NMDF211
NUTRITIONAL BIOCHEMISTRY
Subject Study Guide
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NMDF211 SUBJECT STUDY GUIDE

As students in the ‘knowledge-age’, you are increasingly confronted with a vast array of information that is sometimes conflicting and contested. As students and practitioners, you must be able to seek, evaluate and synthesize information, and be active participants in the development of your own knowledge and understanding. Subsequently, you will become more responsive and dynamic practitioners who are able to ensure your ongoing capacity to effectively work within the changing nature and demands of society and enhance the field of Natural Health Practice.

A solid understanding of nutritional biochemistry is essential to facilitate critical enquiry, interpret mechanistic nutrition research and guides evidence-based practice. This subject integrates knowledge from biomedical science and Foundations of Human Nutrition to further advance students understanding of nutritional biochemistry. Lecturers can access the weekly readings for this subject in the students’ folder. Lecturers are encouraged to bring their own clinical experience to reinforce clinical application as appropriate. Students will have access to the following documents that are created, modified and managed by the Subject Coordinator:

1. Subject Outline
2. Subject Study Guide
3. Handout version of the lecture notes
4. Reading list
5. Weekly readings

Students can download these from Endeavour LMS.

How to best utilize directed self-learning

This Subject Study Guide (SSG) has been produced to assist you to explore, investigate, critically analyze and evaluate the principles and practice in this subject of study and to encourage you to achieve deeper levels of learning. As an approach to study, it is suggested that you read the questions for each session first. These questions will guide you through your reading, note-taking and research.

The following suggestions will assist you to pre-read effectively:

- Highlight the key points during your pre-readings.
- In the case of lengthy readings or documents, summarize and write your own synopsis.
- Answer questions or complete activities as directed.
- Jot down any queries, questions or concerns for discussion in class.

TO START

- Read the Subject Outline and pay particular attention to the Learning Outcomes, Set Texts and Assessment Tasks for this Subject of Study. Make certain that you understand what is expected of you to complete this subject successfully.

Textbook


Recommended readings:


**Recommended Readings:**

The reading materials listed in the weekly students folders on LMS provide additional research information and additional perspective for each weekly session in addition to the text recommended for the subject. Additional readings will enhance the students understanding of the topics covered in NMDF 211 Nutritional Biochemistry.

**Learning Outcomes**

1. Explain the biochemical absorption, storage and metabolic function of macro and micronutrients.

2. Describe the role of nutrients in the optimal functioning of key biochemical pathways in the body.

3. Integrate biochemical mechanisms with disease pathology and clinical treatment options.

4. Provide a coherent argument for the use of nutrient supplementation and food therapy for maintaining and promoting health and wellbeing through optimal biochemical pathway functions.
SESSION 1: Macronutrient Pharmacokinetics

Learning outcomes
Understanding of the metabolism of macronutrients: breakdown, absorption, transportation, distribution, delivery and storage of carbohydrates, lipids and proteins.

Session Overview
This session is designed to give you an overview of digestion, absorption, transport and storage of major macronutrients: carbohydrates, lipids and protein. This session is of vital importance in overall nutritional understanding.

Session Aims
- Understand the biochemical processes underpinning the digestion, absorption, transportation and metabolism of:
  - Carbohydrates
  - Lipids
  - Proteins

Carbohydrates:
They are important food source of energy. The major sources of dietary carbohydrate are the starches and the disaccharides. In the course of digestion, these are hydrolyzed by specific glycosidases to their component monosaccharides, which are absorbed into the circulation from the intestine. The monosaccharides then are transported to the cells of various tissues, passing through the cells’ outer membrane by facilitative transport by way of transporters. Glucose is transported into the cells of many different tissues by the GLUT family of transporters.

Lipids:
Lipids are hydrophobic and require special handling while digesting. Ingested fat must be finely dispersed in the intestinal lumen in order to present a sufficiently large surface area for enzymatic digestion to occur. In the bloodstream, reassembled lipid must be associated with proteins to ensure its solubility in that environment while undergoing transport. The major sites for the formation of lipoproteins are the intestine, which produces them from exogenously derived lipids, and the liver, which forms lipoproteins from endogenous lipids.

Central to the processes of fat transport and storage is adipose tissue, which accumulates fat as triacylglycerol when the intake of energy-producing nutrients is greater than the body’s caloric needs. When there is energy demand, fatty acids are released from storage and transported to other tissues for oxidation.

