Reports—Current Topics—Queries

APPARATUS SHOWS ACTIONS OF MUSCLES IN A JOINTED LIMB

Many students have difficulty in relating anatomic structure to mechanical function. This may be due in part to the two-dimensional nature of textbook illustrations. An examination of the mechanics of the movements of jointed limbs can facilitate both the learning of anatomy and an understanding of animal locomotion. To this end, a simple apparatus (see figure) can be constructed; simple tools and readily available materials are used. Freshly dissected muscle preparations are attached to jointed levers in a variety of ways, and the levers are caused to move by the electrically stimulated contraction of the muscles.

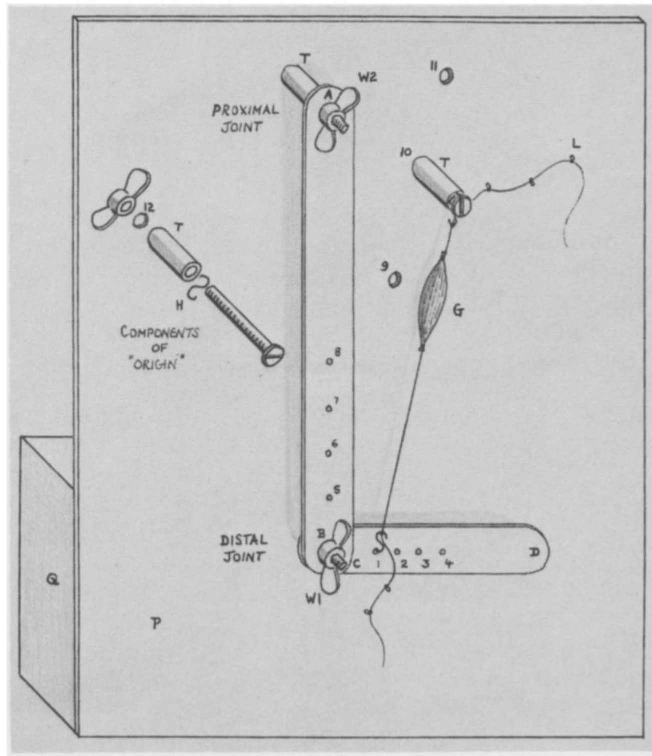
Cut levers AB and CD from 5-mm plywood and drill holes in the positions shown. Use a wing-nut and bolt, W1, to connect B to C to form a movable joint (the "distal" joint). Use another wing-nut and bolt, W2, and a 3-cm section of metal tubing, T, to connect A to a supporting panel, P, to form a second movable joint (the "proximal" joint). Lever AB is therefore suspended at a distance of 3 cm from P. Obtain two additional sets of wing-nuts, bolts, and 3-cm lengths of metal tubing; these sets will subsequently be referred to as "origins."

The supporting panel, P, is a 25-by-35-cm rectangle of 5-mm plywood. Bolt P to a 10-by-10-by-25-cm wooden base, Q. Drill further holes in P as shown in the figure. (All holes are numbered to facilitate descriptions used in the text.) Paint levers AB and CD white and paint panel P black, for optical contrast.

Each time the apparatus is used the procedure is as follows: Dissect out the two gastrocnemius muscles, G, of an anesthetized rat immediately before the demonstration and keep them moist with a saline solution throughout the time that they are in use. Retain the tendons of origin and insertion on the muscle preparations and tie them to separate lengths of white cotton thread that has previously been knotted into a number of loops, L, as shown.

Attach a muscle preparation to one of the positions (holes 9 through 12) on panel P, using an "origin" described earlier and a small S-shaped wire connector hook, H. "Insert" the muscle onto any of the numbered positions on the levers, using a connector hook, which is passed through an appropriate loop in the white cotton thread and into a hole (1 through 8) on a lever.

Adjust wing-nuts W1 and W2 so that movement is possible at only one of the joints at any one time. With the weight of the levers holding cotton threads



Device makes use of fresh muscle preparations.

and muscle in tension, stimulate the belly of the muscle with an appropriate voltage (4 volts) conducted by a length of insulated wire used as a probe. Contraction of the muscle preparation moves the levers for purposes of demonstration.

Demonstration 1 illustrates the contractility of muscle. Attach a muscle by cotton threads to an "origin" in hole 10 and "insert" in hole 1, so that the distal joint forms an approximate right angle. Tighten wing-nut W2 in order to prevent movement at the proximal joint and loosen wing-nut W1 in order to allow movement at the distal joint. Stimulate the belly of the muscle to produce a movement of the distal lever.

