

# Muscular System

## Course

Anatomy & Physiology

## Unit VII

Muscular System

## Essential Question

What are the tissues and systems of the human body?

## TEKS

130.206 (c)  
1A, 1B  
2A, 2B, 2C, 2D,  
2E, 2F, 2G, 2H  
3A, 3B, 3C, 3D,  
3E, 3F  
4D  
5A, 5B, 5C, 5D, 5E  
6A, 6B  
7A, 7B, 7C  
9A, 9B  
10A, 10B, 10C,  
10D  
11A

## Prior Student Learning

Understanding of the cell & tissues biology. Good understanding of body directional terms.

## Rationale

To pursue a career in health care, proficiency in anatomy and physiology is vital.

## Objectives

Upon completion of this lesson, the student will be able to:

- define and distinguish terms pertaining to the muscular system;
- compare and contrast the basic function of the 3 major types of muscle;
- analyze forces and the effects of movement, torque, tension, and elasticity on the human body;
- identify changes in structure and function due to trauma and disease;
- analyze diseases and disorders of the muscular system;
- investigate some of the factors that affect skeletal muscle fatigue; and
- investigate the effects of isometric (static) exercise on cardiovascular response.

## Engage

How does the muscle system work? What happens when muscles get tired?

## Key Points

- I. Introduction
  - A. Over 600 muscles make up muscular system
  - B. 45% of total body weight of an adult
  - C. Made up of bundles of muscle fibers (long slender cells) held together by connective tissue
  - D. When muscle fibers are stimulated by nerves they contract (become short and thick) which causes movement
  - E. Contraction depends on myofilaments: actin and myosin
  - F. Properties
    1. Excitability: ability to receive and respond to a stimulus (neurotransmitter, hormone, local change in pH); response is the generation and transmission of an electrical current (action potential)
      - a. Skeletal muscle responds to stimulus quickly with forceful contraction and then relaxes promptly
      - b. Visceral muscle responds slowly, maintaining contraction over a longer period of time

**Estimated time**  
8-12 hours

c. Cardiac muscle is quicker than visceral muscle and contraction is stronger but of longer duration

2. Contractility: ability to shorten forcibly
3. Extensibility: ability to be stretched
4. Elasticity: ability to resume resting length (of muscle fiber) after being stretched
5. Automaticity: ability of muscle to contract without a nerve supply

#### G. Functions

1. Movement: locomotion/manipulation, heartbeat, moving substances through hollow organs
2. Posture maintenance
3. Stabilization of joints
4. Generation of heat
5. Protection of some internal organs

## II. Types of Muscles

### A. Cardiac

1. Form walls of heart
2. Contract to circulate blood
3. Striated (banded) with lots of mitochondria
4. Involuntary: function without conscious thought or control (autonomic nervous system control)
5. Efferent nerves control rate of contraction based on needs of the body
6. Afferent nerves concerned with sensations of pain, spasm, and stretch
7. Contract at steady rate except for brief bursts of rapid rate, automaticity

### B. Visceral/smooth

1. Found in the internal organs of the body such as the digestive system, respiratory system, blood vessels, and eyes
2. Walls of hollow, visceral organs
3. No striations = smooth
4. Involuntary: function without conscious thought or control (autonomic nervous system control)
5. Efferent (motor) neurons less important
6. Afferent nerves concerned with sensations of pain, spasm, and stretch
7. Steady constant contractions, automaticity

### C. Skeletal

1. 40% of body
2. Attach to and cover bony skeleton

3. Longest fibers of all muscle cells
4. Striated
5. Voluntary: person has control over their action (central and peripheral nervous system control)
6. Efferent nerve fibers from brain and spinal cord send impulses for contraction
7. Afferent nerve fibers from muscle send message to CNS to inform brain of the degree of contraction
8. Contract rapidly, tire easily, tremendous power, adaptable
9. Cause body movement

### III. Methods of Attachment of Skeletal Muscle to Bone

#### A. Tendon

1. Strong, tough connective tissue cord
2. Examples: Achilles tendon which attaches the gastrocnemius muscle on the calf of the leg to the heel bone

#### B. Fascia

1. Tough, sheet-like membrane
2. Covers and protects tissue
3. Example: lumbodorsal fascia which surround the deep muscles of the trunk and back

#### C. Aponeurosis: broad, flat sheet

#### D. Raphe: seam of fibrous tissue

#### E. Origin and Insertion

1. When muscles attach to bones, one end becomes the origin and one end becomes the insertion
2. Origin: end that does not move; usually proximal to insertion
3. Insertion: end that moves when muscle contracts

#### F. Direct (fleshy): epimysium fused to periosteum or perichondrium

#### G. Indirect: more common due to durability and size

1. Connective tissue wrappings extend to form tendons, aponeurosis
2. Anchors muscle to connective tissue of bone or cartilage, fascia of other muscles, or raphe

### IV. Gross and Microscopic Anatomy of Skeletal Muscle

#### A. Each muscle is an organ

#### B. 100's to 1000's of muscle fibers per muscle

#### C. Connective tissue, blood vessels, and nerve fibers

#### D. Connective Tissue Wrappings

1. Endomysium: fine sheath of areolar connective tissue around each muscle fiber

2. Perimysium: collagenic sheath around several muscle fibers bundled together (fascicles)
  3. Epimysium: dense fibrous connective tissue surrounding entire muscle
  4. Deep fascia: fibrous connective tissue that binds muscles into functional groups and wraps other structures
- E. Nerve and Blood Supply
1. Each muscle fiber has nerve ending to control activity
  2. Each muscle has one artery and one or more veins due to tremendous energy needs and metabolic waste production
  3. Enters central part of muscle and branches throughout connective tissue including endomysium for each muscle fiber
- F. Arrangement of Fascicles
1. Determine range of motion and power
  2. Results in muscles with different shapes and functional capabilities
  3. The more fibers “packed “ in, the more powerful
  4. The more parallel the fibers are to the long axis of the muscle, the more they can shorten
  5. Parallel: long axes parallel to long axis is muscle i.e. straplike sartorius or fusiform (spindle shaped) midsection of biceps brachii
  6. Pennate (feather-like): central tendon with short fascicles attached obliquely i.e. unipennate (insertion into only one side of the tendon) -- extensor digitorum; bipennate (most fibers per space therefore very powerful) – rectus femoris; multipennate – deltoid
  7. Convergent: broad origin, fascicles converge toward single tendon i.e. pectoralis major
  8. Circular: fascicles in concentric rings i.e. sphincters – surround external body openings (orbicularis oris, orbicularis oculi)
- G. Microscopic Anatomy
1. Long cylindrical cell with multiple oval nuclei
  2. Sarcolemma: plasma membrane
  3. Syncytium: each muscle fiber is the union of hundreds of embryonic cells
  4. Sarcoplasm: large amount of stored glycogen, some modified organelles, myoglobin (red pigment that stores oxygen)
  5. Myofibrils: “superorganelles”, contractile elements of skeletal muscle cells that consist of chain of smaller

- contractile units (sarcomeres); make up 80% of cell volume; functional unit = chains of sarcomeres
6. Sarcomere: smallest contractile unit of a muscle fiber
  7. Thick filaments: myosin (tail and 2 heads called crossbridges because they link thick and thin myofilaments together during contraction)
  8. Thin filaments: actin with tropomyosin and troponin which help control myosin-actin interactions
  9. Sarcoplasmic reticulum: elaborate smooth endoplasmic reticulum surrounding each myofibril; regulates intracellular levels of ionic calcium (stores and releases it on demand)
  10. T-tubules: where sarcolemma penetrates cell to form hollow elongated tube; conducts nerve impulses to deepest regions of muscle cell

#### H. Muscle Fiber Types

1. Identified on basis of differences in size, speed, endurance
2. Red-slow twitch fibers
  - a. Thin fibers
  - b. Slow acting myosin ATPases
  - c. Red color - large amounts of myoglobin
  - d. Fat metabolism
  - e. Fatigue resistant – aerobic pathways
  - f. High endurance
  - g. Not much power
3. White-fast twitch fibers
  - a. Little myoglobin
  - b. Diameter 2x red slow twitch fibers
  - c. Fast acting myosin ATPases
  - d. Large glycogen reserves (glycolytic fibers)
  - e. Anaerobic pathways
  - f. Fatigable fibers
  - g. Short term, rapid, intense movements
4. Intermediate-fast twitch fibers
  - a. Fast acting
  - b. Fast acting myosin ATPases
  - c. Oxygen dependent
  - d. High myoglobin content
  - e. Less fatigue resistant than red slow twitch fibers
5. Muscles contain a mixture of muscle fiber types
6. Sprinting - white fast twitch 60%
7. Marathon - red slow twitch 80%
8. Posture - red slow twitch
9. Weight lifters - white fast twitch = red slow twitch