Proteins:
Proteins in foods become available for use by the body after they have been broken down into their component amino acids. In the body, proteins play many vital roles including functions in structural capacities, and as enzymes, hormones, transporters, and immunological protectors, among other roles.

The amino acids are used in a variety of ways: (1) for synthesis of new proteins for growth and/or replacement of existing body proteins; (2) for production of important non-protein nitrogen-containing molecules; (3) for oxidation as a source of energy; and (4) for synthesis of glucose, ketones, or fatty acids. The liver is the primary site of amino acid metabolism.
Prescribed Reading from Text:
- Chapter 3 Carbohydrates
- Chapter 5 Lipids
- Chapter 6 Proteins

Additional Readings:
- Unit II Structure and Properties of the Macronutrients
- Unit III Digestion and Absorption of the Macronutrients

Revision Questions:
- Where does absorption of lipids occur in the body?
- Describe the essential components of protein digestion
- What is our main dietary source of energy? How does the body digest, transport and use these?

SESSION 2: Water Soluble Vitamins Pharmacokinetics

Learning outcomes
Understanding of the biochemical processes underpinning the digestion, absorption, transportation and metabolism of water soluble vitamins: Vitamin C, Vitamin B1, Vitamin B2, Vitamin B3, Vitamin B5, Vitamin B6, Vitamin B12, Folate, Biotin.

Session Aims
- Understand the biochemical processes underpinning the digestion, absorption, transportation and metabolism of the water soluble vitamins.

Session Overview
Vitamins are organic compounds with regulatory functions that are required in the diet if the species (humans) is unable to synthesise them. Thus, vitamins are considered essential (in fact vita means “life” in Latin). Moreover, because these substances must be supplied by the diet, their discovery often came about because of their absence in the diet. Vitamins, for the most part, are not related chemically and differ in their physiological roles. The broad classification of vitamins based on certain properties common to each group is:
- Water-soluble vitamins
- Fat soluble vitamins

This session will introduce you to all water soluble vitamins. The body handles the water-soluble vitamins differently from the way it handles the fat-soluble vitamins. Characteristics of water soluble vitamins:
- They are absorbed into portal blood, in contrast to fat-soluble vitamins,
- They cannot be retained for long periods by the body (exception: cobalamin (vitamin B12)).
- Storage occurs only as a result of their binding to enzymes and transport proteins.
- Water-soluble vitamins are excreted in the urine whenever plasma levels exceed renal thresholds.
With the exception of vitamin C (ascorbic acid), water soluble vitamins are members of the B complex. Most of the B-complex group can be further divided according to general function: energy releasing or hematopoietic.

**Prescribed Reading from Text:**
- Chapter 9 Water-Soluble Vitamins; Table 9.1 provides a brief description of Functions, Deficiency Syndromes, Food Sources, Recommended Intake, and Individuals at Risk for Deficiency.

**Recommended Readings:**
  http://pubs.acs.org/doi/abs/10.1021/jf401545z

**Additional Readings:**
- UNIT VI The Vitamins
  - 24. Niacin, Riboflavin and Thiamin
  - 25. Folate, Choline, Folic Acid, Vitamin B12, and Vitamin B6
  - 26. Biotin and Pantothenic Acid
  - 27. Vitamin C

**Revision Questions:**
- Compare the digestion and absorption of Vitamin C and Vitamin B6
- What is the active form of Folate?
- What inhibits absorption of Vitamin B1?

**SESSION 3: Fat Soluble Vitamin and Macromineral Pharmacokinetics**

**Learning outcomes**
Understanding of the biochemical processes underpinning the digestion, absorption, transportation and metabolism of: Vitamin A, Vitamin D, Vitamin E, Vitamin K, Calcium, Magnesium, Phosphorous, Sodium, Potassium.

Session Aims

- Understand the biochemical processes underpinning the digestion, absorption, transportation and metabolism of the fat soluble vitamins and macrominerals.

Session Overview

This Session addresses each of the four fat-soluble vitamins—A, D, E, and K and macrominerals.

Fat soluble vitamins:
The absorption and transport of the fat-soluble vitamins, in contrast to those of the water-soluble vitamins, are closely associated with the absorption and transport of lipids. As with dietary lipids, optimal fat-soluble vitamin absorption requires the presence of bile salts. Similarly, fat-soluble vitamins in the body initially are transported by chylomicrons. Moreover, the fat-soluble vitamins are stored in body lipids, although the amount stored varies widely among the four fat-soluble vitamins.

