

Experiment AM-10: Summation, Tetanus, and Fatigue in an Intact Nerve-Muscle Prep

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Introduction

The functional unit of skeletal muscle activity is the somatic motor unit. It consists of a somatic motor nerve cell and all of the skeletal muscle cells that it controls. The cell body of each somatic motor neuron is located in the ventral horn of the spinal cord (anterior spinal gray) and its axon travels through a spinal nerve to a muscle. Once at the muscle, an axon will innervate at least one muscle fiber, but may also give off collateral branches to innervate other muscle fibers. (Also some somatic motor neurons extend from the brain to muscles of the head region via cranial nerves). Interposed between the axon branches and the muscle fibers is a structure called the neuromuscular junction or the motor end-plate.

During normal movement, the spinal motor neuron is activated and a nerve impulse is propagated down its axon. The impulse spreads out to the axon branches, across the neuromuscular junctions, and full activation of that group of muscle fibers takes place. Exciting all of the motor neurons supplying a muscle can activate all of the fibers in that muscle. Graded contractions therefore can be obtained by activation of fewer or more of these neurons. It is possible to activate almost 100% of these fibers or less than 1%.

The individual nerve fibers possess different thresholds. A low intensity stimulus will readily excite the fibers with the lowest threshold. A further increase will excite more of the fibers in the nerve trunk, which will result in an increase in the force generated. A stimulus that excites all of the fibers innervating a muscle will result in a maximal muscular contraction. It is impossible for a muscle to generate a contraction of greater strength than its maximal contraction strength.

The most convenient way of examining the properties of the motor unit is by use of the nerve-muscle preparation. With an exposed, centrally ligated nerve trunk (e.g. frog sciatic) supplying a muscle group, a stimulator can be used to excite the distal end of the exposed nerve. Activation of part or all of this trunk will cause a contraction in the innervated muscle. However, even when a successfully propagated impulse has been initiated in a nerve fiber, it must be conducted across the neuromuscular junction to be effective in causing a contraction of the muscle. Not only is a finite time occupied in the transmission of the nerve impulse across the junction, but the junction itself is very sensitive to fatigue and to its chemical environment.

Transmission across the end-plate is electrochemical in nature and fatigue itself may be biochemical in nature. Certain drugs abolish end-plate transmission while others enhance it. Tubocurarine (curare) is an example of the former, and neostigmine, the latter. With both drugs it can be shown that the electrical properties of the nerve and muscle membranes themselves remain relatively unaltered.

Neuromuscular blocking drugs such as tubocurarine are used to bring about muscle relaxation during surgery (1) to reduce muscle contraction in the region undergoing surgery, (2) to facilitate endotracheal intubation, (3) to aid in maintaining controlled ventilation, and (4) to reduce the amount of anesthetic agent used. They are also used to reduce laryngeal or general muscle spasms, reduce spasticity in certain neuromuscular diseases, and prevent bone fractures during electroconvulsive therapy.

Drugs such as neostigmine and physostigmine, which enhance end plate transmission, do so by inhibiting acetylcholinesterase, which breaks down acetylcholine. These drugs are used to treat myasthenia gravis, a disease caused by a reduction in the number of effective acetylcholine receptors on the muscle cell membrane, and to reverse drug-induced neuromuscular blockade.