11-1-1989

Muscle Activities That Stretch The Mind

James L. Hanegan

Heather McKean
Eastern Washington University, hmckean@ewu.edu

How-To-Do-It

Muscle Activities that Stretch the Mind

James L. Hanegan
Heather R. McKean

Traditionally, instructors of human anatomy and physiology depend upon physiological monitors to demonstrate the principles of muscle action. Although it's an effective method, it requires that machines be available and in working order. Students spend most of their time learning to use the equipment and interpreting the results rather than understanding the physical properties of muscle.

An inexpensive and easy-to-make wooden model of the musculoskeletal system (Figure 1) relieves these problems and precludes the sacrifice of laboratory animals. Students working with rubber band muscles come to understand the concepts of muscle contraction, muscle fiber recruitment and opposed actions of muscles. In addition, they learn the locations, actions and attachment sites of the major muscle groups that move the limbs. Laboratory worksheets direct students through problem solving, allowing them to discover the principles of muscle action.

Methods of Construction

A wooden skeleton is constructed of pine or fir with joints of ring hooks and hinges (Figure 2). Muscles are simulated by attaching rubber bands to the skeleton with cup hooks. The model represents the shoulder and arm or the hip and leg. For simplicity, the directions for construction are given for the arm and shoulder. The described points of muscle attachment are included for both upper and lower limbs.

Each model will require 24 cup hooks, 6 ring hooks, a package of rubber bands in assorted sizes, 1 1-by-8 pine or fir 16 inches long, 1 1-by-2 pine or fir 28 inches long, wood glue and small wood screws. The wood is cut to the dimensions shown in the figure and the base is assembled using wood screws and glue. The arm and forearm are joined by small wood screws and the 1-inch hinge. The smaller ring hooks are inserted into the radius and ulna as shown and then fastened together by opening one of the rings with pliers and closing it on the second ring. The arm is attached to the base using the ½-inch ring hooks. The cup hooks are screwed in place at the locations indicated by the circles and letters on the diagram. Exact locations are not critical to the function of the model except that the distance between A and B (approximately 12 inches) must be equal to the distance between C and D.

Instructors who have used this model at the high school and junior high school level have employed students in vocational education classes to construct the models for them. The model may be painted and labeled, or left in the natural wood finish. Examples of several muscles attached to the model are shown.

Activity 1.

Muscle contraction

Learning objective: the student will determine the way in which muscles are attached to bones and will identify the direction that muscles move bones at joints.

Attach a rubber band between two hooks so that movement occurs. This represents a muscle contraction. Did you notice that one bone was stationary and the other moved? The point of attachment on the stationary bone is called the origin and the point of attachment on the bone that moved is called the insertion.

1. Identify the point of origin by writing the letter by the hook. ___
2. Identify the point of insertion. ___

Identify the following six major directions of movement.

3. To perform a flexion, attach a rubber band on either side of a joint so that the angle at the joint decreases. An example of flexion is between points ___ and ___. Circle the letter which represents the point of origin.
4. To perform an extension, attach a rubber band on either side of a joint so that the angle at the joint increases. An example of extension is between points ___ and ___. Circle the point of origin.
5. To perform an abduction, attach a rubber band on hooks on either side of a joint so that the limb moves away from the body. An example of abduction is between points ___ and ___. Circle the point of origin.
6. To perform an adduction attach a rubber band on hooks on either side of a joint so that the limb moves toward the body. An example of adduction is between points ___ and ___. Circle the point of origin.
7. To perform a pronation, attach a rubber band between the wrist and the forearm so that the wrist turns in toward the body. An example of pronation is between points ___ and ___. Circle the point of origin.
8. To perform a supination, attach a rubber band between the wrist and the forearm such that the wrist turns away from the body. An example of supination is between points ___ and ___. Circle the point of origin.

James L. Hanegan is professor of biology and physical therapy at Eastern Washington University, Cheney, WA 99004. He received a B.S. in biology from Northern Illinois University, a M.S. in zoology from the University of Maine and a Ph.D. in physiology from the University of Illinois. He teaches courses in anatomy, physiology and neuroscience to biology and physical therapy majors. He has published numerous papers on temperature regulation in insects and mammals. **Heather R. McKean** is assistant professor of biology at Eastern Washington University, where she earned a B.S. and B.A. of education in biology and a M.S. in biology. She teaches freshman biology courses and biology teacher-method courses. She coauthored an article which appeared in the May issue of *ABT*.

