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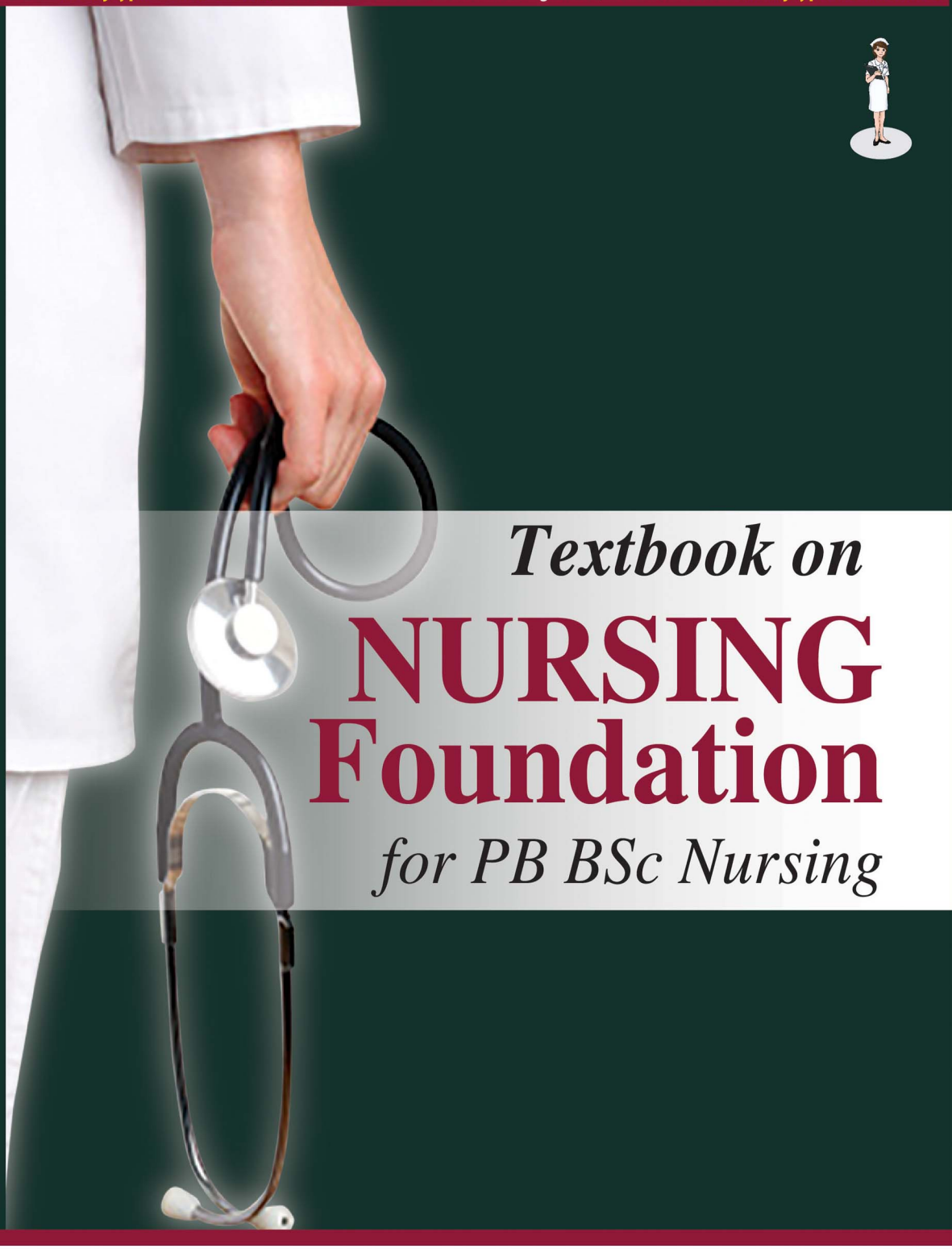

Textbook on NURSING Foundation

for PB BSc Nursing

I Clement

JAYPEE

Contents

1. **Introduction and Thought Process in Regional Pain** 1

2. **Chemical Basis of the Human Body with Relevance to Regional Musculoskeletal Pain** 7
   - An Overview of the Biochemical Makeup of the Human Body *9*
   - Elements and Minerals *10*
   - Measurement of the Biochemical Makeup and Clinical Relevance *19*
   - Blood Groups *20*
   - Blood Tests *20*
   - Types of Blood Tests *21*
   - Hematology *21*
   - Biochemistry *28*
   - Microbiology *44*
   - Serology *44*
   - Other Blood Tests Relevant to Musculoskeletal Pain *44*
   - Waste Product Tests *47*
   - Urine Tests *49*
   - Clinical Laboratory Tests (Normal Values) *52*
   - Cell *57*
   - Bone and Soft Tissue Cancer *59*
   - Tissues *62*

