

SECTION II: ILLUSTRATIONS OF SELECTED WAVEFORMS

FIGURE 1	COMPOUND SENSORY NERVE ACTION POTENTIALS	FIGURE 17	REPETITIVE NERVE STIMULATION
FIGURE 2	SHORT-LATENCY SOMATOSENSORY EVOKED POTENTIALS MEDIAN NERVE	FIGURE 18	INSERTION ACTIVITY
FIGURE 3	SHORT-LATENCY SOMATOSENSORY EVOKED POTENTIALS COMMON PERONEAL NERVE	FIGURE 19	END-PLATE ACTIVITY
FIGURE 4	SHORT-LATENCY SOMATOSENSORY EVOKED POTENTIALS	FIGURE 20	FIBRILLATION POTENTIAL
FIGURE 5	VISUAL EVOKED POTENTIAL	FIGURE 21	POSITIVE SHARP WAVE
FIGURE 6	BRAINSTEM AUDITORY EVOKED POTENTIAL	FIGURE 22	MYOTONIC DISCHARGE
FIGURE 7	M WAVE	FIGURE 23	COMPLEX REPETITIVE DISCHARGE
FIGURE 8	F WAVE	FIGURE 24	FASCICULATION POTENTIAL
FIGURE 9	H WAVE	FIGURE 25	MYOKYMIC DISCHARGE
FIGURE 10	A WAVE	FIGURE 26	NEUROMYOTONIC DISCHARGE
FIGURE 11	T WAVE	FIGURE 27	CRAMP DISCHARGE
FIGURE 12	BLINK RESPONSES	FIGURE 28	MOTOR UNIT ACTION POTENTIALS
FIGURE 13	REPETITIVE NERVE STIMULATION NORMAL RESPONSE	FIGURE 29	SATELLITE POTENTIAL
FIGURE 14	REPETITIVE NERVE STIMULATION DECREMENTING RESPONSE	FIGURE 30	RECRUITMENT PATTERN / INTERFERENCE PATTERN
FIGURE 15	REPETITIVE NERVE STIMULATION	FIGURE 31	SINGLE-FIBER ELECTROMYOGRAPHY
FIGURE 16	REPETITIVE NERVE STIMULATION	FIGURE 32	MACROELECTROMYOGRAPHY
		FIGURE 33	NEEDLE ELECTRODES
		FIGURE 34	FULL WAVE RECTIFIED EMG
		FIGURE 35	SYMPATHETIC SKIN RESPONSE

Each illustration is accompanied by a complete explanation that is, in most cases, the same as that given in the alphabetic section. The definitions have been repeated in full with the illustrations so that readers do not need to refer back and forth between the illustration and definition.

The illustrations have been modified and adapted from materials submitted by AAEM members. The illustrations of the short-latency somatosensory evoked potentials were reprinted from the *Journal of Clinical Neurophysiology* (1978;1:41-53) with permission of the journal editor and the authors.

COMPOUND SENSORY NERVE ACTION POTENTIALS

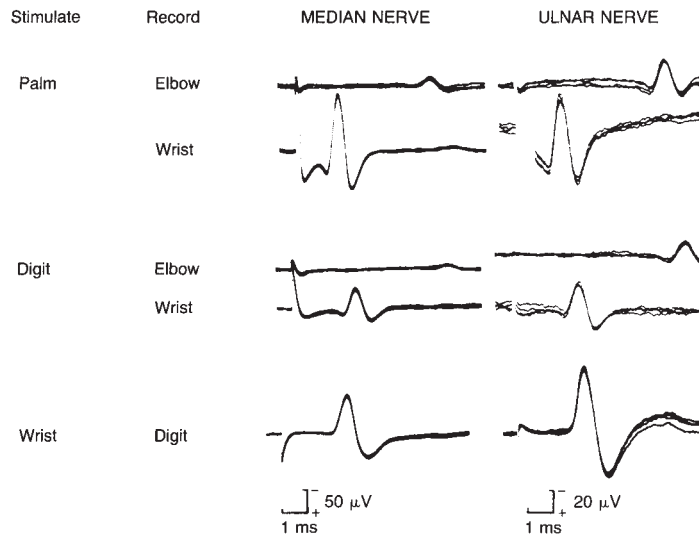


Figure 1. Compound sensory nerve action potentials recorded with surface electrodes in a normal subject. A compound nerve action potential is considered to have been evoked from afferent fibers if the recording electrodes detect activity only in a sensory nerve or in a sensory branch of a mixed nerve, or if the electric stimulus is applied to a sensory nerve or a dorsal nerve root, or an adequate stimulus is applied synchronously to sensory receptors. The amplitude, latency, duration, and configuration should be noted. Generally, the amplitude is measured as the maximum peak-to-peak voltage when there is an initial positive deflection or from baseline-to-peak when there is an initial negative deflection. The latency is measured as either the latency to the initial deflection or the peak latency to the negative peak, and the duration as the interval from the first deflection of the waveform from the baseline to its final return to the baseline. The compound sensory nerve action potential is also referred to by the less preferred terms sensory response, sensory potential, or SNAP.

SHORT-LATENCY SOMATOSENSORY EVOKED POTENTIAL (SSEP)

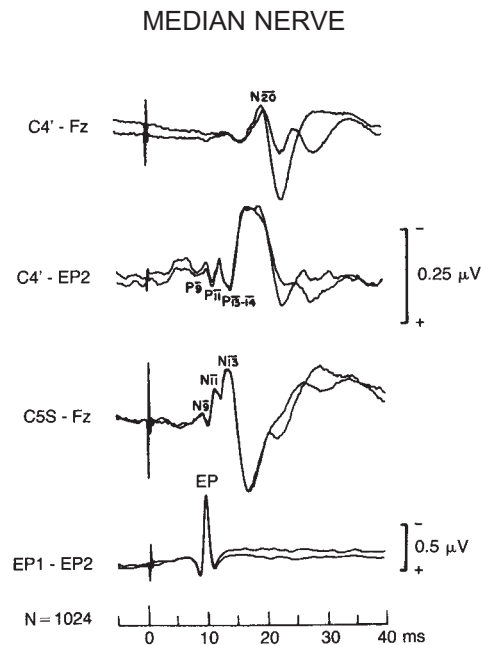


Figure 2. Short-latency somatosensory evoked potentials evoked by stimulation of the median nerve in a normal subject. Recordings were made from the scalp to a cephalic reference (C4'-Fz), the scalp to contralateral Erb's point (C4'-EP2), cervical spine to a frontal reference (C5S-Fz), and ipsilateral Erb's point to the contralateral Erb's point (EP1-EP2). Short-latency somatosensory evoked potentials elicited by electric stimulation of the median nerve at the wrist occur within 25 ms of the stimulus in normal subjects. Normal short-latency response components to median nerve stimulation are designated P9, P11, P13, P14, N20, and P23 in records taken between scalp and noncephalic reference electrodes, and N9, N11, N13, and N14 in cervical spine-scalp derivation. It should be emphasized that potentials having opposite polarity but similar latency in spine-scalp and scalp-noncephalic reference derivations do not necessarily have identical generator sources. The C4' designation indicates that the recording scalp electrode was placed 2 cm posterior to the International 10-20 C4 electrode location.

SHORT-LATENCY SOMATOSENSORY EVOKED POTENTIAL (SSEP) COMMON PERONEAL NERVE

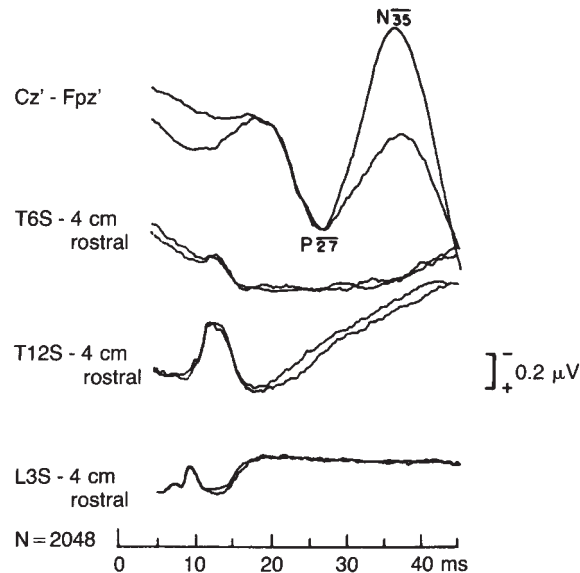


Figure 3. Short-latency somatosensory evoked potentials evoked by stimulation of the common peroneal nerve in a normal subject. Recordings were made from the scalp (Cz'-Fpz'), the mid-thoracic spine (T6S-4 cm rostral), the lower thoracic spine (T12S-4 cm rostral), and the lumbar spine (L3S-4 cm rostral). Short-latency somatosensory evoked potentials elicited by stimulation of the common peroneal nerve at the knee occur within 40 ms of the *stimulus* in normal subjects. It is suggested that individual response components be designated as follows: (1) Spine components: L3 and T12 spine potentials. (2) Scalp components: P27 and N35. The Cz' and Fpz' designations indicate that the recording scalp *electrode* was placed 2 cm posterior to the International 10-20 Cz and Fpz electrode locations.

SHORT-LATENCY SOMATOSENSORY EVOKED POTENTIAL (SSEP) POSTERIOR TIBIAL NERVE

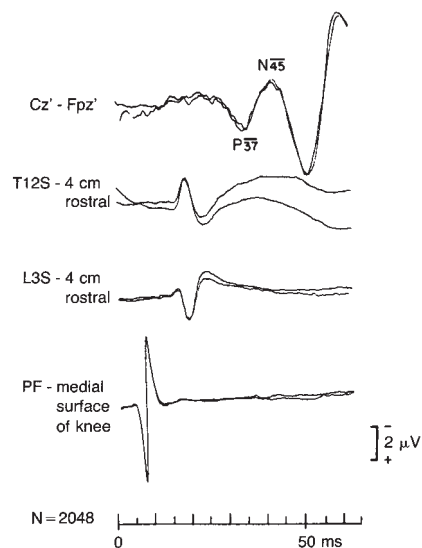


Figure 4. Short-latency somatosensory evoked potentials evoked by stimulation of the posterior tibial nerve at the ankle. Recordings were made from the scalp (Cz'-Fpz'), The lower thoracic spine (T12S-4cm rostral), the lumbar spine (L3S-4cm rostral), and the popliteal fossa (PF-medial surface of knee). Short-latency somatosensory evoked potentials elicited by electric stimulation of the posterior tibial nerve at the ankle occur within 50 ms of the *stimulus* in normal subjects. It is suggested that individual response components be designated as follows: (1) Nerve trunk (tibial nerve) component in the popliteal fossa: PF potential. (2) Spine components: L3 and T12 potentials. (3) Scalp components: P37 and N45 waves. The Cz' and Fpz' designations indicate that the recording scalp *electrode* was placed 2 cm posterior to the International 10-20 system Cz and Fpz electrode locations.

VISUAL EVOKED POTENTIAL (VEP)

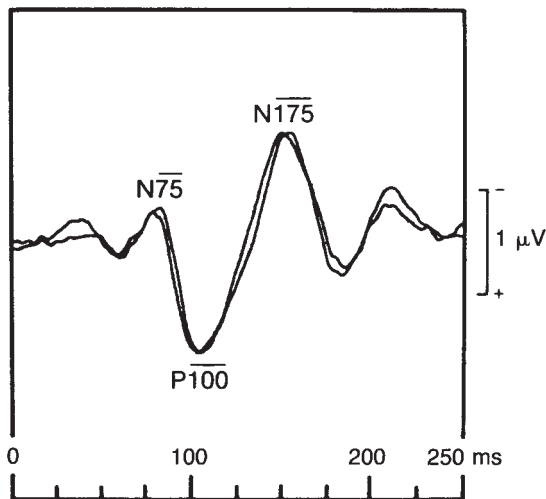


Figure 5. Normal occipital visual evoked potential to checkerboard pattern reversal stimulation recorded between occipital (O1) and vertex (Cz) electrodes showing N75, P100 and N175 peaks. Visual evoked potentials are electric waveforms of biologic origin recorded over the cerebrum and elicited by visual stimuli. VEPs are classified by stimulus rate as transient or steady state and can be further divided by stimulus presentation mode. The normal transient VEP to checkerboard pattern reversal or shift has a major positive occipital peak at about 100 ms (P100), often preceded by a negative peak (N75). The precise range of normal values for the latency and amplitude of P100 depends on several factors: (1) subject variables, such as age, gender, and visual acuity, (2) stimulus characteristics, such as type of stimulator, full-field or half-field stimulation, check size, contrast and luminance, and (3) recording parameters, such as placement and combination of recording electrodes.