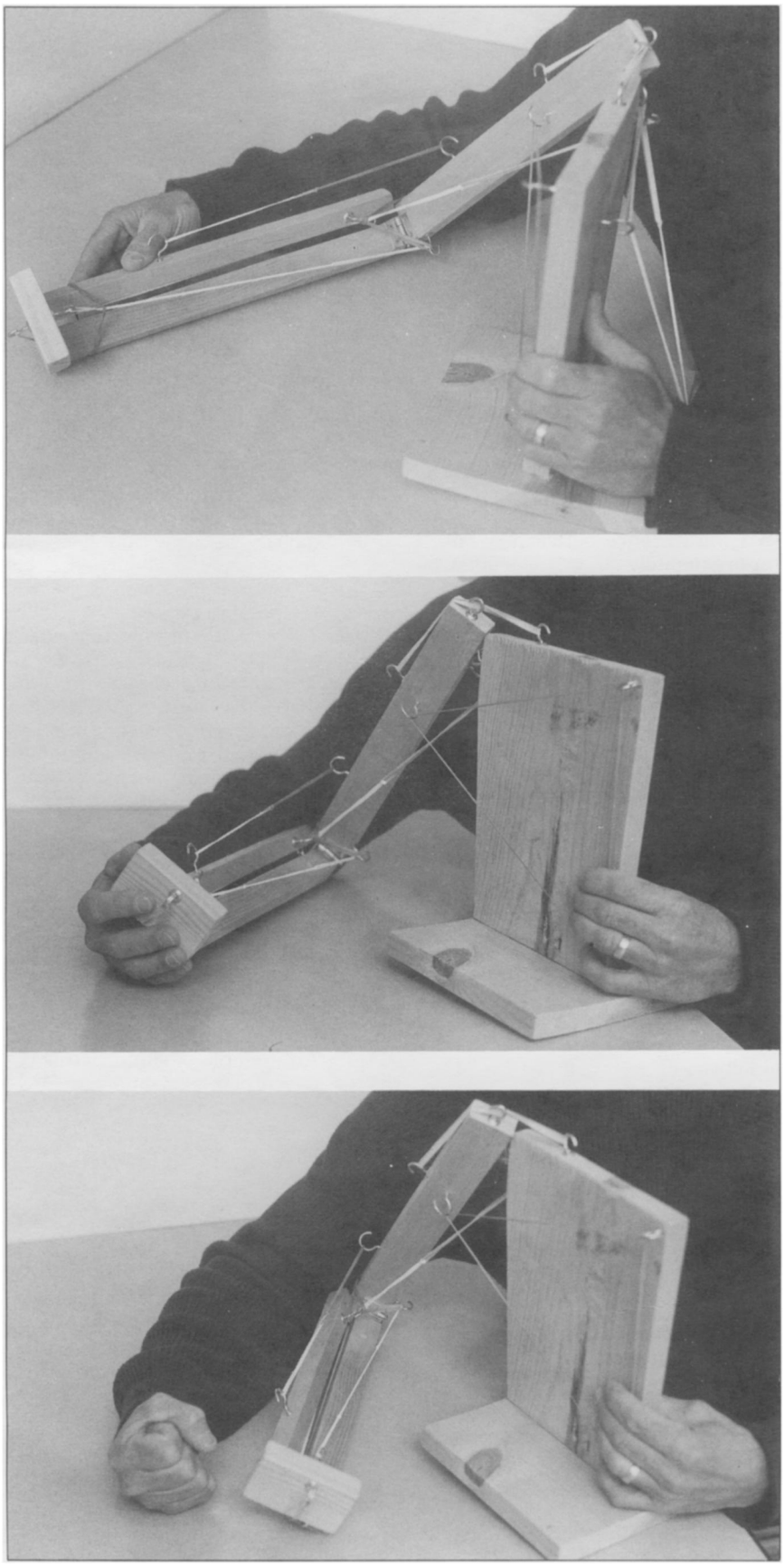

Figure 1. Model of musculoskeleton.

Activity 2.

Movement at a joint

Learning objective: the student will be able to identify the type of joint and recognize the kind of movement which occurs at each of the joints.

Four types of joints are depicted on the model: the ball and socket (shoulder or hip), the hinge joint (elbow or knee), the gliding joint (wrist or ankle) and the pivot joint (radius and ulna or tibia and fibula).

