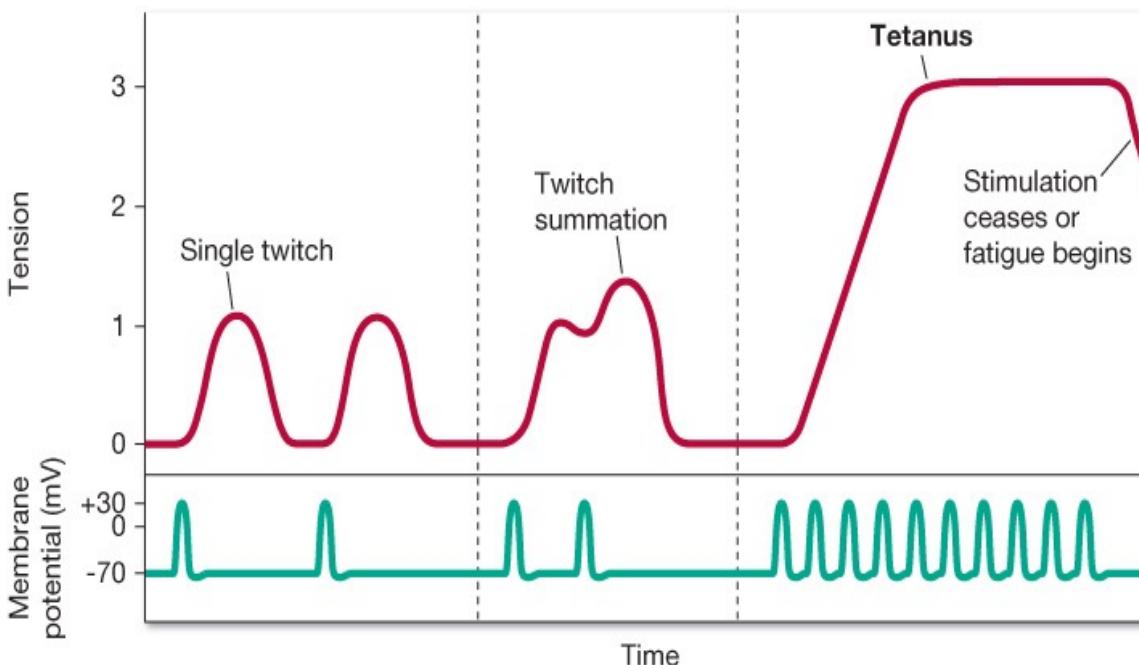
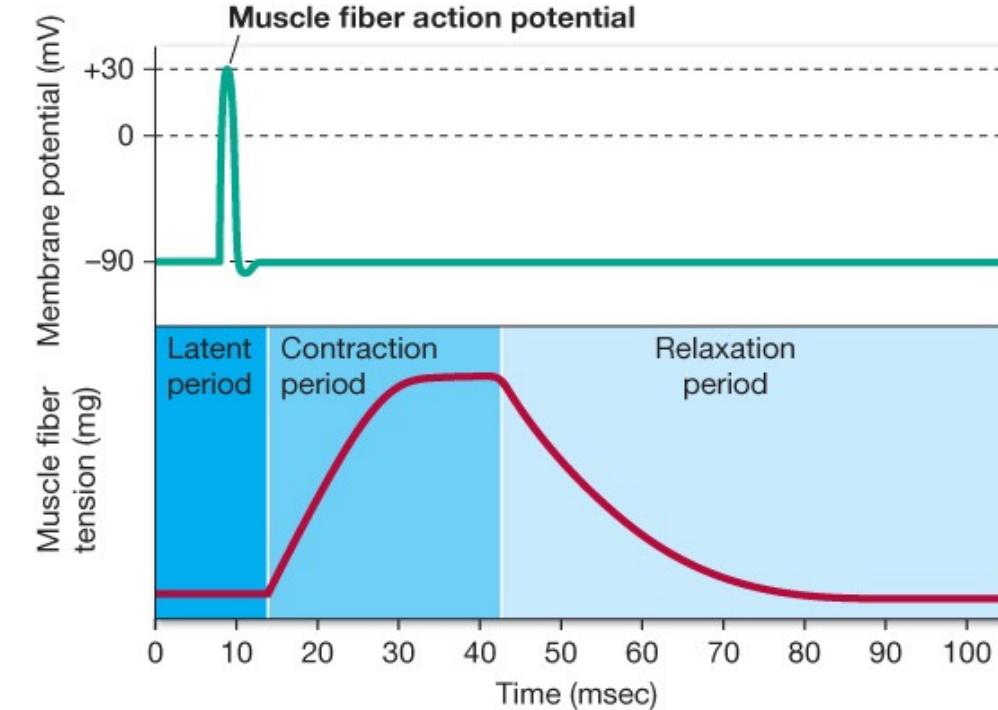
# Physiology of Muscle



