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Physical Education Code:47

Unit–II: Foundation of Physical Education

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At a Glance

Sub Unit – I: Exercise physiology its scope and importance in the field of physical education and sports

- Exercise physiology is the physiology of physical exercise.
- Exercise physiology is an important sub discipline within the discipline of exercise science.
- The word exercise comes from the Latin *exercitus*, "to drive forth," while physiology comes from the words *physis* ("nature") and *logia* ("study").

Sub Unit – II: Cardio respiratory adaptations to long- and short-term physical activities

- Cardio-respiratory fitness refers to the ability of the circulatory and respiratory systems to supply oxygen to skeletal muscles during sustained physical activity.
- *The adaptation takes place in all the organs, systems and functions which are affected by the process of tackling the training and competition demands.*
- As the levels of initial fitness improve, the change in aerobic power decreases regardless of the intensity, frequency or duration of exercise.

Sub Unit – III: Muscle- its types, characteristics and functions. Microscopic structure of muscle fibre. Sliding filament theory of muscular contraction. Types of muscle fibres and sports performance. Muscular adaptations to exercise

- Muscle is the tissue of the body which primarily functions as a source of power
- Skeletal muscle, attached to bones, is responsible for skeletal movements.
- Smooth muscle, found in the walls of the hollow internal organs such as blood vessels, the gastrointestinal tract, bladder, and uterus, is under control of the autonomic nervous system.
- Cardiac muscle, found in the walls of the heart, is also under control of the autonomic nervous system.

Sub Unit – IV: Neuro-muscular junction and transmission of nerve impulse, kinesthetic Sense organs and neural control of motor skills

- Exercise physiology is the physiology of physical exercise.
- Kinesthesis refers to sensory input that occurs within the body. Postural and movement information are communicated via sensory systems by tension and compression of muscles in the body.
- Proprioception, also referred to as kinesthesia, is the sense of self-movement and body position. It is sometimes described as the "sixth sense". Proprioception is mediated by proprioceptors, mechanosensory neurons located within muscles, tendons, and joints.

Sub Unit – V: Bio-chemical aspects of exercise - Metabolism of food products. Aerobic and anaerobic systems during rest and exercise. Direct and indirect methods of measuring energy cost of exercise

- Bio-Chemical aspect of exercise is concerned with the effects of exercise analyzed through molecules, enzyme, metabolism and energy utilization in the cell.
- Glucose is mainly metabolized by a very important ten-step pathway called glycolysis, the net result of which is to break down one molecule of glucose into two molecules of pyruvate.
- Energy metabolism is the general process by which living cells acquire and use the energy needed to stay alive, to grow, and to reproduce.

Sub Unit – VI: Recovery process - Physiological aspects of fatigue. Restoration of energy stores. Recovery oxygen. Nutritional aspects of performance

- Fatigue is a term used to describe an overall feeling of tiredness or lack of energy.
- The main symptom of fatigue is exhaustion with physical or mental activity.
- Sport performance can be improved through training and competition load.

Sub Unit – VII: Environmental influence on human physiology under exercise

Sub Unit – VIII: Women in sports- trainability, Physiological gender differences and special problems of women athletes

Sub Unit – IX: Aging - Physiological consequences, life style management and healthful aging

Sub Unit – X: Physiological responses of various therapeutic modalities and rehabilitation

Sub Unit – XI: Physiological aspects of various Ergogenic aids, Massage manipulations and their physiological responses.

Key Statements

Sub Unit – I: Exercise physiology its scope and importance in the field of physical education and sports

Basic Points:

Knowledge of exercise physiology required to physical educator, team doctor, physiotherapist, dietitian, physical instructor as well as coaches.

Standard Points:

Exercise physiology has a great importance to know the effect of exercise on muscular system, circulatory system, respiratory system, endocrine system, excretory system and also nervous system.

Advance Points:

In the 21st century exercise physiology is used for clinical trial and also for development for the strong immune power in our body.

Sub Unit – II: Cardio respiratory adaptations to long- and short-term physical activities

Basic Points:

Adaptation takes place in phases and at different levels of regulation and hence an attempt to explain adaptation only from energy or metabolic point of view is bound to be incomplete.

Standard Points:

Due to long time high intensity exercise the muscular walls of the heart increase in thickness, particularly in the left ventricle, providing a more powerful contraction.

Advance Points:

Hypertensive persons may benefit from resistance training by adaptation long time exercise with low intensity.

Sub Unit – III: Muscle- its types, characteristics and functions. Microscopic structure of muscle fibre. Sliding filament theory of muscular contraction. Types of muscle fibres and sports performance. Muscular adaptations to exercise

Basic Points:

All muscle tissues have characteristics in common: excitability, contractility, extensibility - they can be stretched and elasticity - they return to normal length after stretching.

Standard Points:

Functions of Muscle: Movement and Regulation, Posture and Support and also Body Temperature Regulation.

Advance Points:

Functional unit of a skeletal muscle fiber is the sarcomere.

Sub Unit – IV: Neuro-muscular junction and transmission of nerve impulse, kinesthetic Sense organs and neural control of motor skills

Basic Points:

A neuromuscular junction is a chemical synapse between a motor neuron and a muscle fiber. It allows the motor neuron to transmit a signal to the muscle fiber, causing muscle contraction.

Standard Points:

Steps in neuromuscular transmission:

1) Nerve action potential.
2) Calcium entry into the presynaptic terminus.
3) Release of Ach quanta.
4) Diffusion of Ach across cleft.
5) Combination of Ach with post-synaptic receptors and Ach breakdown via esterase.
6) Opening of Na+ /K+ channels (cation channels).
7) Postsynaptic membrane depolarization (EPP).
8) Muscle action potential.

Advance Points:

If either the neurotransmitter is being degraded before reaching the other end, or if sufficient amount of neurotransmitter is not being released, the disturbance does not travel in the next neuron or the muscle does not contract. This is called **the all or none law**.

Sub Unit – V: Bio-chemical aspects of exercise - Metabolism of food products. Aerobic and anaerobic systems during rest and exercise. Direct and indirect methods of measuring energy cost of exercise

Basic Points:

"Aerobic" means "relating to, involving, or requiring free oxygen", and refers to the use of oxygen to adequately meet energy demands during exercise via aerobic metabolism.

Standard Points:

Anaerobic exercise is a type of exercise that breaks down glucose in the body without using oxygen, as anaerobic means “without oxygen”.

Advance Points:

The technique of indirect calorimetry relies on the measurement of inspired and expired gas volume, and the concentrations of O_2 and CO_2.

Sub Unit – VI: Recovery process - Physiological aspects of fatigue. Restoration of energy stores. Recovery oxygen. Nutritional aspects of performance

Basic Points:

Higher loads over a period of months and years lead to higher improvement in performance.

Standard Points:

The recovery takes place side by side with the onset of fatigue (during the activity) e. g. re-synthesis of ATP, glycogen, neutralization of lactic acid.

Advance Points:

When it is sure that a state of overload exists then several steps have to take immediately. Load must be reduced considerably and active and passive means of recovery should be stated.

Sub Unit – VII: Environmental influence on human physiology under exercise

Sub Unit – VIII: Women in sports- trainability, Physiological gender differences and special problems of women athletes

Sub Unit – IX: Aging - Physiological consequences, life style management and healthful aging

Sub Unit – X: Physiological responses of various therapeutic modalities and rehabilitation

Sub Unit – XI: Physiological aspects of various Ergogenic aids, Massage manipulations and their physiological responses.