3. **Drug-induced Regional Pain** 64
   - Pharmacology *64*
   - Rationale *64*
   - Drug-induced Myalgia and Arthralgia *65*
   - Drug-induced Neuralgia or Neuropathy *74*

REGIONAL APPLICATION

4. **Cervical Pain** 90
   - Ligaments *91*
   - Musculature *94*
   - Vasculature *95*
   - Cervical Lymph Nodes *96*
   - Thyroid Cartilage and Gland *97*
   - Combined Mechanics of the Upper and Midcervical Spine *97*
   - Mechanism of Dysfunction *100*
   - Palpation Around the Cervical Region *102*

- Vascular, Musculoskeletal and Systemic Red Flags *104*
- Musculoskeletal Red Flags *107*
- Congenital Anomaly *113*
- Systemic Red Flags (Infection/Inflammation) *115*
- Malignancy *116*
- Systemic Mediation *118*
- Lesions *124*
- Description of Examination Procedures *135*
- Clinical Implication *143*

5. Thoracic Pain **173**
- Ligaments *173*
- Musculature *174*
- Neural Anatomy *174*
- Mechanics *175*
- Mechanism of Dysfunction *175*
- Palpation Around the Thoracic Region *176*
- Vascular, Musculoskeletal and Systemic Red Flags *178*
- Malignancy/Neoplasms *180*
- Systemic Mediation *182*
- Vascular *183*
- Infection/Inflammation *183*
- Congenital *185*
- Endocrine *185*
- Autoimmune *185*
- Deficiency *185*
- Lesions *187*
- Description of Examination Procedures *195*

6. Lumbopelvic Pain **203**
- Intervertebral Disc *203*
- Facet Joint *204*
- Ligaments *205*
- Sacrum and Ilia *207*
- Musculature *208*
- Mechanics in the Lumbar Region *208*
- Mechanism of Dysfunction *209*
- Mechanics in the Pelvic Region *209*
- Walking Cycle Relevant to Pelvic Mechanics *210*
- Mechanism of Dysfunction of the Pelvic Complex *211*
- Palpation *212*
- Vascular, Musculoskeletal and Systemic Red Flags *214*
- Musculoskeletal Trauma *218*
- Structural Anomalies *222*
- Systemic Red Flags *223*
- Malignancy *225*
- Systemic Mediation *228*

- Vascular *229*
- Inflammatory/Infection *229*
- Congenital *232*
- Endocrine *235*
- Autoimmune *237*
- Deficiency *239*
- Miscellaneous *239*
- Yellow Flags *239*
- Non-organic Physical Signs in Low Back Pain *240*
- Stage Two of the Three Stage Approach *241*
- Lesions *241*
- Description of Examination Procedures *258*
- Mechanical Dysfunction of the Pelvic Complex *260*
- Torsional Dysfunctions *263*

7. Hip Pain **286**
- Osseous Anatomy *286*
- Ligamentous Anatomy *287*
- Muscular Anatomy *287*
- Relevant Neural Anatomy *287*
- Vascular Anatomy *288*
- Inguinal Lymph Nodes *288*
- Mechanics (Normal Roll-Gliding) *289*
- Palpation Lumbar Spine, Pelvis and Hip *290*
- Stage One *292*
- Musculoskeletal Red Flags *293*
- Vascular *294*
- Inflammatory *294*
- Malignancy *295*
- Congenital *296*
- Autoimmune *296*
- Deficiency *296*
- Stage Two *297*
- Lesions *298*
- Anteromedial Hip Pain/Groin Pain *298*
- Lateral Hip Pain *306*
- Posterior Hip Pain *307*
- Hip Joint Somatic Diagnosis *308*
- Description of Examination Procedures *309*

8. Knee, Ankle and Foot Pain **319**
- Knee *319*
- Ankle and Foot *323*
- Palpation *328*
- Stage One: Principles of Examination *331*
- Vascular *332*
- Malignancy *334*

- Infection/Inflammation *335*
- Congenital *337*
- Endocrine *338*
- Autoimmune *339*
- Deficiency *340*
- Stage Two *341*
- Knee Lesions *343*
- Ankle and Foot Lesions *361*
- Knee Joint Somatic Diagnosis *378*
- Ankle and Foot Somatic Diagnosis *380*
- Description of Examination Procedures *385*

