

# Electromyography (EMG)

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**EMG** - extracellular electrical activity recorded from muscle.

## METHODOLOGY

- spontaneous electrical activity and individual motor units cannot be seen with SURFACE ELECTRODES.
- NEEDLE ELECTRODE placed within muscle.
  - monopolar needle electrode
  - concentric needle electrode (most popular) - fine silver (or platinum) wire, insulated except at its tip, that is contained within pointed steel shaft - potential difference between outer shaft and inner wire is recorded.

upward deflection indicates that active electrode is negative with respect to reference one

- potentials are amplified → evaluated *visually* (on oscilloscope screen) and *aurally* (over loudspeaker).
- motor unit pathology can be localized to nerve\*, muscle, or neuromuscular junction.
  - \*EMG also permits lesion to be localized to spinal cord, nerve roots, plexuses, or peripheral nerves – by topographic pattern of affected muscles.

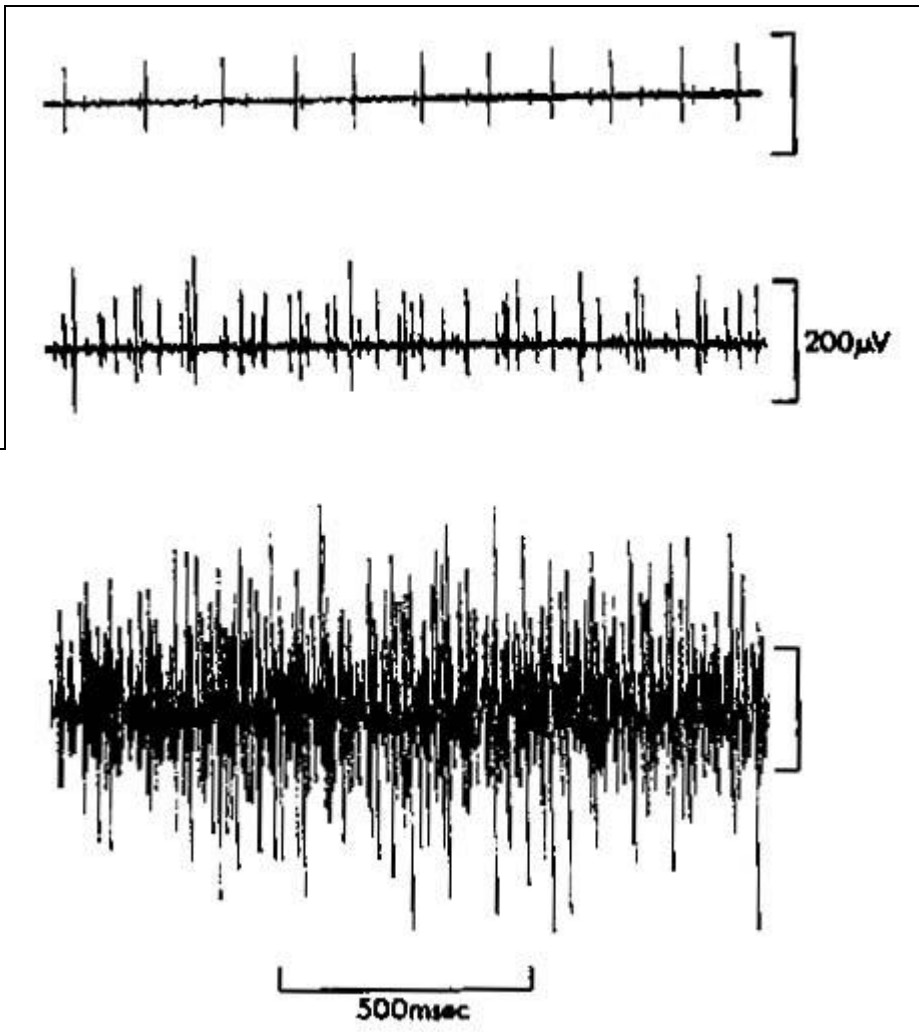
## Usefulness of EMG:

- support of diagnosis** (e.g. myopathy vs. neuropathy)
  - N.B. specific etiologic diagnoses cannot be made!
- confirming clinical phenotype** of muscle involvement established on neurologic examination (i.e. confirming muscle weakness in individual muscles)
- guiding** muscle biopsy

## Normal EMG

Needle electrode is inserted → brief *burst of activity* for ≤ 2-3 seconds → *no spontaneous activity*\*.  
 \*except in endplate region - *endplate "noise"* (nonpropagated miniature endplate potentials generated by spontaneous ACh release).

