NERVE AND SENSORY PHYSIOLOGY

SENSORY RECEPTORS

They are called selective transducers. They convert the stimulus energy into another form of energy. Sensory transduction converts stimuli into graded potential. Such changes in the receptor membrane potential are known as receptor potential. The stimulus opens ion channel in the receptor membrane. The complexity of sensory receptors ranges from free nerve endings to specialized nerve endings and receptor cells. Free nerve endings are simply branched endings of sensory neurons in the skin that function as mechanoreceptors, thermo receptors, and pain receptors. Encapsulated receptors are of several types

a. Meissner corpuscles adapt slowly to vibrations of low frequencies.
b. Ruffini endings are sensitive to steady touching and pressure and to temperature above 45 degrees Celsius.
c. The bulb of Krause is a themoreceptor that is sensitive to temperature below 20 degrees Celsius.
d. Pacinian corpuscles are located both in the dermis and near the joint; they are capable of detecting rapid pressure changes associated with touch and vibrations.

SENSORY REPRESENTATIONS

To create an accurate neural representation of sensory stimuli, the brain must distinguish four stimulus properties.

a. Stimulus modality
b. Stimulus location
c. Stimulus intensity
d. Stimulus duration.

STIMULUS MODALITY

Each receptor type is most sensitive to a particular type of stimulus. The brain thus associates a signal coming from a specific group of receptors with a specific modality. The direct association between a receptor and a sensation is called the labeled line coding. There are at least a dozen conscious sense modalities.

They are broadly classified as

a. Exteroceptors

i. Photoreceptors in the retina for vision. They respond to visible and ultraviolet light.

ii. Chemoreceptors for sensing of smell and taste.

iii. Mechanoreceptors for sensing touch, stretch, hearing, and equilibrium.

iv. Thermoreceptors detects radiant energy including infrared

b. Interoceptors

i. Chemorecepors in the carotid artery and aorta

ii. Mechanoreceptors in the labyrinth

iii. Osmoreceptors in the hypothalamus.

c. Proprioreceptors

i. Muscle spindles responding to changes in the body length

ii. Golgi tendon organ measuring muscle tension.

STIMULUS LOCATION

Each sensory receptor is most sensitive to stimulation of a specific area which defines the receptor's receptive field. When action potentials are elicited from a sensory neuron, the neuron's receptive field codes the stimulus location. Sensory receptive fields vary in size and frequently overlap. Convergence of inputs unto a single sensory neuron enhances that neuron's sensitivity but reduces spatial resolution. The size of neuronal receptive fields representing a given area determines the capacity to discriminate stimuli in an area. Sensory neuronal receptive fields are orderly organized in cortical sensory areas to form topographical maps.

Lateral inhibition; enhances the contrast between the stimulus and its surrounding, facilitating its perception and localization.

STIMULUS INTENSITY

Stimulus intensity is coded by;

a. the number of receptors activated(population coding) from low threshold receptors to high threshold ones
b. the frequency of action potentials(frequency coding) following not a linear but a power relationship

STIMULUS DURATION.

Stimulus duration can be coded by the spike train duration, but not all sensory receptors can sustain their responses. The neural code best reflects the change in stimulation, not the steady state.

SENSORY ADAPTATION

Process by which a sensory system becomes less sensitive to stimuli during prolonged or repeated stimulation. The result is a change in membrane potential as a receptor is subjected to a maintained stimulus.

Phasic Adaptation

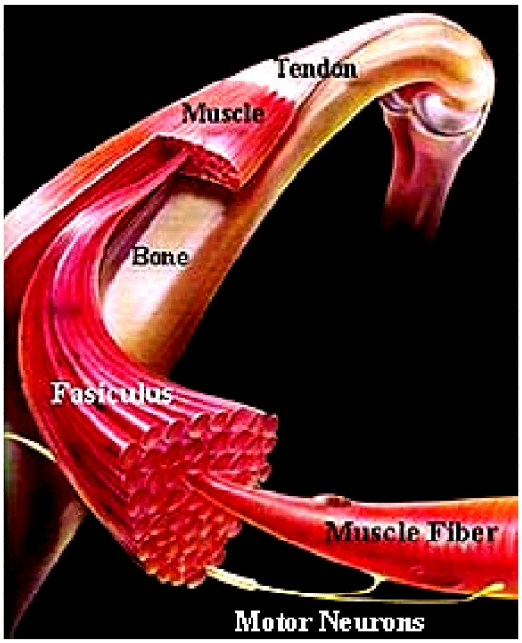
Receptors adapt rapidly. There is an initial burst of action potentials when the stimulus is applied followed by a reduced rate of firing. Examples: odour,touch, and temperature receptors.

