Electromyogram (EMG)

EMG of one Muscle cell

A simple model can be used to aide in understanding the recording of action potentials with extracellular electrodes. Two electrodes are placed a considerable distance apart, directly on the surface of a muscle fiber (Figure 2-10). The electrodes are attached to an oscilloscope that measures voltage changes. To further simplify the model, depolarization, reverse polarization, and repolarization are the only phases of the action potential considered.

In a resting state, the muscle fiber is in equilibrium and, electrically, is positive on the outside and negative on the inside (Figure 2-10). Because the two electrodes are on the outside of the muscle fiber, there is no potential difference between them. The electrical difference and the oscilloscope, thus, remain at baseline. If the fiber is excited to the left of Electrode A, an action potential is initiated and propagated along the fiber toward Electrode A. When the action potential reaches the region under Electrode A, it becomes negative with respect to Electrode B, and the oscilloscope deflects upward. As the action potential continues toward Electrode B, the region under Electrode A repolarizes, and the oscilloscope returns to baseline. When the action potential is between the two electrodes, the region under Electrode A has recovered and the region under Electrode B has not yet depolarized. The difference in potential between the electrodes, therefore, is again zero. The oscilloscope remains at baseline until the region under Electrode B is depolarized. As the action potential moves under the Electrode B, the region becomes negative with respect to the region under Electrode A, and the oscilloscope deflects downward. As repolarization occurs under Electrode B, the difference in potential returns to zero.

The output of this model is two monophasic waves separated by a brief period of time when no potential difference is measured (Figure 2-10). The time between the two waves depends on the conduction velocity of the muscle fiber and the distance between the two electrodes. If the electrodes are placed very close together, for ex[redacted]ple, the two waves temporally summate forming a biphasic wave with a smaller peak to peak amplitude than the monophasic waves. This biphasic wave is similar in appearance to a muscle fiber action potential.

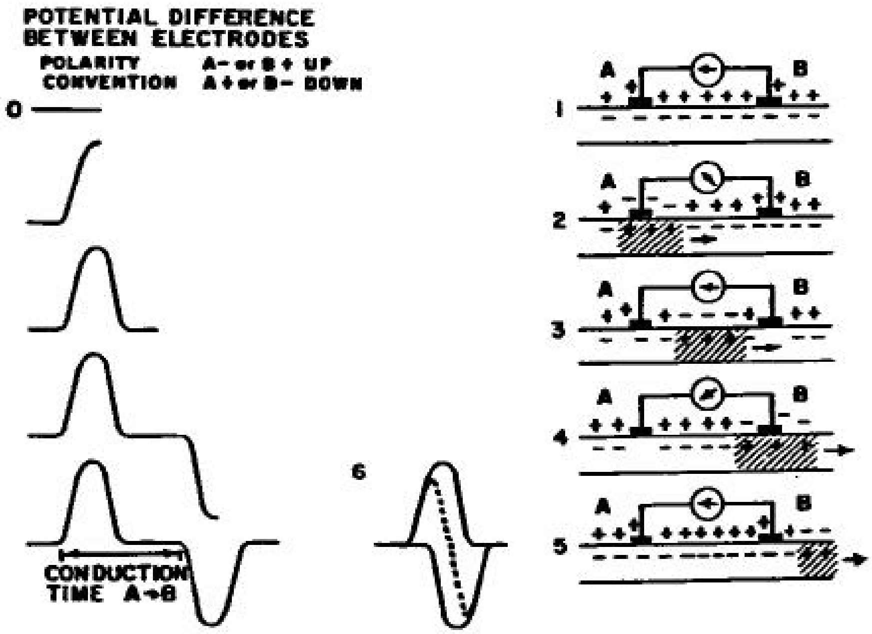

FIGURE 2-10
The measurement of action potentials, with electrodes placed on the surface of isolated irritable tissue.

