

MUSCULAR SYSTEM

OBJECTIVES/RATIONALE

To pursue a career in health care, proficiency in anatomy and physiology is vital. The student will describe biological and chemical processes that maintain homeostasis; analyze forces and the effects of movement, torque, tension, and elasticity on the human body; associate the disease process with changes in homeostasis; identify changes in structure and function due to trauma and disease; and identify normal and abnormal anatomy and physiology.

TEKS: 121.3 (c)(1)(F)(H),
121.4 (c)(1)(G)(H)(I),
121.5 (c)(1)(E)(F)(G)

TAKS ELA 1, 4
Science 2, 5

KEY POINTS

Powerpoint

- I. Introduction
 - A. Why do people lift weights? Why do we exercise our muscles?
 - B. Over 600 muscles make up muscular system
 - C. 45% of total body weight of an adult
 - D. Made up of bundles of muscle fibers (long slender cells) held together by connective tissue
 - E. When muscle fibers are stimulated by nerves they contract (become short and thick) which causes movement
 - F. Contraction depends on myofilaments: actin and myosin
 - G. Myo-, mys-, and sarco- refer to muscle
 - H. Spas- (draw, pull), tens- (stretch), -plegia (paralysis), therap- (treatment), therm- (heat), dynam- (power)
- I. 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
 - 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

J. 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. $ATP \leftrightarrow ADP + PO_2 + \text{energy}$
- 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 $CO_2 + H_2O + \text{energy}$
 - b. Strenuous activity, not enough oxygen - pyruvic acid converted to lactic acid = oxygen debt = cramps
 - c. Oxygen debt: extra amount of O_2 that must be taken in by the body for restorative processes; difference between the amount of 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

ACTIVITIES

- I. Identify and label the skeletal muscles.
- II. Practice Range of Motion Skills (Body Mechanics Lesson).
- III. Practice Sports Medicine Contest Stretches (HOSA).
- IV. Practice Massage Techniques (Massage Therapy Lesson).

MATERIALS NEEDED

Muscles Chart

Muscular System Terminology

Muscular System Vocabulary

1 long table

2 chairs

Relaxing music

Guest Speaker: Psychiatrist, Physical Therapist, Sports Trainer

ASSESSMENT

Successful identification of skeletal muscles.
Completion of activities.

ACCOMMODATIONS

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.

REFLECTIONS

Little Red Riding Hood—A Revised Version

Match the function with the muscle. You may use the same answer more than once.

Once upon a time, there was a young girl named Little Red Riding Hood (so named after the little red cape and hood her beloved grandmother had made for her). One day her grandmother fell ill.

“Little Red Riding Hood,” her mother said, “Your grandmother is ill. I’ve prepared a basket for you to take to her. Don’t waste time in the forest, and don’t talk to *any* strangers along the way!” her mother warned.

“Yes, mother,” replied Little Red Riding Hood, ¹**nodding her head** in affirmation.

“And don’t slump, child! ²**Pull those shoulders back** before you ruin your posture.”

Soon, the little girl was running through the forest to grandma’s house. She stopped briefly to ³**breath in deeply** and admire the smells of the forest and beautiful flowers.

“I know, exclaimed Red Riding Hood, I shall pick some of these lovely flowers for dear, sick grandmamma.” ⁴**Turning her head from side to side**, she spied many colorful species. ⁵**Bending forward at the waist**, she reached for a cluster of blue flowers. ⁶**Closing her fingers** around the flower stems, she picked a fragrant bouquet.

“How lovely!” she murmured, ⁷**flexing her forearm** so that she might smell the newly picked flowers. Noticing a nearby brook, Little Red Riding Hood decided to take off her shoes and socks and cool her legs in the water. ⁸**Bending to first one side then the other**, she unbuckled each shoe. Her feet and toes free, Red Riding Hood ⁹**extended first one leg**, then another as she stepped into the water. Red Riding Hood ¹⁰**closed her eyes** and pretended that magical forest fairies surrounded her. Hearing an unexpected crackle of branches, her eyes flew open and she timidly called out, “Who is there—show yourself...”

Hoping for a fairy friend, she saw instead, the head of a large hairy wolf peaking from behind a rather large tree!

“YIKES!” screeched Riding Hood, ¹¹**eyebrows raised** in alarm over side eyes.

“Don’t be afraid, Red Riding Hood,” he coaxed, with his most sincere ¹²**smile**.