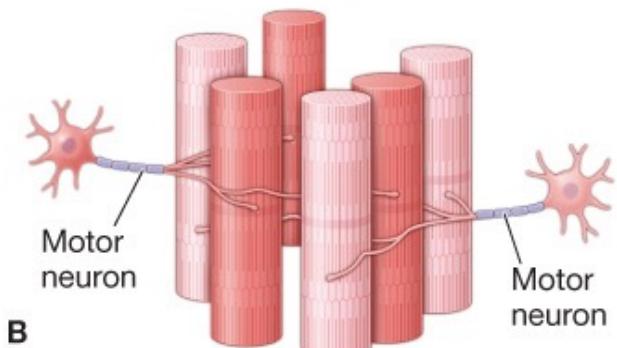
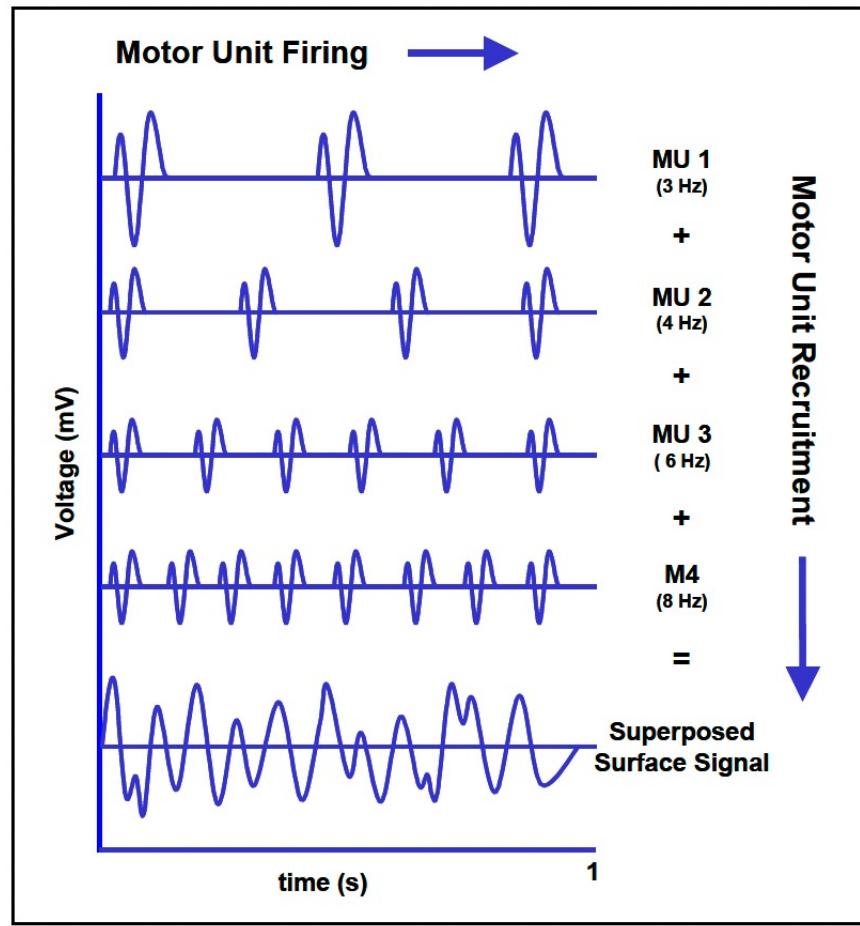
- Action potential—electrical impulse that travels along a motor neuron, causing depolarization of the muscle cell