Key Fact & Figures

Sub Unit – I: Exercise physiology its scope and importance in the field of physical education and sports

2.1.1 Definition of Exercise Physiology

Exercise physiology is the physiology of physical exercise. It is one of the allied health professions that involve the study of the acute responses and chronic adaptations to exercise. Understanding the effect of exercise involves studying specific changes in muscular, cardiovascular, and neuro-humoral systems that lead to changes in functional capacity and strength due to endurance training or strength training. The effect of training on the body has been defined as the reaction to the adaptive responses of the body arising from exercise or as "an elevation of metabolism produced by exercise". Exercise physiologists study the effect of exercise on pathology and the mechanisms by which exercise can reduce or reverse disease progression. Exercise physiology is the study of the body's responses to physical activity. These responses include changes in metabolism and in physiology of different areas of the body like the heart, lungs, and muscles, and structural changes in cells. The word exercise comes from the Latin *exercitus*, "to drive forth," while physiology comes from the words *physis* ("nature") and *logia* ("study").

Definition:

"Exercise physiology is an important sub discipline within the discipline of exercise science."

– S. Brown.

"Exercise physiology is a sub-discipline of kinesiology that addresses the short-term biological responses to the stress of physical activity and how the body adapts to repeated bouts of physical activity over time" – P. Davis.

"Exercise Physiology is the identification of physiological mechanisms underlying physical activity and regular exercise, the comprehensive delivery of treatment services concerned with the analysis, improvement, and maintenance of physical and mental health and fitness, the rehabilitation of heart disease and other diseases and/or disabilities, and the professional guidance and counsel of athletes and others interested in athletics and sports training."

- American Society of Exercise Physiologists (2015)

2.1.2 Scope of Exercise Physiology in the field of Physical Education and sports

1. Knowledge of Exercise Physiology may be utilized by physical education teacher for taking class either in theoretical or practical.
2. The physical instructor may use the knowledge of exercise in their respective field.
3. The team doctors should use the idea of exercise physiology especially orthopedics doctors.
4. The first aider should have basic knowledge of exercise physiology for better support.
5. The coach should have an expertise in the field of exercise physiology.
6. The team yoga trainer also required sufficient knowledge of exercise physiology.
7. The physiotherapist of sportsman should have proper knowledge of exercise physiology.
8. Official of any sports must have the basic knowledge of exercise physiology.
9. The dietician of the sportsman may utilize the knowledge of exercise physiology.
10. The team manager must be proper knowledge of exercise physiology for proper management.

2.1.3 Importance of Exercise Physiology in the field of Physical Education and sports

1. For gathering concept of muscular system and effect of exercise on it.
2. For enriching concept of circulatory system and effect of exercise on it.
3. To know respiratory system and effect of exercise on it.
4. To understand bone and bone joint and effect of exercise on these.
5. To analysis nervous system and effect of exercise on it.
6. For development of knowledge of endocrine system and effect of exercise on it.
7. For synthesis of function of excretory system and effect of exercise on it.
8. For comparing function of reproductive system and effect of exercise on it.
9. For calculating energy expenditure of exercise and effect of exercise on energy cost.
10. For preparing diet chart of athlete and sportsman basis of exercise physiology.
11. For clinical purpose and recovery from injury and also disease of sportsman.
12. For providing first aid in any sports with proper and early rehabilitation.
13. For conducting any physical training under hot, humid and high altitude.
14. For distribution of physical load and adaptation according to sportsman load capacity.
15. For teaching exercise physiology in physical education class detail knowledge of exercise physiology with proper example and scientific analysis is necessary.

Sub Unit – II: Cardio respiratory adaptations to long- and short-term physical activities

2.2.1. Definition of adaptation.

Adaptation is the physical or behavioral characteristic of an organism that helps an organism to survive better in the surrounding environment. The process of tackling training and competition demands leads to disturbance of psychic and physiological state of homeostasis. The human organism tends to restore the state of homeostasis by causing the different systems and functions to adjust to the state of disturbance. This is a simply a functional adjustment but if the homeostasis is optimally disturbed repeatedly for a number of days then the human body responds by causing structural and metabolic changes which enable the body to tolerate load more easily. This is called adaptation. This adaptation also means better performance capacity to tackle the demands which caused the adaptation. The adaptation takes place in all the organs, systems and functions which are affected by the process of tackling the training and competition demands.

Adaptation takes place in phases and at different levels of regulation and hence an attempt to explain adaptation only from energy or metabolic point of view is bound to be incomplete. - Neumann(1988)

2.2.2 Cardio respiratory adaptations to short term physical activities.

Cardio-respiratory fitness (CRF) refers to the ability of the circulatory and respiratory systems to supply oxygen to skeletal muscles during sustained physical activity. The primary measure of CRF is VO_2 max. Regular exercise makes these systems more efficient by enlarging the heart muscle, enabling more blood to be pumped with each stroke, and increasing the number of small arteries in trained skeletal muscles, which supply more blood to working muscles. Exercise improves not just the respiratory system but the heart by increasing the amount of oxygen that is inhaled and distributed to body tissue. There are many benefits of cardio-respiratory fitness. It can reduce the risk of heart disease, lung cancer, type 2 diabetes, stroke, and other diseases. Cardio-respiratory fitness helps improve lung and heart condition, and increases feelings of wellbeing. The American College of Sports Medicine recommends aerobic exercise 3–5 times per week for 30–60 minutes per session, at a moderate intensity, that maintains the heart rate between 65–85% of the maximum heart rate. The cardiovascular system responds to changing demands on the body by adjusting cardiac output, blood flow, and blood pressure. Cardiac output is defined as the product of heart rate and stroke volume which represents the volume of blood being pumped by the heart each minute. Cardiac output increases during physical activity due to an increase in both the heart rate and stroke volume. At the beginning of exercise, the cardiovascular adaptations are very rapid: "Within a second after muscular contraction, there is a withdrawal of vagal outflow to the heart, which is followed by an increase in sympathetic stimulation of the heart. This result in an increase in cardiac output to ensure that blood flow to the muscle is matched to the metabolic needs". Both heart rate and stroke volume vary directly with the intensity of the exercise performed and many improvements can be made through continuous training. Another important issue is the regulation of blood flow during exercise. Blood flow must increase in order to provide the working muscle with more oxygenated blood which can be accomplished through neural and chemical regulation. Blood vessels are under sympathetic tone; therefore, the release of noradrenaline and adrenaline will cause vasoconstriction of non-essential tissues such as the liver, intestines, and kidneys, and decrease neurotransmitter release to the active muscles promoting vasodilatation. Also, chemical factors such as a decrease in oxygen concentration and an increase in carbon dioxide or lactic acid concentration in the blood promote vasodilatation to increase blood flow.[8] As a result of increased vascular resistance, blood pressure rises throughout exercise and stimulates baroreceptors in the carotid arteries and aortic arch. “These pressure receptors are important since they regulate arterial blood pressure around an elevated systemic pressure during exercise”. Although all of the described adaptations in the body to maintain homeostatic balance during exercise are very important, the most essential factor is the involvement of the respiratory system. The respiratory system allows for the proper exchange and transport of gases to and from the lungs while being able to control the ventilation rate through neural and chemical impulses. In addition, the body is able to efficiently use the three energy systems which include the phosphagen system, the glycolytic system, and the oxidative system.

