UNIVERSITY GRANTS COMMISSION

Physical Education Code:47

Unit–II: Foundation of Physical Education

Contents

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

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

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

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

Serial no.	Topics
17.	2.4.1 What is neuro muscular junction?
18.	2.4.2 Transmission of nerve impulse through neuro muscular junction.
19.	2.4.3 Definition of kinesthetic sense
20.	2.4.4 How kinesthetic sense organ control motor skill?

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

Serial no.	Topics
21.	2.5.1 What is Bio-chemical aspects of exercise?
22.	2.5.1 Metabolism of food products
23.	2.5.3 What is Aerobic Exercise?
24.	2.5.4 What is Anaerobic Exercise?
25.	2.5.5 Effect of aerobic exercise at rest.
26.	2.5.6 Effect of exercise during exercise.
27.	2.5.7 Direct method of measuring energy cost of exercise
28.	2.5.8 Indirect method of measuring energy cost of exercise

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

Serial no.	Topics
29.	2.6.1 What is fatigue?
30.	2.6.2 Causes of fatigue.
31.	2.6.3 How do we overcome from fatigue?
32.	2.6.4 What is recovery process?
33.	2.6.5 Physiological aspects of fatigue
34.	2.6.6 Restoration of energy stores
35.	2.6.7 Recovery oxygen
36.	2.6.8 Nutritional aspects of performance

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

Serial no.	Topics
37.	2.7.1 Definition of Environment
38.	2.7.2 Environmental influence on human physiology under exercise

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

Serial no.	Topics
39.	2.8.1 Women in sports - trainability
40.	2.8.2 Physiological gender differences
41.	2.8.3 Special problems of women athletes

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

Serial no.	Topics
42.	2.9.1 What is aging?
43.	2.9.2 Physiological consequences of aging
44.	2.9.3 What is lifestyle?
45.	2.9.4 Life style management
46.	2.9.5 Life style management and healthful aging

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

Serial no.	Topics
47.	2.10.1 What are therapeutic modalities?
48.	2.10.2 Physiological responses of various therapeutic modalities
49.	2.10.3 Rehabilitation

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

Serial no.	Topics
1.	2.11.1 What is Ergogenic Aids?
2.	2.11.2 Physiological aspects of various Ergogenic aids
3.	2.11.3 What is massage?
4.	2.11.4 Types of massage
5.	2.11.5 Massage manipulation
6.	2.11.6 Physiological responses of massage manipulation

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 21^{st} 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 CO_2 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:

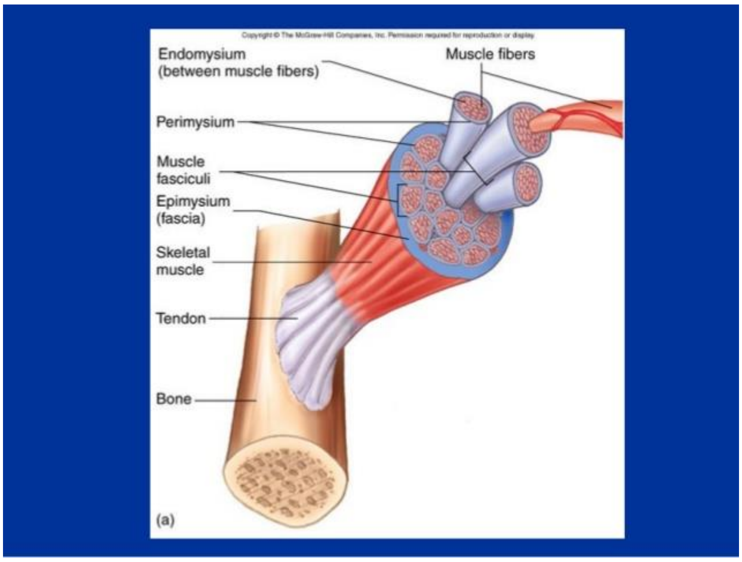
- Muscle: a collection of fascicles
- Fascicle: a collection of muscle cells
- Muscle cell or fiber: collection of myofibrils plus other cell organelles.
- Myofibril: series of sarcomeres
- Sarcomeres: Basic unit of muscle structure and function.
- Filaments: Thick and thin filaments

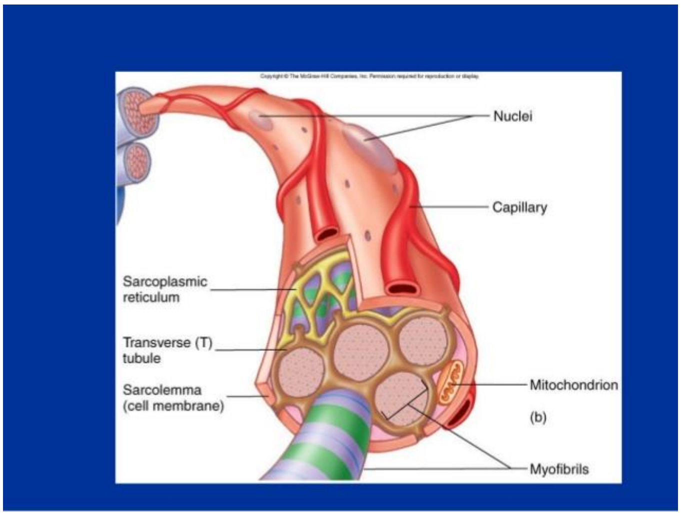
Associated Connective Tissue Organizes Muscle Tissue

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

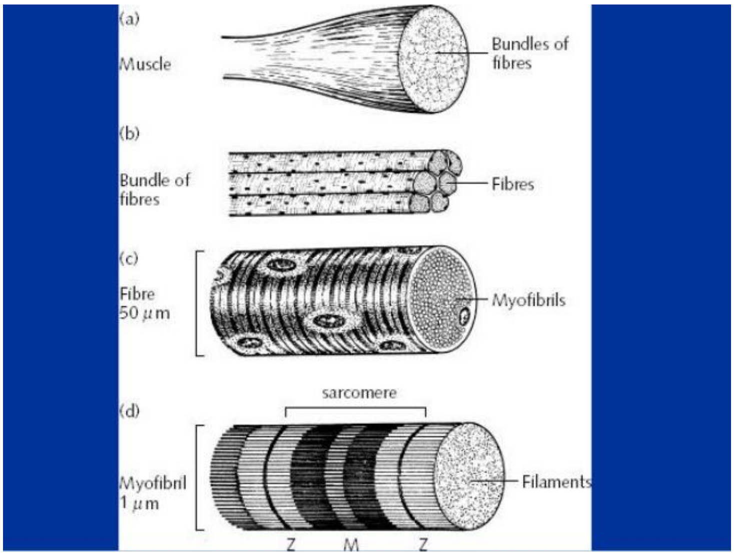
- Endomysium: surrounds fibers
- Perimysium: surrounds fascicle
- Epimysium: surrounds fascicles

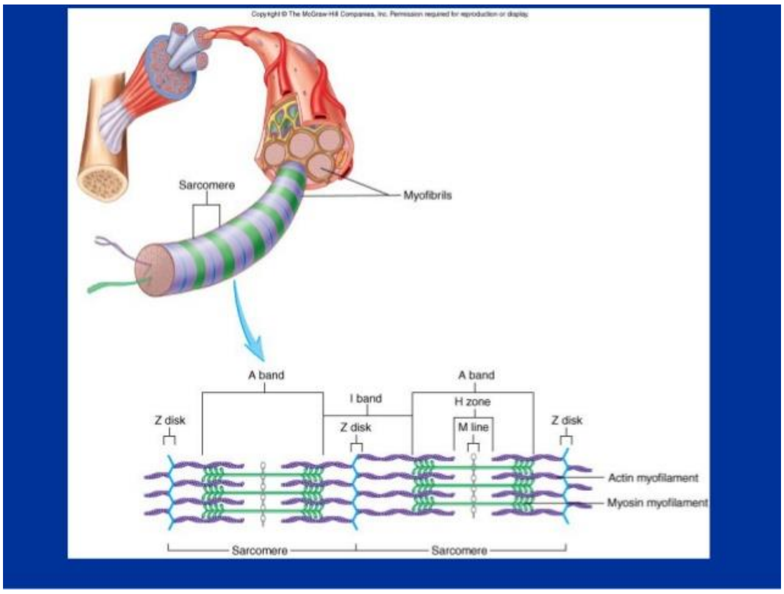
Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of hundreds, or even thousands, of muscle fibers bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the epimysium. Fascia, 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.



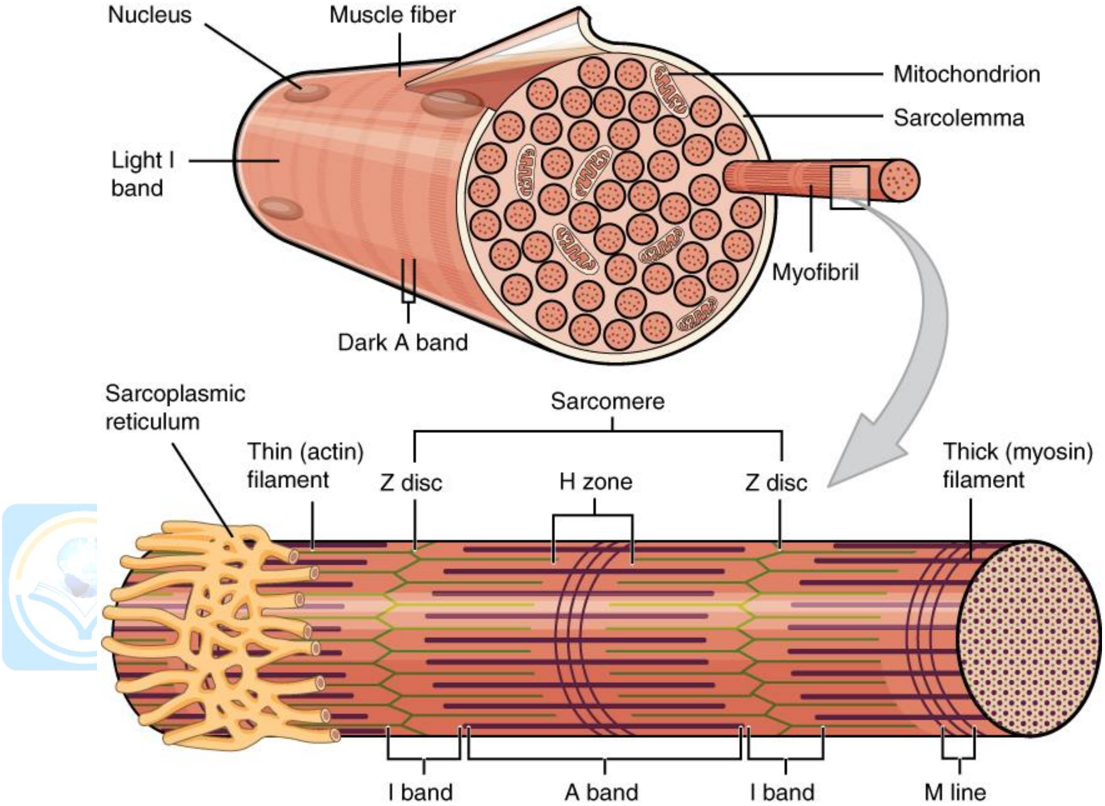


Commonly, the epimysium, perimysium, and endomysium extend beyond the fleshy part of the muscle, the belly or gaster, to form a thick ropelike tendon or a broad, flat sheet-like aponeurosis. The tendon and aponeurosis form indirect attachments from muscles to the periosteum of bones or to the connective 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.



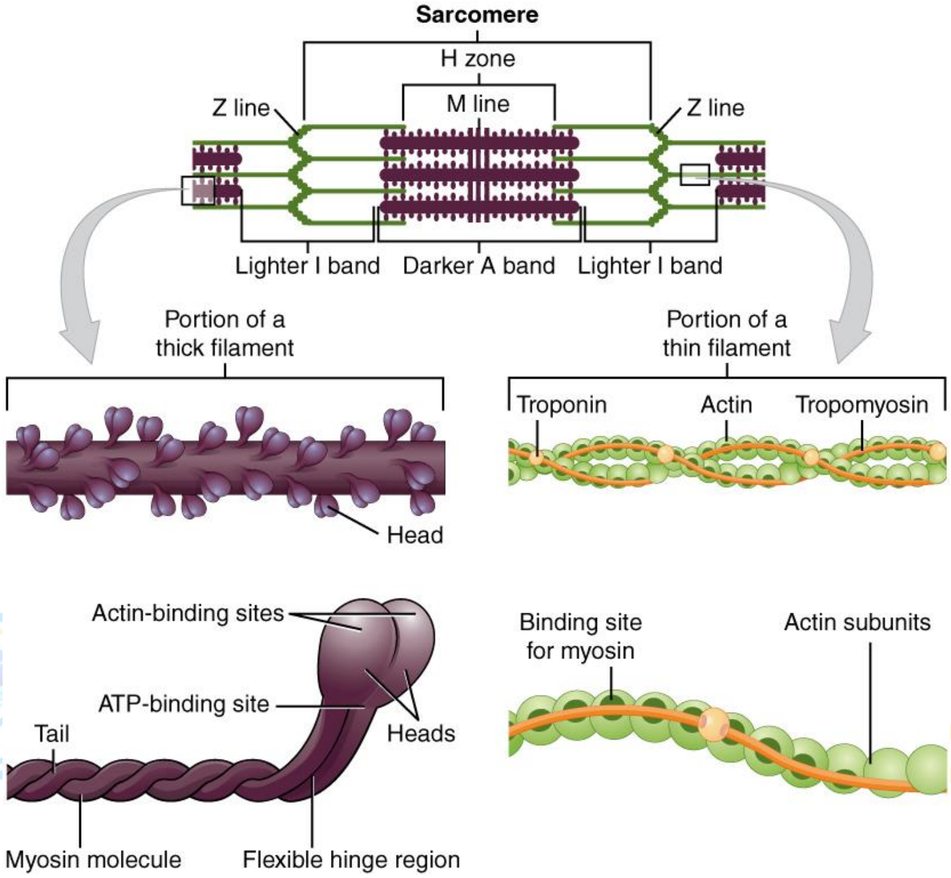


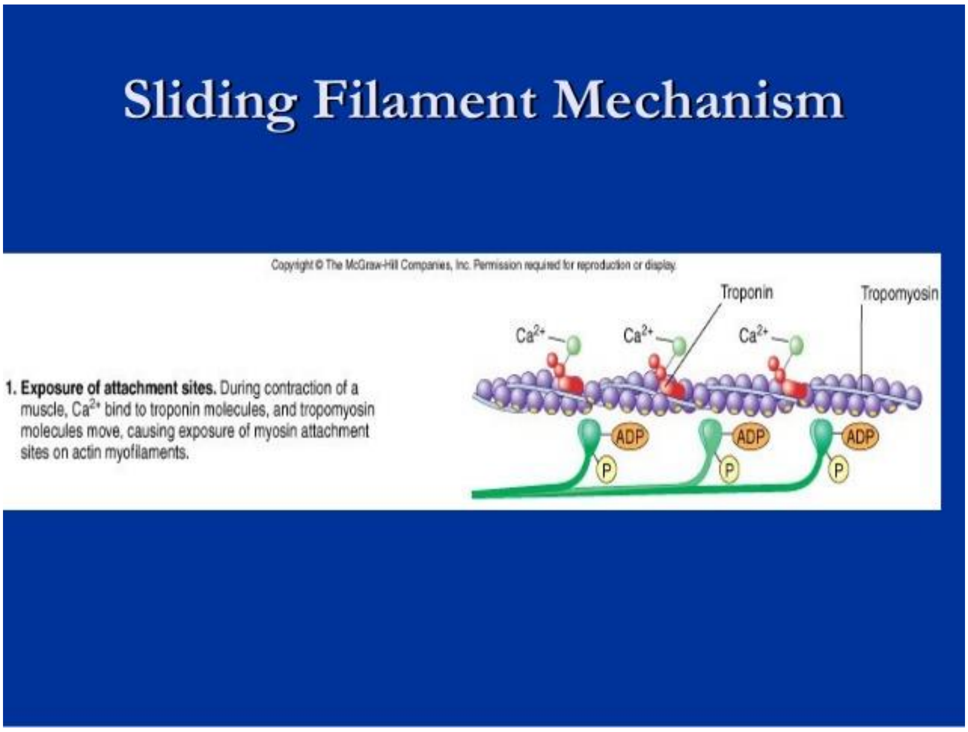
Some other terminology associated with muscle fibers is rooted in the Greek *sarco*, which means "flesh." The plasma membrane of muscle fibers is called the **sarcolemma**, the cytoplasm is referred to as **sarcoplasm**, and the specialized smooth endoplasmic reticulum, which stores, releases, and retrieves 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.

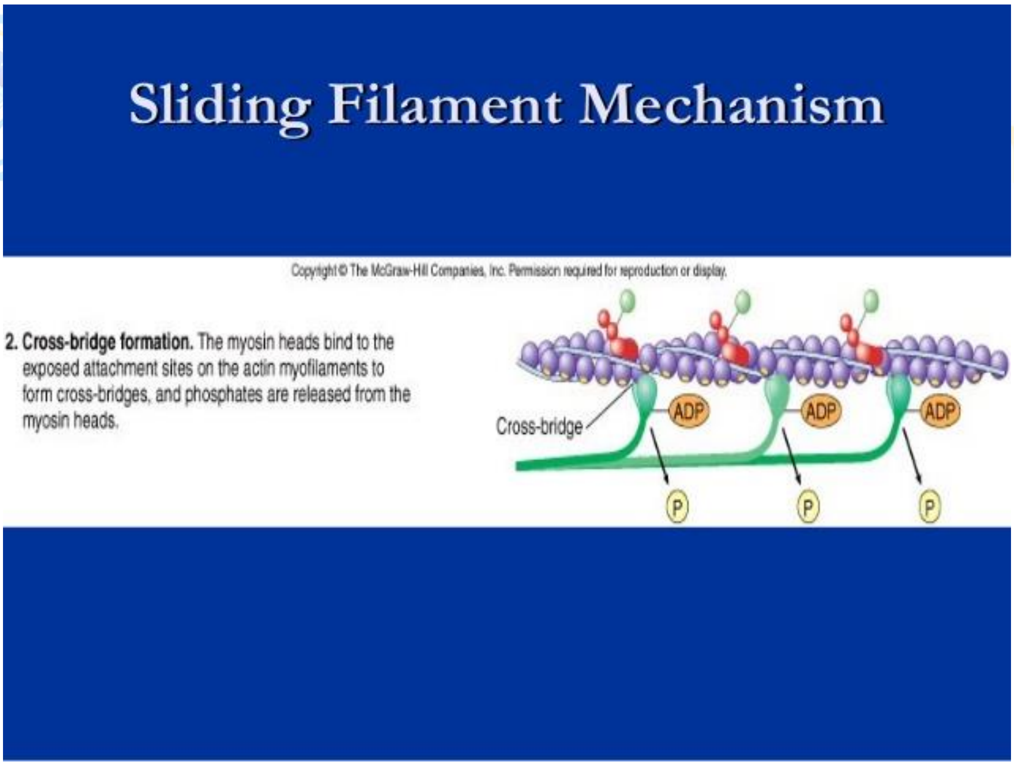


2.3.6 Sliding filament of muscular contraction

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.

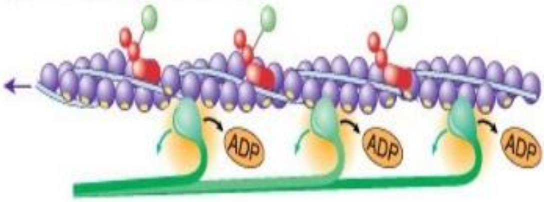



Sliding Filament Mechanism
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
1. Exposure of attachment sites. During contraction of a muscle, Ca^{2+} bind to troponin molecules, and tropomyosin molecules move, causing exposure of myosin attachment sites on actin myofilaments.
Troponin
Tropomyosin
Ca^{2+}
ADP
P


Sliding Filament Mechanism
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
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.
Cross-bridge
ADP
P

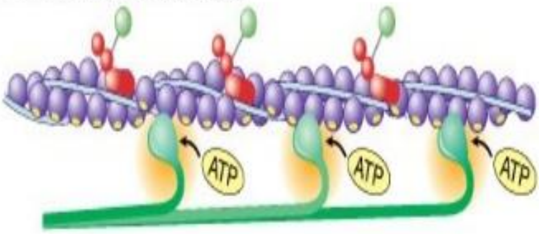
Sliding Filament Mechanism

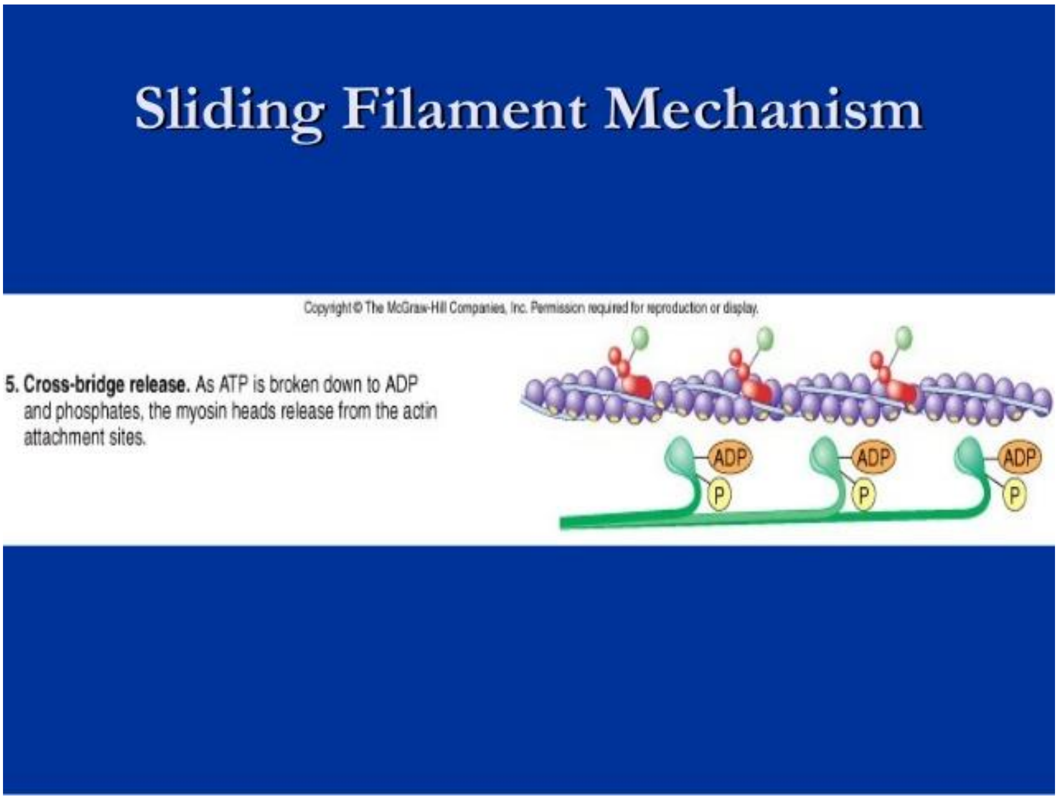
3. Power stroke. Energy stored in the myosin heads is used to move the myosin heads (*green arrows*), causing the actin myofilament to slide past the myosin myofilament (*purple arrow*), and ADP molecules are released from the myosin heads (*black arrows*).



Sliding Filament Mechanism

4. ATP binds to myosin heads. ATP molecules bind to the myosin heads.





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.

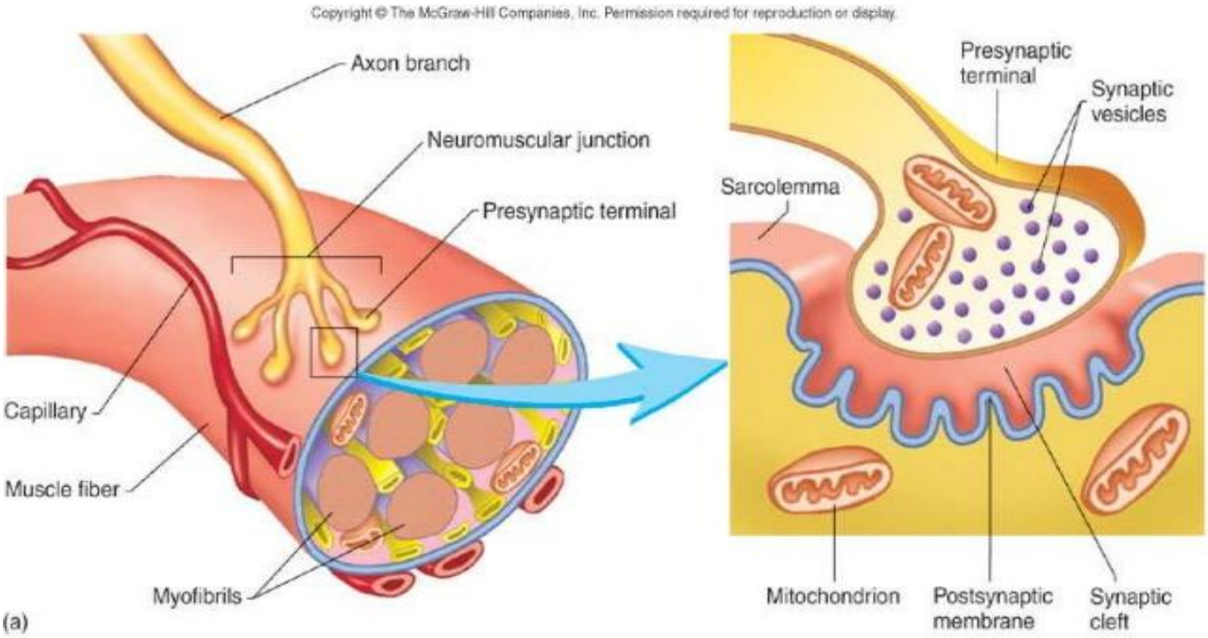
Characteristic	**Slow-twitch**	**Fast-twitch IIa**	**Fast-twitch IIb**
Force production	Low	Intermediate	High
Contraction speed	Slow	Fast	Fast
Fatigue resistance	High	Moderate	Low
Glycolytic capacity	Low	High	High
Oxidative capacity	High	Medium	Low
Capillary density	High	Intermediate	Low
Mitochondrial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

SUB UNIT - IV
Neuro-muscular junction and transmission of nerve impulse, kinesthetic Sense organs and neural control of motor skills

2.4.1 What is neuro muscular junction?

Nerve conduction is nothing but a disturbance, which moves along the entire length of the axon. But when the axon terminates, it ends in a **synapse**. So, in simple terms, a synapse is where an axon ends. On the other end of the synapse, if it is a nerve, it is called a **neuronal synapse**, if it is a muscle; it is called a **Neuro Muscular Junction**. The tip of the axon has a lot of small packets, filled with chemicals, called *the neurotransmitters*. Now when the disturbance reaches the end of the axon, these packets open and a large number of neurotransmitters are released into the synapse. These neurotransmitters are of various types, some are excitatory and some are inhibitory. So basically, the impulse is going wireless here. A large number of molecules are released into the interspaced and many of them reach the other end. Now the neurotransmitter released will reach the other end, which could be a nerve, or a muscle or a gland. If it is a nerve, this impulse travels as a disturbance in the other neuron. If it is an effectors organ, like the muscle, it contracts. However, if the synapse still contains the neurotransmitter, it may repeatedly stimulate the other end, causing undesired effects, so they must be removed. This is done by specific enzymes, which can degrade a particular neurotransmitter. 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**. The neuromuscular junction consists of a motor neuron and a muscle cell separated by a narrow synaptic cleft. The nerve and muscle do not come into direct contact. Transmission of the action potential from the nerve to the muscle occurs by release of acetylcholine from the pre-synaptic nerve terminal.



A **neuromuscular junction** (or **myoneural 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. Muscles require innervation to function and even just to maintain muscle tone, avoiding atrophy. In the **neuromuscular system** nerves from the central nervous system and the peripheral nervous system are linked and work together with muscles. Synaptic transmission at the neuromuscular junction begins when an action potential reaches the pre-synaptic terminal of a motor neuron, which activates voltage-gated calcium channels to allow calcium ions to enter the neuron. Calcium ions bind to sensor proteins (synaptotagmin) on synaptic vesicles, triggering vesicle fusion with the cell membrane and subsequent neurotransmitter release from the motor neuron into the synaptic cleft. In vertebrates, motor neurons release acetylcholine (ACh), a small molecule neurotransmitter, which diffuses across the synaptic cleft and binds to nicotinic acetylcholine receptors (nAChRs) on the cell membrane of the muscle fiber, also known as the sarcolemma. nAChRs are ionotropic receptors, meaning they serve as ligand-gated ion channels. The binding of ACh to the receptor can depolarize the muscle fiber, causing a cascade that eventually results in muscle contraction.

2.4.2 Transmission of nerve impulse through neuro muscular junction.

Each branch of a motor neuron forms a single junction with a muscle fiber. The myelin sheath surrounding the motor axon ends near the surface of the muscle fiber and the axon divides into a number of short processes that lie embedded in grooves on the muscle-fiber surface. This region of the sarcolemma (muscle membrane) is known as the motor end plate. Acetylcholine is the neurotransmitter in these synapses. End-plate potentials (EPPs) can be recorded at the motor end plate when the pre-synaptic membrane is activated to release vesicles containing the acetylcholine.

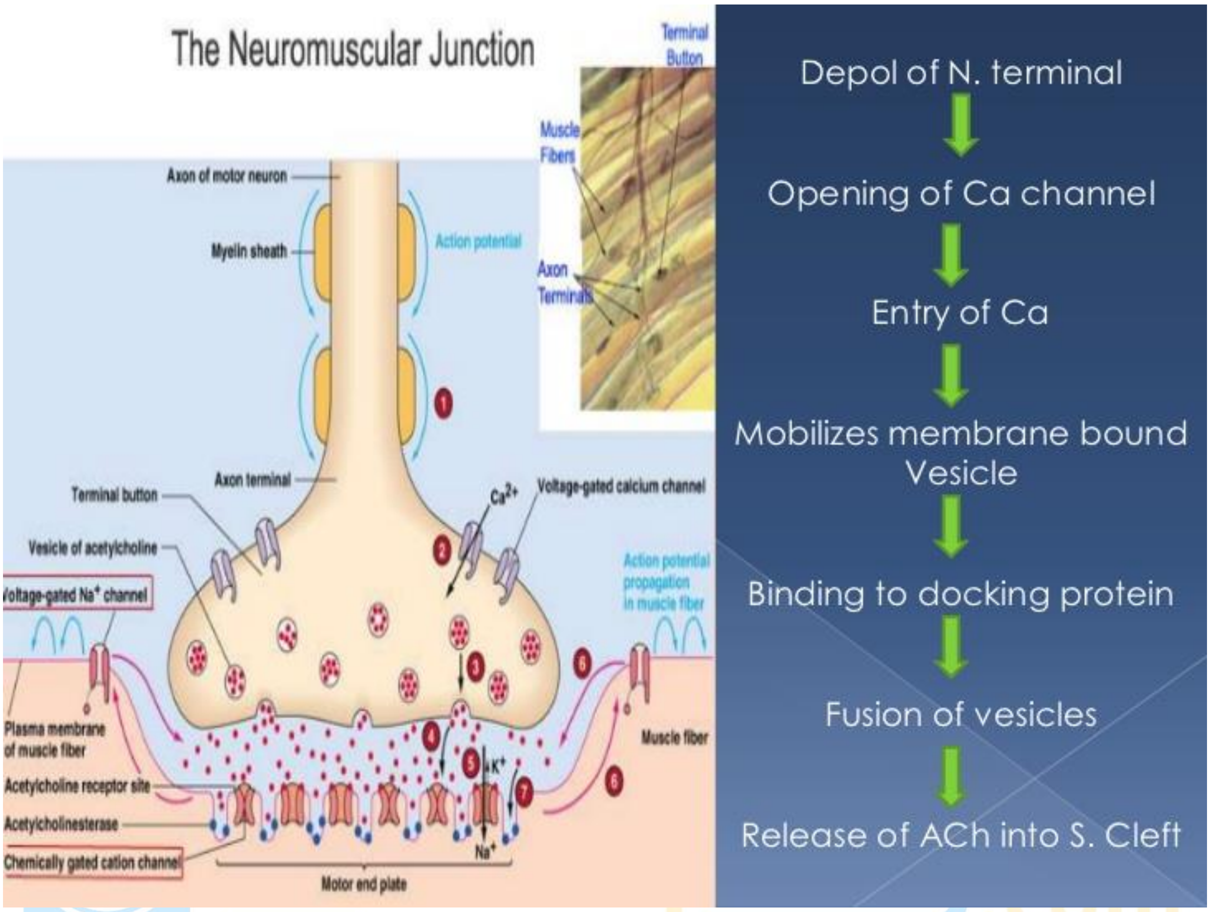
Steps in neuromuscular transmission:

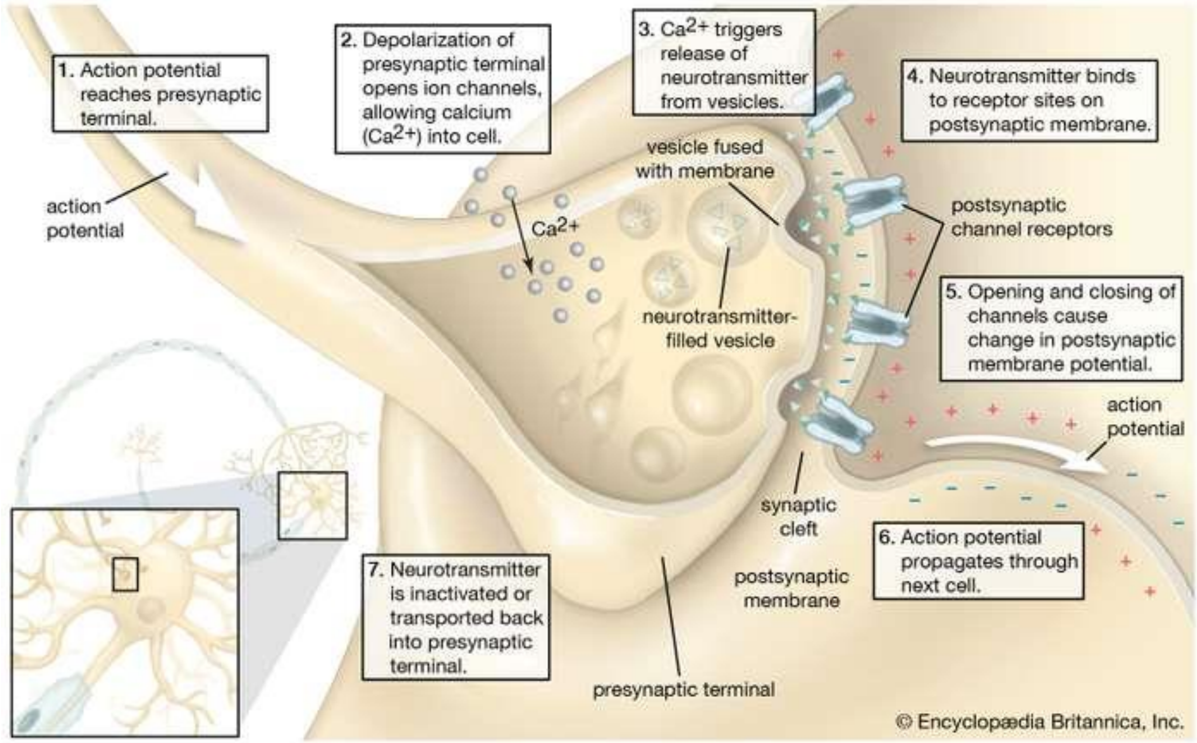
1) Nerve action potential.
2) Calcium entry into the presynaptic terminus.
3) Release of Ach quanta.
4) Diffusion of Ach across cleft.
5) Combination of Ach with post-synaptic receptors and Ach breakdown via esterase.
6) Opening of Na+ /K+ channels (cation channels).
7) Postsynaptic membrane depolarization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

Excitation of the sarcolemma and transverse tubule system causes activation of a population of voltage-gate calcium channels located in the tubules themselves. The channels also known as the dihydropyridine receptors signals, by yet some unknown mechanism, the adjacent calcium-release channels on the sarcoplasmic reticulum (ryanodine receptors) to allow calcium to be released from this storage site. Hence, the intracellular [Ca2+] increases (i.e., sarcoplasmic concentration) which then diffuses and binds to troponin on the thin filaments which allows for crossbridge formation between actin and myosin by removing the steric interaction imposed by tropomyosin. A neuromuscular junction sends excitatory signals from the CNS via the neurotransmitter, acetylcholine which binds to nicotinic receptors on the post-synaptic membrane. The binding causes a local change in the voltage of the sarcolemma affecting neighboring channels (Na+ to enter and eventually K+ to flow out). This ion movement produces the action potential which propagates along the sarcolemma and inward via the transverse tubule system. This rapid voltage change initiates the gating of dihydropyridine receptors which in turn causes the release of calcium from the sarcoplasmic reticulum via the ryanodine receptors. The released calcium binds to troponin inducing a conformation change in tropomyosin, also a component of the contractile apparatus, which in turn allows crossbridge formation between actin and myosin (an energy dependent process). The crossbridge formation leads to muscle fiber shortening and the generation of force. Crossbridge cycling will proceed until calcium dissociates from troponin and the inhibitory influence of tropomyosin is reestablished. The dissociation occurs because calcium release stops and its active uptake (requiring ATP) into the sarcoplasmic reticulum causes a reduction. There are three primary ways a muscle fiber can form ATP during contractile activity: 1) phosphorylation of ADP by creatine phosphate; 2) oxidative phosphorylation of ADP in mitochondria (need myoglobin for oxygen transfer); or 3) substrate phosphorylation of ADP, primarily by the glycolytic pathway in the cytosol (forming lactic acid). The phosphorylation of ADP by creatine phosphate provides a very rapid means of forming ATP at the onset of contractile activity. In a resting muscle fiber, the concentration of ATP is always greater than ADP leading to the reformation of creatine phosphate. During rest muscle fibers build up a concentration of creatine phosphate to a level approximately five times that of ATP. The amount of tension developed by a muscle fiber and thus its strength can be altered not only by the frequency of stimulation, but also by changing the length of the fiber prior to or during contraction. If the frequency of stimulation increase such that relaxation in not complete force will begin to superimpose. Eventually the frequency of stimulation becomes high enough that the force becomes fused. Further increase in the frequency will cause more force to be produced until eventually a maximum is reached. If one stretches skeletal or cardiac muscle the magnitude of subsequent contractions will be altered. If the muscle is unloaded, i.e., the sarcomere spacing compressed, there is little force or shortening that can occur. Skeletal muscle has an optimal length at which force is maximal due to the greatest possible numbers of crossbridge can be formed. Most muscles in the human body are attached so to have near their optimal length at rest. Because skeletal muscle can shorten allowances need to be made for the sarcolemma to also conform to this change without being damaged. Structural proteins are present which link the myofilaments to the surface membrane and extracellular matrix. One of these proteins is dystrophin which is lacking is patients with Muscular Dystrophy.