# Physiology of Muscle

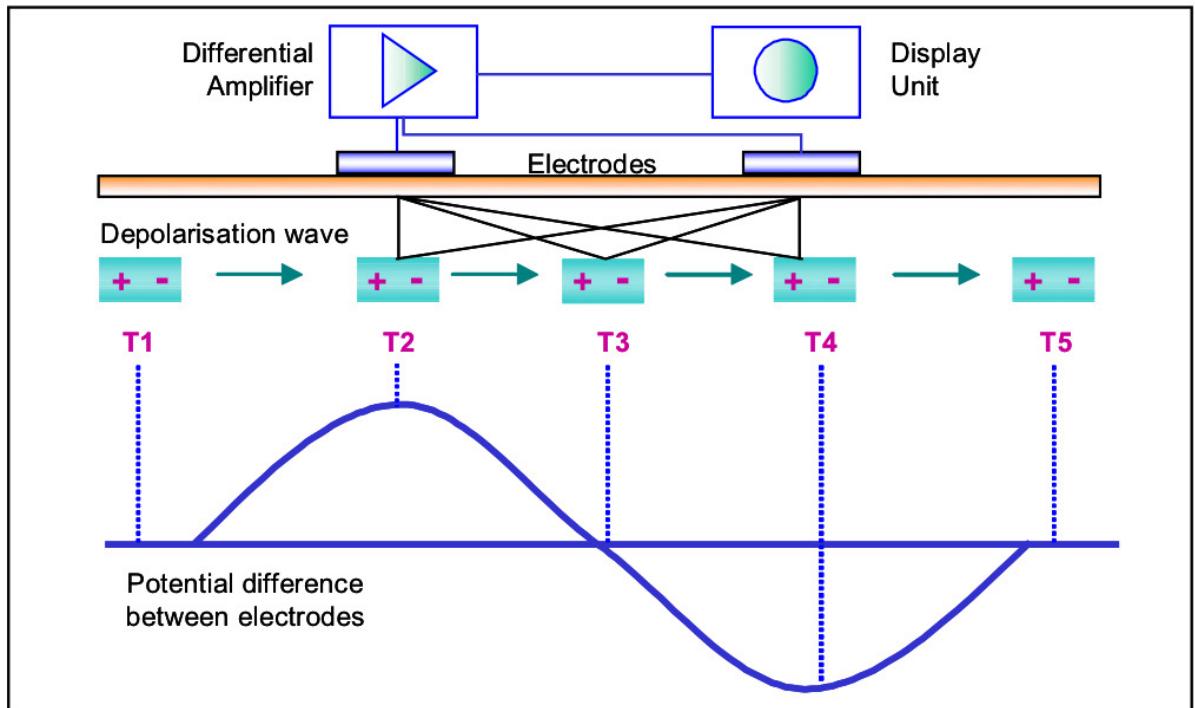


- Relaxed muscle demonstrates periodic firing
- Action potentials are 1-5 ms
- Muscle fiber contraction-relaxation sequence is 30-200 ms
- Subsequent action potentials can be propagated along the muscle fiber before the contraction sequence is completed