9. Shoulder Pain **402**
- Osseous Anatomy *402*
- Ligamentous Anatomy *404*
- Muscular Anatomy *405*
- Labral Anatomy *406*
- Mechanics (Normal Roll-Gliding) *406*
- Mechanism of Dysfunction *408*
- Palpation *409*
- Stage One *410*
- Vascular *411*
- Inflammatory *412*
- Malignancy *414*
- Congenital *414*
- Endocrine *414*
- Autoimmune *414*
- Stage Two *415*
- Lesions *415*
- Superior Shoulder Pain *416*
- Anterior Shoulder Pain *417*
- Lateral Shoulder Pain *421*
- Posterior Shoulder Pain *422*
- Rotator Cuff Impingement *425*
- Types *426*
- Instability *429*
- Shoulder Joint Somatic Diagnosis *431*
- Acromioclavicular *436*
- Sternoclavicular *437*
- Subcranial Spine/Mid Cervical Spine *438*
- First Rib Elevated *438*
- Thoracic Spine *438*
- Description of Examination Procedures *438*

10. Elbow, Wrist and Hand Pain **452**
- Elbow *452*
- Wrist and Hand *458*

- Palpation *462*
- Stage One *464*
- Vascular *465*
- Inflammatory *466*
- Malignancy *467*
- Congenital *468*
- Endocrine *468*
- Autoimmune *469*
- Stage Two *470*
- Medial Elbow Wrist and Hand Pain *471*
- Posterior/Dorsal Elbow Wrist and Hand Pain *475*
- Lateral Elbow Wrist and Hand Pain *478*
- Anterior/Volar Elbow Wrist and Hand Pain *482*
- Wrist and Hand Somatic Diagnosis (For Specific Somatic Dysfunction) *486*
- Description of Examination Findings *489*

Index *499*

2 Chemical Basis of the Human Body with Relevance to Regional Musculoskeletal Pain

Homo sapiens as humans are named, are biological organisms with features common to all living animals. For description the *Homo sapien* will be referred to as a human organism. The human breathes, eats, digests, excretes, moves and reproduces similar to other animals. The basic makeup of the human organism is organic and inorganic, and hence decomposes during death. It has a genetic code that regulates development. Water is the basic physical requirement for survival. The taxonomic classification is given in Table 2.1.

The levels of organization of the human body is as follows:

Chemical/Basis

The human organism is living matter, made up of elements. The atom is the smallest unit of an element. Two or more atoms form a molecule, which are held together by 'bonding' and are known as chemical bonds. Molecules combine to form a compound. Water is a compound with two atoms of hydrogen and one atom of oxygen. There are 110 (114 in some sources) chemical elements represented in the periodic table. 92 (89 in some sources) are naturally occurring, of them 22 (more in other sources) are present in the human body. All matter, living and non-living have a basic chemical makeup and consist of these building units called chemical elements. These chemicals are the basic level of the human organism, prior to the formation of a cell. The human body is a storehouse of

TABLE 2.1: Taxonomic classification

Kingdom	Animalia
Phylum	Chordata
Subphylum	Vertebrata
Class	Mammalia
Order	Primates
Family	Hominidae
Genus	*Homo*
Species	*Sapiens*

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chemical reactions that maintain homeostasis.[7] Their study relevant to health is called biochemistry and is the central science for patient care. Cellular changes occur much after biochemical aberrances.[8,9] Their early identification through biochemical and laboratory analysis is essential to minimize consequences. The medical model aims to alter such chemical aberrances utilizing chemical agents as in pharmacological agents.

As mentioned earlier chemistry is most definitely a central science as it is central to understanding physiology of the human body. Knowing the component atoms and molecules, and their interactions in the body are essential basics for medicine as they order laboratory tests and identify deviations from normal. They subsequently utilize drugs and other strategies to effect the chemical components of the body's mechanisms. From a clinical perspective, the physical therapist's role at a chemical level is not well-structured yet.

Cell

The chemical basis combine to form the cell, which is the basic functional unit of the organism. They are broadly two types prokaryotic and eukaryotic. They contain specific organelles that regulate body function. This is the level where physical therapy interventions may begin. Modalities addressing inflammation may be an example.

Tissues

Similar cells are uniformly spaced and bound together as a tissue. At a tissue level physical therapy interventions are addressed both for diagnosis and treatment. For examples, diagnosis are tissue end feels, trigger points, local tenderness, contractures, tightness, etc. The treatment strategies at the tissue level are well-understood.

Organ

Tissues combine to form an organ as in muscle, joint, heart, lung, etc. The diagnosis and treatment strategies at the organ level are well-understood.

Organ System

The organs, organize to form an organ system as in the musculoskeletal system, cardiovascular system, pulmonary system, etc. The diagnosis and treatment strategies at the organ system level are well-understood.