BRAINSTEM AUDITORY EVOKED POTENTIAL (BAEP)

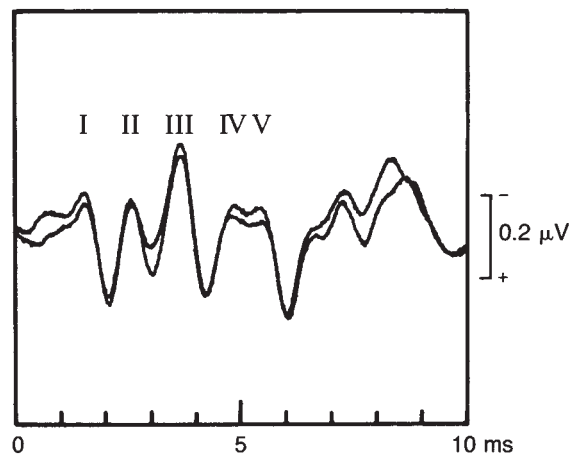


Figure 6. Normal brainstem auditory evoked potential to stimulation of the left ear, recorded between left ear (A1) and vertex (Cz) electrodes. Brainstem auditory evoked potentials are electric waveforms of biologic origin elicited in response to sound stimuli. The normal BAEP consists of a sequence of up to seven waves, designated I to VII, which occur during the first 10 ms after the onset of the stimulus and have positive polarity at the vertex of the head. In this recording, negativity in input terminal 1 or positivity in input terminal 2 causes an upward deflection.

M WAVE

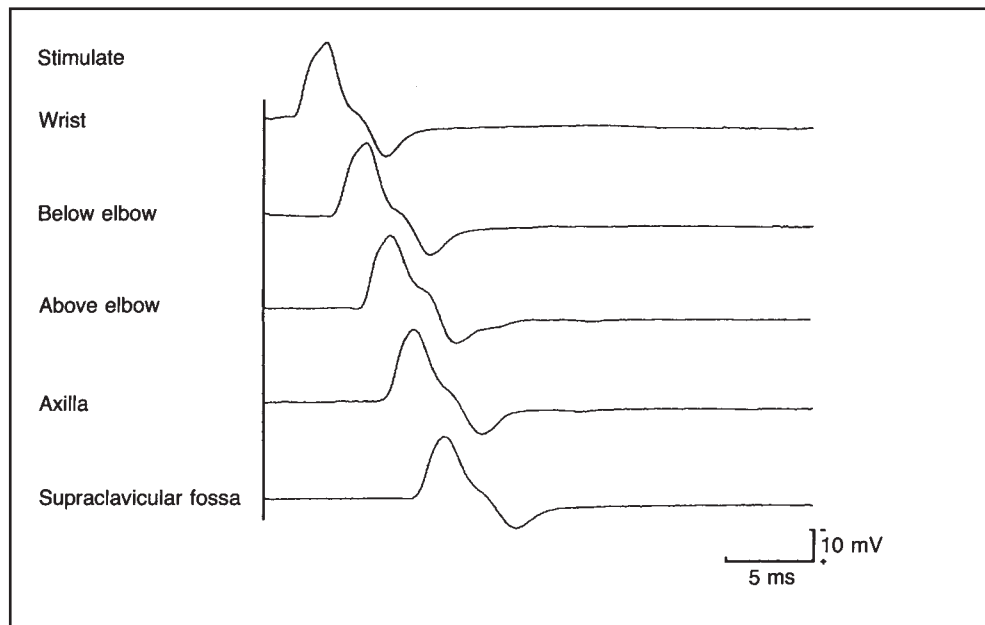


Figure 7. *M waves* recorded with surface *electrodes* over the abductor digiti quinti muscle elicited by electric stimulation of the ulnar nerve at several levels. The *M wave* is a *compound muscle action potential* evoked from a muscle by an electric stimulus to its *motor nerve*. By convention, the *M wave* elicited by a supramaximal stimulus is used for *motor nerve conduction studies*. Ideally, the *recording electrodes* should be placed so that the initial deflection of the *evoked potential* from the *baseline* is negative. The *latency*, commonly called the *motor latency*, is the time from stimulation (ms) to the onset of the first *phase* (positive or negative) of the *M wave*. The *amplitude* (mV) is the *baseline-to-peak* amplitude of the first negative phase, unless otherwise specified. The *duration* (ms) refers to the duration of the first negative phase, unless otherwise specified. Normally, the configuration of the *M wave* (usually biphasic) is quite stable with repeated stimuli at slow rates (1-5 Hz). See *repetitive nerve stimulation*.

F WAVE

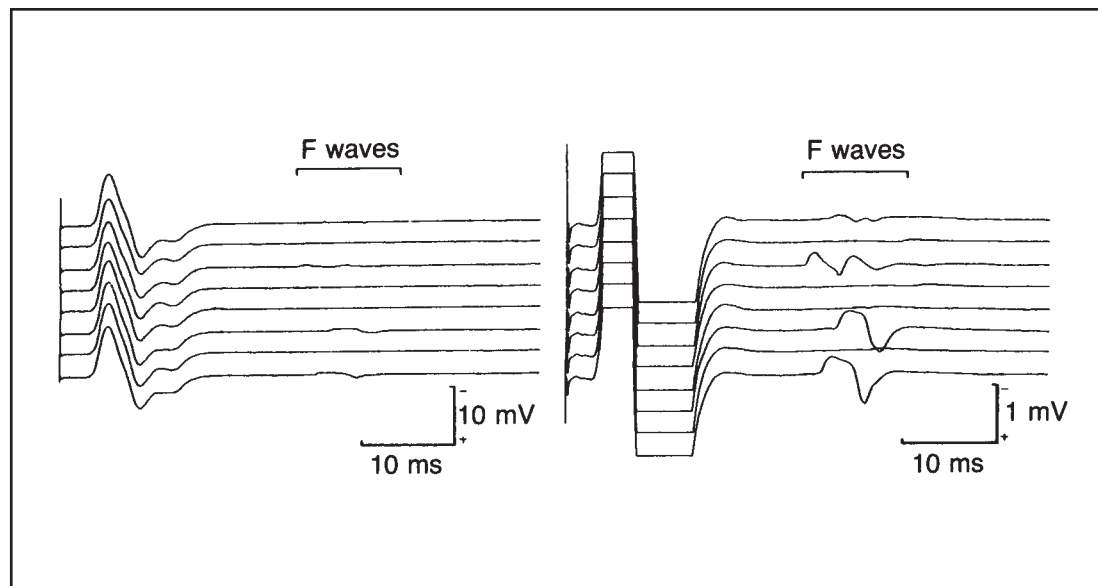


Figure 8. *F waves* recorded with *surface electrodes* over the abductor digiti quinti muscle elicited by electric stimulation of the ulnar nerve at the wrist with two different gain settings. The *F wave* is an *action potential* evoked intermittently from a muscle by a supramaximal stimulus to the nerve. Compared with the maximal *amplitude M wave* of the same muscle, the *F wave* has a smaller amplitude (1-5% of the *M wave*), variable configuration and a longer, more variable *latency*. The *F wave* can be found in many muscles of the upper and lower extremities, and the latency is longer with more distal sites of stimulation. The *F wave* is due to *antidromic activation* of motor neurons. It was named by Magladery and McDougal in 1950. Compare with the *H wave* and the *A wave*. One of the *late responses*.

H WAVE

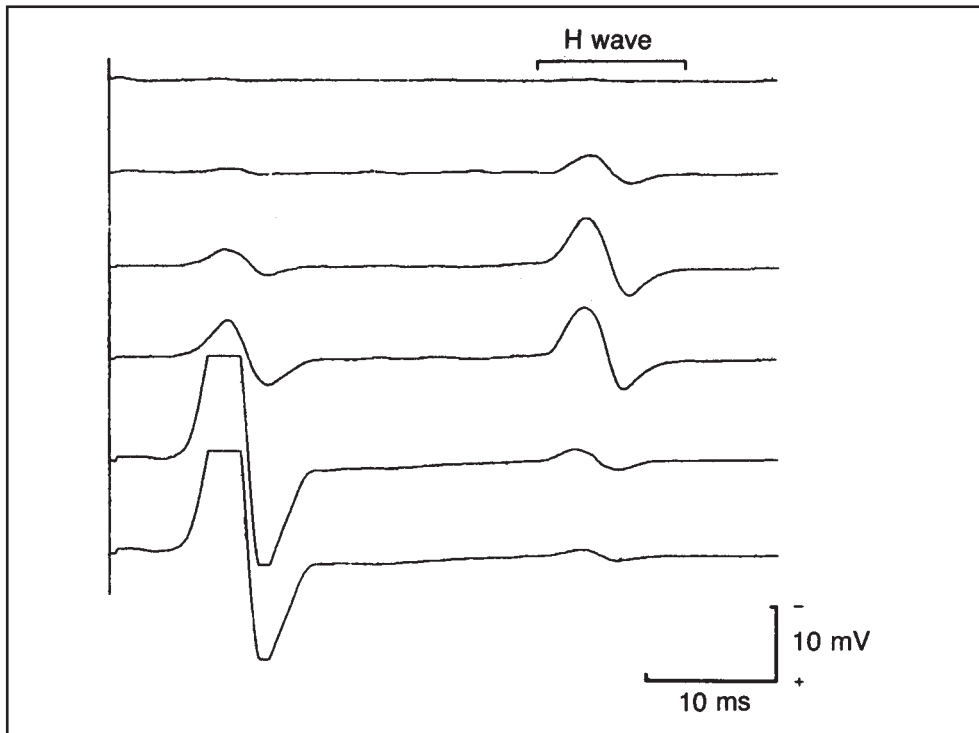


Figure 9. *H waves* recorded with *surface electrodes* over the soleus muscle elicited by electric stimulation of the posterior tibial nerve at the knee. The *stimulus* intensity was gradually increased (top tracing to bottom tracing). The H wave is a *compound muscle action potential* having a consistent *latency* evoked regularly, when present, from a muscle by an electric *stimulus* to the nerve. It is regularly found in adults only in a limited group of physiologic extensors, particularly the calf muscles. The H wave is most easily obtained with the *cathode* positioned proximal to the *anode*. Compared with the maximum *amplitude M wave* of the same muscle, the H wave has a smaller amplitude, a longer *latency*, and a lower optimal stimulus intensity. The latency is longer with more distal sites of stimulation. A stimulus intensity sufficient to elicit a maximal amplitude M wave reduces or abolishes the H wave. The H wave is thought to be due to a *spinal reflex*, the Hoffmann reflex, with electric stimulation of afferent fibers in the *mixed nerve* to the muscle and activation of motor neurons to the muscle mainly through a monosynaptic connection in the spinal cord. The reflex and wave are named in honor of Hoffmann's description in 1918. Compare with the *F wave*.