## V. Physiology of Skeletal Muscle Contraction

### A. Energy Sources

1. Breakdown of adenosine triphosphate (ATP)
2.  $\text{ATP} \leftrightarrow \text{ADP} + \text{PO}_2 + \text{energy}$
3. Energy for resynthesis comes from breakdown of carbohydrates, i.e. glycogen or glucose which then results in formation of pyruvic acid
4. Results depend on amount of oxygen available
  - a. Moderate activity, adequate amounts of oxygen - pyruvic acid converted to  $\text{CO}_2 + \text{H}_2\text{O} + \text{energy}$
  - b. Strenuous activity, not enough oxygen - pyruvic acid converted to lactic acid = oxygen debt = cramps
  - c. Oxygen debt: extra amount of  $\text{O}_2$  that must be taken in by the body for restorative processes; difference between the amount of  $\text{O}_2$  needed for totally aerobic respiration during muscle activity and the amount that is actually used

### B. Contractility

1. Involves protein filaments: actin and myosin located in sarcoplasm
2. Chemical changes:
  - a. Nerve impulse alters sarcolemma
  - b. Sodium enters cell and causes release of calcium from sarcoplasmic reticulum
  - c. Calcium combines with troponin on the actin to cause contraction
  - d. Relaxation of muscle requires energy to transport calcium back into the sarcoplasmic reticulum
3. Electrical changes
  - a. Clinical significance: diagnostics i.e. EKG, EEG, EMG
  - b. All or None Law: each muscle cell, when stimulated, gives total response or it does not contract at all
  - c. Strength depends on the number of muscle cells stimulated and the condition of the muscle

### C. Force of Contractions

1. Number of muscle fibers contracting
2. Relative size of muscle (regular exercise increases strength by causing muscle cells to hypertrophy)
3. Series-elastic elements: muscle must be attached to movable structures and connective tissues must be pulled taut (stretch and recoil), transfer tension to the

load

4. Degree of muscle stretch: a severely stretched muscle cannot develop tension

#### D. Muscle Tone

1. Steady partial contraction present at all times
2. State of tension when awake
3. State of readiness to act; enables muscles for immediate response
4. Does not produce active movement
5. Keeps muscles firm healthy
6. Stabilizes joints
7. Maintains posture
8. Loss of muscle tone
  - a. Can occur in severe illness such as paralysis, palsy
  - b. When muscles are not used for a long period of time: atrophy, waste away (degeneration and loss of mass)
  - c. Complete immobilization of muscle (complete bed rest or loss of neural stimulation or in a cast): strength decreases 5% per day; paralysis = atrophy to  $\frac{1}{4}$  initial size; muscle tissue replaced by fibrous connective tissue - muscle rehabilitation impossible; delay with electrical stimulation
  - d. Lack of use can result in contracture (permanent contraction of muscle due to spasm or paralysis)
    - (1.) Severe tightening of a flexor muscle
    - (2.) Results in bending of a joint
    - (3.) When no ATP available, state of continuous contraction results because crossbridges are unable to detach
    - (4.) Foot drop = common
    - (5.) Fingers, wrists and knees as well as other joints can be affected
9. Rigor mortis: muscle shortens, becomes rigid due to decrease in ATP
10. Muscle fatigue
  - a. Muscle unable to contract
  - b. Tension drops to zero
  - c. Inability to generate enough ATP to power the contractile process
  - d. Relative deficit of ATP -- NOT total absence
  - e. Excessive accumulation of lactic acid and ionic imbalances
11. Spasm: sudden involuntary contraction of muscle

12. Clonic: alternating spasm with relaxation
13. Tonic: sustained
14. Tetanus: smooth sustained contraction
15. Tetany: result of low calcium; increases excitability of neurons; loss of sensation, muscles twitching, convulsions; untreated - spasms of larynx, respiratory paralysis, death

#### E. Sliding Filament Theory

1. Individual sarcomeres shorten, myofibrils shorten, whole cell shortens
2. Thin filaments slide past thick filaments so actin and myosin overlap
3. Muscle fibers activated by nervous system, crossbridges attach to active (myosin binding) sites on actin pulling thin filaments toward center of sarcomere (multiple attachments and detachments); requires calcium
4. Crossbridge attachment, power stroke, crossbridge detachment, "cocking" of myosin head
5. Single power stroke of all crossbridges in muscle results in shortening of only 1% (most muscles shorten 30% - 35%) therefore multiple attach-detach sequences needed
6. Actin – myosin irreversibly crosslinked due to calcium influx into cell
7. Rigor mortis: illustrates that crossbridge detachment is ATP driven; muscles begin to stiffen 3 – 4 hours after death; peak rigidity at 12 hours; stiffness dissipates over next 48 – 60 hours

#### F. All or None Response

1. Once the muscle fiber has been stimulated to contract, the muscle fiber will contract to its fullest extent
2. Each muscle is served by at least one motor nerve, which contains hundreds of neuromuscular junctions with each single muscle fiber
3. Motor neuron and all the muscle fibers that it supplies is called a motor unit
4. When a motor neuron fires, all the muscle fibers that it innervates respond by contracting
5. Average 150 muscle fibers per motor unit
6. Average 4 to several hundred muscle fibers per motor unit for fine motor control i.e. controlling fingers and eye movements

#### G. Neuromuscular Junction

1. Motor neurons stimulate muscle fibers

2. Axons divide and end at each of the single muscle fibers forming the neuromuscular junction
3. Synaptic cleft: calcium and acetylcholine (neurotransmitter) fill cleft, attach to the receptors, and stimulate muscle fiber to contract (ACh is broken down immediately)
4. Curare (used for intubation anesthesia) and organophosphate poisons bind to the receptor sites and block ACh attachment

## VI. Interactions of Skeletal Muscles

A. Muscles do not act independently

B. Prime Mover/Agonist

1. Provides major force for producing a specific movement
2. Initiates movement
3. Example: biceps brachii - elbow flexion

C. Antagonist

1. Oppose or reverse a particular movement
2. Example: triceps brachii - elbow extension

D. Synergist

1. Aid agonists by promotion of same movement or by reducing undesirable/unnecessary movements
2. Example: muscles which help make fist without bending wrist

E. Fixator

1. Synergists which immobilize a bone or a muscle origin
2. Example: muscles to stabilize scapula

## VII. Actions or Movements of Skeletal Muscles

A. Goniometry: measurement of joint movement

B. Adduction: moving a body part toward the midline

C. Abduction: moving a body part away from the midline

D. Flexion: decreasing the angle at a joint

E. Extension: increasing the angle at a joint

F. Hyperextension: increases the angle beyond the anatomical position

G. Circumduction: the distal end of an extremity inscribes a circle while the shaft inscribes a cone

H. Rotation: revolving a part about the longitudinal axis

1. Internal: move toward the midline or medially
2. External: move away from the midline or laterally

I. Supination: turn the palm upward; "what's up?"

J. Pronation: turn the palm downward

K. Inversion: turn the plantar surface away from the midline

- L. Plantar flexion (extension): move the sole of the foot downward as in standing on the toes
- M. Dorsiflexion: move the sole of the foot upward

#### VIII. Muscle Nomenclature

- A. Location i.e. external oblique, pectoralis
- B. Origin and insertion i.e. brachioradialis, occipitofrontal
- C. Number of heads i.e. biceps, triceps
- D. Function i.e. ulnar flexor (flexes wrist), buccinator (cheek muscle used to blow a trumpet)
- E. Size i.e. vastus medialis
- F. Shape i.e. deltoid
- G. Orientation of bundles of muscle fibers i.e. rectus abdominus (straight muscle of abdomen), orbicularis oris (circular around mouth)
- H. Adjectives to describe muscles
  1. bi-, tri-, quadri- : 2, 3, 4
  2. Externus: exterior
  3. Gracilis: slender
  4. Latissimus: wide
  5. Longissimus: long
  6. Longus: long
  7. Medius: intermediate
  8. Orbicularis: around
  9. Quadratus: square
  10. Rectus: straight
  11. Rhomboideus: diamond shaped
  12. Scalenes: irregular triangle
  13. Teres: round
  14. Transverse: crosswise
  15. Vastus: great

#### Activity

- I. Identify anatomical structures of muscular system on dissected cat. (*This can be accomplished as a virtual tour on the internet, or if your budget allows, the students can dissect cats.*)
- II. Identify and label the skeletal muscles.
- III. Role play the Muscle Mechanic's Skit.
- IV. Complete the Muscle Madness Activity.
- V. Complete the Muscle Memory Activity.
- VI. Complete the Muscle System Vocabulary.
- VII. Research and report on the cause and effect of disease, trauma, and congenital defects on the structure and function of cells, tissues, organs, and systems as well as research technological advances and limitations in the treatment of muscle skeletal system disorders.
- VIII. Complete the Investigating Muscle Fatigue Laboratory Investigation.
- IX. Complete the Chicken Leg Activity.