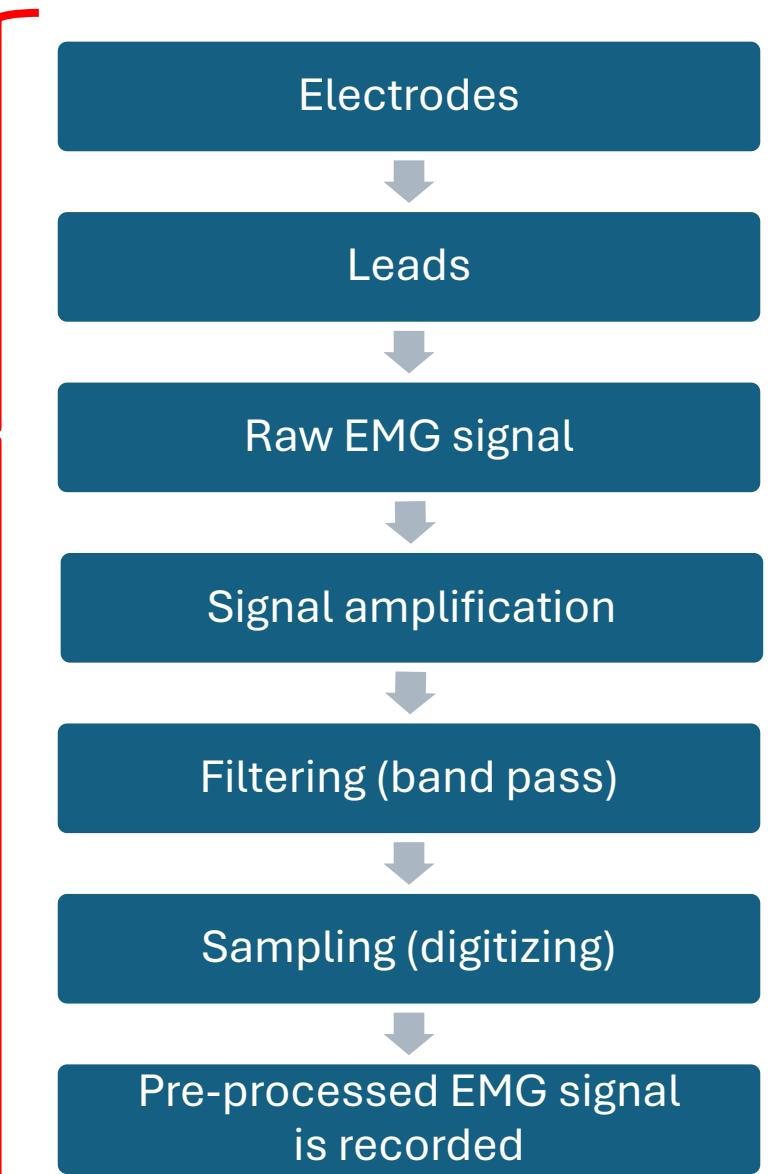
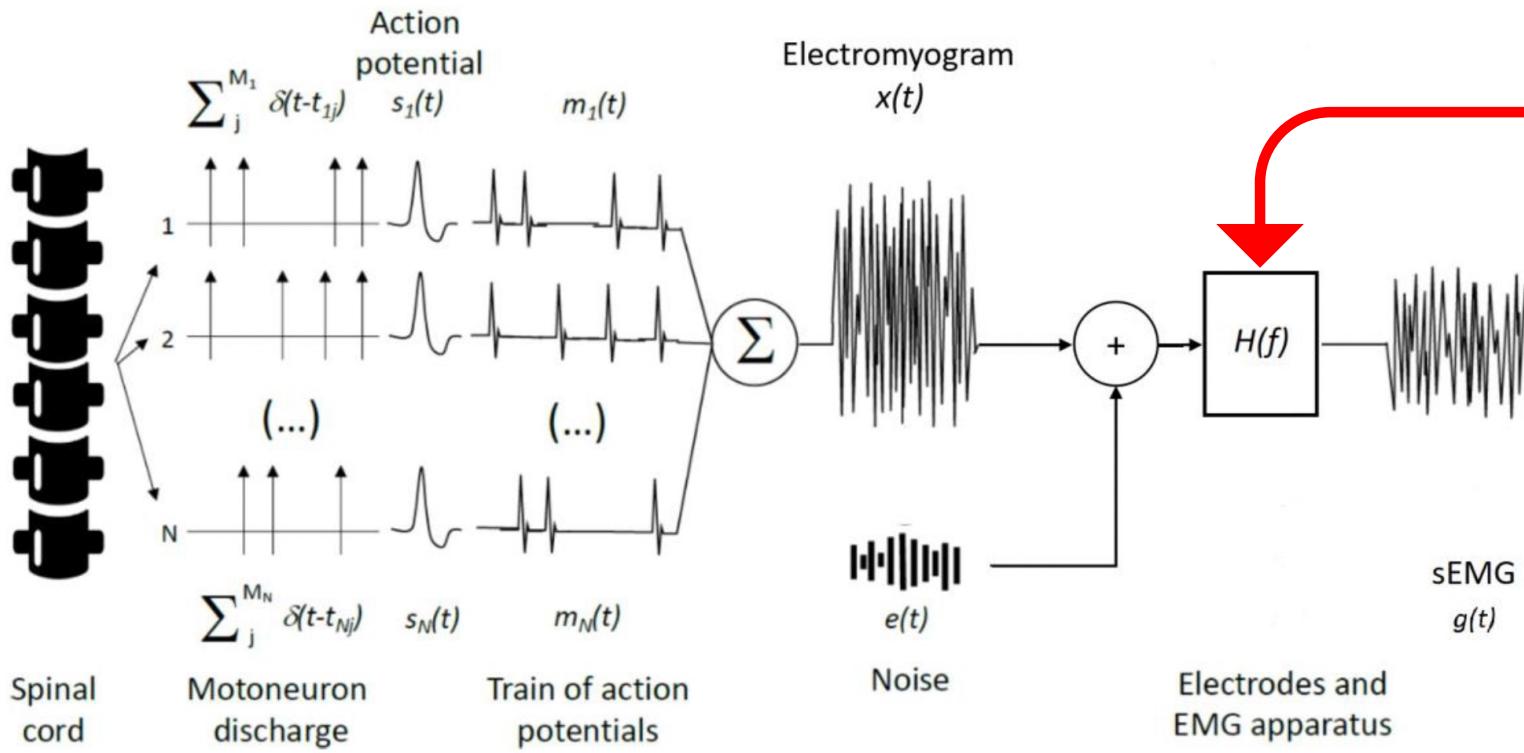
# Muscle Activity to EMG Signal