A WAVE

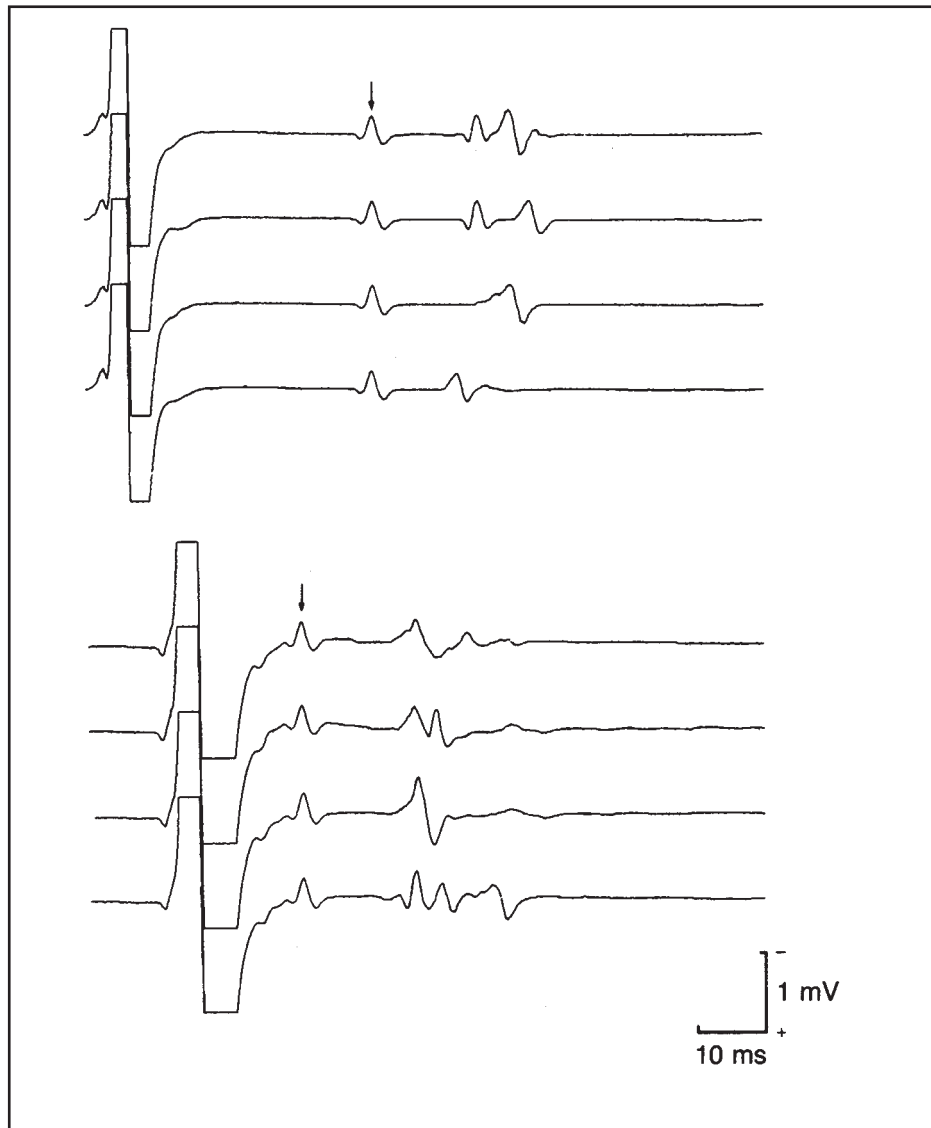


Figure 10. A waves (under arrow markers) recorded with surface electrodes over the abductor hallucis brevis elicited by electric stimulation of the posterior tibial nerve at the level of the ankle (top four traces) and at the level of the knee (bottom four traces). The A wave is a compound muscle action potential evoked consistently from a muscle by submaximal stimuli to the nerve and frequently abolished by supra-maximal stimuli. The amplitude of the A wave is similar to that of the F wave, but the latency is more constant. The A wave usually occurs before the F wave, but may occur afterwards. It is thought to be due to extra discharges in the nerve, ephapses between adjacent nerve fibers, or axonal branching. Compare with the F wave.

T WAVE

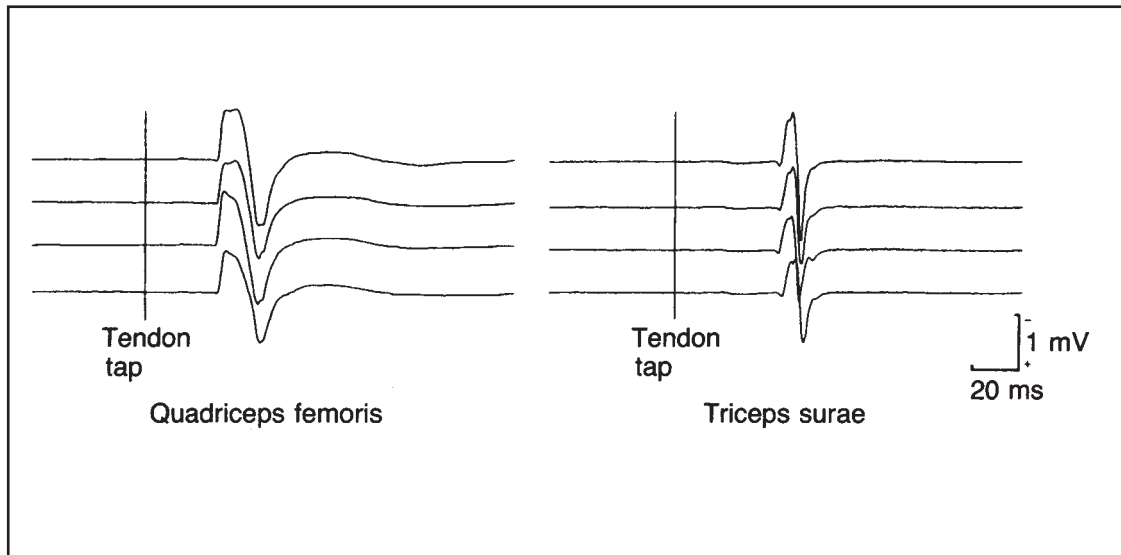


Figure 11. *T waves* produced by triggering a microswitch in the handle of a *reflex hammer* by striking the patellar tendon (quadriceps femoris) or the Achilles tendon (triceps surae). The *T wave* is a *compound muscle action potential* evoked by rapid stretch of a tendon, as part of the *muscle stretch reflex*.

BLINK RESPONSES

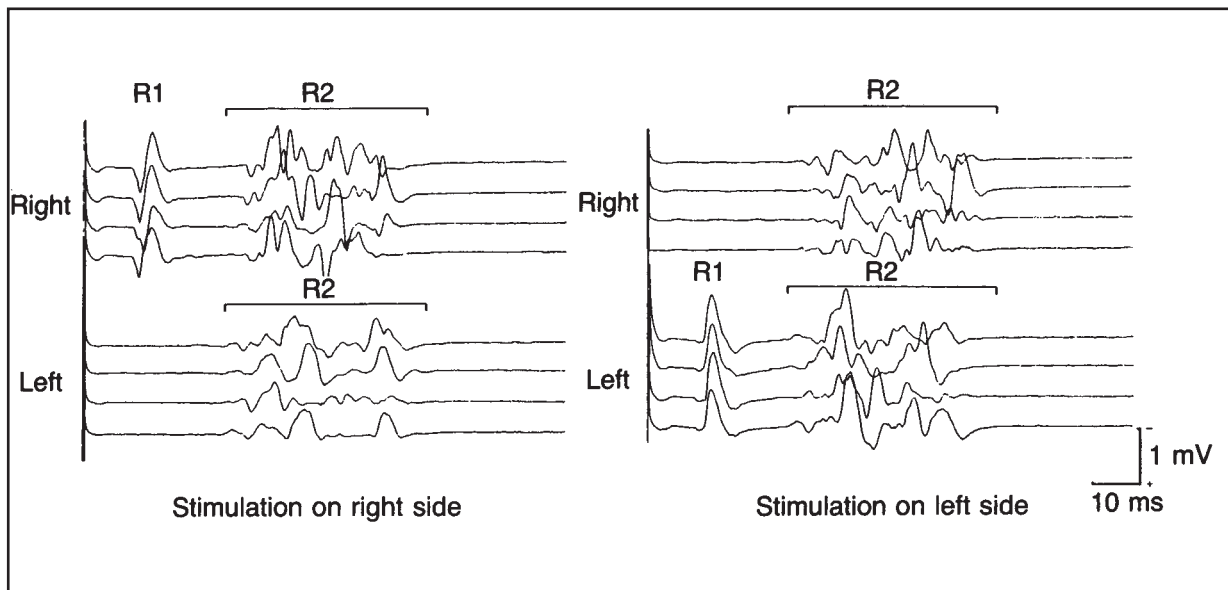


Figure 12. *Blink responses* recorded with surface *electrodes* over the right orbicularis oculi (upper tracings) and left orbicularis oculi (lower tracings) elicited by electric stimulation of the supraorbital nerve on the right (left tracings) and on the left (right tracings). The blink responses are *compound muscle action potentials* evoked from orbicularis oculi muscles as a result of brief electric or mechanical *stimuli* to the cutaneous area innervated by the supraorbital (or less commonly, the infraorbital) branch of the trigeminal nerve. Typically, there is an early compound muscle action potential (*R1 wave*) ipsilateral to the stimulation site with a *latency* of about 10 ms and a bilateral late compound muscle action potential (*R2 wave*) with a latency of approximately 30 ms. Generally, only the *R2 wave* is associated with a visible twitch of the orbicularis oculi. The configuration, *amplitude*, *duration*, and latency of the two components, along with the sites of recording and the sites of stimulation, should be specified. *R1* and *R2* waves are oligosynaptic and polysynaptic brainstem *reflexes*, respectively, together called the *blink reflex*. The afferent arc is provided by the sensory branches of the trigeminal nerve, and the efferent arc is provided by facial nerve motor fibers.

REPETITIVE NERVE STIMULATION NORMAL RESPONSE

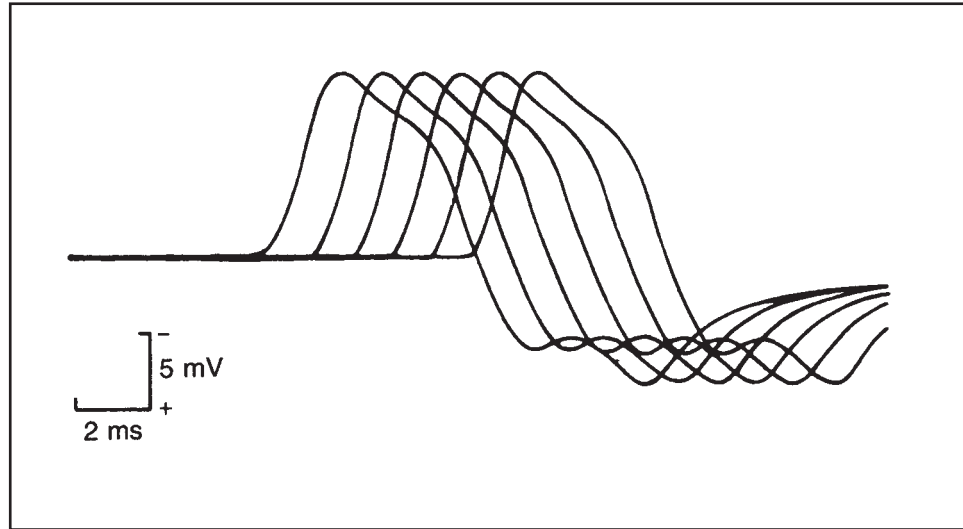


Figure 13. Repetitive nerve stimulation study in a normal subject. The successive M waves are displayed to the right. The M waves were recorded with surface electrodes over the hypothenar eminence (abductor digiti quinti) during ulnar nerve stimulation at a rate of 3 Hz. Note the configuration of the successive M waves is unchanged. Repetitive nerve stimulation is a technique of repeated *supramaximal stimulation* of a nerve while recording M waves from the muscle innervated by the nerve. It is commonly used to assess the integrity of neuromuscular transmission. The number of *stimuli* and the *frequency* of stimulation should be specified. *Activation procedures* performed prior to the test should be specified, e.g., sustained voluntary *contraction* or contraction induced by nerve stimulation. If the test was performed after an activation procedure, the time elapsed after it was completed should also be specified. The technique is commonly used to assess the integrity of neuromuscular transmission. For a description of specific patterns of responses, see *incrementing response*, *decrementing response*, *facilitation*, and *postactivation depression*.