## **Assessment**

Successful identification of skeletal muscles  
Successful completion of activities.  
Laboratory Investigation Rubric

## **Materials**

Activity I. Dissection Cat --1 for every 2-4 students, and dissection tools AND/OR computers with internet access  
Activity II. Copies major skeletal muscle diagram for students to label  
Activity III. Copies Muscle Mechanic's Skit  
Activity IV. Copies of Muscle Madness Activity  
Activity V. Copies of Muscle Memory Activity  
Activity VI. Copies of Muscle System Vocabulary  
Activity VII. Computers with internet access  
Activity VIII. Copies of Investigating Muscle Fatigue Procedure and Work Sheet for each student and the following supplies:  
Grip exerciser or spring clamp  
Metric ruler  
Blood pressure cuff  
Grip dynamometer  
Stopwatch  
Two sphygmomanometers  
Stethoscope  
Activity IX. Copies of Chicken Leg Activity Handout and the following supplies:  
Hind quarter chicken parts (contact the local butcher for these)  
Small dissection or fingernail scissors  
Forceps or tweezers  
4x4 gauze sponges  
Foam meat trays  
Gloves  
Paper towel  
Wet wipes  
Table covering

## **Accommodations for Learning Differences**

For reinforcement, the students will color and label a diagram of the muscles of the body.

For enrichment, the students will research and report on a neuromuscular disease.

## **National and State Education Standards**

### National Health Science Cluster Standards

#### HLC01.01 Academic Foundations

Health care workers will know the academic subject matter required (in addition to state high school graduation requirements) for proficiency within their area. They will use this knowledge as needed in their role.

#### HLC10.01 Technical Skills

Health Care Workers will apply technical skills required for all career specialties. They will demonstrate skills and knowledge as appropriate.

### **TEKS 130.206 (c)**

- (1) (A) demonstrate safe practices during laboratory and field investigations;  
(B) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials;
- (2) (A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;  
(B) know that hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;  
(C) know scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but they may be subject to change as new areas of science and new technologies are developed;  
(D) distinguish between scientific hypotheses and scientific theories;  
(E) plan and implement descriptive, comparative, and experimental investigations, including asking questions, formulating testable hypotheses, and selecting equipment and technology;  
(F) collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as calculators, spreadsheet software, data-collecting probes, computers, standard laboratory glassware, microscopes, various prepared slides, stereoscopes, metric rulers, electronic balances, hand lenses, Celsius thermometers, hot plates, lab notebooks or journals, timing devices, Petri dishes, lab incubators, dissection equipment, meter sticks, and models, diagrams, or samples of biological specimens or structures;  
(G) analyze, evaluate, make inferences, and predict trends from data;  
(H) communicate valid conclusions supported by the data through methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports;
- (3) (A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of

- scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;
- (B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;
- (C) draw inferences based on data related to promotional materials for products and services;
- (D) evaluate the impact of scientific research on society and the environment;
- (E) evaluate models according to their limitations in representing biological objects or events;
- (F) research and describe the history of science and contributions of scientists.
- (4) (D) analyze the effects of energy excess in disorders such as obesity as it relates to cardiovascular and musculoskeletal systems;
- (5) (A) explain the coordination of muscles, bones, and joints that allows movement of the body;
- (B) investigate and report the uses of various diagnostic and therapeutic technologies;
- (C) interpret normal and abnormal contractility conditions such as in edema, glaucoma, aneurysms, and hemorrhage;
- (D) analyze and describe the effects of pressure, movement, torque, tension, and elasticity on the human body;
- (E) perform an investigation to determine causes and effects of force variance and communicate findings;
- (6) (A) investigate and describe the integration of the chemical and physical processes, including equilibrium, temperature, pH balance, chemical reactions, passive transport, active transport, and biofeedback, that contribute to homeostasis;
- (B) determine the consequences of the failure to maintain homeostasis;
- (7) (A) illustrate conduction systems such as nerve transmission or muscle stimulation;
- (B) investigate the therapeutic uses and effects of external sources of electricity on the body system;
- (C) evaluate the application of advanced technologies such as electroencephalogram, electrocardiogram, bionics, transcutaneous electrical nerve stimulation, and cardioversion;
- (9) (A) identify the effects of environmental factors such as climate, pollution, radioactivity, chemicals, electromagnetic fields, pathogens, carcinogens, and drugs on body systems;
- (B) explore measures to minimize harmful environmental factors on body systems;
- (10) (A) analyze the relationships between the anatomical structures and physiological functions of systems, including the integumentary, nervous, skeletal, musculoskeletal, cardiovascular, respiratory,

- gastrointestinal, endocrine, and reproductive;
  - (B) evaluate the cause and effect of disease, trauma, and congenital defects on the structure and function of cells, tissues, organs, and systems;
  - (C) research technological advances and limitations in the treatment of system disorders;
  - (D) examine characteristics of the aging process on body systems; and
- (11) (A) explain embryological development of tissues, organs, and systems.

#### Texas College and Career Readiness Standards

##### English Language Arts

II. B. Understand new vocabulary and concepts and use them accurately in reading, writing, and speaking.

III. B. Develop effective speaking styles for both group and one-on-one situations.

IV. A. Apply listening skills as an individual, and as a member of a group in a variety of settings.

B. 2. Listen actively and effectively in one-on-one communication situations.

##### Science

1.A.1. Utilize skepticism, logic, and professional ethics in science.

1.A.2. Use creativity and insight to recognize and describe patterns in natural phenomena.

1.A.3. Formulate appropriate questions to test understanding of a natural phenomenon.

1.A.4. Rely on reproducible observations of empirical evidence when constructing, analyzing, and evaluating explanations of natural events and processes.

1.E.2. Use essential vocabulary of the discipline being studied.

3.A.1. Use correct applications of writing practices in scientific communication

# **Muscle Madness**

**Developed by Dr. J. Stephen Robinson**

**Objective:** To identify muscles on an atlas

## **Materials**

Overhead  
Transparencies of muscle views  
Paper sheets (8" x 5 ½ ) with names of muscles

## **Preparation**

1. Prepare transparencies of muscle locations from an atlas (easily found on Internet).
2. Color in 4-5 muscles using a different color for each muscle.
3. Cut 8 ½ "x11" sheets of paper in half (width-wise) for as many muscles as are being studied.
4. Write the name of a muscle on each sheet one set in red and another in black.
5. Stack the muscle name-sheets in two piles (red and black) on a table in the front of the room.

## **Competition**

1. Divide the class into two equally skilled teams and have them choose team names.
2. Make a scoreboard on the whiteboard to tally the points.
3. Each team selects a player to go on the first turn.
4. The instructor places a covered transparency on the overhead and announces a color; the transparency is then uncovered for about 5 seconds.
5. The designated player for each team rushes to the front table and searches in the stack of muscles for the correct name.
6. When found, the player raises it over his/her head and immediately calls out the name of the muscle.
7. If correct, the instructor states "correct." If wrong the instructor says nothing.
8. The team that identifies the muscle correctly first gets a point for their team.
9. The team with the most points wins.

## **Comments**

Four or five transparencies with 4-5 muscles each should suffice. It is important that teammates do not shout out the name of the muscle or in any other way assist the player designated to go to the stacks. Penalty points can be assessed for breaking this rule. A variation is to let the students use their notes the first time and then play by memory only.

# Muscle Memory

Developed by Dr. J. Stephen Robinson

**Objective:** To match muscles with their actions using a “Sticky Cloth”

**Materials:**

- Satin or sateen cloth (4' x 8') of dark color
- White board or display board large enough for the cloth
- Can of Dry Mount spray
- Paper sheets (8" x 5 ½ ) with names of muscles
- Paper sheets (8" x 5 ½ )with actions above muscles

**Preparation:**

1. Hang the sateen cloth on whiteboard or on wall
2. Spray the cloth with Dry Mount spray (preferably the night before).
3. Cut 8 ½x11" sheets of paper in half (width-wise) for as many muscles as are being studied.
4. Write the name of a muscle on one sheet and its corresponding action on another sheet of paper using large, clearly legible lettering (black marker for muscles and red marker for actions). Be certain the ink does not bleed through the paper.
5. Suspend a string dividing the cloth into left and right halves.
6. Stick the muscle name-sheets face in (toward the wall) on the left side of the cloth in random order.
7. Stick the muscle action sheets similarly face in on the right side.

**Competition**

1. Divide the class into two equally skilled teams and have them choose team names.
2. Make a scoreboard on the whiteboard to tally the points.
3. Flip a coin to decide which team goes first.
4. The first team selects a player to go on the first turn.
5. The player goes to the cloth and chooses a muscle sheet from the left side and attempts to choose a matching sheet from the action (right) side.
6. If they do not match, the sheets are turned over again and the player returns to his team. Usually the first several players will not be successful because they are working with the most unknowns.
7. The other team sends a player to the board to repeat the matching game.
8. If a match is made, the sheets are left face out for the rest of the game, and the team gets one point.
9. This continues alternating teams until all the muscles have been matched.
10. The team with the most points wins.