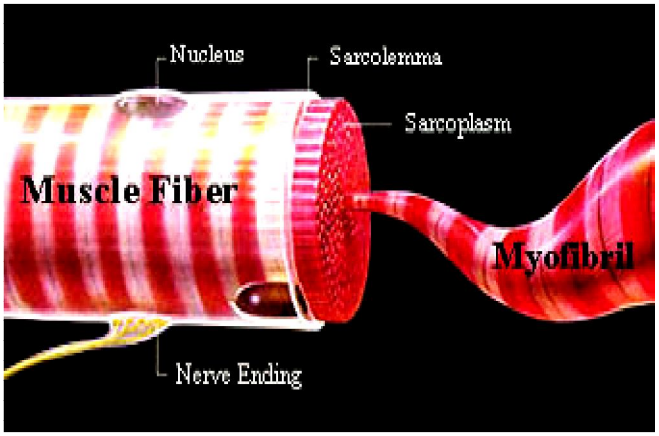
Tonic Adaptation

Receptors do not adapt or adapt slowly. Continue to fire at a relatively constant rate as long as the stimulus is applied. Examples: Pain receptors

MUSCULOSKELETAL PHYSIOLOGY

O.E. Adeleye



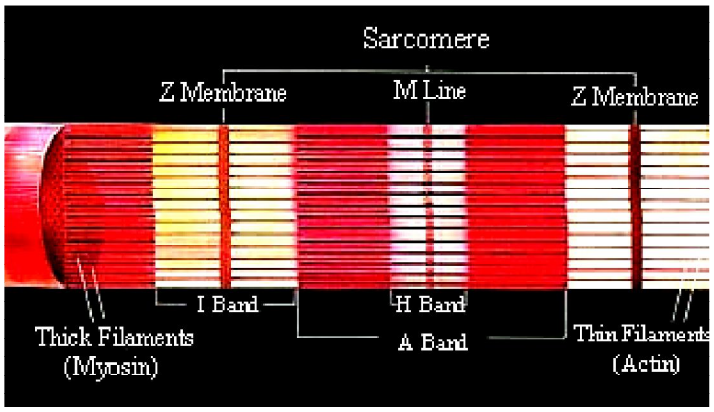


PHYSIOLOGICAL ANATOMY OF SKELETAL MUSCLE

The muscle is made up of numerous **fibers** 10-80µm in diameter. In most muscles, about 98% of these fibers extend throughout the entire length of the muscle and each is innervated by only a simple nerve ending located normally in the middle of the nerve fiber. The cell membrane of a muscle fiber is called the **sarcolemma**. It consists of a true cell membrane called the plasma membrane and an outer coat made up of a thin layer of polysaccharide material that contains numerous collagen **fibrils**. At each end of the muscle fiber, the surface layer of sarcolemma fuses with a tendon fiber and the tendon fibers in turn collect into bundles to form the muscle tendons that insert into the bone. Each muscle fiber is made up of several 100 to1,000s of **myofibrils** which are the organelles responsible for the contractile property of muscle cells. They are elongated protein threads 1-3µm in diameter in vertebrate skeletal muscle and lie with their axes parallel to the long axis of the muscle fiber.

The interior of muscle cells or fibers is literarily packed with myofibrils. It has been shown that 80-87% of the interior of skeletal muscle cells and approximately 50% of cardiac muscle cells are occupied by myofibrils. Each myofibril is made up of about 1,500 adjacent **myosin** filaments and 3000 **actin** filaments.

Actin filaments are large, polymerized protein molecules that are responsible for the actual muscle contraction and are the most abundant contractile protein in any muscle. In skeletal and cardiac muscle cells, adjacent myofibrils lie with their light and dark bands in register and this confers a cross-striated appearance on the entire cells, hence the name striated muscle. In the myofibrils, the thick filaments are the myosin filament, while the thin are actin filament. Myosin and actin filament partially interdigitate such that, longitudinally, the myofibrils have alternate light and dark bands.



Striations in skeletal muscle as seen under the microscope

The light bands contain only actin filaments and because they are **isotropic to polarized light**, they are called "**I bands"**. Similarly, the dark bands which contain myosin filaments and sometimes the end of actin filament where they overlap are called "**A bands"**, because they are **anisotropic to polarized light**.

There are projections from the sides of the myosin filament called **cross-bridges**. They protrude from the surface of myosin filaments along the entire length except in the center. It is the interaction between these cross-bridges (projections) and the actin filament that causes contraction of muscles.

The light I band is divided by a dark membrane called the **Z - disk or Z - line**. The filament extends on either side of the Z – disk or Z – line to interdigitate with the myosin filament. The Z - line passes from one myofibril to the other such that all the myofibrils are attached to one another all the way along the entire fiber, thus the entire muscle fiber has alternate **dark and light bands** and this is also true of individual myofibrils. These bands give the skeletal muscle its characteristic cross striations.