- Interference signal—the coalescence of many different motor units



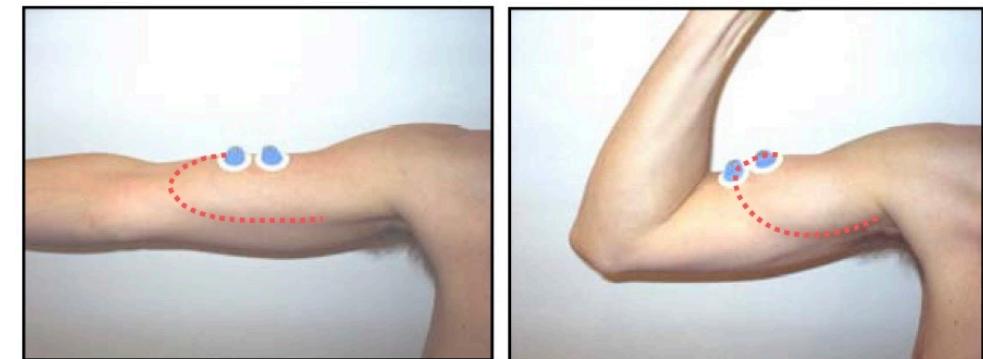
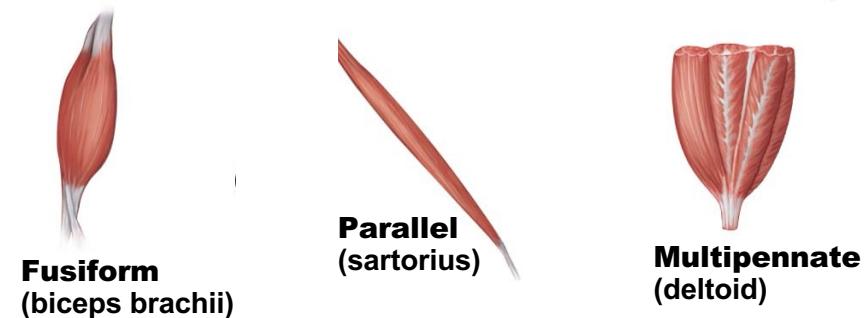
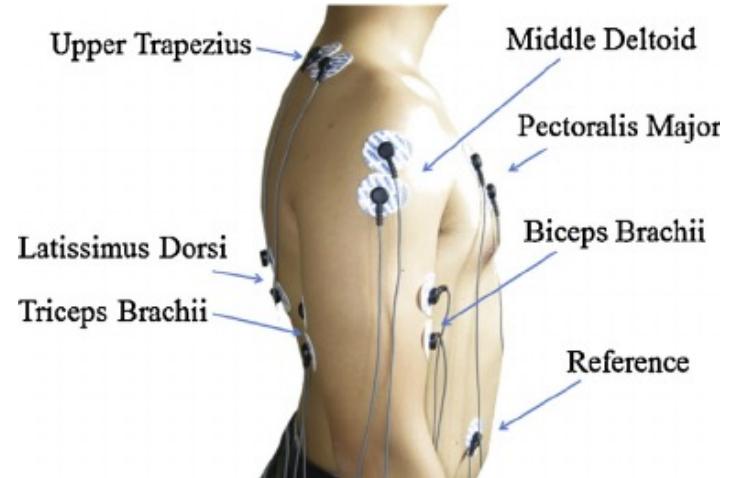
- Electrical dipole—forms an electrical potential difference between the spaced electrodes