**Comments**

The sticky cloth is a good tool to use for teaching as it can be used to stick up all sorts of messages and does not require tape, tacks, or staples. Plus the sheets can be changed or removed quickly and thus re-arranged. It is a great tool with which to do concept webs (mind mapping) or to plan a program. This tool has an advantage over the flannel board as any type of thin paper can be used for the drawings. Once the cloth is prepared, it need only be sprayed once every 40-50 uses. I have gone for a whole year without needing to re-spray the cloth. When not in use, roll it up (sticky side in) and secure it above the whiteboard until needed again.

## Muscles: Name, Location, Function

Location/Function	Name	Origin/Insertion	Action
<b>Scalp</b>	Frontalis no bony attachments	O = galea aponeurotica I = skin of eyebrows & root of nose	Raises eyebrows; wrinkles forehead skin horizontally
	Occipitalis	O = occipital bone I = galea aponeurotica	Fixes aponeurosis; pulls scalp back posteriorly
<b>Face</b>	Orbicularis oculi	O = frontal & maxillary bones & ligaments around orbit I = tissue of eyelid	Winking, blinking, squinting, "crow's feet" of aging
	Zygomaticus	O = zygomatic bone I = skin & muscle at corner of mouth	Smiling muscle
	Orbicularis oris	O = indirect from maxilla & mandible I = muscle & skin at angles of mouth	"kissing" muscle, "tragedy mask" muscle
	Buccinator	O = molar region of maxilla & mandible I = orbicularis oris	Whistling, blowing, sucking, holds food between teeth
<b>Mastication</b>	Masseter	O = zygomatic arch I = angle & ramus of mandible	Prime mover of jaw closure; elevates mandible
	Temporalis	O = temporal fossa I = coronoid process of mandible via tendon that passes beneath the zygomatic arch	Synergist muscle for jaw closure
<b>Tongue Movement</b>	Genioglossus	O = internal surface of mandible near symphysis I = inferior aspect of tongue & body of hyoid bone	Protrudes tongue, can depress tongue with other muscles
	Styloglossus	O = styloid process of temporal bone I = lateral inferior aspect of tongue	Retracts & elevates tongue
<b>Anteriolateral Neck</b>	Sternocleidomastoid	O = manubrium of sternum & medial portion	Prime mover of active head

		of clavicle I = mastoid process of temporal bone	flexion
	Scalenes	O = transverse processes of cervical vertebrae I = anterolateral on first 2 ribs	Elevate first 2 ribs (inspiration); important in coughing; flex & rotate neck
<b>Thorax: Breathing</b>	External Intercostals	O = inferior border of rib above I = superior border of rib above	Pulls ribs toward one another to elevate the rib cage; inspiration
	Internal Intercostals	O = superior border of rib below I = inferior border (costal groove) of rib above	Depress rib cage; expiration
	Diaphragm	O = inferior border of rib cage & sternum, costal cartilage of last 6 ribs & lumbar vertebrae I = central tendon	Prime mover of inspiration
<b>Anterior/Posterior Thorax</b>	Pectoralis minor	O = anterior surfaces of ribs 3 – 5 I = coracoid process of scapula	Ribs fixed = draws scapula forward & downward; Scapula fixed = draws rib cage superiorly
	Trapezius	O = occipital bone, ligamentum nuchae, spines of C7, all thoracic vertebrae I = continuous along acromium & spine of scapula & lateral third of clavicle	Stabilizes, raises, retracts, rotates scapula; shrug shoulders, extend head
	Rhomboids	O = spinous processes of C7 & T1 (minor) & spinous processes of T2 – T5 (major) I = medial border of scapula	Act with trapezius to “square shoulders”; rotate scapula, “paddling” a canoe, stabilize scapula
<b>Crossing Shoulder Joint/Movement of</b>	Pectoralis major	O = clavicle, sternum, cartilage of ribs 1 – 6, aponeurosis of external	Prime mover for shoulder flexion & adduction; prime

<b>Humerus</b>		oblique muscle I = short tendon into greater tubercle of humerus	mover of arm flexion & adduction
	Latissimus dorsi	O = indirect attachment via lumbodorsal fascia into spines of lower 6 thoracic vertebrae, lumbar vertebrae, lower 3-4 ribs, iliac crest I = floor of intertubercular groove of humerus	Adducts shoulder; extension of shoulder joint; "swimmer's back" muscles; prime mover of arm extension; arm adductor
	Deltoid	O = insertion of trapezius, lateral third of clavicle, acromium & spine of scapula I = deltoid tuberosity of humerus	Flexion & medial rotation of humerus
	Rotator cuff muscles: supraspinatus, infraspinatus, teres minor, subscapularis	O = fossa of scapula, lateral border of dorsal scapular surface I = greater tubercle of humerus	Stabilizes shoulder joint, prevents downward dislocation of humerus, holds head of humerus in glenoid cavity, rotates humerus laterally
<b>Anterior/Lateral Abdominal Wall</b>	Rectus abdominus	O = pubic crest & symphysis I = xiphoid process & costal cartilage of ribs 5 – 7	Flex & rotate lumbar region of vertebral column; fix & depress ribs, stabilize pelvis, increase intra-abdominal pressure
	External oblique	O = fleshy strips from outer surfaces of lower 8 ribs I = linea alba, pubic crest & tubercle, iliac crest	Aids rectus abdominus; aids muscles of back in trunk rotation & lateral flexion
	Internal oblique	O = lumbodorsal fascia, iliac crest, inguinal ligament I = linea alba, pubic crest, last 3 ribs	Same as external obliques

	Tranversus abdominus	O = inguinal ligament, lumbodorsal fascia, cartilages of last 6 ribs, iliac crest I = linea alba, pubic crest	Compresses abdominal contents
<b>Muscles Crossing Elbow Joint/Flexion &amp; Extension of Forearm</b>	Triceps brachii	O = scapula, humerus I = olecranon process of ulna	Prime mover of forearm extension, assists in arm adduction, stabilizes shoulder
	Biceps brachii	O = Humerus I = radial tuberosity	Flexes elbow joint, supinates forearm
	Brachialis	O = humerus & deltoid muscle I = ulna & capsule of elbow joint	Major forearm flexor
<b>Muscles of Forearm Movement of Wrist, Hand, Fingers</b>	Pronator teres	O = humerus & ulna I = radius	Pronates forearm
	Flexor carpi radialis	O = humerus I = metacarpals (guide for radial pulse)	Flexor of wrist, abducts hand
	Flexor carpi ulnaris	O = humerus & ulna I = metacarpals	Flexor of wrist, adducts hand, stabilizes wrist
	Flexor digitorum profundus	O = ulna I = distal phalanges	Finger flexor
	Pronator quadratus	O = ulna I = radius	Pronates forearm
	Extensor carpi radialis longus & brevis	O = humerus I = metacarpal	Extends & abducts wrist
	Extensor digitorum	O = humerus I = phalanges	Prime mover of finger extension
	Abductor pollicis longus	O = radius & ulna I = metacarpal	Abducts & extends thumb
	Extensor pollicis brevis & longus	O = radius & ulna I = thumb	Extends thumb

<b>Muscles Crossing Hip and Knee Joints</b>	Sartorius	O = anterior superior iliac spine I = tibia	“Tailor’s muscle”; flexes & laterally rotates knee; crosses leg
	Adductor longus	O = pubic symphysis I = linea aspera	Adducts, flexes, laterally rotates thigh
	Gracilis	O = pubis I = tibia	Adducts thigh, flexes, medially rotates leg when walking
	Rectus femoris	O = iliac spine, acetabulum I = patella, tibia	Extends knee, flexes thigh
	Vastus lateralis	O = greater trochanter I = patella, tibia	Extends knee
	Vastus medialis	O = linea aspera I = patella, tibia	Extends knee, stabilizes patella
	Vastus intermedius	O = femur I = patella, tibia	Extends knee
	Gluteus maximus	O = ilium, sacrum, coccyx I = femur	Major extensor of thigh
	Gluteus medius	O = ilium I = femur	Abducts, medially rotates thigh, steadies pelvis, critical in walking
	Gluteus minimus	O = ilium I = femur	Same as gluteus medius
	Biceps femoris	O = ischium, femur I = fibula, tibia	Extends thigh, flexes knee, laterally rotates leg
	Semitendinosus	O = ischium I = tibia	Extends thigh, flexes knee, medially rotates leg
	Semimembranosus	O = ischium I = tibia	Same as semitendinosus
<b>Muscles That Move Ankle and Toes</b>	Tibialis anterior	O = tibia I = metatarsal	Prime mover of dorsiflexion, inverts foot
	Extensor digitorum longus	O = tibia I = phalanges	Dorsiflexes foot, prime mover of toe extension

	Gastrocnemius	O = femur I = calcaneus	Plantar flexes foot, can flex knee
	Soleus	O = tibia, fibula I = calcaneus	Plantar flexes ankle, important for walking, running, dancing