1. Which kinds of joints can produce flexion?_____
2. Which kinds of joints can produce extension?_____
3. Which kinds of joints can produce abduction?_____
4. Which kinds of joints can produce adduction?_____
5. Which kinds of joints can produce pronation?_____
6. Which kinds of joints can produce supination?_____

Activity 3.

Description of muscle action

Learning objective: the student will know the names, actions and origins/insertions of the major muscles that move the limbs. *Principles of Human Anatomy* by Gerard J. Tortora (Harper and Row, New York, 1986) or *Concepts of Human Anatomy and Physiology* by Kent M. Van DeGraff and Stuart Ira Fox (Wm. C. Brown, 1986) provide good illustrations of the muscles and their origins and insertions.

Directions: For each of the following muscles, connect a rubber band between the given points. Determine the action of the muscle and identify which point is the origin and which is the insertion. Circle the origin.

Upper body

1. Pectoralis major: points A and IJ.
   Muscle action: _____
2. Latissimus dorsi: points K and L.
   Muscle action: _____
3. Biceps brachii: points G and H.
   Muscle action: _____
4. Wrist flexors: points M and X; points M and Y.
   Muscle action: _____
5. Pronator: points M and H.
   Muscle action: _____

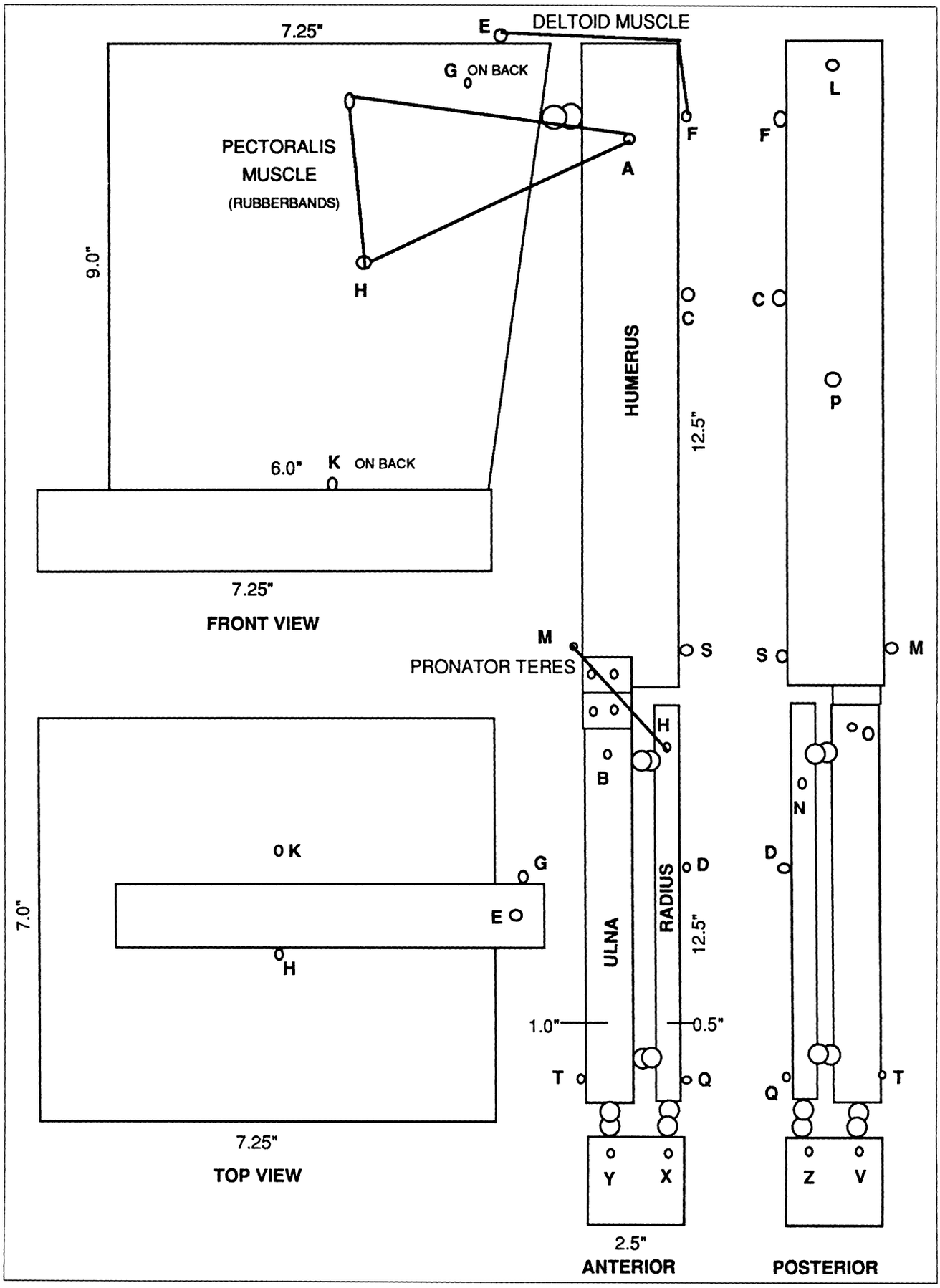

Figure 2. Details for the construction of the musculoskeleton model.

6. Brachialis: points A and B.
   Muscle action: _____
7. Brachioradialis: points C and D.
   Muscle action: _____

Lower body

8. Leg adductors: points G and P.
   Muscle action: _____
9. Gluteus muscles: points E and C.
   Muscle action: _____
10. Hamstring muscles: points A and H; points A and B.
    Muscle action: _____
11. Sartorius muscle: points E and B.
    Muscle action: _____
12. Gastrocnemius muscle: points B and H to point Y.
    Muscle action: _____
13. Peroneus muscles: points N and X.
    Muscle action: _____

Directions: For the following muscles, use the clue of muscle action to determine the muscle's site of origin and insertion.

Upper body

14. Deltoid muscle action: abducts upper arm.
    Origin: ___ Insertion: ___
15. Triceps brachii action: extends the forearm.
    Origin: ___ Insertion: ___
16. Wrist extensors: extends the hand at the wrist.
    Origin: ___ Insertion: ___
17. Supinator: rotates the thumb from inside to outside.
    Origin: ___ Insertion: ___

Lower body

18. Quadriceps: extend the leg at the knee.
    Origin: ___ Insertion: ___
19. Tibialis anterior: raises the top of the foot toward the tibia (dorsiflexion).
    Origin: ___ Insertion: ___
20. Tensor fasciae latae: abducts the thigh.