EMG of a Motor Unit

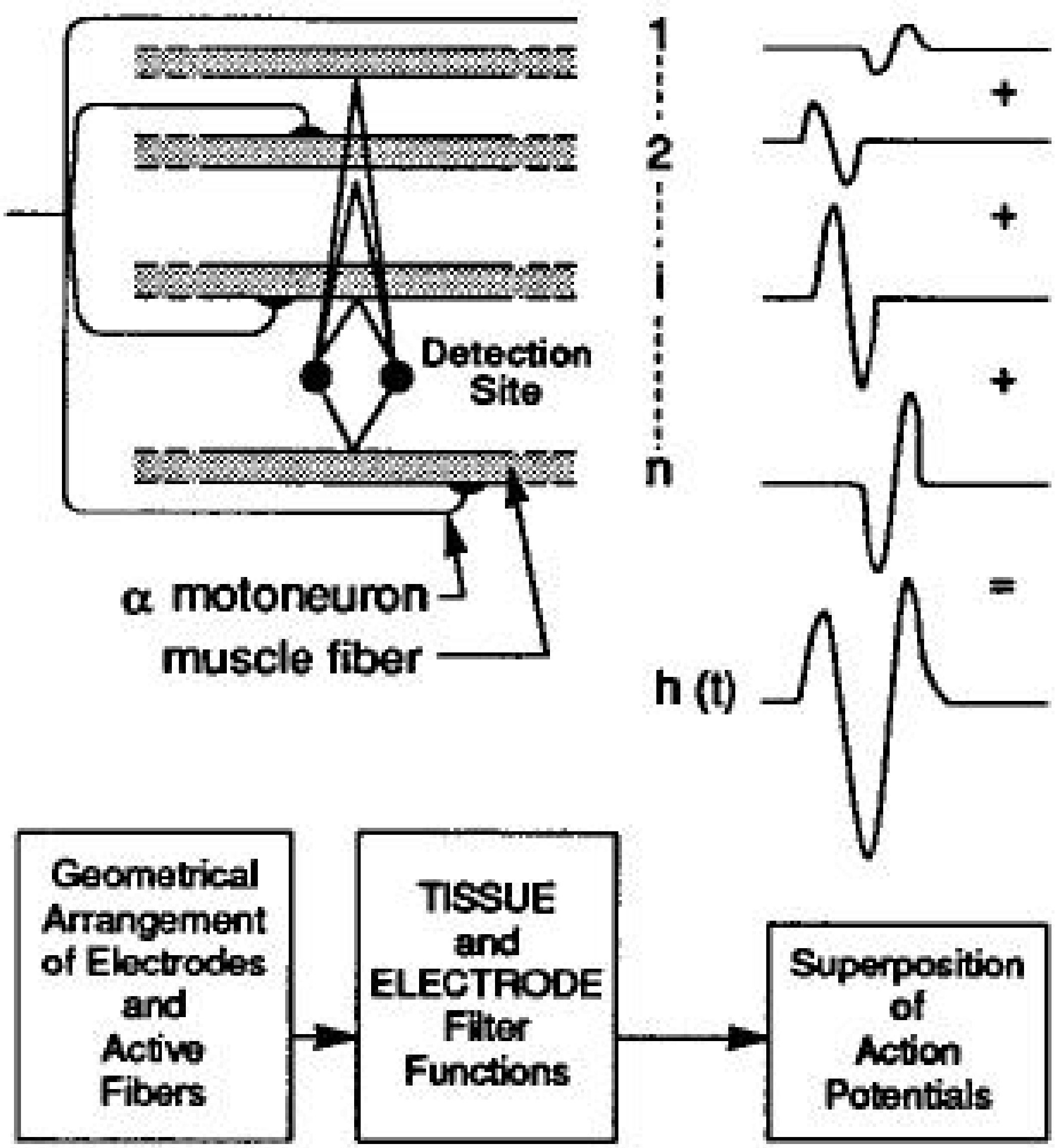

FIGURE 2-11

Schematic representation of the generation of the motor unit action potential.

Fiber Types

Innervation ratios may not be an appropriate means of understanding the function of motor units during human movement. A better approach may be to think about the characteristics of muscle fibers. Motor units and muscle fibers can be classified on the basis of their mechanical, metabolic, and histochemical properties. Most studies describing these characteristics use animal models, and the results must be applied cautiously to humans. There are several methods of classifying muscle fibers. One method identifies three major fiber types: types I, IIA, and IIB.[17] Another system classifies the three types as SO (slow twitch oxidative), FOG (fast twitch oxidative), and FG (fast twitch glycolytic)[18] (Figure 2-14).

The type I, or SO, fibers are characterized as red fibers having a high resistance to fatigue. These fibers, with a high concentration of mitochondria and an excellent blood supply, use aerobic metabolism almost exclusively. These slow twitch fibers are well suited for sustained muscle contractions.

The intermediate type IIA, or FOG, fibers are pale, fast twitch fibers having considerable capacity for aerobic metabolism. They have a reasonable concentration of mitochondria and capillaries making them suitable for sustained phasic activity.

The type IIB, or FG, fibers are white or fast twitch fibers with a high capacity for anaerobic glycolysis and a low capacity for aerobic metabolism. They have a low concentration of mitochondria and a poor capillary bed giving them a low resistance to fatigue. These fibers probably are best suited for short term phasic activity.

Type IIA (FOG) and IIB (FG) muscle fibers are innervated by alpha motor neurons with fast conduction velocities. Type I (SO) fibers are innervated by slower conducting alpha motor neurons. The same type of muscle fibers congregate to form homogeneous motor units.[4,19] We, therefore, can speak of and functionally describe fast twitch motor units and slow twitch motor units.[19]

Burke classified motor units as S (slow twitch) containing type I (SO) muscle fibers, FR (fast twitch, fatigue resistant) motor units containing type IIA (FOG) muscle fibers, and FF (fast twitch, fatigable) units containing type IIB (FG) muscle fibers. Motor unit classification is more functional and useful in ergonomics than muscle fiber classifications.

The slow twitch motor units (S) have distinctive characteristics that differentiate them from the other two types of motor units. The S motor unit has low conduction velocity, long twitch contraction times, and low contraction velocity. Twitch contraction times of 90 to 160 msec and contraction velocities of 2 fiber lengths/sec have been reported.[19–21] Slow twitch motor units have a low contraction threshold of below 30% of twitch tension. They can fire continuously for long periods at relatively low frequencies. This ability makes the S motor unit particularly well suited and economical for both low-level isometric, concentric, and eccentric contractions that occur repetitively at low frequencies.[21,22]

The fast twitch, fatigue resistant (FR) motor units have a high conduction velocity and short twitch contraction time. The FR motor units have a low contraction threshold and, for the most part, are recruited with the slow twitch motor units. The FR units exhibit a greater resistance to fatigue and produce less tetanic force than FF motor units.[19,20,23]

The fast twitch, fatigable (FF) motor units have high conduction velocities, short twitch contraction times and high contraction velocities. Twitch contraction times of 40 to 84 msec and contraction velocities of 6 fiber lengths/sec have been reported.[19,21,23] The FF motor units have a contraction threshold of above 30% twitch tension. They fire intermittently at high rates for short intervals and are well suited for short-duration powerful isometric, concentric, or eccentric contractions. There is a positive relationship between power output and percentage of fast twitch glycolytic fibers.[24] The peak power output of FOG fibers, in fact, has been reported as fourfold that of SO fibers, as a result of shortening velocity.[25]