## Muscular System Vocabulary

1. abduct:
2. actin:
3. action potential:
4. adduct:
5. aerobic:
6. aerobic endurance:
7. aerobic exercise:
8. anaerobic:
9. anaerobic threshold:
10. antagonist:
11. aponeurosis:
12. arrector pili:
13. ataxia:
14. atrophy:
15. biceps:
16. calcaneal tendon:
17. calcium channel blockers
18. contraction:
19. contracture:
20. convulsion:
21. cramp:
22. effector:
23. electromyography:
24. endomysium:
25. epimysium:
26. fascia:
27. fascicle:
28. fibromyositis:
29. fibrosis:
30. fibrositis:
31. fixator:
32. flaccid:
33. fulcrum:
34. hernia:
35. hypertrophy:
36. insertion:
37. irritability:
38. isometric contraction:
39. isotonic contraction:
40. kymograph:
41. lever system:
42. mechanical advantage:
43. mechanical disadvantage:
44. muscle fatigue:
45. muscle spindle:

46. muscle tone:
47. myalgia:
48. myectomy:
49. myoclonus:
50. myofibril:
51. myofilament:
52. myoglobin:
53. myokymia:
54. myoma:
55. myomalacia:
56. myopathy:
57. myosclerosis:
58. myositis:
59. myosin:
60. myotonia:
61. origin:
62. paralysis:
63. peristalsis:
64. perimysium:
65. pronation:
66. resistance exercise:
67. RICE:
68. sarcomere:
69. sarcolemma:
70. sarcoplasm:
71. spasm:
72. sphincter:
73. strain:
74. supination:
75. synergist:
76. tendonitis:
77. tetanus:
78. twitch:

## Muscular System Vocabulary

1. abduct: to move away from the midline of the body
2. actin: a contractile protein of muscle
3. action potential: the change in electrical potential of a muscle fiber when stimulated
4. adduct: to move toward the midline
5. aerobic: oxygen requiring
6. aerobic endurance: the length of time a muscle can continue to contract using aerobic pathways
7. aerobic exercise: exercise such as biking, swimming, jogging that causes more efficient muscle and general body metabolism resulting in greater endurance, strength, and resistance to fatigue
8. anaerobic: not requiring oxygen
9. anaerobic threshold: the point at which muscle metabolism converts to anaerobic glycolysis
10. antagonist: muscle that reverses, or opposes the action of another muscle
11. aponeurosis: fibrous or membranous sheet connecting a muscle and the part it moves
12. arrector pili: tiny, smooth muscles attached to hair follicles
13. ataxia: disruption of muscle coordination resulting in inaccurate movements
14. atrophy: reduction in size or wasting away of an organ or cell resulting from disease or lack of use
15. biceps: two-headed, especially applied to certain muscles
16. calcaneal tendon: tendon that attaches the calf muscles to the heel bone; Achilles tendon
17. calcium channel blockers: drugs that interfere with the movement of calcium across the plasma membrane, thus inhibiting muscle contraction
18. contraction: to shorten or develop tension, an ability highly developed in muscle cells
19. contracture: fibrosis of connective tissue in skin, fascia, muscles, or joint capsules that prevents normal mobility of the related tissue or joint
20. convulsion: a rapid series of involuntary muscular contractions and relaxations, especially of the skeletal muscles
21. cramp: sustained spasm, or titanic contraction, of an entire muscle, which lasts for just a few seconds or several hours, causing the muscle to become taut and painful
22. effector: muscle capable of being activated by nerve endings
23. electromyography: the recording, study, preparation, and interpretation of graphic records of the contractions of muscles as a result of electrical stimulation
24. endomysium: thin connective tissue surrounding each muscle cell
25. epimysium: sheath of fibrous connective tissue surrounding a muscle
26. fascia: layers of fibrous tissue covering and separating muscles
27. fascicle: bundle of muscle fibers bound together by connective tissue
28. fibromyositis: a group of conditions involving inflammation of a muscle, its connective tissue coverings and tendons, and capsules of nearby joints
29. fibrosis: the abnormal formation of , or degeneration into, fibrous tissue; may occur around the membranes of the lungs as a result of an inflammation or pneumonia; may also occur in and around the arteries, the uterus, the myocardium, and other areas due to inflammation or disease
30. fibrositis: an inflammation and hyperplasia of white fibrous tissue, especially that which

forms muscle sheaths and fasciae layers

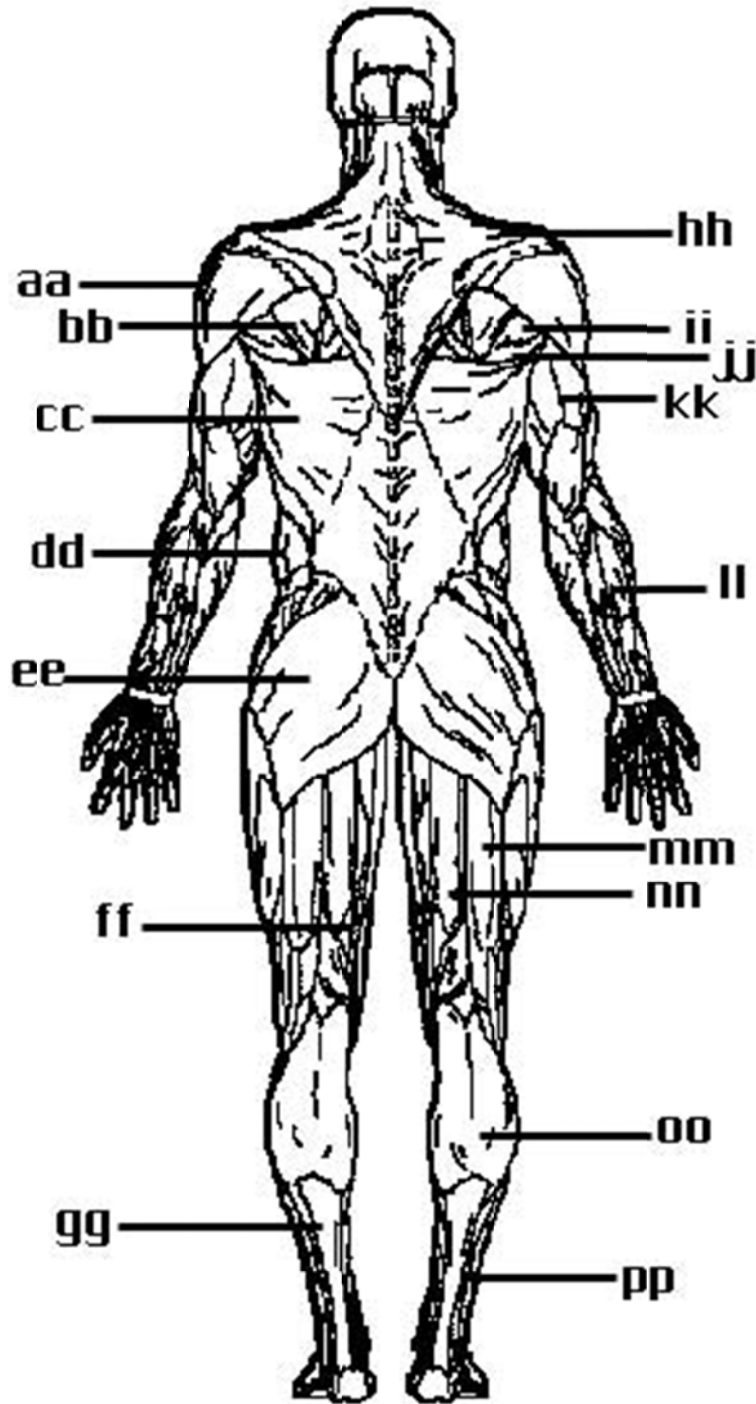
31. fixator: muscle that immobilizes one or more bones, allowing other muscles to act from a stable base
32. flaccid: a condition in which the muscles are uncommonly weak, flabby, or soft; may be indicative of a defect in muscular tone
33. fulcrum: the fixed point on which a lever moves when force is applied
34. hernia: protrusion of an organ through its body cavity wall
35. hypertrophy: increase in size of a tissue or organ independent of the body's general growth
36. insertion: movable attachment of a muscle
37. irritability: ability to respond to a stimulus
38. isometric contraction: contraction in which the muscle does not shorten (the load is too heavy) but its internal tension increases
39. isotonic contraction: contraction in which the muscle tension remains constant and the muscle shortens
40. kymograph: a recording instrument used in muscle physiology experiments
41. lever system: consists of a lever (bone), effort (muscle action), resistance (weight of object to be moved) and fulcrum (joint)
42. mechanical advantage: condition that occurs when the load is close to the fulcrum and the effort is applied far from the fulcrum
43. mechanical disadvantage: condition that occurs when the load is far from the fulcrum and the effort is applied near the fulcrum
44. muscle fatigue: state of physiological inability to contract; results from relative deficit of ATP, excessive accumulation of lactic acid, ionic imbalances
45. muscle spindle: encapsulated receptor found in skeletal muscle that is sensitive to stretch
46. muscle tone: sustained partial contraction of a muscle in response to stretch receptor inputs; keeps muscle healthy and ready to act
47. myalgia: muscle pain
48. myectomy: surgical removal of a portion of a muscle
49. myoclonus: the spastic, shock-like contractions of a part of a muscle or the entire muscle; usually a symptom of a convulsive disorder
50. myofibril: rod-like bundle of contractile filaments found in muscle cells
51. myofilament: actin and myosin bands within sarcomeres
52. myoglobin: red pigment that stores oxygen within muscle cells
53. myokymia: an involuntary twitching or quivering of a muscle
54. myoma: a tumor characterized by containing muscle tissue
55. myomalacia: the abnormal softening of muscle tissue
56. myopathy: disease of muscles
57. myosclerosis: the abnormal hardening of muscle tissue
58. myositis: inflammation of a muscle or muscles
59. myosin: one of the principal contractile proteins found in muscle
60. myotonia: a condition involving irregular tonic spasms of a muscle or the temporary rigidity of a muscle after normal contraction
61. origin: attachment of a muscle that remains relatively fixed during muscular contractions
62. paralysis: a temporary or permanent loss of functional motion or sensation of a muscle