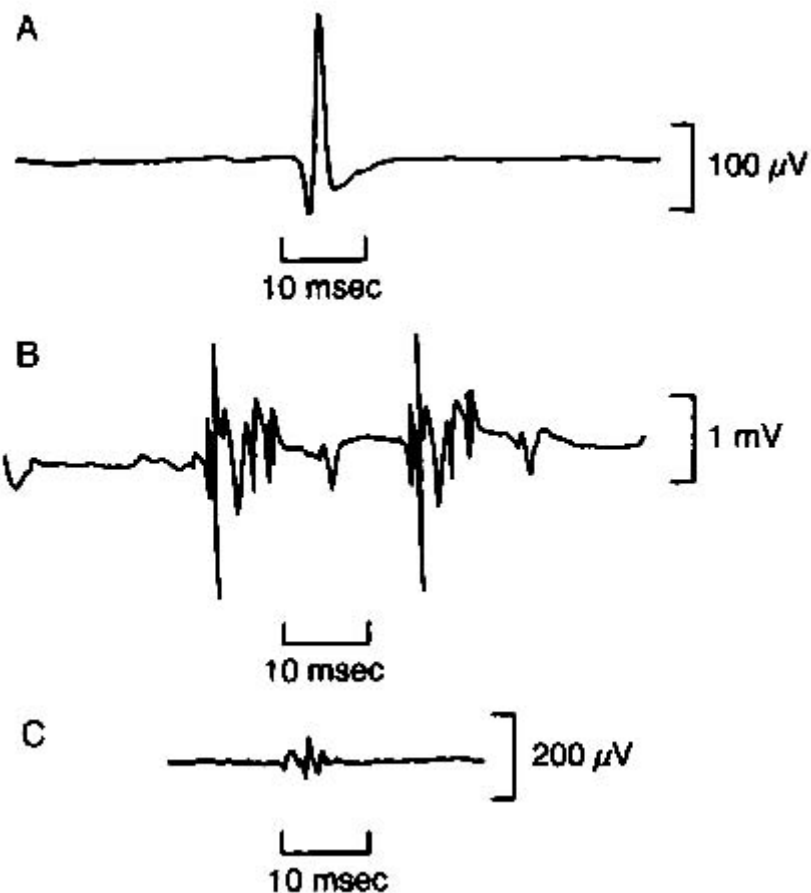
- slight voluntary contraction is initiated → few motor units are activated - fire *irregularly at low rate*.
- increasing effort → fire *more rapidly*; at certain firing rate, additional units are *recruited*.
- maximal effort → so many units are recruited that *individual potentials cannot be distinguished* – “complete interference pattern”.
  - normal recruitment pattern on maximal effort is dense with no breaks in baseline;
  - amplitude of envelope (excluding single high-amplitude spikes) is 2-4 mV (using concentric needle with standard recording area 0.07 mm<sup>2</sup>).



Normal extracellularly recorded individual **motor unit action potentials** are *biphasic* or *triphasic*.

- duration 2-15 msec.
- amplitude 200 μV - 3 mV.
- polyphasic* potentials (> 4 phases) are nonspecific findings:
  - occur in both neurogenic and myogenic disease;
  - also are found in small numbers (10-15%) in all normal muscles.

- Normal triphasic potential.
- Long-duration, high amplitude polyphasic potential (shown twice) – *neuropathic potential*.
- Short-duration, low-amplitude, polyphasic potential – *myopathic potential*.



## Abnormal EMG

Evaluate:

- insertional** activity
- spontaneous** activity
- voluntary** activity:

- a) motor unit form (**individual action potentials** - amplitude, duration, number of phases) - during *minimal* volitional activity.
  - b) density of motor units (**recruitment pattern**) - during *maximal* volitional activity.
- EMG requires patient cooperation for full relaxation and maximal voluntary muscle contraction – EMG is less useful in pediatrics.