Refer Chapter 10 The fat-soluble Vitamins, Table 10.1 and 10.2 in Gropper S, Smith J (2016) Advanced Nutrition and Human Metabolism 7th ed, Wadsworth Cengage Learning, Canada, provides an overview of the discovery, function, deficiency syndrome, food sources, and recommended dietary allowance (RDA) or adequate intake (AI) of each of the fat-soluble vitamins.

Macro minerals:
The minerals constitute only about 4% of total body weight though they are of great importance in normal nutrition and metabolism.
Their functions are:
- Provide the medium essential for normal cellular activity,
- Determine the osmotic properties of body fluids,
- Impart hardness to bones and teeth, and
- Function as obligatory cofactors in metallo-enzymes.

Macro minerals, also called major minerals or macronutrient elements, are distinguished from the micro minerals by their occurrence in the body. The major minerals of the human body traditionally include calcium, phosphorus, magnesium, sodium, potassium, and chloride.

Refer Chapter 11 Macro minerals, Table 11.1 in Gropper S, Smith J (2016) Advanced Nutrition and Human Metabolism 7th Ed, Wadsworth Cengage Learning, Canada, for an overview of the macro minerals, including information on general functions, approximate body content, some enzyme cofactors, deficiency signs, food sources, and recommended intakes.

Prescribed Reading from Text:
- Chapter 10 Fat-Soluble Vitamins
- Chapter 11 Major Minerals

Discussion: Clinical issues of micronutrient metabolism:
Perspectives: Osteoporosis and Diet pp 450-453. Also in PDF version in Session 3 readings as necessary for class discussion.

Recommended Readings


Additional Readings:


- UNIT VI The Vitamins
  - 28. Vitamin K
  - 29. Vitamin E
  - 30. Vitamin A
  - 31. Vitamin D

- UNIT VII The Minerals
  - 32. Calcium and Phosphorus
  - 33. Magnesium
  - 34. Sodium, Chloride, and Potassium
  - 35. Body Fluids and Water Balance

Revision Questions:

- Compare the manufacture and production of Vitamins D and K
- Why are calcium and magnesium inter-dependent minerals?
- Explain the process of absorption, transportation and storage of Vitamin A.

SESSION 4: Micromineral Pharmacokinetics

Learning outcomes

Understanding of the biochemical processes underpinning the digestion, absorption, transportation and metabolism of: Iron, Molybdenum, Copper, Zinc, Selenium, Chromium, Iodine, Boron, Vanadium.

Session Aims

- Understand the biochemical processes underpinning the digestion, absorption, transportation and metabolism of the microminerals and ultra-trace elements.

Session Overview

This session covers most micronutrients and few ultra-trace elements. Micronutrients are also known as essential minerals or trace elements. Criteria to establish essentiality of a mineral:

- It is present in all healthy tissue of living things.
- Its concentration from one animal to the next is fairly constant.
• Withdrawing it from the body induces reproducibly the same physiological and structural abnormalities, regardless of species studied.
• Adding it either reduces or prevents these abnormalities.
• The abnormalities induced by deficiencies are always accompanied by specific biochemical changes.
• These biochemical changes can be prevented or cured when the deficiency is prevented or cured.

The difference in body content between the macro and microminerals is quite large. The body’s content of the macro minerals ranges from ~35 to 1,400 g, and that of the trace elements ranges from <1 mg to ~4 g. This session also covers two of the five ultra-trace elements (Boron and Vanadium). However, while copper, chromium, fluoride, iodine, molybdenum, and selenium are considered ultra-trace elements by definition, the Food and Nutrition Board includes them under “Micro Minerals,” based on the establishment of either an AI or an RDI.


Recommended Readings:


Additional Readings:

• UNIT VII The Minerals
  ○ 36. Iron
  ○ 37. Zinc, Copper, and Manganese
  ○ 38. Iodine
Revision Questions:

- Which minerals act as antagonists to zinc?
- What is the process of absorption, transport, metabolism and storage of copper?
- Which minerals act as catalysts in the process of hormone production?

SESSION 5: Nutrients that resist digestion, microbiota and malabsorption syndromes

Learning outcomes

Understanding of the biochemical processes associated with fibre fermentation, classification, characteristics and functions of dietary fibre; definition of prebiotics and associated health benefits, the effects of gut microbiota on digestion, nutrient status and health.