“My mother told me not to talk to strangers,” she firmly informed him as she quickly ¹³**tiptoed** across the forest floor to retrieve her shoes and basket.

“Yes, and quite right,” agreed the wolf. “But. . .I’m not a stranger. My no!” he reasoned while ¹⁴**adducting his arms across his chest** in a submissive fashion. “I know your name, don’t I? A stranger wouldn’t know your name,” he laughed. “Besides, I’ve come to keep you company. Here, let me help you with that heavy load,” he suggested as he ¹⁵**abducted an arm** in the direction of the food basket.

Snatching the basket, Red Riding Hood immediately ¹⁶**put her arm behind her back**, attempting to hide and protect her foods. *This* is for my sick grandmother who lives on the other side of the woods,” she righteously exclaimed.

The wolf called out cunningly as Red Riding Hood hurried off, “Well, now—you wouldn’t want to forget these flowers. I’m sure granny will *love* them.”

Hesitantly, Red Riding Hood turned around.

“Thank you,” she said as the ¹⁷**extended her elbow** and ¹⁸**hand** toward the bouquet.

“Certainly,” responded the wolf in his most formal manner. “Have a nice walk.”

Red Riding Hood was a little anxious after her chance meeting with the wolf and decided to go directly to grandma’s house. Unbeknownst to her, the wolf took a short cut to grandma’s.

“Grandma, Grandma, it is me—Little Red Riding Hood. I’ve come with food and flowers,” she called out.

“Yes, dear—come to granny’s room. I’m not feeling well,” grandma replied in a throaty voice.

“Oh, grandma,” Red Riding Hood said ¹⁹**wrinkling her forehead** in concern. “Your eyes—they look so big.”

“Better to see you with, my dear,” crooned grandma.

“Red Riding Hood ²⁰**opened her astonished mouth** as she once again remarked, “But grandma, your ears—they look so, so, big . . . and hairy!”

“Better to hear you with, my dear.”

“But grandma, your mouth—it looks so great!”

Better to eat you with!” shouted the drooling wolf as he threw off grandma’s night bonnet and blankets while leaping at the young girl.

Red Riding Hood ran to grandma’s yard and ²¹**blew** the bullhorn for help. The mean-spirited wolf chased Red Riding Hood around the yard, ²²**snapping shut his jaw** in happy anticipation of tasting her flesh.

Soon a hunter from the forest arrived. ²³**Adducting his arm across his chest**, he raised his gun at eye level and shot the sly, arrogant wolf between the eyes.

“I will cut his skin off and hang it in the forest for all to see,” the hunter promised. “Let this be a warning to all wolves who would have us for dinner!”

As the hunter cut into the wolf’s stomach, however, out popped grandma! In the wolf’s hurry to devour her, he had swallowed her whole. What a happy reunion she and

Little Red Riding Hood had as they ran towards each other, ²⁴**arms extended** and big ²⁵**smiles** spreading across their faces.

WORD BANK

Biceps brachii
Buccinator
Deltoid
Digastric
Diaphragm/ Intercostals
External abdominal obliques
Flexor & extensor digitorum group
Frontalis
Gastrocnemius
Gluteus maximus
Gluteus medius
Latissimus dorsi
Masseter
Orbicularis oculi
Orbicularis oris
Pectoralis major
Quadriiceps femoris
Rectus abdominus
Sartorius
Serratus anterior
Sternocleidomastoid
Temporal
Titialis anterior
Trapezius
Triceps brachii
Zygomaticus

KEY - Little Red Riding Hood-A Revised Version

- 1.sternocleidomastoid
- 2.trapezius
- 3.diaphragm/intercostals
- 4.sternocleidomastoid
- 5.rectus abdominus
- 6.flexor digitorum
- 7.biceps brachii
- 8.abdominal obliques
- 9.quadriceps femoris
- 10.orbicularis oculi
- 11.frontalis
- 12.zygomaticus
- 13.gastrocnemius
- 14.pectoralis major
- 15.deltoid
- 16.latissimus dorsi
- 17.triceps brachii
- 18.extensor carpi
- 19.frontalis
- 20.orbicularis oris
- 21.buccinator
- 22.masseter
- 23.pectoralis major
- 24.deltoid
- 25.zygomaticus

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**

Author: Bob Taylor, Ph.D.
Department of Physiology
The University of Kentucky Medical Center
Lexington, Kentucky 40536-0084

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)

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 2					Calcium								Calcium	
						A								
	T-tubule				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							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 3					Calcium							Calcium		
	T-tubule				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								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.