#### Prolonged INSERTION ACTIVITY

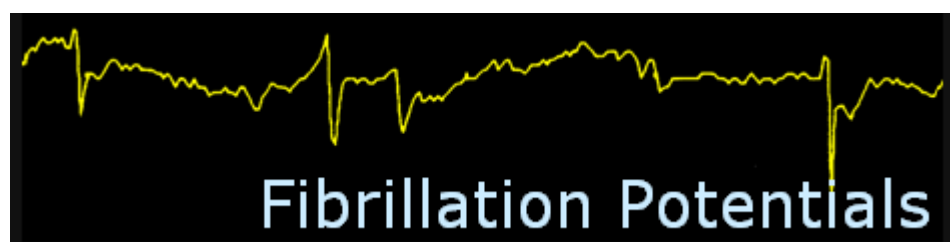
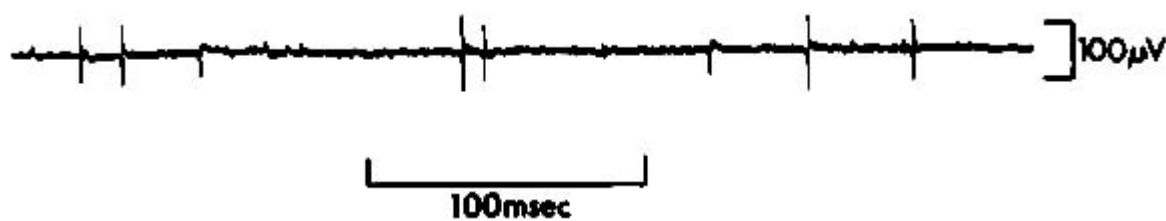
- a) acute **denervation**
- b) active (usually inflammatory) **myopathy**

#### Abnormal SPONTANEOUS ACTIVITY

Denervated muscle fibers discharge spontaneously!  
→ fibrillation potentials and positive sharp waves.

**Fibrillation potential** - biphasic (or triphasic) discharge with positive onset (except in endplate region);

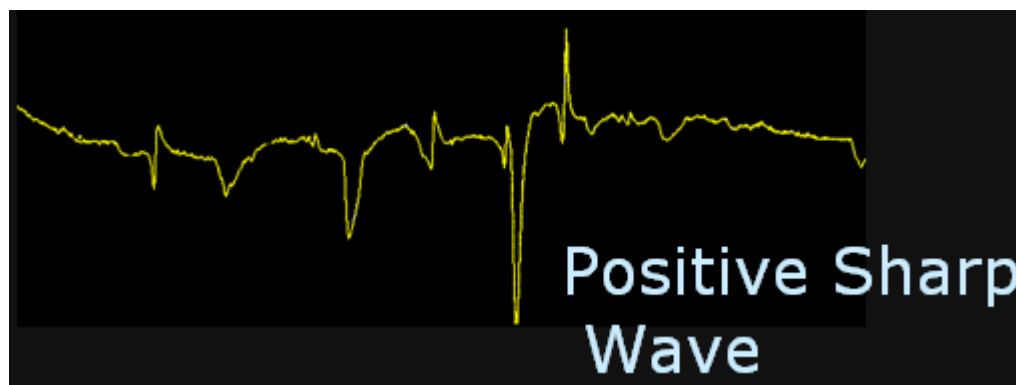
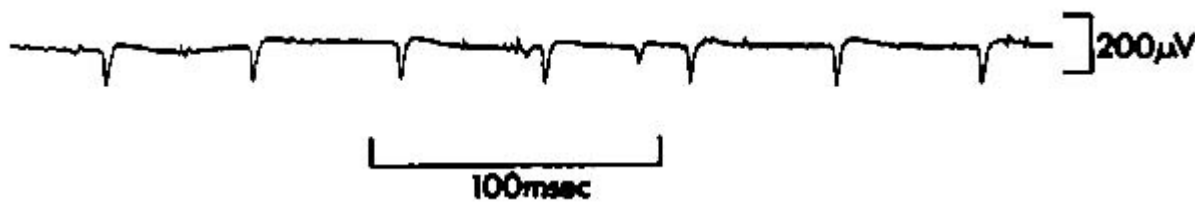
- represents action potential generated in **single muscle fiber** (so cannot be detected by clinical examination).
- amplitude up to 300  $\mu\text{V}$ , short duration  $\leq 5$  msec, frequency  $\leq 20$  Hz.
- usually fire rhythmically - reflect oscillations of resting membrane potential of muscle fibers.
- etiology - INCREASED MUSCLE IRRITABILITY:
  - 1) **denervated muscle**:
    - may not appear even for 3-4 weeks after acute neuropathic lesion.
    - found earlier in proximal muscles (in distal muscles may appear only after 4-6 weeks).
    - once present, persist indefinitely unless reinnervation occurs or muscle completely degenerates so that no viable tissue remains.
  - 2) occasionally in some active **myogenic disorders** (inflammatory, muscular dystrophies, muscle trauma, certain metabolic disorders [e.g. acid maltase deficiency]).



**Positive sharp waves** - initial positive\* deflection → slow deflection in negative direction.

\* traveling wave terminates at point of needle recording, so there is no upgoing negative phase.

- found *in association with fibrillation potentials*.
- amplitude up to 300  $\mu\text{V}$ , duration  $\geq 10$  msec, frequency up to 100 Hz.