Session Aims

- Understand the biochemical processes of the nutrients that resist digestion, gut microbiota and their influence on gut health

Key Concepts

- Nutrients that resist digestion
  - Dietary fibre
  - Function fibre
    - Soluble and insoluble
- Effects of GUT microbiota on digestion, nutrient status and systemic physiology
  - Prebiotic and microbiota synergy
- Intolerance and malabsorption syndromes

Prescribed Reading from Text:

Recommended Readings:


**SESSION 6: Liver detoxification pathways**

**Learning outcomes**

Understanding of the biochemical processes involved in liver detoxification phases 1 and 2; methylation, homocysteine and alcohol detoxification and detrimental effects associated with excessive consumption.

**Session Aims**

- Review hepatic function.
- Describe the liver detoxification pathways and the role of nutrient substrates, cofactors and enzymes involved in optimising liver function.
- Review of hepatic dysfunction including NAFLD, fibrosis and cirrhosis.
- Discuss the harmful health impacts of alcohol consumption.
- Determine nutritional support for hepatic dysfunction and disease.

**Session Overview**

We have seen that liver plays an important role in metabolism. It also filters and detoxifies the blood. The detoxification process occurs in liver and about 99% of blood gets purified in liver and only 1% of impurities/toxic materials are left for kidney to filter. This session describes the two phase process of liver detoxification. The phase I detoxification breaks down toxins and chemicals into intermediate metabolites. Phase II detoxification system conjugates intermediate metabolites with a variety of different enzymes and neutralizes the intermediate metabolite or makes the metabolite easier to eliminate via either bile or urinary excretion. Role of various nutrients and food is also established which control and regulate the whole biochemical process of liver detoxification.

Alcohol (ethanol) is consumed in the form of alcoholic beverages such as beer, wines, and distilled spirits. Though it is not a natural nutrient it yields 7 kcal/29 kJ per gram and may account for up to 10% of the total energy intake of moderate consumers and up to 50% for alcoholics. It is readily absorbed through the entire gastrointestinal tract and transported unaltered in the bloodstream and then oxidatively degraded in tissues, primarily the liver, first to acetaldehyde and then to acetate. Acetate subsequently is converted to acetyl CoA and oxidised via the Krebs cycle. Thus, the liver plays an important role in alcohol detoxification as well. At least three enzyme systems are capable of alcohol oxidation (detoxification):

- Alcohol dehydrogenase (ADH)
- The cytochrome P-450 system
- Catalase-H2O2 system
Importance of nutrients in alcohol detoxification, liver functioning and reducing alcohol cravings is also discussed under this session.

**Prescribed Reading from Text:**
- Chapter 5 Lipids; Ethyl alcohol: metabolism and biochemical impact

**Recommended Readings:**

**Review Questions**
- What are the principle differences in Phase 1 and Phase 2 liver detoxification?
- Which peoples may have difficulty metabolising alcohol?
- Why is homocysteine important?
- List the nutrients important for reducing alcohol craving.

**SESSION 7: Energy Metabolism Part I**

**Learning outcomes**
Understanding of the biochemical processes underlying energy metabolism in the body: glycolysis, glycogenesis, glycolysis, Krebs cycle, substrate phosphorylation, electron transport chain, and gluconeogenesis.
Session Aims
- Understand the biochemical processes and the associated nutritional cofactors underpinning energy systems in the human body.

Session Overview
- This session focuses on the metabolic regulation of energy systems. The biochemical processes and the associated nutritional cofactors for Carbohydrate metabolism in the human body will be covered under this session.
- In the cells, monosaccharides first are phosphorylated at the expense of ATP and then can follow any of several integrated pathways of metabolism. Cellular glucose can be converted to glycogen, primarily in liver and skeletal muscle, or it can be routed through the energy-releasing pathways of glycolysis, the tricarboxylic acid cycle (TCA cycle) or Krebs cycle and Electron Transport Chain (etc).
- Non-carbohydrate substances derived from the other major nutrients, the glycerol from triacylglycerols (fats) and certain amino acids, can be converted to glucose or glycogen by the pathways of gluconeogenesis. In gluconeogenesis, the reactions are basically the reversible reactions of glycolysis, shifted toward glucose synthesis in accordance with reduced energy demand by the body. The Cori cycle describes the liver’s uptake and gluconeogenic conversion of muscle-produced lactate to glucose.