Human Organism

Finally, the organ systems combine to form the organism, the human body as a whole.

The chemical, cellular and tissue levels are microscopic, where as the organ, system, and organism levels are macroscopic. The point being brought out here is that a physical therapy diagnosis is at a macroscopic and morphological level

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beginning at the level of tissues. There seems no scope of what the physical therapist is capable of at a chemical and cellular level. The void should be addressed by identifying the chemical makeup of the human body to understand the relevance of its deviations to dysfunction and pain.[6]

Biochemistry and laboratory analysis is a science by itself, addressing all chemical bases of the human body and identifying chemical homeostasis or the presence of disease. This literature review, however has an emphasis on regional pain. The relevance of this chapter to the physical therapist is for the fact that most diagnosis in physical therapy occurs at the morphological level. One has to understand that changes at the cellular and morphological level occur much after changes at a chemical level. Most physical therapy instruction is deficient with regards to the chemical basis of the human body. The reason may be due to the fact that physical therapists do not diagnose on the basis of lab tests or prescribe medication to alter the body's chemical reactions. However, the relevance may begin at this level in that alterations in the chemical parameters may offer an indication to the possible source of regional pain mediation. If the source of pain is identified at a chemical and cellular level an appropriate cross referral may be instituted. The goal of this chapter is to offer some light to this area that needs exploration by the field of physical therapy. The need is as follows:

1. To have an understanding of basic biochemical and laboratory parameters.
2. To identify the presence of chemical mediation to the pain in question.
3. To suggest appropriate measures in terms of addressing such a chemical mediation by cross referral and avoiding a waste of time in treating the morphological component.

The clinical relevance of the chemical basis of life is an essential requisite in physical therapy curriculums. Although its influence on basic human physiology may be touched upon, often 'there endeth the lesson', with no implication on it's clinical relevance to the physical therapist. The clinicians ability to stay familiar with the biochemical basis of the human body, the consequence of its alterations, being able to order a lab test and interpreting it appropriately may throw light in the ability to perform an effective differential screening in musculoskeletal practice.

ORGANIZATION

The description may be in the following order:

1. An overview of the biochemical makeup of the human body.
2. Measurement of the biochemical makeup and clinical relevance.

AN OVERVIEW OF THE BIOCHEMICAL MAKEUP OF THE HUMAN BODY

The percentage majority of the human body is carbon, hydrogen, oxygen and nitrogen, which comprise 96% of body composition. Calcium, potassium, phosphorus and sulfur form 3% of body composition. The chemical elements available in trace quantities are boron, copper, cobalt, chlorine, chromium, fluorine, iodine, iron, molybdenum, magnesium, manganese, nickel, sodium,

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silicon, selenium, tin, vanadium and zinc. They form the remaining 1%, however, they are essential for normal functioning of the body. Hence, the minerals and elements responsible for normal functioning of the human body are enumerated. Those relevant to neuromusculoskeletal dysfunction are elaborated.

ELEMENTS AND MINERALS

Most minerals are compounds, which means that they are a combination of elements. Elements are substances that cannot be separated into simpler substances. Salt is made up of the elements sodium and chloride. Water is made up of the elements hydrogen and oxygen. A compound is a substance formed, when two or more elements are chemically joined. Water, salt and sugar are examples of compounds. When the elements are joined, the atoms lose their individual properties and have different properties from the elements they are composed of. A chemical formula is a way to express the composition of the compounds. Letters, numbers, and symbols are used to represent elements and the number of elements in each compound. Oxygen is the most abundant element in the earth's crust and in the body. The body's 43 kg of oxygen, is found mostly as a component of water, which makes up 70% of total body weight. Oxygen is also an integral component of biological molecules as in proteins, nucleic acids [deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)], carbohydrates, and fats.

Normal biochemical homeostasis is maintained by chemical reactions occurring in the human body using the organic constituents. These chemical reactions are facilitated by enzymes in the body whose numbers and specific function is beyond the scope of this literature review. However some enzymes relevant to musculoskeletal dysfunction will be touched upon. These enzymes require minerals to be activated. Hence minerals in their essential quantities are required for homeostasis.

Elements and their Functions

Oxygen, Hydrogen, Carbon and Nitrogen (96%)

Oxygen

Oxygen is the most vital ingredient to sustain life. Oxygen inhaled is delivered by the lungs through the blood to all of the body's organs and cells, which in turn produce energy to conduct various life sustaining activities. It is the presence of oxygen that makes planet earth conducive for life. The biological compounds essential for bodily functions are predominantly made by oxygen, hydrogen, carbon and nitrogen. They are:

- Proteins
- Fats (lipids)
- Carbohydrates
- Nucleic acids.