Spontaneous fibrillation potentials + positive sharp waves:



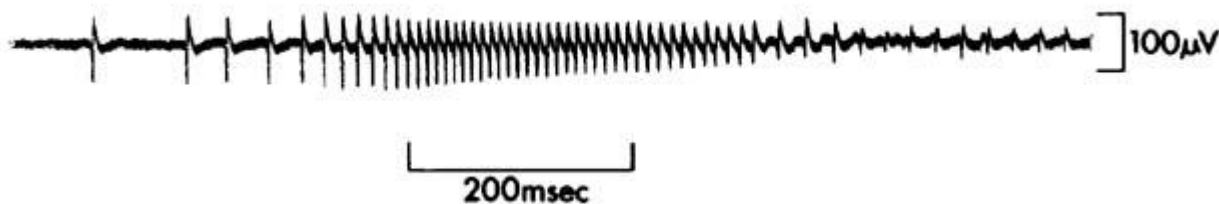
**Fasciculation potential** - spontaneous activation of *all muscle fibers in motor unit*.

- indistinguishable from normal motor unit action potentials!
- amplitude & duration greater than fibrillation potential.
- *sudden dull thump* over loudspeaker.
- etiology - **disease of anterior horn cells**\*, very occasionally certain myopathic disorders (e.g. thyrotoxicosis), sometimes as isolated phenomenon without pathological significance (benign fasciculations).

\*may arise at any site along motor axon or motoneuron body.

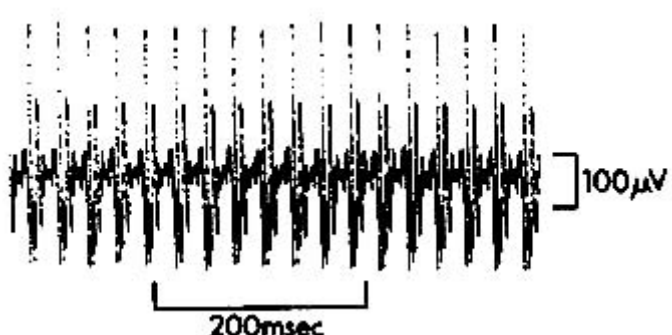
**Myotonic discharges** - spontaneous repetitive high-frequency **trains of action potentials** derived from *single muscle fibers*; decreasing amplitude and frequency.

- etiology - **myotonic disorders**, acid maltase deficiency.
- sound myographically like "dive bomber".



**Complex repetitive discharges** - constant high frequency and amplitude; starts and stops abruptly and does not wax and wane (vs. myotonia) - sounds like "jack hammer".

- **etiology** - **chronic partial denervation**, certain muscular dystrophies or inflammatory muscle disorders.
- **arise in muscle itself** - initiated by fibrillating fiber that depolarizes **adjacent fibers** by ephaptic transmission.



**Myokymia** - spontaneous **grouped pattern of firing** of motor units (double, triple, or multiple discharges → period of silence → another grouped discharge).

- **etiology** - see p. Mov3 >>  
EMG myokymia may be found in some individuals without any clinically visible twitching!

**Nascent polyphasic potentials** - indicative of muscle reinnervation. see p. PN7 >>

**Abnormalities of MOTOR UNIT ACTION POTENTIALS**

Needle electrodes record only from portion of motor unit, but change in amplitude and duration is diagnostic.

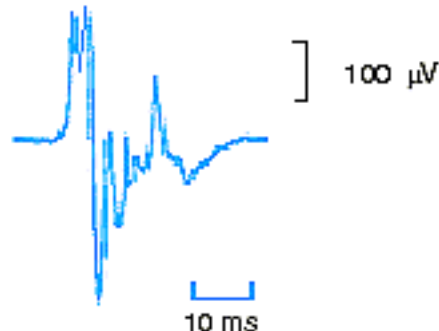
Normal triphasic potential



Myopathic polyphasic potential



Neuropathic polyphasic potential



**Myopathies** (↓number of muscle fibers in individual motor units; number of motor units is normal):

- myopathic potentials - ↓duration & amplitude (i.e. **recruitment density is normal**, but envelope amplitude is reduced);  
pathognomonic finding of myopathy: full recruitment in weak, wasted muscle.
- ↑incidence of **polyphasic potentials**.
- because individual motor units generate less tension than normal, **increased number is recruited** for any given degree of voluntary activity (**rapid recruitment**).