Each branch of a motoneuron forms a single junction with a muscle fiber. The myelin sheath surrounding the motor axon ends near the surface of the muscle fiber and the axon divides into a number of short processes that lie embedded in grooves on the muscle-fiber surface. This region of the sarcolemma (muscle cell membrane) is known as the motor end plate. Acetylcholine is the neurotransmitter in these synapses. End-plate potentials (EPPs) can be recorded at the motor end plate when the presynaptic membrane is activated to release vesicles containing the acetylcholine. 1) Nerve and muscle have separate, intact, plasmalemmas, which are separated by a 50 nm gap (500Å) known as the synaptic cleft. 2) An unmyelinated motoneuron terminal (i.e. presynaptic end of the axon) sits in a specialized groove of the skeletal muscle fiber to form the neuromuscular end plate. a) There is only one presynaptic nerve per muscle fiber. b) Each motoneuron has several ending; each innervates only one muscle fiber. c) All of the muscle fibers in a given motor unit contract in unison when their motoneuron fires an action potential. d) All muscle fibers in a motor unit are of the same fiber type (either all-slow or fast twitch). 3) The junction or end plate region of the skeletal muscle fiber is specialized and different from the rest of the plasmalemma. a) Synaptic infoldings of the plasmalemma in the cleft greatly increase the membrane surface area. b) Receptors (protein molecules) for acetylcholine (ACHR) are located near the cleft edge of the infoldings. In denervated muscle fibers, the ACHRs spread of the entire muscle plasmalemma (sarcolemma). i) The skeletal neuromuscular junction ACHR is nicotinic sensitive receptor. ii) The nicotinic ACHR structure is well characterized (i.e., cloned and sequenced) iii) In its protein moiety, the ACHR contains: (1) Binding sites for acetylcholine (ACH) and like molecules (agonists and antagonists). (2) Ligand-gated cation channel (3) Several types of modulator sites c) The are 5 subunits of the ACHR: 2 alpha, beta, gamma and epsilon. d) The channel and the ACH binding sites are on the alpha subunits. e) The ACHR is a non-specific cation channel which opens and closes in response to ACH binding and unbinding (insensitive to TTX or TEA) i) In the presence of an elevated [ACH] in the cleft ACH binds to the extracellular side of the receptor and the channel opens. Fast Reaction 2[A] + [R] < -- > [AR] + [A] < -- > A2R < -- > A2R* Channel closed closed closed open States: ↓ ↑ AR A2R desensitized←Desensitized ii) The binding of the 2 ACH molecules to a single receptor elicits positive cooperativity. iii) When the ACHR channel opens at a normal muscle fiber resting membrane potential, Em =90 mV, the net current through the channel is inward and depolarizing. iv) ACH unbinds from the ACHR after the channel closes when the [ACH] in the endplate decreases due to diffusion from the cleft and is broken down by an acetylcholinesterase (ACHE). Prolonged ACH (> 100 msec) stimulation leads to inactivation of the channels through a change to the desensitized state. v) Then the end plate channel opens, net current (I) from all cations in inward: this positive charge (q+) movement through the myoplasm to the surrounding sarcolemma cause a capacitate change (depolarization) which then affects the gating of the voltage-sensitive Na+ and K+ channels. vi) ACHRs can be irreversibly blocked by the snake poison vii) Curare block binding of ACH to its receptors. Curare is a non-activating or non-depolarizing block. viii) Nicotine acts at the NMJ and binds to the ACHR. ix) There are substances, which mimic ACH, but are not readily broken down by ACHE, thus that cause and initial opening of the channel and then inactivation through desensitization. Succinylcholine is one of these depolarizing muscle relaxants. 4) The nerve terminal has vesicles (50 nm in diameter) containing ACH which fuse with the plasmalemma and release ACH into the cleft after the nerve AP depolarizes the membrane and Ca2+ enters through channels in the nerve terminal. a) Formation of ACH in nerve terminal. Acetyl Transferase AcetylCoA + Choline ------------------------ > ACH + CoA b) ACH is stored in vesicles in the nerve terminal. c) Quantum: Smallest amount of ACH released. Probably the amount of ACH in a “standard” presynaptic vesicle is: Quantum = 2,000 to 10,000 ACH molecules. 5) The NMJ cleft is filled with extracellular fluid and ground substance, which also contains the enzyme acetylcholinesterase (ACHE). ACHE ACH -------------- > Acetate + Choline 6) ACHE acts only on unbound ACH. Acetate and choline are transported back into the nerve terminal. Acetate is converted to acetylCoA (in mitochondria) and then combines with choline to reform ACH. a) Organophosphates inhibit ACHE and thus prolong ACH lifetime. Inhibitors of ACHE are: physostigmine and neostigmine, which are used clinically to reverse neuromuscular blockage. Characteristics of ACH release: 1) As a result of AP depolarization, Ca2+ enters the nerve terminal through a voltagegated channel. a) 4 Ca2+ act cooperatively to release one quantum. b) Reducing extracellular Ca2+ reduces ACH release.

c) Mg2+ competes with Ca2+ and does not active ACH release; increasing extracellular Mg2+ decreases ACH release. 2) One nerve AP causes the release of approximately 300 quanta (vesicles) 1 AP ------ > 300 quanta released ----------- > 1,500,000 ACh molecules (assuming 5,000 ACH/quantum) Some of this ACH diffuses out from the cleft and some is broken down by ACHE: approximately 200,000 molecules bind to ACHR to open channels in the endplates. 3) Factors which alter or block nerve APs will alter ACH release: a) Local anesthetics (e.g., procaine) inhibit voltage-gated Na+ channels and interfere with AP transmission in the nerve. Some local anesthetics also act on the ACHR by promoting desensitization and/or by blocking the channel. b) An increase [K]o causes prolonged depolarization of the nerve and thus partial inactivation of the voltage-gated Na+ channels, thus alters AP transmission. Hemicholinium inhibits uptake of choline into the nerve terminus and thus decreases ACH production and storage. The result is decreases ACH/quantum. Botulinum toxins block the release of ACH from the nerve terminals (i.e.,


The Neuromuscular Junction
Terminal Button
Muscle Fibers
Axon Terminals
Axon of motor neuron
Myelin sheath
Action potential
Terminal button
Axon terminal
Voltage-gated calcium channel
Vesicle of acetylcholine
Voltage-gated Na+ channel
Action potential propagation in muscle fiber
Plasma membrane of muscle fiber
Muscle fiber
Acetylcholine receptor site
Acetylcholinesterase
Chemically gated cation channel
Motor end plate
Depol of N. terminal
Opening of Ca channel
Entry of Ca
Mobilizes membrane bound Vesicle
Binding to docking protein
Fusion of vesicles
Release of ACh into S. Cleft



paralysis from bad tuns). Characteristics of the End Plate Potential (EPP): 1) Opening of the end plate channels and the subsequent net inward current sets up a transient depolarization of the sarcolemma adjacent to the end plate. a) The end plate potential (EPP) spreads electrotonically and thus decrements in amplitude with distance from the end plate region. The EPP itself in not propagated but serves as the stimulus to drive the Em to threshold for an AP to be initiated. The EPP can be seen in isolation of an AP by treating the muscle fibers with tetrodotoxin (TTX) which blocks the voltage-gated Na+ channels. b) The EPP brings the adjacent sarcolemma to and beyond threshold: the voltagegated channels in the non-endplate region of the membrane are then responsible for the propagation of the AP throughout the length of the muscle fiber. c) EPPs last approximately 5-10 msec. d) Normally: 1 nerve AP --> 1 EPP -- > 1 muscle AP -- > a single twitch e) The typical EPP amplitude is –30 mV, which represents current through approximately 100,000 open ACH endplate channels. 2) Mini-EPPS (MEPPs) occur spontaneously independent of the nerve AP, although membrane depolarization increases and hyperpolarization decreases their frequency of occurrence. a) Are due to the release of quantum = approximately 5,000 ACH molecules. b) Amplitudes are approximately 0.5 to 1 mV. c) Ca2+ and Mg2+ do not alter the magnitude or time course of MEPPs, but due alters the number released.

2.4.3 Definition of kinesthetic sense

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. Even when the body remains stationary, the kinesthetics sense can monitor its position. Humans possess three specialized types of neurons responsive to **touch** and stretching that help keep track of body movement and position. The first class, called Pacinian corpuscles, lies in the deep subcutaneous fatty tissue and responds to pressure. The second class of neurons surrounds the internal organs, and the third class is associated with muscles, tendons, and joints. These neurons work in concert with one another and with cortical neurons as the body moves. Through your sense of kinesthesis, you can tell where different parts of your body are located even if your eyes are closed or you are standing in a dark room. For example, when you are riding a bicycle, receptors in your arms and legs send information to the brain about the position and movement of your limbs. When you think of the five major senses (vision, smell, touch, taste, and hearing), you might note that these all tend to focus on perceiving stimuli outside of the self. Kinesthesis is one type of sense that is focused on the body's internal events. Rather than using this sense to detect stimuli outside of the self, your sense of kinesthesis allows you to know where your body is positioned and to detect changes in body position. When you need to perform a complex physical action, your sense of kinesthesis allows you to know where your body is and how much further it needs to go.

2.4.4 How kinesthetic sense organ control motor skill?

Proprioception, also referred to as **kinaesthesia**, 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. There are multiple types of proprioceptors which are activated during distinct behaviors and encode distinct types of information: limb velocity and movement, load on a limb, and limb limits. Vertebrates and invertebrates have distinct but similar modes of encoding this information. The central nervous system integrates proprioception and other sensory systems, such as vision and the vestibular system, to create an overall representation of body position, movement, and acceleration. In vertebrates, limb velocity and movement (muscle length and the rate of change) are encoded by one group of sensory neurons (Type Ia sensory fiber) and another type encode static muscle length (Group II neurons). These two types of sensory neurons compose muscle spindles. There is a similar division of encoding in invertebrates; different subgroups of neurons of the Chordotonal organ encode limb position and velocity. To determine the load on a limb, vertebrates use sensory neurons in the Golgi tendon organs: type Ib afferents. These proprioceptors are activated at given muscle forces, which indicate the resistance that muscle is experiencing. Similarly, invertebrates have a mechanism to determine limb load: the Campaniform sensilla. These proprioceptors are active when a limb experiences resistance. A third role for proprioceptors is to determine when a joint is at a specific position. In vertebrates, this is accomplished by Ruffini endings and Pacinian corpuscles. These proprioceptors are activated when the joint is at a threshold, usually at the extremes of joint position. Invertebrates use hair plates to accomplish this; a row of bristles located along joints detect when the limb moves. The sense of proprioception is ubiquitous across mobile animals and is essential for the motor coordination of the body. Proprioceptors can form reflex circuits with motor neurons to provide rapid feedback about body and limb position. These mechanosensory circuits are important for flexibly maintaining posture and balance, especially during locomotion. For example, consider the stretch reflex, in which stretch across a muscle is detected by a sensory receptor (e.g., muscle spindle, chordotonal neurons), which activates a motor neuron to induce muscle contraction and oppose the stretch. During locomotion, sensory neurons can reverse their activity when stretched, to promote rather than oppose movement.

In humans, a distinction is made between *conscious* proprioception and *non-conscious* proprioception:

- Conscious proprioception is communicated by the dorsal column-medial lemniscus pathway to the cerebrum.
- Non-conscious proprioception is communicated primarily via the dorsal spinocerebellar tract and ventral spinocerebellar tract, to the cerebellum.
- A non-conscious reaction is seen in the human proprioceptive reflex, or righting reflex—in the event that the body tilts in any direction, the person will cock their head back to level the eyes against the horizon. This is seen even in infants as soon as they gain control of their neck muscles. This control comes from the cerebellum, the part of the brain affecting balance.

Proprioception is mediated by mechanically sensitive **proprioceptor neurons** distributed throughout an animal's body. Most vertebrates possess three basic types of proprioceptors: muscle spindles, which are embedded in skeletal muscle fibers, Golgi tendon organs, which lie at the interface of muscles and tendons, and joint receptors, which are low-threshold mechanoreceptors embedded in joint capsules. Many invertebrates, such as insects, also possess three basic proprioceptor types with analogous functional properties: chordotonal neurons, campaniform sensilla, and hair plates. The initiation of proprioception is the activation of a proprioreceptor in the periphery. The proprioceptive sense is believed to be composed of information from sensory neurons located in the inner ear (motion and orientation) and in the stretch receptors located in the muscles and the joint-supporting ligaments (stance). There are specific nerve receptors for this form of perception termed "proprioreceptors", just as there are specific receptors for pressure, light, temperature, sound, and other sensory experiences. Proprioreceptors are sometimes known as adequate stimuli receptors. TRPN, a member of the transient receptor potential family of ion channels, has been found to be responsible for proprioception in fruit flies, nematode worms, African clawed frogs, and zebrafish. PIEZO2, a nonselective cation channel, has been shown to underlie the mechanosensitivity of proprioceptors in mice. The channel mediating human proprioceptive mechanosensation has yet to be discovered. Proprioception of the head stems from the muscles innervated by the trigeminal nerve, where the GSA fibers pass without synapsing in the trigeminal ganglion (first-order sensory neuron), reaching the mesencephalic tract and the mesencephalic nucleus of trigeminal nerve. Although it was known that finger kinesthesia relies on skin sensation, recent research has found that kinesthesia-based haptic perception relies strongly on the forces experienced during touch. This research allows the creation of "virtual", illusory haptic shapes with different perceived qualities. Proprioception is what allows someone to learn to walk in complete darkness without losing balance. During the learning of any new skill, sport, or art, it is usually necessary to become familiar with some proprioceptive tasks specific to that activity. Without the appropriate integration of proprioceptive input, an artist would not be able to brush paint onto a canvas without looking at the hand as it moved the brush over the canvas; it would be impossible to drive an automobile because a motorist would not be able to steer or use the pedals while looking at the road ahead; a person could not touch type or perform ballet; and people would not even be able to walk without watching where they put their feet. Oliver Sacks reported the case of a young woman who lost her proprioception due to a viral infection of her spinal cord. At first, she could not move properly at all or even control her tone of voice (as voice modulation is primarily proprioceptive). Later she relearned by using her sight (watching her feet) and inner ear only for movement while using hearing to judge voice modulation. She eventually acquired a stiff and slow movement and nearly normal speech, which is believed to be the best possible in the absence of this sense. She could not judge effort involved in picking up objects and would grip them painfully to be sure she did not drop them. The proprioceptive sense can be sharpened through study of many disciplines. Examples are the Feldenkrais method and the Alexander Technique. Juggling trains reaction time, spatial location, and efficient movement. Standing on a wobble board or balance board is often used to retrain or increase proprioception abilities, particularly as physical therapy for ankle or knee injuries. Slacklining is another method to increase proprioception. Standing on one leg (stork standing) and various other body-position challenges are also used in such disciplines as yoga, Wing Chun and tai chi. The vestibular system of the inner ear, vision and proprioception are the main three requirements for balance. Moreover, there are specific devices designed for proprioception training, such as the exercise ball, which works on balancing the abdominal and back muscles.

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

2.5.1 What is a Bio-chemical aspect of exercise?

Biochemists study such things as the structures and physical properties of biological molecules, including proteins, carbohydrates, **lipids**, and nucleic acids; the mechanisms of enzyme action; the chemical regulation of metabolism; the chemistry of **nutrition**; the molecular basis of genetics (inheritance); the chemistry of **vitamins**; energy utilization in the cell; and the chemistry of the immune response. Fields closely related to biochemistry include biophysics, cell biology, and molecular biology. Bio-Chemical aspect of exercise is concerned with the effects of exercise analyzed through molecules, enzyme, metabolism and energy utilization in the cell.

Regardless of the type, intensity, or duration of exercise, the energy required for the muscular work is derived from the production and utilization of high energy phosphate bonds from adenosine tri-phosphate (ATP). Small amounts of ATP can be stored in skeletal muscle to be available immediately for short bursts of activity. For longer, more sustained muscle work, additional high-energy phosphate bonds must be produced by the muscle cell. Fuel in the form of glucose and free fatty acids is metabolized in the muscle cell to produce ATP. At this point the circulatory system and lungs become important; not only glucose and fatty acids but also oxygen, which is crucial for the metabolism of these fuels, must be brought to exercising muscle while, simultaneously, the products of their catabolism must be removed. Glucose metabolism in exercising muscle can be divided conveniently into two steps: During the anaerobic (glycolytic~ cycle, oxygen is not required to metabolize glucose to the intermediate compound pyruvate, which is in turn in equilibrium with lactate. However, only 2 moles of ATP are generated. The bulk of ATP is produced during the oxidative (aerobic) step. When pyruvate is metabolized to carbon dioxide and water, an oxygen-requiring process, 34 moles of ATP are produced. Metabolism of fatty acids, which provide a huge energy reservoir, requires oxygen; they cannot be metabolized anaerobically. Exercise is defined as aerobic when all the ATP required for its performance can be generated by complete metabolism of fatty acids and glucose with oxygen to produce carbon dioxide and water. For each individual the level of intensity of aerobic exercise varies with the level of fitness; beyond this the individual must perform anaerobically. This level has been termed the anaerobic threshold. The changes that occur with increasing workload and that define the anaerobic threshold. As the intensity of exercise or work rate increases, oxygen consumption and carbon dioxide production similarly increase. The ventilatory rate increases to meet the added oxygen requirements and to remove, through the lungs, the increased carbon dioxide produced by the exercising muscle. The anaerobic threshold is reached when the energy requirements of the exercising muscle exceed the subject's aerobic capacity. Oxygen consumption is maximal by definition, but carbon dioxide production continues to increase and indeed rises precipitously beyond the anaerobic threshold. The lungs must respond by substantially increasing the ventilatory rate to excrete the increased carbon dioxide.

Anaerobic Glycolysis

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. This also produces a net two molecules of ATP, the energy currency of cells, along with two reducing equivalents of converting NAD^+ (nicotinamide adenine dinucleotide: oxidized form) to NADH (nicotinamide adenine dinucleotide: reduced form). This does not require oxygen; if no oxygen is available (or the cell cannot use oxygen), the NAD is restored by converting the pyruvate to lactate (lactic acid) (e.g., in humans) or to ethanol plus carbon dioxide (e.g., in yeast). Other monosaccharides like galactose and fructose can be converted into intermediates of the glycolytic pathway.

Aerobic

In aerobic cells with sufficient oxygen, as in most human cells, the pyruvate is further metabolized. It is irreversibly converted to acetyl-CoA, giving off one carbon atom as the waste product carbon dioxide, generating another reducing equivalent as NADH. The two molecules acetyl-CoA (from one molecule of glucose) then enter the citric acid cycle, producing two molecules of ATP, six more NADH molecules and two reduced (ubi)quinones (via $FADH_2$ as enzyme-bound cofactor), and releasing the remaining carbon atoms as carbon dioxide. The produced NADH and quinol molecules then feed into the enzyme complexes of the respiratory chain, an electron transport system transferring the electrons ultimately to oxygen and conserving the released energy in the form of a proton gradient over a membrane (inner mitochondrial membrane in eukaryotes). Thus, oxygen is reduced to water and the original electron acceptors NAD^+ and quinone are regenerated. This is why humans breathe in oxygen and breathe out carbon dioxide. The energy released from transferring the electrons from high-energy states in NADH and quinol is conserved first as proton gradient and converted to ATP via ATP synthase. This generates an additional *28* molecules of ATP (24 from the 8 NADH + 4 from the 2 quinols), totaling to 32 molecules of ATP conserved per degraded glucose (two from glycolysis + two from the citrate cycle). It is clear that using oxygen to completely oxidize glucose provides an organism with far more energy than any oxygen-independent metabolic feature, and this is thought to be the reason why complex life appeared only after Earth's atmosphere accumulated large amounts of oxygen.

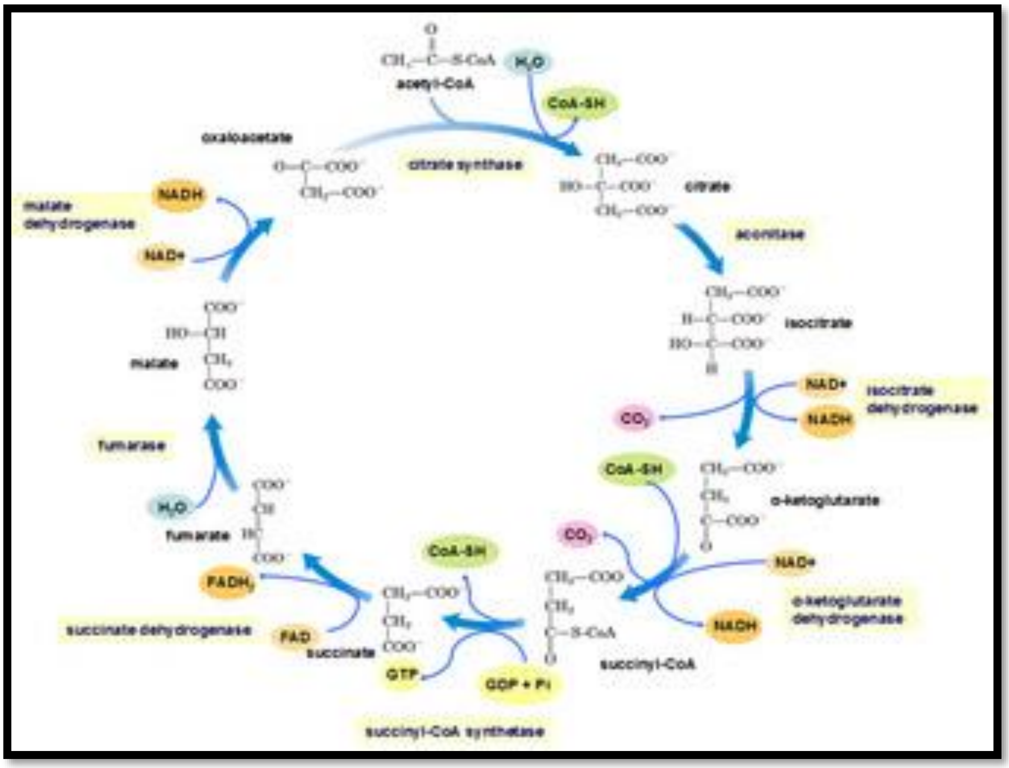
Gluconeogenesis

In vertebrates, vigorously contracting skeletal muscles (during weightlifting or sprinting, for example) do not receive enough oxygen to meet the energy demand, and so they shift to anaerobic metabolism, converting glucose to lactate. The combination of glucose from non-carbohydrates origin, such as fat and protein. This only happens when glycogen supplies in the liver are worn out. The pathway is a crucial reversal of glycolysis from pyruvate to glucose and can utilize many sources like amino acids, glycerol and Krebs Cycle. Large scale protein and fat catabolism usually occur when those suffer from starvation or certain endocrine disorders. The liver regenerates the glucose, using a process called gluconeogenesis. This process is not quite the opposite of glycolysis, and actually requires three times the amount of energy gained from glycolysis (six molecules of ATP are used, compared to the two gained in glycolysis). Analogous to the above reactions, the glucose produced can then undergo glycolysis in tissues that need energy, be stored as glycogen (or starch in plants), or be converted to other monosaccharides or joined into di- or oligosaccharides. The combined pathways of glycolysis during exercise, lactate's crossing via the bloodstream to the liver, subsequent gluconeogenesis and release of glucose into the bloodstream is called the Cori cycle.

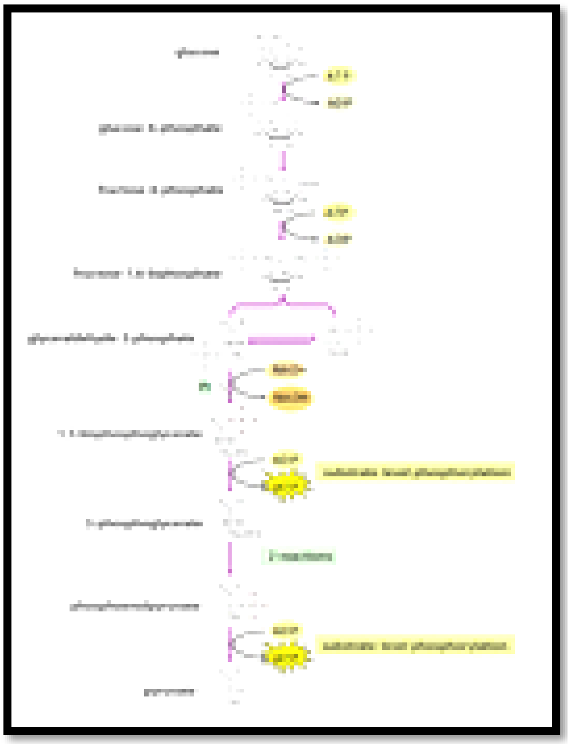
2.5.2Metabolism of food products

Energy metabolism is the general process by which living cells acquire and use the energy needed to stay alive, to grow, and to reproduce. How is the energy released while breaking the chemical bonds of nutrient molecules captured for other uses by the cells? The answer lies in the coupling between the oxidation of nutrients and the synthesis of high-energy compounds, particularly ATP, which works as the main chemical energy carrier in all cells.

There are two mechanisms of ATP synthesis: 1. oxidative phosphorylation, the process by which ATP is synthesized from ADP and inorganic phosphate (Pi) that takes place in mitochondrion; and 2. substrate-level phosphorylation, in which ATP is synthesized through the transfer of high-energy phosphoryl groups from high-energy compounds to ADP. The latter occurs in both the mitochondrion, during the tricarboxylic acid (TCA) cycle, and in the cytoplasm, during glycolysis. In the next section, we focus on oxidative phosphorylation, the main mechanism of ATP synthesis in most of human cells. Later we comment on the metabolic pathways in which the three classes of nutrient molecules are degraded. The metabolic reactions are energy-transducing processes in which the oxidation-reduction reactions are vital for ATP synthesis. In these reactions, the electrons removed by the oxidation of fuel molecules are transferred to two major electron carrier coenzymes, nicotinamide adenine dinucleotide (NAD^+) and flavin adenine dinucleotide (FAD), that are converted to their reduced forms, NADH and $FADH_2$. Oxidative phosphorylation depends on the electron transport from NADH or $FADH_2$ to O_2, forming H_2O. The electrons are "transported" through a number of protein complexes located in the inner mitochondrial membrane, which contains attached chemical groups (flavins, iron-sulfur groups, heme, and cooper ions) capable of accepting or donating one or more electrons. These protein complexes, known as the electron transfer system (ETS), allow distribution of the free energy between the reduced coenzymes and the O_2 and more efficient energy conservation. The electrons are transferred from NADH to O_2 through three protein complexes: NADH dehydrogenase, cytochrome reductase, and cytochrome oxidase. Electron transport between the complexes occurs through other mobile electron carriers, ubiquinone and cytochrome c. FAD is linked to the enzyme succinate dehydrogenase of the TCA cycle and another enzyme, acyl-CoA dehydrogenase of the fatty acid oxidation pathway. During the reactions catalysed by these enzymes, FAD is reduced to $FADH_2$, whose electrons are then transferred to O_2 through cytochrome reductase and cytochrome oxidase, as described for NADH dehydrogenase electrons. The electron transfer through the components of ETS is associated with proton (H^+) pumping from the mitochondrial matrix to inter membrane space of the mitochondria. These observations led Peter Mitchell, in 1961, to propose his revolutionary chemiosmotic hypothesis. In this hypothesis, Mitchell proposed that H^+ pumping generates what he called the proton motive force, a combination of the pH gradient across the inner mitochondrial membrane and the transmembrane electrical potential, which drives the ATP synthesis from ADP and Pi. ATP is synthesized by the ATP synthase complex, through which H+ protons return to the mitchondrial matrix. Paul Boyer first described the ATP synthase catalytic mechanism and showed both that the energy input from the H^+ gradient was used for ATP release from the catalytic site, and that the three active sites of the enzyme worked cooperatively in such a way that ATP from one site could not be released unless ADP and Pi were available to bind to another site. Inter conversion of energy between reduced coenzymes and O_2 directs ATP synthesis, but how (and where) are NADH and $FADH_2$ reduced? In aerobic respiration or aerobiosis, all products of nutrients' degradation converge to a central pathway in the metabolism, the TCA cycle. In this pathway, the acetyl group of acetyl-CoA resulting from the catabolism of glucose, fatty acids, and some amino acids is completely oxidized to CO_2 with concomitant reduction of electron transporting coenzymes (NADH and $FADH_2$). Consisting of eight reactions, the cycle starts with condensing acetyl-CoA and oxaloacetate to generate citrate (Figure 3). The next seven reactions regenerate oxaloacetate and include four oxidation reactions in which energy is conserved with the reduction of NAD^+ and FAD coenzymes to NADH and $FADH_2$, whose electrons will then be transferred to O_2 through the ETS. In addition, a GTP or an ATP molecule is directly formed as an example of substrate-level phosphorylation. In this case, the hydrolysis of the thioester bond of succinyl-CoA with concomitant enzyme phosphorylation is coupled to the transfer of an enzyme-bound phosphate group to GDP or ADP. Importantly, although O_2 does not participate directly in this pathway, the TCA cycle only operates in aerobic conditions because the oxidized NAD^+ and FAD are regenerated only in the ETS. Also noteworthy is that TCA cycle intermediates may also be used as the precursors of different biosynthetic processes. The TCA cycle is also known as the Krebs cycle, named after its discoverer, Sir Hans Kreb. Krebs based his conception of this cycle on four main observations made in the 1930s. The first was the discovery in 1935 of the sequence of reactions from succinate to fumarate to malate to oxaloacetate by Albert Szent-Gyorgyi, who showed that these dicarboxylic acids present in animal tissues stimulate O_2 consumption. The second was the finding of the sequence from citrate to α-ketoglutarate to succinate, in 1937, by Carl Martius and Franz Knoop. Next was the observation by Krebs himself, working on muscle slice cultures, that the addition of tricarboxylic acids even in very low concentrations promoted the oxidation of a much higher amount of pyruvate, suggesting a catalytic effect of these compounds. And the fourth was Krebs's observation that malonate, an inhibitor of succinate dehydrogenase, completely stopped the oxidation of pyruvate by the addition of tricarboxylic acids and that the addition of oxaloacetate in the medium in this condition generated citrate, which accumulated, thus elegantly showing the cyclic nature of the pathway.



Glycolysis is the pathway in which one glucose molecule is degraded into two pyruvate molecules. Interestingly, during the initial phase, energy is consumed because two ATP molecules are used up to activate glucose and fructose-6-phosphate. Part of the energy derived from the breakdown of the phosphoanhydride bond of ATP is conserved in the formation of phosphate-ester bonds in glucose-6-phosphate and fructose-1,6-biphosphate. In the second part of glycolysis, the majority of the free energy obtained from the oxidation of the aldehyde group of glyceraldehyde 3-phosphate (G3P) is conserved in the acyl-phosphate group of 1,3-bisphosphoglycerate (1,3-BPG), which contains high free energy. Then, part of the potential energy of 1,3BPG, released during its conversion to 3-phosphoglycerate, is coupled to the phosphorylation of ADP to ATP. The second reaction where ATP synthesis occurs is the conversion of phosphoenolpyruvate (PEP) to pyruvate. PEP is a high-energy compound due to its phosphate-ester bond, and therefore the conversion reaction of PEP to pyruvate is coupled with ADP phosphorylation. This mechanism of ATP synthesis is called substrate-level phosphorylation. For complete oxidation, pyruvate molecules generated in glycolysis are transported to the mitochondrial matrix to be converted into acetyl-CoA in a reaction catalyzed by the multienzyme complex pyruvate dehydrogenase. When Krebs proposed the TCA cycle in 1937, he thought that citrate was synthesized from oxaloacetate and pyruvate (or a derivative of it). Only after Lipmann's discovery of coenzyme A in 1945 and the subsequent work of R. Stern, S. Ochoa, and F. Lynen did it become clear that the molecule acetyl-CoA donated its acetyl group to oxaloacetate. Until this time, the TCA cycle was seen as a pathway to carbohydrate oxidation only. Most high school textbooks reflect this period of biochemistry knowledge and do not emphasize how the lipid and amino acid degradation pathways converge on the TCA cycle.



Cells extract energy from foods through a series of reactions that have negative free energy changes. Much of the free energy released is not allowed to dissipate as heat, but is captured in chemical bonds formed by other molecules for use throughout the cell. In almost all organisms the most important molecule for capturing and transferring free energy is adenosine triphosphate, or ATP. The useful free energy in an ATP molecule is contained in highenergy phosphoanhydride bonds.

2.5.3What is Aerobic Exercise?

Aerobic exercise is physical exercise of low to high intensity that depends primarily on the aerobic energy-generating process. "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. Generally, light-to-moderate intensity activities that are sufficiently supported by aerobic metabolism can be performed for extended periods of time. What is generally called aerobic exercise might be better termed "solely aerobic", because it is designed to be low-intensity enough so that all carbohydrates are aerobically turned into energy. When practiced in this way, examples of cardiovascular or aerobic exercise are medium to long distance running or jogging, swimming, cycling, walking and yoga.

2.5.4What is Anaerobic Exercise?

Anaerobic exercise is a type of exercise that breaks down glucose in the body without using oxygen, as anaerobic means “without oxygen”. In practical terms, this means that anaerobic exercise is harder but shorter than aerobic exercise. The biochemistry of anaerobic exercise involves a process called glycolysis, in which glucose is converted to adenosine triphosphate (ATP), which is the primary source of energy for cellular reactions. Lactic acid is produced at an increased rate during anaerobic exercise, causing it to build up quickly. The build-up of lactate above the lactate threshold (also called anaerobic threshold) is a major contributor to muscle fatigue. Anaerobic exercise may be used by personal trainers to help their clients build endurance, muscle strength, and power.

2.5.5Effect of exercise during exercise.

Cooper himself defines aerobic exercise as the ability to use the maximum amount of oxygen during exhaustive work. Cooper describes some of the major health benefits of aerobic exercise, such as gaining more efficient lungs by maximizing breathing capacity, thereby increasing ability to ventilate more air in a shorter period of time. As breathing capacity increases, one is able to extract oxygen more quickly into the blood stream, increasing elimination of carbon dioxide. With aerobic exercise the heart becomes more efficient at functioning, and blood volume, hemoglobin and red blood cells increase, enhancing the ability of the body to transport oxygen from the lungs into the blood and muscles. Metabolism will change and enable consumption of more calories without putting on weight. Aerobic exercise can delay osteoporosis as there is an increase in muscle mass, a loss of fat and an increase in bone density. With these variables increasing, there is a decrease in likelihood of diabetes as muscles use sugars better than fat. One of the major benefits of aerobic exercise is that body weight may decrease slowly; it will only decrease at a rapid pace if there is a calorie restriction, therefore reducing obesity rates.

Health benefits

Among the recognized health benefits of doing regular aerobic exercise are:

- Strengthening the muscles involved in respiration, to facilitate the flow of air in and out of the lungs
- Strengthening and enlarging the heart muscle, to improve its pumping efficiency and reduce the resting heart rate, known as aerobic conditioning
- Improving circulation efficiency and reducing blood pressure
- Increasing the total number of red blood cells in the body, facilitating transport of oxygen
- Improving mental health, including reducing stress and lowering the incidence of depression, as well as increased cognitive capacity.
- Reducing the risk for diabetes (One meta-analysis has shown, from multiple conducted studies, that aerobic exercise does help lower Hb A_{1C}levels for type 2 diabetics)
- Reducing the risk of death due to cardiovascular problems

High-impact aerobics activities (such as jogging or using a skipping rope) can:

- Stimulate bone growth
- Reduce the risk of osteoporosis for both men and women

Aerobic exercises might have especially benefitted additional to cancer therapy. As this topic becomes more and more important, Knips et al. conducted a Cochrane review with randomised controlled trials in 2019 to re-evaluate the safety, efficacy and feasibility of physical exercises in addition to the standard treatment for adult patients with haematological malignancies. The exact inclusion and exclusion criteria and further details can be found in the original Cochrane review. The study participants were in disease stage I to IV. As aerobic physical exercises were only an additional treatment, participants also received chemotherapies or stem cell transplantations/ bone marrow transplantations. Knips et al. compared aerobic physical exercises additional to the standard treatment to standard treatment alone: The evidence is very uncertain about the effect of aerobic physical exercises on anxiety and serious adverse events. Aerobic physical exercises may result in little to no difference in the mortality, in the quality of life and in the physical functioning. These exercises may result in a slight reduction in depression. Furthermore, aerobic physical exercises probably reduce fatigue.

Body performance benefits

In addition to the health benefits of aerobic exercise, there are numerous performance benefits:

- Increasing storage of energy molecules such as fats and carbohydrates within the muscles, allowing for increased endurance
- Neovascularization of the muscle sarcomeres to increase blood flow through the muscles
- Increasing speed at which aerobic metabolism is activated within muscles, allowing a greater portion of energy for intense exercise to be generated aerobically
- Improving the ability of muscles to use fats during exercise, preserving intramuscular glycogen
- Enhancing the speed at which muscles recover from high intensity exercise

Neurobiological effects

- Improvement in brain structural connections
- Increase in gray matter density
- New neuron growth
- Improvement in cognitive function (cognitive control and various forms of memory)
- Improvement or maintenance of mental health

Effects of anaerobic exercise:

Oxygen is required for the body to be able to use fat for fuel. Since aerobic exercise uses oxygen to produce energy, it can use both fat and glucose for fuel. Anaerobic exercise, on the other hand, can only use glucose for fuel. Glucose is available in the muscles for quick and short bursts of movement, and can be used when the aerobic system is maxed out for a short period of time. When you begin to exercise vigorously, there is a temporary shortage of oxygen getting delivered to your working muscles. That means anaerobic exercise must be fueled using glucose through a process called glycolysis. Glycolysis occurs in muscle cells during high-intensity training without oxygen, producing energy quickly. This process also produces lactic acid, which is the reason why your muscles get so tired after the energy burst. By engaging in anaerobic exercise regularly, your body will be able to tolerate and *eliminate lactic acid more effectively. That means you'll get tired less quickly.*

The benefits

If anaerobic exercise sounds like a lot of work, that's because it is. But the benefits that come with the intense fitness regime are enough to make you want to power through your next workout.