# EMG Recording Procedure



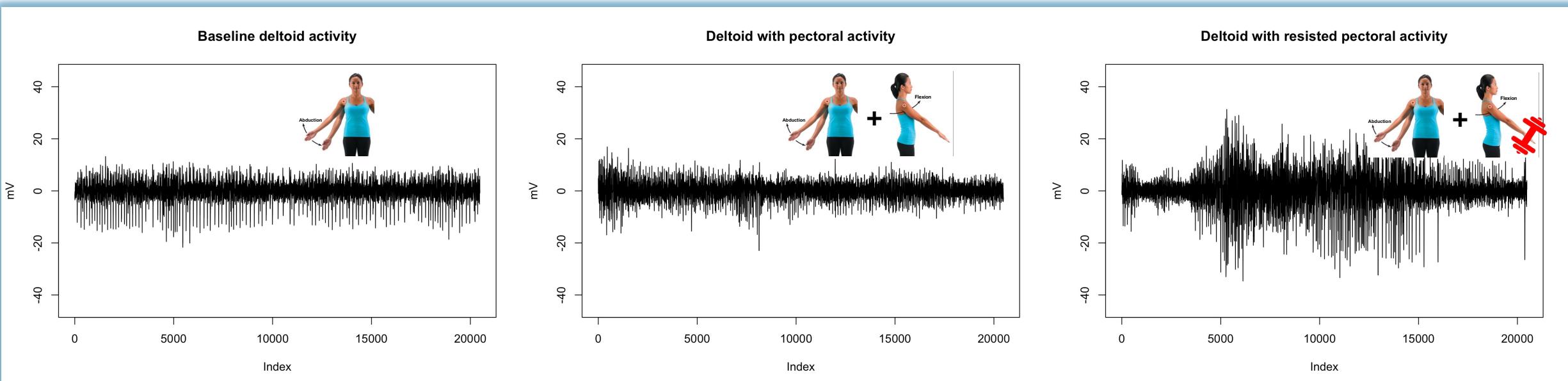
# EMG Recording Considerations

- Tissue characteristics
- Electrode impedance ( $\leq 5000 \Omega$ )
- Electrode arrangement: parallel to muscle fibers
- Electrode position
- Amplification—gain adjusted to account for  $<50 \mu\text{V}$  up to  $\sim 1000 \mu\text{V}$
- Signal-conditioning filter—band pass 20-500 Hz
- Sampling rate—sparse sampling will lead to aliasing effects



# Details of Dataset

- Single session of surface EMG recordings from the deltoid (shoulder) muscle
- Old, poorly documented, not collected for research
  - Likely many unknown sources of error
- Recorded during prompted movements
  - Start and stop times of each movement were flagged manually on keyboard
- Exploratory data analysis revealed possibly different patterns during different movements