The portion of the myofibril that lies between two successive Z - lines is called a sarcomere. The length of a sarcomere in a muscle fiber that is at its normal fully stretched resting state length is about 2µm. At this state, the actin filament completely overlaps the myosin filament and is just beginning to overlap one another.

On closer examination, another region in the A band is seen where myosin filament do not overlap and only myosin filaments are present. This zone is called the **H – zone or H band**.

H band are rare in a normally functioning muscle, because normal sarcomere contraction occurs only when the length of the sarcomere at rest is between 1-2µ. Within this range, the ends of the actin filament not only overlap the myosin filament, but also overlap one another.

The myofibrils are suspended inside a muscle fiber in an intercellular matrix called the **sarcoplasm**. This comprises the usual intercellular components and its fluid also contains large amount of K^{+}, Mg^{++} and PO_4^{2-} and enzymes. Large number of mitochondria are located between and parallel to the myofibrils and this is a condition that indicates that the contracting myofibrils are in great need of large amount of energy (ATP) formed by the mitochondria.

Muscle cells also contain **sacrotubular system** and a series of **membranous tubules** that have a special structure and function.

The sarcoplasm contains an extensive endoplasmic reticulum called the **sarcoplasmic reticulum (SR)**. The more rapidly contracting muscle types are characterized by very extensive SR. The SR is composed of longitudinal tubules that lie parallel to the myofibrils and the two ends of each tubule ends in a bulbous structure called **lateral cisternae**.

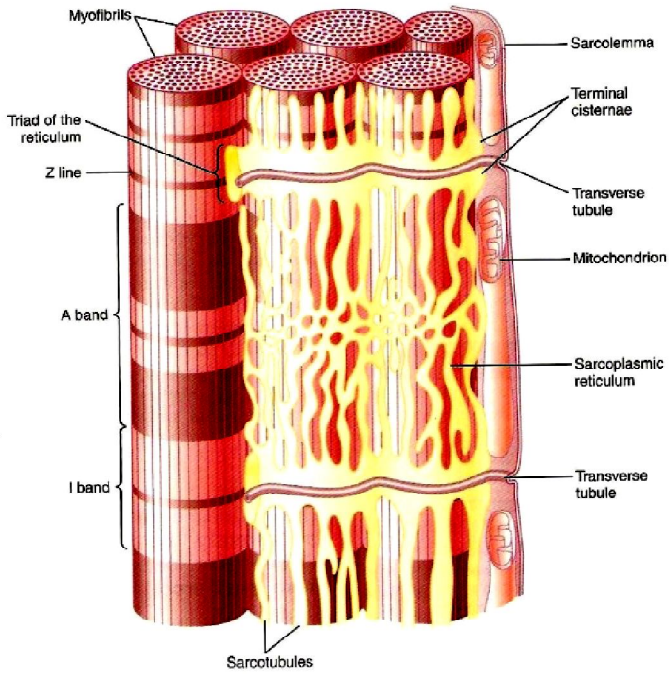


FIGURE 6-3 ■ Diagram of skeletal muscle showing the juxtaposition of myofibrils, transverse (T) tubules, and sarcoplasmic reticula. (From Guyton AC, Hall JE: *Textbook of medical physiology,* ed 11, Philadelphia, 2006, Saunders.)

<u>Sacrotubular system</u>

This system is divided into two sets of membranous tubules that do not open into one another but are able to transfer signals between themselves.

These two sets are called **Transverse or T system** and **Longitudinal or L system**. Longitudinal or L system is synonymous to the SR and structurally analogous (resembles) endoplasmic reticulum (ER) of other vertebrates.

Transverse System

The T system contains a set of tubules formed by invagination of the plasmalemma. They run parallel to the long axis of the muscle cell. The lumen of transverse tubules (T - tubules) opens to the extracellular space because they are invaginations of the plasmalemma.

T tubules occur at very regular intervals along the length of the muscle cell and in some muscles are found at the level of every Z disc i.e. there is one tubule for every sarcomere in such muscles. In most mammalian skeletal muscles however, T tubules are found at the level of every A - I junction giving two T tubules for every sarcomere and this type is usually found is fast acting muscles.

T tubules conduct signals from the sarcolemmal action potential (AP) to the interior of the muscle cell and in this way, myofibrils located in the center of the muscle all receive the signal to contract almost at the same time as those on the periphery.

L Tubule ≡ Sarcoplasmic Reticulum (SR)

Sarcoplasmic reticular tubules have the remarkable ability to accumulate Ca^{2+} against a concentration gradient. Most of the Ca^{2+} in resting muscle cells is localized in the lateral cisternae bound to a protein called **<u>CALSEQUESTRIN</u>**. A signal produced by the passage of an AP along the T tubule causes some of the Ca^{2+} in the lateral cisternae to be dislodged (disgorged) into the interior of the muscle cells and this results is free intracellular Ca^{2+} concentration rising momentarily. The increase in Ca^{2+} concentration triggers muscle contraction.