**Neuropathies** (↓number of motor units):

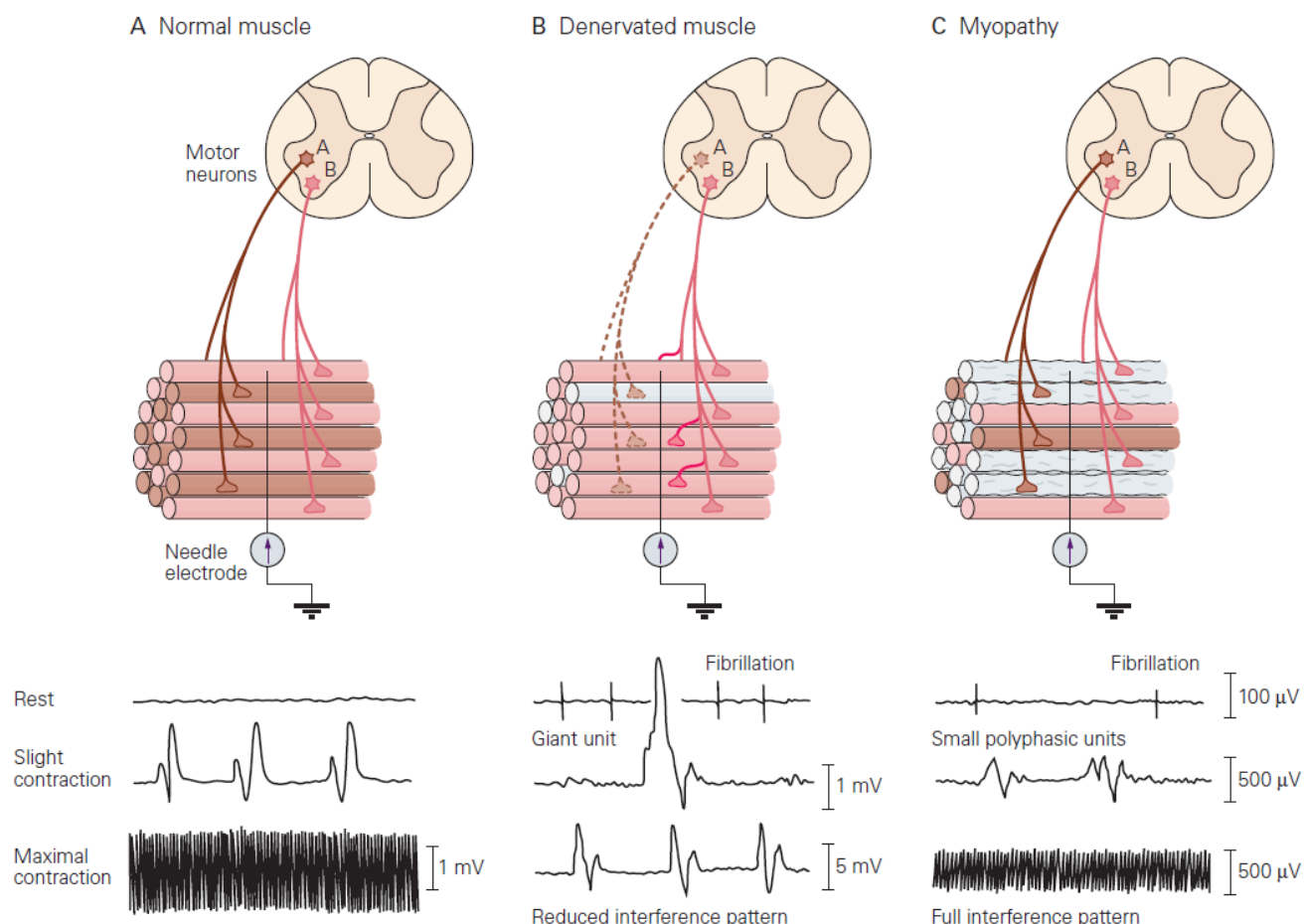
- ↓**recruitment density**, s. decreased recruitment (reduced interference pattern);  
sometimes only one unit can be recruited by maximal effort, and this unit may fire faster than 40 Hz (discrete recruitment).
- during voluntary activity, there is compensatory **increase in rates** at which individual remaining units begin firing and at which they fire before additional units are recruited.
- after reinnervation, surviving axons branch to innervate adjacent muscle fibers, thus enlarging number of muscle fibers per unit → ↑**duration & amplitude** (> 10 msec, > 5 mV) of motor unit action potentials (neuropathic potentials) which frequently are **polyphasic**.