1. **Increases bone strength and density:**
Anaerobic activity like resistance training can increase the strength and density of your bones. This can also decrease your risk of osteoporosis.
2. Promotes weight maintenance:
In addition to helping your body handles lactic acid more effectively; anaerobic exercise can help you maintain a healthy weight. The effect of regular aerobic exercise on body fat is small; HIIT training can result in modest reductions in stomach body fat.
3. Increases power:
It can increase muscle power. Players who did eight 20- to 30-second wind sprints three days a week saw their power increase by an average of 15 percent throughout the season.
4. **Boosts metabolism:**
Anaerobic exercise helps boost metabolism as it builds and maintains lean muscle. The more lean muscle you have, the more calories you'll burn during your next sweat session. High-intensity exercise is also thought to increase your post-workout calorie burn.
5. **Increases lactic threshold:**
By regularly training above your anaerobic threshold, the body can increase its ability to handle lactic acid, which increases your lactic threshold. Increase ability to work out harder, for longer.
6. **Fights depression:**
Anaerobic exercise, like strength training, can boost player's mood and even fight depression.
7. **Reduces risk of disease:**
Gains in strength and bone density attained by high-intensity anaerobic training, like bodyweight squats and pushups, can reduce your risk for diabetes and heart disease.
8. **Protects joints:**
By building your muscle strength and muscle mass, your joints will be better protected, meaning you'll have greater protection against injury.
9. Boosts energy:
Consistent anaerobic exercise increases body's ability to store glycogen (what your body uses as energy), giving you more energy for your next bout of intense physical activity. This can improve athletic ability.

2.5.6Direct method of measuring energy cost of exercise

The direct calorimetry technique measures the rate of heat loss by the subject using a calorimeter. It is the most accurate method for quantifying metabolic rate There are 4 types of direct calorimeters, namely the "isothermal direct calorimeters" (also known as "heat-flow or heat-conduction calorimeters") which work by maintaining a constant wall temperature by means of a constant temperature fluid (commonly water) in a jacket or bath surrounding the animal chamber, or in a network of copper tubing bonded to an exterior wall surface; the "heat sink direct calorimeters" which are made of a chamber from which heat lost by the subject is removed by a liquid-cooled heat exchanger; the "direct convection calorimeters" which consist of an insulated chamber ventilated with an air flow at a known rate. The system works by determining the temperature and enthalpy differences between the air entering and exiting an insulated chamber; and the "direct differential calorimeters" which involve 2 identical chambers, one housing the subject and the other having an electric heater adjusted to yield identical temperature increases in both chambers.

2.5.8 Indirect method of measuring energy cost of exercise

The technique of indirect calorimetry relies on the measurement of inspired and expired gas volume, and the concentrations of O_2 and CO_2. Various methods are used for gas collection, including the Douglas Bag, the canopy, and the face mask. Indirect calorimetry is an accurate and non-invasive method, and it can allow the assessment of energy expenditure on field through the use of ambulatory metabolic systems. Energy expenditure is calculated by Weir's formula which is as follow:

Energy expenditure (kcal) = $3.941 \times VO_2$ (L) + $1.106 \times VCO_2$ (L)

where VO_2 is the volume of consumed O_2 and VCO_2 is the volume of produced CO_2.

In case of REE calculation, the abbreviated Weir's formula is mostly used:

REE (kcal/day) = ($3.941 \times VO_2$ [L/min] + $1.106 \times VCO_2$ [L/min]) $\times$ 1,440

where VO_2 is the volume of consumed O_2 and VCO_2 is the volume of produced CO_2.

Indirect calorimetry is the most widely used method to assess energy balance, including those involving patients in clinical setting. In other studies, it has served as a reference method to assess the accuracy of other methods of energy expenditure measurement, such as the validation of accelerometers or predictive equations for REE. In comparison to the direct calorimetry, the method is more affordable, and presents the advantage of providing information on the metabolic fuels being combusted in addition to measuring the metabolic rate.

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

2.6.2What is fatigue?

Fatigue is a term used to describe an overall feeling of tiredness or lack of energy. It isn't the same as simply feeling drowsy or sleepy. When an athlete fatigued, he have no motivation and no energy. Being sleepy may be a symptom of fatigue, but it's not the same thing. Fatigue is a common symptom of many medical conditions that range in severity from mild to serious. It's also a natural result of some lifestyle choices, such as lack of exercise or poor diet. If your fatigue doesn't resolve with proper rest and nutrition, or you suspect it's caused by an underlying physical or mental health condition, then it is required to diagnose the cause of athlete fatigue and work with you to treat it.

2.6.3Causes of fatigue.

Life style:

- physical exertion
- lack of physical activity
- lack of sleep
- being overweight or obese
- periods of emotional stress
- boredom
- grief
- taking certain medications, such as antidepressants or sedatives
- using alcohol on a regular basis
- using illicit drugs, such as cocaine
- consuming too much caffeine
- not eating a nutritious diet

Physical health:

- anaemia
- arthritis
- fibromyalgia
- chronic fatigue syndrome
- infections, such as cold and flu
- Addison's disease, a disorder that can affect your hormone levels
- hypothyroidism, or underactive thyroid
- hyperthyroidism, or overactive thyroid
- sleep disorders, such as insomnia
- eating disorders, such as anorexia
- autoimmune disorders
- congestive heart failure
- cancer
- diabetes

- kidney disease
- liver disease
- chronic obstructive pulmonary disease (COPD)
- emphysema

Mental health:

- anxiety,
- depression
- Seasonal affective disorder.
- stress
- bereavement and grief
- eating disorders
- boredom
- emotional exhaustion or burnout
- life events, such as moving home or getting a divorce

The main symptom of fatigue is exhaustion with physical or mental activity. A person does not feel refreshed after resting or sleeping. It might also be hard for them to carry out their daily activities, including work, household chores, and caring for others.

The symptoms of fatigue may be physical, mental, or emotional:

Common symptoms associated with fatigue can include:

- aching or sore muscles
- apathy and a lack of motivation
- daytime drowsiness
- difficulty concentrating or learning new tasks
- gastrointestinal problems, such as bloating, abdominal pain, constipation, or diarrhea
- headache
- irritability or moodiness
- slowed response time
- vision problems, such as blurriness

2.6.4 How do we overcome from fatigue?

- **Sufficient Sleep:**

Getting good quality sleep is an important part of managing fatigue.

To practice good sleep hygiene:

- Aim to go to bed and wake up at the same time each day, even on days off.
- Set the bedroom temperature at a comfortable level. Cooler may be better.
- Make sure that the room is dark and quiet.
- Avoid screen time an hour before sleeping, as the light and sounds from a television, computer, or phone screen can stimulate brain activity and affect sleep quality.
- Avoid eating shortly before going to bed.
- As bedtime approaches, try to slow down both physically and mentally. Taking a warm bath or listening to some soothing music can help clear the mind of stressful and worrying thoughts before going to sleep.

Keeping a sleep diary to detect patterns may also help.

- **Eating and drinking habits:**

Diet can affect how tired or energetic a person feels. Maintaining a moderate and well-balanced diet can lead to better health and better sleep.

- Eat small, frequent meals throughout the day.
- Eat snacks that are low in sugar.
- Avoid junk food and follow a well-balanced, healthful diet.
- Consume plenty of fresh fruits and vegetables.
- Avoid consuming caffeine in the afternoon and evening.

- **Health and Physical Fitness:**

Getting regular physical activity can help reduce fatigue and improve sleep.
Those who have not been physically active for some time should introduce exercise gradually. A doctor or sports therapist can help.
People should exercise during the time of day that is most productive for them.

- **Yoga and mindfulness:**

In one study, people with multiple sclerosis who completed 2 months of mindfulness meditation reported that levels of fatigue, anxiety, and depression fell, while quality of life improved.

- **Decrease the intensity and volume of load:**

Sportsman recovers faster from intensive loads as compared to voluminous loads. High intensity causes fatigue faster but after the activity the recovery is also faster. But in general it is quite impossible. Due to this decrease of the intensity and volume of load it is necessary to decrease the intensity and volume of load.

- **Changing of nature of load:**

In sports training different types of load are given to improve different performance factors. Recovery after loads in which phosphates are used for energy production is the fastest. Recovery from loads which result in depletion of glycogen stores is longer. Recovery from fatigue caused by strength training takes 1-2 days or even longer. Recovery of bones, ligaments, tendons etc, takes several days. Smaller muscles recover faster than bigger muscles.

- **Change in Daily Routine:**

Proper control of daily routine is indispensable for recovery from fatigue of training and competition. Daily routine sets the daily or circadian rhythm. If the bio-rhythm is frequently distributed by changes in the daily routine then the recovery process are negatively affected.

- **Decrease the total load:**

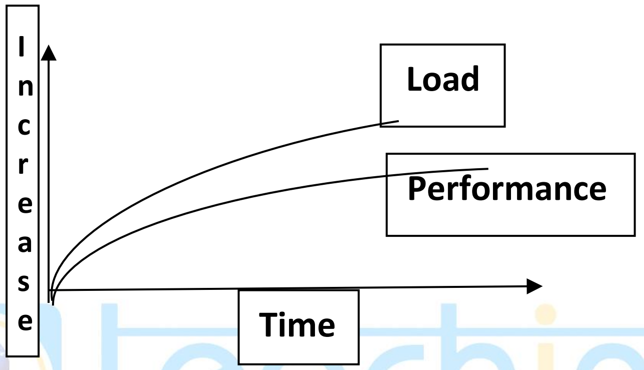
Total load is the product of training and competition load plus the other types of loads and stresses on the sportsman during the day (for example: family, profession, illness, weather, environment etc.). Total load beyond the tolerance of sportsman leads to slowing down of recovery process.

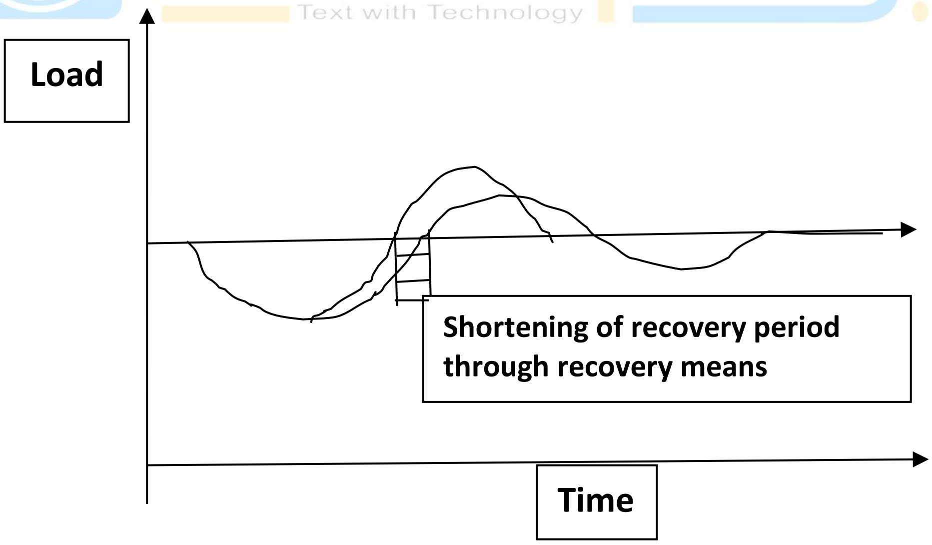
- **Change in training methodical means:**

Change in Macro, Meso and Micro cycles, proper warming up, right sequence of exercises and tasks, proper rest, cool down exercises and also use of physiotherapeutic means can give recovery from fatigue.

2.6.5 What is recovery process?

Sport performance can be improved through training and competition load. In other words performance and load are inter-related. Higher loads over a period of months and years lead to higher improvement in performance. This relationship however is not a linear relationship. With the improvement in training state higher quantities of load are required to the improvement of training state higher quantities of load are required to achieve lesser increases in performance. The sportsmen of higher performance level now days are tacking extreme quantities of load in order to improve their performance. Extremely high loads cannot be tackled for long by sportsmen unless the recovery process are supported and accelerated by some means. By adopting recovery means, appropriately fitted in the daily routine of the sportsmen, the total period of recovery can be considerably shortened.





Recovery can be conducted with following three different phases:

1. **Phase-I**

   In this phase 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. The pace of recovery in this phase is crucial for long duration sports and is largely determined by the functional capacity of the various organs and systems.

2. **Phase-II**
   This phase starts after the cessation of physical activity and ends with the restoration of homeostasis. It lasts from a few minutes to 2-3 hours. The recovery in this phase can be accelerated by adopting active means of recovery, deep breathing, and ingestion of carbohydrate rich drinks containing recommended vitamins, salts and minerals.
3. **Phase-III**
   This phase of recovery can last from several hours to several days. The recovery process in this phase is anabolic in nature. The substances enzymes, proteins etc. which were depleted or broken down during the activity are re-synthesized or rebuilt in this phase.
   Certain factors affecting the pace of recovery those are follows:
   1. Intensity and volume of load
   2. Nature of load
   3. Health and physical fitness
   4. Nutrition
   5. Sleep
   6. Daily routine
   7. Total load

Recovery process will be more effective if it is tackled by the combined effort of the coach, sportsman and physician. Whenever need a psychologist or some other expert should be involved. The coach has to bear the main responsibility and should take the initiative and should organize the whole process of tackling the overload. Because of multitude of causes and symptoms there cannot be a set procedure for tackling overload. Some guide lines are essential for recovery:

1. State of overload must be recognized, through psychic symptoms as early as possible.
2. When it is sure that a state of overload exists then several steps have to taken immediately. Load must be reduced considerably and active and passive means of recovery should be stated. Diet should be checked and if required additional supplement of vitamins etc. should be given. A medical checkup should be done to rule out medical reasons. Competitions should be avoided. Specific means of training should be replaces by general means. An effort should be made to make the sportsman for relaxed and comfortable.
3. A systematic and concerned effort should be stated to find out the causes of overload. In this exercise the coach should involve the sportsman, his friends and colleagues, his family members, doctor or physician and if needed a psychologist also. The aim should be to pin point the reasons of overload and not the analysis of symptoms.
4. The causes of overload should be recovered and if needed the training should be re-planned.
5. The sportsman should start training again but the load should be increased carefully and gradually. The specific means of training should also be increased gradually. The active and passive means of recovery should also be gradually brought to the previous level.

2.6.6 Physiological aspects of fatigue

Like physiotherapeutic means the psychological means have also assumed greater importance for accelerating the recovery process. The recovery process is controlled by vegetative nervous system which is not under voluntary control. The psychological means somehow enable the sportsman to voluntarily control the vegetative functions for the purpose of recovery. These means have to be taught to the sportsman by an expert and after some time the sportsman is able to use these independently with good results. These means can be used by sportsman during and after the training sessions or just before sleep. These are very good for achieving relaxation and sound sleep.

2.6.7 Restoration of energy stores

Intense or prolonged physical exercise leads to fatigue, which is the inability to immediately perform exercise at the same levels of intensity and duration. This condition involves the loss of body water, the depletion and exhaustion of fuel stores, imbalances in the status of nutrients (including sodium, lipids and amino acids) and various homeostatic disturbances of hormones and the immune system. Recovery following exercise is the physiological process of reassembling the energy and physiological resources until one is able to deliver maximal performance once more. Food and drinks, rest, sleep and time are all elements necessary for the successful restoration of the athletic functions of the body and mind. Nutrition is only one part of the recovery process, but it is of vital importance for rehydration, refueling the body and replacing tissue proteins that have suffered wear and tear during the exercise. The main focus of this review is the restoration of muscle glycogen and lipid stores after exercise, and the nutritional recommendations that can be derived from applied scientific research to optimize this process. Nutritional facts that have been established during the period of recovery will be recalled, but only the more recent findings will be developed and references to many of them will be given. This choice should not mislead the reader into believing that this topic is just being discovered. However, recent developments in proton magnetic resonance spectroscopy (1H-MRS) have provided new insights into the uniqueness of the lipids located in muscle fibers and their relation to diet and exercise, and will be discussed in more detail. Recovery is not only a period needed to offset the disturbances caused by exercise. It is also an active phase during which the anabolic stimuli triggered by muscle contraction start developing their effects.

Use of muscle energy stores during exercise:

Glycogen:

Glycogen is the storage form of carbohydrates in the body. Its concentration in muscle of someone consuming a mixed diet averages 15 g·kg wet mass–1. Glycogen is used during exercise in proportion to the work intensity. Its stores in the muscle cells (about 0.5 kg) may easily be reduced to 20%, even concurrently with the ingestion of sports drinks during the exercise. Higher glycogen contents at the onset of exercise result in higher rates of use. Regeneration of muscle glycogen is crucial before another hard bout of exercise can be performed.

Lipids:

During prolonged exercise, body lipids can provide approximately as much energy as body glycogen, such that 0.2 to 0.3 kg of body fat may be utilized. If this fat came from adipose tissue lipids, which amount to some 10 kg, even in a lean male, this would be of little consequence. However, up to half of the lipids that serves as fuels for exercise are stored locally as droplets in the muscle cells. Their content in muscle averages 5 g·kg wet mass–1. Intramyocellular lipids (IMCL1), the mass of which is composed of triacylglycerol, may decrease to 20% of their resting level during endurance exercise. Higher muscle lipid contents at the onset of exercise seem to result in higher rates of use. The issue of whether females consume more myocellular triacylglycerol, as reported using biochemical determination is still debatable, since a preliminary report using 1H-MRS indicates the contrary. So far, a direct link between IMCL levels and endurance performance has not been established, but it is less than 10 years since non-invasive technology has permitted investigations into the causes and factors involved in IMCL fluctuations. In contrast, the relationship of glycogen concentration in muscle with diet and performance is 35 years old. Glycogen is used for the benefit of the muscle where it is stored. Muscles that remain inactive during work are not depleted. This has implications on the need for replenishment of glycogen, depending on whether the same or other muscles are going to be recruited in the follow-up exercise. The same property may also apply to lipids since mTAG data obtained in extensor muscle after one-legged knee extension exercise and IMCL data obtained in soleus muscle have shown lower lipid concentrations in the exercised versus the inactive muscle.

Proteins:

Proteins are subject to constant remodeling mediated by variable rates of synthesis and breakdown. They are not used quantitatively to any great extent during the exercise itself unless the glycogen stores are depleted, but many of their component amino acids – the building blocks of proteins – are subject to considerable conversions and inter-organ trafficking. For example, the branched-chain amino acids (BCAA: leucine, isoleucine, valine) and glutamate are increasingly metabolized in muscles during exercise. Glutamine and alanine are exported from muscle to liver and kidney where glucose can be produced from them de novo. The increased diversion of energy and amino acids towards events of muscle contraction during exercise suggests that the availability of substrates may limit post exercise muscle protein repair.

Recovery and the option to let nature follow its course:

There is only a weak relationship between the energy and nutrient deficits induced by physical exercise and subsequent spontaneous dietary intake. Contrary to a commonly held view, there is usually no automatic increase in hunger or energy intake as a result of exercise-induced energy deficit. If exercise is intense, appetite may even be suppressed. The drive to restore energy balance is slow to operate, certainly slower than what is recommended for a fast recovery to be able to perform once again. It is entirely possible to neglect any intentional action to promote recovery, because recovery will be achieved slowly by a spontaneous eating and drinking behavior guided by thirst and appetite. This natural course is sufficient for someone who has no particular athletic ambition and who has several days in front of him to fully recover until the next challenge. Someone whose primary motivation for practicing sports is to control body weight and reduce body fat will not have to rush to restore his energy balance. On the other hand, those wishing to train often and hard for a rapid and injury-free progression, or those considering two or more demanding physical workouts with little interval between, will be aware of the need to shorten recovery and will want to take appropriate dietetic measures. Only active feeding practices, sometimes against one's «gut feelings» will yield optimal results.

Restoration of muscle glycogen:

Restoration of muscle glycogen proceeds faster when the stores are depleted than when they are not. It is believed that activation of the enzyme glycogen synthase and facilitation of glucose transport across the muscle fiber membrane act in concert to speed up glycogen resynthesis after glycogen has been depleted to very low levels. For instance, Price et al. compared the rate of muscle glycogen recovery after a depletion of equal magnitude starting from a normal or from a glycogen-loaded situation. They found that the rate of glycogen resynthesis was faster when the glycogen remaining after the exercise was lower, and concluded that the absolute level remaining was a more decisive factor than the degree of depletion. Furthermore, two distinct pools of glycogen in muscle with different granular structures (proglycogen and macroglycogen) appear to be resynthesized at different rates in response to carbohydrate intake. Total muscle glycogen resynthesize occurs in a biphasic pattern. The first phase is short (less than 1–2 hours), rapid and insulin independent. The second phase is insulin dependent, and although it can proceed in the absence of carbohydrate intake glycogen resynthesize will be very slow. When carbohydrates are ingested, blood glucose and insulin are raised and glycogen resynthesize is accelerated. There are several factors related to the ingestion of carbohydrates that have been described to influence glycogen storage. The quantity of carbohydrate and the timing of ingestion at the end of the exercise are the most important ones. Other factors that play a role in glycogen storage are the type of carbohydrate, the form of ingestion (liquid or solid) and finally whether the carbohydrate supplement is taken alone or is co-ingested with protein.

Amount of carbohydrate:

The primary factor required to replenish liver and muscle glycogen is the amount of carbohydrate ingested. A direct relationship between carbohydrate intake and the rate at which glycogen is resynthesized is well established, with a maximal postexercise storage rate over a day achieved at intakes of about 7–10 g carbohydrate per kg body mass (g·kg–1). A recent confirmation of this notion was provided by Fairchild et al., who found that 10 g carbohydrate·kg–1·day–1 led to supranormal amounts of muscle glycogen within only 24 h after short bouts of near-maximal exercise. Such a brief and intense glycogen depletion technique occurs with little total energy expenditure, which might facilitate the complete restoration of muscle reserves during the subsequent day.

Timing of carbohydrate ingestion:

The second factor required to replenish body glycogen effectively, is timing. If the next exercise session takes place less than half a day after the first one, carbohydrate feedings should be initiated immediately at the end of the first session. Thus, one takes advantage of the fast storage phase that follows glycogen depletion and which only lasts a couple of hours. If carbohydrate ingestion is delayed after the end of exercise for any reason (such as priority being given to fluid intake, lack of appetite or simple negligence), the rate of glycogen accretion may be slowed by half. For instance, Levenhagen et al. found that leg glucose uptake, which is related to glycogen resynthesize in leg muscles, was increased 3- fold above basal when supplemented immediately post exercise, but only 40% above basal when supplemented 3 hours after. The amount of carbohydrates required for an optimal rate of glycogen resynthesize during the first 1 to 4 hours of recovery approximates 1.2 to 1.5 g·kg–1·h–1. A recommended strategy is to ingest a bolus drink as soon as possible, then follow with smaller quantities every 30 min or every hour. Because a large volume of liquid in the stomach is a key determinant for fast gastric emptying, this will ensure the immediate delivery of substantial amounts of carbohydrate to the small intestine, from which glucose can pass to the blood without delay at a rate that remains high for several hours.

Type of carbohydrate:

Another factor to consider is the type of carbohydrate. Glycogen is made of glucose molecules, so that dietary carbohydrates made of glucose (starch, maltodextrins, dextrose) are its most natural dietary precursors. Fructose is a sugar that seems to be easily stored in liver glycogen. However, fructose and fructose-containing sugars (e.g. sucrose – table sugar) are not optimal for muscle glycogen storage because they are less insulinogenic than glucose, and because fructose needs to first be transformed in the liver before it can be released into the circulation as glucose and taken up by muscle. For instance, Bowtell et al. compared glucose and sucrose drinks and found that a glucose polymer drink (330 ml, concentration 18.5%) promoted a slightly more rapid storage of glycogen in skeletal muscle during the 4-h period of recovery than an isoenergetic sucrose drink. This was supported by the lower plasma glucose concentration produced by the sucrose drink, which was attributed to the fructose moiety of the sucrose. Part of this effect may be related to the lower osmolality of the polymer drink facilitating gastric transit, however the calculated rates of gastric emptying of both drinks were similar. It should be noted that the amount of carbohydrate ingested, expressed per hour, was small (0.2 g·kg–1·h–1). In another study, Piehl Aulin et al. compared two energy equivalent, concentrated carbohydrate drinks (150 g·l –1, 300 g carbohydrate over 90 min), one containing a polyglycolide (osmolarity 84 mosmol·l –1), and one containing monomers and oligomers of glucose (350 mosmol·l –1) on muscle glycogen resynthesize. Mean glycogen synthesis rate was significantly higher during the initial 2 h after the polyglycolide drink compared with the glucose drink (10 vs. 6 mmol·kg–1·h–1). These data indicate that the osmolality of the carbohydrate drink may influence the rate of resynthesize of glycogen in muscle. It is tempting to speculate that the transit of the hypotonic polymer drink through the stomach was faster than that of the hypertonic glucose drink, however mean blood glucose and insulin concentrations did not differ between the two drinks, which argues against this explanation. Of the two chief physical factors defining the concentration of carbohydrate solutions (mass concentration and molar concentration), it is clear that osmolality plays a weaker role on the speed of gastric emptying than energy density, or the weight of the carbohydrate dissolved. This was again recently confirmed (preliminary data) when gastric osmolality was found to have little effect on the gastric emptying rate, at least of dilute carbohydrate solutions. The reason why, despite this, more energy dense hypotonic carbohydrate drinks may promote faster glycogen storage than hypertonic ones is unclear.

Glycemic index:

The glycemic index of a carbohydrate or a carbohydrate-rich food is a normalized score of the magnitude of the rise in blood glucose induced by its ingestion. As a fast, meaningful, and prolonged elevation in blood sugar concentration over a few hours is required for optimal glycogen resynthesize, high glycemic index carbohydrates ingested at frequent intervals following exercise are the best choice. This is not difficult to achieve with beverages, as most of them are composed of easily available sugars with a high glycemic index. If the supplement is a food (e.g. an energy bar), some critical sense is occasionally needed to select the one with an appropriate formulation. Combinations of different nutrients in a food, such as lipids or fiber, can reduce the glycemic index of the carbohydrate component.

Liquid and solid carbohydrate supplements:

As the immediate post exercise phase usually overlaps with the need to achieve complete rehydration, the most practical form of carbohydrate at this time is a sports drink. Furthermore, following strenuous exercise a drink is often more easily tolerated by the gut than a solid food and it may be the only practical way to deliver carbohydrate energy effectively. Another occasion when beverages are preferred is when the recovery time before the next exercise is short: carbohydrates in solution transit through the stomach with less delay, they increase blood glucose and insulin earlier than solids because of the time needed for digestion of the solid food mass. With a food, there may be further delay due to fat or dietary fiber components. The exact formulation of a post exercise carbohydrate drink, although important, is probably less critical than that of a drink consumed during exercise, when gastrointestinal function is compromised and concurrent needs compete with each other (e.g. optimal rehydration competing with optimal energy supply). Overall, the consumption of concentrated carbohydrate solutions (up to 30% by weight) enhances carbohydrate delivery and glycogen synthesis, despite impaired gastric emptying and fluid replacement. When there is plenty of time for recovery (one day or more), the form of ingestion, the type and glycemic index of the carbohydrates, are much less important. The consumption of regular carbohydrate-rich foods and more balanced meals can be resumed promptly after the first hours.

Additional role of proteins:

The efficacy of a particular carbohydrate in promoting resynthesize of glycogen stores is largely dependent on the glucose and insulin responses to the carbohydrate load. Attempts have been made to boost the insulin response of carbohydrates through co-ingestion of proteins or amino acids, because this may increase insulin concentration above that reached with carbohydrates alone. Early investigations suggested higher rates of glycogen resynthesize with, rather than without co-ingestion of proteins. Subsequently, the addition of arginine (0.08 g·kg–1·h–1), one of the most effective insulin secretagogues, to carbohydrate (maltodextrin, 1.0 g·kg–1·h–1) did not increase the rate of glycogen storage, although significance was approached. These results were difficult to interpret because, due to the addition of the nitrogenous component to that of carbohydrate, the diets were no longer isoenergetic. Moreover, as found later, the carbohydrate supply was suboptimal, leading perhaps to overstating the benefit of the amino acid component. Another study investigated the effect of incorporating whey protein and arginine, both of which have specific stimulating effects on insulin secretion, into a high carbohydrate drink. A preparatory trial confirmed that plasma insulin concentrations were significantly higher after ingestion of a solution of carbohydrate based on fermented cereals associated with protein plus arginine, compared with ingestion of carbohydrate alone. The drinks in the study were isoenergetic and provided carbohydrates at a rate presumed to saturate digestion and glycogen synthesis. The carbohydrate drink (1.7 g·kg–1·h–1), and the protein-carbohydrate drink (0.5 g protein–1·h–1 + 1.2 g carbohydrate–1·h–1) were ingested after a glycogen depleting cycle exercise. This resulted in equal glycogen resynthesize in the quadriceps muscles over the next 4 hours. Carrithers et al. also investigated the effect of carbohydrate (glucose 1.0 g·kg–1·h–1) with the isoenergetic substitution (25%) of either protein from milk or a mixture of essential free amino acids. They found no difference in glycogen resynthesize in the first 4 h of recovery from a glycogen depleting exercise. In a protocol identical to that used to study different carbohydrates, Bowtell et al. found that ingestion of glutamine (8 g) promoted the storage of muscle glycogen to an extent similar to that after ingestion of glucose polymer, but the amount of carbohydrate ingested was modest (0.2 g·kg–1·h–1) and there was no control group without supplement, which would have been useful in this design. In a systematic series of studies, van Loon et al. first identified leucine, phenylalanine and tyrosine as having strong correlations with the insulin response when co-ingested with carbohydrates in resting conditions. In a second step, they addressed the post exercise period and found that a mixture of leucine, phenylalanine and arginine (alone or together with a wheat protein hydrolysate) produced a large insulinotropic effect when ingested in combination with carbohydrates. Having identified compositions that markedly elevate insulin levels and plasma amino acid availability, they then examined the effect of a dietary manipulation in which the nitrogenous component was either included in exchange for carbohydrate (isoenergetic supplement), or added to the carbohydrate content (isocarbohydrate supplement) on glycogen storage. When 0.4 g hydrolysate per kg body mass per hour was added to 0.8 g carbohydrate–1·h–1 (i.e. isocarbohydrate), the insulin response and muscle glycogen synthesis were elevated compared with the carbohydrate alone, however 1.2 g·kg–1·h–1 carbohydrate without amino acids (i.e. isoenergetic) was as efficient, if not more, as carbohydrate plus amino acids in increasing glycogen synthesis. Subsequently, this group reassessed the issue of the upper limit of carbohydrate that would show an effect. They added proteins to a larger intake of carbohydrate (1.2 g·kg–1·h–1). Although the addition of 0.4 g·kg–1·h–1 protein and amino acids to carbohydrate during recovery from exercise increased insulin levels, there was no difference in plasma glucose nor muscle glycogen synthesis. Similarly, van Hall et al. compared the intake of carbohydrate (sucrose 1.25 g·kg–1·h–1) with that of the same amount of carbohydrate plus a whey protein hydrolysate (0.30 g·kg–1·h–1). Because they used sucrose, which is not as insulinogenic as glucose or maltodextrin, and selected whey protein hydrolysates, which are known to be easily digestible and to induce a high insulin stimulation, the conditions were such as to maximize the difference in insulin stimulation between treatments, despite the high level of carbohydrate intake. Nevertheless, although the carbohydrate whey supplement resulted in higher circulating insulin concentrations than the carbohydrate alone, these authors found equal rates of glucose uptake and glycogen storage in leg muscles over the next 4 hours. They suggested that the difference might have been caused by reduced glucose appearance from the gastrointestinal tract in relation to the higher energy load of the protein-carbohydrate drink. Finally, Ivyet al. reassessed the issue of isoenergetic versus is carbohydrate carbohydrate-protein supplements. In their study, glycogen resynthesize was followed by 13C-NMR during 4 hours of recovery with a better time resolution than is permitted by the invasive biopsy method. The carbohydrate-protein supplement (carbohydrate 0.55 g·kg–1·h–1, protein 0.2 g·kg–1·h–1) ingested early after and 2 hours after the end of exercise resulted in greater glycogen resynthesize than with carbohydrate alone, both at equal carbohydrate content and at equal energy content. The observed difference was due to higher rates of glycogen synthesis only occurring in the first 40 min of recovery, not later. Together, these data underscore the importance of early post exercise refeeding and mitigate the role of high circulating insulin per se, as well as the relevance of proteins and insulinogenic amino acids, on glycogen storage. To maximize the rate of muscle glycogen storage during short-term recovery, it is concluded that a large carbohydrate supplement ingested as soon after exercise as possible is the most effective option. If less carbohydrate consumption is desired, a similar rate of glycogen storage can be achieved with the addition of protein and amino acid supplements. Furthermore, if the results of the study by Ivy et al. can be confirmed, they suggest that a carbohydrate-protein supplement would be advantageous when the recovery time is extremely limited.

Protein and tissue repair:

The ingestion of protein together with carbohydrate would be of moderate interest if glycogen restoration was the only of one's concerns. However, the addition of protein with carbohydrate may stimulate amino acid uptake and protein accretion. This could be important for rapid tissue repair and initiation of muscle building. The coincidence of three factors is important to activate net protein synthesis: the stimulus of muscle contraction, the availability of insulin, and the availability of amino acids. Presumably this is best achieved with carbohydrate-protein ingestion during recovery. Recently, Levenhagen et al. reported that, similar to carbohydrate homeostasis, ingestion of a nutrient supplement early after 60 min of moderate-intensity cycling exercise (rather than 3 hours later) enhanced accretion of whole body and leg protein, suggesting a common mechanism of exercise-induced insulin action. In an extension of this study, the authors compared the effect of a protein + carbohydrate (10 g + 8 g) supplement with that of carbohydrate alone on protein homeostasis. The combined supplement resulted in a net leg uptake of essential amino acids and net whole-body and leg protein gain. In contrast, carbohydrate alone resulted in a net loss of protein. Larger amounts of carbohydrates, such as those needed for glycogen replenishment (~200 g), may be more anabolic than the small quantity given here (8 g) over 3 hours, but the findings suggest that the availability of amino acids is more important than the availability of energy for post exercise repair and synthesis of muscle proteins. Essential amino acids, including the branched-chain amino acids and particularly leucine, seem to be the most effective. In a recent study, 8 g of BCAA or a placebo was given to subjects during ergometer cycle exercise and a 2-h recovery period. The results suggested that BCAA had a protein-sparing effect, either protein synthesis had been stimulated and/or protein degradation had decreased. The effect did not seem to be mediated by insulin. Together with other data, this suggests that relatively small amounts of essential amino acids stimulate protein synthesis during recovery. Milk proteins are good dietary sources of essential amino acids and preference should be given to fractions that are digested and released faster from the stomach, such as the proteins from whey (in contrast to casein).

Timing of protein ingestion:

The ingestion of an amino acid-carbohydrate solution (6 g essential amino acids, 35 g sucrose in 500 ml) before resistance exercise was recently shown to result in a greater response of net protein synthesis than that obtained when the solution was consumed after the exercise. This may be due to a greater delivery of amino acids to the muscles when blood flow is elevated, resulting in better permeation and higher tissue concentration of precursor molecules at the end of exercise, when energy can again be released for anabolic purposes. Furthermore, this effect observed acutely in the first 2 hours of recovery seems to be reflected in a positive nitrogen balance over the full 24-h period, suggesting that muscle mass could increase if the intervention was carried out over longer periods of time, in comparison with sedentary activities without supplement. The latter result obtained over 24 hours is not quite unexpected, since the term of comparison was a 24-h period of very sedentary activities, a situation which tends to be catabolic. It remains to be demonstrated whether exercise plus the solution promotes a more positive 24-h protein balance, considering potential influences of physical exercise on protein metabolism during the rest of the day (meals, night period). The concept of pre-exercise ingestion for a post exercise outcome is appealing for muscle activities involving intermittent resistance work. It would not be advised in relation with long-lasting aerobic exercise, where cardio circulatory and gastrointestinal limitations are predominant and the nutritional priority must be given to maintaining hydration and blood glucose. Flooding the body with urea-producing proteins before or during endurance exercise would only add a further load to the already metabolically stressed kidneys.

Restoration of muscle triacylglycerol:

Until recently, changes occurring in myocellular triacylglycerol concentrations during recovery from exercise were not well documented, although it has been supposed for a long time that variations of the lipid intake could be a major factor contributing to the fluctuation of TAG stores in skeletal muscles. Using 1H-MR spectroscopy (see footnote 1), Boesch et al. reported that the time constant of IMCL recovery was ~40 h in one male subject who experienced a 40% exercise-induced fall in IMCL, but dietary intake during that time was self-selected and not controlled.

Low lipid intake:

Stereological, biochemical as well as magnetic resonance spectroscopy studies indicate that when a low fat diet(<20-25% below energy) or in other words a very high carbohydrate diet, is consumed after exercise to speed up glycogen reloading, IMCL fail to return to their pre-exercise concentrations until three or even five to seven days of recovery. It was also repeatedly observed that IMCL continue to decrease for at least one day after the end of exercise on such diets, in line with the fact that whole body fat oxidation remains elevated after exercise. In studies where mTAG concentrations did not decrease during exercise, they did afterwards if low-fat recovery diets were consumed. These led Kiens et al. to suggest that muscle glycogen resynthesize has such a high metabolic priority during recovery that combustion of lipids is necessary to cover energy expenditure in muscle and that mTAG provides a substantial part of it. However, their hypothesis is difficult to reconcile with the view that a low fat (high carbohydrate) diet increases glucose availability, thereby increasing muscle malonyl coenzyme A, which in turn suppresses the transfer of fatty acids into the mitochondria for subsequent oxidation. On the other hand, physical activity inhibits malonyl-CoA during both exercise and the recovery period.