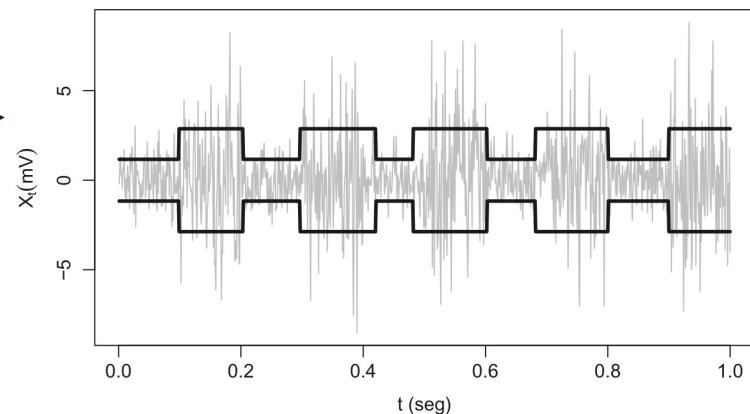


# Background on Method

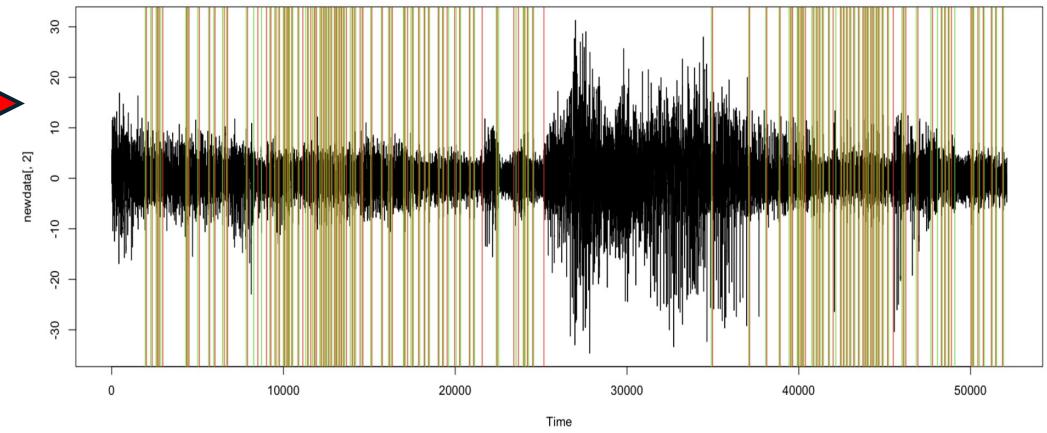
- Search for methods to analyze EMG  
→ biosignalEMG R package
- Package includes function for detecting activity patterns in EMG
  - Heteroscedastic change-point model
  - Assumes normally-distributed time series data with non-constant variance, which is used to determine signal phase