Prescribed Reading from Text:
- Chapter 3 Carbohydrates; Integrated Metabolism in Tissues

Recommended Readings:

Additional Readings:
- UNIT IV Metabolism of the Macronutrients
12. Carbohydrate Metabolism: Synthesis and Oxidation

Revision Questions:
- What is the major site of glycogen synthesis and storage?
- What is glycolysis?
- What is the function of glutamine in relation to lactic acid?

SESSION 8: Energy Metabolism Part II

Learning outcomes
Understanding of the biochemical processes underpinning lipid (fat) metabolism in the body.

Session Aims
- Understand the biochemical processes and the nutritional factors underpinning energy systems in the human body.

Session Overview
- The biochemical reactions and the associated nutritional factors underpinning lipid metabolism in the human body is studied under this session.
- Adipose tissue stores fat as triacylglycerol when the intake of energy-producing nutrients is greater than the body’s caloric needs. When there is energy demand, fatty acids are released from storage and transported to other tissues for oxidation.
- The fat mobilisation follows the adipocyte’s response to specific hormonal signals that stimulate the activity of the intracellular lipase. Fatty acids are a rich source of energy. Their mitochondrial oxidation furnishes large amounts of acetyl CoA for Krebs cycle catabolism, and in situations of low carbohydrate intake or use, as occurs in starvation or diabetes, the rate of fatty acid oxidation increases significantly with concomitant acetyl CoA accumulation. This causes an increase in the level of the ketone bodies—organic acids that can be harmful through their disturbance of acid-base balance but that also are beneficial as sources of fuel to tissues such as muscle and brain in periods of starvation.
- Dietary lipid has been implicated in atherogenesis, the process leading to development of the degenerative cardiovascular disease called atherosclerosis. Moreover, inflammation and oxidised LDLs are major contributors to atherogenesis. Saturated fatty acids having medium-length chains, along with unsaturated trans-fatty acids, are associated with hyper-cholesterolemia, whereas mono- and poly-unsaturated cis-fatty acids tend to lower serum cholesterol.

Prescribed Readings from Text:
- Chapter 5 Lipids; Integrated Metabolism in Tissues

Activity Reading:

**Recommended Readings:**


**Additional Readings:**


- UNIT IV Metabolism of the Macronutrients
  - 16. Metabolism of Fatty Acids, Acylglycerols, and Sphingolipids
  - 18. Lipid Metabolism: Polyunsaturated Fatty Acids

**Revision Questions:**

- Give a summary of Lipogenesis.
- Why is cholesterol essential for the body?

**SESSION 9: Managing Oxidation**

**Learning outcomes**

Understanding of the biochemical processes underpinning oxidative processes in the body, including both endogenous and exogenous free radicals and antioxidants; regeneration (Redox) pathways.

**Session Aims**

- Describe the nutritional biochemistry through which key nutrients have an anti-oxidant function.
Describe the nutritional biochemistry through which key nutrients have a ‘redox’ effect on oxidised compounds

State the importance of balance within the utilisation of key nutrients when utilising antioxidants.

Session Overview

There are various nutrients in our body that function as antioxidants (Vitamins, peptides, coenzymes, minerals etc). This session comprehensively reviews how all of these individual nutrients function together to protect the body from destructive radicals and destructive non radical species. First half of the session reviews free radical chemistry. It then addresses how free radicals and selected non radicals are generated in the body, the damage caused by reactive oxygen and nitrogen species, and how the antioxidant nutrients function together to eliminate destructive radical and non-radical species.

Prescribed Reading from Text:

Chapter 10, The Fat-soluble Vitamins; Perspective: The Antioxidant Nutrients, Reactive Species, and Disease.

Recommended Readings:


Review Questions:

What are the main endogenous antioxidants?
Name 3 exogenous antioxidants.
Which nutrients effectively ‘recycle’ each other?

SESSION 10: Amino Acid Biochemistry

Learning outcomes

Understanding of the biochemical processes underpinning amino acid biochemistry.