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Low levels of oxygen in the human body can cause sleeping disorders, drowsiness and fatigue, headaches, digestive disorders, breathing problems, muscle and joint pain, emotional disturbances, memory problems, infections and premature aging. Red blood cells (RBC) must ideally carry sufficient oxygen through the arteries to the internal organs for sustaining life. Normally, when RBC pass through the lungs, 95–100% of them are saturated with oxygen to carry. A reliable method of measuring oxygen saturation is an arterial blood gas (ABG) test. For this test, a small sample of blood is drawn directly out of an artery (not the median cubital vein as done routinely). Arterial blood can be directly tested for its oxygen level, level of carbon dioxide and the pH of the blood. An ABG test measures the following:

Partial pressure of oxygen (PaO_2): This measures the pressure of oxygen dissolved in the blood and how well oxygen is able to move from the lungs into the blood.

Partial pressure of carbon dioxide ($PaCO_2$): This measures how much carbon dioxide is dissolved in the blood and how well carbon dioxide is able to move out of the body.

pH: The pH measures hydrogen ions (H^+) in blood. The pH of blood is usually between 7.35 and 7.45. A pH of less than 7.35 is called acid and a pH greater than 7.45 is called alkaline.

Bicarbonate (HCO_3): Bicarbonate is a chemical that keeps the pH of blood from becoming too acid. If the pH level drops, HCO_3 is absorbed by the kidneys and returned to the blood instead of passing out of the body in the urine.

Oxygen content (O_2CT) and oxygen saturation (O_2 sat): Oxygen content, measures the amount of oxygen in the blood, whereas oxygen saturation measures how much of the hemoglobin in the RBC is carrying oxygen (O_2).

Indications for an ABG test are to:

1. Identify severe breathing problems and lung diseases, such as asthma, cystic fibrosis, or chronic obstructive pulmonary disease.
2. Monitor effectiveness of treatment for lung diseases.
3. Identify, if one needs extra oxygen or help with breathing as in assisted mechanical ventilation.
4. Find out if a certain patient is receiving the right amount of oxygen when oxygen is used as a treatment adjunct.
5. Measure the acid-base level in the blood of people, who have certain disease conditions and better yet possibly for unresolved chronic ailments.

Complete blood count (CBC): It can detect ranges of red blood cells (which carry oxygen) detecting anemia which, when present, can cause a wide range of musculoskeletal symptoms.

Hydrogen and carbon

The human body is made up mostly of water and is the medium in which all bodily chemical reactions take place. Hydrogen is an important component of water. Hydrogen ions are also necessary for cells to make adenosine triphosphate (ATP)

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the available source of energy. Organic molecules contain carbon and by linking smaller molecules, carbon is able to form very large polymers or macromolecules, which are important to human physiology. These are carbohydrates and lipids or fats. Carbon also combines with nitrogen to form proteins and nucleic acids.

Carbohydrates

These important carbon-based molecules are vital to life, in that they provide cells with energy. Most are sweet tasting and are also known by the colloquial term, sugar. Monosaccharide are the simplest sugars. Disaccharides are carbohydrates composed of two monosaccharide linked together. Sucrose is composed of glucose and fructose. Maltose is composed of glucose and glucose chains. Lactose, milk sugar, is composed of glucose and galactose.

Lipids

Lipids are predominantly composed of hydrogen and carbon atoms linked together. They are not very soluble in water. There are four main classes of lipids.

1. Fatty acids are chains of carbon and hydrogen .
2. Triacylglycerols, or triglycerides, account for the majority of lipids in the body. When a triacylglycerol is hydrolyzed, the fatty acids are released from the glycerol and the products can be metabolized in order to provide energy for cell functions.
3. Within the family of triacylglycerols are phospholipids, which are very important in building membranes within the body.
4. Steroids are composed of four interconnected carbon atom rings. For example, steroids are sex hormones (testosterone and estrogen), cholesterol and cortisol.

Nitrogen

Nitrogen compounds are basic building blocks in biology. Organisms use nitrogen, containing amino acids from food sources in the manufacture of proteins and nucleic acids.

Proteins

In addition to the common four elements of carbon, hydrogen, oxygen and nitrogen, proteins also contain sulfur and other elements in small amounts. Proteins are very large molecules of linked subunits called amino acids. The proteins in living organisms are composed of the same set of 20 amino acids. Proteins are the body builders.

