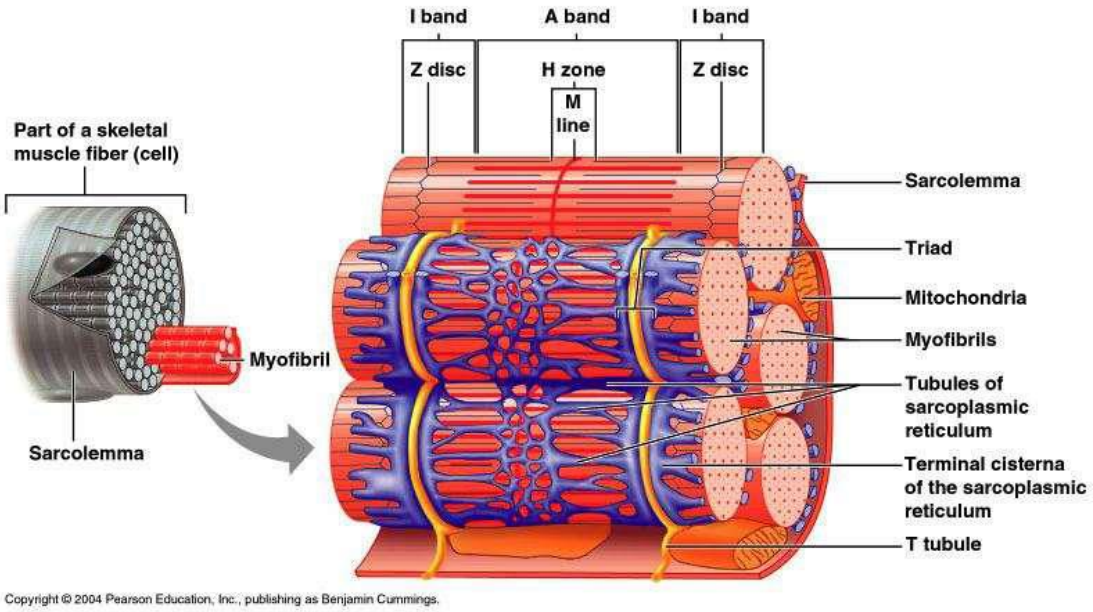
The Muscular System

The **muscular system** is the biological system of humans that produces movement. The muscular system, in vertebrates, is controlled through the nervous system, although some muscles, like cardiac muscle, can be completely autonomous. **Muscle** is contractile tissue and is derived from the mesodermal layer of embryonic germ cells. Its function is to produce force and cause motion, either locomotion or movement within internal organs. Much of muscle contraction occurs without conscious thought and is necessary for survival, like the contraction of the heart or peristalsis, which pushes food through the digestive system. Voluntary muscle contraction is used to move the body and can be finely controlled, such as movements of the finger or gross movements that of the biceps and triceps.

Muscle is composed of muscle cells (sometimes known as "muscle fibers").Within the cells are myofibrils; myofibrils contain sarcomeres which are composed of actin and myosin. Individual muscle cells are lined with endomysium. Muscle cells are bound together by perimysium into bundles called fascicles. These bundles are then grouped together to form muscle, and is lined by epimysium. Muscle spindles are distributed throughout the muscles, and provide sensory feedback information to the central nervous system. Skeletal muscle,which involves muscles from the skeletal tissue, is arranged in discrete groups. An example is the biceps brachii. It is connected by tendons to processes of the skeleton. In contrast, smooth muscle occurs at various scales in almost



Types

There are three types of muscle:

• **Smooth muscle** or "involuntary muscle" consists of spindle shaped muscle cells found within the walls of organs and structures such as the esophagus, stomach, intestines, bronchi, uterus, ureters, bladder, and blood vessels.Smooth muscle cells contain only one nucleus and no striations.

• **Cardiac muscle** is also an "involuntary muscle" but it is striated in structure and appearance. Like smooth muscle, cardiac muscle cells contain only one nucleus. Cardiac muscle is found only within the heart.

• **Skeletal muscle** or "voluntary muscle" is anchored by tendons to the bone and is used to effect skeletal movement such as locomotion. Skeletal muscle cells are multinucleated with the nuclei peripherally located.Skeletal muscle is called 'striated' because of the longitudinally striped appearance under light microscopy.

Functions of the skeletal muscle include:

• Support of the body

• Aids in bone movement

• Helps maintain a constant temperature throughout the body

• Assists with the movement of cardiovascular and lymphatic vessels through contractions

• Protection of internal organs and contributing to joint stability

Cardiac and skeletal muscle are striated in that they contain sarcomere and are packed into highly-regular arrangements of bundles; smooth muscle has neither. Striated muscle is often used in short, intense bursts, whereas smooth muscle sustains longer or even near-permanent contractions.

Skeletal muscle is further divided into several subtypes:

• Type I, slow oxidative, *slow twitch*, or "red" muscle is dense with capillaries and is rich in mitochondria and myoglobin, giving the muscle tissue its characteristic red color. It can carry more oxygen and sustain aerobic activity.