Contraction is the unique property of the muscle tissue, as illustrated by the fact that stimulation at any point with a wide range of voltages produces only contraction of the muscle; indeed, the same effect is produced if the muscle is inverted so that the points of origin and insertion are reversed.

Demonstration 2 illustrates isometric contraction. Using the same arrangement as above, tighten both wing-nuts so that movement is not possible at either joint. Stimulation produces a noticeable increase in the maximum diameter of the muscle belly. Hence the force of the muscular contraction may be exerted upon a joint without producing movement—provided the joint is fixed by moments as great as the moment exerted by that muscular contraction. (A moment about any point is defined as the product of a force and the perpendicular distance of the line of action of the force from that point.) This kind of contraction is known as isometric contraction, as opposed to the isotonic contractions demonstrated earlier.

Demonstration 3 shows that a single muscle may be capable of producing movement at either of two joints. Using the same arrangement as in demonstration 1, tighten wing-nut W1 in order to prevent movement at the distal joint and loosen wing-nut W2 in order to permit movement at the proximal joint. Stimulation of the muscle now produces movement of the whole "limb," with the distal lever held in a flexed position.

This is an opportune time to discuss the role of muscles as prime movers and as fixators. Examples of each may then be demonstrated with the living subject, with special reference being given to muscles that cross two joints.

Demonstration 4 shows that the force of muscular contraction is constant along its line of action. Holes 9, 10, and 11 in P are in linear arrangement with hole 1 in the distal limb. By altering the length of the cotton thread to the "insertion" of the muscle and moving the "origin" to holes 9 and 11, it can be shown that contraction produces the same movement of the distal lever (with W2 fixed) as was produced when the origin was at hole 10.

However, the mechanical terms the inertial properties of the limb have now been altered. The farther the muscle is situated from the distal lever, the lower will be the moment of inertia of the whole limb, including the muscle (about the proximal joint). The concept of moment of inertia must be discussed, but the phenomenon may be illustrated by using a metronome. It can be seen that if the weight-bob of the metronome represents the mass of a muscle, the lever has a much higher natural frequency when the muscle is kept closer to the proximal joint of the system. Moving the weight distally produces a decrease in the natural frequency of the lever.

Examples of running efficiency in cloven-hooved animals, the agility of shorter-legged animals, and the typical physiques of various groups of athletes may be discussed. The role of tendons as weight-saving transmitters of force will be described subsequently but should be mentioned at this time.

Demonstration 5 illustrates the function of tendon. Replace the cotton thread of the insertion by a 5-cm length of 1-by-1-mm elastic rubber. When the muscle is stimulated, the lower limb will move erratically and out of phase with the contraction. If the joints are locked or the lever is weighted, the rubber will stretch, and no movement of the lever will be produced.

For synchronous and positive transmission of forces, tendons must be relatively inelastic. Microscopic and gross sections of tendon may be examined at this time.

Demonstration 6 illustrates the effects of moving the position of the insertion of a muscle. With the "origin" in hole 10 and the proximal joint "fixed" with W2, move the insertion successively from holes 1 through 4. It will be observed that the amplitude and velocity of the movement decrease as the "insertion" is moved farther from the distal joint. This demonstration may be varied by using "insertions" 5 through 8 on the proximal lever, to obtain comparable results.

The physics of levers should be dicussed. Examples of the different classes of lever and their occurrence in animal skeletons may be illustrated.

Demonstration 7 illustrates group muscle action. Attach the second gastrocnemius muscle with its "origin" at hole 12 and its "insertion" at hole 5, and attach the first muscle with its "origin" at hole 11 and its insertion in hole 6. Loosen the proximal joint and "fix" the distal joint in a near-vertical position. Arrange the cotton threads so that the distal joint can move a short distance to the left and to the right without restriction.

Alternate stimulation of each muscle produces a "walking action" of the limb. Discuss the role of the muscles as prime movers and as antagonists and comment briefly on the reciprocal action of the nervous system.

Numerous other demonstrations are possible with slight modifications to the apparatus.

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Book on Bikeway Planning

California has made a study of the most feasible and inexpensive ways of accommodating bicyclists on public roads, and the results are now available in book form. Besides design information, the book contains a brief history of the bicycle in America, a review of bike-transportation experience in Europe and elsewhere, and analyses of bicyclists' needs. The report, costing $2, is available from Kenneth Bandow, Division of Highways, State Department of Public Works, 1120 N St., Sacramento, Calif. 95814.

Oil on Troubled Waters

According to the National Audubon Society, oil spills from ocean-going tankers contributed only 2% of the 5 billion tons of oil and other petroleum products released into the waters of the world last year. Most of the oil damage started inland, with motor and industrial oils accounting for 68% of the total of this kind of water pollution.