Chapters 1 & 3

INTAKE: DIGESTION, ABSORPTION, TRANSPORT, AND EXCRETION OF NUTRIENTS

&

INTAKE: THE NUTRIENTS AND THEIR METABOLISM
Objectives

- Review the path of food through the GI tract
- Explain the role of each organ of the GI tract including the accessory organs
- Explain digestion and absorption of CHO, FAT and PRO
- Explain the structure of the macronutrients
- Know the role of dietary fiber
- List the fat and water soluble vitamins
- Describe the major role of the vitamins
- Explain the deficiency and toxicity symptoms of the vitamins
- Know food/supplement sources of vitamins
- Describe which minerals are major and trace
- Explain the role of the minerals in our health
- Know food/supplement sources of minerals
Gastrointestinal Tract (GIT)

- Extracts macronutrients (protein, carbohydrates, lipids, water, and ethanol) from ingested foods and beverages
- Absorbs necessary micronutrients and trace elements
- Serves as a physical and immunologic barrier
- Is one of the largest organs; has the greatest surface area and the greatest number of immune cells
The Digestive System

- Salivary glands: (mucus and digestive enzymes)
- Parotid
- Sublingual
- Submaxillary
- Epiglottis (open) (closed)
- Esophagus
- Trachea
- Tooth
- Tongue
- Diaphragm
- Liver (bile)
- Liver ducts
- Cystic duct
- Gallbladder
- Duodenum
- Bile duct opening
- Ascending colon
- Cecum
- Appendix
- Ileum
- Esophagus
- Stomach
- Spleen
- Pancreas (digestive enzymes and insulin)
- Pancreatic duct
- Transverse colon
- Descending colon
- Jejunum
- Sigmoid colon
- Rectum
- Anus
Features of Digestion and Absorption

- 92% to 97% of the diet is absorbed
- Small intestine: key role in digestion and absorption
- Intestines: 7 m long
  - Villi and microvilli or brush border
The Health of the Body Depends on the Health of the GIT

- After only a few days of starvation, the GIT atrophies
- The cells lining the GIT have a lifespan of only 3 to 5 days
- The cells lining the GIT are more susceptible to damage by:
  - Nutrient deficiency
  - Damage from toxins and irradiation
  - Disruption in blood flow
Gastric secretions contain hydrochloric acid, pepsin, gastric lipase, mucus, intrinsic factor, and gastrin (hormone that stimulates secretion of gastric acid (HCl))

- Food becomes semiliquid chyme
- Acid reduces the number of microorganisms
- Solid meal empties in 2 to 3 hours
Sites of Secretion, Digestion, and Absorption
Small Intestine

- Primary organ of nutrient and water absorption
- Surface area is increased by length, folds, villi, and microvilli
- Fats are emulsified, digested, and absorbed in micelles
Summary of Fat Absorption
Transport Pathways Through the Cell Membrane

Diffusion
- Channel protein
- Simple diffusion
- Facilitated diffusion

Active transport
- Carrier proteins
- Energy
- ATP
Large Intestine

- 1.5 m long: cecum, colon, and rectum
- Nutrients formed here: vitamin K, vitamin $\text{B}_{12}$, thiamin, riboflavin
- Bacterial action to produce gases and organic acids
- Colonic salvage: SCFA production through fermentation
- Water reabsorption
The Gradual Breakdown of Large Starch Molecules

[Diagram showing the breakdown of starch molecules into glucose molecules through the action of salivary, pancreatic, and intestinal enzymes.]
Sites of Secretion and Absorption into Gastrointestinal Tract
Macronutrients

- Carbohydrates
- Fats and lipids
- Alcohol
- Amino acids and protein
### Saccharides

<table>
<thead>
<tr>
<th>Monosaccharides</th>
<th>Oligosaccharides</th>
<th>Polysaccharides</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Glucose</td>
<td>- Polymers containing 2 to 20 sugar molecules</td>
<td>- Amylose</td>
</tr>
<tr>
<td>- Fructose</td>
<td>- Readily water soluble and often sweet</td>
<td>- Amylopectin</td>
</tr>
<tr>
<td>- Galactose</td>
<td></td>
<td>- Resistant starch</td>
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</tbody>
</table>

### Disaccharides
- Sucrose
- Lactose
- Maltose

### Oligosaccharides
- Polysaccharides
  - Amylose
  - Amylopectin
  - Resistant starch
  - Dextrins
  - Glycogen (animal carbohydrate)
Fiber

Types of fiber:
- Cellulose
- Beta-glucans
- Chitin and chitosan
- Hemicellulose
- Pectins, gums, and mucilages
- Fructans
- Algal polysaccharides
- Lignin