2.2.3 Cardio respiratory adaptations to long term physical activities.

Heart Size	• The muscular walls of the heart increase in thickness, particularly in the left ventricle, providing a more powerful contraction. • The left ventricles internal dimensions increase as a result of increased ventricular filling.
Stroke Volume (SV)	• The increase in size of the heart enables the left ventricle to stretch more and thus fill with more blood. The increase in muscle wall thickness also increases the contractility resulting in increased stroke volume at rest and during exercise, increasing blood supply to the body.
Resting Heart Rate (RHR)	• As cardiac output at rest remains constant the increase in stroke volume is accompanied by a corresponding decrease in heart rate.
Cardiac Output (Q)	• Cardiac output increases significantly during maximal exercise effort due to the increase in SV. This results in greater oxygen supply, waste removal and hence improved endurance performance.
Blood Pressure (BP)	• People with blood pressure in the ‘normal’ ranges experience little change in BP at rest or with exercise; however hypertensive people find that their BP’s reduce towards normal as they do more exercise. This is due to a reduction in total peripheral resistance within the artery, and improved condition and elasticity of the smooth muscle in the blood vessel walls.

Within each level of exercise duration, frequency, programme length or initial fitness level, the greatest improvements in aerobic power occur when the greatest challenge to aerobic power occurs i.e., when intensity is from 90 to 100% of $\dot{V}O_{2max}$. The pattern of improvement where different intensities are compared with different durations suggests that when exercise exceeds 35 minutes, a lower intensity of training results in the same effect as those achieved at higher intensities for shorter durations. Frequencies of as low as 2 per week can result in improvements in less fit subjects but when aerobic power exceeds 50 ml/kg/min, exercise frequency of at least 3 times per week is required. As the levels of initial fitness improve, the change in aerobic power decreases regardless of the intensity, frequency or duration of exercise. Maximal gains in aerobic power are elicited with intensities between 90 to 100% $\dot{V}O_{2\,max}$, 4 times per week with exercise durations of 35 to 45 minutes, it is important to note that lower intensities still produce effective changes and reduce the risks of injury in non-athletic groups.

The cardiovascular system, composed of the heart, blood vessels, and blood, responds predictably to the increased demands of exercise. With few exceptions, the cardiovascular response to exercise is directly proportional to the skeletal muscle oxygen demands for any given rate of work, and oxygen uptake (VO ˙ 2) increases linearly with increasing rates of work.

Cardiac Output: Cardiac output (Q) is the total volume of blood ˙ pumped by the left ventricle of the heart per minute. It is the product of heart rate (HR, number of beats per minute) and stroke volume (SV, volume of blood pumped per beat). The arterial-mixed venous oxygen (A-- vO2) difference is the difference between the oxygen content of the arterial and mixed venous blood. A person's maximum oxygen uptake (VO˙ 2 max) is a function of cardiac output (Q) multiplied by the ˙ A-- vO2 difference. Cardiac output thus plays an important role in meeting the oxygen demands for work. As the rate of work increases, the cardiac output increases in a nearly linear manner to meet the increasing oxygen demand, but only up to the point where it reaches its maximal capacity (Q max). ˙ To visualize how cardiac output, heart rate, and stroke volume change with increasing rates of work, consider a person exercising on a cycle ergometer, starting at 50 watts and increasing 50 watts every 2 minutes up to a maximal rate of work. In this scenario, cardiac output and heart rate increase over the entire range of work, whereas stroke volume only increases up to approximately 40 to 60 percent of the person's maximal oxygen uptake (VO˙ 2 max), after which it reaches a plateau. Recent studies have suggested that stroke volume in highly trained persons can continue to increase up to near maximal rates of work (Scruggs et al. 1991; Gledhill, Cox, Jamnik 1994).

Blood Flow: The pattern of blood flow changes dramatically when a person goes from resting to exercising. At rest, the skin and skeletal muscles receive about 20 percent of the cardiac output. During exercise, more blood is sent to the active skeletal muscles, and, as body temperature increases, more blood is sent to the skin. This process is accomplished both by the increase in cardiac output and by the redistribution of blood flow away from areas of low demand, such as the splanchnic organs. This process allows about 80 percent of the cardiac output to go to active skeletal muscles and skin at maximal rates of work (Rowell 1986). With exercise of longer duration, particularly in a hot and humid environment, progressively more of the cardiac output will be redistributed to the skin to counter the increasing body temperature, thus limiting both the amount going to skeletal muscle and the exercise endurance (Rowell 1986).

Blood Pressure: Mean arterial blood pressure increases in response to dynamic exercise, largely owing to an increase in systolic blood pressure, because diastolic blood pressure remains at near-resting levels. Systolic blood pressure increases linearly with increasing rates of work, reaching peak values of between 200 and 240 millimeters of mercury in normotensive persons. Because mean arterial pressure is equal to cardiac output times total peripheral resistance, the observed increase in mean arterial pressure results from an increase in cardiac output that outweighs a concomitant decrease in total peripheral resistance. This increase in mean arterial pressure is a normal and desirable response, the result of a resetting of the arterial baroreflex to a higher pressure. Without such a resetting, the body would experience severe arterial hypotension during intense activity (Rowell 1993). Hypertensive patients typically reach much higher systolic blood pressures for a given rate of work, and they can also experience increases in diastolic blood pressure. Thus, mean arterial pressure is generally much higher in these patients, likely owing to a lesser reduction in total peripheral resistance. For the first 2 to 3 hours following exercise, blood pressure drops below pre exercise resting levels, a phenomenon referred to as post exercise hypotension (Isea et al. 1994). The specific mechanisms underlying this response have not been established. The acute changes in blood pressure after an episode of exercise may be an important aspect of the role of physical activity in helping control blood pressure in hypertensive patients.

Oxygen Extraction: The A-- vO2 difference increases with increasing rates of work and results from increased oxygen extraction from arterial blood as it passes through exercising muscle. At rest, the A-- vO2 difference is approximately 4 to 5 ml of O2 for every 100 ml of blood (ml/100 ml); as the rate of work approaches maximal levels, the A-- vO2 difference reaches 15 to 16 ml/100 ml of blood.

Coronary Circulation: The coronary arteries supply the myocardium with blood and nutrients. The right and left coronary arteries curve around the external surface of the heart, then branch and penetrate the myocardial muscle bed, dividing and subdividing like branches of a tree to form a dense vascular and capillary network to supply each myocardial muscle fiber. Generally one capillary supplies each myocardial fiber in adult humans and animals; however, evidence suggests that the capillary density of the ventricular myocardium can be increased by endurance exercise training. At rest and during exercise, myocardial oxygen demand and coronary blood flow are closely linked. This coupling is necessary because the myocardium depends almost completely on aerobic metabolism and therefore requires a constant oxygen supply. Even at rest, the myocardium's oxygen use is high relative to the blood flow. About 70 to 80 percent of the oxygen is extracted from each unit of blood crossing the myocardial capillaries; by comparison, only about 25 percent is extracted from each unit crossing skeletal muscle at rest. In the healthy heart, a linear relationship exists between myocardial oxygen demands, consumption, and coronary blood flow, and adjustments are made on a beat-to-beat basis. The three major determinants of myocardial oxygen consumption are heart rate, myocardial contractility, and wall stress (Marcus 1983; Jorgensen et al. 1977). Acute increases in arterial pressure increase left ventricular pressure and wall stress. As a result, the rate of myocardial metabolism increases, necessitating an increased coronary blood flow. A very high correlation exists between both myocardial oxygen consumption and coronary blood flow and the product of heart rate and systolic blood pressure (SBP) (Jorgensen et al. 1977). This socalled double product (HR • SBP) is generally used to estimate myocardial oxygen and coronary blood flow requirements. During vigorous exercise, all three major determinants of myocardial oxygen requirements increase above their resting levels. The increase in coronary blood flow during exercise results from an increase in perfusion pressure of the coronary artery and from coronary vasodilation. Most important, an increase in sympathetic nervous system stimulation leads to an increase in circulating catecholamines. This response triggers metabolic processes that increase both perfusion pressure of the coronary artery and coronary vasodilation to meet the increased need for blood flow required by the increase in myocardial oxygen use.