Nucleic acids

Nucleic acids store, transmit and express genetic information and are composed of subunits called nucleotides. Nucleotides contain a phosphate group, a sugar and a ring of carbon and nitrogen atoms. The ring is also known as the base because it can accept hydrogen ions (protons). Nucleotides are linked together by bonds between the phosphate group of one nucleotide and the sugar of the next one. In this fashion, nucleotides form long chains. DNA stores genetic information in the sequence of the nucleotide subunits. RNA uses the information stored in DNA to write the instructions for linking together specific sequences of amino acids in order to form polypeptides per original DNA instructions. A DNA molecule looks like a double helix, RNA is a single chain of nucleotides.

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Summary

- Oxygen, carbon, hydrogen and nitrogen combine to form protein
- Oxygen, carbon and hydrogen combine to form carbohydrates
- Carbon and hydrogen combine to for lipids
- Carbon and nitrogen combine to form nucleic acids
- Oxygen and carbohydrates combine to produce energy
- Hydrogen and lipids combine to produce energy
- Oxygen and hydrogen combine to form water.

Clinically, poor hydration (water) and high uric acid can increase susceptibility to tendinitis. Carbohydrate deficiency can cause hypoglycemia, fatigue, distress, delirium and muscle atrophy. Protein deficiency causes sugar cravings, chronically low levels of energy, muscle cramps, slow wound healing, anemia and osteoporosis.

Minerals and their Functions

Calcium, Potassium, Phosphorus and Sulfur (3%)

Calcium

It builds bones and teeth, assists to maintain muscle contraction, heart action, nerve impulses, and blood clotting.

Deficiency: Nerve and muscle impairments, skeletal muscle spasm and heart failure.

Toxicity: Increased calcium levels may increase the risk for formation of kidney stones and soft tissue calcification.

Potassium

It maintains cell membrane potential, acid base balance, nerve conduction and heart rhythm.

Deficiency: Fatigue, insomnia, myalgia, muscle weakness, nerve symptoms, memory loss, anxiety, skin lesions, heart problems and in severe cases death.

Toxicity: Irregular heartbeat heart attack, nausea, diarrhea, ulcers and kidney disease.

Phosphorus

Phosphorus helps with energy production, acid-base balance, assists metabolism, is a component of cell membranes, builds bones and teeth, and assists calcium absorption.

Deficiency: Since most people get sufficient quantities of phosphorus from their diets, deficiency is rare. Anorexia, impaired growth, osteomalacia, skeletal demineralization, proximal muscle atrophy and weakness, cardiac arrhythmias, respiratory insufficiency, erythrocyte and lymphocyte dysfunction, susceptibility to infectious rickets, nervous system disorders and in severe cases, death.

Toxicity: Muscle twitching and jerking, convulsions.

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Sulfur

It plays an important role in collagen production. It also assists with cellular respiration, and vitamin B metabolism. It is an important part of protein and present in four amino acids: methionine, cystine, cysteine, and taurine. Sulfur is also present in two B vitamins, thiamine and biotin. Thiamine is important to skin and biotin to hair.

Deficiency: Since most people get sufficient quantities of sulfur from their diets, sulfur deficiency is extremely rare. Symptoms of deficiency may include skin disorders, muscle and joint pain, nerve disorders, circulatory disorders, stress, infection, and constipation.

Toxicity: There are no reported toxicities as excess sulfur is excreted in the urine.

Trace Minerals (1%)

Boron

Boron affects calcium and magnesium metabolism and membrane function. It is essential for efficient absorption of calcium and helps to significantly reduce the loss of calcium, magnesium and phosphorus in postmenopausal women. It is also considered helpful for ischemic heart disease and other forms of cardiovascular disease.

Deficiency: Boron deficiency signs may be related to vitamin D deficiency and osteoporosis.

Toxicity: Nausea, poor appetite, weight loss and infertility. Acute toxicity can cause kidney damage and death.

Copper

Copper helps with hemoglobin formation, RNA production, elastic tissue formation, cholesterol utilization. It also activates the enzyme oxidase. A severe disorder that impairs absorption of nutrients as in Crohn's disease, may cause copper deficiency. A high intake of zinc or iron can decrease the absorption of copper.

Deficiency: Copper deficiency is rare and is seen commonly among premature infants recovering from poor nutrition, or severe diarrhea. Symptoms of copper deficiency include arthritis, myelopathy, anemia, leukopenia, fatigue, bleeding under the skin, damage to blood vessels and an enlarged heart. The diagnosis of copper deficiency is based on symptoms and on blood tests that detect low levels of copper and ceruloplasmin (a protein containing copper).

Toxicity: Allergies, hair loss, psychological disorders, myalgia and neuralgia and hypertension.