- or muscles due to an impairment of the neural or muscular mechanism
63. peristalsis: progressive, wavelike contractions that move foodstuffs through the alimentary canal or other hollow organs
  64. perimysium:
  65. pronation: inward rotation of the forearm causing the radius to cross diagonally over the ulna à palms facing posteriorly
  66. resistance exercise: high intensity exercise in which the muscles are pitted against high resistance or immovable forces, and, as a result, muscle cells increase in size
  67. RICE: rest, ice, compression, and elevation; standard treatment for a pulled muscle or excessively stretched tendon or ligaments
  68. sarcomere: the smallest contractile unit of muscle
  69. sarcolemma: plasma membrane of muscle cell
  70. sarcoplasm: cytoplasm of muscle cell but it contains unusually large amounts of stored glycogen and myoglobin
  71. spasm: a sudden involuntary muscle twitch ranging in severity from merely irritating to very painful
  72. sphincter: a circular muscle surrounding an opening; acts as a valve
  73. strain: excessive stretching and possible tearing of a muscle due to muscle overuse or abuse
  74. supination: the outward rotation of the palms causing palms to face anteriorly
  75. synergist: muscle that aids the action of a prime mover by effecting the same movement or by stabilizing joints across which the prime mover acts to prevent undesirable movements
  76. tendonitis: an inflammation of a tendon and the tendon-muscular attachment
  77. tetanus: a state of sustained contraction of a muscle that is a normal aspect of skeletal muscle functioning
  78. twitch: a single, rapid contraction of muscle in response to a stimulus

**References for the Vocabulary:**

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# Label the Muscles – Posterior View



## KEY - Label the Muscles – Posterior View

aa. deltoid

bb. rhomboid major

cc. latissimus dorsi

dd. external oblique

ee. gluteus maximus

ff. semimembranosus

gg. Achilles tendon

hh. trapezius

ii. teres minor

jj. teres major

kk. triceps

ll. "extensors"

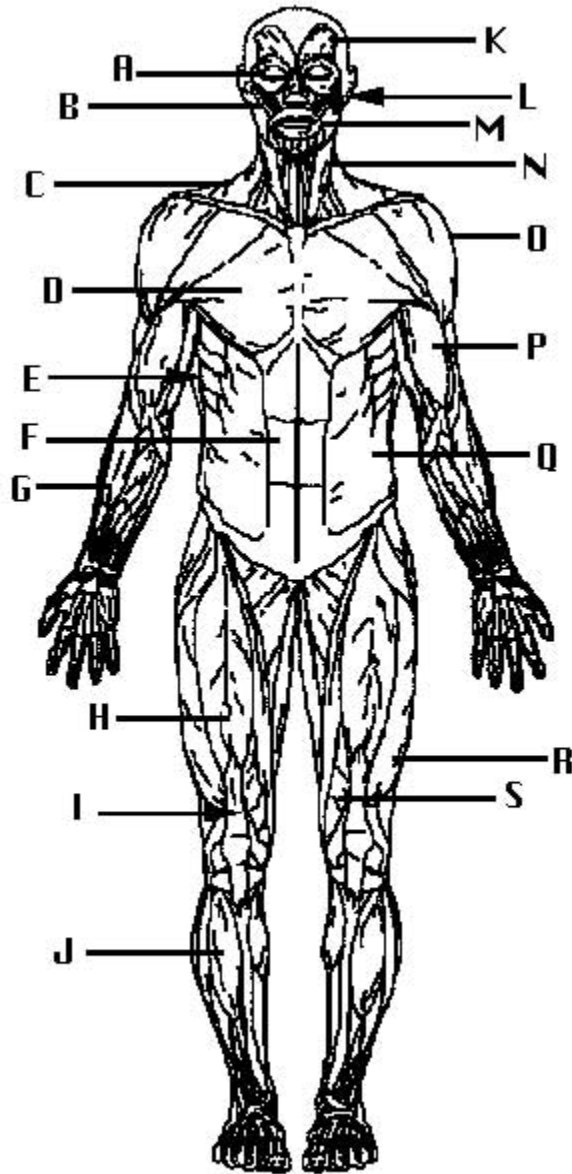
mm. biceps femoris

nn. semitendinosus

oo. gastrocnemius

pp. soleus

Label the Muscles – Anterior View



<http://phs.psd3.org/science/anatomy/muscular.html>

## KEY - Label the Muscles – Anterior View

- A. orbicularis oculi
- B. zygomaticus
- C. trapezius
- D. pectoralis major
- E. serratus anterior
- F. rectus abdominis
- G. "flexors"
- H. rectus femoris
- I. patellar ligament
- J. tibialis anterior
- K. frontalis
- L. masseter
- M. orbicularis oris
- N. sternomastoid
- O. deltoid
- P. biceps brachii
- Q. external oblique
- R. vastus lateralis
- S. vastus medialis

# Muscle Mechanics Skit

Provided Compliments of the STARS Program  
Sponsored by The University of Texas Southwestern Medical Center at Dallas  
Developed by The University of Kentucky Science Outreach Center

This skit is designed to introduce students to the key concepts of muscle mechanics. It is intended to enhance and clarify concepts that would normally be presented in a 1 hour lecture.

Materials Needed:

1. 11 very cooperative student volunteers
2. 11 signs (with string attached to place around neck)
  - 2 – **Calcium**
  - 2 – **Actin**
  - 2 – **Myosin**
  - 1 – **ACh**
  - 1 – **ATP**
  - 1 – **A.P. “Sparky”**
  - 2 – **T-tubules**
3. 2 broom stick/mop handles > 3 feet (or any long lightweight stick)
4. 6 – 12 empty (clean) aluminum cans
5. 1 long table and 2 chairs

Terms to Know:

1. ACh: acetylcholine. It is thought to play an important role in the transmission of nerve impulses at synapses and myoneural junctions. Either excessive or deficient action of acetylcholine at the motor end plates may result in neuromuscular block.
2. Actin: Protein derived from the actomyosin in muscle. In response to chemical changes in the tissue, actin may have a globular or an elongated form. This property is important in contracting and relaxing muscle tissue.

3. Actomyosin: The combination of actin and myosin in a muscle. Upon muscle stimulation, these substances shorten without changing their volume and thus cause contraction of the muscle.
4. A.P.: Action Potential. The change in electrical potential of nerve or muscle fiber when stimulated.
5. ATP: Adenosine triphosphate. A compound of adenosine containing three phosphoric acid groups. This substance is present in all cells, but particularly in muscle cells. When this substance is split by enzyme action, energy is produced. The energy of the muscle is stored in this compound.
6. Calcium: Calcium is essential for the function of nerves and muscles, including the myocardium, and for maintaining the permeability of membranes. Low blood calcium causes tetany with muscular twitching, spasms, and convulsions.
7. Hydrolysis: A chemical decomposition in which a substance is split into simpler compounds by the addition or taking up of the elements of water.
8. Myosin: A protein present in muscle fibrils. The molecular structure of myosin is thought to be responsible for the properties of muscle tissue, namely, birefringence, double refraction, contractility, and elasticity. Myosin combines with actin to form acto-myosin.
9. T-tubules Transverse (crosswise) tubule (a small tube)

Setting:

This can be done in front of the classroom – be creative!!!

Assign each student a “role” to play as you demonstrate the key steps and components of the contraction of skeletal muscle. Using diagram 1 as a guide, arrange the students with their proper identifying signs.