**Diseases of neuromuscular transmission** (reduced safety factor for neuromuscular transmission → variation in number of muscle fibers firing with each discharge of unit):

- motor unit action potentials **vary in amplitude & area**;
- excess of **small, short-duration potentials**.
- **increased jitter** at single-fiber EMG. *see below >>*

*Quantitative motor unit potential analysis provides more reliable correlation with muscle and nerve disease than muscle biopsy!*

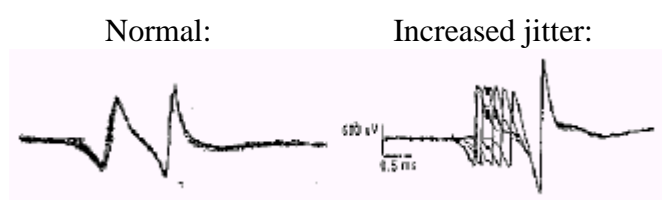
**Contracture** (involuntary, sustained muscle contraction in phosphorylase deficiency) - **electrical silence**.



**Single-fiber EMG**

- action potentials recorded from two or more **muscle fibers belonging to same motor unit**.
- special electrode.
- **temporal variability (jitter)** between two action potentials at consecutive discharges is measured.
- jitter reflects variation in neuromuscular transmission time in two motor endplates involved (i.e. variation in latency between nerve stimulus and resulting muscle action potentials).

- normal jitter is 10-50  $\mu$ sec.
- main clinical application - **diseases of neuromuscular transmission** - *increased jitter, impulse blocking* (failed muscle fiber activation).
  - clinical muscle weakness correlates with impulse blocking.
  - normal single-fiber EMG rules out disorder of neuromuscular transmission!
  - single-fiber EMG is *more sensitive* than repetitive nerve stimulation or determination of acetylcholine receptor antibody levels in diagnosing myasthenia gravis!



## EMG according to disorder

### Denervation

- 1) INSERTIONAL ACTIVITY - **increased** (e.g. bizarre high frequency discharges).
- 2) SPONTANEOUS ACTIVITY - **fibrillations, positive sharp waves, fasciculations, complex repetitive discharges**; increased **polyphasic** action potentials.
- 3) VOLUNTARY ACTIVITY - **neuropathic potentials** ( $\uparrow$ duration & amplitude);  $\downarrow$ recruitment density.
- 4) OTHER STUDIES - prolonged "*F response*", lost *H reflex*. see p. D22 >>

### Myopathy

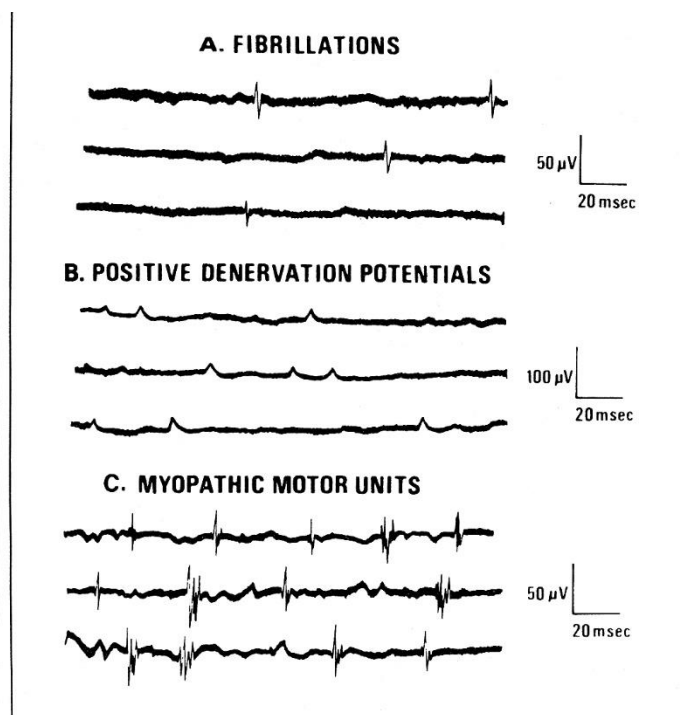
- 1) INSERTIONAL ACTIVITY - **increased** (e.g. bizarre high frequency discharges).
- 2) SPONTANEOUS ACTIVITY - complex **polyphasic** motor unit potentials; some myopathies (e.g. polymyositis, muscular dystrophies) may show **fibrillations, positive sharp waves**.
- 3) VOLUNTARY ACTIVITY - **myopathic potentials** ( $\downarrow$ duration & amplitude); **rapid recruitment**.