Cobalt

Cobalt is a component of vitamin B_{12}, hence, cobalt deficiency is seen as an off shoot of vitamin B_{12} deficiency. People requiring additional cobalt are usually vegetarians. While deficiency can cause problems, so can excess (over 30 mg/

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day). Signs associated with excess B_{12} include nausea, heart failure, goiter, kidney damage, hypothyroidism and nerve damage.

Deficiency: Anemia, fatigue, menstrual problems, diarrhea, depression, peripheral neuropathy and myelopathy.

Toxicity: Nausea, heart failure, goiter, kidney damage, hypothyroidism and nerve damage.

Chlorine

Naturally chlorine exists in the body as chloride. It is important in acid base balance, the formation of digestive juices particularly gastric juices. It helps to cleanse blood, reduce excess fat, keep joints supple, and expel waste matter.

Deficiency: Digestive disorders and constipation.

Toxicity: Hypertension, anemia and shingles.

Chromium

Chromium helps with glucose and cholesterol utilization, insulin activity and heart muscle function.

Deficiency: Increased blood cholesterol, aberrant sugar metabolism with insulin inhibition, atherosclerosis of the aorta, high blood pressure, anxiety, impaired physical growth, delayed healing time, fatigue, decreased fertility and longevity.

Toxicity: Too much chromium can be as bad as insufficient chromium.

Fluorine

Fluorine (fluoride) is a component of bones and tooth enamel. Fluorine appears to increase deposition of calcium, thereby strengthening teeth and bones. Levels in drinking water artificially fluoridated with sodium fluoride can often reach toxic levels which then has an adverse effect on many enzymes.

Deficiency: Dental caries, osteoporosis.

Toxicity: Spinal deformity, nausea, diarrhea, chest pain, itching, fluorosis, patches on teeth.

Iodine

It is essential in small amounts for proper functioning of the thyroid gland.

Deficiency: Goiter and weight problems.

Toxicity: Goiter.

Iron

Iron helps with hemoglobin formation, electron transport, oxygen transport and is an enzyme activator.

Deficiency: Deficient situations cause iron deficiency anemia. This condition causes extreme fatigue, weakness, myalgia, shortness of breath, pale skin, headache, light-headedness, cold hands and feet, soreness of the tongue, brittle nails, unusual cravings for ice, dirt or starch, poor appetite and restless legs syndrome.

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Toxicity: Nausea, constipation, diarrhea, hemochromatosis and sometimes death, if improperly treated.

Molybdenum

This mineral is an enzyme activator and assists with uric acid formation.

Deficiency: Central nervous system dysfunction.

Toxicity: It is associated with joint pain as toxic levels increase uric acid production and may cause gout like symptoms.

Magnesium

Magnesium is important to calcium and potassium homeostasis. Numerous biochemical and physiological processes require or are modulated by magnesium, including energy production, protein synthesis, muscle contractions and vascular tone. Extracellular magnesium concentrations are critical to the maintenance of electrical potentials of nerve and muscle membranes and for transmission of impulses across neuromuscular junctions.

Deficiency: Magnesium deficiency is common since this mineral is refined out of many foods during processing. It is also elaborate and may be of relevance to the physical therapist owing to the common occurrence and musculoskeletal implications. They are the following:

Muscle twitches, cramps, muscle tension, muscle soreness, back aches, neck pain, tension headaches and temporomandibular joint (TMJ) dysfunction. Magnesium deficiency symptoms involving the peripheral nervous system include numbness, tingling. Other non-musculoskeletal symptoms include chest tightness or a peculiar sensation on/with inability to take a deep breath, sighing. Other symptoms are constipation, urinary spasms, menstrual cramps, difficulty swallowing or a lump in the throat—especially provoked by eating sugar, photophobia—especially difficulty adjusting to oncoming bright headlights in the absence of eye disease, loud noise sensitivity, insomnia, anxiety, hyperactivity and restlessness with constant movement, panic attacks, agoraphobia, and premenstrual irritability. Symptoms or signs of the cardiovascular system include palpitations, heart arrhythmias, angina, high blood pressure and mitral valve prolapse. People with magnesium deficiency often seem to be 'uptight.' Other general symptoms include a salt craving, both carbohydrate craving and carbohydrate intolerance, especially of chocolate, and breast tenderness.

Toxicity: Weakness, lethargy and central nervous system depression

Manganese

Manganese assists in carbohydrate metabolism, protein metabolism, nerve tissue, connective tissue and joint fluid production and vitamin B_1 utilization

Deficiency: Ataxia, fainting, hearing loss, weak tendons and ligaments, diabetes and myasthenia gravis.