Diagram 1															
		T-tubule		Calcium	Actin	-	-	-		-	-	-	Actin	(broom handles are represented by dotted lines)	
ACh	“Sparky” the AP							M y o s i n		M y o s i n					
		T-tubule		Calcium				ATP							
								Coke Cans							

Script:

**ACh** makes a short “jump” which causes **Sparky** to begin moving. **Sparky the AP** moves between two students who sit in 2 chairs and act as a **T-tubule** through which the **AP** must pass. The presence of the **AP** causes the **calcium** ions to be released into the “neighborhood” or milieu of the **actin** and **myosin** contractile elements. The two **calcium** students should move over and place one hand on the shoulder of the **actin** players. (See Diagram 2)

Diagram					Calcium							Calcium		
2														
					Calcium							Calcium		
	T-tubule				Actin	-	-	-		-	-	-	Actin	(broom handles are represented by dotted lines)
ACh		“Sparky” the AP						M		M				
								y		y				
								o		o				
								s		s				
								i		i				
								n		n				
	T-tubule							ATP						
								Coke Cans						

The **actin** players should be holding a long broom handle out to one side. The **myosin** players should be seated at a nearby table with one arm extended to one side as shown in the diagram. In the presence of **calcium**, the **actin** and **myosin** elements are attracted to each other. This is represented by the movement of the **myosin** player’s

arm such that they gently grab a point on the broom stick while the arm is flexed at the elbow. Once the broom stick has been grasped, the **myosin** player will extend their arm in a forward position. This extension will cause each of the **actin** filament players to be “pulled” slightly toward one another in a sliding motion. This illustrates the shortening of the muscle fiber. See Diagram 3. For each extending motion the **myosin** makes, the **ATP** will crush a can, illustrating the energy that is released by **ATP hydrolysis**.

Diagram					Calcium							Calcium		
3														
	T-tubule				Actin	-	-	-	-----	-	-	-	Actin	(broom handles are represented by dotted lines)
ACh		“Sparky” the AP						M		M				
								y		y				
								o		o				
								s		s				
								i		i				
								n		n				
	T-tubule							ATP						
								Coke Cans						

## Rules That Must Be Obeyed

1. **Calcium** players cannot move from their starting positions until the **AP** player enter the **T-tubule**.
2. **Myosin** players cannot move their arms up to “attach” to the broomstick of the **actin** player unless and until calcium players are present and “touching” **actin** on the shoulder.
3. **Myosin** players must maintain their grip on the broomstick until the **ATP** player places an empty aluminum can on the table and crushes it in his hand. At this time they release their grip, flex their arm, and (if calcium is present) re-grip the broomstick.
4. As long as **calcium** is present, **myosin** players MUST continue to “cycle” through reaching up for the **actin** and extending their arm, all the time obeying Rule #3.
5. Once the **myosin** player lets go of the broomstick (when **calcium** releases from **actin**) the **actin** player must return back to his original standing position (step back).

### Purpose:

Although this sounds complicated at first, I would suggest that the leader and some assistants help the players move through their actions individually until everyone understands their role. SLOWLY move through the entire process while explaining to or questioning the rest of the audience.

### Variation:

Now for the fun part! The leader may now present some “problem” to the class. For example, what would happen if **calcium** was removed from the system? With the **calcium** players removed from the skit for a moment remind everyone about the rules stated above and watch the contractile machinery grind to a halt. At this point make sure that all participants understand the importance of the role of **calcium** in muscle contraction.

Now try this one! Remove the **ATP** player and once again remind the rest of the players to follow the rules very carefully. This exercise illustrates the effects of the system when the source of energy to reset the **myosin** crossbridges is removed. As a result, the “human machine” should find itself locked in rigor mortis. In other words, the **myosin** players cannot let go of the broomsticks and the **actin** players are forced to remain in the contracted state. This is exactly what happens when a body dies and the muscles are “locked” in place and become stiff.

Be creative as you obey the rules and experiment with other changes in your skeletal muscle system. It is my desire that this exercise/skit be enjoyed by the students and that they realize that learning science can be a pleasurable and valuable experience. If there are any comments or questions regarding how this can be expanded or improved, please let me know. Have fun and watch out or you may learn something.

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# INVESTIGATING MUSCLE FATIGUE

Lab Developed by:

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## Before starting:

- I. Review muscular system
  - A. Types of muscles
    1. Skeletal
    2. Smooth
    3. Cardiac
  - B. Structure of muscles
    1. Fibers
    2. Myofibrils
      - a. Striated – I bands and A bands make up the sarcomere.
      - b. Unstriated
    3. Neuromuscular junction
    4. Motor units
- II. Muscle contraction – depends on several cellular and chemical processes to make the myofibrils move.
  - A. Contractile Proteins
    1. Thin filaments
      - a. actin
      - b. tropomyosin
      - c. troponin
    2. Thick filaments – The myosin molecule has a “head” and a “tail”.
- III. Molecular basis of contraction
  - A. Sliding filament theory – Individual sarcomeres shorten when the muscle contracts.
  - B. Crossbridge cycle – Actin binds to myosin and forms a “crossbridge” (linkage) shortening the muscle fiber.
  - C. Regulatory proteins and calcium
    1. Tropomyosin and troponin inhibit actin from binding to myosin.
    2. Calcium allows actin to form a crossbridge with myosin
    3. Dystrophin supports the sarcolemma against the forces of contracting.  
Prevents Duchenne Muscular Dystrophy
  - D. Stimulus for contraction
    1. Depends on a neurotransmitter diffusing across the synaptic cleft causing a muscle impulse.
    2. The muscle impulse causes the release of calcium from the sarcoplasmic reticulum.
  - E. Energy sources for contraction
    1. ATP – is the immediate source of energy but it is only found in small amounts in muscle.
    2. Creatine phosphate –
      - a. stores high energy bonds that can be used to make ATP

b. present in muscles four to five times the concentration of ATP

IV. Mechanics of muscle contraction

A. Types of contractions

1. isotonic – the muscle shortens
2. isometric (static)
  - a. the muscle develops tension but does not shorten;  
the heart must work harder because little vasodilation takes place in the peripheral neural systems at work when muscles are exercised.
3. “Central command” located in the higher centers in the brain and is responsible for heart rate and strength of contraction.
4. Feedback mechanism which monitors the buildup of cellular waste and signals the brainstem to increase cardiac output.

B. Twitch

C. Tetanus

V. Muscle fatigue – The inability of a muscle to contract (maintain tension).

A. build up of lactic acid

B. lack of ATP

C. lack of blood flow to muscle

Complete the Muscle Fatigue Laboratory Investigation.

Complete the Response to Isometric Exercise Laboratory Investigation.

**MATERIALS**

Grip exerciser or spring clamp  
Metric ruler  
Blood pressure cuff  
Grip dynamometer

Stopwatch  
Two sphygmomanometers  
Stethoscope

**ASSESSMENT**

Laboratory Investigation Rubric

# Investigating Muscle Fatigue

## Purpose:

In this activity students will investigate some of the factors that affect skeletal muscle fatigue.

## Background Information:

## Materials:

- Grip exerciser or spring clamp
- Metric ruler
- Blood pressure cuff

## Procedure:

### Part I

1. Using your dominant hand, squeeze the handles of the exerciser together as hard as you can.
2. Exercise the hand by rapidly squeezing the handles together 10 times in quick succession (no slacking!). Hold the jaws open on the 10<sup>th</sup> try and immediately measure the width of the opening. Record this value in the data table.
3. After a brief rest (5 seconds) repeat Step 2. Continue to do so until you have completed a total of 5 measurements. Be sure to record the data each time.
4. Allow a 5-minute recovery period.

### Part II

- 1 Repeat Step 1 with the hand used previously. Record the initial data in the table.
- 2 Place the blood pressure cuff around the upper arm and inflate to about 160 mm Hg.
- 3 Repeat the exercise portion of the activity as described above, recording all data.

## Data

### Part I – Without Cuff

Distance jaws held apart (cm) \_\_\_\_\_  
before exercise

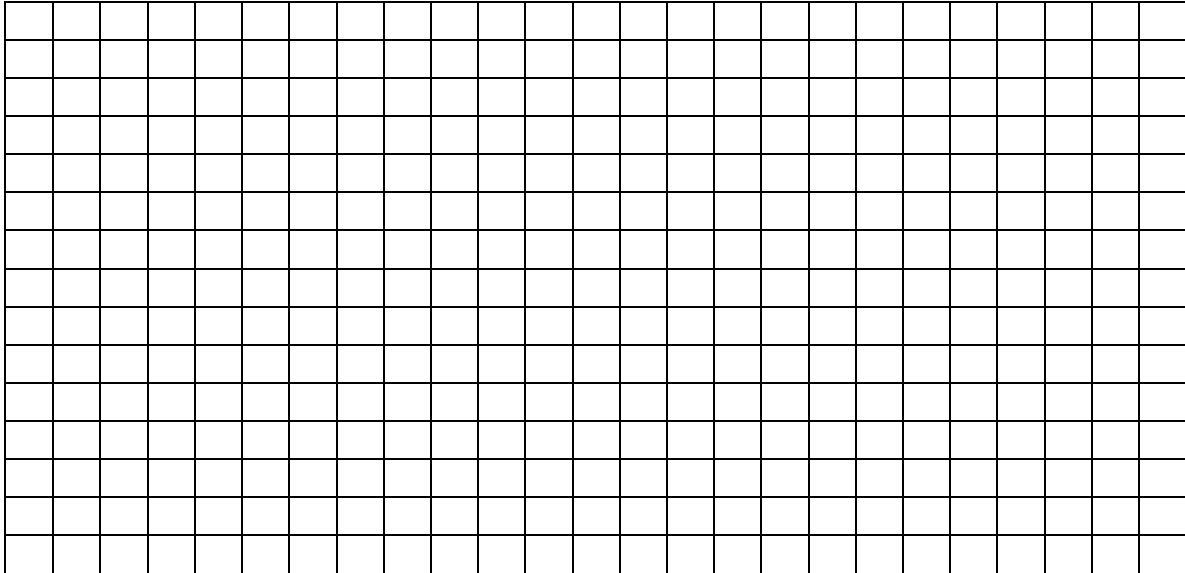
- Trial 1 \_\_\_\_\_  
Trial 2 \_\_\_\_\_  
Trial 3 \_\_\_\_\_  
Trial 4 \_\_\_\_\_  
Trial 5 \_\_\_\_\_