### Neuromuscular junction disorders

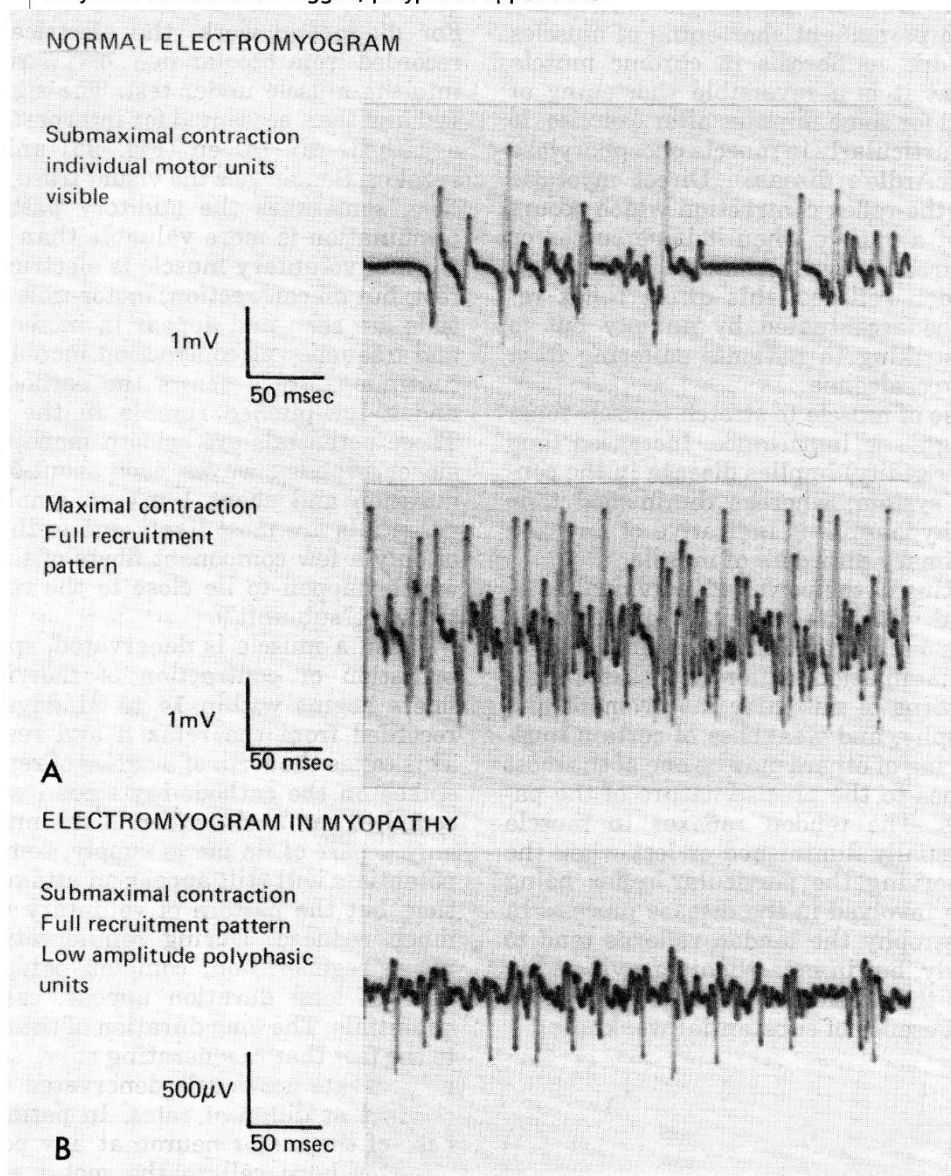
- 1) **abnormal repetitive motor nerve stimulation** results. see p. D22 >>
- 2) increased **jitter, blockings** on *single fiber EMG*.

### Myotonia

- SPONTANEOUS hyperexcitability: repetitive high-frequency **trains of action potentials**; wax and wane in amplitude and frequency.