Respiratory Responses to Exercise: The respiratory system also responds when challenged with the stress of exercise. Pulmonary ventilation increases almost immediately, largely through stimulation of the respiratory centers in the brain stem from the motor cortex and through feedback from the proprioceptors in the muscles and joints of the active limbs. During prolonged exercise, or at higher rates of work, increases in CO2 production, hydrogen ions

(H+), and body and blood temperatures stimulate further increases in pulmonary ventilation. At low work intensities, the increase in ventilation is mostly the result of increases in tidal volume. At higher intensities, the respiratory rate also increases. In normal-sized, untrained adults, pulmonary ventilation rates can vary from about 10 liters per minute at rest to more than 100 liters per minute at maximal rates of work; in large, highly trained male athletes, pulmonary ventilation rates can reach more than 200 liters per minute at maximal rates of work.

Resistance Exercise: The cardiovascular and respiratory responses to episodes of resistance exercise are mostly similar to those associated with endurance exercise. One notable exception is the exaggerated blood pressure response that occurs during resistance exercise. Part of this response can be explained by the fact that resistance exercise usually involves muscle mass that develops considerable force. Such high, isolated force leads to compression of the smaller arteries and results in substantial increases in total peripheral resistance (Coyle 1991). Although high-intensity resistance training poses a potential risk to hypertensive patients and to those with cardiovascular disease, research data suggest that the risk is relatively low (Gordon et al. 1995) and that hypertensive persons may benefit from resistance training (Tipton 1991; American College of Sports Medicine 1993.

Sub Unit – III

Muscle- its types, characteristics and functions. Microscopic structure of muscle fibre. Sliding filament theory of muscular contraction. Types of muscle fibres and sports performance. Muscular adaptations to exercise.

2.3.1 What is Muscle?

A band or bundle of fibrous tissue in a human or animal body that has the ability to contract, producing movement in or maintaining the position of parts of the body is called muscle. Muscle is the tissue of the body which primarily functions as a source of power. There are three types of muscle in the body. Muscle which is responsible for moving extremities and external areas of the body is called "skeletal muscle." Heart muscle is called "cardiac muscle." Muscle that is in the walls of arteries and bowel is called "smooth muscle."

Skeletal Muscle

Skeletal muscle, attached to bones, is responsible for skeletal movements. The peripheral portion of the central nervous system (CNS) controls the skeletal muscles. Thus, these muscles are under conscious, or voluntary, control. The basic unit is the muscle fiber with many nuclei. These muscle fibers are striated (having transverse streaks) and each acts independently of neighboring muscle fibers.

Smooth Muscle

Smooth muscle, found in the walls of the hollow internal organs such as blood vessels, the gastrointestinal tract, bladder, and uterus, is under control of the autonomic nervous system. Smooth muscle cannot be controlled consciously and thus acts involuntarily. The non-striated (smooth) muscle cell is spindle-shaped and has one central nucleus. Smooth muscle contracts slowly and rhythmically.

Cardiac Muscle

Cardiac muscle, found in the walls of the heart, is also under control of the autonomic nervous system. The cardiac muscle cell has one central nucleus, like smooth muscle, but it also is striated, like skeletal muscle. The cardiac muscle cell is rectangular in shape. The contraction of cardiac muscle is involuntary, strong, and rhythmical.

2.3.3 Characteristics of Muscles.

All muscle tissues have **4 characteristics** in common:

1. excitability
2. contractility
3. extensibility - they can be stretched
4. elasticity - they return to normal length after stretching

2.3.4 Function of Muscles.

1) Movement and Regulation.
Examples related to:

- Skeletal muscle: Movement of skeleton
- Cardiac muscle: Movement (contraction) of heart
- Smooth muscle: Regulation of blood vessel diameter, bronchiole diameter, movement of material in gastrointestinal tract.

2) Posture and Support3) Body Temperature Regulation.

2.3.5 Microscopic structure of muscle fibre

Levels of Organization of Skeletal Muscle:

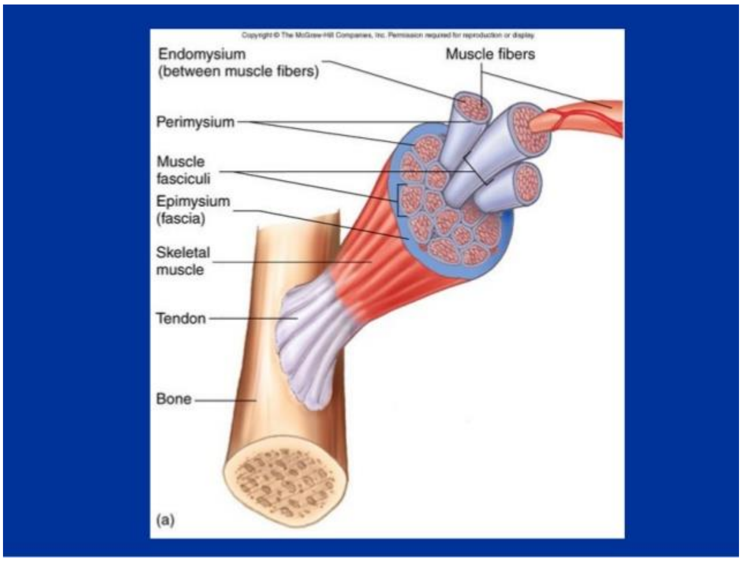
- Muscle: a collection of fascicles
- Fascicle: a collection of muscle cells
- Muscle cell or fiber: collection of myofibrils plus other cell organelles.
- Myofibril: series of sarcomeres
- Sarcomeres: Basic unit of muscle structure and function.
- Filaments: Thick and thin filaments

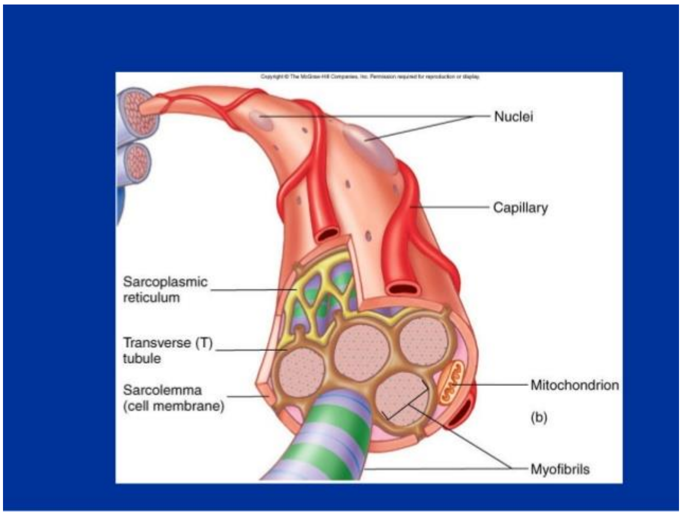
Associated Connective Tissue Organizes Muscle Tissue

Bundles of muscle fibers are grouped or bundled together by connective tissue.