REPETITIVE NERVE STIMULATION DECREMENTING RESPONSE

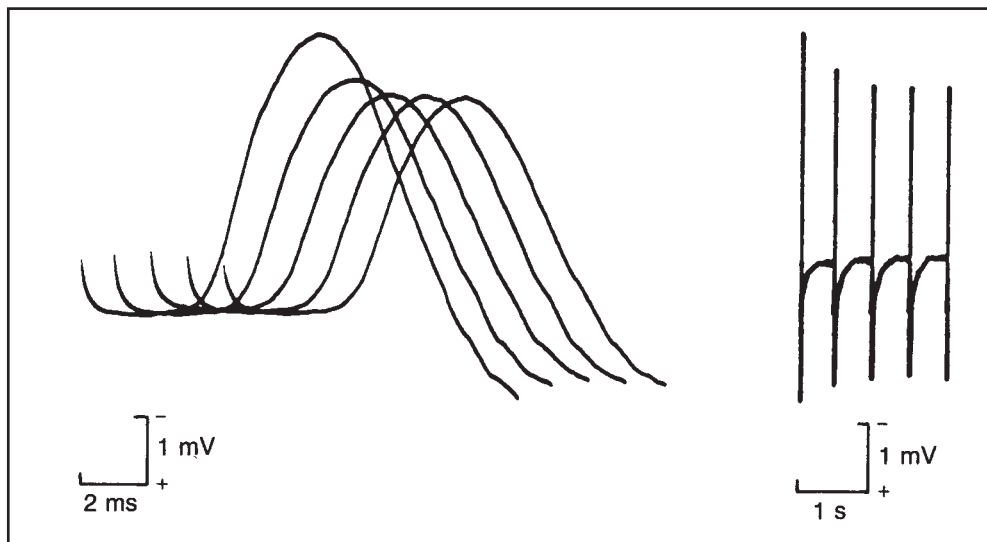


Figure 14. Repetitive nerve stimulation study in a patient with *myasthenia gravis*. Successive M waves were recorded with surface electrodes over the rested nasalis muscle during repetitive facial nerve stimulation at a rate of 2 Hz, with a display to permit measurement of the *amplitude* and *duration* of the negative phase (left) or peak-to-peak amplitude (right). A *decrementing response* is a reproducible decline in the amplitude and/or area of the M wave of successive responses to repetitive nerve stimulation. The rate of stimulation and the total number of *stimuli* should be specified. Decrementing responses with disorders of neuromuscular transmission are most reliably seen with slow rates (2 to 5 Hz) of nerve stimulation. A decrementing response with repetitive nerve stimulation commonly occurs in disorders of neuromuscular transmission, but can also be seen in some *polyneuropathies*, *myopathies*, and *motor neuron disease*. An artifact resembling a decrementing response can result from movement of the stimulating or recording electrodes during repetitive nerve stimulation (*pseudodecrement*). Contrast with *incrementing response*.

REPETITIVE NERVE STIMULATION INCREMENTING RESPONSE

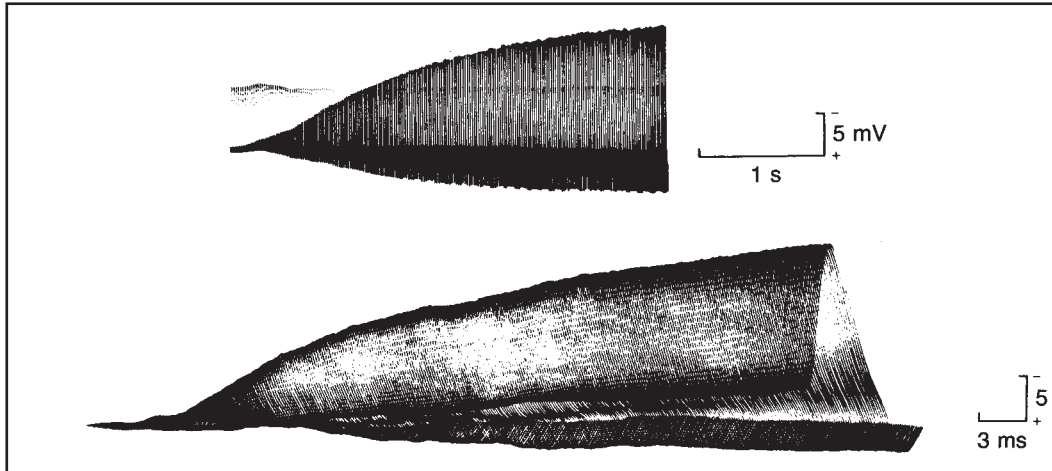


Figure 15. Repetitive nerve stimulation study in a patient with Lambert-Eaton myasthenic syndrome (LEMS). An *incrementing response* was recorded with *surface electrodes* over the hypothenar eminence (abductor digiti quinti) during repetitive ulnar nerve stimulation at a rate of 50 Hz with a display to permit measurement of the peak-to-peak *amplitude* (top) or amplitude and *duration* of the negative phase (bottom). An incrementing response is a reproducible increase in amplitude and/or area of successive responses (*M waves*) to repetitive nerve stimulation. The rate of stimulation and the number of *stimuli* should be specified. An incrementing response is commonly seen in two situations. First, in normal subjects the configuration of the M wave may change with repetitive nerve stimulation so that the amplitude progressively increases as the duration decreases, but the area of the M wave remains the same. This phenomenon is termed *pseudofacilitation*. Second, in disorders of neuromuscular transmission, the configuration of the M wave may change with repetitive nerve stimulation so that the amplitude progressively increases as the duration remains the same or increases, and the area of the M wave increases. This phenomenon is termed *facilitation*. Contrast with *decrementing response*.

REPETITIVE NERVE STIMULATION

NORMAL (N), MYASTHENIA GRAVIS (MG), LAMBERT-EATON MYASTHENIC SYNDROME (LEMS)

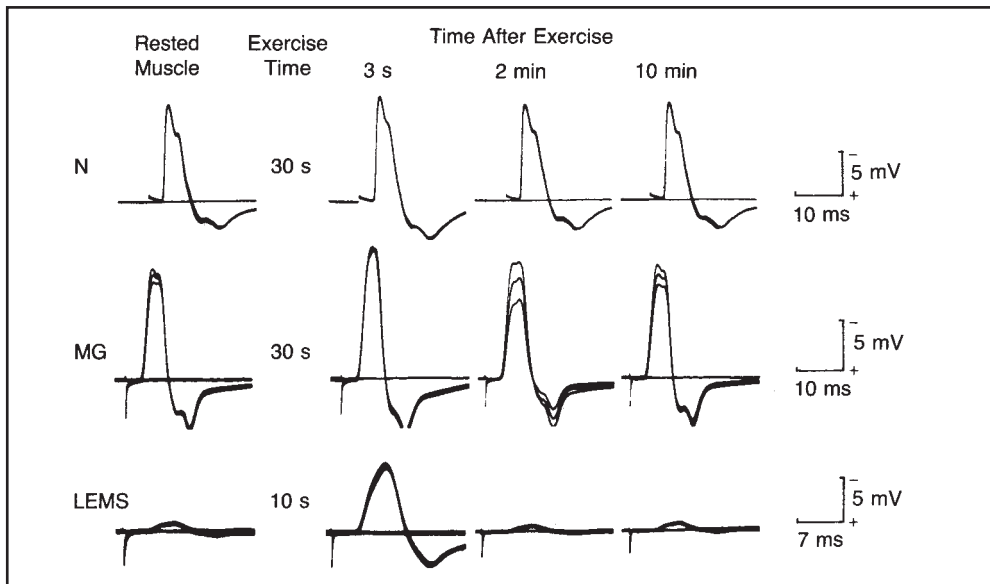


Figure 16. Repetitive nerve stimulation studies in a normal subject (N) and patients with *myasthenia gravis* (MG) and Lambert-Eaton myasthenic syndrome (LEMS). Three successive *M waves* were elicited by repetitive nerve stimulation at a rate of 2 Hz. The three *responses* were superimposed. This method of display emphasizes a change in the configuration of successive responses, but does not permit identification of their order. In each superimposed display of three responses where the configuration did change, the highest amplitude response was the first, and the lowest amplitude response was the third. After testing the rested muscle, the muscle was maximally contracted for 10 to 30 seconds (exercise time). Repetitive nerve stimulation was carried out again 3 s, 2 min, and 10 min after the exercise ended. The results illustrate *facilitation* and *postactivation depression*.

REPETITIVE NERVE STIMULATION PSEUDOFACILITATION

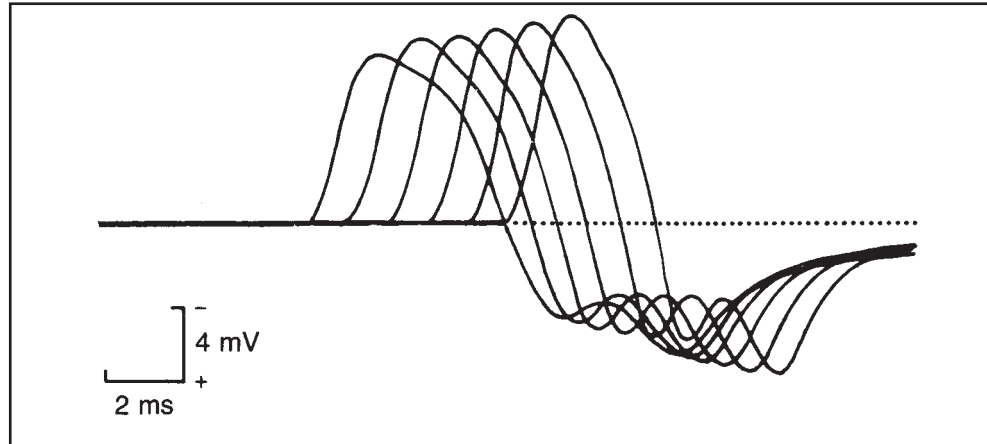


Figure 17. Repetitive nerve stimulation study in a normal subject. The successive M waves were recorded with surface electrodes over the hypothenar eminence (abductor digiti quinti) during ulnar nerve stimulation at a rate of 30 Hz. Pseudofacilitation may occur in normal subjects with repetitive nerve stimulation at high (20-50 Hz) rates or after strong volitional contraction, and probably reflects a reduction in the temporal dispersion of the summation of a constant number of muscle fiber action potentials due to increases in the propagation velocity of muscle cell action potentials with repeated activation. Pseudofacilitation should be distinguished from facilitation. The recording shows an incrementing response characterized by an increase in the amplitude of the successive M waves with a corresponding decrease in the duration, resulting in no change in the area of the negative phase of successive M waves.