### Part II – With Cuff

Distance jaws held apart (cm) \_\_\_\_\_  
before exercise

- Trial 1 \_\_\_\_\_  
Trial 2 \_\_\_\_\_  
Trial 3 \_\_\_\_\_  
Trial 4 \_\_\_\_\_  
Trial 5 \_\_\_\_\_

Prepare a line graph of the data you collected. The trial number should be on the x-axis and the distance the jaws were held open on the y-axis. You should have two sets of data points on the same graph, one without the cuff and one with the cuff in place. Be sure you label axes and give your graph a descriptive title.



**Conclusion:**

1. What happened to your “strength” as you progressed through Part I? How does your graph show this?
2. How did the rate at which you became fatigued differ between Part I and Part II? How does your graph show this?
3. What types of nutrients are required by muscles during exercise? How are these actually delivered to the muscle?
4. How is the delivery of these nutrients hampered by the exercise of a muscle?



## Response to Isometric Exercise

**Purpose:** The student will investigate the effects of isometric (static) exercise on cardiovascular response and relate this to the underlying neural mechanisms at work.

### Background:

### Materials:

Grip dynamometer  
Stopwatch  
Two sphygmomanometers  
Stethoscope

### Procedure:

1. Divide into groups of five. Choose one person for each of the following jobs: subject, blood pressure monitor, pulse monitor, timer/recorder, and someone to inflate the second occlusion cuff.
2. Read over the entire procedure, making note of the timing of the measurements. Practice the procedure at least once with all participants. Do not inflate the occlusion cuff during practice runs.
3. Have the volunteer sit in a chair. Using the grip dynamometer, determine the maximum force that the volunteer can exert with their dominant hand. Their target force for this activity will be about 30% of that value. (If a rubber ball or spring exerciser is used, they should try to estimate their grip force to be in this range.)
4. Place the blood pressure cuff on the other arm. Take an initial reading. Record the systolic and diastolic pressures in the data table. Leave the cuff on the volunteer's arm.
5. Determine the volunteer's resting heart rate by taking their radial pulse. Record the heart rate in the data table.
6. Place the occlusion cuff on the upper part of the exercising arm. Do not inflate.
7. The volunteer will then exert a force on the dynamometer approximately 30% of their maximum and maintain it for three minutes.
8. At one minute the blood pressure will be taken. The monitor will have to anticipate this reading and inflate the cuff prior to the time mark so that the reading is as close to one minute as possible.
9. A pulse reading should be taken immediately following the blood pressure reading.
10. Repeat the readings of blood pressure and pulse rate at the two and three minute marks.
11. Just following the three-minute reading, the occlusion cuff should be inflated to 200mm Hg. This will cut off all blood flow to the arm. As soon as the pressure reaches 200 mm Hg the volunteer should stop exercising.
12. At four minutes, check blood pressure and pulse. Deflate the occlusion cuff immediately.
13. Take a final blood pressure reading and pulse at 5 minutes.
14. Calculate MAP and record the values in the table.
15. Make a line graph of your results. You should have one line for each of these values: systolic pressure, diastolic pressure, MAP and heart rate.

**Data:**

	<b>Initial</b>	<b>1 Minute</b>	<b>2 Minutes</b>	<b>3 Minutes</b>	<b>4 Minutes</b>	<b>5 Minutes</b>
<b>Systolic</b>						
<b>Diastolic</b>						
<b>MAP</b>						
<b>Heart Rate</b>						

**Conclusion:**

1. Describe what happened to the volunteer's MAP and heart rate during isometric (static) exercise. How would these values differ from values taken during a dynamic exercise? What would account for any difference?
  
2. How did heart rate and blood pressure change during the time the blood flow was occluded? Which of the two systems, Central Control or Feedback, was most active at this time? Relate this information to your observations.
  
3. What was happening during the last minute? How does the data show this?

# Chicken Leg Investigation

**Teacher Instructions:** *The Chicken Leg Investigation is an inexpensive and convenient way to review the integumentary, skeletal, muscular systems and introduce the nervous system.*

Time: 30 to 45 minutes

## Materials:

- Hind quarter chicken parts (contact the local butcher for these)
- Small dissection or fingernail scissors
- Forceps or tweezers
- 4x4 gauze sponges
- Foam meat trays
- Gloves
- Paper towel
- Wet wipes
- Table covering

## Strategy:

Divide the students into teams of two or three. Each student team is given one chicken leg on a foam meat tray, gloves for each student, and instruments for dissection. The tables or desks should be covered with paper or plastic. Wet wipes and paper towel are used to clean up after the dissection.

## Instructions:

This is an exploration experience lab. Students are encouraged to share what they find as they explore the chicken leg. The rules of dissection are to be explained as follows: the students should accomplish most of the simple dissection with their finger, and then continue, using dissection tools.

Introduce the lab by explaining that most surgical dissection is accomplished with the finger and a 4x4 sponge. The students remove the skin from the chicken and hold it up to the light to visualize the capillaries and note the accessory structures. As dissection is occurring, point out the loose connective tissue substances that are holding the skin to the muscles deep fascial layer.

Students are then asked to look for structures in the muscles and the bone, and to observe the structures while figuring out the function. The hind quarter of the chicken has the following structures which are identified easily by the student:

The teacher should walk around the classroom and answer questions as they arise. The students will get the most from the experience by sharing with one another as they complete the task. ***The discovery is the activity.***

# Chicken Leg Investigation

## Materials:

Hind quarter chicken parts  
Small dissection or fingernail scissors  
Forceps or tweezers  
4x4 gauze sponges  
Foam meat trays  
Gloves  
Paper towel  
Wet wipes  
Table covering

## Instructions:

This is an exploration experience. You are encouraged to share what you find as you explore the chicken leg. You will accomplish simple dissection with your finger as much as possible and then continue using the dissection tools.

Most surgical dissection is accomplished with the finger and a 4x4 sponge. Remove the skin from the chicken and hold it up to the light to visualize the capillaries and note the accessory structures. Observe the loose connective tissue substances that are holding the skin to the muscles deep fascial layer.

Look for structures in the muscles and the bone and to observe the structures while figuring out the function.

## Look for the following:

- |   |                                 |
|---|---------------------------------|
| 1. Skin                                       | 12. Ball and socket joint       |
| 2. Arrector pili muscle structure in the skin | 13. Hinge joint                 |
| 3. Capillaries                                | 14. Blood vessels               |
| 4. Adipose tissue                             | 15. Blood clots                 |
| 5. Loose connective tissue                    | 16. Injuries to the chicken leg |
| 6. Fascia                                     | 17. Bone structures             |
| 7. Muscle                                     | 18. Bone tissue                 |
| 8. Muscle bundles                             | 19. Hematopoiesis               |
| 9. Fascicles                                  | 20. Fossa                       |
| 10. Tendon                                    | 21. Hyaline cartilage           |
| 11. Ligament                                  | 22. Vertebrae                   |
|   | 23. Spinal cord material        |

("Medical anatomy and," 2005)

## Laboratory Investigation Rubric

Student: \_\_\_\_\_ Date: \_\_\_\_\_

<b>Scoring Criteria</b>	<b>4 Excellent</b>	<b>3 Good</b>	<b>2 Needs Some Improvement</b>	<b>1 Needs Much Improvement</b>	
Problem is appropriately identified.					
Problem is precise, clear, and relevant.					
Association between the problem and the predicted results is direct and relevant.					
All variables are clearly operationalized.					
Demonstrates comprehension of the use of scientific concepts and vocabulary.					
All significant data is measured.					
Data is recorded effectively and efficiently.					
Data table is well designed to the task requirements.					
All graphs are appropriate.					
All data accurately plotted.					
Graph visually compelling, highlights conclusions of the study.					
Conclusion relates directly to hypothesis.					
Conclusion has relevancy in resolution of the original problem.					
Conclusion relates the study to general interest.					