High lipid intake:

In contrast, Jansson and Kaijser found that feeding a high-fat diet for five days resulted in 80% higher mTAG concentrations than feeding a low-fat diet. The investigation of Starling et al. was the first, to the author's knowledge, to examine the effect of different dietary compositions on mTAG concentration during an acute period after prolonged exercise. Subjects ingested an isoenergetic high-fat (68% of energy) or low-fat (5%) diet following a 2-h cycling exercise. After a day of recovery, total mTAG concentration was higher (121% of resting levels) for the high-fat compared with the low-fat trial (83%). Expectedly, the effect of high fat diets on the rate of post exercise IMCL recovery is not identical in different muscles. This is illustrated by the case of a marathon runner, whose IMCL content in tibialis anterior (TA), vastus medialis (VM) and vastus intermedius (VI) muscles after 2 days of recovery on a 63% fat energy diet each reached a different value relative to the pre-exercise concentration (TA 70%, VM 109% and VI 193%). Concentrations after a low-fat diet (6% energy) in the same muscles were then only 47–48% of initial in all three leg muscles. A practical question is to understand how IMCL content responds to different amounts of dietary lipids. In a pilot study with two subjects, three widely different levels of lipids were fed in isoenergetic diets for 32 hours after running for 2 h. The degree of IMCL storage in TA muscle was minimal with the lower-fat diet (15% energy), whereas with both the intermediate (40%) and the higher-fat (70%) diets, its concentration reached similarly high values, indicating that a maximal effect on 24-h storage was to be expected already at the intermediate fat intake. Interestingly, the absolute storage rate with both intermediate and high-fat diets was much greater in the subject who was a trained runner (3.1 and 3.2 mmol·kg muscle wet weight–1·24 h–1) than in the subject who was a cyclist of equal VO2max (0.7 and 0.9 mmol·kg ww–1·24 h–1). The large variation in IMCL storage observed between muscles and individuals involves a number of factors such as muscle type, training status and specificity, effective recruitment in the work, initial content, and degree of depletion by exercise, and possibly uncontrolled physical activity during the replenishment period. The exact role of each need's clarification. One of the major physiological adaptations to endurance training is to enhance the capacity for fat metabolism (fatty acid extraction by muscle, transport protein capacity, activities of carnitine palmitoyl transferase I and oxidative enzymes, larger IMCL stores). We investigated if there was evidence of a similar metabolic adaptation to training in the ability to speed up IMCL storage. Trained and sedentary men underwent ~25% IMCL depletion by running for two hours at ~50% VO2peak. When they consumed a 55% fat energy diet during recovery, IMCL concentrations in the TA muscle returned fully to resting levels after 15 h in both groups. In line with this observation, no difference between resting trained and untrained muscles was found in the expression of diacylglycerol acyltransferase, an intrinsic membrane protein providing the crucial final step in IMCL synthesis (Schmitt et al., unpublished observation). Independently, trained females who were depleted to the same extent as in the above study recovered in 22 h on a diet containing 35% fat energy, the proportion found in a typical normal diet. Clearly present literature indicates that with suitable amounts of lipids in the diet, post exercise IMCL stores can be completely replenished in less than a day, in both athletes and sedentary individuals.

Evidence has been provided that IMCL replenishment is strongly and positively dependent on the intake of dietary fat, like glycogen is on the intake of carbohydrate. Minimal lipid intake during recovery leads to no change or a further depression in IMCL concentrations. Very high fat intake for as little as one day may cause an overshoot of IMCL concentrations to between 120 and 170% of their initial levels. The idea that muscle triacylglycerol could be super compensated, like glycogen, is not new. In 1989 for example, the question was raised if it was also possible to «lipid load». At this point in time, no recommendation can be made to target such high lipid storage, neither from the standpoint of performance nor of safety. Conversely, it would be wise to avoid emptying IMCL stores prior to undertaking a prolonged competitive exercise. Consequently, a balance should be found such that average IMCL concentrations are maintained.

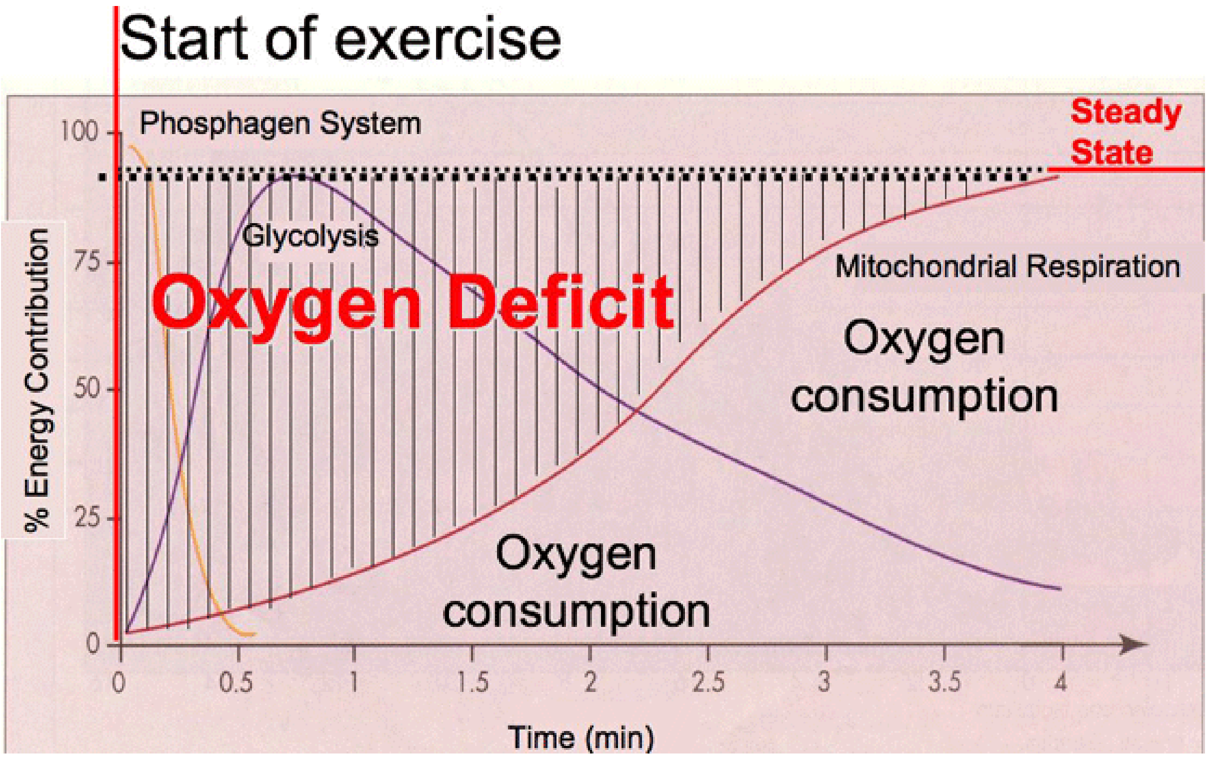
When replenishment of muscle glycogen after exercise is required to be complete within a day, athletes should ingest 1 to 1.5 g carbohydrates per kg body mass as soon as possible after the end of exercise, preferably as a drink. They should then continue to consume carbohydrates at regular intervals for at least 4 hours.

If they find such high amounts of carbohydrates difficult to tolerate, they may ingest less carbohydrate in a nutrient combination containing 10–20% protein from an easily digestible source such as whey.

They should then resume eating regular meals with high carbohydrate content. If they have a prolonged physical challenge ahead, the meals should also supply normal amounts of dietary lipids (a «carbonara party» type of meal instead of the «pasta party»).
For rapid tissue repair and initiation of muscle building, resistance athletes and fitness fans may wish to consume proteincarbohydrate combinations after their exercise session. They could also choose to ingest this type of supplement before the session.

2.6.7 Recovery oxygen

Excess post-exercise oxygen consumption (EPOC, informally called after burn) is a measurably increased rate of oxygen intake following strenuous activity. In historical contexts the term "oxygen debt" was popularized to explain or perhaps attempt to quantify anaerobic energy expenditure, particularly as regards lactic acid/lactate metabolism; in fact, the term "oxygen debt" is still widely used to this day. However, direct and indirect calorimeter experiments have definitively disproven any association of lactate metabolism as causal to an elevated oxygen uptake. In recovery, oxygen (EPOC) is used in the processes that restore the body to a resting state and adapt it to the exercise just performed. These include: hormone balancing, replenishment of fuel stores, cellular repair, innervation and anabolism. Post-exercise oxygen consumption replenishes the phosphagen system. New ATP is synthesized and some of this ATP donates phosphate groups to creatine until ATP and creatine levels are back to resting state levels again. Another use of EPOC is to fuel the body's increased metabolism from the increase in body temperature which occurs during exercise. EPOC is accompanied by an elevated consumption of fuel. In response to exercise, fat stores are broken down and free fatty acids (FFA) are released into the blood stream. In recovery, the direct oxidation of free fatty acids as fuel and the energy consuming re-conversion of FFAs back into fat stores both take place. The EPOC effect is greatest soon after the exercise is completed and decays to a lower level over time. One experiment found EPOC increasing metabolic rate to an excess level that decays to 13% three hours after exercise, and 4% after 16 hours.[citation needed] Another study, specifically designed to test whether the effect existed for more than 16 hours, conducted tests for 48 hours after the conclusion of the exercise and found measurable effects existed up to the 38-hour post-exercise measurement. Studies show that the EPOC effect exists after both aerobic exercise and anaerobic exercise. Such comparisons are problematic, however, in that it is difficult to equalize and subsequently compare workloads between the two types of exercise. For exercise regimens of comparable duration and intensity, aerobic exercise burns more calories during the exercise itself, but the difference is partly offset by the higher increase in caloric expenditure that occurs during the EPOC phase after anaerobic exercise. Anaerobic exercise in the form of high-intensity interval training was also found in one study to result in greater loss of subcutaneous fat, even though the subjects expended fewer than half as many calories during exercise. Whether this result was caused by the EPOC effect has not been established, and the caloric content of the participants' diet was not controlled during this particular study period. According to Dictionary.com, oxygen deficit is "the difference between oxygen intake of the body during early stages of exercise and during a similar duration in a steady state of exercise." It is sometimes considered as the formation of oxygen debt. "Oxygen deficit exists when a body's consumption of oxygen exceeds its intake." Oxygen deficit occurs naturally during strenuous exercise. When exercise triggers an oxygen deficit, the body will work to replenish oxygen levels during what is known as a recovery period. During this recovery period, oxygen consumption increases. For example, in a finite time frame of one hour, a person needs 1.5 liters of oxygen to perform a physical function and this person inhales 1.0 liters, then the oxygen deficit is 0.5 liters/hour. The accumulation of the deficit during the total exercise of four hours would be an oxygen debt of 2.0 liters (4 hours x 0.5 liters per hour). Can oxygen help with oxygen deficit and oxygen debt? Available in a handheld, portable oxygen can, Oxygen Plus is easy to slip into your gym bag for those hard-hitting workouts. The active ingredient in Oxygen Plus is pure recreational oxygen, which is more than four times the amount of oxygen found in ambient, everyday air. In its ability of provide an increased percentage of oxygen into the body, Oxygen Plus can help with both oxygen deficit and oxygen debt. Supplementing a workout with Oxygen Plus *decreases the oxygen deficit* (or improves the efficiency of dynamic oxygen deficit) during exercise. An improved efficiency of the oxygen deficit translates into *enhanced performance and endurance*. Additionally, an oxygen boost from Oxygen Plus can also help to provide a *more efficient recovery from oxygen debt*. That's why breathing "sport oxygen," such as Oxygen Plus, before, during and after a workout can help you go farther, perform better and feel more like you again. Pick up a 6-pack of the O+ Biggi today and take some hits as part of your workout routine to begin testing, and seeing, the results. During the first few minutes of cardiovascular exercise, the anaerobic energy systems (CP-ATP and glycolysis) supply the needed ATP for this work. The energy provided during this deficit phase of exercise is employed until a steady-state (or steady-rate) of oxygen consumption is utilized, thus indicating that mitochondrial respiration is the dominant energy system being utilized. However, it should be noted that energy for exercise is not merely the result of a series of energy systems "switching on" and "switching off," but rather the smooth blending and overlap of the body's three energy systems.



EPOC stands for the Excess Post exercise Oxygen Consumption. This is the recovery period after cardiovascular exercise where there is elevated oxygen consumption. It can be described as the amount of oxygen consumed during recovery in excess of that which would have ordinarily been consumed at rest. Some factors that contribute to EPOC include the replenishment of CP and ATP, the conversion of lactate to pyruvate, and the resynthesize of glycogen. In addition, during this recovery period the increased oxygen demand is needed to help the body in adjusting the increased body temperature, heart rate and ventilation to a resting level, as well as the reoxygenation of hemoglobin (in the blood). The body adapts to stress overload placed upon it by becoming more efficient. To stress the body to cause an increase in efficiency, the athlete needs to increase the lactate above that which he/she can tolerate. This is done in training by exercising at a high intensity for several short periods and recovering between hard bouts, allowing excess lactate to clear the muscle. The higher the intensity, the greater the lactate build-up. The less the rest between hard bouts, the higher the lactate build-up. A proper mix of hard efforts with short recovery, and some medium hard efforts with longer recovery, will raise both the lactate threshold and the VO2max. Also, endurance exercise is included to increase overall musculoskeletal health. Remember, while training the aerobic energy system the athlete will also be training the phosphagen and glycolytic system.

2.6.8Nutritional aspects of performance

Balanced load containing all the required nutrients is indispensable for recovery. Recovery in the first few hours after the activity is the fastest and if required nutrients like carbohydrates, sodium, potassium, and vitamins are given, particularly in liquid form, after a few minutes of activity, the recovery is accelerated. Balanced food, taken in five meals spread over the day, is considered ideal for good recovery. Fixed timings of meals and good eating habits are also helpful for faster recovery. Dietary supplements contain one or more dietary ingredients (including vitamins; minerals; amino acids; herbs or other botanicals; and other substances) or their constituents is intended to be taken by mouth as a pill, capsule, tablet, or liquid. Athletes may choose to consider taking dietary supplements to assist in improving their athletic performance There are many other supplements out there that include performance enhancing supplements (steroids, blood doping, creatine, human growth hormone), energy supplements (caffeine), and supplements that aid in recovery (protein, BCAAs). Athletes sometimes turn to energy supplements to increase their ability to exercise more often. Common supplements to increase an athlete's energy include: Caffeine, Guarana, Vitamin B12, and Asian ginseng. Guarana is another supplement that athletes take to enhance their athletic ability, it is frequently used for weight loss and as an energy supplement. Caffeine, a common energy supplement, can be found in many different forms such as pills, tablets or capsules, and can also be found in common foods, such as coffee and tea. A 2009 study from the University of Texas reports that caffeinated energy drinks decrease sporting performance. They found that after drinking an energy drink, 83% of participants improved their physical activity parameters by an average of 4.7%. This was attributed to the effects of caffeine, sucrose and Vitamin B in the drink - however scientific consensus does not support the efficacy of using Vitamin B as a performance enhancer. To explain the performance improvement the writers report an increase in blood levels of epinephrine, norepinephrine and beta-Endorphin. The adenosine receptor antagonism of caffeine accounts for the first two, while the latter is accounted for by the Neurobiological effects of physical exercise. Caffeine has been around since the 1900s and became popularly used in the 1970s when its power of masking fatigue became highly recognized. Similarly, the caffeine found in energy drinks and coffee shows an increased reaction performance and feelings of energy, focus and alertness in quickness and reaction anaerobic power tests. In other words, consuming an energy drink or any drink with caffeine increases short time/rapid exercise performance (like short full-speed sprints and heavy power weight lifting). Caffeine is chemically similar to adenosine, a type of sugar that helps in the regulation of important body processes, including the firing of neurotransmitters. Caffeine takes the place of adenosine in your brain, attaching itself to the same neural receptors affected by adenosine, and causing your neurons to fire more rapidly, hence caffeine's stimulating effects. Carbohydrates are also a very common form of energy supplements, as all sugars are carbohydrates. Products like Gatorade and Powerade are formulated with simple sugars such as sucrose and dextrose. Carbohydrates are necessary as they maintain blood glucose levels and restore muscle glycogen levels. Common supplements to help athletes recover from exercising include protein and amino acid supplements. The main use for athletes to take dietary proteins are for hormones, oxygen transport, cellular repair, enzymes and conversion to fuel. The intake of protein is a part of the nutrient requirements for the normal athlete and is an important component of exercise training. In addition, it aids in performance and recovery. Dietary protein intake for well-trained athletes should occur before, during and after physical activity as it is advantageous in gaining muscle mass and strength. However, if too much protein and amino acid supplements is consumed it can be more harmful to the body than it is beneficial; health risks include: dehydration, gout, calcium loss, liver, renal damage, diarrhea, bloating, and water loss. A bountiful protein diet must be paired with a healthy, well-rounded meal plan and regular resistance exercise. Characteristics of this particular diet include the type of exercise, intensity, duration and carbohydrate values of diet. The most effective way to secure the natural nutrients required by the body for optimum health and physiological performance is by consuming vitamins, minerals, proteins, fats, sugars and carbohydrates, which can be procured from fresh fruits and vegetables. Post-exercise nutrition is an important factor in a nutrition plan for athletes as it pertains to the recovery of the body. Traditionally, sports drinks such as Gatorade and Powerade, are consumed during and after exercise because they effectively rehydrate the body by refueling the body with minerals and electrolytes. Electrolytes regulate the body's nerve and muscle function, blood pH, blood pressure, and the rebuilding of damaged tissue. These types of drink are commonly made of glucose and sucrose in water and have been seen to improve the football players' performance. A substitute for sports drinks is milk, which contains many electrolytes, nutrients and other elements that help to make it an effective post-exercise beverage. It is true that milk helps replace fluids and electrolytes lost after the athlete has worked out. A recovery drink is supposed to replenish the sugar lost, and help recover the muscles to be able to workout at full intensity by the next time they workout. When compared to plain water or sports drinks, research supported by the Dairy and Nutrition Council suggests that chocolate milk is more effective at replacing fluids lost through sweat and maintaining normal body fluid levels. Athletes drinking chocolate milk following exercise-induced dehydration had fluid levels about 2 percent higher (on initial body mass) than those using other post-exercise recovery beverages. These results allowed for prolonged performance, especially in repeated bouts of exercise or training. In the extreme case of performance-enhancing supplements, athletes, particularly bodybuilders may choose to use illegal substances such as anabolic steroids. These compounds which are related to the hormone testosterone, can quickly build mass and strength, but have many adverse effects such as high blood pressure and negative gender specific effects. Blood doping, another illegal ergogenic, was discovered in the 1940s when it was used by World War II pilots. Blood doping also known as blood transfusions, increases oxygen delivery to exercising tissues and has been demonstrated to improve performance in endurance sports, such as long-distance cycling. The supplement, Creatine, may be helpful for well-trained athletes to increase exercise performance and strength in relation with their dietary regimen. The substance glutamine, found in whey fiber supplements, is the most abundant free amino acid found in the human body. It is considered that glutamine may have a possible role in stimulated anabolic processes such as muscle glycogen and protein synthesis, for well-trained and well-nourished athletes. Other popular studies done on supplements include androstenedione, chromium, and ephedra. The findings show that there are no substantial benefits from the extra intake of these supplements, yet higher health risks and costs.

Sub Unit – VII
Environmental influence on human physiology under exercise

2.7.1 Definition of Environment

The sum total of all surroundings of a living organism, including natural forces and other living things, which provide conditions for development and growth as well as of danger and damage is called environment. On the other hand, **environment** is a place where different things are such as a swampy or hot environment. It can be living (biotic) or non-living (abiotic) things. It includes physical, chemical and other natural forces. Living things live in their environment. They constantly interact with it and adapt themselves to conditions in their environment. In the environment there are different interactions between animals, plants, soil, water, and other living and non-living things.

2.7.2 Environmental influence on human physiology under exercise

Climate change, and related issues like pollution, water shortages and ecosystem disruption, are among the most pressing political and sociological (and, of course, environmental) issues of the contemporary moment, and will be for the foreseeable future. Consider, for example, that according to a 2014 report from the World Health Organization, "climate change is expected to cause approximately 250 000 additional deaths per year between 2030 and 2050; 38 000 due to heat exposure in elderly people, 48 000 due to diarrhea, 60 000 due to malaria, and 95 000 due to childhood under nutrition" (WHO Factsheet, no date; see WHO, 2014). Rising water levels from melting glaciers, natural disasters associated with a higher number of extreme storms, and food shortages due to variable rain and rising temperatures are some of the problems that climate scientists expect to account for these deaths – with a projected rise of 2°C in global temperature being the tipping point for many of these trends (Romm, 2016). Although questions remain about the extent to which and precise nature in which problems of this kind will manifest, few credible scientists deny the dangerous effects of carbon emissions associated with human activity, or that we should respond with urgency. At the same time, there is also widespread agreement that there is still time to reduce global warming trends such that many devastating and irreversible impacts might be avoided – if (and only if) strong measures are taken to reduce carbon-emitting activity (Romm, 2016). Attempts to respond to this incentive have been at the core of recent meetings and agreements among the world's governments, and form the basis of several of the United Nations' Sustainable Development Goals, as outlined in the UN document Transforming our World: The 2030 Agenda for Sustainable Development (United Nations, 2015). Still, and even with these important attempts to counter environment-related risks, many who study environmental issues from a range of fields agree that better strategies for addressing these issues – and much more accountability from stakeholders – are needed (Ferre, 2017). There are of course no easy solutions to the problems at hand, but, as many environmental sociologists and others suggest, if we put as much time into thinking about alternative solutions as we do into executing the solutions that are commonly privileged at present – neoliberal solutions that many see as being more 'business-friendly' than environment-friendly – new possibilities for creating change would undoubtedly emerge through these acts of agency (Rice, 2016). In this chapter, we consider what environmental issues – and responses to these issues – have to do with sport and physical culture. We focus especially on how these issues have been addressed in the field of environmental sociology, and by sociologists of sport. Our hope is to provoke thinking and discussion about status quo responses to sport-related environmental issues, and to consider what it would mean to respond to environmental concerns in new and alternative ways. We begin our analysis by outlining the range of concerns that have been raised about sport's relationship with the environment in Canada and beyond. Specifically, we will consider, on the one hand, how sport has been (and could be) impacted by climate change and related concerns noted above. On the other hand, we will look at how sport itself (e.g., hosting sport events; stadium and arena construction for professional sports franchises; plane travel; golf course development) is thought to be environmentally impactful. In this latter task, we will also describe some of the ways that sport managers and mega-event organizers have responded to environment-related issues. We then consider some of the assumptions, strengths, and weaknesses underlying two of the main approaches to dealing with environmental issues, 'sustainability' and 'ecological modernization' (or 'EM'). From there, we delve into a discussion of environmental politics as they relate to sport and to critical theory. Here, we will consider how sociological questions around power and power relations are relevant to thinking about why sustainability and EM are, in fact, the main approaches to sport-related environmental problems. At this time, we also describe forms of resistance to and alternatives to the usual strategies for addressing environmental issues related to sport. We also consider how a sociological imagination might help us develop more inclusive plans for addressing these issues. We conclude by focusing on ways that further progress might be made on sport-related environmental issues, and the kinds of questions that sociologists of sport are especially well positioned to ask about these issues. there are two main ways to think about sport's relationship with the environment. The first relates to how environmental changes impact sport and the second relates to how sport itself can be environmentally impactful. In both cases, the overriding problem is that the earth is currently being treated in an unsustainable way – something that can be construed as a matter of (in) equity. First, environmental issues are relevant to ethical questions of intergenerational inequity – meaning that future generations will be negatively impacted by the environment related activities of current generations. For example, the problems noted in the introduction to this chapter are ones that will be felt most by those living in the middle and latter part of this century. The generations we are referring to here will, of course, have had no input into the decisions that were made in the past that have contributed to global warming and other environmental and structural issues; nor will they necessarily have had input into the types of political solutions that are currently being proposed to address these problems. There is the also the matter of trans frontier inequity, meaning that environment related activities taking place in one part of the world often have negative impacts on those living elsewhere. We can think in this case about how those living in certain regions of the world are more at risk for losing land that can be used for growing food, as unfertile desert areas become more expansive over time due to global warming (Romm, 2016). Others will be more at risk for losing coastal areas to rising sea levels. In each of these cases, the problems will emerge partly because of the carbon-emitting activities of many people who do not live in the most-effected areas. Intra-generational inequity is a consideration too, meaning that the negative impacts of (for example) climate change can be unevenly distributed across populations (e.g., wealthier and more mobile people may be better able to cope with weather extremes and some of the other issues noted above). In this sense, environment-based inequity is tied together with other inequities (e.g., those related to social class differences). There is the matter of interspecies inequity too – since the environmental impacts of the activities of humans also have implications for plants and non-human animals as well. In all, the issue is not that sport alone is a driving force for these problems; rather, the fate of sport and the fate of the environment are in many ways intertwined. It is also notable here how the historical and comparative aspects of Mills's sociological imagination are pertinent here, helping us 'see' the variable and inequitable impacts of environmental problems. The cover story of a March 2007 issue of Sports Illustrated, entitled "Sports and Global Warming: As the World Changes, So Do the Games We Play," included a stark image of the Florida Marlins Major League Baseball pitcher Dontrelle Willis standing knee-deep in water in a flooded Dolphin Stadium in Miami (since renamed Hard Rock Stadium). While the image was of course manipulated to depict the stadium deluge, the point of both the image and the story was to highlight how environmental issues such as rising water levels due to climate change may inhibit and/or negatively alter sport in the future. With respect to sport stadiums and rising water levels, the story notes the likelihood that 13 major stadiums in the United States (not to mention stadiums and other sport venues in other parts of the world) will be under water by the year 2100. The story highlights other environmental impacts too, such as shortened ski seasons due to global warming and the expansion of the ash borer beetle's habitat (which could threaten baseball bat production – Wolff, 2007; also see Perkins, Mincyte, & Cole, 2010). These are potential futures, but sport is dealing with more immediate concerns as well, especially in the context of sport mega-events such as the Olympic Games. Particularly notable in this context are the effects of polluted air and water on competing athletes. There were, for example, significant concerns about the health of athletes in the build-up to the Rio 2016 Olympics, especially for those taking part in the sailing competition in Guanabara Bay and in the rowing, canoeing, and kayaking events in Lagoa Rodrigo de Freitas – both highly polluted bodies of water. Sport scholars Jules Boykoff and Gilmar Mascaren has (2016) offer a poignant description of the issues at hand: Approximately a year before the Olympics were to commence, Associated Press published a blockbuster investigative report revealing every single Olympic water venue [for the Rio Games] to be unsafe. The waterways gurgled with human sewage that conveyed "dangerously high levels of viruses and bacteria." This was not only a health threat for Olympic athletes, but for everyday Rio residents. Whoever swam in the water was at risk to "explosive diarrhea, violent vomiting, respiratory trouble and other illnesses." Ingesting only three teaspoons of the polluted water afforded a 99 percent chance of infection by virus (though that did not mean that individual would automatically fall ill). Even contracting Hepatitis, A was possible (Boykoff & Mascarenhas, 2016, p. 6, drawing on a report by Brooks and Barchfield, 2015). Similar concerns arose prior to the Beijing 2008 Olympics, compelling Chinese officials to devise an emergency plan to temporarily address the problem of air pollution in the lead up to the Games. The plan included shutting down factories in and around Beijing and restricting car usage. Other longer-term measures adopted by the 2008 Games' organizing committee included, "replacing coal with natural gas; closing cement, lime, and brick plants; implementing vehicle emission standards; reforestation; sweeping and sprinkling roads; and, moving factories away from the city" (McLeod et al., 2018, p. 29). Although there was some evidence that these actions at least partially mitigated some negative aspects of the pollution in Beijing (in the short term at least), some athletes were still affected. The renowned Ethiopian distance runner Haile Gebrselassie, an asthmatic, reportedly pulled out of the marathon due to fear for his health, while the US triathlete Jarrod Shoemaker trained using a pollution-mitigating mask in preparation for the Games – a dystopic image if there ever was. The underlying problem was that Beijing and surrounding areas of nor the as tern China had “the world's worst nitrogen dioxide levels, according to satellite images taken by the European Space Agency in 2005” – and that high levels of nitrogen dioxide “can cause eye, nose, and throat irritation, and may cause impaired lung function and increased respiratory infections” (as reported in Vause, 2008). Of course, the issues raised here pertain to many cities around the world, and to non-elite athletes who enjoy exercising outdoors as much as elite athletes involved in major competitions. For example, in recent summers, the City of Vancouver has been put on high alert as smoke from forest fires across the province drifted into the lower mainland of the city. University of British Columbia physiologist Michael Koehle has commented in local and national media on whether it is safe to exercise outdoors in such conditions (e.g., Hutchison, 2017), basing his opinion on studies to which he has contributed on exposure to pollution and exercise performance (e.g., Giles and Koehle, 2014). This research raises significant questions about the day-to-day impacts of cycling or running, for example, in higher pollution areas in cities like Vancouver – findings suggest that exercisers should be especially wary of where they are exercising (with some parts of cities being more polluted than others), and the time of day they choose to be active. Indeed, in the summer of 2018, as forest fires burned across the Province of British Columbia, two triathlons were cancelled by officials in Penticton and in Kelowna as a result of poor air quality, while residents as far away as Edmonton were cautioned to avoid exercising outdoors over this time. Other scholars, like University of Waterloo geographer Dan Scott and his colleagues (Scott et al., 2018), focus more on the viability of particular sports at the Winter Olympics in the future, with sports like skiing especially being threatened by global warming (e.g., due to decreases in snow levels). In all, the manner in which environmental changes impact on sport and physical culture is an increasingly salient concern, especially for those tasked with managing sport now and into the future. That said, sociologists of sport tend to focus more on ways that playing sports and/or hosting sport events have environmental impacts. Concerns about the environmental impacts of hosting sport mega-events like the Olympic and Paralympic Games have understandably received the most attention in this area of study and practice, as the impacts are so widespread and complex. To assess the impacts of such events requires attending to: the impacts of all the sports involved (e.g., the impacts of all skiing events on mountain areas, paddling events on water areas, and the range of impacts of developing/maintaining a golf course); the additional impacts of building new facilities, long distance transportation by athletes and spectators, and in some cases alterations to and destruction of sensitive ecosystems; and the complex and massive impacts of various forms of spectator consumption (e.g., food waste) (see Dolf, 2017). Assessing all of these elements independently or in combination is a tall order. It is also controversial, especially if we consider what is at stake with such an evaluation for event organizers and other stakeholders (VanWynsberghe, 2015). One point is not debatable though: the Olympic and Paralympic Games have immense environmental impacts. For this reason, the leading players and beneficiaries in the mega-event industry have been critiqued over the years for both their environmental impacts and their environmental management strategies – though in some cases they have earned praise as well. On the negative side, the IOC and local organizing committees have been disparaged by activists and critics when publicly funded ‘white elephant’ facilities – e.g., bobsleigh and luge run – are built with enormous environmental costs, only to be left largely unused after events are done. A recent article in Business Insider, entitled, “What abandoned Olympic venues from around the world look like today" (Davis, 2018) is laden with bleak images of abandoned venues in former host cities (focusing on Rio, Beijing, Athens and Sarajevo, in particular). Similar concerns about the destruction of sensitive ecosystems were highlighted around the recent 2018 Pyeoung Chang Winter Games (e.g., the razing of an ancient forest to build a ski venue – see Yoon, 2017) and around the 2014 Sochi Games, which took place inside the Sochi National Park – "a region that contains the greatest species diversity of anywhere in Russia and is encompassed by a UNESCO World Heritage area" (Chestin, 2014). These concerns, though, rarely triumph over the economic interests associated with holding mega-events like the Olympic Games and their associated development opportunities. A broader question was underlined by Igor Chestin, Director of the Russian World Wildlife Fund, who noted that, "the most symbolic failure of the 2014 Winter Olympics came before even a brick was laid, when the government decided to host the games inside the Sochi National Park" in the first place. Chestin's point foreshadows upcoming sections in this chapter, where we speak to the role of politics in environmental decision-making and the ability of certain groups to exercise moral and intellectual leadership (i.e., hegemony) in these debates. That said, on the positive side of things, there are many examples of how the Olympic movement has led to different forms of environmental progress. In 1994, the IOC declared 'the environment' the third pillar of the Olympic movement. Since then, organizing committees have sought not only to mitigate environmental impacts, but to highlight and advertise their pro-environment legacies (Cantelon and Letters, 2000; Chappelet, 2008). Indeed, according to the IOC's rules, bid cities are required to do as much, and are investing significant resources in doing so. Although there is much that one can learn about the impacts of sport on the environment by looking at sport mega-events, there is a range of more sport-specific environmental impacts – also positive and negative – that have attracted attention over time: the alteration or reduction of wetland areas due to modifications of rivers and lakes for water sports like paddling and canoeing; the destruction of natural vegetation and soil erosion due to alpine skiing; the impacts of golf course construction on natural habitats and risks to the health of wildlife and humans from chemicals commonly used to maintain golf courses; the impacts of spectator sports generally (e.g., carbon emissions associated with arenas with ice rinks and spectator attendance at hockey and skating events). the waste produced in the making of (and failure to recycle) sports apparel/equipment. Moreover, and just as the IOC and organizing committees have responded to concerns about the environmental impacts of the Olympics with pro-environment public relations campaigns and activities, so have others in the sports industry done much the same.

So, what is sustainability, and what does it have to do with sport organizations and their responses to environmental issues? The term sustainable, or sustainability, was developed as a response to the view that modern life had become unsustainable from an environmental perspective. Specifically, sustainability was devised as an integrated strategy for addressing economic, social, and environmental issues – what is commonly known as the 'triple bottom line' (Chernushenko et al. 2001, p. 10). The classic definition of sustainability, offered in the 1986 report Our Common Future (produced for the World Commission on Environment and Development), refers to a society's capacity to '[meet the] needs of the present without compromising the ability of future generations to meet their own needs'.

Corporate environmentalist: Industry-led techniques and strategies for dealing with environmental issues.

Ecological modernization: A theoretical approach to understanding the relationship between humans and environmental issues that is focused on ways that humans can continue to 'progress' (e.g., economically) without long-term negative impacts on the environment because humans will also progress in their development of 'green' or 'super industrial' technologies that will minimize or eliminate these impacts.

Greenwashing: The term used to describe disingenuous attempts to promote pro-environment work and attitudes – disingenuous in that the practices in question are not actually eco-friendly, or in that they arguably serve to mask practices that are damaging to the environment. It also refers to situations where the eco-friendliness of pro-environment work is overstated, such that 'appearing green' is prioritized over 'being green'.

Intergenerational inequity: Referring here to ways that future generations may be negatively impacted by the environment-related activities of current generations – and recognizing that future generations have no 'say' about the decisions that may impact them.

Interspecies inequity: Referring to the ways that the activities of humans also have implications for plants and (non-human) animals – and that humans may disregard or deemphasize these implications.

Intra-generational inequity: Referring here to the need to account for existing social inequalities of all kinds (e.g., around class, gender, ethnicity and 'race') when devising sustainability projects and considering the impacts of environmentally-damaging behaviors.

Precautionary approach (or 'precautionary principle'): Refers to the view that in the face of uncertainty (e.g., about human impacts of global warming, or the effects of chemical use on human health) the default response should be to act preventively and shift the burden of proof for doing an activity to the proponents of an activity.

Sustainability: Refers here to an integrated strategy for addressing economic, social, and environmental issues – what is commonly known as the 'triple bottom line.' The classic definition for sustainability, offered in the 1986 report Our Common Future (produced for the World Commission on Environment and Development), refers to our society's capacity to '[meet the needs] needs of the present without compromising ability of future generations to meet their own needs' (see Brundtland, 1987).

Trans frontier inequity – Referring to ways that environment-related activities taking place in 'local' contexts may have a negative impact on those living in other places.

2.7.2.1 Effect of Hot and Humid condition on sports:

Games in Manaus, Brazil, a city along the famous Amazon River, have been played in temperatures in the high 80's and humidity levels approaching 70%. This makes for very difficult playing conditions, and TV images of highly conditioned athletes cramping late in a game have been plentiful.

Even NBA basketball fans have seen the effects of high heat and humidity. During the NBA Finals in San Antonio the arena's air conditioning went out and temperatures neared 90 degrees. By the fourth quarter, at a very critical point of the game, Miami Heat star LeBron James was forced to the sidelines by debilitating cramps.

High heat and humidity lead to two problems in the exercising body: 1) increased core body temperature and 2) dehydration. Increased body temperature (hyperthermia) leads to decreased muscle endurance, which means the muscle's ability to contract repeatedly or in a sustained manner over long periods of time. High core temps also cause a shift in energy production from aerobic to anaerobic mechanisms, which means the body has to use up its muscle energy stores more rapidly. Unfortunately, during a longer athletic event, the rate of adding energy (sports drinks, energy bars, gels, etc.) can't keep up with the rate of losing energy when heat and humidity are high. Finally, high body temperature causes a decrease in blood flow to the heart as blood pools in the limbs. If the heart doesn't get as much blood, it can't pump as much oxygenated blood back to the muscles.

Dehydration often occurs long before some athletes realize it or before cramps set in. Athletes can lose as much as 2 to 8 % of their body weight during high intensity exercise, and the rate of fluid absorption from the gut just can't keep up with that rate of loss. Dehydration causes a decrease in VO2max, which means the body can't utilize oxygen as efficiently to provide energy. Dehydration also contributes to the decrease of heart blood pumping mentioned above.

So what can be done to combat or prevent the effects of high heat and humidity?

If you paid attention to news reports building up to the start of the World Cup, you heard about teams from all over the world flying to places with higher heat and humidity to train. Several teams trained in Miami, some in Latin America, and a few went right to Brazil. Acclimatization to higher temps and humidity can occur fairly quickly, as quickly as 7-10 days.