INSERTION ACTIVITY

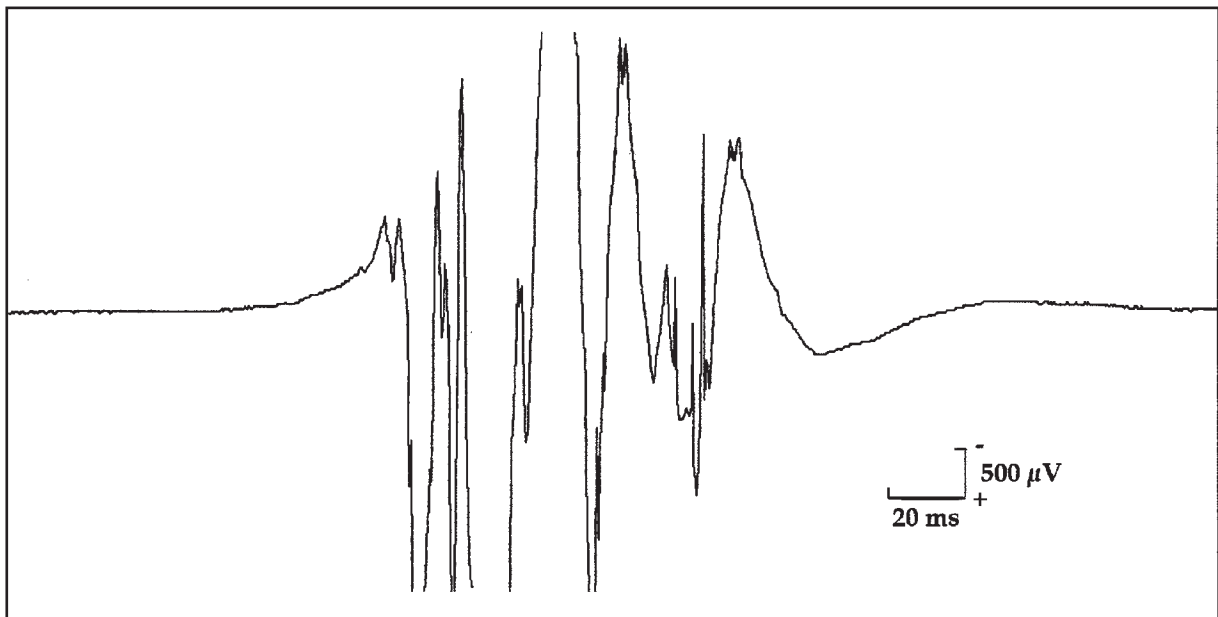


Figure 18. Insertion activity recorded by an intramuscular needle electrode in a normal subject. Insertion activity is the electric activity caused by insertion or movement of a needle electrode within a muscle. The amount of the activity may be described as normal, reduced, or increased (prolonged), with a description of the waveform and repetitive rate.

END-PLATE ACTIVITY

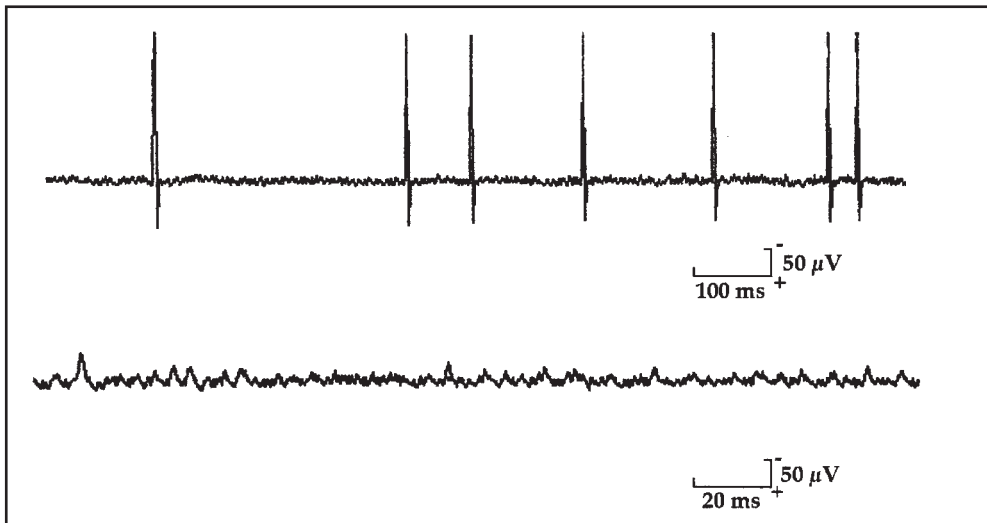


Figure 19. Spontaneous activity recorded by an intramuscular *needle electrode* close to muscle end-plates. May be either of two forms:

1. *Monophasic end-plate activity* (upper and lower traces): Low amplitude (10 to 20 μV), short-duration (0.5 to 1 ms), monophasic (negative) potentials that occur in a dense, steady pattern and are restricted to a localized area of the muscle. Because of the multitude of different potentials occurring, the exact frequency, although appearing to be high, cannot be defined. These nonpropagated potentials are probably *miniature end-plate potentials* recorded extracellularly. This form of end-plate activity has been referred to as *end-plate noise* or *sea shell sound* (*sea shell noise or roar*).
2. *Biphasic end-plate activity* (upper trace): Moderate amplitude (100 to 300 μV), short-duration (2 to 4 ms), biphasic (negative-positive) spike potentials that occur irregularly in short bursts with a high frequency (50 to 100 Hz), restricted to a localized area within the muscle. These propagated potentials are generated by muscle fibers excited by activity in nerve terminals. These potentials have been referred to as *end-plate spikes*, and, incorrectly, *nerve potentials*.

FIBRILLATION POTENTIAL

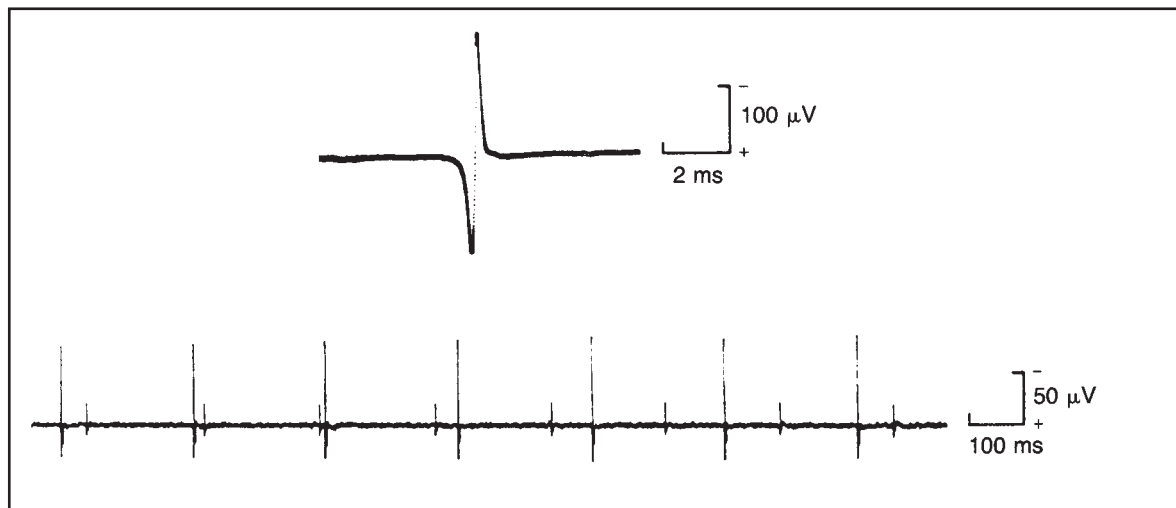


Figure 20. Fibrillation potentials recorded by an intramuscular *needle electrode*. The top trace shows the waveform of a single fibrillation potential. The bottom trace shows the pattern of discharge of two other fibrillation potentials which differ with respect to amplitude and discharge frequency. A fibrillation potential is the electric activity associated with a spontaneously contracting (fibrillating) muscle fiber. It is the *action potential* of a single muscle fiber. The action potentials may occur spontaneously or after movement of the needle electrode. They usually fire at a constant rate, although a small proportion fire irregularly. Classically, the potentials are biphasic spikes of short duration (usually less than 5 ms) with an initial positive phase and a peak-to-peak amplitude of less than 1 mV. When recorded with concentric or monopolar needle electrodes, the firing rate has a wide range (1 to 50 Hz) and often decreases just before cessation of an individual discharge. A high-pitched regular sound is associated with the discharge of fibrillation potentials and has been described in the older literature as "rain on a tin roof." In addition to this classic form of fibrillation potentials, *positive sharp waves* may also be recorded from fibrillating muscle fibers when the action potentials arise from an area immediately adjacent to the needle electrode.

POSITIVE SHARP WAVE

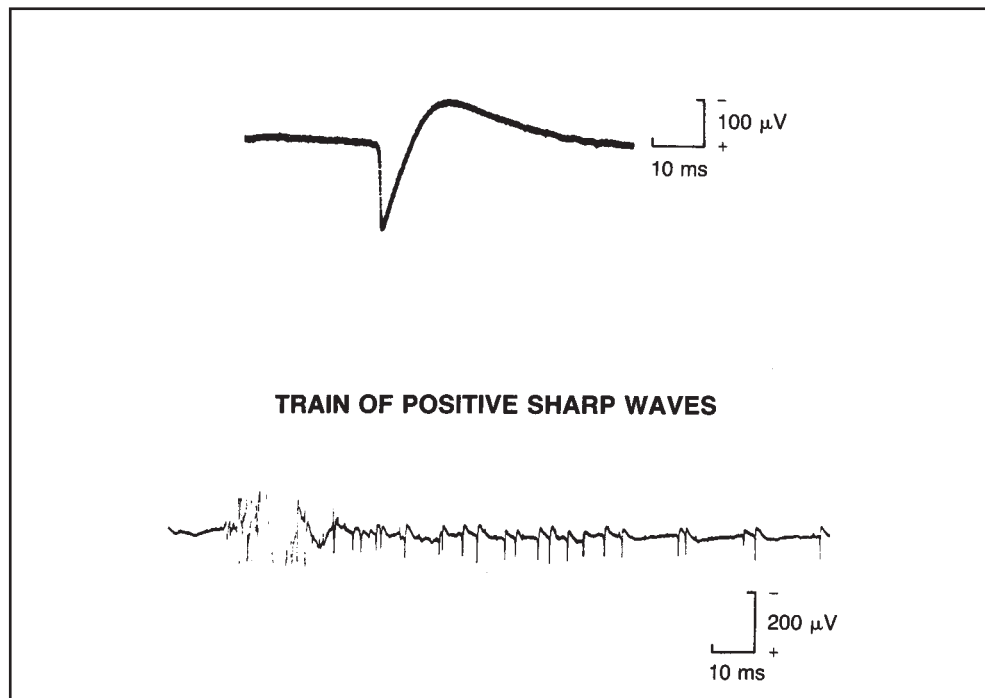


Figure 21. Positive sharp waves recorded by an intramuscular *needle electrode*. The top trace shows a single positive sharp wave. The bottom trace shows the pattern of initial *discharge* of a number of different positive sharp waves after movement of the needle electrode in a denervated muscle. A positive sharp wave is a biphasic, positive-negative *action potential* initiated by needle movement and recurring in a uniform, regular pattern at a rate of 1 to 50 Hz. The discharge *frequency* may decrease slightly just before cessation. The initial positive deflection is rapid (<1 ms), its *duration* is usually less than 5 ms, and the *amplitude* is up to 1 mV. The negative *phase* is of low amplitude, with a duration of 10 to 100 ms. A sequence of positive sharp waves is commonly referred to as a *train of positive sharp waves*. Positive sharp waves can be recorded from the damaged area of fibrillating muscle fibers. Their configuration may result from the position of the needle electrode which is believed to be adjacent to the depolarized segment of a muscle fiber injured by the electrode. Note that the positive sharp *waveform* is not specific for muscle fiber damage. *Motor unit action potentials* and potentials in *myotonic discharges* may have the configuration of positive sharp waves.