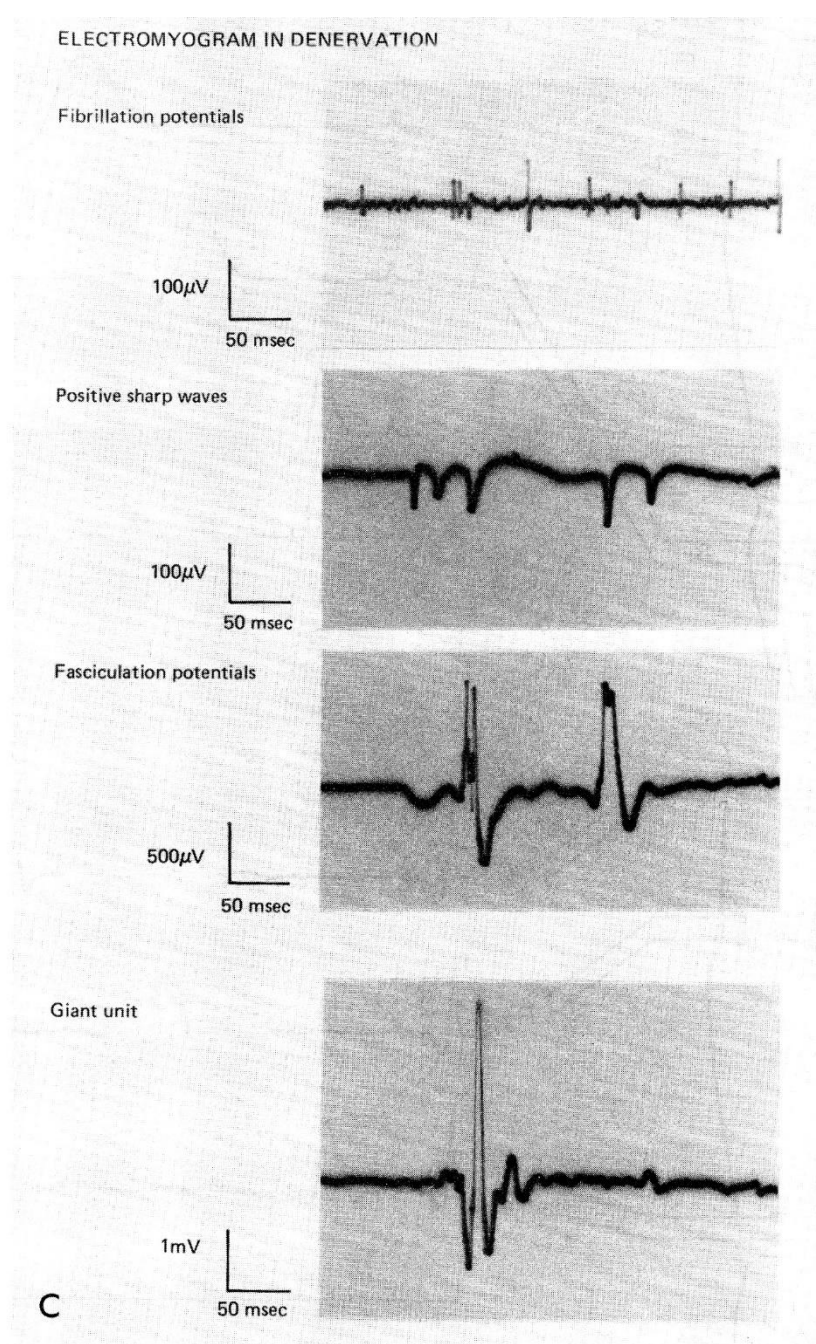


Electromyographic features. **A.** Fibrillations consist of spontaneous depolarization of single muscle fibers that have been denervated. They appear as short duration di- or triphasic potentials of low amplitude. **B.** Positive denervation potentials also occur spontaneously in denervated muscle fibers. They are larger in amplitude and longer in duration than fibrillations. There is initial rapid upward phase followed by slower return to baseline. **C.** Myopathic action potentials are low in amplitude and short in duration. They have characteristic ragged, polyphasic appearance.



**A,** The normal electromyogram. Upper: Submaximal contraction. Note that the individual motor units here vary between 1.5 and 3 mV in amplitude and are of approximately 5 to 7 msec duration. Lower: During maximal contraction there is a full "interference pattern"; the spikes of greater amplitude represent action potentials derived from motor units lying relatively close to the recording electrode, while those of lower amplitude are derived from motor units lying some distance away.

**B,** The electromyogram in myopathy. The constituent motor units are greatly reduced in amplitude and duration and many are polyphasic.



C, The electromyogram in denervation. From top to bottom: (1) Spontaneous fibrillation. This is recorded from relaxed resting muscle; the individual potentials measure no more than about 100  $\mu$ V in amplitude and are of about 1 msec duration. (2) Positive sharp waves (saw tooth potentials); also recorded from relaxed resting muscle. This phenomenon is occasionally seen in denervated muscle. (3) Fasciculation potentials firing spontaneously; also recorded from relaxed resting muscle in a patient with motor neurone disease; these potentials are morphologically indistinguishable from motor unit action potentials. (4) A giant motor unit action potential of approximately 5 mV in amplitude occurring during volitional activity in a patient with motor neurone disease.

BIBLIOGRAPHY for ch. "Diagnostics" → follow this [LINK >>](#)