Session Aims

Overview of deamination and urea cycle
Describe the biochemical pathways associated with amino acid metabolism.
Describe the biochemical pathways associated with energy cycle component production.
Describe the biosynthesis of neurotransmitters from amino acid precursors.
Session Overview

The liver is the primary site of amino acid metabolism. After digestion of proteins in gastrointestinal tract proteins are carried to liver via blood and here they are used for:

- synthesis of new proteins/amino acids for growth and/or replacement of existing body proteins;
- production of important non-protein nitrogen-containing molecules e.g. purines, pyrimidines, neurotransmitters;
- oxidation as a source of energy; and
- synthesis of glucose, ketones, or fatty acids

All these biochemical pathways associated with amino acid metabolism and the biosynthesis of purines, pyrimidines and neurotransmitters from amino acid precursors are mainly covered under this session. Also biosynthesis of pyruvate, acetyl co A and various substrates within Krebs cycle is discussed. All these biosynthesis processes require various nutrients for the activity of enzymes involved. The role of nutrients in biochemical processes of the body is the core of this session.

Prescribed Reading from Text:

- Chapter 6 Protein; Amino acid metabolism

Recommended Readings:


Review Questions:

- What foods are high in purines and what are the health implications in predisposed individuals who consume large amounts of these?
- Which amino acid and which nutrients are required for production of Melatonin and Serotonin?
- Where is glutamine used in the body?

SESSION 11: Blood Cell Biochemistry and Immunity

Learning outcomes

Understanding of the biochemical processes underpinning the role of nutrients in blood cells and introduction of gut-associated-immune-tissue (GALT) and role in immunity.
Session Aims

- Overview of haemopoietic subdivisions and lineages
- In-depth coverage of erythropoiesis – red blood cell production, regulation and nutrient requirements
- In-depth coverage of leukopoiesis – white blood cell production, regulation and nutrient requirements
- Introduction to immune system and GALT.

Session Overview

In this session the role of various nutrients for Haemopoiesis are discussed. All blood cells are differentiated from common pluripotent stem cell. This differentiation is based on various nutrients, for example Erythropoietin (EPO), a cytokine produced in the kidneys induces red blood cell (erythrocyte) differentiation in the bone marrow. This is reason why recombinant form EPO is extensively used for treatment of anaemias. Apart from differentiation process all these blood cells require different nutrients as co factors to carry their normal functioning. Role of nutrients in normal functioning of blood cells are also established under this session.

Review Questions:

- Where is erythropoietin produced and what is its’ function?
- What cofactors are necessary for Red Blood Cells?
- Describe Mast cells and their cofactors

Recommended Readings:

  http://www.nature.com/icb/journal/v92/n1/full/icb201354a.html
  http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3847738/

SESSION 12: Inflammation

Learning outcomes

Understanding of the biochemical processes underpinning inflammatory processes.

Session Aims

- Describe the biochemical pathways associated with inflammation and their associated nutritional cofactors.
- Describe the relationship between nutrition and immune function.
- Define the role of specific nutrients on immune function.
- Describe the impact of adiposity, metabolic syndrome on inflammatory processes.
Session Overview

This session explains the biochemical pathways associated with inflammation and their associated nutritional cofactors and describes relationship between nutrition and immune function. Metabolism of Eicosanoids - the most potent regulators of cellular function is also studied here. Functions of Eicosanoids include:

- Anti-inflammatory function
- Regulate smooth muscle contraction
- Increase water and sodium excretion
- Modulators e.g. some eicosanoids stimulate while others inhibit the same process.

This session describes role of various chemicals and nutrients that act as cofactors in each phase of inflammation and also covers the important anti-inflammatory nutrients.

Recommended Readings:


Review Questions:

- Describe eicosanoids and the functions they are involved in
- Name the amino acids and mineral required for formation of Glutathione

SESSION 13: Homeostatic maintenance

Learning outcomes
Understanding of the biochemical processes underpinning inflammatory processes.

**Session Aims**
- Body fluid, electrolytes and the role of the kidneys
- Acid-base balance and associated disorders
- Regulation of pH

**Key Concepts**
- Water distribution in the body and fluid compartments
- Osmotic pressure, characterisation of solutions and filtration forces
- Role of the kidneys
- Electrolytes and concentration in body fluids
- Acid-base balance and regulation of pH
- Acid-alkaline hypothesis
  - Estimating the potential renal acid load (PRAL) of foods
  - Primary benefits that may result from adherence to an alkaline diet

**Prescribed Reading from Text:**
- Chapter 12 Water and electrolytes

**Recommended Readings:**
- http://www.hindawi.com/journals/jeph/2012/727630/