MYOTONIC DISCHARGE

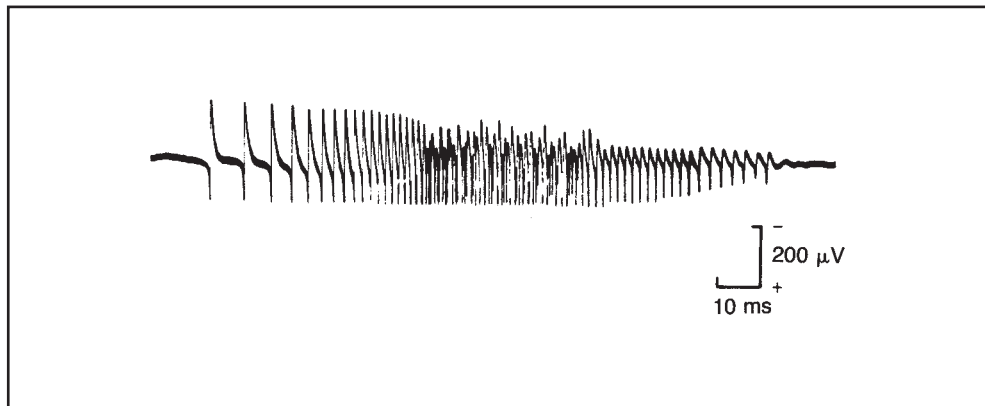


Figure 22. Myotonic discharge recorded by an intramuscular needle electrode. A myotonic discharge is a *repetitive discharge* which fires at rates of 20 to 80 Hz. There are two types: (1) biphasic (positive-negative) *spike potentials* less than 5 ms in *duration* resembling *fibrillation potentials*, and (2) *positive waves* of 5 to 20 ms duration resembling *positive sharp waves*. Both potential forms are recorded after *needle electrode* insertion, voluntary muscle *contraction* or muscle percussion, and are due to independent, repetitive discharges of single muscle fibers. The *amplitude* and *frequency* of the potentials must both wax and wane to be identified as a myotonic discharge. This change produces a characteristic musical sound in the audio display of the *electromyograph* due to the corresponding change in pitch, which has been likened to the sound of a “dive bomber.” Contrast with *waning discharge*.

COMPLEX REPETITIVE DISCHARGE

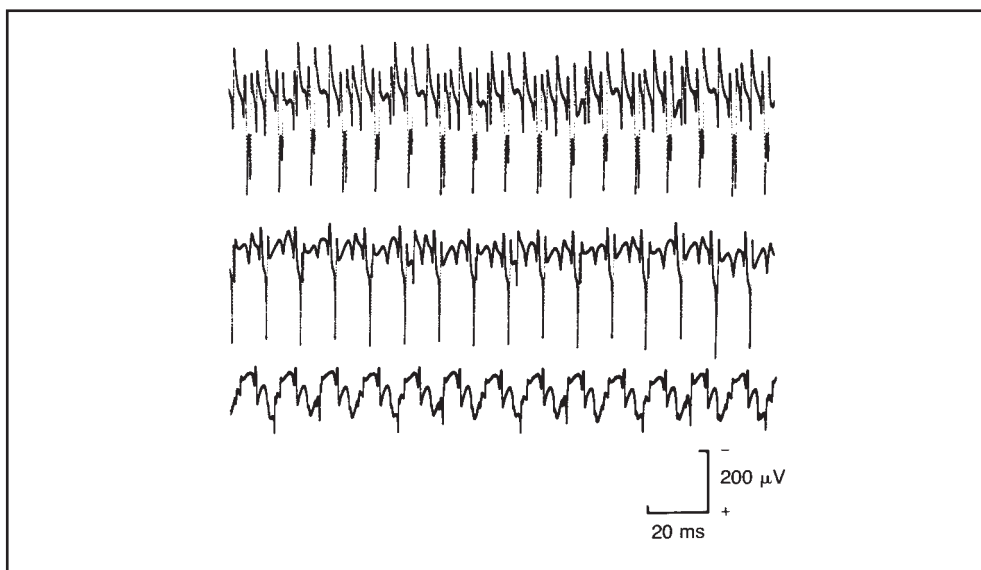


Figure 23. *Complex repetitive discharges* recorded by an intramuscular *needle electrode*. A complex repetitive discharge is a polyphasic or serrated *action potential* that may begin spontaneously or after needle movement. The *discharges* have a uniform *frequency*, *shape*, and *amplitude*, with abrupt onset, cessation, or change in configuration. Amplitudes range from 100 μV to 1 mV and the frequency of discharge from 5 to 100 Hz. This term is preferred to *bizarre high frequency discharge*, *bizarre repetitive discharge*, *bizarre repetitive potential*, or *pseudomyotonic discharge*.

FASCICULATION POTENTIAL

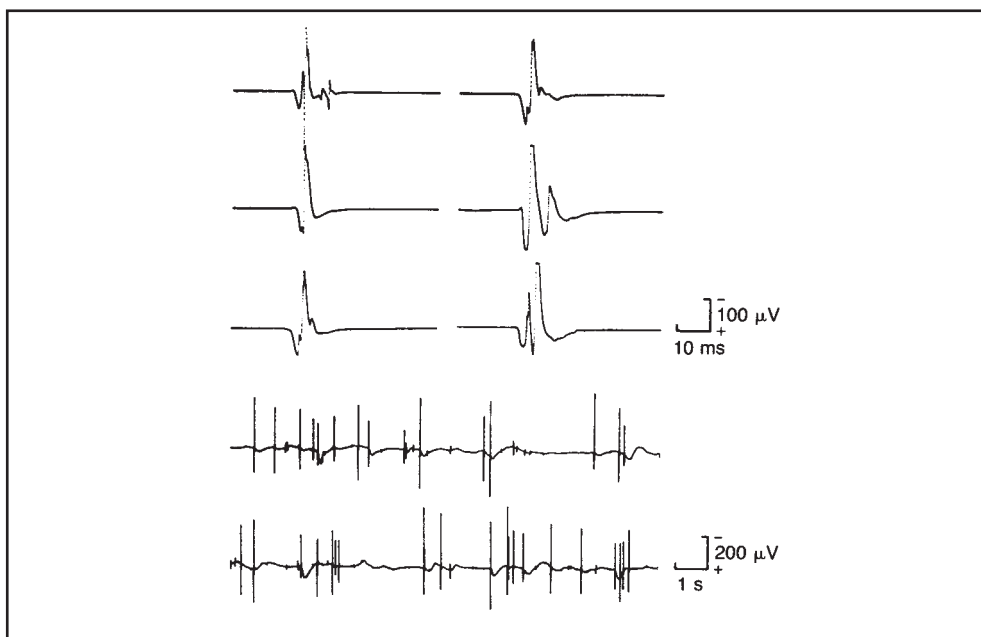


Figure 24. *Fasciculation potentials* recorded by an intramuscular *needle electrode*. Six different fasciculation potentials are displayed in the top traces, on a time scale which permits characterization of the individual *waveforms*. The bottom two traces display fasciculation potentials on a time scale which demonstrates the random discharge pattern. A fasciculation potential is an *action potential* which is often associated with a visible *fasciculation*. It has the configuration of a *motor unit action potential* but occurs spontaneously. Most commonly these potentials occur sporadically and are termed “single fasciculation potentials.” Occasionally, the potentials occur as a *grouped discharge* and are termed a “brief *repetitive discharge*.” The repetitive firing of adjacent fasciculation potentials, when numerous, may produce an undulating movement of muscle (see *myokymia*). Use of the terms *benign fasciculation* and *malignant fasciculation* is discouraged. Instead, the configuration of the potentials, peak-to-peak *amplitude*, *duration*, number of *phases*, and stability of configuration, in addition to the *frequency* of occurrence, should be specified.

MYOKYMIC DISCHARGE

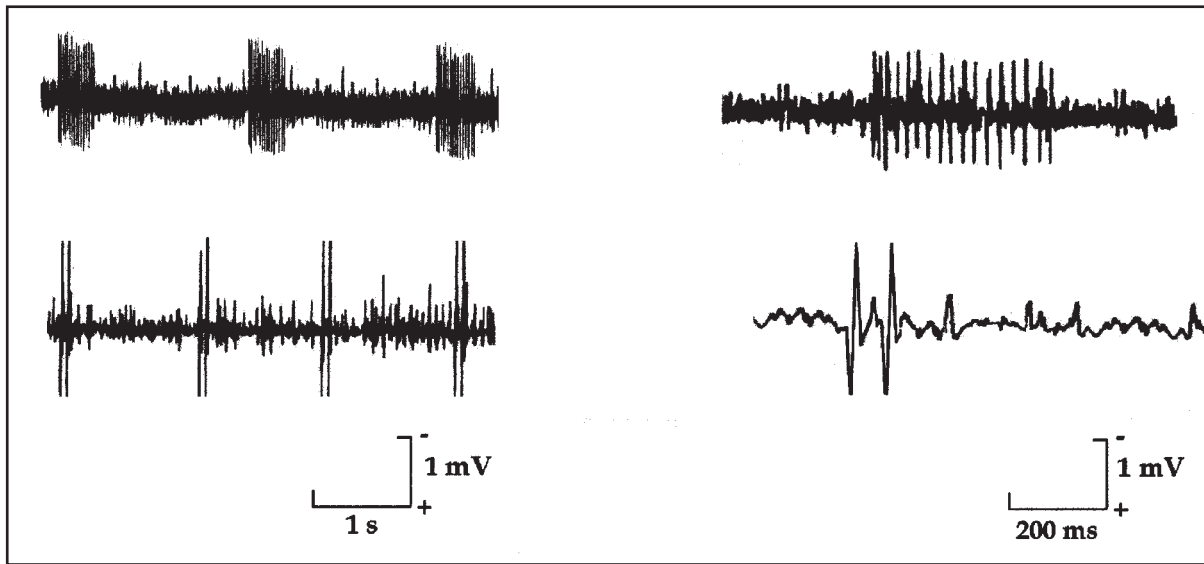


Figure 25. Tracings of two different *myokymic discharges* recorded with an intramuscular *needle electrode* are displayed on a time scale (left) which illustrates the firing pattern and with a different time scale (right) which illustrates that the individual *potentials* have the configuration of a *motor unit action potential*. A myokymic discharge is a group of motor unit action potentials that fire repetitively and may be associated with clinical *myokymia*. Two firing patterns have been described. (1) Commonly, the discharge is a brief, repetitive firing of single motor unit action potentials for a short period (up to a few seconds) at a uniform rate (2 to 60 Hz) followed by a short period (up to a few seconds) of silence, with repetition of the same sequence for a particular *potential*. (2) Rarely, the potential recurs continuously at a fairly uniform firing rate (1 to 5 Hz). Myokymic discharges are a subclass of *grouped discharges* and *repetitive discharges*.

NEUROMYOTONIC DISCHARGE

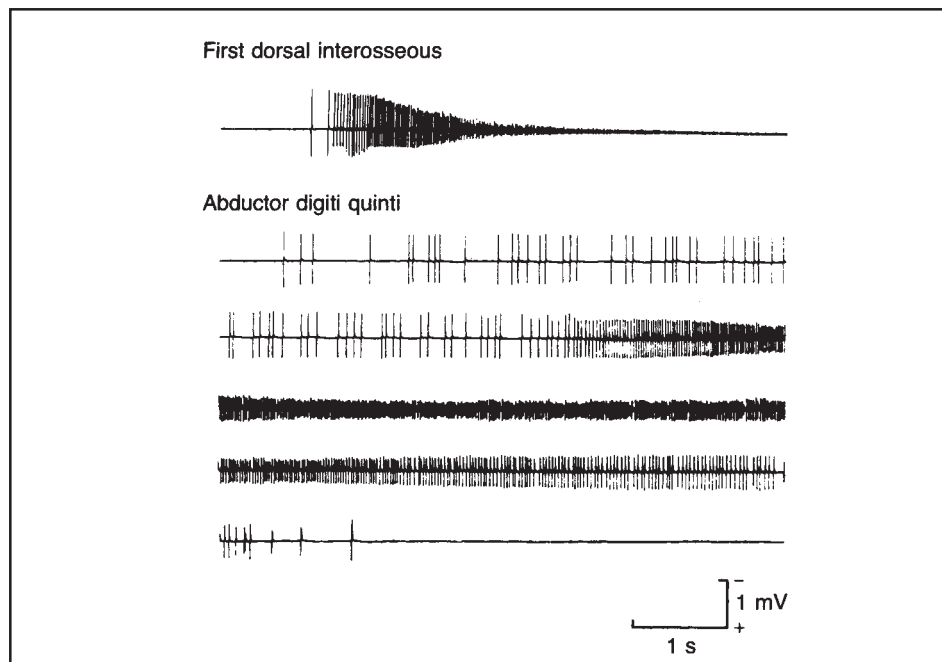


Figure 26. *Neuromyotonic discharges* recorded by an intramuscular *needle electrode* are shown on a time scale which illustrates the characteristic firing pattern. A neuromyotonic discharge is a burst of *motor unit action potentials* which originates in motor axons firing at high rates (150 to 300 Hz) for a few seconds. They often start and stop abruptly. The *amplitude* of the waveforms typically wanes. *Discharges* may occur spontaneously or be initiated by *needle electrode* movement, voluntary effort, ischemia, or percussion of a nerve. These discharges should be distinguished from *myotonic discharges* and *complex repetitive discharges*. They are one type of electrical activity that may be recorded in patients who have clinical *neuromyotonia*.