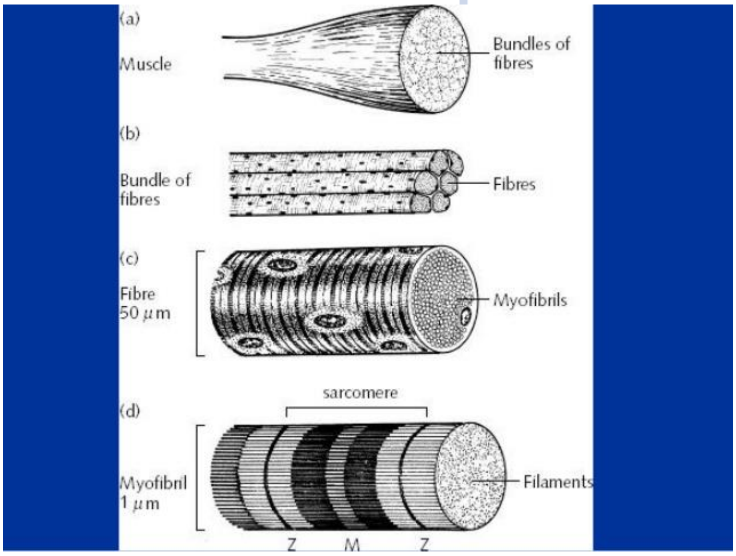
- Endomysium: surrounds fibers
- Perimysium: surrounds fascicle
- Epimysium: surrounds fascicles

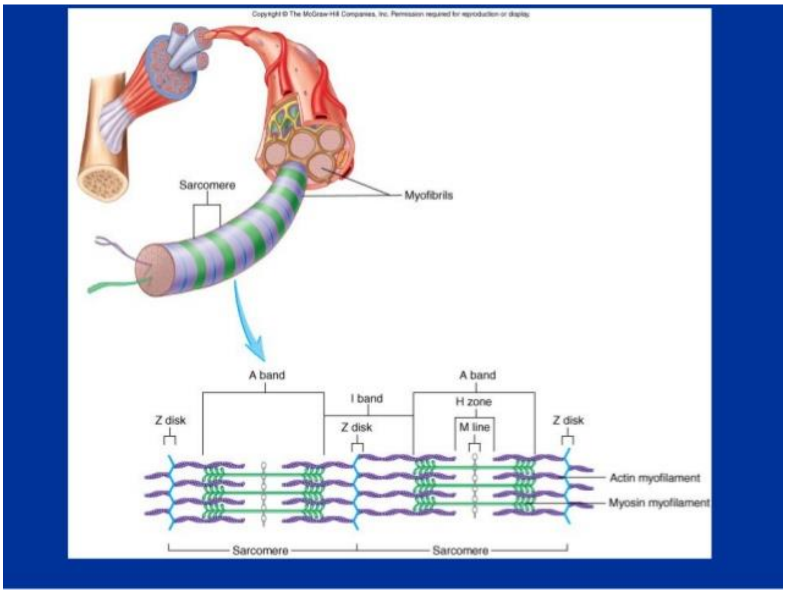
Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of hundreds, or even thousands, of muscle fibers bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the epimysium. Fascia, connective tissue outside the epimysium, surrounds and separates the muscles. Portions of the epimysium project inward to divide the muscle into compartments. Each compartment contains a bundle of muscle fibers. Each bundle of muscle fiber is called a fasciculus and is surrounded by a layer of connective tissue called the perimysium. Within the fasciculus, each individual muscle cell, called a muscle fiber, is surrounded by connective tissue called the endomysium. Skeletal muscle cells (fibers), like other body cells, are soft and fragile. The connective tissue covering furnish support and protection for the delicate cells and allow them to withstand the forces of contraction. The coverings also provide pathways for the passage of blood vessels and nerves.



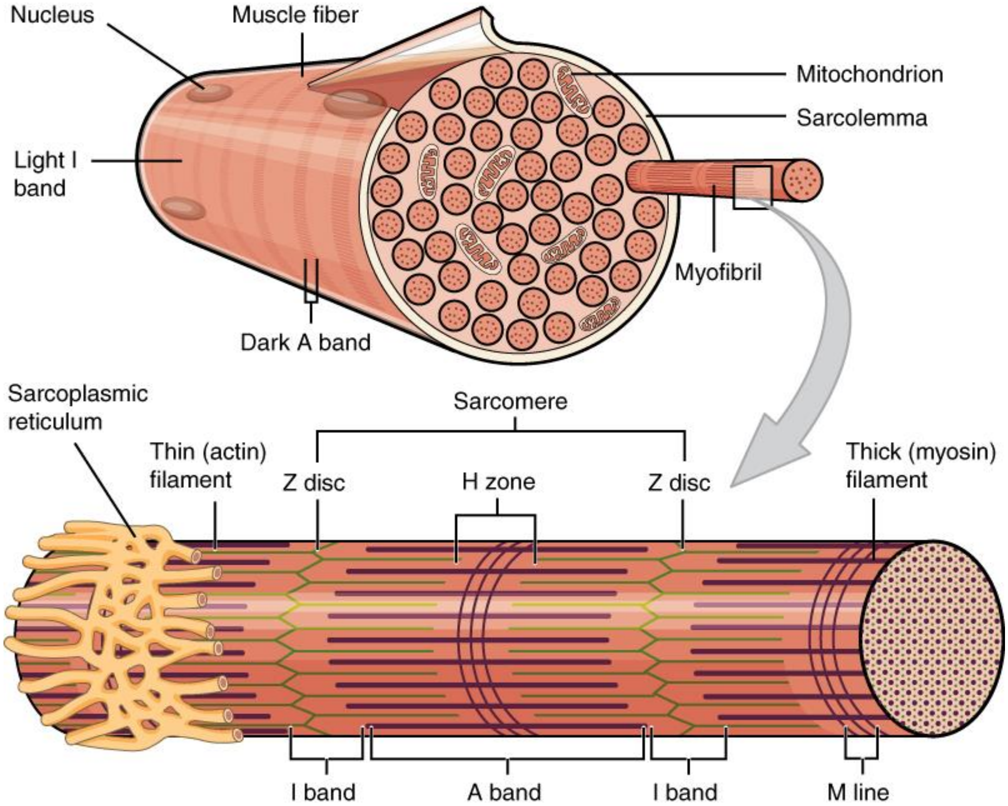


Commonly, the epimysium, perimysium, and endomysium extend beyond the fleshy part of the muscle, the belly or gaster, to form a thick ropelike tendon or a broad, flat sheet-like aponeurosis. The tendon and aponeurosis form indirect attachments from muscles to the periosteum of bones or to the connective tissue of other muscles. Typically a muscle spans a joint and is attached to bones by tendons at both ends. One of the bones remains relatively fixed or stable while the other end moves as a result of muscle contraction. Skeletal muscles have an abundant supply of blood vessels and nerves. This is directly related to the primary function of skeletal muscle, contraction. Before a skeletal muscle fiber can contract, it has to receive an impulse from a nerve cell. Generally, an artery and at least one vein accompany each nerve that penetrates the epimysium of a skeletal muscle. Branches of the nerve and blood vessels follow the connective tissue components of the muscle of a nerve cell and with one or more minute blood vessels called capillaries.