Recommendations:
- 38 g/day for men
- 25 g/day for women

Varies based on its solubility
- Insoluble fiber increases stool volume and decreases gastrointestinal (GI) transit time
- Soluble fiber slows GI transit time, binds cholesterol and minerals, and decreases nutrient absorption
- Fermented into short-chain fatty acids
Glycemic Index

• Ranks carbohydrates based on their ability to raise blood glucose levels
• Advantages of foods with low glycemic index
• Evidence on the use of the glycemic index to modify diets and prevent and control chronic disease is not yet conclusive
Lipids

Functions
- Energy (9 kcal/g)
- Organ positioning, protection
- Fat-soluble vitamins and phytochemicals

Types of lipids
- Triglycerides
- Phospholipids (e.g., lecithin)
- Sterols (e.g. cholesterol)

Triglycerides in the diet
- Saturated (SFA)
- Monounsaturated (MFA)
- Polyunsaturated (PUFA)
  - Essential fatty acids
    - Omega-3
    - Omega-6
Lipids- Omega 3 FA

- Found primarily in marine oil
- EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid)
- Beneficial effects have been shown in many diseases
- Optimal omega-6:omega-3 is 2:1 to 3:1
- U.S. consumption is 8:1 to 12:1
Alcohol

- 7 kcal/g
- Metabolized primarily by the liver enzyme alcohol dehydrogenase (ADH)
- ADH requires niacin and thiamine to function
Amino Acids and Protein

- Essential amino acids
- Nonessential amino acids
- Vegetable vs. animal protein
- Complementary proteins
- Protein digestibility corrected amino acid score (PDCAAS)
- Denaturation
## Summary of Vitamins

<table>
<thead>
<tr>
<th>Fat Soluble</th>
<th>Water-Soluble</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Vitamin A</td>
<td>• Thiamin</td>
</tr>
<tr>
<td>• Vitamin D</td>
<td>• Riboflavin</td>
</tr>
<tr>
<td>• Vitamin E</td>
<td>• Niacin</td>
</tr>
<tr>
<td>• Vitamin K</td>
<td>• Pantothenic acid</td>
</tr>
<tr>
<td></td>
<td>• Vitamin B6</td>
</tr>
<tr>
<td></td>
<td>• Folate</td>
</tr>
<tr>
<td></td>
<td>• Vitamin B12</td>
</tr>
<tr>
<td></td>
<td>• Biotin</td>
</tr>
<tr>
<td></td>
<td>• Vitamin C</td>
</tr>
</tbody>
</table>
Vitamin A Retinol (animal sources) and carotenoids (plant sources)

**Essential roles in**
- vision
- normal cell differentiation
- and cell surface function
- growth and development
- immune functions,
- reproduction

**Deficiency**
- Blindness in the developing world
- Night blindness
- Xerophthalmia, hyperkeratosis
- Increased risk for infection

**Toxicity**
- Bone pain and fragility
- Hydrocephalus and vomiting (infants and children)
- Dry, fissured skin
- Brittle nails
- Hair loss (alopecia)
- Gingivitis
- Anorexia
- Irritability
- Fatigue
- Abnormal liver function
Vitamin D

Production in skin when exposed to UV irradiation
Functions as a steroid hormone
Maintains calcium and phosphorus homeostasis

**Deficiency**
- Rickets in children
- Osteomalacia in adults

**Toxicity**
- Excessive calcification of bones
- Kidney stones
- Metastatic calcification of soft tissue (kidney, heart, lung, and tympanic membrane)
- Hypercalcemia
- Headache
- Weakness
- Nausea and vomiting
- Constipation
Vitamin D
Vitamin E

- "Vitamin E" is the collective name for a group of 8 lipid-soluble compounds with distinctive antioxidant activities
- Protection against damage by reactive oxygen species
- Tocopherols and tocotrienols
Vitamin K - Phylloquinones and menaquinones

Blood clotting and bone formation

Best sources
- green leafy vegetables
- smaller amounts in dairy products, meats, eggs, fruits, and cereals

Deficiency
- Hemorrhage
- Fatal anemia
- Hemorrhagic disease in newborns
- Hip fracture in older adults
Thiamin (B1)

- Carbohydrate metabolism and neural function
- Richest sources are yeast and liver; cereal grains provide most in human diets
- Destroyed by heat, oxidation, and radiation; stable when frozen
Riboflavin (B2)

- Essential for metabolism of carbohydrates, amino acids, and lipids; supports antioxidant protection
- Green leafy vegetables are rich sources; most comes from meat, dairy products, and fortified grains in the American diet
Niacin (B3)

- Essential for energy production and metabolism
- Biosynthesis (from tryptophan), absorption, transport, and storage
- Sources: lean meats, poultry, fish, peanuts, and yeasts

Deficiency: Pellagra, Casals necklace
4 Ds
- Dermatitis
- Diarrhea
- Dementia
- Death
Pantothenic Acid