Toxicity: Excess manganese interferes with the absorption of dietary iron. Long-term exposure to excess levels may result in irondeficiency anemia. Symptoms of

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toxicity mimic those of Parkinson's disease (tremors, stiff muscles) and excessive manganese intake can cause hypertension in patients older than 40.

Sodium

Sodium helps to maintain electrolyte balance, body fluid volume and nerve impulse condition.

Deficiency: Muscle cramps, fatigue and hair loss.

Toxicity: High blood pressure, fluid retention and swelling.

Silicon

It helps with bone formation, collagen formation, cartilage formation and elastic tissue formation.

Deficiency: Deficiency of silicon in animals causes retarded growth and abnormal bone development. A deficiency in human beings can lead to soft brittle nails, symptoms of aging of the skin such as wrinkles, thinning or loss of hair, poor bone development, osteoporosis. The chief symptom of silicon deficiency is sensitiveness to cold: one always feels cold even in the hot months.

Toxicity: No reported toxicity.

Selenium

Selenium is an important part of antioxidant enzymes that protect cells against the effects of free radicals that are produced during normal oxygen metabolism. The body has developed defenses such as events to control levels of free radicals because they can damage cells and contribute to the development of some chronic diseases. Selenium is also essential for normal functioning of the immune system and thyroid gland.

Deficiency: Immune deficiency.

Toxicity: Nerve abnormality, impaired immune function, diarrhea, hair loss.

Tin

Tin is associated with iodine, the same way as calcium is associated with magnesium. The greatest concentration of tin in the body is in the thymus gland. Since the thymus is a key immune system gland, it may be involved in autoimmune disease, thyroid diseases, growth and protein synthesis.

Deficiency: Cardiac disease, thyroid disease, peripheral swelling and fatigue.

Toxicity: Calcium loss and calcium imbalance.

Vanadium

This is required for glucose tolerance factor, for proper development of bones, cartilage and teeth and for cellular metabolism.

Deficiency: Deficiency in animals causes infertility, reduction in red blood cell production leading to anemia; iron metabolism defects; and poor bone, tooth and cartilage formation. A deficiency may be linked to reproductive problems and kidney disease, high cholesterol, obesity.

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Toxicity: Slow growth, diarrhea and death.

Zinc

Zinc helps with protein synthesis, carbon dioxide transport, sexual function, insulin storage, carbohydrate metabolism, wound healing.

Deficiency: Hair loss, skin lesions, diarrhea, and wasting of body tissues, delayed wound healing. Eyesight, taste, smell and memory are also connected with zinc. A deficiency in zinc can cause malfunctions of these organs and functions. Relevance to the musculoskeletal clinician would be wasting of body tissues, delayed wound healing.

Toxicity: Impairs copper absorption, weakens immune system.

Enzymes

Enzymes are chemical substances produced in the living organism. They are organic catalysts that control all the chemical reactions that take place in a living system. Enzymes are part of all living cells, including those of plants and animals. They are activated by minerals hence increasing the importance of the presence of adequate mineral content. There are over 20,000 enzymes in the human body. This estimate is based on the number of bodily processes that seem to require action. However, so far only about 1000 enzymes have been identified, but their essential role in nutrition and other living processes has been firmly established. Enzymes assist and act as catalyst for a chemical reaction. As our biochemical physiology is all about chemical reactions, enzymes play an integral role. Deficiencies can cause a deficient chemical reaction resulting in altered physiology and subsequent pathology. Their function is temperature specific and they are very specific to the chemical action and to perform.

Vitamins

Vitamins are components of food that are needed for growth, reproduction, and maintaining good health. Although vitamins are necessary to maintain good health, they are neither sources of energy nor significant contributors to the substance of the body. They act principally as regulators of metabolic processes. In general, most of them cannot be formed in the body—except niacin and vitamins A, D and K. For those who are in relatively good health, most health care providers believe that adequate levels of the essential vitamins can be obtained through well-balanced diets. The use of supplements to boost levels of these substances in the body has been the focus of much research and debate. The vitamins include vitamin A, vitamin D, vitamin E, and vitamin K, which are the fat-soluble vitamins and folate, vitamin B complex (vitamin B_{12}, biotin, vitamin B_6, niacin, thiamin, riboflavin, pantothenic acid) and vitamin C, which are the water-soluble vitamins. Vitamins are required in the diet in only tiny amounts, in contrast to the energy components of the diet, such as sugars, starches and fats. However, not receiving sufficient quantities of a certain vitamin can be devastating, resulting in vitamin deficiency diseases such as scurvy, pellagra, or rickets. Conversely, consuming too much of a certain vitamin can be toxic to a person's system. Vitamin tests

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