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 " x 11" 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. Then the transparency is 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 of 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 ½ x 11" 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 or 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
Scalp	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
Face	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
Mastication	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
Tongue Movement	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	Retracts & elevates tongue

		I = lateral inferior aspect of tongue	
Anteriolateral Neck	Sternocleidomastoid	O = manubrium of sternum & medial portion of clavicle I = mastoid process of temporal bone	Prime mover of active head 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
Thorax: Breathing	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
Anterior/Posterior Thorax	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	Act with trapezius to “square shoulders”; rotate scapula, “paddling” a canoe, stabilize scapula

		scapula	
Crossing Shoulder Joint/Movement of Humerus	Pectoralis major	O = clavicle, sternum, cartilage of ribs 1 – 6, aponeurosis of external oblique muscle I = short tendon into greater tubercle of humerus	Prime mover for shoulder flexion & adduction; prime 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
Anterior/Lateral Abdominal Wall	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	Compresses

		ligament, lumbodorsal fascia, cartilages of last 6 ribs, iliac crest I = linea alba, pubic crest	abdominal contents
Muscles Crossing Elbow Joint/Flexion & Extension of Forearm	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
Muscles of Forearm/Movements of Wrist, Hand, Fingers	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

Muscles Crossing Hip and Knee Joints	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
Muscles That Move	Tibialis anterior	O = tibia	Prime mover of dorsiflexion, inverts

Ankle and Toes		I = metatarsal	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

Clinical and Related Terms

- 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; the electric current propagated down the sarcolemma in order for the skeletal muscle to contract
- 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; at ATP demands below this threshold light to moderate muscular activity can continue for several hours if well conditioned; peak levels using anaerobic glycolysis will fatigue muscles after 1-2 minutes
- 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; cause the hair to stand upright when activated
- 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.calcanal 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; used to enhance blood flow through the heart by relaxing smooth muscle in the walls of cardiac blood vessels
- 18.circumduction: movement of a body part so that it outlines a cone in space
- 19.contraction: to shorten or develop tension, an ability highly developed in muscle cells
- 20.contracture: fibrosis of connective tissue in skin, fascia, muscles, or joint capsules that prevents normal mobility of the related tissue or joint; in the total absence of ATP, a state of continuous contraction results because the cross bridges are unable to detach, i.e. writer's cramp
- 21.convulsion: a rapid series of involuntary muscular contractions and relaxations, especially of the skeletal muscles; usually symptomatic of some type of CNS disorder such as epilepsy, tetanus, poisonings, chemical disorders, etc.; in children, the cause most often is high fever; accurate observation and charting of the disorder is important to ascertain the cause
- 22.crampp: 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; common in calf, thigh, and hip muscles, and usually occurs at night or after exercise; may reflect low blood sugar levels, electrolyte depletion (Na⁺, Ca⁺⁺), dehydration, irritability of spinal cord neurons; simultaneously squeezing and stretching the cramped muscle may help

- 23.effector: muscle capable of being activated by nerve endings
- 24.electromyography: the recording, study, preparation, and interpretation of graphic records of the contractions of muscles as a result of electrical stimulation; used in diagnosis of diseases such as polio and ALS
- 25.endomysium: thin connective tissue surrounding each muscle cell
- 26.epimysium: sheath of fibrous connective tissue surrounding a muscle
- 27.fascia: layers of fibrous tissue covering and separating muscles
- 28.fascicle: bundle of muscle fibers bound together by connective tissue
- 29.fibromyositis: a group of conditions involving inflammation of a muscle, its connective tissue coverings and tendons, and capsules of nearby joints; symptoms are nonspecific and often include varying degrees of tenderness associated with specific trigger points
- 30.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
- 31.fibrositis: an inflammation and hyperplasia of white fibrous tissue, especially that which forms muscle sheaths and fasciae layers; usually causes pain and stiffness; commonly called muscular rheumatism
- 32.fixator: muscle that immobilizes one or more bones, allowing other muscles to act from a stable base
- 33.flaccid: a condition in which the muscles are uncommonly weak, flabby, or soft; may be indicative of a defect in muscular tone
- 34.fulcrum: the fixed point on which a lever moves when force is applied
- 35.hernia: protrusion of an organ through its body cavity wall; may be congenital, but most often caused by heavy lifting or obesity and subsequent weakness
- 36.hypertrophy: increase in size of a tissue or organ independent of the body's general growth
- 37.insertion: movable attachment of a muscle
- 38.irritability: ability to respond to a stimulus
- 39.isometric contraction: contraction in which the muscle does not shorten (the load is too heavy) but its internal tension increases; seen in muscles that act primarily to maintain upright posture or hold joints in stationary positions i.e. holding squat position
- 40.isotonic contraction: contraction in which the muscle tension remains constant and the muscle shortens; concentric → muscle shortens and does work i.e. kicking a ball, picking up a book; eccentric → muscle contracts as it lengthens i.e.calf muscle as person walks up a long steep hill
- 41.kymograph: a recording instrument used in muscle physiology experiments; the device uses a writing pen that moves in response to the force applied and that marks that response on a rotating drum