CRAMP DISCHARGE

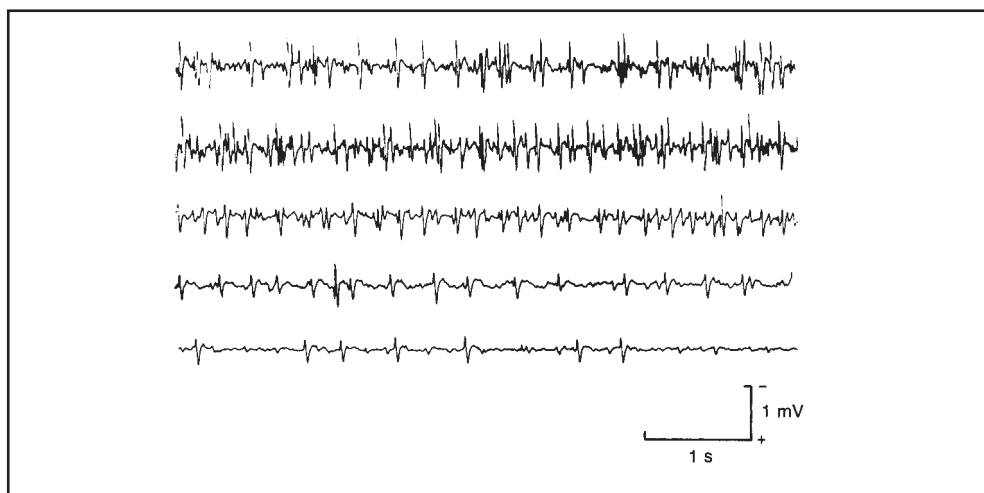


Figure 27. Cramp discharges recorded by an intramuscular *needle electrode*. A cramp discharge arises from the involuntary repetitive firing of motor unit action potentials at a high frequency (up to 150 Hz) in a large area of muscle, usually associated with painful muscle contraction. Both the discharge frequency and the number of motor unit action potentials firing increase gradually during development, and both subside gradually with cessation. See *muscle cramp*.

MOTOR UNIT ACTION POTENTIALS



Figure 28. A selection of different *motor unit action potentials* recorded with an intramuscular *needle electrode*. A motor unit action potential is a *potential* which reflects the electrical activity of a single *motor unit*. It is the *compound action potential* of those muscle fibers within the recording range of an *electrode*. When it is produced by voluntary muscle contraction, the potential is characterized by its consistent appearance and relationship to the force of contraction. The following parameters may be specified, quantitatively if possible, after the recording *electrode* is placed randomly within the muscle.

1. Configuration
 - a. Amplitude, peak-to-peak (μV or mV).
 - b. Duration, total (ms).
 - c. Number of *phases* (*monophasic, biphasic, triphasic, tetraphasic, polyphasic*).
 - d. Sign of each *phase* (negative, positive).
 - e. Number of *turns*.
 - f. Variation of shape (*jiggle*), if any, of consecutive *discharges*.
 - g. Presence of *satellite* (*linked potentials*), if any.
 - h. *Spike* duration, the duration of the spike including *satellites*.
2. *Recruitment* characteristics
 - a. *Threshold* of activation (first recruited, low threshold, high threshold).
 - b. *Onset frequency*
 - c. *Recruitment frequency* (Hz) or *recruitment interval* (ms) of individual potentials.

Descriptive terms implying diagnostic significance are not recommended, e.g., *myopathic, neuropathic, regeneration, nascent, giant, BSAP* and *BSAPP*. See *polyphasic action potential, serrated action potential*.

SATELLITE POTENTIAL

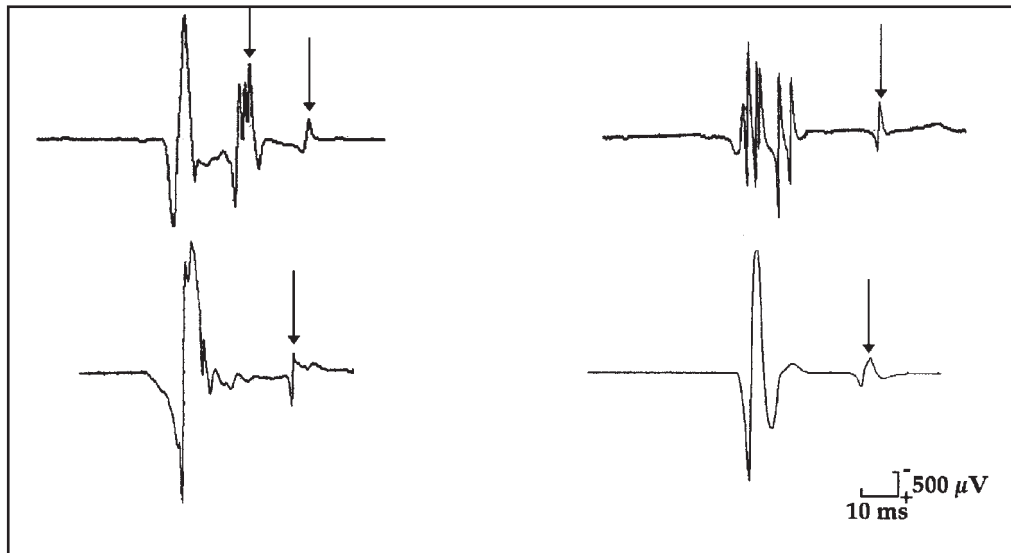


Figure 29. Four discharges of the same *motor unit action potential* with *satellite potentials* are indicated by the arrows. A *satellite potential* is a small *action potential* separated from the main *motor unit action potential* by an *isoelectric interval* which fires in a *time-locked relationship* to the main *action potential*. These *potentials* usually follow, but may precede, the main *action potential*. Less preferred terms include *late component*, *parasite potential*, *linked potential*, and *coupled discharge*.

RECRUITMENT PATTERN/INTERFERENCE PATTERN

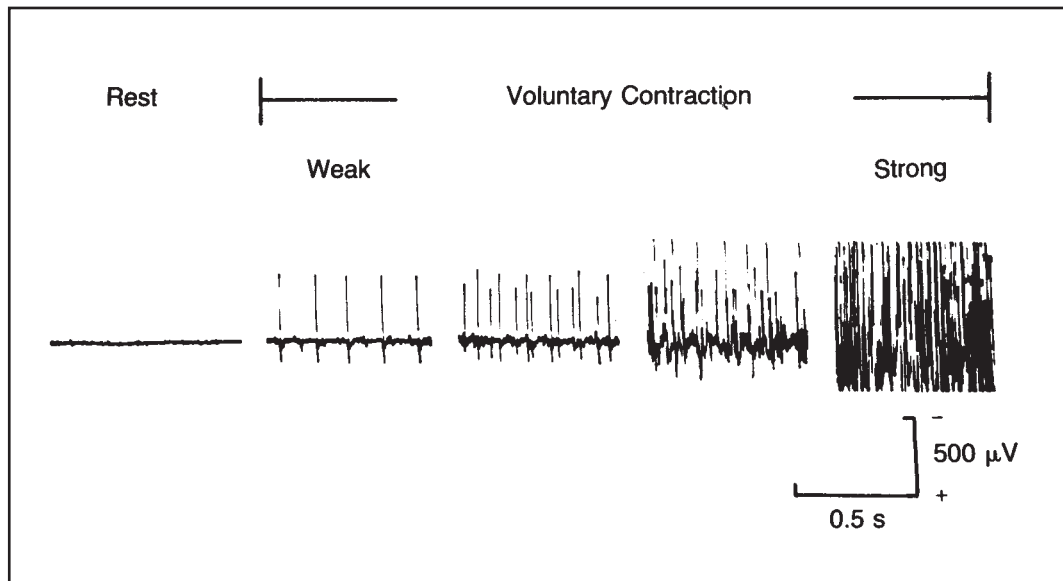


Figure 30. Recordings made with an intramuscular *needle electrode* at five different levels of force of voluntary contraction. *Recruitment* refers to the successive *activation* of the same and new *motor units* with increasing strength of voluntary muscle contraction. The *recruitment pattern* is a qualitative and/or quantitative description of the sequence of appearance of *motor unit action potentials* during increasing voluntary muscle contraction. The *recruitment frequency* and *recruitment interval* are two quantitative measures commonly used. The *interference pattern* is the electric activity recorded from a muscle with a *needle electrode* during maximal voluntary effort. A full interference pattern implies that no individual *motor unit action potentials* can be clearly identified (see tracing on far right). A reduced interference pattern (intermediate interference pattern) is one in which some of the individual *motor unit action potentials* may be identified while others cannot due to superimposition of *waveforms*. The term *discrete activity* is used to describe the electric activity recorded when each of several different *motor unit action potentials* can be identified due to limited superimposition of *waveforms*. The term *single unit pattern* is used to describe a single *motor unit action potential*, firing at a rapid rate (should be specified) during maximum voluntary effort. The force of contraction associated with the interference pattern should be specified.