Prevention for heat/humidity effects is conditioning. Better-conditioned athletes suffer less performance loss in high heat and humidity because they have a higher blood volume, better VO2max, sweat rate and more efficient use/replacement of energy stores. World Cup athletes have been training for several months (in addition to playing in their normal club/team roles) in preparation for this major event.

Fluid replacement is critical for events in high heat and humidity. Fluid replacement starts before an event, continues during it, and doesn't stop until long afterwards. Drinking to thirst and keeping urine clear (not dark yellow) are good measures. Wearing light-weight, light-colored clothes of open-weave natural fibers (cotton, wool) or fluid-wicking fibers help increase evaporation and cool the body.

Even here in Utah where the humidity is low, we're susceptible to heat-related performance drop or even heat illness if we're not careful. Be smart and enjoy the sun. Then, after a great, hot workout, find a cool drink and a TV positioned right below a soothing fan to enjoy some incredible World Cup matches!

2.7.2.2 Effect of High Altitude on sports:

Athletes will typically experience two different types of effects upon their ability to perform at high-altitude venues. The first is physiological, determined by the body's reaction to a thin, less-oxygenated atmosphere. The second effect is impacts that are sport-specific but equally pronounced: how the physical components of a particular sport are altered in high altitude performance.

High altitude is the description given any locale where the athlete begins to experience the limitations that a reduced oxygen intake place upon the body. Scientists generally classify elevations of 6,500 ft (2,000 m) as high altitude because of the pronounced difference in oxygen content; the effect of altitude may be experienced at lower elevations. The human body has a built-in mechanism to counter the effects of low oxygen in the immediate atmosphere. When the body senses that it is not receiving its accustomed level of oxygen, it determines that it must produce a greater number of erythrocytes (red blood cells), which carry oxygen to the bloodstream. The increase of transportation capability means that the body will be optimizing the amount of available oxygen. The process by which erythrocytes are increased commences with the release of a hormone in the kidneys known as erythropoietin (EPO), which acts as a trigger to the production of erythrocytes centered in the bone marrow of the long bones of the body, primarily the femur (thigh). The acclimatization of the body to an oxygen-reduced environment is not instantaneous; high altitude adaptations begin immediately. An athlete will be as much as 75% accustomed to the thin air within 7-10 days of exposure to the conditions, with full acclimatization within 15-20 days. High altitude training is a proven effective performance-enhancing tool, as the ability of an athlete to utilize greater amounts of oxygen will naturally support improved capabilities. The physiological benefits of high altitude training continue for between one to three months after the return of the athlete to sea-level training conditions.

The physics of high-altitude sports performance and the advantages derived by the competitors in such venues are as varied as they are emphatic. The 1968 Olympics held in Mexico City were the first games staged at a high altitude (7,349 ft [2,300 m]), and the number of world records set was indicative of the impact of the thinner air on performance. American Bob Beamon set a long jump event record of 29 ft 2 in (9.3 m), which shattered the then-existing standard by over 2 ft (.6 m), in a discipline where records are almost always broken in increments of fractions of an inch. Lee Evans of the United States set a world record of 43.86 seconds in the 400-m race, a mark that stood for almost 20 years. Records fell in almost every track event from the 100-m to the 1,500-m; the longer distances posed difficulties for the athletes that were not entirely accustomed to the high-altitude effects. Intense research conducted in the wake of the world record onslaught at Mexico City confirmed that the reduced wind resistance and drag upon the competitors' bodies in the thin air permitted the athletes to move with greater efficiency. So long as the event did not involve prolonged duress to the aerobic energy system and its dependency upon maximal amounts of oxygen, an athlete could expect better performances in higher altitude. Not only does the moving body encounter reduced air resistance, any objects thrown, such as a discus or javelin, would tend to travel further as well. The effects of high altitude are well known in different professional team sports. The visiting soccer team to venues such as Mexico City and La Paz, Bolivia (where the stadium attitude of over 11,000 ft [3,400 m], is the highest in international soccer), will likely not be able to perform at a maximum level unless it has trained at altitude. To a lesser but measurable degree, Denver, Colorado's Mile High Stadium, situated at 5,500 ft above sea level (1,700 m), has been regarded as a difficult competitive environment for visiting American football teams since it was opened.

Altitude is a significant performance factor in the game of baseball, especially with respect to how far a batted ball will carry in the thinner air. The professional baseball stadium in Denver is known as a hitter's park for this reason, as are a number of National Collegiate Athletic Association (NCAA) venues in the western United States that are constructed at elevations greater than 5,000 ft (1,550 m). Research conducted at various times has concluded that a baseball will travel between 3% and 7% further in air at these altitudes than a similarly struck ball at sea level, assuming that the temperature is constant. An object will travel further in warmer, less dense air than it will in cold air.

Altitude training has emerged as a way to gain a tactical advantage over the competitor. It entails breathing in a reduced percentage of oxygen (hypoxia), either natural or simulated, with a goal of improved athletic performance. The optimal altitude for this type of training is unknown; however, most research studies have been conducted at moderate altitudes (2000-3000 m). At these elevations, a reliable erythropoietin response has been observed with minimal side effects. There are 3 basic models for altitude training: live high, train high (LHTH); live low, train high (LLTH); and live high, train low (LHTL). In locations where training at altitude is not always geographically possible, simulated altitudes are often employed. Altitude training can be simulated (normorbaric hypoxia) through an altitude simulation room, tent, or hypobaric chamber.

2.7.2.3 Effect of Cold on sports:

As temperatures fall, so blood pressure increases as blood is taken away from the skin surface increasing the amount in the core. This puts extra strain on the heart. Think of it as the same volume of fluid flowing through reduced pipe work. As the body loses more heat, it has to work harder to maintain a stable temperature by generating more heat. The most easily and quickly metabolized fuel, glucose, is used for heat generation first, before use for muscular contraction. Colder muscles are less efficient muscles -It's a simple case of the effect of temperature on chemical reactions. When it is cooler, reactions take place more slowly, the rule of thumb is that reaction rates slow to a half of what they were for each 10C (18F) fall. Muscular contraction is a series of chemical reactions. When we think of our "normal body temperature" this actually means the core temperature, brain, heart and major organs, this is what we keep constant. The rest of the body works on a "nice if we can" basis. Ideally the whole body is kept close to the core temperature but as the temperature falls it becomes increasingly difficult to do this for all parts and so those parts furthest from the core cool down most as they are losing the most of the valuable heat. Arm and leg muscles in particular are affected by falling temperatures.

Too much fast twitch activity and not enough slow twitch leads to extra lactate production**.** Muscles have a mix of fast-twitch and slow-twitch fibers, in normal aerobic exercise the slow fibers which have much greater stamina do most or all of the work. For short bursts of energy, the fast fibers get brought in for extra speed and/or power. When muscles operate less efficiently due to colder temperatures it's a case of "all hands-on deck" for the muscle fibres. Fast twitch muscle fibers that wouldn't be needed much of the time at higher temperatures have to help out to generate the required power at lower temperatures. Fast twitch fibers produce lactic acid that the slower ones wouldn't if they were working more efficiently. Lactic acid means an increased metabolic load on the body which means less efficiency and getting into oxygen debt which has to be paid at some point, either by stopping or reducing output. **Colder muscles mean less efficient, weaker muscles with less stamina.**

Increased danger of pulling muscles - Warming up before exercise is important to prevent pulling muscles, low temperatures mean that muscles cool down faster and take longer to warm in the first place.

Slowed reaction times due to cold nerves - Nervous impulses in a similar manner to muscle contraction are the result of a string of complex chemical reactions. As the temperature falls those chemical reactions take place more slowly and so responses are slower.

Glucose is used up more quickly, so stamina decreases - glucose is the body's preferred fuel, readily and quickly metabolized and mobilized from stored glycogen in the liver and muscles. As energy consumption increases in cold conditions, so these energy stores are used up more quickly. Fat and protein oxidation for energy are not increased in the same manner, taking longer to be mobilized. The net result is that immediately available energy stores are depleted more quickly in cold conditions so decreasing stamina.

Hydration - When it's warm and you sweat, it makes you feel thirsty as a reminder to replace the lost fluid. In the cold, this mechanism doesn't work so well and counter-intuitively it can be more likely to become dehydrated when exercising in cold than hot conditions. It doesn't help that cold drinks in cold conditions aren't that tempting, especially when compared to a refreshing cold drink in the heat.

There is usually significantly less water loss from sweating in the cold. **Water loss from breathing is significantly increased.** Warm air holds much more water vapor than cold air, so when warm air is breathed in it has a lot of moisture already. When you breathe in cold air, it has less moisture of its own on the way in, even if external conditions are quite damp. It's nice and warm inside your body and so the air gets warmed up and topped up with moisture from your respiratory system. The net result is a much less obvious loss of water and less immediate desire to drink to top up. You should be aware of this and make sure you hydrate during exercise in the cold as you would when it is warm.

Exercising in very cold conditions especially below freezing point can pose problems with cold related injuries such as frost nip, frost bite and hypothermia. Most of the time when active, you will be generating sufficient heat to avoid these things, though trial and hopefully not too much error is the way to go by not getting too far away from home to start with before you have your clothing sorted.

Hypothermia can easily happen above freezing point, it occurs when the core body temperature falls below normal, mild hypothermia is easy to develop, especially when cold is combined with wet conditions.

Hypothermia - A serious situation where the temperature of the body core falls from 37C, down to 35C or less, only a small drop. Initially you will be aware of this with plenty of warning from shivering, numb extremities, reduced dexterity and feeling miserably cold. The remedy is of course to warm up, put more clothes on or go indoors. More on hypothermia.

Frost nip and frost bite - These descriptive conditions can physically damage bits of your body. They both occur when blood flow slows to an extremity to prevent heat loss. That part is beginning to be sacrificed for the greater good of the whole, you need to do something about it asap!

Frost nip can be identified by the skin turning a very un-natural pale color as there is little or no blood passing through it, it is quite a clear change in skin color from normal. The nose, ears, cheeks, fingers and toes are first affected. It is not so easy to notice in yourself, it should be watched for it in companions, all should all be made aware of what it is and know to look out for it. If you spot frost nip, then the affected area should be warmed up with a gently placed glove or similar - **don't rub!**. The best treatment is getting indoors to a warm place. If spotted quickly frost nip can be dealt with easily, the effects are readily reversible and not permanent. If not dealt with it may lead to:

Frost bite - more seriously, ice crystals can form inside body cells killing them in the process, in a similar manner to burns. Superficial frostbite is recoverable though can be intensely painful as the nerve endings are still intact and registering the damage. Deep frostbite can lead to tissue loss of fingers, toes and even parts of limbs.

Wind chill - A breeze on a warm day is welcome and will make little difference to comfort when outdoors. At colder temperatures the effect is disproportionate and becomes greater the colder it gets. If it is calm when you first go out, don't assume that it will remain calm and be aware that a small increase in the wind will have a large effect on its ability to cool you down. One of the most obvious weather impacts on winter athletes is tightness. Winter athletes must take extra precaution while warming up to make sure they do not incur any muscle damage. While even a brief warm up of fewer than 10 minutes has been shown to improve performance and reduce the risk of injury, a more comprehensive warm up ensures safety. For example, athletes should start out with some light activities before stretching. That's because stretching a cold muscle can result in pulling or straining it. Aerobic light warm-ups are key for waking up necessary muscles, ligaments, and tendons.

How do Olympic winter athletes warm up properly? It's all about continuous movement while they're on the slopes. Elena High, Snowboarding Half pipe competitor from the U.S., admits that shrugging her shoulders throughout the day helps bring blood flow to her fingers and keeps her arms warm. Continuing to stay warm after you warm up is key – no matter how silly you look while doing it.

This isn't a well-known fact among cold weather athletes and spectators, but it's true. Yes, cold weather can trigger asthma. Exercise-induced asthma is extremely common among people who work out in cold climates. It doesn't matter if you're jogging or if you're an Olympic cross-country skier – Winter sport induced asthma is extremely common.

While any exercise outdoors in any climate can pose an asthma risk to even the most seasoned athletes, it's the cold, dry area that increases the risk during the winter months. For many people with regular asthma, just stepping outside in frigid temperatures is enough to cause coughing, wheezing, and chest tightness.

Luckily, there are ways for winter athletes to fight this issue. Rescue inhalers that deliver bronchodilators, like albuterol, fight symptoms by relaxing the muscles that line the airways in the lungs. Athletes can also take precautions like warming up properly and remembering to breathe through the nose. Wearing the right equipment, like a scarf around your mouth, can help prevent symptoms too.

Did you know that the human body is more prone to dehydration in the winter? We know, it doesn't seem to make sense. Let us explain.

Think about this: Are you thirsty in the cold? The answer is probably not. This is because the cold diminishes the body's thirst response thanks to our blood vessels constricting when we're cold. This allows the body to maintain warmth in its center and cut off flow to the extremities (hence the need for shoulder shrugging from Impact #1).

Basically, our bodies fool us into thinking we're properly hydrated. We feel hydrated but we're not. Athletes drinking less water, coupled with the fact our bodies aren't conserving water, inevitably leads to a lot of dehydrated winter athletes.

Athletes are safest when they wear extra clothing, drink more water, and limit the amount of fluid lost. Portable packs with water reserves in them are essential for skiers, snowboarders, and other winter athletes who may not realize just how dehydrated they really are.

Not all of the impacts on our list are bad! Believe it or not, cold weather increases the ability to focus. This is because cooling down the body in a hot environment without external help is harder to accomplish than warming it up in a cold environment.

If you've ever played or coached a sport, you know just how important focus is during the game. Although they're freezing, winter athletes definitely have the upper hand when it comes to focus – as long as they're not focusing on how they can't feel their feet anymore!

The homeothermic animal exposed to cold is faced with the problem of a rapid loss of heat and a consequent lowering of body temperature. However, such exposure brings into play a variety of regulatory mechanisms which contribute to the maintenance of a normal body temperature. The human's first response is to decrease heat loss by peripheral vasoconstriction. This is under the influence of the sympathetic nervous system through stimulation of peripheral thermoreceptors. Peripheral vasoconstriction occurs in mosi 1I areas of the body with the exception of the head where up to 255 of the total heat losses can take place. At the same time, the splanohnio vessels vasodilate to allow the shunting of blood to the core thereby increasing tissue insulation. If the environmental temperature continues to decline, heat production mechanisms are initiated. Shivering begins from stimulation of peripheral, as well as, central thermoreceptors and is under control of the central nervous system (CNS). This process involves the normal mechanisms of muscular contraction and the effect of raising heat production is much like that of light exercise. Shivering is an active process and may be considered an exercise response without definite work output. Heat production can be increased 3 to 4 times above resting in ths temperature range 0-10 0C (32- 50°F). The increased heat production and oxygen uptake due to shivering would appear to be the result of an increased heart rate and cardiac output as occur during mild exercise. However, Raven, et. al. (18) showed (in man at rest exposed to 50 C(41 0 F) for 2 hours) that an increased cardiac output (heart rate x stroke volume) was primarily due to an increased stroke volume while heart rate remained constant and low. The heart rate response to shivering, therefore, is in striking contrast to the mechanism by which the heart responds to exercise where an increased cardiac output up to an oxygen uptake of 1-2 L/min is primarily due to an increased heart rate. Higher circulating catecholamine levels may be partly responsible for the increased stroke volume. In addition, peripheral vasoconstriction (powerful enough to cause a shift of blood into the central circulation and increase the mean blood pressure) may also be a key factor. Thus, pressure mechanisms working through the baron receptors to reflex depress heart rate may explain why heart rate fails to respond to the increased circulatory demands of cold exposure. The Effect of Cold on Human Performance SUBMAXIMAL EXERCISE RESPONSES The stimuli of cold and exercise result in opposite, conflicting physiological responses (unlike that during heat exposure) and which one predominates depends upon such factors as environmental temperature, intensity of exercise, clothing insulation, and tissue insulation. In general, the oxygen cost of exercise in cold is commonly increased when compared with the cost of performing the same exercise intensity at normal environmental temperatures. From the data of Stromme, et.al. (20) where resting oxygen uptake is 50% higher in a 5 C(141 F) environment, one can see that at low exercise intensities oxygen uptake Is higher than In a neutral environment; shivering and exercise have an additive effect on oxygen uptake. At higher exercise intensities (oxygen uptake of 1.2-1.5 L/uin) there is no difference between the two environments. Thus, a critical level of heat production is required before the influence of cold-induced shivering is counteracted. Heart rate is also lower during light exercise in the cold when compared to a neutral environment due to the continued predominance of the cold stimulus over that of exercise. With increased exercise intensity, and thus decreased cold dominance, the heart rate comes under more normal cardiovascular control. The competing stimuli of cold and exercise also affect the core and skin temperature responses. At low exercise Intensities, the core temperature cannot be maintained in the cold and will fall after about one hour of exercise. At higher intensities, rectal temperature begins to increase. This again leads to conflicting stimuli, which result in reduced shivering and sympathetic vasoconstrictor activity. The increased core temperature stimulates central thermo-receptors for heat loss. However, cold receptors in the skin are simultaneously signaling the thermoregulatory center to conserve heat. The result is that the skin temperature will decline or remain steady during exercise in the cold, but areas over active muscles will be at higher temperatures during exercise than at rest. This allows more heat to be lost thru convection and evaporation, although convection is the major avenue of heat loss during exercise in the cold.

MAXIMAL EXERCISE RESPONSES: Although little work has been done to determine the effects of cold on the capacity of the individual to perform maximal exercise, the available data show that maximal exercise responses (e.g. oxygen uptake, ventilation, heart rate, blood lactate) are unaltered during short term exposures (1-5 hr.) to ambient temperatures as low as -20 0 C(-4 0 F). Thus, during maximal exercise, the exercise stimulus overrides that of cold such that the ability of the cardiovascular system to maximally transport oxygen to the exercising muscles remains intact. However, a much different situation is seen if the core temperature is depressed. Bergh and Ekblom induced different core and muscle temperatures in subjects by having them swim in cold water; they reported a decrease of 5-6% in maximal oxygen uptake and 8 beats per minute in heart rate per degree decrease in core temperature. They suggest that the primary effect of cold is a direct action on the heart, reducing the rate and thus the transport of oxygen to the muscle.

ENDURANCE PERFORMANCE: The effects of acute cold exposure on the ability of the human to perform prolonged exercise have received little attention, and reports which have been published are largely anecdotal or subjective in nature. Over 40 years ago, Adolph and Molnar reported that subjects became confused and exhausted while exercising on a cycle ergometer in an ambient temperature of 0 C(32OF) for one hour at an intensity they had easily maintained for four hours under warmer conditions. More recently, Faulkner,et.al. reported a much poorer performance in all classes of skiers during the 1979 Canadian Ski marathon, where temperatures reached -28 0 C (-18.4 0 F), compared to 1978 when conditions were considerably milder. This was largely attributed to the direct effects of cold, which appeared to induce an early onset of fatigue. Under more controlled conditions, Patton and Vogel found a 40% decrease in submaximal endurance time to exhaustion using a cycle ergometer in subjects exposed to a chamber temperature of -20°C (-4 0 F) compared to +20 0C (680 F). As previously noted, a decrease in core temperature significantly reduces the transport of oxygen to exercising muscles. In addition, Bergh and Ekblom also showed that the average endurance time during maximal intensity exercise is markedly reduced when core temperature is decreased. A number of studies h3ve demonstrated that a decrease in muscle temperature can drastically affect muscular contraction and thus exercise performance. In isometric contractions, force development is not significantly affected until muscle temperatures drop below 27 0 C(80.6°F). At such temperatures, maximal tension development and endurance time are decreased. In contrast, dynamic muscular contraction$ are affected at much higher temperatures. Power output during maximal leg cycling declines approximately 4-6% per degree C from a muscle temperature of 38 to 30°C (100 to 86°F) as a result of a decrease In both the force and velocity of contraction. There are several poss0ole reasons why cooling may inhibit force production by the muscle. Vangaard has shown that cooling of the motor fibers of the nerve decreases conduction velocity and thus the recruitment of muscle fibers close to the muscle surface. A lower muscle temperature would also presumably cause a decrease in the rate of chemical reactions in the muscle cell, decrease the rate of cross bridge formation, and Increase the viscosity of the sarcoplasm, which would increase the resistance to cross bridge formation. The energy expenditure of exercising in the cold is often greater than comparable activity in warm environments. Shivering, movement over snow and ice, as well as the weight and bulk of cold-weather clothing are the primary factors responsible for this added energy cost. With respect to the latter, it has been shown that as the bulk of the clothing worn is increased, there is an increased caloric expenditure which is greater than could be accounted for by the weight of the clothing alone. This extra caloric output has been attributed to a "hobbling effect", which is an interference of movement of the body's joints produced by the bulk of clothing. In addition, Teitlebaumi and Goldman demonstrated an increase in the metabolic cost of exercising with multilayered clothing over the corresponding cost of just carrying the weight and has attributed this to a "frictional drag" between layers as one layer of material slides over another during movement. A decrease in the energy sources available for muscular contraction could also Impact upon performance during cold exposure. Recently, Jaoobs,et.al. showed that glycogen utilization is increased 23% during light exercise at 9°C (48.2 0 F) compared to 21°C(69.8°F). This decrease in energy availability was attributed to the Increased shivering thermogenesis of cold exposure. It Is well known that dehydration has a marked effect on exercise performance in a warm environment. It is now recognized that the cold also provides an environment where severe dehydration can occur. In the cold there Is an insidious loss of water as well as a decrease in the sensation of thirst. The loss of water is primarily from sweating in response to the increased energy demands of performing in the cold. Until recently, it had been thought that considerable water loss occurred from the respiratory tree as a result of humidifying the very dry air that is Inhaled. However, recent data suggest that only small amounts of water are lost even during the high ventilator flows of exercise. An increase in urine production is known to occur during cold exposure primarily from the increased filling of the deep capacitance vessels which causes an indirect suppression of anti-diuretic hormone. However, it is doubtful that this condition contributes significantly to the total water loss during prolonged physical activity in the cold. Acclimatization to Cold Considerable attention has been devoted to the question of how and to what extent man acclimatizes to cold. The published work in this area has been reviewed by Horvath and by Haymes and Wells. Acclimatization refers to the physiological changes occurring within the lifetime of an organism which reduce the strain caused by stressful changes in the natural living. The human physiological adjustments to prolonged cold stress are less effective than those to heat. Most of the evidence for the existence of general acclimatization to cold is derived from the study of populations indigenous to cold climates. However, ethnic differences are more properly considered as adaptation and almost certainly involve the process of genetic selection. Information obtained from chronic exposure of individuals native to temperate regions is inconclusive and the question of whether humans can acclimatize to cold remains unresolved. However, some authors have reported a decrease in shivering after repeated cold exposures while others have reported an increased metabolic response. Such findings have led to the characterization of two patterns of general acclimatization - an insulative and metabolic type, respectively. Interest has been expressed as to whether the state of an individual's physical fitness modifies the metabolic and circulatory responses to cold exposure. It has been suggested that improved physical fitness, brought about by strenuous muscular exercise, improves the tolerance to cold. Studies of the effect of physical conditioning on tolerance to cold have had, in general, a common pattern. Subjects are tested during a standard cold exposure before and after a period of exercise training lasting several weeks. In general, peripheral temperatures in the cold have been found to be slightly increased following training, but increased metabolic compensation for the higher peripheral temperatures has not been a consistent finding in every study. Indeed, data from the most recent study showed decreases in metabolic rate and peripheral temperatures during acute cold exposure following 9 weeks of intense aerobic training. Thus, the evidence is meager that the physically fit Individual i3 more tolerant of cold in a resting situation. and questions remain about the role that improved aerobic fitness has in modifying responses to a cold stress. An interesting feature of exercise in the cold is the thermal protection of the upper airways during the performance of activities such as Jogging or cross-country skiing. Although the physiological effects of cold air breathing are not fully known, studies on animals and humans have shown that the warming effects of upper respiratory passages preclude the possibility of cold injury to lung tissue. Upper airway freezing is relatively unknown, even under conditions of strenuous exercise in the cold. Recently, McFadden, et. al, characterized the Intrathoracic thermal events during cold air breathing (-18.6 0 C;-2.2 0 F) at multiple levels of ventilation by inserting a flexible probe containing thermistors into the tracheobronchial tree. At rest, temperatures ranged from 29°C(84.2 0 F) in the upper trachea to 34°C(93.2°F) in the subsegmental bronchi, and at ventilations in excess of 100 1/min, the temperatures in the proximal and distal airways were 20.5(68.9°F) and 31.6 0C(88.9°F), respectively. They concluded that heat and water transfers were not confined to a single region of the trachea bronchial 0 tree, but involved as much as was necessary to complete the task. The greater the ventilation and colder the inspired air, the lower the temperature of the gas at any point in the airways; thus, air must travel further into the lung before It reaches body conditions of temperature and saturation. McFadden, et. Al. further concluded that events transpiring during inspiration set the stage for thermal recovery during expiration. Heating and humidifying the air cools the mucosa, and as the air exits the alveoli, it begins to undergo a continuous loss of heat with a resultant drop in temperature and water vapor. On the average, the temperature of expired air tends to be 1-2°C greater than that during inspiration at any given location. The temperature of gas decreases, so does the ability to hold moisture and the latter is conserved by condensation onto the airway surface. This information, therefore, does not support the notion that major degrees of airway drying take place when large thermal burdens are imposed on the airways since most of the water used to saturate the air upon inspiration would be recovered during the condensation that occurs during expiration. Studies evaluating the effects of cold air breathing on airway resistance have found small but significant increases during inhalation. Such changes have been ascribed to the direct stimulation of tracheobronchial receptors which increase constriction since this response can be reversed by epinephrine (a bronchodilator). A greater concern, however, is the effect of cold-air inhalation during strenuous exercise. While no measurements of airway resistance have been made during exercise in the cold, a number of studies have shown that maximal ventilation is unaffected by cold-air breathing. Such data suggest that, in normal individuals, the stimulus of exercise and the associated increase in epinephrine secretion overcomes bronchoconstriction from cold air seen at rest. Thus, there is no reduction in the functional capacity of the respiratory system. Individuals with certain medical conditions are at an increased risk of developing symptoms when exercising in a cold air environment. In the asthmatic patient, the well documented phenomenon of exercise-induced bronchoconstriction is markedly enhanced when breathing cold air, while the effects of cold air at rest are very small. Thus, a positive interaction occurs between two common natural stimuli, in the induction of asthmatic attacks. The symptoms of cardiac patients also ca, he exacerbated by the cold. Inhalation of, or exposure to, cold may precipitate angina pectoris (chest pain) at lower exercise Intensities than would occur In a thermoneutral environment. The decreased tolerance is the to result from an increase in the resistance to blood flow in response to the peripheral vasoconstriction which accompanies cold exposure. The consequent increase in blood pressure, by increasing the oxygen demands of the heart, provokes angina pectorals. The principle medical problems which may occur from the exposure to a cold environment are frostbite and whole-body hypothermia. The pathophysiology, recognition, and treatment of these conditions have recently been reviewed and will be briefly outlined here. This is the literal freezing of body tissue, typically in the extremities, which can lead to tissue loss if not detected and treated early. As ice crystals form in the extracellular spaces, water is drawn out of the cells, increasing the intracellular electrolyte concentration leading to the mechanical destruction of cells. Damage to blood vessels, particularly in endothelial cells, causes loss of vascular tubular integrity, resulting in tissue swelling and loss of distal nutritive blood flow. The severity of the injury depends on the length of time the tissue is frozen and the depth of cooling. The longer the tissue remains frozen, the closer it gets to ambient temperature (assuming a significant below-zero amoience), and the more serious the injury will be happened. Frostbite can be divided into three stages, based upon the depth and thus the severity of the tissue freeze. Sometimes called frostnip, incipient frostbite usually only involves the tips of the ears, nose, toes, fingers, and the cheeks. The individual is usually unaware that frostnip has occurred until warned that the skin has become white or blanched. This condition develops slowly and is painless. Treatment is to rewarm the skin by applying firm pressure with a hand (no rubbing) or other warm body part, by blowing warm breath on the spot, or by submerging in warm water. The area will tingle slightly as it thaws. Superficial frostbite involves the skin and the tissue just beneath the skin. While the skin itself is firm, white, and waxy in appearance, the tissue beneath it is usually soft. The skin should never be rubbed; as the area thaws, it will become purple or mottled blue and will tingle and burn after becoming initially numb. The area usually swells during thawing. In deep frostbite, the tissue beneath the skin is solid to the touch; it may involve the entire hand or foot. This can result in permanent tissue loss if treatment is not immediately initiated. The treatment of choice is to rapidly rewarm the area by submerging in a 400-'440C (1014-1100F) water bath. Frostbite is a preventable condition which occurs in anyone exposed to subfreezing temperatures without adequate thermal protection, or in those individuals whose sensorium is disturbed by alcohol or other drugs. In general, frostbitten tissue should be kept frozen if there is any chance of refreezing. Tissue should be thawed rapidly because slow rewarming leads to greater tissue loss. However, care should be taken not to exceed a rewarming temperature of

44 0 °C (1100F). Hypothermia. This condition, defined as a core temperature of 35 C (950F) or below, occurs in those who are unable to protect themselves from the cold or who do not recognize that they are losing heat rapidly. Although neonates, the elderly, and unconscious, immobile, or drugged persons are the usual victims of accidental hypothermia, the condition is now seen with Increasing frequency in healthy young individuals who exhaust themselves during physical activity in a cold environment. The progressive clinical features of hypothermia, which are evident as body core temperature falls, are depicted in Table 4. Initial signs include fatigue, weakness, and slowing of gait. Uncontrolled, violent shivering is an important clue to an impending decrease in core temperature, but may not be detected during heavy exercise or when wearing protective clothing. As the core temperature declines, muscular coordination becomes affected, judgment is impaired and hallucinations may occur. At temperatures below 32°C (89.6 0P), shivering will cease and further cooling will be rapid, with the loss of consciousness and marked effects on the cardio respiratory system. The profoundly hypothermic patient is comatose and hypo reflexic. Death ensues as a result of ventricular fibrillation or cardiac standstill. The prompt recognition of this life-threatening condition and the effective restoration of body heat are important prerequisites to a favorable outcome. Once an individual has been recognized as hypothermic, immediate steps should be taken to minimize further heat loss (remove wet clothing, keep dry, insulate, wrap in blankets, etc.) and to add heat In whatever form Is available (give warm fluids, put in sleeping bag with warm, heat packs, contact with another person, eta). If the hypothermic Individual is unconscious, Insulation and rapid transport to a medical facility are essential to a successful outcome. Rewarming procedures should not be attempted in the field situation since they are time-consuming. Fraught with many medical problems which cannot be addressed under such conditions. The real key to effective management of the hypothermic person lies in prevention. Those who enjoy outdoor activities despite cold' temperatures should be alerted to the risks of hypothermia, warned athirst the added hazards of wet conditions and wind chill, advised about clothing that provides maximal thermal protection, and be able to find shelter before the onset of exhaustion. Prevention of Cold Injury

COLD INJURY AND EXERCISE: In contrast to the well-publicized medical problems which arise from exercise performed in hot environmental conditions, relatively little attention has been paid to the potential for cold injury during prolonged exercise in a cold environment. However, there appears to be an increasing number of. reports of hazards resulting from exhaustion due to physical activity in the cold. One of the best illustrations was depicted by Pugh in a report on the 1964 Four Inns Walking competition, an event popular in the scouting movement in England, where three scouts lost their lives due to accidental hypothermia. While the race was well organized and all recognized safety precautions were taken, in retrospect, many conditions were present which are now known to contribute to fatal accidents during physical performance in the cold (e.g., wet-cold conditions, wind, inadequate clothing worn by the hikers, fatigue and exhaustion). The inquest summary and interpretation by Pugh should be required reading for all individuals engaged in exercise in cold environments. More recently, Jones et al reported that the most common medical diagnosis, following a cool weather marathon (7.9-0o.8 0 C; 46.2-51.40F) was hypothermia. This was based upon symptoms of uncontrolled shivering and complaints of cold. Maughan, et. al. further reported that a decrease in core temperature Is not uncommon following a marathon run In cool conditions, particularly

In inexperienced runners who frequently an the second half more slowly than the first half. Such runners may be able to maintain core temperature initially, but with the slow pace of the second half, especially on cool, wet and windy days, hypotdiermia can develop. Race organizer and medical teams who deal with such events, as well as individuals who participate in any outdoor physical activity, should be aware of the risks of hypothermia and be prepared to deal with them.

RISK FACTORS FOR COLD INJURY: The maintenance of homoeothermic and prevention of peripheral cold injury depend upon i balance between climatic factors, on the one hand, and protective clothing and the individual's ability to generate body heat, on the other. There are a number of factors which plane an individual at a Table 5 Increased risk for the development of cold injury. These, are shown in Table 5. The presence of moisture in clothing or on the skin increases the heat lost by the body, and increases one's cold injury. Clothing insulation can be reduced up to 30% of increases either from internal sweat production or from external sources such as rain and snow. Sweating is a problem for many athletes who exercise in the cold, particularly during periods of low activity or rest when heat is lost rapidly from the body when clothing is wet. Wind Is another condition which can be devastating to the maintenance of a normal body temperature. As the velocity of air movement increases, the convective heat loses increases, reducing the skin temperature and increasing the risk of frostbite. Heat loss is particularly increased if wind is allowed to penetrate the outer garments, thereby reducing their insulation. The Windchill index is a very valuable Instrument, therefore, in evaluating the combined effects of air velocity and temperature on subjective comfort and the danger of freezing injury. Clothing is obviously a crucial factor in combating the effects of temperature, moisture, and wind; clothing should vary based upon the severity of these conditions. The effective insulation provided by clothing is a function of the air layer next to the skin, the thickness of the clothing and the amount of air trapped in the layers. The two basic principles in the proper use of clothing are that it be multiple layered and that it allows for adequate ventilation. Multilayered clothing systems are essential during exercise in the cold because layers can be removed to balance the amount of insulation to the level of energy expenditure. The outer layer should be both water repellent and wind resistant, with the inner layers providing the insulation. Wool, goose down, and synthetic fibers all have good insulative qualities by effectively trapping air within the garment. The innermost layer should not only provide insulation but also remove (wick) moisture away from the skin to reduce evaporative heat loss. To provide maximum protection, clothing must also be kept clean and dry. The use of any foreign substance which promotes either heat loss or Interferes with central thermoregulation obviously enhances the risk of developing cold injury. Alcohol ingestion Is a particular problem, in that It not only promotes peripheral vasodilatation, thus increasing heat loss, but also lowers blood glucose levels. This, in turn, inhibits shivering and increases the susceptibility to hypothermia. Skiers and other outdoor enthusiasts should be aware of these effects and the increased risks when alcohol is consumed.

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

2.8.1 Women in sports – trainability

Trainability refers to the faster adaptation to stimuli and the genetic endowment of athletes as they respond individually to specific stimuli and adapt to it accordingly. Trainability has been defined as the responsiveness of developing individuals to the training stimulus at different stages of growth and maturation. The average woman is smaller than the average man, and therefore has a smaller heart muscle and consequently lower VO2 (oxygen consumption) maximum. Women have 30% lower concentration of hemoglobin, the primary mechanism that transports oxygen through the body. Because of this, a woman's cardiovascular system may be up to 30% less proportional to a man. Maintaining adequate iron levels in female athletes is an ongoing concern. When the women's menstrual cycle begins, 25% of women become iron deficient. Iron deficiency is higher in menstruating women; 0-19% for iron deficiency anemia and 20-62% for nonanemic iron deficiency. A woman's body temperature fluctuates during the course of the menstrual cycle. Muscle growth is regulated by hormones such as testosterone, which is 10 times more prevalent in men than women. Generally, women have 20% less muscle mass; however, when strength is measured in terms of lean body mass this difference is reduced. Estrogen is produced in much greater amounts in women and results in wider hips and increased amounts of fatty tissue. Women generally have 20-26% fat tissue and men have 15-20%. The extent to which one retains fat is influenced by diet and exercise. Women's fat tissue is preferentially distributed around the buttocks and breasts. Women generally have smaller, less dense bones and begin growing two years earlier than men because of female hormones. Women are more prone to osteoarthritis (common "wear and tear" arthritis) and osteopenia (low bone mineral density) due to factors identified in the Female Athlete Triad. Many athletes do not consume sufficient levels of calcium, particularly those who restrict caloric intake or eliminate dairy products from their dietary intake. 80% of variance in bone mass density is attributed to genetic factors. Lean body mass, estrogen, and exercise are other important influences. Men produce more sweat and start sweating earlier during activity than women. This may be an advantage for men in a hot, dry environment (as sweat cools the body), however dehydration is a potential problem. Sweat electrolyte losses differ between children, adolescents, and adults, as the ability to sweat and regulate temperature is dependent more on maturation than gender. Dehydration is more detrimental to children than to adults. Children's energy requirements during walking and running can be as much as 30% higher than in adults per kilogram of body mass. When considering the development and implementation of a training regimen for female athletes, coaches must first have an understanding of the female's physiological processes and appreciate how they differ from a male. Emerging research in prevention and training practices show that gender conscious approaches to physical training and conditioning for female athletes help to reduce the likelihood of anterior cruciate ligament (ACL) injuries. The occurrence of a high proportion of ACL injuries through non-contact (forces applied to the knee at the time of injury were a result of the athlete's movements, not contact with another athlete) mechanisms is significant. This points to features of the athlete's movement, not the circumstances of the sport activity, as the precipitating event for the injury

(Women's Sports Foundation, 2009). The "Female Athlete Triad" is a medical condition unique to females that is a combination of three interrelated conditions that can be associated with athletic training: disordered eating, amenorrhea, and osteoporosis (Hobart & Smucker, 2000). While each of these conditions has potential damaging effects, together the risks are far greater.

1. Disordered eating occurs along a wide spectrum ranging from calorie, carbohydrate, protein and/or fat restriction to the more extreme eating disorders such as anorexia nervosa and bulimia nervosa. Disordered eating can cause decreased bone mineral density, gastrointestinal problems, cardiovascular abnormalities and psychiatric problems such as depression, anxiety and even suicide. Female athletes who have a negative energy balance (consume less calories than they expend) inhibit their body's potential for optimal growth and reduce their capacity to reach maximum peak performance.