Results from package developer using synthetic data

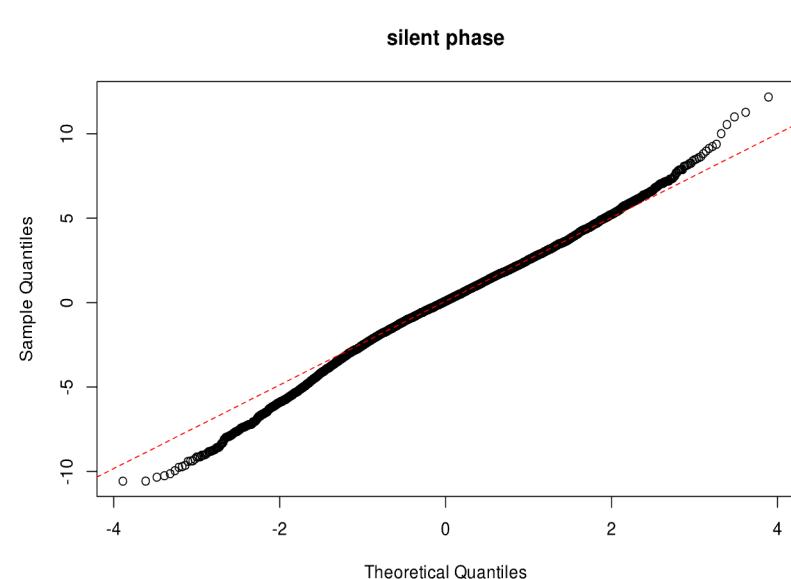
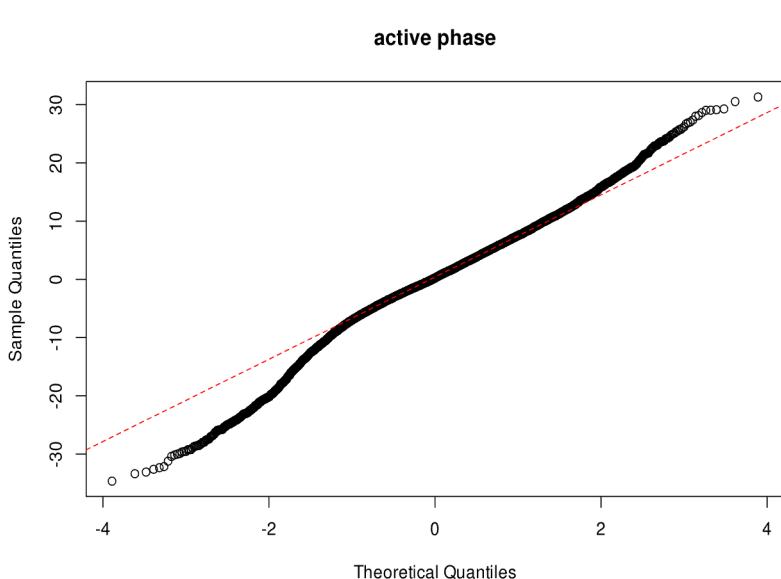
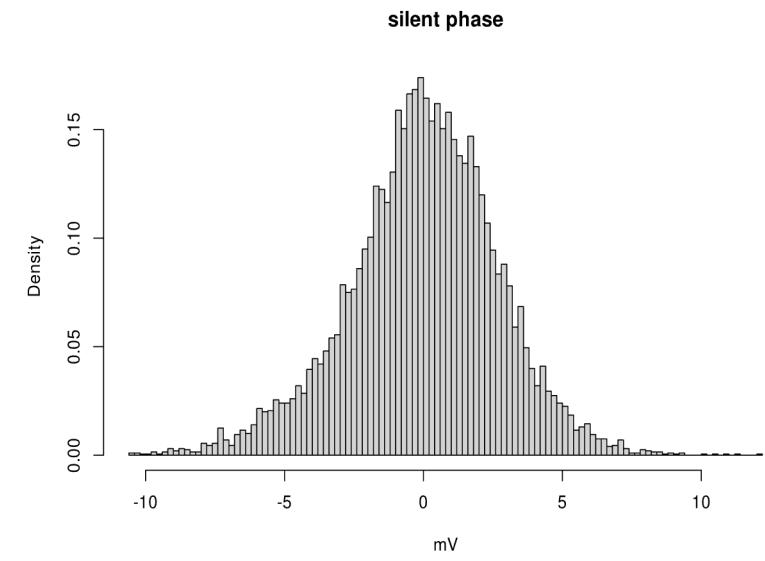
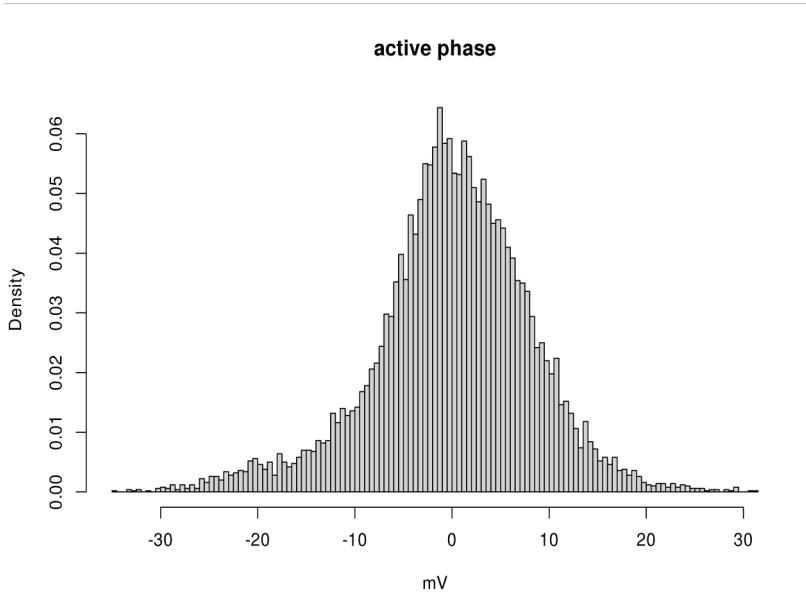


Results from our attempt using the package on our data



# Method

1. Assumptions:  
time-dependent,  
normally-distributed  
(within phase),  
non-constant  
variance  
(across  
phases)



# Method

## 2. Model: heteroscedastic process

- Log-likelihood of this function is difficult to maximize with vector of indicator functions
- Constrain maximization by coercing b vector to behave like indicator variables
- Optimization by iterative process

# Method

3. *A posteriori* processing: ensure that the phases are coherent and smooth over noise

# Method

4. Evaluate results: test model performance
  - Percentage of classification error

# Limitations

# References

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