• Type II, *fast twitch*, muscle has three major kinds that are, in order of increasing contractile speed:

• a) Type IIa, which, like slow muscle, is aerobic, rich in mitochondria and capillaries and appears red.

• b) Type IIx (also known as type IId), which is less dense in mitochondria and myoglobin. This is the fastest muscle type in humans. It can contract more quickly and with a greater amount of force than oxidative muscle, but can sustain only short, anaerobic bursts of activity before muscle contraction becomes painful (often attributed to a build-up of lactic acid). N.B. in

some books and articles this muscle in humans was, confusingly, called type IIB

• c) Type IIb, which is anaerobic, glycolytic, "white" muscle that is even less dense in mitochondria and myoglobin. In small animals like rodents or rabbits this is the major fast muscle type, explaining the pale color of their meat.

For most muscles, contraction occurs as a result of conscious effort originating in the brain. The brain sends signals, in the form of action potentials, through the nervous system to the motor neuron that innervates the muscle fiber.

However, some muscles (such as the heart) do not contract as a result of conscious effort. These are said to be autonomic. Also, it is not always necessary for the signals to originate from the brain. Reflexes are fast, unconscious muscular reactions that occur due to unexpected physical stimuli. The action potentials for reflexes originate in the spinal cord instead of the brain. There are three general types of muscle contractions, skeletal muscle contractions, heart muscle contractions, and smooth muscle contractions.

Muscular System Working With Other Body Systems

• 1. Homeostasis

• 2. Protection

• 3. Calcium Metabolism

• 4. Maintaining Body Temperature

Skeletal Muscle Contractions

Steps of a skeletal muscle contraction:

• An action potential reaches the axon of the motor neuron.

• The action potential activates voltage gated calcium ion channels on the axon, and calcium rushes in.

• The calcium causes acetylcholine vesicles in the axon to fuse with the membrane, releasing the acetylcholine into the cleft between the axon and the motor end plate of the muscle fiber.

• The skeletal muscle fiber is excited by large mylenated nerve fibers which attach to the neuromuscular junction.There is one neuromuscular junction for each fiber.

• The acetylcholine diffuses across the cleft and binds to nicotinic receptors on the motor end plate, opening channels in the membrane for sodium and potassium. Sodium rushes in, and potassium rushes out. However, because sodium is more permeable, the muscle fiber membrane becomes more positively charged, triggering an action potential.

• The action potential on the muscle fiber causes the sarcoplasmic reticulum to release calcium ions(Ca++).

• The calcium binds to the troponin present on the thin filaments of the myofibrils. The troponin then allosterically modulates the tropomyosin. Normally the tropomyosin physically obstructs binding sites for cross-bridge; once calcium binds to the troponin, the troponin forces the tropomyosin to move out of the way, unblocking the binding sites.

• The cross-bridge (which is already in a ready-state) binds to the newly uncovered binding sites. It then delivers a power stroke.

• ATP binds the cross-bridge, forcing it to conform in such a way as to break the actin-myosin bond. Another ATP is split to energize the cross bridge again.

• Steps 7 and 8 repeat as long as calcium is present on thin filament.

• Throughout this process, the calcium is actively pumped back into the sarcoplasmic reticulum. When no longer present on the thin filament, the tropomyosin changes back to its previous state, so as to block the binding sites again. The cross-bridge then ceases binding to the thin filament, and the contractions cease as well.

• Muscle contraction remains as long as Ca++ is abundant in sarcoplasm.

Types of Contractions:

• Isometric contraction--muscle does not shorten during contraction and does not require the sliding of myofibrils but muscles are stiff.

• Isotonic contraction--inertia is used to move or work. More energy is used by the muscle and contraction lasts longer than isometric contraction. Isotonic muscle contraction is divided into two categories: concentric, where

the muscle fibers shorten as the muscle contracts (ie. biceps brachialis on the up phase of a biceps curl); and eccentric, where the muscle fibers lengthen as they contract

The Efficiency of Muscle Contraction:

• Only about 20% of input energy converts into muscular work. The rest of the energy is heat.

• 50% of energy from food is used in ATP formation.

• If a muscle contraction is slow or without movement, energy is lost as maintenance heat.

• If muscle contraction is rapid, energy is used to overcome friction.

Summation of Muscle Contraction: It is the adding together of individual muscle twitches to make strong muscle movements.

• Multiple motor unit summation--increasing number of motor units contracting simultaneously.

• Wave summation--increasing rapidity of contraction of individual motor units.

• Tetanization--higher frequency successive contractions fuse together and cannot be distinguished from one another.

Sliding Filament theory

When a muscle contracts, the actin is pulled along myosin toward the center of the sarcomere until the actin and myosin filaments are completely overlapped. The H zone becomes smaller and smaller due to the increasing overlap of actin and myosin filaments, and the muscle shortens. Thus when the muscle is fully contracted, the H zone is no longer visible (as in the bottom diagram, left). Note that the actin and myosin filaments themselves do not change length, but instead slide past each other.