2. Amenorrhea is a type of menstrual dysfunction defined as the absence of a menstrual period in a woman of reproductive age. Menarche (the onset of the menstrual cycle) occurs at the later stages of puberty in girls. The average age of menarche is 12 years, but occurs anywhere between ages 8 and 16 years of age. A "normal" menstrual period usually occurs every 28 days, from the first day of a period to the first day of the next (this can vary from 22 to 36 days). Each period usually lasts from 3 to 7 days, with the average being 5. Irregular periods are common in early adolescence and it may take several years from the start of menstruation for periods to settle into a pattern. Even after adolescence, many factors can affect the timing of menstruation. Lack of caloric intake, training intensity (including overtraining in younger athletes) and previous menstrual functioning can all affect the menstrual cycle. While low energy availability is the primary factor leading to reproductive irregularities, associative factors include low body weight and/ or low body fat. It is important for coaches and athletes to understand the negative consequences of amenorrhea, including lower bone mineral density, higher incidence of stress fractures and infertility, and lower levels of the hormone's estrogen and/or progesterone leading to lifelong health consequences that can potentially be fatal.

3. Disordered eating and menstrual dysfunction are common risk factors for osteopenia (condition) and osteoporosis (disease), whereby bone mineral density is lower than normal, leading to increased risk of fracture. The integrity of bone formation, growth and maintenance can be negatively affected by limited calcium intake as a result of disordered eating habits, and low estrogen levels due to menstrual dysfunction. This can result in a greater risk of premature osteoporosis, and can make athletes more susceptible to stress fractures which may inevitably force an athlete to discontinue all training for a significant amount of time.
Know about the risk factors for female athletes and educate athletes, parents and administrators.
Educate yourself and your athletes about ACL-injury prevention methods, such as stretching, strength training, balance and plyometrics training (Harber, 2010).
Implement a screening program for risk factors as a prevention method, including information to dispel misconceptions about body weight, body composition, and athletic performance.
Know that critical years for maximizing bone mass density start with the pre-pubertal and pubertal stages, and extend into the early 20's. Energy deficits during this time can lead to impaired bone mineral density acquisition and increased risk of stress fractures.

Communicate to athletes that optimal health is vital to prevent lost training or competition time due to injury resulting from unhealthy behaviours.
Know that female athletes participating in endurance sports (e.g. middle- or long-distance running, cross-country skiing), aesthetic sports (figure skating, synchronized swimming, gymnastics), and weight classification sports (wrestling, boxing, rowing) can feel pressured to try and reach an unrealistic body weight in the hopes of achieving greater success.
Become familiar with signs and symptoms of an athlete struggling with disordered eating; often teammates know before a coach does.
Understand that disordered eating behaviours can result from psychological factors, such as low self-esteem, poor coping skills, perfectionism, obsessive compulsive traits, depression, anxiety and perceived loss of control.
Understand that during menstruation female athletes may avoid disclosing why they are not feeling well. To promote and maintain females' participation in sport and physical activity, coaches need to understand what motivates female athletes to participate and provide an environment that addresses those needs. Research indicates that girls and women become involved in physical activity and sport for many reasons. Most commonly, females are attracted to sport for the elements of affiliation, skill development, personal improvement, a nurturing environment and a social network. Women who have positive sporting experiences may benefit from enhanced health and wellbeing, fostered self-esteem and empowerment, enhanced social inclusion and integration, and being provided with leadership opportunities (Mulholland, 2008). Common barriers to females' involvement in physical activity and sport are a lack of encouragement, a lack of opportunity, lack of basic skills, conflict with other activities, low self-esteem and low self-efficacy, and parents, coaches and peers who perpetuate stereotypes of femininity by associating sport with masculinity.
Create a fun environment by incorporating social time and a variety of team and individual challenges.
Encourage females' involvement through friends and social networks.
Invest time to develop positive social relations amongst team mates.
Run positive programs where girls and women experience success through skill development and goal accomplishment.
Give athletes responsibility for certain aspects of the program, such as running warm-up or planning social events; provide leadership opportunities for ALL team members.
Create physical challenges that allow females to positively experience their athletic capabilities.
Inform parents of team philosophy, emphasizing that their commitment and encouragement are important.
Introduce athletes to female athletes as positive role models (e.g. involve high school athletes as "junior" coaches for younger children, have college/university athletes participate in a team practice, or watch professional elite games as a team).

2.8.2 Physiological gender differences

The human genome consists of two copies of each of 23 chromosomes (a total of 46). One set of 23 comes from the mother and one set comes from the father. Of these 23 pairs of chromosomes, 22 are autosomes, and one is a sex chromosome. There are two kinds of sex chromosomes–"X" and "Y". In humans and in almost all other mammals, females carry two X chromosomes, designated XX, and males carry one X and one Y, designated XY. A human egg contains only one set of chromosomes (23) and is said to be haploid. Sperm also have only one set of 23 chromosomes and are therefore haploid. When an egg and sperm fuse at fertilization, the two sets of chromosomes come together to form a unique "diploid" individual with 46 chromosomes. The sex chromosome in a human egg is always an X chromosome since a female-only has X sex chromosomes. In sperm, about half the sperm have an X chromosome and half have a Y chromosome. If an egg fuses with sperm with a Y chromosome, the resulting individual is male. If an egg fuses with sperm with an X chromosome, the resulting individual is female. There are rare exceptions to this rule in which, for example, XX individuals develop as males or XY individuals develop as females. Chromosomes are not the final determinant of sex. In some cases, for example, chromosomally female babies that have been exposed to high levels of androgens before birth can develop masculinized genitals by the time they are born. There are other variations of sex chromosomes that lead to a variety of different physical expressions. The X-chromosome carries a larger number of genes in comparison to the Y-chromosome. In humans, X-chromosome inactivation enables males and females to have an equal expression of the genes on the X-chromosome since females have two X-chromosomes while males have a single X and a Y chromosome. X-chromosome inactivation is random in the somatic cells of the body as either the maternal or paternal X-chromosome can become inactivated in each cell. Thus, females are genetic mosaics.

- Externally, the most sexually dimorphic portions of the human body are the chest, the lower half of the face, and the area between the waist and the knees.
- Males weigh about 15% more than females, on average. For those older than 20 years of age, males in the US have an average weight of 86.1 kg (190 lbs.), whereas females have an average weight of 74 kg (163 lbs.).
- On average, men are taller than women, by about 15 cm (6 inches). American males who are 20 years old or older have an average height of 176.8 cm (5 ft 10 in). The average height of corresponding females is 162 cm (5 ft 4in).
- On average, men have a larger waist in comparison to their hips than women.
- Women have a larger hip section than men, an adaptation for giving birth to infants with large skulls.
- In women, the index and ring finger tends to be the same length, whereas men's ring finger tends to be longer.
- Males in general have denser, stronger bones, tendons, and ligaments.
- Female skulls and head bones differ in size and shape from the male skull, with the male mandible generally wider, larger, and squarer than the female In addition, males generally have a more prominent brow, an orbital with rounded border, and more greatly projecting mastoid processes.
- Males have a more pronounced Adam's apple or thyroid cartilage (and deeper voices) due to larger vocal cords.
- In males, the second digit (index finger) tends to be shorter than the fourth digit (ring finger), while in females the second digit tends to be longer than the fourth.
- Males have slightly larger teeth than females and a greater proportion of the tooth in males is made up of dentine, whereas females have proportionately more enamel.

- Females in general have lower total muscle mass than males, and also having lower muscle mass in comparison to total body mass; males convert more of their caloric intake into muscle and expendable circulating energy reserves, while females tend to convert more into fat deposits. As a consequence, males are generally physically stronger than females. While individual muscle fibers have similar strength between male and female, males have more fibers as a result of their greater total muscle mass. Males remain stronger than females when adjusting for differences in total body mass, due to the higher male muscle-mass to body-mass ratio. The greater muscle mass is reported to be due to a greater capacity for muscular hypertrophy as a result of higher levels of circulating testosterone in males.
- Gross measures of body strength suggest that women are approximately 50-60% as strong as men in the upper body, and 60-70% as strong in the lower body. One study of muscle strength in the elbows and knees—in 45 and older males and females—found the strength of females to range from 42 to 63% of male strength. Another study found men to have significantly higher hand-grip strength than women, even when comparing untrained men with female athletes. Differences in width of arm, thighs and calves also increase during puberty.
- Males typically have larger tracheae and branching bronchi with about 56% greater lung volume per body mass. They also have larger hearts, 10% higher red blood cell count, and higher hemoglobin hence greater oxygen-carrying capacity. They also have higher circulating clotting factors (vitamin K prothrombin and platelets). These differences lead to faster healing of wounds and higher peripheral pain tolerance.
- Women generally have a higher body fat percentage than men, whereas men generally have more muscle tissue mass.
- Women usually have lower blood pressure than men, and women's hearts beat faster, even when they are asleep.
- Men and women have different levels of certain hormones. Men have a higher concentration of androgens while women have a higher concentration of estrogens.
- Adult men have approximately 5.2 million red blood cells per cubic millimeter of blood, whereas women have approximately 4.6 million.
- Females typically have more white blood cells (stored and circulating), more granulocytes, and B and T lymphocytes. Additionally, they produce more antibodies at a faster rate than males. Hence, they develop fewer infectious diseases and succumb for shorter periods.
- Recent findings revealed that there are several differences in cellular characteristics (e.g., cytoskeleton) of female and male cells.

2.8.3 Special problems of women athletes

Puberty Until puberty, girls and boys do not differ significantly in most measurements of body size, composition and physiological responses to exercise, although there is great individual variation. This, in itself, can have a huge bearing on athletic performance both physically and psychologically, especially as the majority of competition is based on the age of the athletes and not their stage of development. Young people who develop earlier than their peers often leave their sport at around the age of 14 or 15, as the average and late matures catch up. This is due to frustration because, up until this point, they have always relied upon their advanced developmental age for success and, as a result, many do not develop the necessary skills or fitness to continue to excel in their sport. The coach's role in managing the challenges faced in guiding athletes through puberty is therefore key. The actual process of puberty takes about four years for both girls and boys; though it begins, on average, two years earlier in girls. At puberty, due to the influence of increased estrogen and testosterone, body composition begins to change markedly. In addition to the onset of menstruation, estrogen causes increased fat deposits in females, particularly in the hips and thighs, and an increased rate of bone growth. As well as the physical change, girls will go through emotional changes; hormones sometimes produce mood swings that can vary in intensity. Feelings of depression or irritability alternate with periods of relative calm. It's not unusual for girls to feel a certain amount of stress over the rapid changes their bodies are undergoing, and this sometimes leads to periods of insecurity as well. As coaches, you cannot predict the impact puberty may have on the young female athlete and should consequently be cautious in your approach to talent identification. Menstruation and the female athlete Assessing and taking into account the impact the menstrual cycle has on female athletes is something often overlooked by coaches for a variety of reasons.

• Embarrassment on the part of the coach and/or fear of embarrassing the athlete
• An assumption that the athlete would mention it if it were a problem
• Being unsure whether it is either appropriate or necessary to raise the topic
• A lack of confidence or knowledge about the potential impact of the menstrual cycle on athletic performance
• Fear of causing offence, especially for cultural reasons
• Some coaches have simply never thought about it. In reality, while many women experience little difference in terms of performance during their menstrual cycle, it can present challenges for those who are affected by it and their coaches.

For some, the premenstrual stage may be accompanied by the following symptoms: mood changes; fluid retention; breast tenderness; abdominal pain; headaches; and fatigue. There may also be a reduction in both aerobic capacity and strength during this phase (known as premenstrual syndrome [PMS]) and into the menses stage. However, it is important to note that state of mind and attitude can exaggerate these symptoms/effects and we cannot assume all female athletes experience all (or any) of these.

- Managing sensitive conversations:

• Pick your moment carefully
• Be clear about what you want to say and ensure it is relevant
• Be sensitive of others overhearing the conversation
• Consider whether the training environment is the appropriate place for the conversation
• Maintain a clear purpose to the conversation and be clear as to whether you are looking to achieve a specific outcome from it (e.g. whether you intend to raise an issue, resolve an issue or gain some information)
• Use correct language (e.g. period, PMS) and make sure the athlete understands
• Be honest; if necessary, acknowledge that you feel awkward having this conversation as this may actually lead to a more open and relaxed experience
• Draw on examples of other athletes'/women's experiences of which you may have first-hand knowledge (while maintaining confidentiality)
• Female athletes who participate in sports involving jumping and making swift changes of direction have been found to have twice to six times the risk of injury compared with male athletes participating in similar sports.

The injuries are not predominantly a result of contact between players, but more often in response to jumps, hard landings, sudden pivots. Exercise scientists have been unable to provide a single reason as to why females have more injuries; however, a variety of theories have been given, including: differences in training and/or coaching of male and female athletes; variations in ligament laxity; and anatomical differences (e.g. women having wider hips than men and the effects of hormonal changes during the menstrual cycle). Specifically, in relation to knee injuries, recent research (Sports Injury Bulletin, 2010) has suggested that the higher prevalence of injury in female athletes may simply be down to female athletes' tendency to land from jumps with straighter knees than males and that the imbalance between quadriceps and hamstring strength is more marked than in men. Both of these are issues that can be addressed through training.

• A woman's lung capacity is, on average, 25–30% lower than a men. Men can process more oxygen, giving them an advantage when undertaking aerobic training.

• The average female heart is 25% smaller than the average males. Consequently, male hearts are able to pump more blood with each beat. The larger size of a man's heart also means a lower resting heart rate (on average, 5–8 beats per minute slower than a woman's), which is also apparent when they are training at a submaximal level.

• A man's body is on average 10–15% larger than a woman's and 30% stronger, particularly in the upper body. Some women have a lower center of gravity than men and may, therefore, have to overcome more resistance than men in activities that require movement of the lower body.

Think about how you could change your approach to your coaching sessions. You don't have to be able to identify with everything on this factsheet, but the differences you will achieve from changing a minor part of your coaching methodology could bring great results. There are five other factsheets in the series. Each one explores a different area surrounding women in sport, which may help inform your approach to your current coaching practice. The factsheets are:

• Coaching Myth Buster
• Female Psychology and Considerations for Coaching Practice
• Developing Female Coaches
• Coaching Female High-Performance Athletes
• Socially Inclusive Coaching.

Sub Unit – IX

Aging - Physiological consequences, life style management and healthful aging

2.9.1 What is aging?

Aging can simply refer to the passage of time and can even have a positive connotation as in "aging wine." On the other hand, term "aging" refers to the biological process of growing older in a deleterious sense, what some authors call "senescence" (Williams, 1957; Comfort, 1964; Finch, 1990). "Aging" is more accessible; "senescence" now also frequently refers to cellular senescence. Aging is one of the most complex biological processes, whose definition is intrinsically related to its phenotype.

Aging is a complex process composed of several features: 1) an exponential increase in mortality with age; 2) physiological changes that typically lead to a functional decline with age; 3) increased susceptibility to certain diseases with age. So, aging is a progressive deterioration of physiological function, an intrinsic age-related process of loss of viability and increase in vulnerability.

Gerontology normally refers to the study of the biological process of aging, not its medical consequences. Generally, I use geriatrics to refer specifically to the medical study of diseases and problems of the elderly. Technically, gerontology includes both the biological and the medical branches of the study of aging, but in other context of the biology of aging, gerontology usually refers to the study of the biological aspects of aging, unless otherwise specified. Biogerontology refers specifically to the biological study of aging and is also used, usually interchangeably, with gerontology.

Life expectancy is how long, on average, an organism can be expected to live. Longevity is the period of time an organism is expected to live under ideal circumstances. Lifespan is defined as the period of time in which the life events of a species or sub-species (e.g., a strain or population) typically occur. Lifespan and longevity can sometimes be used interchangeably, though they have slightly different meanings. For humans, lifespan and longevity are about the same in industrial nations, but when studying species in the wild, one can expect that lifespan will be lower than longevity since feral conditions are certainly not ideal for assessing longevity. For most purposes, life expectancy, average longevity, and average lifespan have the same meaning. Maximum longevity and maximum lifespan are the maximum amount of time animals of a given species or sub-species can live--typically, the record longevity for that species. The maximum longevity of humans is 122 years, recorded by the late Jeanne Calment.

Ageing is process of becoming older. The term refers especially to human beings, many animals, and fungi, whereas for example bacteria, perennial plants and some simple animals are potentially biologically immortal. In the broader sense, aging can refer to single cells within an organism which have ceased dividing (cellular senescence) or to the population of a species (population ageing). In humans, aging represents the accumulation of changes in a human being over time and can encompass physical, psychological, and social changes. Reaction time, for example, may slow with age, while knowledge of world events and wisdom may expand. Aging is among the greatest known risk factors for most human diseases: of the roughly 150,000 people who die each day across the globe, about two thirds die from age-related causes. The causes of aging are uncertain; current theories are assigned to the damage concept, whereby the accumulation of damage (such as DNA oxidation) may cause biological systems to fail, or to the programmed aging concept, whereby internal processes (such as DNA methylation) may cause aging. Programmed aging should not be confused with programmed cell death (apoptosis).

Mortality can be used to define biological aging, which refers to an organism's increased rate of death as it progresses throughout its lifecycle and increases its chronological age. Another possible way to define aging is through functional definitions, of which there are two main types. The first describes how varying types of deteriorative changes that accumulate in the life of a post-maturation organism can leave it vulnerable, leading to a decreased ability of the organism to survive. The second is a senescence-based definition; this describes age-related changes in an organism that increase its mortality rate over time by negatively affecting its vitality and functional performance. An important distinction to make is that biological aging is not the same thing as the accumulation of diseases related to old age; disease is a blanket term used to describe a process within an organism that causes a decrease in its functional ability.

2.9.2 Physiological consequences of aging

Human aging, physiological changes that take place in the human body leading to senescence, the decline of biological functions and of the ability to adapt to metabolic stress. In humans the physiological developments are normally accompanied by psychological and behavioral changes, and other changes, involving social and economic factors, also occur. Aging begins as soon as adulthood is reached and is as much a part of human life as are infancy, childhood, and adolescence. Gerontology (the study of aging) is concerned primarily with the changes that occur between the attainment of maturity and the death of the individual. The goal of research in gerontology is to identify the factors that influence these changes. Application of this knowledge can reduce the severity of some disabilities commonly associated with aging.

The biological-physiological aspects of aging include both the basic biological factors that underlie aging and the general health status. Since the probability of death increases rapidly with advancing age, it is clear that changes must occur in the individual which make him or her more and more vulnerable to disease. For example, a young adult may rapidly recover from pneumonia, whereas an elderly person may die. Physiologists have found that the performance of many organs such as the heart, kidneys, brain, or lungs shows a gradual decline over the life span. Part of this decline is due to a loss of cells from these organs, with resultant reduction in the reserve capacities of the individual. Furthermore, the cells remaining in the elderly individual may not perform as well as those in the young. Certain cellular enzymes may be less active, and thus more time may be required to carry out chemical reactions. Ultimately the cell may die. Thus, with increasing age, the heart becomes more vulnerable to cardiovascular disease. Even in the absence of detectable disease, the heart undergoes deleterious changes with advancing age. Structural changes include a gradual loss of muscle fibres with an infiltration of adipose tissue (fat) and connective tissue. There is a gradual accumulation of insoluble granular material (lipofuscin, or “age pigment”) in cardiac muscle fibres. These granules, composed of proteins and lipids, make their first appearance by age 20 and increase gradually, so that by age 80 they may occupy as much as 5–10 percent of the volume of a muscle fibre. The heart also shows a gradual reduction in performance with advancing age. The amount of blood pumped by the heart diminishes by about 50 percent between ages 20 and 90 years. There are marked individual differences in the effects of age. For example, some 80-year-old individuals may have cardiac function that is as good as that of the average 40-year-old individual.

Under resting conditions, the heart rate does not change significantly with age. During each beat, however, the muscle fibres of the heart do not contract as rapidly in the old as in the young. This reduction in power, or rate of work, is due to the age-associated reduction in the activities of certain cellular enzymes that produce the energy required for muscular contraction. In spite of these changes, the heart, in the absence of disease, is able to meet the demands placed upon it. In response to physical exercise, it can increase its rate to double or triple the amount of blood pumped each minute, although the maximum possible output falls, and the reserve capacity of the heart diminishes with age. Arteriosclerosis, or hardening of the arteries, increases markedly in incidence with age and is often regarded as part of aging. This is not necessarily true. Arteriosclerosis may appear even in adolescents. It is a progressive disorder and is present to some extent in practically all individuals by middle life. It is, therefore, impossible to make a clear distinction between the effects of aging and the effects of disease in blood vessels in humans. In some animal species—for example, the rat—that do not develop arteriosclerosis, age changes in the heart and blood vessels can be identified.

In general, blood vessels become less elastic with advancing age. There is a progressive thickening of the walls of larger blood vessels with an increase in connective tissue. The connective tissue itself becomes stiffer with increasing age. This occurs because of the formation of cross-links both within the molecules of collagen, a primary constituent of connective tissue, and between adjacent collagen fibres. These changes in blood vessels occur even in the absence of the deposits on the arterial wall characteristic of atherosclerosis, which interfere with blood flow through the arteries. The gradual loss of elasticity increases with resistance to the flow of blood so that blood pressure may increase. This in turn increases the work that the heart must do in order to maintain the flow of blood.

While both systolic and diastolic blood pressures (blood pressures at contraction and dilation of the heart, respectively) increase with age, the rate of systolic increase exceeds that of diastolic so that the pulse pressure widens. The increase in pressure stops in the eighth decade of life, and there may even be a slight decline in pressure in extreme old age. On the average, obese people have higher blood pressures than those with normal body weights. Since the incidence of obesity increases with age at least up to age 55–60, this factor may contribute in part to the increase in blood pressure with age.

Loss of teeth, which is often seen in elderly people, is more apt to be the result of long-term neglect than a result of aging itself. The loss of teeth and incidence of oral disease increase with age, but, as programs of water fluoridation are expanded and the incidence of tooth decay in children is reduced, subsequent generations of the elderly will undoubtedly have better teeth than the present generation. While it is true that the secretion by the stomach of hydrochloric acid, as well as other digestive enzymes, decreases with age, the overall process of digestion is not significantly impaired in the elderly. Sugar, proteins, vitamins, and minerals are absorbed from the stomach and intestine as well in the elderly as in the young. Some investigations indicate a slight impairment in fat absorption, but the reduction is probably of little practical significance.

These findings have important implications for nutrition of the elderly. There is no evidence that the intake of any nutrient, such as vitamins and minerals, need be increased in the elderly because of impaired absorption. Nutritional deficiencies can be avoided as long as the diet is varied to assure adequate intake of all nutritional elements. Deficiencies are most likely to develop from poor eating habits, such as excessive intake of carbohydrate with a reduction in protein. In the elderly these deficiencies are most apt to be in the intake of protein, calcium, iron, vitamin A, and thiamine. Changes in the structures of the brain due to normal aging are not striking. It is true that with advancing age there is a slight loss of neurons (nerve cells) in the brain. The total number of neurons is extremely large, however, so that any losses probably have only a minor effect on behaviour. Since the physiological basis of memory is still unknown, it cannot be assumed that the loss of memory observed in elderly people is caused by the loss of neurons in the brain.

Neurons are extremely sensitive to oxygen deficiency. Consequently, it is probable that neuron loss, as well as other abnormalities observed in aging brains, results not from aging itself, but from disease, such as arteriosclerosis, that reduces the oxygen available to areas of the brain by reducing the blood supply. Genetic and environmental factors, such as exposure to certain chemicals, smoking, or lack of exercise, may also contribute to memory impairment and reduced cognitive ability in the elderly. For example, increased waist circumference and obesity later in life are linked to thinning of the cerebral cortex and cognitive decline; the cerebral cortex is composed primarily of neuronal cell bodies, the deterioration of which is associated with memory and cognitive impairment.

There are probably functional changes in the brain that account for the slowing of responses and for the memory defects that are often seen in the elderly, and even small changes in the connections between cells of the brain could serve as the basis for marked behavioral changes, but, until more is known about how the brain works, behavioral changes cannot be related to physiological or structural changes. It is known that, because of the slow course of aging, the nervous system can compensate and maintain adequate function even in centenarians.

Human behaviour is highly dependent on the reception and integration of information derived from sensory organs, such as the eye and ear, as well as from nerve endings in skin, muscle, joints, and internal organs. There is, however, no direct relation between the sensitivity of receptors and the adequacy of behaviour, because the usual level of stimulation is considerably greater than the minimum required for stimulation of the sense organs. In addition, an individual adapts to gradual impairments in one sensory organ by using information available from other sense organs. Modern technology has also provided eyeglasses and hearing aids to compensate for reduced acuity in the sense organs.

Aging also brings about a reduction in the ability to change the focus of the eye for viewing near and far objects (presbyopia), so that distant objects can ordinarily be seen more clearly than those close at hand. This change in vision is related to a gradual increase in rigidity of the lens of the eye that takes place primarily between ages 10 and 55 years. After age 55 there is little further change. Many people in their 50s adopt bifocal glasses to compensate for this physiological change. The sensitivity of the eye under conditions of low illumination is less in the old than in the young; that is, “night vision” is reduced. Sensitivity to glare is also greater in the old than in the young. The incidence of diseases of the eye, such as glaucoma and cataracts (characterized, respectively, by increased intra-ocular pressure and opaque lenses), increases with age, but advances in surgery and contact lenses have made it possible to remove cataracts and restore vision to many individuals.

Hearing does not change much with age for tones of frequencies usually encountered in daily life. Above age 50, however, there is a gradual reduction in the ability to perceive tones at higher frequencies. Few persons over age 65 can hear tones with a frequency of 10,000 cycles per second. This loss of perception of high frequencies interferes with identifying individuals by their voices and with understanding conversation in a group but does not ordinarily represent a serious limitation to the individual in daily life. Listening habits and intellectual level play an important role in determining the ability to understand speech, so that there is often a disparity between measurements of pure tone thresholds and ability to perceive speech. After age 70 other sense organs may show a reduction in sensitivity. Reduced taste sensitivity is associated with atrophy and loss of taste buds from the tongue in the elderly. The effect of aging on the sense of smell has not been precisely determined because this sense is extremely difficult to assess quantitatively; in addition, smoking and exposure to occupational odours and noxious substances in the air influence sensitivity to smells. Sensitivity to pain is difficult to evaluate quantitatively under controlled laboratory conditions. There is some evidence that it diminishes slightly after age 70. There is a general slowing of responses in the elderly. Reflexes become slightly more sluggish, and the speed of conduction of impulses in nerves is slightly slowed. Old people require more time to respond to the appearance of a light than do young. The slowing with age is greater in situations where a decision must be made. For example, more time is required to initiate a response in experiments in which the instructions are “Press the button with your right hand when the green light comes on, but with your left hand when the red light comes on” than if the instructions are, “Push the button if either light comes on.” From these and other experiments it is concluded that the primary site of slowing of responses is within the brain rather than in the end organ (eye) itself.

The primary age change in the skin is a gradual loss of elasticity. Although this basic change plays a role, other factors, such as exposure to the weather and familial traits, also contribute to the development of wrinkles and the pigmentation associated with senescence. The ability of the skin to take up slack and remain closely adherent to the underlying structures is due to the presence of fibres of the protein's elastin and collagen. Studies of the minute structures of the skin show a gradual reduction in elastin. In addition, the collagen fibres show an increase in cross-links, which greatly restricts the elastic properties of the collagen network. Because of the importance of hormones in the regulation of many physiological systems, impairments in the endocrine system have traditionally been cited as important determinants in aging.

Thyroxine, the hormone secreted by the thyroid gland, regulates the level of activity of all the cells of the body. When thyroxine secretion is reduced, all metabolic processes proceed at a reduced rate and basal metabolism falls. (Metabolism consists of the chemical changes taking place within the cells of an organism during the processes of growth and restoration of tissues and the production of energy necessary for bodily processes; basal metabolism is the metabolism, as measured by the rate at which heat is given off, when an organism is in a resting and fasting state.) Since basal metabolism decreases with age, it seemed reasonable to ascribe aging to a loss of thyroid function, but this assumption has proved to be incorrect. Experimental studies have shown that the ability of the thyroid gland to produce thyroxine is not reduced in the elderly, and that there is a reduction in the utilization of thyroxine in various tissues of the body. Further studies of cellular metabolism are needed to find out why this is so.

Since aging is associated with reduced ability to adjust to stresses, and since the adrenal cortex (the outer part of the adrenal gland) plays a role in many of these adjustments, numerous attempts have been made to assess senescent changes in the function of the adrenal cortex. Although after the age of 50 there is a reduction in blood levels of the hormones secreted by the adrenal cortex, the ability of the gland to produce hormones when stimulated by the experimental administration of adrenocorticotrophic hormone (ACTH), the pituitary hormone that regulates the activity of the adrenal cortex, has been shown to be as good in the old as in the young. The pituitary gland is often referred to as the master gland of the body, since it produces hormones that stimulate the activities of other endocrine glands, such as the adrenal, the thyroid, and the ovary. It was therefore once assumed that reduction in the function of these glands associated with aging is due to lack of proper stimulation from the pituitary gland. Methods for determination of the very small amounts of these regulating hormones present in the blood have been developed and as yet no systematic studies of age differences in blood levels of these hormones have been reported.

The pancreas secretes insulin, the hormone that regulates the utilization of sugar and other nutrients in the body. When the pancreas fails to produce adequate amounts of insulin, diabetes mellitus occurs. One test for diabetes involves measuring the rate of removal of sugar from the blood—that is, the glucose tolerance test. One characteristic of aging is a reduction in the rate of removal of excess sugar from the blood. At present it is not known whether this represents the early stages of diabetes or whether it is a normal age change. It does appear in aged individuals who do not show any of the other symptoms of diabetes. Furthermore, it has been shown that, unlike the diabetic, elderly subjects can, with additional stimulation, produce more insulin. In normal young persons, the pancreas releases more insulin in response to even a slight rise in blood sugar levels. In the elderly, the sensitivity of the pancreas is reduced so that a higher level of blood sugar is required to stimulate it to action. With maximum stimulation the pancreas in the aged can produce as much insulin as the pancreas in the young.

It has long been known that the excretion of both male and female sex hormones diminishes with age. In the female, the excretion of estrogens (female sex hormones) falls markedly at menopause. In the male, the excretion of androgens (male sex hormones and their degradation products) falls gradually over the age span 50–90, so that the existence of a male "climacteric" is highly improbable. Sexual activity, as reported in interview studies, diminishes progressively between the ages of 20 and 60 in both males and females. In males the frequency of marital intercourse falls from an average of four per week in 20-year-olds to one per week in 60-year-olds. Practically all males aged 20–45 reported some level of sexual activity. Between the ages of 45 and 60 only about 5 percent of males reported loss of sexual activity. Few systematic studies have been made of sexual behaviour in individuals over the age of 60, but clinical reports indicate that at least some males remain sexually active at 90. There are wide individual differences in the level of sexual activity in both males and females. In humans, sexual behaviour is influenced more by psychological and social factors than by the levels of sex hormones circulating in the blood. Nevertheless, the use of male sex hormones has had a long, and stormy, history as a rejuvenating agent for males. Attempts to rejuvenate elderly males by injecting crude extracts from testicles of animals, as well as various androgenic compounds, were made, but the effects, if any, were only transitory. In the early 1900s, sex glands from other animals were transplanted into humans, but the results were questionable and the side effects were often disastrous. At about the same time, an operation was devised in which the spermatic ducts were tied off. It was assumed that preventing the loss of sperm would stimulate the sex glands to produce androgenic hormones which would rejuvenate the individual. None of these assumptions proved correct, so that operation was soon abandoned as a rejuvenating procedure.

Since tissue loss does occur with aging, the administration of anabolic steroids (hormones that promote the buildup of tissues) may represent an important future development. The compounds that are available have a number of undesirable side effects and cannot be used routinely. Chemists and pharmacologists continue research to produce new steroids that will have anabolic effects without the decreasing. With aging, the bones gradually lose calcium. As a result, they become more fragile and are more likely to break, even with minor falls. Healing of fractures is also slower in the old than in the young. Recent advances in orthopedic surgery, with the replacement of parts of a broken bone or joint with new structures or the introduction of metallic pegs to hold broken parts together, have been of great value to elderly people. The incidence of osteoporosis, a disease characterized by a loss of calcium and minerals from bone, also increases with age. It occurs more frequently in women after menopause than in men and is especially evident in the spinal column. Back pain is a primary symptom of the disease. It can be treated by increasing calcium intake in association with the administration of anabolic hormones.

The mobility of joints diminishes with age and the incidence of arthritis increases. Vital capacity, or the total amount of air that can be expelled from the lung after a maximum inspiration, diminishes with age, as does the total volume of air that can be contained in the lungs. In contrast, the amount of air that cannot be expelled from the lung increases. These changes in respiratory mechanisms are primarily a reflection of the increased stiffness of the bony cage of the chest and decreased strength of the muscles that move the chest during respiration. The lung also contains elastin and collagen to give it elastic properties. As indicated previously, the formation of cross-links in elastin and collagen that takes place with aging reduces the elastic properties of the lung. The transfer of oxygen and carbon dioxide from the air in the lungs to the blood is influenced by the amount of blood flowing through the lungs as well as by the amount of air moved in and out. The characteristics of the membranes that separate blood and air in the lungs are also important in maintaining an adequate supply of oxygen to the body. Although with age there is a slight reduction in the amount of oxygen that can be moved from the air to the blood in the lungs, the reduction becomes apparent only when large amounts of oxygen are required, as during strenuous exercise. It is thought that a primary factor in the impairment of oxygen transfer in the lungs of elderly subjects is the lack of appropriate adjustment of the blood flow to the air sacs in the lung. Emphysema, abnormal distension of the lungs with air, is a lung disease reaching its highest incidence between ages 45 and 65. In the United States the death rate from emphysema increased dramatically in the mid-20th century and remained high. Smoking, which causes bronchitis (inflammation of the bronchi), was the primary contributing factor behind the increase. The combination of signs and symptoms of emphysema and bronchitis is known as chronic obstructive pulmonary disease (COPD), a progressive respiratory disease. Measurements of lung function are significantly lower in cigarette smokers than in nonsmokers of the same age. Values for cigarette smokers are, on the average, about equal to those of nonsmokers who are 10–15 years older. There is evidence, however, that when cigarette smokers quit smoking, measurements of pulmonary function closely approach those of nonsmokers within one to two years, even in the case of heavy smokers 50–60 years old.

The kidney removes wastes from the body by separating them from the blood and forming urine. In this process many substances are accumulated in the urine at a higher concentration than in the blood. With advancing age the concentrating ability of the kidney falls, so that a greater volume of water is required to excrete the same amount of waste material. This loss in concentrating ability is probably partially offset by a decrease in the excretory load because of reduced activity, alterations in food intake, and the reduction in muscle mass of the elderly. These changes in kidney function may not be reflected in urine volume, since volumes fluctuate widely at all ages and are determined primarily by fluid intake. The reduction in renal (kidney) function is due in part to a gradual reduction in blood flow to the kidney. Since the kidney receives a great excess of blood (about 25 percent of the blood pumped by the heart each minute), the reduction with age does not normally result in an accumulation of waste products in the blood. Any such accumulation is the result of disease that damages the kidney. The reduced concentrating ability of the kidney results from a loss of some of the nephrons, the fulsome physiological characteristics, such as the mechanisms that regulate the acidity of the blood or its sugar level, are adequate to maintain normal levels under resting conditions even in very old people. However, the aged require more time than the young to reestablish normal levels when changes from the normal occur. In order to test the effectiveness of control mechanisms of the body, physiologists produce changes experimentally and determine the rate of recovery. When the acidity of the blood is increased to the same extent in old and young subjects, it is returned to normal within 6–8 hours in the young, while in the elderly 18–24 hours are required. Similarly, the rate of return to fasting levels after sugar has been administered intravenously or orally is slower in the old than in the young. The response to insulin, which accelerates the removal of sugar from the blood, is also diminished in the elderly. The body's physiological mechanisms for adjusting to changes in environmental temperature are less adequate in the old than in the young. Consequently, older people may prefer more uniform and slightly higher temperatures than the young. High temperatures are more hazardous to the elderly, and the incidence of heat prostration in hot weather increases with age. Exercise is one of the physiological stresses of daily living. In reasonable amounts it is a valuable stimulus to maintain physiological vigour. A number of studies have indicated a lower incidence of cardiovascular disease among adults who indulge in physical activity than in those who do not. The capacity to perform muscular work diminishes progressively in the elderly. Muscle strength diminishes, though the reduction in strength is less in muscles that continue to be used throughout adult life than in those that are not. Thus, a part of the reduction in muscle strength may be an atrophy of disuse. Maximum work capacity is reduced in the elderly, largely because of the inability to deliver enough oxygen to the working muscles. In the young, the need for oxygen is met for the most part by increasing the heart rate. Under conditions of maximum work, young adults can increase their heart rate to over 200 beats per minute, the elderly to only about 150 per minute. In addition, the transfer of oxygen from the lungs to the blood is reduced in the elderly under conditions of strenuous exercise. With less than maximum exercise, there is a greater increase in blood pressure, heart rate, and respiration in the old than in the young; that is, a given work load induces a greater physiological stress in the old than in the young. Furthermore, recovery of blood pressure, heart rate, and respiration to resting values takes longer in the old.

2.9.3 What is lifestyle?

Lifestyle is the interests, opinions, behaviours, and behavioural orientations of an individual, group, or culture. The term was introduced by Austrian psychologist Alfred Adler with the meaning of "a person's basic character as established early in childhood", as in his 1929 book, *The Case of Miss R.* The broader sense of lifestyle as a "way or style of living" has been documented since 1961. Lifestyle is a combination of determining intangible or tangible factors. Tangible factors relate specifically to demographic variables, i.e. an individual's demographic profile, whereas intangible factors concern the psychological aspects of an individual such as personal values, preferences, and outlooks. A healthy or unhealthy lifestyle will most likely be transmitted across generations. According to the study done by Case et al. (2002), when a 0-3-year-old child has a mother who practices a healthy lifestyle, this child will be 27% more likely to become healthy and adopt the same lifestyle. For instance, high income parents are more likely to eat more fruit and vegetables, have time to exercise, and provide the best living condition to their children. On the other hand, low-income parents are more likely to participate in unhealthy activities such as smoking to help them release poverty-related stress and depression. Parents are the first teacher for every child. Everything that parents do will be very likely transferred to their children through the learning process. A way of living of individuals, families (households), and societies, which they manifest in coping with their physical, psychological, social, and economic environments on a day-to-day basis. Lifestyle is expressed in both work and leisure behavior patterns and (on an individual basis) in activities, attitudes, interests, opinions, values, and allocation of income. It also reflects people's self image or self concept; the way they see themselves and believe they are seen by the others. Lifestyle is a composite of motivations, needs, and wants and is influenced by factors such as culture, family, reference groups, and social class.