    Origin: ___ Insertion: ___

Activity 4.

Antagonistic & synergistic muscle groups

Learning objective: the student will recognize muscles which have opposing actions and muscles which perform the same action.

Muscles work in pairs to move bones in opposite directions. Opposing pairs of muscles are said to be antagonistic. Write in column B the name of a muscle that is antagonistic to the muscle given in column A. Hint: Flexors are antagonistic to extenders, abductors are antagonistic to adductors and pronators are antagonistic to supinators.

Column A	Column B
1. biceps brachii	_____
2. deltoid	_____
3. pronator	_____
4. wrist extender	_____
5. hamstrings	_____
6. tensor fascia latae	_____
7. tibialis anterior	_____

Some muscles work in pairs to move the limb in the same direction. These muscles are termed synergists. Name one pair of synergistic muscles.

8. _____

Activity 5.

Comparing muscle attachments for strength & motion

Learning objective: the student will understand that the site of muscle insertion determines the amount of weight that can be supported and the distance of limb movement.

1. Attach one rubber band representing the brachialis. Add weights until the forearm is in the extended position. (Use standard metric weights.) The amount of weight equals ___ g. Measure the distance between the origin and the insertion in the fully extended position. It is ___ cm.
2. Attach one rubber band representing the brachioradialis. Add weights until the forearm is in the extended position. The amount of weight equals ___ g. Measure the distance between the origin and the insertion in the fully extended position. It is ___ cm.
3. Which muscle supported the most weight? ___ Which muscle appears to be stronger? ___
4. Measure the distance between the insertion of the brachialis and the hinge joint. It is ___ cm. The distance between the insertion of the brachioradialis and the hinge joint is ___ cm. If the distance is increased between the insertion point and the hinge joint, would the amount of weight supported be greater or smaller? ___
5. In the fully flexed position the distance between the origin and insertion of the brachialis equals ___ cm. The distance between the origin and insertion of the brachioradialis in the fully flexed position equals ___ cm. Compare these measurements to those taken when in the fully extended position. Which muscle shortened the least? ___ Which muscle moved the forearm the greatest distance with the least effort? ___

Activity 6.

General properties of muscle fibers

Learning objective: the student will understand the force of muscle action on the lever systems of bones and joints.