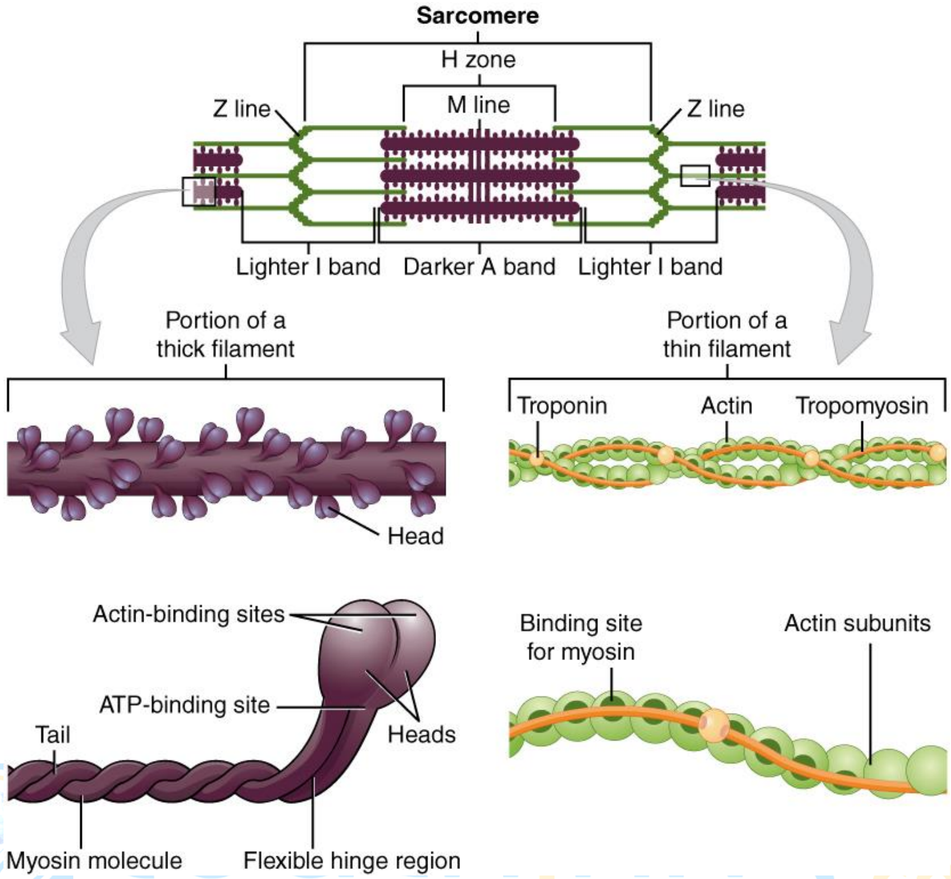


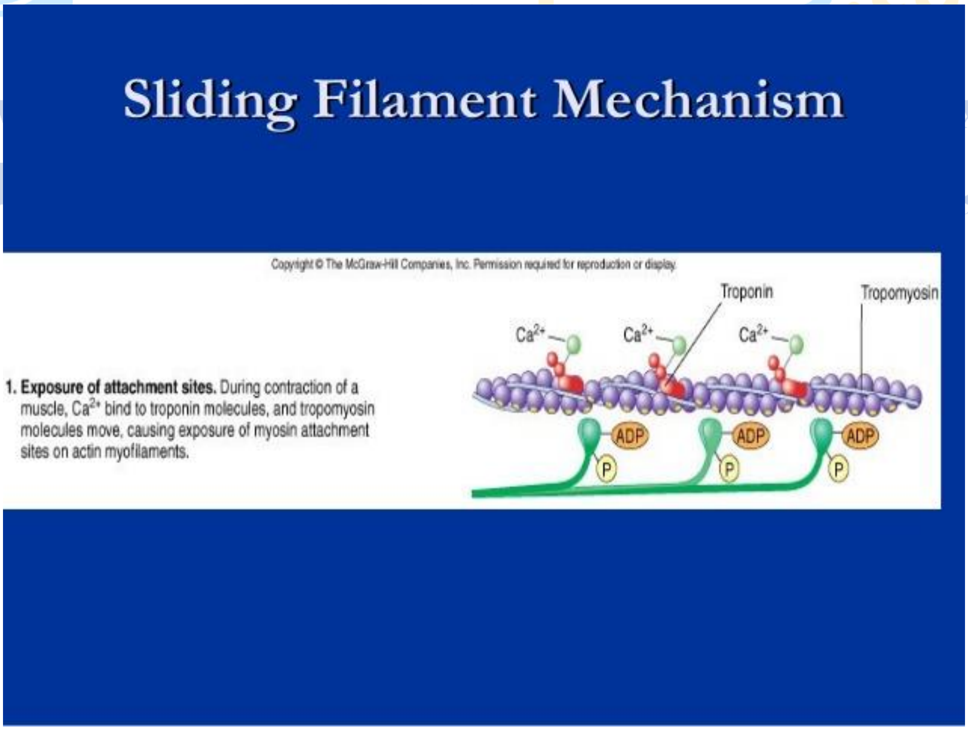
Some other terminology associated with muscle fibers is rooted in the Greek *sarco*, which means "flesh." The plasma membrane of muscle fibers is called the **sarcolemma**, the cytoplasm is referred to as **sarcoplasm**, and the specialized smooth endoplasmic reticulum, which stores, releases, and retrieves calcium ions (Ca^{++}) is called the **sarcoplasmic reticulum (SR)**. As will soon be described, the functional unit of a skeletal muscle fiber is the sarcomere, a highly organized arrangement of the contractile myofilament's **actin** (thin filament) and **myosin** (thick filament), along with other support proteins. The sarcomere is the functional unit of the muscle fiber. The sarcomere itself is bundled within the myofibril that runs the entire length of the muscle fiber and attaches to the sarcolemma at its end. As myofibrils contract, the entire muscle cell contracts. Because myofibrils are only approximately 1.2 μm in diameter, hundreds to thousands (each with thousands of sarcomeres) can be found inside one muscle fiber. Each sarcomere is approximately 2 μm in length with a three-dimensional cylinder-like arrangement and is bordered by structures called Z-discs (also called Z-lines, because pictures are two-dimensional), to which the actin myofilaments are anchored. Because the actin and its troponin-tropomyosin complex (projecting from the Z-discs toward the center of the sarcomere) form strands that are thinner than the myosin, it is called the **thin filament** of the sarcomere. Likewise, because the myosin strands and their multiple heads (projecting from the center of the sarcomere, toward but not all to way to, the Z-discs) have more mass and are thicker, they are called the **thick filament** of the sarcomere.



2.3.6 Sliding filament of muscular contraction

The **sliding filament theory** explains the mechanism of muscle contraction based on muscle proteins that slide past each other to generate movement. According to the sliding filament theory, the myosin (thick) filaments of muscle fibers slide past the actin (thin) filaments during muscle contraction, while the two groups of filaments remain at relatively constant length. It was independently introduced in 1954 by two research teams, one consisting of Andrew F. Huxley and Rolf Niedergerke from the University of Cambridge, and the other consisting of Hugh Huxley and Jean Hanson from the Massachusetts Institute of Technology. It was originally conceived by Hugh Huxley in 1953. Andrew Huxley and Niedergerke introduced it as a "very attractive" hypothesis. Before the 1950s there were several competing theories on muscle contraction, including electrical attraction, protein folding, and protein modification. The novel theory directly introduced a new concept called cross-bridge theory (classically swinging cross-bridge, now mostly referred to as cross-bridge cycle) which explains the molecular mechanism of sliding filament. Cross-bridge theory states that actin and myosin form a protein complex (classically called actomyosin) by attachment of myosin head on the actin filament, thereby forming a sort of cross-bridge between the two filaments. The sliding filament theory is a universally accepted explanation of the mechanism that underlies muscle contraction.