SINGLE FIBER ELECTROMYOGRAPHY

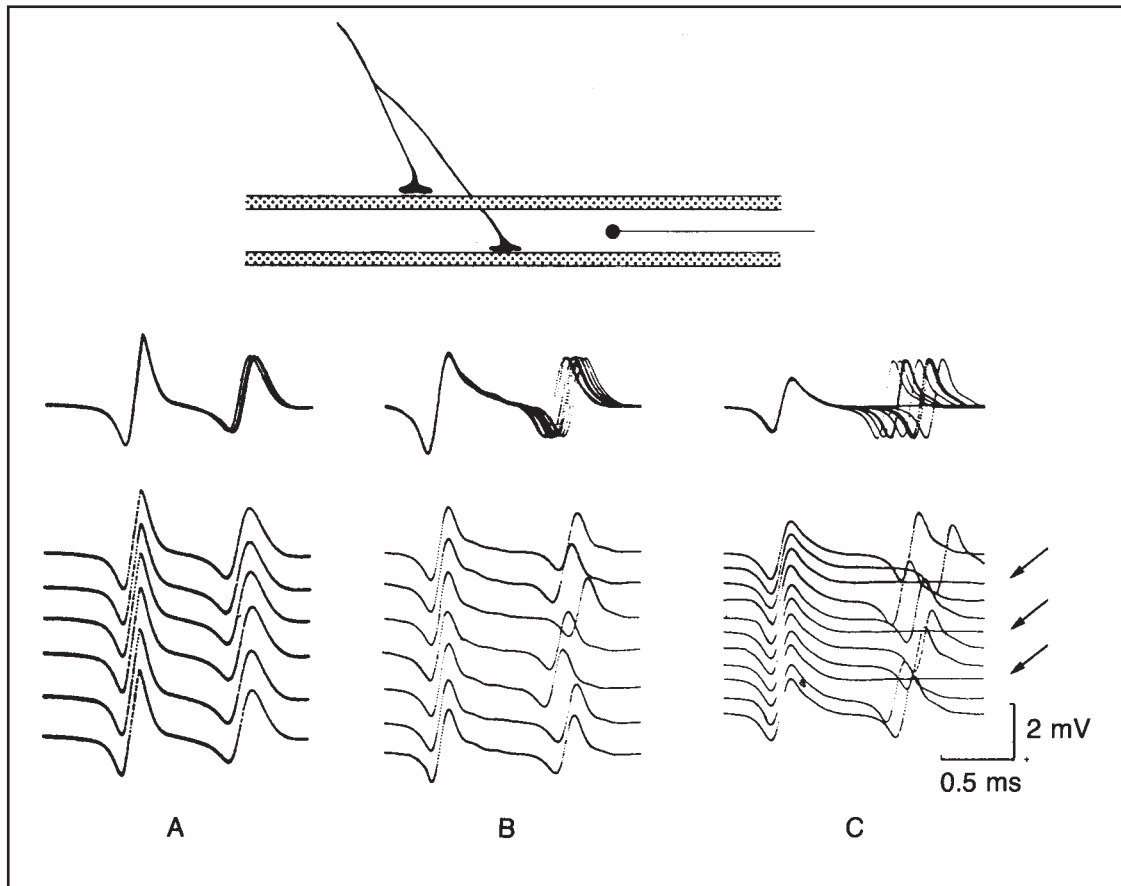


Figure 31. Schematic representation of the location of the recording surface of a *single fiber needle electrode* recording from two muscle fibers innervated by the same motor neuron (row 1). Consecutive *discharges* of a *potential pair* are shown in a superimposed display (row 2) and in a *raster display* (row 3). The potential pairs were recorded from the extensor digitorum communis of a patient with *myasthenia gravis*. They show normal jitter (column A), increased jitter (column B), and increased jitter and *impulse blocking* (column C, arrows). Jitter is synonymous with “single fiber electromyographic jitter.” It is the variability of the *interpotential interval* between two *muscle fiber action potentials* belonging to the same *motor unit* on consecutive discharges. It is usually expressed quantitatively as the mean value of the difference between the interpotential intervals of successive discharges (the *mean consecutive difference, MCD*). Under certain conditions, jitter is expressed as the mean value of the difference between interpotential intervals arranged in the order of decreasing interdischarge intervals (the *mean sorted difference, MSD*).

MACROELECTROMYOGRAPHY (MACRO-EMG)

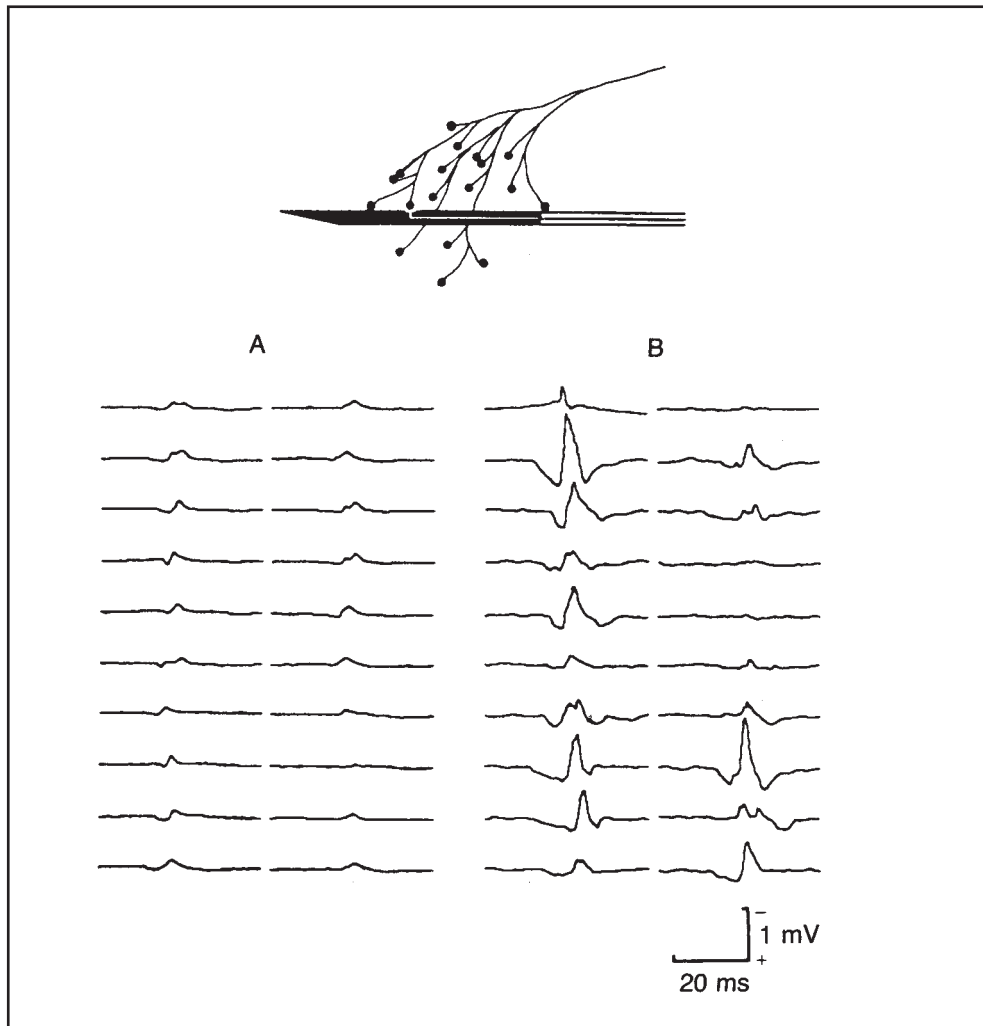


Figure 32. Schematic representation of the location of the recording surface of the *macro-EMG needle electrode* recording from all the muscle fibers innervated by the same motor neuron (upper diagram). *Macro motor unit potentials* recorded by the technique of *macroelectromyography* (lower traces) from a healthy subject (column A) and from a patient with amyotrophic lateral sclerosis (column B). Macroelectromyography is a general term referring to the technique and conditions that approximate recording of all *muscle fiber action potentials* arising from the same *motor unit*.

NEEDLE ELECTRODES

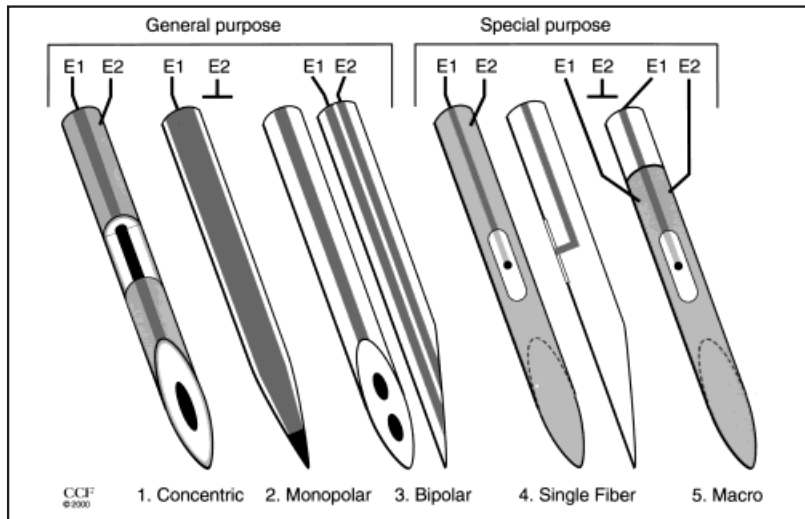


Figure 33. Schematic representation of five different types of needle electrodes. (1) The *concentric needle electrode* consists of a hollow, stainless steel cannula (light gray) containing a centrally located wire (black) from which it is insulated. The latter serves as the *active electrode (E1)*, while the entire barrel of the needle serves as the *reference electrode (E2)*. (2) The *monopolar needle electrode* consists of a solid stainless steel needle coated with insulation except for its distal tip, which serves as the cone-shaped recording surface (E1). The reference electrode (E2) consists of either another monopolar needle electrode or a *surface electrode*. (3) The *bipolar needle electrode* consists of a stainless steel hollow cannula which contains two wires, insulated from each other and from the cannula itself. The exposed distal tips of these wires on the bevel surface serve as the active (E1) and reference (E2) electrodes. (4) *Single fiber needle electrode*. Similar to the concentric needle electrode, the proximal portion of this electrode consists of a hollow cannula, which contains a central wire from which it is insulated. This wire, instead of ending on the bevel tip, is exposed through a side port in the cannula opposite the bevel tip. The bared area serves as the active electrode (E1) while the surface of the cannula serves as the reference electrode (E2). (5) The *macro-EMG needle electrode* consists mainly of a modified single fiber needle electrode. Two different *potentials* are recorded. The first is recorded from the single fiber EMG needle electrode. The recording surface opposite the bevel of the needle serves as the active electrode (E1), and the uninsulated portion of the cannula (light gray) serves as the reference electrode (E2). The potential recorded from this electrode is used to trigger the sweep for recording the *macro motor unit potential* from the second electrode. The second electrode consists of the uninsulated portion of the cannula, which serves as the active electrode (E1). A surface electrode serves as the reference electrode (E2).

FULL WAVE RECTIFIED EMG

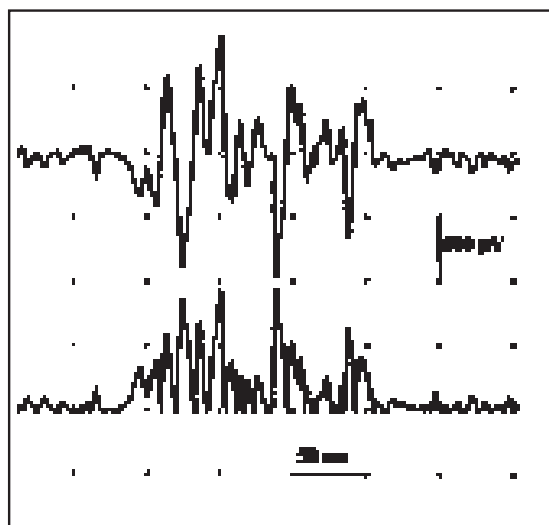


Figure 34. Motor unit action potentials recorded normally (top sweep) and simultaneously as a *full wave rectified EMG* signal (bottom sweep). A full wave rectified EMG signal is the absolute value of the raw EMG signal. Full wave rectification involves inverting all the waveforms below the *isopotential line* and displaying them with opposite polarity above the line. A technique used to analyze *kinesiologic EMG* signals.

SYMPATHETIC SKIN RESPONSE

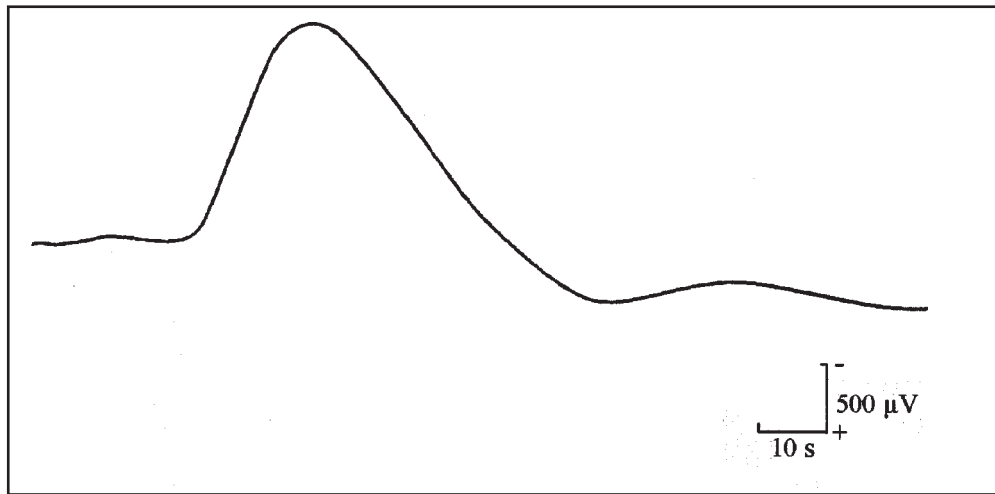


Figure 35. *Sympathetic skin response* recorded from the palm following stimulation of the contralateral median nerve. The sympathetic skin response is an electric *potential* resulting from electrodermal activity in sweat glands in response to both direct and peripheral or sympathetic trunk stimulation of autonomic activity.