- 42.lever system: consists of a lever (bone), effort (muscle action), resistance (weight of object to be moved) and fulcrum (joint)
- 43.mechanical advantage: condition that occurs when the load is close to the fulcrum and the effort is applied far from the fulcrum; allows a small effort exerted over a relatively large distance to move a large load over a small distance
- 44.mechanical disadvantage: condition that occurs when the load is far from the fulcrum and the effort is applied near the fulcrum; the effort applied must be greater than the load to be moved
- 45.muscle fatigue: state of physiological inability to contract; results from relative deficit of ATP, excessive accumulation of lactic acid, ionic imbalances
- 46.muscle spindle: encapsulated receptor found in skeletal muscle that is sensitive to stretch
- 47.muscle tone: sustained partial contraction of a muscle in response to stretch receptor inputs; keeps muscle healthy and ready to act
- 48.myalgia: muscle pain
- 49.myectomy: surgical removal of a portion of a muscle
- 50.myoclonus: the spastic, shocklike contractions of a part of a muscle or the entire muscle; usually a symptom of a convulsive disorder
- 51.myofibril: rod-like bundle of contractile filaments found in muscle cells; 100s to 1000s per single muscle fiber; 80% of cellular volume; consists of a chain of smaller contractile units (sarcomeres)
- 52.myofilament: actin and myosin bands within sarcomeres
- 53.myoglobin: red pigment that stores oxygen within muscle cells
- 54.myokymia: an involuntary twitching or quivering of a muscle
- 55.myoma: a tumor characterized by containing muscle tissue; may be benign or malignant
- 56.myomalacia: the abnormal softening of muscle tissue
- 57.myopathy: disease of muscles
- 58.myosclerosis: the abnormal hardening of muscle tissue
- 59.myositis: inflammation of a muscle or muscles; may be caused by an infection, infestation, injury, or other factors
- 60.myosin: one of the principal contractile proteins found in muscle
- 61.myotonia: a condition involving irregular tonic spasms of a muscle or the temporary rigidity of a muscle after normal contraction
- 62.origin: attachment of a muscle that remains relatively fixed during muscular contractions
- 63.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
- 64.peristalsis: progressive, wavelike contractions that move foodstuffs through the alimentary canal or other hollow organs
- 65.perimysium:
- 66.pronation: inward rotation of the forearm causing the radius to cross diagonally over the ulna à palms facing posteriorly
- 67.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
- 68.RICE: rest, ice, compression, and elevation; standard treatment for a pulled muscle

- or excessively stretched tendon or ligaments
- 69.sarcomere: the smallest contractile unit of muscle; extends from one Z line to the next
- 70.sarcolemma: plasma membrane of muscle cell
- 71.sarcoplasm: cytoplasm of muscle cell but it contains unusually large amounts of stored glycogen and myoglobin
- 72.spasm: a sudden involuntary muscle twitch ranging in severity from merely irritating to very painful; may be due to chemical imbalances; in spasms of the eyelid or facial muscles (called a tic) may be due to psychological factors
- 73.sphincter: a circular muscle surrounding an opening; acts as a valve
- 74.strain: excessive stretching and possible tearing of a muscle due to muscle overuse or abuse; the injured muscle becomes painfully inflamed and adjacent joints are usually immobilized
- 75.supination: the outward rotation of the palms causing palms to face anteriorly
- 76.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
- 77.tendonitis: an inflammation of a tendon and the tendon-muscular attachment i.e. tennis elbow; may involve calcium deposits in chronic cases
- 78.tetanus: a state of sustained contraction of a muscle that is a normal aspect of skeletal muscle functioning
- 79.twitch: a single, rapid contraction of muscle in response to a stimulus

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