2.9.4 Life style management

Lifestyle management is the outsourcing of personal tasks to commercial firms and individuals. Lifestyle managers or personal assistants act as an intermediary between suppliers of commercial services and consumers who are unwilling or unable to carry out a given task for themselves. These firms typically present their offer in terms of time-saving or access to expertise, with some firms also positioning their service as a luxury good.

.

2.9.5 Life style management and healthful aging

Like many other parts of life and business, human resources have a unique life cycle. The HR life cycle is basically the sequence of the stage's employees go through and the role human resource managers are tasked to take on during each one of those stages. The HR lifecycle is a concept in human resources management that describes the stages of an employee's time with a given organization and the responsibilities of the human resources department at each stage. Each stage of the HR lifecycle presents its own challenges and opportunities. When there's a breakdown at any stage of the HR lifecycle, you need to take the necessary steps to sort out the issue such that both your employees and your business continue to grow. Below are the seven stages of the human resource's lifecycle that you need to be paying attention to as a manager:

Attraction

The first step to having great employees on your team is attracting them to your workplace – getting them to notice your employer brand. However, employer branding is not about advertising that you are a good employer. It's about being one. It's easy to think that throwing cooler, wackier perks in the workplace is the key to attracting the very best talent to your team but that just isn't it. Yes, perks are cool – playing ping pong at work is really fun. Yes, they improve day-to-day life for your employees. However, they alone aren't going to attract and keep people at your company. Your mission, current employees, company culture, and the opportunities for growth in your organization offers carry far more weight than any exciting games or free snacks. Your employer brand is what helps prospective job applicants buy into what your company is all about—your culture, people, and purpose. Your employer brand effectively highlights these qualities that make your organization a special place to work, setting you apart from the crowd, humanizing your organization, and ultimately inspiring candidates to apply for your consideration.

Recruitment

Hiring the right people is very vital to the growth and productivity of any business. In order to succeed in the recruitment phase of the HR lifecycle, your human resources department needs to:

- create a strategic staffing plan with a thorough understanding of the positions that need to be filled and what will be expected of an employee;
- create compensation and benefits packages competitive enough to attract the top talent;
- develop an interviewing protocol suitable for the positions looking to be filled;
- place the job ads in the right channels where they can be picked up by the right talent;
- select candidates whose résumés look promising, conducting employment interviews, and;
- administer assessments such as personality profiles to choose the best applicant for the job.

Onboarding

Onboarding is the process by which new employees are introduced to your organization. It is through this process that the employee becomes a member of the company's workforce through learning her new job duties, establishing relationships with co-workers and supervisors and developing a niche.

The role of human resources management at this stage is to:

- convey your organizational brand and values;
- explain your company culture (both people and professional), and;
- align institutional expectations and performance.

Creating a structured onboarding program is the key to getting the most of out of this stage of the HR lifecycle. According to a 2007 study by the Wynhurst Group, when employees go through structured onboarding, they are 58 percent more likely to remain with the organization after three years.

Enablement

This stage of the HR lifecycle entails orienting new hires and formally introducing them to your organization and its culture, mission, vision, and values. Orientation is usually conducted as a conference-style event where information is delivered to the new hires through presentations and question-and-answer sessions. Companies often schedule time for each of their leaders to come in and greet new employees, introduce themselves and explain their roles within the business.

The roles of human resource managers during the enablement stage include:

- introducing the new hires to the company mission, vision, and values;
- guiding new employees through the paperwork they need to complete;
- introducing new hires to benefit plans, answering questions about how and when to use them;
- introducing new hires to the workplace's safety, health, and any other key policies;
- ensuring new employees have all the tools they need to get started with the actual tasks of their new position including passwords, identification, parking passes, etc., and;
- introducing new employees to the rest of your staff and assigning a coworker to them to support their transition and help them feel more connected with your company.

Development

This is the stage at which the employee and the human resources department work out her long-term career goals with the company. Human resource managers can use personality profile testing at this stage to help the employee determine their best career options with the company. Career development opportunities are essential to keep an employee engaged with the company over time. Once an employee has established themselves at the company and determined their long-term career objectives, the HR department must try to help him meet their goals, if they are realistic. This can include professional growth and training to prepare the employee for positions of greater responsibility.

Retention

This stage of the HR lifecycle gives you the opportunity to re-energize your staff, thank them for their hard work, and recognize important milestones. HR departments can show employees appreciation by offering unique benefits such as flexible work schedules, gift cards, and extra paid time off. Great businesses find a way to identify and celebrate the employees who are going above and beyond, and then take deliberate measures to nurture and groom them to continue working for the company.

Separation

All cycles must come to an end – including HR life cycles. Sometimes it ends with retirement, leaving to return to school, leaving for more pay or better benefits, to tend to family responsibilities or involuntary downsizing for economic or strategic reasons.

Whatever the case, the role of HR in this process is to manage the transition by:

- ensuring that all policies and procedures are followed;
- carrying out an exit interview if that is company policy, and;
- removing the employee from the system as smoothly as possible.

All these stages of the HR lifecycle require your organization to have the right people, processes and HR technology in place in order for them to happen smoothly and run effectively. A well-executed HR lifecycle is often what separates companies enjoying high performing staff from those suffering from high turnover rates.

Happiness begins from the moment you do something for others. Those who consistently help others, are happy, and do not come across any obstacles in their lives. Research indicates that they are less stressed and experience improved mental health. The purpose of life is to serve others. However, when doing so, you should not expect something in return; your intention should be to lessen other people's misery. **"Service to others should be sincere and done from the heart; only then it is fruitful."** Do any trees eat their own fruit? No. This teaches us that human beings should not only use their mind, body and speech for themselves, but also to serve others. When you do this, nature in turn will reward you. **Your constant inner intent should be towards helping others.** If you are unable to do so for any reason, you can also **make sure that you do not hurt anyone.** This is an indirect way to help those around you. The Simply Human Lifestyle (SHL) is human beings being human. It consists of The Four Pillars: Eat. Sleep. Move. Enjoy -- LIKE A HUMAN. It is a way to try and get people to think on their own about how we, as humans, are designed to function. My goal for creating the SHL is to try and help anyone who is not happy with the way they look, feel, and/or perform. My goal is to get information out there that will help people regain their health and wellness -- if they want to be healthy. If you are already healthy and happy and enjoying life -- then congratulations -- these guidelines may not apply to you.

The Simply Human Lifestyle is not a quick fix or a 30-day plan. There are no supplements you MUST take. There are no gimmicks. It is not a cut and dry, one size fits all rule book. It requires personal experimentation, research and seeking. What is being sought after are the ways to eat, move and sleep that are the most human. Again -- the four pillars of the SHL are

- Eating human food in ways humans are supposed to eat
- Moving in ways that humans are supposed to move
- Sleeping like humans are supposed to sleep
- Enjoying life like humans are supposed to enjoy life.

All of the pillars are connected. You can't just do one of the four pillars and expect to be healthy. And you can't do all but one and expect to be healthy. They're all connected and they all interact with each other in some way -- physically or psychologically -- they are all connected.

I believe humans, in our best intentions, have let technology and innovation get in the way of human beings being human. Technology, intervention and innovation have done great things for commerce, information sharing, science, education, and world affairs. But the human himself (or herself) has paid the price.

Examples of these negative effects are

- Synthetic foods
- Fortified foods
- Most supplementation
- Expensive and hi-tech running shoes
- Prime Time TV
- Most pharmaceuticals
- Iatrogenic affects
- Food scales
- Counting calories

The Simply Human Lifestyle (SHL) tries to mitigate the negative effects that modern technology and civilization/domestication have placed on our health. The SHL is NOT against advances in modern medicine that deal with communicable diseases, high-risk pregnancies and sewing limbs back on (aka emergencies). It is against the "pill for every ill" system that has been set up. It is *for* prevention and *against* defaulting to treatment plans only. The SHL wants health care providers to think about the person who has the illness not just the illness the person has. The SHL is not concerned with weight or other health markers. Those things will all take care of themselves if HEALTH is the goal. The SHL wants humans to ask themselves why they make choices they make and do things that they do. The SHL wants humans to understand that it is OK to change and evolve because as soon as you stop changing, you start dying.

THE SIMPLY HUMAN LIFESTYLE -- ENJOY

All 4 pillars are equally important -- but if I was being tortured and had to say which was most important, I'd probably say "enjoy" through my tears. This is the part of the Simply Human Lifestyle that deals with having fun and managing stress levels. It means laughing when a huge truck splashes water all over you. It's stopping and smelling the roses. Enjoying life includes playing -- basketball, tag, rolling around on the ground with your kids or grandkids, nieces or nephews. It’s taking a walk on a beautiful day and letting the sun shine on your face. It’s seeing the glass as half full. I write down 5 things I’m grateful for everyday -- just to remind myself how many great things I have in my life. I also try to spend some time quieting my mind every day. It doesn’t matter how good you’re eating, sleeping or moving -- if you’re not enjoying yourself, you’ll never be the healthiest version of yourself you can be.

THE SIMPLY HUMAN LIFESTYLE -- MOVING

An easy way to remember the philosophy for moving is -- Move slow a lot. Lift heavy things correctly. Work on mobility. The SHL wants humans to try and use self-propulsion as much as humanly possible. The SHL is not opposed to endurance training or events but it does want humans to understand the serious effects of chronic exercise/cardio and oxidative stress. The SHL does not believe an hour of cardio a day is necessary for human health. The SHL believes that running on a treadmill will get you exactly where the treadmill will -- nowhere. Walking is the most important form of movement to the SHL.

THE SIMPLY HUMAN LIFESTYLE -- SLEEP

The SHL is a *proponent* of regular sleeping patterns and getting as much sleep as possible before midnight, and an *opponent* of ramming artificial lights into your eyes after the sun goes down. The SHL is a fan of wearing orange-tinted glasses after the sunset that block out blue light and in favor of sleep masks to attain complete darkness while sleeping. The SHL believes that circadian rhythms are hugely important and largely ignored in today's society.

THE SIMPLY HUMAN LIFESTYLE -- FOOD

What is human-food? is a volatile question and very confusing to some. I believe we have overcomplicated food and that food choices should be simple, wholesome, delicious and satiating -- NOT void of nutritional value and density. The variety of foods that humans have thrived on throughout history is extremely diverse. The list of "foods that are OK for humans to eat" is incredibly long and is different for every person and every genome type. There is no "absolute truth" list of foods that applies to everyone.

However, there is an "absolute truth" list of **FOODS TO AVOID.**

And that list looks like this:

- processed sugar
- foods not found in nature (which includes most grains that have been grossly modified from their natural state, trans fats, food colorings and other things made in a lab)
- vegetable oils
- diet soda
- foods that can't grow in the geographic regions where your ancestors are from

The SHL is a proponent of a 'no sugars, no grains' approach and advises to avoid legumes and vegetable oils. The SHL believes in letting animals be animals and is strongly against feed lots, chicken factories and pig crates. Grass fed meats, pastured pigs and chickens, wild caught seafood and dairy from grass-fed cows are all good things in the eyes of the SHL. The SHL loves bone broth and marrow. The SHL also loves organ meats such as liver, tongue, kidney and heart.

THE SIMPLY HUMAN LIFESTYLE -- SHOPPING LIST

there are obviously hundreds more foods out there that the SHL would consider real, human food, this is just a starting point -- and these guidelines are for people who don't look, feel and perform how they want

- extra virgin coconut oil*
- MCT oil
- unsalted, organic butter*
- Extra Virgin Olive Oil* this brand is my favorite
- heavy whipping cream*
- lard or tallow
- free range eggs*
- veggie or beef bouillon cubes (not the low sodium)

variety of grass-fed or wild caught meat sources (fat cuts -- not lean or “skinless”)

- beef
- tuna steak
- salmon
- sardines
- herring
- pork
- chicken

Veggies and Fruits*

- broccoli
- asparagus
- spinach
- romaine
- mustard greens
- collard greens
- kale
- cucumbers
- squash (spaghetti, butternut, yellow)
- berries (all kinds)*
- tomatoes
- avocado
- onions

Raw, Unsalted and Unshelled Nuts

- macadamia
- almonds
- brazil nuts
- pecans
- filberts

coffee*

**denotes that organic is important*

THE SIMPLY HUMAN LIFESTYLE -- GETTING STARTED: NUTRITION

Begin to Eliminate or Completely Eliminate:

- sugars (any form or anything ending in “ose” [dextrose, maltose, fructose] except what is naturally in foods listed above)
- grains (wheat, bread, corn, soy, rye, barley, oats, etc...)
- artificial sweeteners (half and half, aspartame, etc...)
- polyunsaturated fats (vegetable oils [corn, soy, cottonseed], hydrogenated or partially hydrogenated oils, margarine)
- part-skim milk and/or pastuerized cheese, or yogurt (full fat, organic, raw of these are OK)

Protein:

The SHL is not a fan of super specific macro-nutrient portioning -- but to get started, here is an idea of what you could do:

- take ideal weight and divide it by1.5 and 2, that’s roughly your ideal protein intake range (ex: 180 lbs / 2 = 90, 180 lbs / 1.5 = 120. Range of 90-120 for 180 pound weight goal)
- take that number and divide by 7 (or just divide your ideal weight by 14), that’s how many blocks of protein you should aim for per day -- give or take a few grams
- 1 block of protein = 1 oz meat or cheese, 1 egg, 2 oz nuts So if ideal weight is 180, divided by 2 is 90, divided by 7 is 12.8 so shoot for 13 blocks give or take a few. That's easier than having to calculate calories for every little thing you eat
- Example: 3 eggs for breakfast, 4 ounce steak at lunch, 5 oz tuna steak at dinner (I would do all that at dinner since I usually only eat one large meal per day -- which makes an incredibly satisfying dinner...a feast if you will)

limit nuts to no more than 2 oz, 3-4 days per week (if any at all -- I've figured out that I just have to stay away from nuts for the most part)

Carbs:

no more than 100g per day -- I feel best when I'm getting around 50g per day

Here are some examples of amounts of veggies equaling 25g of carbs:

- 13 oz of broccoli (almost a pound of broccoli)
- 9 oz kale
- 22 oz asparagus (almost 1.5 pounds of asparagus)
- 24 oz spinach
- 26 oz romaine
- 40 oz cucumbers w/o peel (2.5 POUNDS!!)
- 26 oz mushrooms
- 25 oz zucchini

so there should be no shortage of veggies on this life-style

Fats:

- eat fats from top of shopping list until sated/full
- cook with butter, extra virgin olive oil, lard, tallow and coconut oil

Miscellaneous

- full fat, plain yogurt is OK as long as it doesn't cause gastric stress
- eat whole, real human foods
- don’t eat anything with more than 5 ingredients
- majority of foods should come from refrigerator or freezer not a box

- eat food that will eventually spoil in a short time

The SHL does not recommend a "cheat" or "treat" day. Eat fatty, delicious, yummy, human food all the time and you won't have to reward yourself after a week of restriction. The SHL believes that system is not sustainable.

Lifestyle is a way used by people, groups and nations and is formed in specific geographical, economic, political, cultural and religious text. Lifestyle is referred to the characteristics of inhabitants of a region in special time and place. It includes day to day behaviors and functions of individuals in job, activities, fun and diet.

In recent decades, life style as an important factor of health is more interested by researchers. According to WHO, 60% of related factors to individual health and quality of life are correlated to lifestyle. Millions of people follow an unhealthy lifestyle. Hence, they encounter illness, disability and even death. Problems like metabolic diseases, joint and skeletal problems, cardio-vascular diseases, hypertension, overweight, violence and so on, can be caused by an unhealthy lifestyle. The relationship of lifestyle and health should be highly considered.

Today, wide changes have occurred in life of all people. Malnutrition, unhealthy diet, smoking, alcohol consuming, drug abuse, stress and so on, are the presentations of unhealthy life style that they are used as dominant form of lifestyle. Besides, the lives of citizens face with new challenges. For instance, emerging new technologies within IT such as the internet and virtual communication networks, lead our world to a major challenge that threatens the physical and mental health of individuals. The challenge is the overuse and misuse of the technology.

Therefore, according to the existing studies, it can be said that: lifestyle has a significant influence on physical and mental health of human being. There are different forms of such influences. Consanguinity in some ethnicity is a dominant form of life style that it leads to the genetic disorders. Reformation of this unhealthy life style is a preventing factor for decreasing the rate of genetic diseases. In some countries, the overuse of drugs is a major unhealthy life style. Iran is one of the 20 countries using the most medications. They prefer medication to other intervention. Furthermore, in 15–40% of cases they use medications about without prescription. Pain relievers, eye drops and antibiotics have the most usage in Iran. While self-medications such as antibiotics have a negative effect on the immune system, if the individual would be affected by infection, antibiotics will not be effective in treatment. Overall, 10 percent of those who are self-medicated will experience severe complications such as drug resistance. Sometimes drug allergy is so severe that it can cause death.

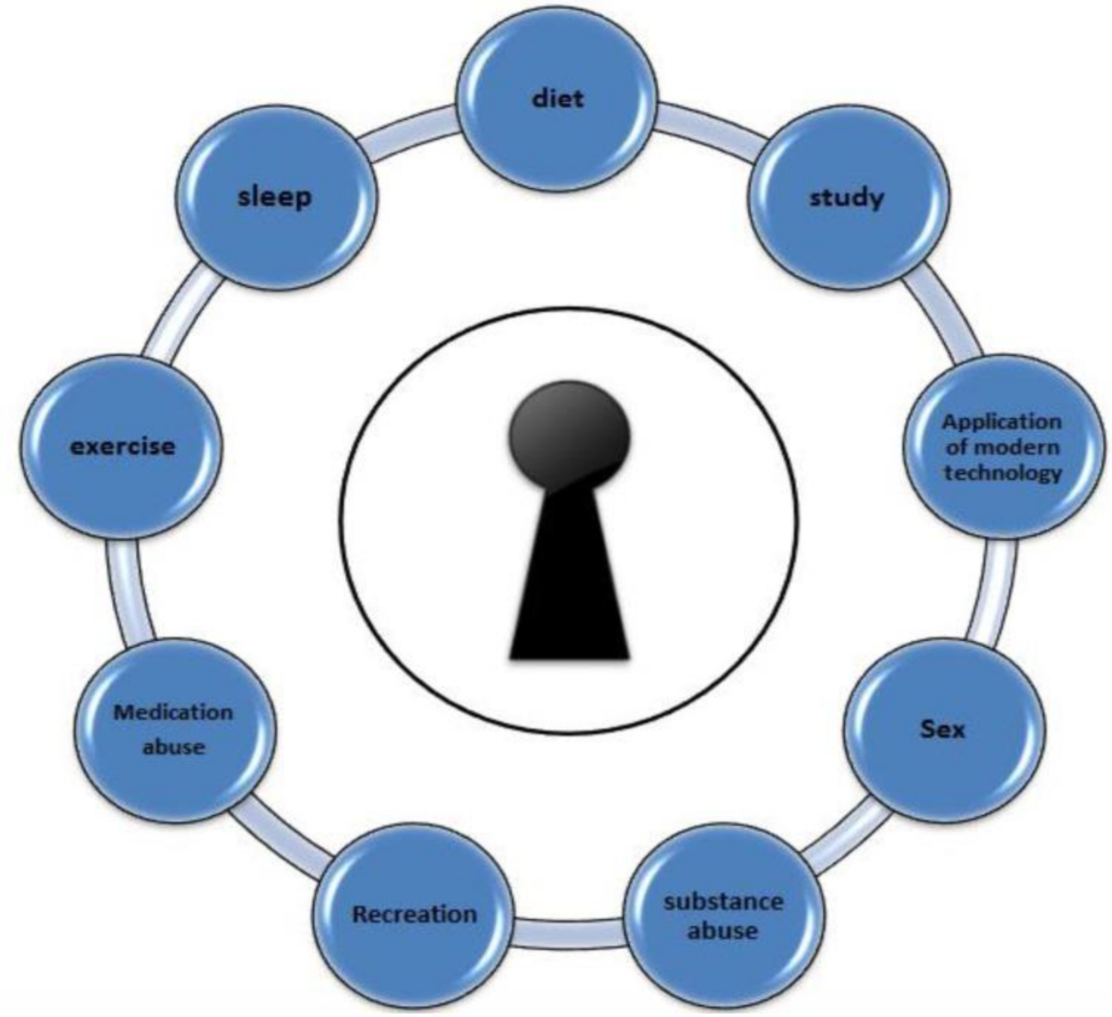
Finally, variables of lifestyle that influence on health can be categorized in some items:

1. **Diet and Body Mass Index (BMI)**: Diet is the greatest factor in lifestyle and has a direct and positive relation with health. Poor diet and its consequences like obesity is the common healthy problem in urban societies. Unhealthy lifestyle can be measured by BMI. Urban lifestyle leads to the nutrition problems like using fast foods and poor foods, increasing problems like cardiovascular.
2. **Exercise:** For treating general health problems, the exercise is included in life style. The continuous exercise along with a healthy diet increases the health. Some studies stress on the relation of active life style with happiness.
3. **Sleep:** One of the bases of healthy life is the sleep. Sleep cannot be apart from life. Sleep disorders have several social, psychological, economical and healthy

consequences. Lifestyle may effect on sleep and sleep has a clear influence on mental and physical health.

4. **Sexual behavior:** Normal sex relation is necessary in healthy life. Dysfunction of sex relation is the problem of most of societies and it has a significant effect on mental and physical health. It can be said that dysfunctional sex relation may result in various family problems or sex related illnesses like; AIDS
5. **Substance abuse:** Addiction is considered as an unhealthy life style. Smoking and using other substance may result in various problems; cardiovascular disease, asthma, cancer, brain injury. According to the resent studies in Iran, 43% of females and 64% of males experience the use of hubble-bubble. A longitudinal study shows that 30% of people between 18–65 years old smoke cigarette permanently.
6. **Medication abuse:** It is a common form of using medication in Iran and it is considered as an unhealthy life style. Unhealthy behaviors in using medication are as followed: self-treatment, sharing medication, using medications without prescription, prescribing too many drugs, prescribing the large number of each drug, unnecessary drugs, bad handwriting in prescription, disregard to the contradictory drugs, disregard to harmful effects of drugs, not explaining the effects of drugs.
7. **Application of modern technologies:** Advanced technology facilitates the life of human beings. Misuse of technology may result in unpleasant consequences. For example, using of computer and other devices up to midnight, may effect on the pattern of sleep and it may disturb sleep. Addiction to use mobile phone is related to depression symptoms.
8. **Recreation:** Leisure pass time is a sub factor of life style. Neglecting leisure can bring negative consequences. With disorganized planning and unhealthy leisure, people endanger their health.
9. **Study:** Study is the exercise of soul. Placing study as a factor in lifestyle may lead to more physical and mental health. For example, prevalence of dementia, such as Alzheimer's disease is lowering educated people. Study could slow process of dementia.

With a look at existing studies in health domain, 9 key factors can be suggested for healthy life style. In regard to each factor, the systematic planning in micro and macro level can be established. It can provide a social and individual healthy lifestyle.



Sub Unit – X

Physiological responses of various therapeutic modalities and rehabilitation

2.10.1 What are therapeutic modalities?

Therapeutic modalities are commonly used by physiotherapists to help their patients/clients achieve therapy goals. Electro-physical agents are used to create physiological effects, and these electrotherapy modalities have been making part of the physiotherapy-used modalities for decades. The choice of which modality to use may depend on a specific condition, patient's needs and goals. This page will look at the rationale for use of a modality and its safety considerations.

Electrical stimulating currents such as transcutaneous electrical nerve stimulation (TENS) and interferential current (IFC) utilize electrical energy, the flow of electrons or other charged particles from one area to another, causing depolarization of muscle or nervous tissue. Electrical stimulation has most commonly been used for the modulation of pain through stimulation of cutaneous sensory nerves and the following analgesic mechanisms:

1. Activation of large diameter A-beta fibers inhibits the pain transmission, carried by A-delta and C afferent fibers, from the spinal cord to the brain - also known as the gate control theory of pain
2. Stimulation of A-delta and C fibers causes the release of endogenous opioids (endorphin and enkephalin) resulting in prolonged activation of descending analgesic pathways

Thermotherapy and cryotherapy, the application of therapeutic heat and cold, are referred to as conductive modalities - they utilize the conduction of thermal energy to produce a local and occasionally a generalized heating or cooling of superficial tissues with a maximum depth of penetration of 1 cm or less.

Thermotherapy includes warm whirlpool, warm hydrocollator packs, paraffin baths, and fluidotherapy. Primary physiological effects of heat include:

- Vasodilation and increased blood flow
- Increased metabolic rate
- Relaxation of muscle spasm
- Pain relief via the gate-control mechanism and reduced ischemia
- Increased elasticity of connective tissue

It also works by stimulating fibroblast proliferation, accelerating endothelial cell proliferation, and improved phagocytic activity of inflammatory cells. Heat is believed to have a relaxing effect on muscle tone by reducing muscle spindle and gamma efferent firing rates; there is also the theory that relaxation of muscle is assumed to occur with the disappearance of pain.

Cryo therapy includes ice massage, cold hydro collator packs, cold whirlpool, cold spray, contrast baths, ice immersion, cold compression, and cryokinetics, Primary physiological effects of cold include:

- Vasoconstriction and decreased blood flow (within first 15 - 20 minutes)
- Decreased metabolic rate
- Pain relief with decreased muscle spasm via gate-control mechanism and decreased nerve conduction velocity

Restriction of local blood flow reduces the potential for edema to develop. Slower metabolism releases fewer inflammatory mediators, reduces edema formation and decreases oxygen demand of tissues to minimize their chances of further injury from ischemia. Cold decreases local neural activity, appears to raise the threshold stimulus of muscle spindles and depresses the excitability of free nerve endings, resulting in an increased pain threshold and reduced muscle spasm.

Ultrasound utilizes sound energy, pressure waves created by the mechanical vibration of particles through a medium. The flow of ultrasound may be delivered as an uninterrupted stream (continuous mode) or delivered with periodic interruptions (pulsed mode). Ultrasound is classified as a deep heating modality capable of producing a temperature increase in tissues of considerable depth because it travels very well through homogenous tissue (e.g. fat tissue). Traditionally it has been used for its thermal effects but it is capable of enhancing healing at the cellular level. Continuous ultrasound is most commonly used when thermal effects are desired but non-thermal effects will also occur. It has been shown to alter all phases of tissue repair: stimulates phagocytic activity of inflammatory cells such as macrophages, and promotes release of chemical mediators from inflammatory cells which attract and activate fibroblasts to the site of injury, stimulates and optimizes collagen production, organization and ultimately functional strength of scar tissue. An examination of research studies to assess changes in blow flow with ultrasound produced inconclusive results; however, recent studies show that nitric oxide released by ultrasound therapy may be a potent stimulator of new blood vessel growth at the site of injury. Ultrasound also aids in pain relief and the literature has proposed reduced conduction of pain transmission as a possible mechanism for the analgesic effects. More recently, low-intensity pulsed ultrasound has been shown to accelerate the rate of healing of fresh fractures due to the enhancement of angiogenic, chLight Amplification for the Stimulated Emission of Radiation (LASER) utilizes electromagnetic radiant energy, the movement of photons through space. The low-power or cold laser produces little or no thermal effects but seems to have some significant effect on soft-tissue and fracture healing as well as on pain management. Light at the wavelength typically employed in laser therapy is readily absorbed by enzymes, hemoglobin, fibroblasts, and neurologic tissue. Laser has been shown to stimulate cell degranulation causing the release of potent inflammatory mediators such as growth factors, activate phagocytic processes at the site of injury, and activate fibroblast cell function to increase collagen deposition and improve tensile strength. Some reports also show a small decrease in edema produced by inflammation following laser therapy. Absorption by hemoglobin releases nitirc oxide resulting in endothelial cell proliferation and increased microcirculation. Low dosages also result in significantly decreased sensory nerve conduction velocity effect in reducing pain.

2.10.2 Physiological responses of various therapeutic modalities

Therapeutic modalities represent the administration of thermal, mechanical, electromagnetic, and light energies for a specific therapeutic effect; for example, to decrease pain, increase range of motion (ROM), improve tissue healing, or improve muscle activation. The terms *therapeutic modalities* and *physical agents* are often used interchangeably to describe a wide array of treatments and interventions that provide a variety of therapeutic benefits. The term *physical agents* reflects the use of physical energies—such as thermal, mechanical, electromagnetic, or light—but fails to include the purpose or intention of their application. The term *therapeutic modalities*, as used throughout this text, more appropriately reflects the ability of these interventions to provide therapeutic benefits. Therapeutic modalities have long been, presently are, and will continue to be a part of rehabilitation and are used to complement other elements of the more comprehensive patient care plan, such as therapeutic exercise (e.g., strengthening, stretching, neuromuscular reduction, balance), manual therapy (e.g., joint and tissue mobilization, manipulation), and patient education (e.g., body mechanics, postural retraining, home exercise program, risk reduction). Cold therapy and compression may be used in the early phases of rehabilitation to limit swelling and pain that a patient may experience following acute injury or surgery. Continuous ultrasound or other heat therapy may be applied to improve elasticity of ligaments or joint capsular structures before beginning ROM activities in a patient who has deficient ROM. Electrical stimulation may be used to increase activation and facilitate volitional recruitment of skeletal muscle until the patient can effectively contract the muscle and begin additional activities. These examples reflect the complementary use of modalities to achieve clinical goals. Because the effectiveness of these treatments may vary from patient to patient, the practitioner is challenged to identify those patients who are more likely to respond to a specific intervention. In this manner, the practitioner must consider or judge the probability or likelihood that a given intervention will help a particular patient. These decisions and others represent the basis of *clinical decision-making*. Competency with clinical decision-making is the basis for effective patient outcomes and attainment of goals. Therefore, clinical decision-making can be thought of as the process of using information, experience, and judgments to decide which clinical interventions will most likely improve the problems identified in the examination. The bottom line is this: When identifying and establishing an intervention plan, the focus should be on selecting interventions that will most likely achieve positive results or outcomes—both quantitative and qualitative. When judiciously selected and applied, therapeutic modalities may play a significant role in successful patient care.

2.10.3 Rehabilitation

The process of helping a person who has suffered an illness or injury restore lost skills and so regain maximum self-sufficiency. Rehabilitation exercise aims to bring back full function following injury through restoring muscle strength, endurance, power, and improving flexibility. Rehabilitation is as important as treatment following any injury but is often forgotten. It is really important to understand that injuries will improve and heal more successfully if an exercise plan is followed. However, every person responds differently and healing times will vary. The main thing to remember is that prevention is better than cure and a good, well thought out rehabilitation plan will help keep injuries at bay. Rehabilitation exercises should begin as soon as possible after the acute phase which is typically around 72 hours. Exercises should be pain free with a few rare exceptions. There are three different stages within rehabilitation that are important to stick to if returning to pain-free daily life and/or sporting activities:

- **Early stage rehabilitation:** gentle exercise allowing for the damaged tissue to heal.
- **Mid stage rehabilitation:** progressive loading to the muscles, tendons, bones or ligaments. This develops tensile strength producing a healed tissue that will be able to withstand the stresses and strains of everyday life and exercise.
- **Late stage rehabilitation:** functional exercises and drills to improve your strength, flexibility and stamina, and to stress the new tissues to ensure the body is ready for pain-free daily movement and exercise.

Combining sports massage and rehabilitation following an injury is a fantastic way to get back to fitness quickly and to prevent further injuries from happening.

Benefits of exercise rehabilitation

Benefits include;

- faster recovery
- reduced pain
- restoring muscle strength, endurance and power
- improving flexibility
- enhanced proprioception (an essential part of our bodies' ability to move) and improved balance

- injury prevention
- creating resilience and reducing chances of re-injury

What conditions would benefit from exercise rehabilitation?

- chronic injuries, such as long-term back pain, knee pain, and ankle instability
- hypermobility
- injuries not responding to manual treatment, this may be due to weakness in muscles or poor posture

Exercise rehabilitation can also help to;

- support specific sporting goals
- improve strength and fitness
- improve posture and flexibility

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

2.11.1 What is Ergogenic Aids?

In the context of sport, an ergogenic aid can be broadly defined as a technique or substance used for the purpose of enhancing performance. Ergogenic aids have been classified as nutritional, pharmacologic, physiologic, or psychologic and range from use of accepted techniques such as carbohydrate loading to illegal and unsafe approaches such as anabolic-androgenic steroid use. The efficacy of many of these techniques is controversial, whereas the deleterious side effects are clear. Physical therapists should be able to recognize the signs of ergogenic aid abuse in individuals under their care, and they should be aware of the side effects of these aids. Moreover, the physical therapist can serve as a resource for those individuals seeking information on the risks and benefits of ergogenic aids. People use performance enhancers to improve their performance during high-intensity physical exercise. A

performance enhancer, or ergogenic aid, is anything that gives you a mental or physical edge while exercising or competing. This can range from caffeine and sports drinks to illegal substances. There are a variety of both safe and harmful ergogenic aids.
The NCAA and the Olympics commission have banned some substances. This is because they offer an unfair advantage or can cause harm to the athlete. These include:

Anabolic and other steroids

Anabolic and other steroids are illegal in sporting events and according to the law. The side effects are numerous and potentially fatal. Examples include androstenedione, stanozolol, axiron, and fortesta.

Dehydroepiandrosterone (DHEA)

DHEA is possibly the most abundant steroid in humans. Using synthetic versions to increase steroid production is potentially dangerous.

Diuretics

Diuretics are medications that cause a person to urinate more frequently. Athletes use diuretics in the hopes that they will help dilute performance-enhancing drugs. Diuretics can cause a variety of harmful side effects such as cramping, dizziness, blood pressure drops, and electrolyte imbalances.

Blood doping

Blood doping is the process of boosting red blood cells to help carry more oxygen to the muscles and lungs. It can be done through a blood transfusion or by taking drugs like erythropoietin.
Erythropoietin is a medication doctors prescribe for people who don't make a lot of red blood cells. Athletes use the medicine to make more red blood cells in their bodies. This can increase a person's ability to use oxygen because these cells carry oxygen. Endurance athletes may especially try to use erythropoietin because they believe they can perform longer with more oxygen. However, using the medication when not medically needed can cause blood clots and death.
Blood doping is the process that cost Lance Armstrong his Tour de France titles.

Ephedrine

Ephedrine is a central nervous stimulant. Ephedrine produces similar effects to adrenaline, but it too can be dangerous. It can cause serious cardiovascular effects, including stroke, and a whole host of other problems. Both athletic organizations and the FDA have banned it.

2.11.2 Physiological aspects of various Ergogenic aids

Ergogenic aids are mechanical, nutritional, pharmacological, physiological and psychological tools that athletes use to increase energy, performance and recovery. Commonly used ergogenic aids include dried adrenal glands, amino acids, bee pollen, caffeine, carnitine, chromium, creatine, ginseng, glucosamine and protein powders. Side effects from high doses may include allergic reactions, central nervous system and gastrointestinal disorders, and kidney damage. Anabolic steroids, androstenedione (andro) and DHEA, beta-hydroxy-beta-methyl butyrate (HMB), gamma hydroxybutyric acid (GHB) and human growth hormone (HGH) may cause significant side effects, and, in some cases, death. The International Olympic Committee has banned androstenedione and human growth hormone, and the National Collegiate Athletic Association (NCAA) has banned caffeine at the 600-milligram level (six to eight 8-ounce cups of brewed coffee daily). Consistent sport-specific training; well-designed sport-specific diets supported by adequate fluids, vitamin and mineral supplements; and rest are still the safest strategies for sports performance. The field of sports nutrition is growing to address these and other strategies. But so are ergogenic aids, especially through the Internet. Lactic acid is produced in muscle cells when NADH + H^+ formed in glycolysis is oxidized to NAD^+ by a transfer of the hydrogen ions to pyruvic acid ($C_3H_4O_3$), which, in turn, is reduced to lactic acid ($C_3H_6O_3$). In muscle tissue, lactic acid is produced in amounts that are in equilibrium with pyruvic acid under normal resting conditions. In addition, lactic acid is always produced by red blood cells, portions of the kidneys, and certain tissues within the eye. Both resting and exercise values depend on the balance between lactic acid production (appearance) and removal (disappearance, or clearance). This balance of appearance and disappearance is called *turnover*. At normal pH levels lactic acid almost completely (≈99%) dissociates into hydrogen ions (H^+) and lactate ($C_3H_5O_3^-$, designated as La^-). Thus technically, lactic acid is formed, but lactate is what is measured in the bloodstream. Despite this distinction, the terms *lactic acid* and *lactate* are often used synonymously. When production exceeds removal, lactate is said to accumulate. The questions, then, especially during exercise, are what conditions result in lactic acid production and what processes lead to lactic acid/lactate removal?

The following precautions are advised:

1. Individuals with preexisting kidney dysfunction or those at high risk for kidney disease (e.g., diabetics and individuals with a family history of kidney disease) should either avoid creatine supplementation or undergo regular medical monitoring. Regular checkups are recommended for everyone taking creatine because any individual may react adversely to any substance, and excess creatine is a burden that must be eliminated by the kidneys.
2. Individuals wishing to maintain or decrease body weight while participating in strenuous exercise should avoid creatine supplementation.
3. High-dose creatine supplementation should be avoided during periods of physical activity under high thermal stress.
4. Adequate fluid and electrolytes should always be ingested.
5. Individuals younger than the age of 18 should not supplement with creatine.
6. Pregnant or lactating females should not supplement with creatine.
7. The ingestion of creatine during exercise should be avoided.

2.11.3 What is massage?

Massage is a therapeutic manipulation of the soft tissues of the body with the goal of achieving normalization of those tissues. Massage can have mechanical, neurological, psychological, and reflexive effects. Massage can be used to reduce pain or adhesions, promote sedation, mobilize fluids, increase muscular relaxation, and facilitate vasodilation. Massage easily can be a preliminary treatment to manipulation; however, it clearly targets the health of soft tissues, while manipulation targets joint segments. Massages consists primarily of hand movements, some of which may be traction based. Traction is defined as the act of drawing or pulling or application of a pulling force. Traction sometimes involves equipment but also can be applied manually. In addition, traction affects changes in the spinal column itself with soft tissues only secondarily changed. Effects massage, like those of traction, tend to be fairly non-specific.