Sarcomere
H zone
M line
Z line
Z line
Lighter I band
Darker A band
Lighter I band
Portion of a thick filament
Portion of a thin filament
Troponin
Actin
Tropomyosin
Head
Actin-binding sites
ATP-binding site
Tail
Heads
Myosin molecule
Flexible hinge region
Binding site for myosin
Actin subunits


Sliding Filament Mechanism
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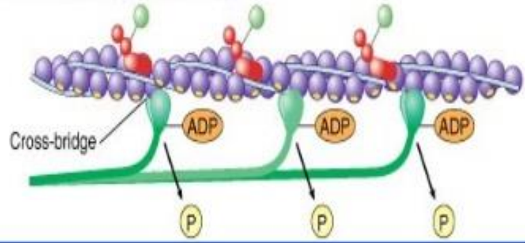
1. Exposure of attachment sites. During contraction of a muscle, Ca2+ bind to troponin molecules, and tropomyosin molecules move, causing exposure of myosin attachment sites on actin myofilaments.
Troponin
Tropomyosin
Ca2+
Ca2+
Ca2+
ADP
ADP
ADP
P
P
P

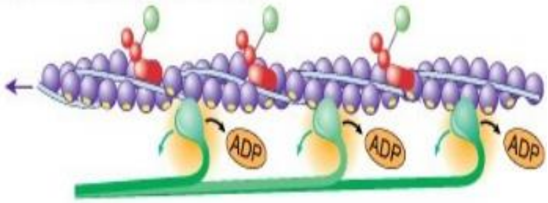
Sliding Filament Mechanism

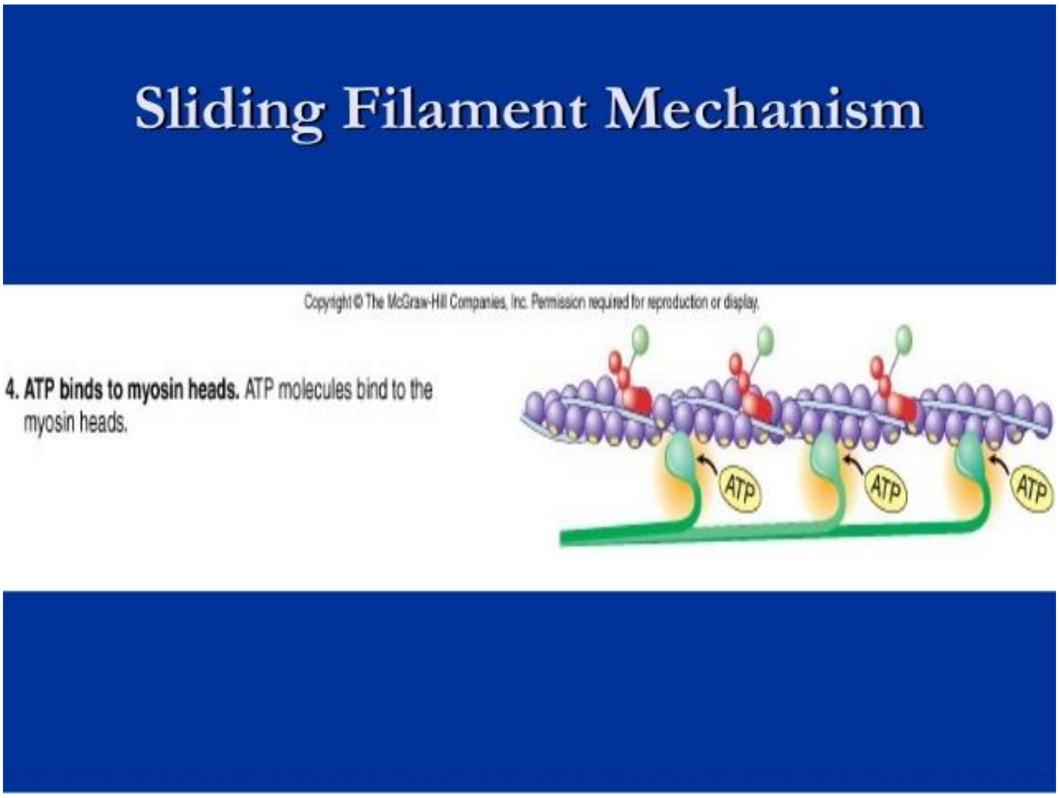
2. Cross-bridge formation. The myosin heads bind to the exposed attachment sites on the actin myofilaments to form cross-bridges, and phosphates are released from the myosin heads.

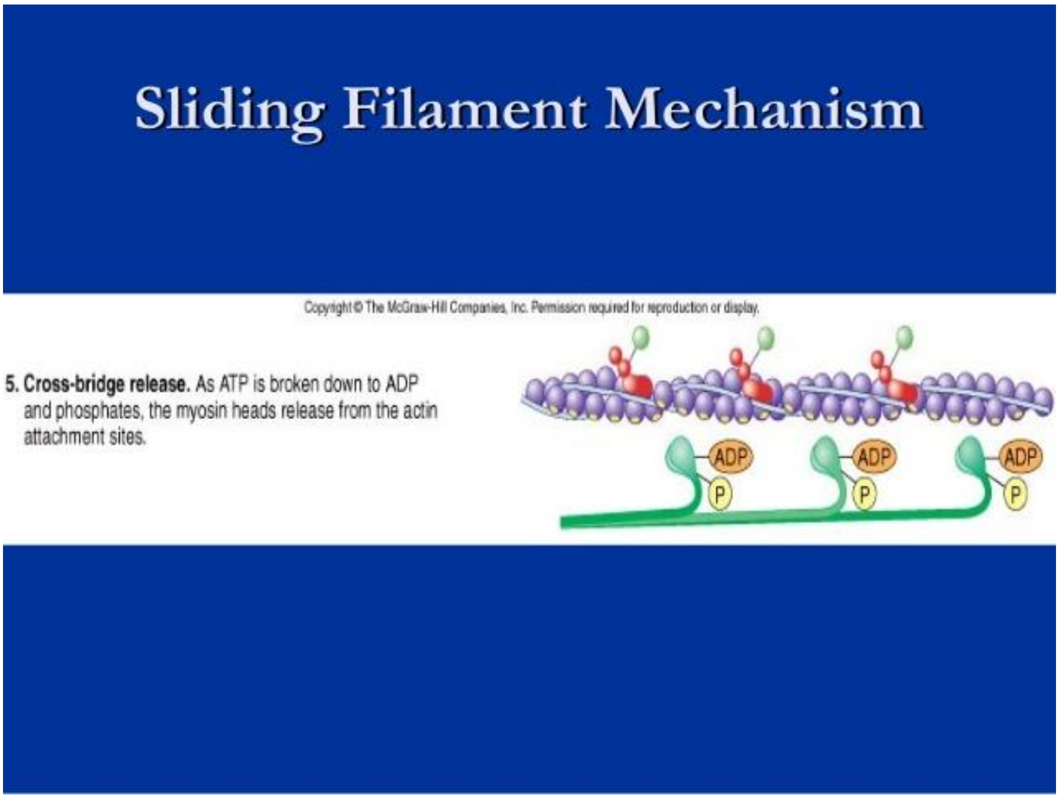


Sliding Filament Mechanism

3. Power stroke. Energy stored in the myosin heads is used to move the myosin heads (*green arrows*), causing the actin myofilament to slide past the myosin myofilament (*purple arrow*), and ADP molecules are released from the myosin heads (*black arrows*).