1. Connect a single rubber band representing the brachialis. Measure the distance in centimeters between the origin and insertion. This distance is equal to ___.
2. Using a protractor, measure the angle in degrees between the humerus and ulna. It is ___.
3. Add a second rubber band which mimics an increase in the number of muscle fibers activated. The distance between the origin and insertion is ___ cm, and the angle of flexion is ___.
4. Add a third rubber band and remeasure. The distance is ___ cm. and the angle of flexion is ___.
5. Line up three arm models with one, two and three rubber bands in the brachialis position. Beginning with the arm in the extended position, release the three forearms simultaneously. Which forearm moved the fastest? ___ Which forearm moved the furthest? ___ The speed and distance of movement is dependent upon the number of muscle fibers activated. This is the concept of muscle fiber recruitment.

Answer Sheet

Activity 1.

1) any origin point 2) any insertion point 3) any two points on either side of the hinge joint 4) any two points on either side of the hinge joint 5) E and F or E and C 6) G and P or A and H 7) M and H or Q and T 8) M and N

Activity 2.

1) elbow, knee, shoulder, hip, wrist, ankle 2) elbow, knee, shoulder, hip, wrist, ankle 3) shoulder and hip 4) shoulder and hip 5) joint between radius and ulna 6) joint between radius and ulna

Activity 3.

1) flexes (and adducts) arm; origin = IJ; insertion = A
2) extends (and adducts) arm; origin = K; insertion = L
3) flexes (and supinates) arm; origin = G; insertion = H
4) flexion at wrist; origin = M; insertion = X and Y
5) pronation of forearm; origin = M; insertion = H
6) flexes forearm; origin = A; insertion = B
7) flexes forearm; origin = C; insertion = D
8) abduction of thigh; origin = G; insertion = P
9) extends (and abducts) thigh; origin = E; insertion = C
10) flexes leg; origin = A; insertion = H and B
11) flexes and rotates leg (flexes thigh); origin = E; insertion = D
12) plantar flexes foot; origin = B and H; insertion = Y
13) plantar flexes foot; origin = N; insertion = X
14) origin = E; insertion = F
15) origin = L and G; insertion = O
16) origin = O; insertion = Z and V
17) origin = M; insertion = H
18) origin = L; origin = O
19) origin = O; insertion = U
20) origin = E; insertion = O or S

Activity 4.

1) triceps brachii 2) pectoralis major 3) supinator 4) wrist flexors 5) quadriceps 6) leg adductors 7) gastrocnemius 8) brachialis, brachioradialis and biceps brachii

Activity 5.

1) variable; approximately 30 cm.
2) variable but should be greater than answer one; approximately 30 cm.
3) brachioradialis; brachioradialis
4) approximately 2 cm; approximately 15 cm; greater
5) approximately 22 cm; approximately 15 cm; brachialis; brachialis

Notes to Instructor for Activity 5

In the above example two muscles of the same strength cross and act on the elbow joint. The brachialis is inserted closer to the joint than the brachioradialis. Though equal in distance between points of origin and insertion, the brachioradialis produces a more powerful movement, as evidenced by the increase in weight required to extend the forearm. Therefore, the strength of movement depends on placement of the insertion. The further the point of insertion is from the joint, the greater the lever advantage or strength in moving the forearm.

In looking at the range of motion in this experiment, the brachialis moves the hand through a greater range than the brachioradialis for a given degree of contraction. This is because the insertion is closer to the joint and a small contraction leads to a large movement of the forearm. The range of movement decreases with insertion distance from the joint and strength increases with insertion distance. Thus, maximal strength and maximal range of motion are incompatible in the same muscle. For this reason, acting on each joint are different groups of flexors (extensors, etc.) which are specialized for strength or range of motion.

Activity 6.

1) approximately 25 cm
2) approximately 120°
3) approximately 24 cm; approximately 90°
4) approximately 23 cm; approximately 60°
5) the arm with three rubber bands; the arm with three rubber bands

Additional Activities

The above activities are meant to be an introduction to the study of muscle function. Additional muscle groups can be added by simply attaching more cup hooks. Since the model works well for both the arm and leg, comparative studies of limb movement can be accomplished. Attach muscles to two models, one assembled as the arm and the other as the leg, and determine which muscles perform the same relative movements. For example, compare abduction of the arm (deltoid muscle) with abduction of the thigh (tensor fascia latae).

To study the relative tension in different muscle groups and their action over more than one joint, the student can stimulate a given anatomical position on the model. For example, the arm can be held in the classic "flexed biceps" position. This requires the student to select and attach the appropriate "muscle" rubber bands.