2.11.4 Types of massage

Various forms of massage, traction, and manipulation have been used in medicine throughout the world for several thousand years. Each modality represents treatment for pain sought by a steadily increasing number of people. Throughout history, massage has been woven into the cultural context of medicine. Massage consists of both Eastern and Western variants has been reversed into a resurgence of interest. The people are pursing massage in increasing numbers for various reasons, (e.g., relief of pain, relaxation, conditioning). While little doubt exists, that massage is beneficial for certain conditions, additional research is needed to establish its profile of efficacy.

Western

Western massage is the most common type of massages practiced today. Western massage organizes variations of soft tissue manual therapy into categories. The essence of Western massage is use of the hands to apply mechanical forces to the skeletal muscles and skin, although the intent may be to affect either more superficial or deeper tissues. Types of basic Western massage are characterized by whether (1) the over the skin, i.e., effleurage, (2) soft tissue is compressed between the hands or fingers and thumb, i.e., petrissage, (3) the skin or muscle is impacted with repetitive compressive blows, (i.e., tapotement), or (4) shearing stresses are created at tissue interfaces below the skin, i.e., deep friction massage.

Effleurage

* In this approach, the practitioner's hands glide across the skin overlying the skeletal muscle being treated.
* Oil or powder is incorporated to reduce friction; hand-to-skin contact is maintained throughout the massage strokes.
* Effleurage can be superficial or deep.
* Light strokes energize cutaneous receptors and act by nonreflexive or vascular reflexive mechanisms, whereas deep stroke techniques mechanically mobilize fluids in the deeper soft tissue structures.
* Deep stroking massage is performed in the direction of venous or lymphatic flow, whereas light stroking can be in any direction desired.
* Effleurage may be used to gain initial relaxation and patient confidence, occasionally to diagnose muscle spasm and tightness, and to provide contact of the practitioner's hands from one area of the body to another.
* The main mechanical effect of effleurage is to apply sequential pressures over contiguous soft tissues so that fluid is displaced ahead of the hands as tissue compression is accomplished.

Petrissage

* Petrissage involves compression of underlying skin and muscle between the fingers and thumb of one hand or between the two hands
* Tissue is squeezed gently as the hands move in a circular motion perpendicular to the direction of compression.
* The main mechanical effects are compression and subsequent release of soft tissues, reactive blood flow, and nonreflexive response to flow.

Tapotement

*This percussion-oriented massage involves striking soft tissue with repetitive blows, using both hands in a rhythmic, gentle, and rapid fashion
* Numerous variations can be defined by the part of the hands making an impact with the body.

* The therapeutic effect of tapotement may result from compression of trapped air that occurs on impact.
* The overall effect of tapotement may be stimulatory, therefore, healthy persons with increased tolerance of this approach are more likely to find this type of massage useful.

Deep friction

*Pressure is applied with the ball of the practitioner's thumb or fingers to the patient's skin and muscle.
* The main effect of deep friction massage is to apply shear forces to underlying tissues, particularly at the interface between two tissue types, e.g., dermis-fascia, fascia-muscle, muscle-bone.
* Deep pressure keeps superficial tissues from sharing so that shear and force are directed at the deeper tissue surface interface.
* Deep friction massage frequently is used to prevent or slow adhesions of scar tissue.

Eastern massage

Over the centuries, Eastern massage systems have been an integral part of the cultures where they are practiced. Systems for evaluation, diagnosis, and treatment generally are not grounded in conventional Western neurophysiology. Eastern massage includes, among other approaches. Shiatsu, (i.e., a Japanese system based on traditional Chinese Meridian theory with principles of Western science). The theory of Shiatsu is based upon the system of the 12 traditional Chinese meridians (i.e., major channels) of the body in which the energy or life force, or Chi circulates. Acupressure pressure points, situated along the course of channels, allow access to these channels. Acupressure applies massage forces, largely through digital pressure, to the same points treated with acupuncture needles. Imbalances of energy along the meridians are believed to cause disease and can be rectified by localized finger pressure.

Reflexology and auriculotherapy

*These systems of massage share the meridian concept with Shiastsu.
* In these approaches, the meridians are believed to have whole body representations on the extremities (similar to the homunculus of the brain).
* The feet (in reflexology) and the ear (in auriculotherapy) have been mapped in detail.

Massages technique

The practitioner controls several variables of massage, including milieu. Actual application of treatment includes rhythm, rate, pressure, direction, and duration.

Most massage approaches involve a friction-reducing medium, so that the hands of the practitioner move along the patient's skin with minimal friction. Powders or oils often are used. Massage strokes also should be regular and cyclic. The rate of application, for massage varies with the type of technique. In some approaches, e.g., tapotement, percussion, the rate is several times per second while in others it is much slower.

The amount of pressure depends upon technique and desired results. Light pressure may produce relaxation and relative sedation and may decrease spasm; breakdown of adhesions and intervention at a deeper tissue level may require heavier pressure. Treatment of edema and stretching of connective tissue generally requires intermediate amounts of pressure. Direction of massage often is centripetal to provide better mobilization of fluids toward the central circulation. The sequence of tissues treated often is performed in centripetal fashion.

When muscles are treated, motions generally are kept parallel to muscles fibers. If the treatment goal is to reduce adhesions, shearing forces are circular or at least include cross-fiber components. The area to be treated with massage depends upon the condition being treated and may vary from a well-circumscribed area to treatment depends upon the area being treated, desired therapeutic goals, and patient tolerance. Wide variation exists regarding treatment duration, which often is guided by changes occurring to tissue during massage application. If massage is performed before other treatments, duration may be determined by the result needed in order to optimize the next treatment step. Duration of a massage therapy program can range from one week to months and depends upon verifiable therapeutic goals. Patients must be re-examined from time to time, depending upon diagnosis and therapeutic goals, to ensure satisfactory progress.

Physiologic effects of massage

Massage produces some mechanical effects. Mechanical pressure on soft tissue displaces fluids. Fluid moves in the direction of lower resistance under the static forces of the practitioner's hands, but a moving locus of pressure creates a pressure gradient. Assuming no significant resistance, pressure is lower proximal to the practitioner's advancing hand. Once mobilized fluid leaves the soft tissues, it enters the venous or lymphatic low-pressure systems. The amount of fluid mobilized in any single treatment is likely to be quite small; however, the physiatrist needs to be aware of this physiologic effect in patients with significantly compromised cardiovascular or renal function. When treating lymphedema, massage is performed more proximally and then moves distally, based upon the belief that proximal blockage in the lymph channels must be opened first to allow for subsequent distal mobilization of fluid and protein. Kneading and stroking massage decreases edema; compression converts non-pitting to pitting edema. In addition to strictly mechanical effects, these massage approaches release histamine, causing superficial vasodilation to assist in washing out metabolic waste products. Venous return increases, which subsequently increases stroke volume.

Some evidence suggests that massage increases blood flow contractually, however, the mechanism of this postulated action has not been well established. These effects on mobilization of fluids are more important in flaccid or inactivated limbs because normal compression supplied by skeletal muscle contraction usually is not present in those cases, Studies in recent years suggest that massage may decrease blood viscosity and hematocrit and increase circulating fibrinolytic compounds. Preliminary data suggest an explanation for the success of massage in decreasing deep vein thrombosis (DVT). Massage may be contraindicated in the presence of existing thrombosis. Other blood compounds that show increases through massage include myoglobin, creatine kinase, lactate dehydrogenase, and glutamic oxaloacetic transaminase. Temporary increases in these substances represent local muscle cell leakage from applied pressure. Lactate decreases in massaged muscles as well. Massage may decrease muscle spasm and increase force of contraction of skeletal muscle. Decreased spasm and increased endurance may result from wash out of metabolic waste products by fluid mobilization and increased blood flow, Decreased muscle soreness probably results from metabolic wash out.

Reflexive changes

Massage can stimulate cutaneous receptors, spindle receptors, and superficial skeletal muscle as well. These structures produce impulse that reach the spinal cord, producing various effects, including moderation of the facilitated segment. Somatovisceral reflex changes to the viscera are possible in this model.

Psychological effects of massage

Massage generally increases feelings of relaxation and well-being in patients. Whether this is from placebo effect or the result of some previously undiscovered reflex is not fully understood. Practitioners often incorporate a variety of psychophysical techniques, such as guided imagery into massage treatment.

Therapeutic goals and indications for massage therapy

Massage may be used as primary therapeutic intervention or as an adjunct to other therapeutic techniques. Uses can include, but are not limited to (1) mobilization of intertissue fluids, (2) reduction or modification of edema, (3) increase of local blood flow. (4) decrease of muscle soreness and stiffness, (5) moderation of pain, (6) facilitation of relaxation, and (7) prevention or elimination of adhesions. Massage may be used to alter pathophysiology of a primary condition, e.g., contracture or to prevent or modify deleterious effects of a previously used treatment modality.

Hospitalized patients who receive massage express improvements in mood, body image, self-esteem, and perceived levels of anxiety. This phenomenon is facilitated by reduction in physical symptoms and distress and may be accompanied by decreased tension, anxiety, and pain perception.

Another therapeutic effect derived from massage is muscle relaxation. Massage appears to reduce tone and enhance circulation to the area. Muscle relaxation also may result from increased sensory stimulation caused input to the spinal cord may result in changes in reflex pathways, leading to central modulatory decreases of muscle tone.

Massage can affect both local and remote circulation in skin and subcutaneous tissue. Studies suggest that massage also may decrease the likelihood of DVT by decreasing the hematocrit and overall blood viscosity and by increasing circulating fibrinolytic compounds.

Other effects of massage are enkephalin release, endorphin production, promotion or absorption of fibrous tissue, restoration of connective tissue pliability, improvement of lymphatic flow (in some studies up to 7-9 times), and increase level of natural killer (NK) cells.

Traction

Traction is the act of drawing or pulling and relates to forces applied to the body to stretch a given part or to separate two or more parts. Currently, traction is used effectively in treatment of fractures. In physiatry practice, use of traction often is limited to the cervical or lumbar spine with the goal of relieving pain in, or originating from those areas.

Since the days of Hippocrates, correction of scoliosis also has involved traction. Recently, various methods of traction have been performed that include having the patient apply pulling force manually with free weights and a pulley, using motorized equipment, inversion techniques, or an overhead harness.

Physiologic effects of traction

In the cervical spine, the most reproducible result of traction in elongation. In a classic study. Cyriax reported applying force of 300 pounds manually, with a resultant 1 cm increase in cumulative lumbar spine interspace distance. Studies have shown that optimum weight for cervical traction to accomplish vertebral separation is 25 pounds. Additionally, 2-20 mm elongation of the cervical spine has been shown to be achievable with 25 or more pounds of tractive force. Studies have shown that anterior intervertebral space shown the most increase in cervical flexion of 30^0. Traction in the extended position generally is not recommended because it is often painful and may increase risk of complications from vertebral basilar insufficiency or spinal instability.

Once friction is overcome in the lumber spine, the major physiologic effect of traction is elongation. Investigators have reported widening of lumbar interspaces requiring between 70-300 pounds of pull. This widening averaged up to slightly more than 3 mm at one intervertebral level. The length of time that the separation persists remains indeterminate with studies documenting distraction durations of 10-30 minutes after treatment.

Data on dimensional and pressure changes of lumbar discs caused by traction are not conclusive. Decrease in intradiscal pressure with 50-100 pounds of traction have been documented, but evidence exists that some applications actually cause increase in intradiscal pressure. Therefore, evidence is inconclusive with much information favoring at least temporary reduction of the herniated component of an abnormal lumbar disc with concomitant traction.

Lumbar traction

The Agency for Health Care Policy and Research (AHCPR) review of the literature on traction resulted in a conclusion that "spinal traction is not recommended in the treatment of acute low back problems." Studies that claim improvement after traction report modest and very short-term improvements with limited or no improvement in overall function. Additionally, these studies have significant design flaws. While a particular group of patients may benefit from a particular type of traction for either short-term or long-term improvement in functional outcome, the literature currently does not identify this patient population.

Cervical traction

Few randomized controlled trials address patient outcomes after cervical traction. While many studies have produced statistically significant findings, the actual clinical significance of those findings is not clear.

Techniques for applying traction

Cervical traction generally is accomplished with a free weight and pulley system or an electrical motorized device. Adequate pull is achieved by using a head or chin sling attached to a system that can provide pull in a cephalad direction. Motorized devices are applied easily but require the patient to be attended. Free weight and pulley system often are used in the home with 20 or more pounds of water or sand and a pulley system attached to a door. If a tractive force of only 20 pounds is possible, the system is likely to fail to achieve therapeutic results. Advise patients not to attempt cervical traction at home alone because they may find themselves in uncomfortable positions and may need assistance doffing the traction devices.

Most home traction systems are difficult for patients to set up without assistance. Home cervical traction may cause increase in pain or may fail to produce significant pain relief unless professionally monitored on a periodic basis. At the initiation of home traction, the patient is required to demonstrate proper use of equipment to the satisfaction of the prescribing physician or therapist.

In the lumbar spine, adequate pull with weights and pulleys or motorized devices to achieve vertebral distraction usually can be obtained with the proper apparatus. Generally, a harness is attached around the pelvis (to deliver a caudal pull), and the upper body is stabilized by a chest harness or voluntary arm force (for the cephalad pull). Motorized units have the advantage of allowing intermittent traction with less practitioner intervention. If the goal of tractive force is to distract lumbar vertebrae, 70-150 pounds of pull usually are needed. Friction between the treatment table and patient's body usually requires tractive force of 26% of the total body weight before effective traction to the lumbar spine is possible. Many traction devices use a split table that eliminates the lower body segment friction.

Body weight theoretically should provide enough pull to distract lumbar vertebrae and eliminate mechanical devices. Gravity traction is applied almost exclusively in the lumbar region. After 10 minutes of inversion traction, documented increases in intervertebral separation are noted; however, side effects also are reported frequently, including increased blood pressure, periorbital and pharengonal petechiae, headaches, blurred vision, and contact lens discomfort.

Manipulation

Therapeutic manipulation has been practiced in almost all countries of the world since at least the time of Hippocrates. Recent times have seen rapid growth of manipulation and manual therapy and an increase in its public use. Some healthcare professional's opposition to the use of manipulation explained by the fact that manipulation requires skills significantly different than those acquired in allopathic medical schools. This difference separates practitioners who possess manipulation skills from those who do not. The techniques used in manipulation also fall outside of the mainstream of allopathic medicine.

Manipulation generally is directed at restoration of normal motion and elimination of pain secondary to disturbed biomechanics.

A consensus definition of manipulation is the use of the hands applied to the patient incorporating the use of instructions and maneuvers to achieve maximal painless movement and posture of the musculoskeletal system. Most common types of manipulation involve passive mechanical forces applied to specific vertebral segments, regions, or other joint segments of the musculoskeletal system with a primary goal of restoration of diminished ROM.

Techniques of Manipulation

Introductions to the most common techniques of manipulation presently used are presented below. This list is limited to techniques that physicians are most likely to encounter.

Direct thrust

Direct, e.g., high velocity/low amplitude thrust techniques, including European mobilization with impulse, involve diagnosis of dysfunction of a vertebral segment by identifying position or motion abnormalities of related tissue texture changes, including tenderness to (1) palpation or (2) induced motion. The practitioner than rotates, side bends, and either flexes or extends the adjacent vertebral segments, locking the facet so that further motion is limited to the segment in question. The vertebral segment then is moved passively to its limit of motion or barrier to remove slack motion, and a small force, localized to the specifically identified joint, is applied to hold that position. Brief controlled thrust is applied in the direction perceived as limited, and a small motion in the desired direction occurs as the vertebra crosses its barrier. Forces, duration of actions, acceleration, and displacement values for direct thrusting techniques have been measured. These forces peak in the range of 100-400 Newton's over a period of approximately 150 milliseconds. Direct manipulative techniques featuring forces applied over transverse or spinous processes are short lever techniques. If force is applied distant to the vertebra through the locked column, the procedure is considered a long-lever technique. All direct thrust techniques must have forces well localized and specifically directed, and structural diagnosis must be adequate before their application.

Articulatory technique

Articulatory technique, also referred to as low velocity/ high amplitude, involves passive movement of a vertebral joint within reduced ROM defined by its resting position and dysfunctional limitation of motion. Extent of motion at its end point may vary, but the ultimate end point and dysfunctional barrier become the same, with the barrier becoming attenuated with repeated motion. The quality or feel of induced motion, in addition to the quantity of force and excursion, are normalized by this procedure. A small amount of additional force occasionally may take the vertebra through its harrier or restriction.

Indirect positional techniques

Indirect positional techniques, e.g., counter strain and functional techniques are based on the underlying principle that somatic dysfunction or hypomobility is caused by an inappropriately firing muscle group, rather than shortened passive tissues, such as joint capsule, ligament, or fascia. Thrust, articulation, and muscle energy techniques employ forces that could be expected to lengthen shortened passive tissues, whereas these positional techniques change an inappropriate engram of muscle behavior.

Counter strain

Developed by jones, counter strain is an indirect myofascial technique that shares with functional technique and emphasis on relative positioning of a joint or body part as an essential component of treatment. Counter strain treatment involves placing a joint or body part into position of maximal ease or comfort, thereby relaxing ligamentous and myofascial soft tissue. This relaxation allows inappropriately shortened muscles to reset their spindles, which then normalizes proprioceptive input into the spinal cord. The restricting muscle generally is shortened excessively by this positioning, e.g., counter strain, and its antagonist muscle is overstretched, e.g., strained gently in the process. Find the optimal treatment position by minimizing pain associated with palpatory pressure over a tender point and, once this position of maximizing pain associated with palpatory pressure over a tender point and, once this position of maximum ease is found, hold it for approximately 90-120 seconds with concurrent tender point monitoring. During this time, tenderness should fade to no more than 20-3-% of its initial value. Occasional small fine-tuning passive positioning movements with verbal feedback from the patient may be needed. Tenderness is part of this feedback system; therefore, the patient must respond to the practitioner’s questions. Return the patient slowly to a neutral position in one plane of motion at a time to prevent recurrence of inappropriate muscle firing.

Counter strain is considered an indirect technique because positioning is always in a direction away from the restricted motion. If multiple tender points are encountered, treat them in order of decreasing tenderness. Then address areas of highest accumulation of tender points (first proximally then distally).

Tender points are found beneath the skin through palpatory examination over shortened and restricted muscles or over related anatomic structures, e.g., tendons muscles, and ligaments. Tendon points generally do not coincide with trigger points or points associated with fibromyalgia. Counter strain tender points usually are small fibrotic discrete areas thought to be manifestations of distal somatic dysfunction and are not associated with other signs of fibromyalgia, nor are they paired. Counter strain tender points are distributed widely in generally reproducible locations, depending on the nature and location of associated somatic dysfunctions. Those associations are not based upon known neurophysiologic or neuroanatomic referral patterns.

Counter strain is considered safe, effective, gentle, and atraumatic, so it is a very useful technique for the older, hospitalized, or immune compromised patient, as well as for apprehensive patients and children. Counter strain techniques are easy to perform, forgiving for the novice learner, and easily incorporated by the patient into a prescribed home exercise program.

Functional techniques

Functional techniques, as well as counter strain, have a methodologic approach, oriented to resetting inappropriate afferent impulses from nociceptors and mechanoreceptors, resulting in efferent alpha motor activity to the skeletal muscle, by placing the joint or body part into a position of maximum ease. Unlike in counter strain, however, the position is found and monitored by the practitioner, sensing either increased resistance to trials of small induced motions or increased tissue tension of the nearby tissue when motion is induced. The most relaxed position is held in this balanced state.

Functional technique practitioners feel that inherent body motions, e.g., respiration allow the firing pattern of the afferent muscles to reset so they are normalized in neutral position. This approach, also unlike counter strain, does not make use of tender points and may be somewhat more objective because practitioner's palpatory findings determine positions of balance.

The practitioner puts the patient through a sequence of positions with the goal of progressing toward anatomic neutral as the position of maximum ease or balance. Functional techniques are useful in both acute and chronic conditions because focus of this treatment is in the quality rather than quantity of motion, with restoration of normal function implying normal quality and ROM. Functional techniques require significant experience on the part of the practitioner.

Muscle energy

Muscle energy is a direct non-thrusting technique (also known in the US as isometrics and in Europe as mobilization) and has a strong relationship to proprioceptive neuromuscular facilitation. The physician positions the patient and removes slack as in direct thrust procedures and subsequently prevents active motion of the affected vertebral segment away from its barrier. The patient then exerts minimal-to-moderate isometric force against resistance offered by the physician for approximately 5-10 seconds and subsequently relaxes. The physician then finds that the barrier has been displaced and that the affected segment moves beyond its original barrier. This procedure is repeated 2-3 times with diminishing gains and increased ROM.

Soft tissue technique

Soft tissue technique uses mechanical stretch of skin, muscle, and fascia to increase motion. Lateral and linear stretch and deep inhibitory pressure are the most common procedures used. Soft tissue techniques are useful in virtually all patients and may function as first step in manipulative treatment involving multiple techniques. Soft tissue techniques are very valuable in encouraging circulation and enhancing venous and lymphatic flow. The overall purpose of soft tissue technique is to relieve fascial and superficial muscle tension. Soft tissue techniques are learned easily and can be incorporated into clinical practice with virtually no difficulty.

Myofascial release

Myofascial release techniques are directed at vertebral, segmental, or generalized hypomobility. Myofascial release can be indirect, i.e., when a restricted area is placed into a position of little resistance until subsequent relaxation occurs or direct, i.e., when the affected area is placed against a restrictive barrier with constant force until fascial release occurs. All the myofascial of the body are interconnected, and, when one area is tight or restricted, diminished movement occurs not only locally but, potentially, in distant related areas.

Myofascial release practitioners palpate to assess tissue response and adjust applied forces of stretch, pressure, twist, or traction until affected tissues change toward normal. This progression may occur over a short period of time and is referred to as release. The mechanism of release may be biomechanical or nonreflexive; however, fascial resistance to force applied should be symmetric, and the tissue should be relatively mobile and responsive to force being applied Myofascial release combines mechanical approaches of direct thrust, articulatory techniques, and muscle energy with nonreflexive approaches of counter strain, functional, and soft tissues techniques. Effective use of myofascial release requires considerable palpatory skill and experience, and training time is relatively long compared to that for other manipulative approaches.

Craniosacral therapy

Craniosacral manipulation is based upon the concept of a primary respiratory mechanism, i.e., a cyclic, palpable, rhythmic wave of inherent motion appreciated most easily in the cranial and sacral areas. This wave may represent a continuous state of flux of cerebrospinal fluid (CSF). This primary mechanism may entail inherent mobility of the central nervous system (CNS), CSF fluctuation, cranial bone articular mobility, involuntary motion between the sacrum and ilia, and mobility of interspinal and intercranial membranes.

The craniosacral practitioner palpates the head and/ or sacrum to feel pulsations of the wave motion, occurring in the range of 8-12 pulses per minute, as well as to evaluate symmetry, regularity, frequency, and amplitude of the wave. When abnormalities are found, apply general pressure to the skull and sacral areas to restore the wave to normal symmetry rhythm and amplitude.

While this technique is considered somewhat controversial among non-practitioners, its largest subset of potential patients may be infants with failure to thrive, birth defects, or head injuries, as well as adults with neurologic of this manipulative approach requires physicians to have at least passing familiarity with it. Proficiency with craniosacral manipulation requires considerable training and experience.

2.11.5 Massage manipulation

Few risks are involved in manipulative care. Complications from isometric or articulatory treatments have not been reported. The number of reports of complication of direct thrust manipulation actually is quite small, considering the number of manipulations performed annually. Most potential complications of manipulative care are avoidable.

Evidence for the benefits of manipulation is mounting. Proponents report excellent results in treating. Proponents report excellent results in treating acute, as well as chronic, musculoskeletal problems. Empirically, these outcomes are comparable to those achieved with more conventional treatments, many of which carry no proof of efficacy. Manipulative care has been shown to decrease use of medication and physical therapy, to be superior to conventional treatment and placebo manual care, and to be most efficacious in persons with non-complicated acute LBP. Manipulation results in less disability and faster recovery, greater improvement in pain and activity tolerance, and is a valuable adjunct to an on-going exercise program. Manipulation has been shown to be useful in treatment of upper. Middle, and peri respiratory infections, as well as advanced cardiopulmonary disease, headache, and neck pain.

Indications for manipulation

Manipulation is appropriate for a variety of musculoskeletal problems, especially those of the thorax, rib cage, upper and lower extremities, back, pelvis, and neck. It is also useful when loss of motion or function is encountered or when localized tenderness or pain in noted on induced motion. Some clinical situations, e.g., acute fractures, disc herniations with neurologic signs, tumors, acute inflammation, and joint disease may not respond to manipulative care because of local conditions, or at least put them under concurrent care of the practitioner. Some physicians use manipulation for treatment, while others provide it in a more prophylactic manner.

Side effects of manipulation

The most commonly reported side effect is transient increase in discomfort lasting approximately 6-72 hours. Minor temporary autonomic effects, e.g., early or increased menses, increased perspiration, and vasomotor changes have been reported.

Duration of manipulative care

Direct techniques, e.g., high velocity-low amplitude thrust usually have immediate effect, and improvement is seen within a week. Indirect techniques may take longer for effect to be seen. If the patient's condition does not improve objectively within 2-4 weeks, revaluation of the structural diagnosis, manipulative approach, or other therapeutic plan in indicated. Determine duration of each course of therapy on an individual case-by-case basis.

Therapeutic Exercise

Therapeutic Exercise seeks to accomplish the following goals:

- Enable ambulation
- Release contracted muscles, tendons, and fasciae
- Mobilize joints
- Improve circulation
- Improve respiratory capacity
- Improve coordination
- Reduce rigidity
- Improve balance
- Promote relaxation
- Improve muscle strength and, if possible, achieve and maintain maximal voluntary contractile force (MVC)
- Improve exercise performance and functional capacity (endurance)

Physiologic Aspects of Physical Fitness

Compared to a less fit, individual, a physically fit person demonstrates the following physiologic profile:

- Higher oxygen consumption (ml/min)
- Greater cardiac output per minute
- Higher stroke volume and total blood volume
- Greater oxygen extraction by the tissues

- Greater cardiac volume
- Lower resting pulse rate
- Greater muscle strength
- Lower blood pressure on exercise
- Lower pulse rate on exercise
- Better adaptation of circulation and respiration to effort.

The last three features above, i.e., lower pulse and blood pressure with exercise and better adaptation of circulation and respiration to effort are characteristic features of improved endurance.

Decreased physical fitness may result from various diseases, especially when accompanied by prolonged recumbency, or inactivity such as a sedentary life style and a low level of physical activity. Increased physical fitness, on the other hand, is associated with a decreased incidence of hypertension and coronary artery disease (CAD), and with improved long-term prognosis in patients with angina pectoris and survivors of myocardial infraction (MI). However, the duration, frequency, intensity and type of therapeutic exercise that brings about this beneficial effect have not been established. Debate continues as to whether a better cardiac status allow for a higher level of physical activity and, consequently, better physical fitness, or vice versa.

2.11.6 Physiological responses of massage manipulation

Therapeutic Exercises aimed at achieving and maintaining physical fitness fall into three major categories, each with a specific purpose.

1. Endurance training that requires isotonic (dynamic) exercise technique
2. Muscle strength training that requires isometric (static) exercise technique.
3. Techniques to maintain flexibility.

Isotonic (dynamic) muscle contraction

Isotonic exercise also is called active range of motion (AROM) exercise. The muscle shortens during isotonic exercise. Isotonic muscle contraction causes a rise in the heart rate and a marked increase in stroke volume that results in an increase in cardiac output and a net decrease in peripheral resistance (due to vasodilatation of contracted muscles). A moderate rise in systolic blood pressure occurs, but the diastolic pressure usually remains unchanged. Eccentric isotonic training does not produce an increase in muscle strength, but concentric isotonic training does. However, isometric exercise is the most effective exercise for increasing the muscle contractile force. The isotonic exercise is suitable for endurance training but not for training of muscle strength. In endurance training large muscle groups are engaged in a continuous aerobic activity.

Application to healthy individuals

- Exercises such as walking, running, jogging, dancing, stair climbing, cycling, swimming, rowing, skating, and cross-country skiing are recommended for performance at an intensity of 60-90% of maximum heart rate or to a heart rate at 50-85% of maximum O_2 uptake.
- If the maximum attained heart rate (HR max) has not been estimated, the age adjusted maximum heart rate (AAMHR) can be calculated from the following formula.
  HR max = 220 – Age

Note that this formula can be inaccurate in the ill or elderly patient.

- The endurance training should be structured to include 5 minutes of warm-up activity, 30 minutes of training, and a 5-minute period for cool down.
- The minimum duration of endurance training for healthy men and women recommended by the American College of Sports Medicine (ACSM) is 20-60 minutes 3-5 days a week.

Application to patients

- For at risk patients, especially those with cardiac or respiratory disease, a less intense training regimen must be used, with the training heart rate not exceeding that attained at 50-60% of maximum O_2 uptake.
- In the absence of data regarding the maximum attained heart rate measurements, it is prudent not to allow the patient to exceed the heart rate of 130 beats per minute (bpm). In elderly patients and patients at risk, the intensity, frequency, and duration of therapeutic exercise should be established for each patient individually through prior medical evaluation.

Isometric (static) muscle training

Isometric (static) muscle training also is referred to as resistive strength training (RST) or resistive exercise because resistance is applied to the contracting muscle, preventing it from shortening. Daily application of this technique for six seconds only, using two-thirds of maximal contractile force, results in an optimal increase of muscle strength. Progressive increase in the resistance, frequency enhances the effect. Isometric training requires great caution because it causes a rise in heart rate (due to decreased vagal tone and increased discharge of cardiac sympathetic nerves). Within a few seconds of the start of isometric exercise, both the systolic and diastolic blood pressures rise. The stroke volume changes relatively little, and the blood flow to the steadily contracting muscle is reduced as a result of compression of its blood vessels. The heart rate rises even when contraction is prevented by infusion of neuromuscular blocking drug locally or at the mere thought of carrying out the muscle contraction, suggesting the action of a psychic stimulus.

Application to health individuals

For healthy men and women, the ASCM currently recommends “at least one set of 8-12 repetitions of 8-10 RST exercises that condition the major muscle groups at least twice a week.”

Application to patients

- As with the isotonic dynamic exercise, the intensity, frequency, and duration of isometric static exercise must be established for each patient individually, according to the results of the prior medical evaluation.
- Since this form of training requires great caution, it may be prudent, especially in patients with cardiovascular diseases, not to extend the duration of an isometric contraction beyond six seconds. The pause between two isometric contractions should equal or exceed 20 seconds to allow time for the reconstitution of ATP.

An allied technique for training of muscle strength

Proprioceptive neuromuscular facilitation (PNF) is an excellent technique for training of muscle strength. Similarly based on applying resistance to muscle contraction to facilitate enhancement of muscle contractile force. PNF is suitable for patients with upper motor neuron lesions accompanied by spasticity, but it also may be used to initiate muscle contraction is cases of partial peripheral nerve damage and extreme muscle weakness.

Techniques for the maintenance of flexibility

Active assistive range of motion (AAROM) exercises are used when the patient has very weak muscles or when joint pain limits movement. During AAROM exercises, it is important to avoid forcing the joint and/or soft tissues beyond the point of pain. In patients who cannot exercise actively, passive range of motion (PROM) exercise, consisting of stretching immobile muscles and joint capsules to prevent joint stiffness and muscle contracture, is used. Joint flexibility is achieved by means of steady and slow manual stretching of large muscle groups and joint capsules or with the help of mechanical devices. As a preliminary exercise prior to isotonic or isometric training PROM should be performed during the first warm-up and the last cool-down phases. Although this article focuses on techniques used to enhance physical fitness, other therapeutic exercise modes and combinations of techniques are employed to threat a whole range of conditions. These techniques have become a part of established therapeutic exercise routines practiced in general hospitals.

Recumbent and convalescing patients

- Recumbent and convalescing patients require maintenance by means of AAROM or PROM exercises, aided or performed by a physical therapist to preserve full joint mobility and prevent joint stiffness and muscle contractures.
- During or immediately after the patient's hospital stay, refer the patient to a physical training program or design and individual therapeutic regimen appropriate to the patient's physical fitness. Thus, maintenance, or training of physical fitness, can be performed either by means of a individual program to be carried out by the patient at home or by participation in a group training programme.
- Circle training favored example a group-training programme that combines isotonic and isometric exercises. Circle training commences with a warm-up phase and ends with a cool-down phase. The training sequence consists of alternating circulation training, e.g., jogging, ergometer cycle training with muscle training or muscle relaxation techniques, or the muscle training sequence is carried out in alternating muscle groups, e.g., abdominal, shoulder, leg muscles interspaced with 2-3 minutes of circulation training.

Mechanical aids for training and maintaining physical fitness

- Example of mechanical aids used for physical fitness training include as electrically braked cycle ergometer, treadmill, rowing apparatus, bed bicycle, arm cycle, pulleys, free weights, weight-training machines, indoor stair stepper, medical exercise balls, and a pool.

Table: Some Therapeutic Exercise Routines Practiced in General Hospitals

Department	Disease	Therapeutic Exercise
Cardiac	* Ischemic heart disease (CID) * Post MI * Stable angina * Stable chronic heart failure (CHF) with sinus rhythm and ejection fraction of < 40% * Neurocirculatory asthenia	* AROM; isotonic (dynamic) muscle training, (e.g., after a 5 minute warm-up, exercise until the heart rate reaches that attained at 50% of VO2 max.) to train endurance. * Training muscle strength by RST; resistive isometric (static) training which must be carried out with great caution and adjusted to the level of the physical fitness of each individual patient. * Isotonic training to increase endurance and isometric exercise to train muscle strength * Graded physical training
Medicine	* Obesity	* Daily activity level is adjusted to the daily insulin dose.
Endocrine	* Diabetes	* Postural drainage exercises
Pulmonary	* Pneumonia * Chronic bronchitis * Bronchiectasis * Asthma *Emphysema * Respiratory insufficiency * Restrictive lung disease	*Breating techniques * Relaxation techniques * Stretching exercises to mobilize respiratory muscles Note : The level of physical effort should be limited because exercise may provoke bronchospasm. * Preoperative and postoperative exercises * Preoperative and postoperative exercises
Surgery	* Surgical patients * Fractures	* Mobilizing and stretching of joints

Orthopedics Burns Rehabilitation Rhemumatoid arthritis	* Coxarthrosis * Gonarthrosis * Amputations * Scoliosis * Kyphosis * Intermittent claudication * Cervical, dorsal, and lumbar problems * Morbus Bechterew (Ankylosing Spondylitis) * Pregnancy and postdelivery	* Isometric training of muscle strength and isotonic exercise to train endurance * Janda exercises * Ejventh muscle stretching * Graded isotonic lower limb training * Treadmill * Elaborate rehabilitation exercises assisted by the physical therapist * Traning of Swedish back school * Treatment of muscle contractures * Myofascial release * Flexibility training (stretching) to mobilize joints * Isometric and PNF training of muscle strength in muscles that have become weakened and in the back extensors and abdominal muscles. Graded fitness training. * Mobilization of spinal vertebrae * Flexibility Training * Gentle fitness training * Prenatal and postnatal exercises * Relaxation techniques * Preoperative and postoperative exercises * Training to reduce lymphatic edema * Gentle training of physical fitness * Isometric exercises to pelvic muscles * PNF * Bobath

Gynecology and abstetrics	* Surgical patients	* Training of muscle strength
	* After mastectomy	* Training of balance and coordination
		* Later training and maintenance of general physical fitness
	* Osteoporosis	* PNF and physical fitness training
	* Urinary incontinence	* Increasing and maintaining flexibility
Neurology	* Cerebrovascular accident (CVA)	* Training of physical fitness
		* Isometric and isotonic training Relaxation techniques :
		* Jacobson relaxation techniques
		* Autogenic training
		* Gentle isotonic training
	* Multiple sclerosis	
	* Parkinson disease	
Psychiatry	* Myopathies	

Although the blood flow in skeletal muscle is low at rest (2-3mL/100g/min), Several factors, e.g., drop in tissue PO_2, decrease of PCO_2, contribution of vasodilator metabolites cause a high blood flow in an exercising muscle. The vasodilator metabolites include a decrease of O_2 tension, decrease of pH, an increase of CO2 tension, decrease of osmolality, and a rise in adenosine or in temperature and an accumulation of lactic acid and potassium. Potassium, which causes arteriolar vasodilation in skeletal muscle, has been identified as one the most important vasodilator metabolites. In patients who have potassium depletion, a smaller increase in muscle blood flow and a more severe exertional rhabdomyolysis were observed. Magnesium (Mg), which control the movement and is essential for the action of adenosine (known to cause vasodilatation in cardiac muscle, but not in skeletal muscle), when depleted also gives rise to vasoconstriction and causes a severe exertional rhabdomyolysis like that reported in potassium depletion states. Since the 1970s, the pivotal role of Mg, not only in the vasodilatation of capillaries and arteries but in determining and regulating cardiac, smooth, or skeletal muscle contraction force, has become increasingly evident.

The Biochemical Aspect of Therapeutic Exercise

In light of the new understanding of the biochemical aspect of exercise physiology, it becomes clear that investigation of the patient's laboratory status (especially in at-risk patients) must be a routine part of instituting a physical training program. A number of laboratory parameters, such as levels of potassium, phosphate, iron, zinc, and copper, to name a few besides Mg, have been reported as associated with muscle strength and, therefore, require screening. However, Mg plays a crucial role because it enhances physical fitness and exerts a cardioprotective effect when available in good supply, but when deficient, it poses many health hazards, some of which can prove life threatening. This makes it important to screen patients for Mg status, to treat deficiencies when present, and to prevent its occurrence by using Mg as an adjunct to therapeutic exercise. Thus, both the physiologic and the biochemical aspects of exercise must be considered when planning a therapeutic exercise programe that should consist of (1) techniques to improve the patient's specific clinical condition and (2) techniques to help the patient reach optimal physical fitness.