2.3.7 Types of muscle fibre

Slow twitch:

- has lots of tiny blood vessels called capillaries (and so looks red)
- has many mitochondria (sites of energy production)

- has lots of myoglobin (the oxygen transporting and storage protein of the muscle)
- carries more oxygen
- doesn't get tired easily (can sustain aerobic activity)
- can contract slowly
- **is found in large numbers in the postural muscles of the neck**

Fast twitch :

Type IIa

- is aerobic like slow muscle
- is rich in capillaries
- looks red

Type IIx

- has fewer mitochondria and less myoglobin
- can contract more quickly than Type IIa
- can contract with more force than aerobic muscle
- can sustain only short, anaerobic bursts of activity before muscle contraction
- becomes painful (e.g. getting the stitch)
- is the fastest muscle type in humans

Type IIb

- is anaerobic white muscle
- is even less dense in mitochondria and myoglobin
- can contract even more quickly
- is the major fast muscle type in small animals like rodents or rabbits (which explains why their meat is so pale)

1.3.8 Slow Twist muscle fibre and sports performance

1. Slow-twitch fibers contain mitochondria, the organelles that use oxygen to help create adenosine triphosphate (ATP), which is the chemical that actually fuels muscle contractions, and are considered aerobic.
2. Slow-twitch fibers are also called red fibers because they contain more blood-carrying myoglobin, which creates a darker appearance.
3. Because they can provide their own source of energy, slow-twitch fibers can sustain force for an extended period of time, but they are not able to generate a significant amount of force.
4. Slow-twitch fibers have a low activation threshold, meaning they are the first recruited when a muscle contract. If they can't generate the amount of force necessary for the specific activity, the fast-twitch muscle fibers are engaged.
5. The tonic muscles responsible for maintaining posture have a higher density of slow-twitch fibers.
6. Steady-state endurance training can help increase mitochondrial density, which improves the efficiency of how the body uses oxygen to produce ATP.

Slow-twitch fibers have specific characteristics for how they function, which means physical education teacher can be trained to be more aerobically efficient with the proper exercise program.

Techniques for Training Slow-twitch Fibers:

- Exercises that feature sustained isometric contractions with little-to-no joint movement keep the slow-twitch muscle fibers under contraction for an extended period of time.

This can help improve their ability to utilize oxygen to produce energy. Examples include the front plank, the side plank and the single-leg balance.

- Resistance-training exercises using lighter weights with slower movement tempos for higher numbers of repetitions (i.e., more than 15) can engage the slow-twitch fibers to use aerobic metabolism to fuel the activity.
- Circuit training, which involves alternating from one exercise to the next with little-to-no rest while using lighter weights, can be an effective way to challenge slow-twitch fibers.
- Body-weight exercises for higher numbers of repetitions can be an effective way to challenge aerobic metabolism, which helps improve the efficiency of slow-twitch fibers.
- When working with body-weight only or lighter amounts of resistance, use shorter rest intervals of approximately 30 seconds between sets to challenge the slow-twitch fibers to use aerobic metabolism to fuel the workout.

1.3.9 Fast Twist muscle fibre and sports performance

1. Fast-twitch fibers can be further classified into (1) fast-twitch IIa - fast oxidative glycolytic, because they use oxygen to help convert glycogen to ATP, and (2) fast-twitch type IIb - fast glycolytic, which rely on ATP stored in the muscle cell to generate energy.
2. Fast-twitch fibers have a high threshold and will be recruited or activated only when the force demands are greater than the slow-twitch fibers can meet.
3. The larger fast-twitch fibers take a shorter time to reach peak force and can generate higher amounts of force than slow-twitch fibers.
4. Fast-twitch fibers can generate more force, but are quicker to fatigue when compared to slow-twitch fibers.
5. The phasic muscles responsible for generating movement in the body contain a higher density of fast-twitch fibers.
6. Strength and power training can increase the number of fast-twitch muscle fibers recruited for a specific movement.
7. Fast-twitch fibers are responsible for the size and definition of a particular muscle.
8. Fast-twitch fibers are called “white fibers” because do not contain much blood, which gives them a lighter appearance than slow-twitch fibers.

The characteristics of fast-twitch fibers are more suited for explosive, strength- and power-based sports like football. Therefore, when physical education teacher talks about how a training program benefits a specific type of muscle fiber, he beings accurate with the science.
If physical education teacher wants to engage more fast-twitch fibers to help you increase strength levels or become more explosive, here are a few specific techniques that work.
Techniques for Engaging Fast-twitch Fibers:

- Resistance training with heavy weight stimulates muscle motor units to activate more muscle fibers. The heavier the weight, the greater the number of fast-twitch fibers that will be recruited.
- Performing explosive, power-based movements, whether it is with a barbell, kettlebell, medicine ball or simply your own body weight, will recruit greater levels of fast-twitch fibers.
- Fast-twitch fibers will fatigue quickly, so focus on using heavy weight or explosive movements for only a limited number of repetitions (e.g., two to six) for maximum effectiveness.

- Because they deplete energy quickly, fast-twitch fibers require longer rest periods to allow motor units to recover and to replace spent ATP. Therefore, allow at least 60 to 90 seconds of rest after each explosive or strength exercise.

1.3.10 Muscular adaptations to exercise

Understanding how the physiology of the body adapts to exercise can help physical education teacher develop more effective exercise programs for your specific needs. Genetics determines how much of each muscle-fiber type you possess; however, identifying whether you are fast- or slow-twitch dominant would require an invasive muscle biopsy. Therefore, if you find that you tend to enjoy more endurance-based activities and that they are relatively easy for you, you probably have a greater number of slow-twitch fibers. Conversely, if you really dislike going for long runs, but enjoy playing sports that rely on short bursts of explosive movements, or if you like weight training because it is relatively easy, you are probably fast-twitch fiber dominant. An exercise program that applies the right training strategies for your muscle fibers can help you to maximize the efficiency and enjoyment of your workout time.

Characteristic	**Slow-twitch**	**Fast-twitch IIa**	**Fast-twitch IIb**
Force production	Low	Intermediate	High
Contraction speed	Slow	Fast	Fast
Fatigue resistance	High	Moderate	Low
Glycolytic capacity	Low	High	High
Oxidative capacity	High	Medium	Low
Capillary density	High	Intermediate	Low
Mitochondrial density	High	Intermediate	Low
Endurance capacity	High	Moderate	Low

You can modify fiber types through exercise. **Type I muscle fibers can be developed through endurance training**, such as low resistance, high repetition, or long duration, low intensity. **Type II muscle fibers can be developed through strength training**. Resistance training increases the size of both type I and type II muscle fibers. Greater growth (i.e., hypertrophy) occurs in type II fibers and increases actin and myosin filaments. This results in an increased ability to generate force. **Fast-twitch fibers can also recruit slow-twitch fibers**: endurance training at high-intensity intervals can be effective in improving aerobic power. **Tapering** during training programs (reducing volume and intensity), can also **improve the strength and power of type IIA fibers without decreasing type I performance**. One study investigated muscle fiber changes in recreational runners training for a marathon. After 13 weeks of increasing mileage and a three-week tapering cycle, not only did the functions of type I and type IIa fibers improve, but type IIa continued to improve significantly during the tapering cycle.

We think, the weightage of ***text*** is only 10 percent, the rest 90 percent of weightage lies within our remaining five services: solution of ***1250 previous years questions*** and ***1000 model questions*** (unit and subunit wise) with proper explanation, ***on-line MOCK test series***, ***last minute suggestions*** and ***daily updates*** because it will make your preparation innovative, scientific and complete. Access these five services from our website: www.teachinns.com and qualify not only the eligibility of assistant professorship but also junior research fellowship.

Abbreviation:

1. **Text: Unit wise separate pdf**
2. **PYQs: Previous Years Questions**
3. **MQs: Model Questions**
4. **LMS: Last Minute Suggestion**
5. **OMT: Online MOCK Test**
6. **DU: Daily Updates**