- Critical role in metabolism; integral part of coenzyme A
- Present in all plant and animal tissues
- Deficiency impairs lipid synthesis and energy production
Vitamin $B_6$ (Pyridoxine)

- Metabolism of amino acids, neurotransmitters, glycogen, heme, and steroids
- Good sources include meats, whole grains, vegetables, nuts
Folate

Formation and maturation of red and white blood cells in bone marrow; single-carbon carrier in heme formation

Rich sources include,
- Liver
- Mushrooms
- green leafy vegetables

Deficiency
- Impaired biosynthesis of DNA and RNA
- Megaloblastic, macrocytic anemia
- Neural tube defects
Vitamin $\text{B}_{12}$ (Cobalamin)

<table>
<thead>
<tr>
<th>Richest sources</th>
<th>Deficiency</th>
</tr>
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<tbody>
<tr>
<td>Liver</td>
<td>Impaired cell division</td>
</tr>
<tr>
<td>Kidney</td>
<td>Megaloblastic anemia</td>
</tr>
<tr>
<td>Milk</td>
<td>Neurologic abnormalities</td>
</tr>
<tr>
<td>Eggs</td>
<td>Pernicious anemia</td>
</tr>
<tr>
<td>Fish</td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td></td>
</tr>
<tr>
<td>muscle meats</td>
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</tr>
</tbody>
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*Not naturally found in plant foods*
Biotin

Rich sources
- Milk
- Liver
- egg yolks
- a few vegetables

Deficiency is rare: parenteral nutrition
Ascorbic Acid (Vitamin C)

Synthesis of collagen and carnitine and other metabolic reactions; antioxidant; promotes resistance to infection

Best sources
- Fruits
- Vegetables
- Organ meats

Deficiency
- Easily destroyed by oxidation; lost in cooking water
- Scurvy
- Impaired wound healing; edema; hemorrhages; and weakness in bone, cartilage, teeth, and connective tissues

Toxicity
- GI disturbances and diarrhea
Mineral Classifications

- Macrominerals
- Microminerals
- Ultratrace minerals

Bioavailability of Minerals

- Reduced by binding to free fatty acids, precipitation, mineral–mineral interactions, organic inhibitors such as phytates and oxalates, stress
- Enhanced by ascorbic acid (for nonheme iron), hemostatic adaptations
Calcium

Functions
- Acquire optimal bone mass and density
- Maintain bone health
- Transport functions of cell membranes
- Nerve transmission
- Regulation of heart muscle function
- Blood clotting
- Role in obesity

Deficiency
- Lower peak bone mass
- Osteomalacia/Osteoporosis
- Chronic diseases, such as colon cancer, hypertension, osteoporosis
- May be implicated in the development of hypertension
Phosphorus

Functions
- High-energy phosphate bonds in ATP and other cellular forms of energy
- Phospholipids
- Enzyme activation and buffer system
- Bones and teeth

Sources
- Meat, poultry, fish, and eggs
- Milk and milk products
- Nuts and legumes
- Cereals and grains
- Food additives
Magnesium

Functions
- Cofactor for more than 300 enzymes
- Neuromuscular transmission and activity
- Bone density

Sources
- Milk
- Bread
- Coffee
- Ready-to-eat cereals
- Beef
- Potatoes
- Dried beans and lentils
Sulfur

- Constituent of three amino acids: cystine, cysteine, and methionine
- May be considered an antioxidant
- Essential component of three vitamins: thiamin, biotin, and pantothenic acid
- Food sources include meat, poultry, fish, eggs, dried beans, broccoli, and cauliflower
Microminerals (Trace Elements)

- Essential to optimal growth, health, and development
- Exist in two forms
  - As charged ions
  - Bound to proteins or complexed in molecules
Iron

Heme vs. nonheme iron
Mucosal block

Functions of Iron
- Red blood cell function
- Myoglobin activity
- Numerous heme and nonheme enzymes
- Oxidation-reduction activity in respiratory gas transport and cytochrome activity
- Immune function and cognitive performance

Sources
- Liver
- Seafood
- Kidney, heart
- Lean meat, poultry
- Dried beans and vegetables
- Egg yolks
- Dried fruits
- Dark molasses
- Whole-grain and enriched breads and cereals

Iron Deficiency
- Hypochromic, microcytic anemia
- Caused by injury, hemorrhage, illness, and unbalanced diet
- Athletic amenorrhea

Iron Overload
- Major cause is hemochromatosis
- Hemosiderosis may lead to hemochromatosis
- Risks of iron supplements for older adults
Zinc

Functions
- in association with more than 300 enzymes
- Synthesis or degradation of major metabolites
- Structural roles in proteins
- Intracellular signal in brain cells
- Transport processes, immune function, and genetic expression

Sources of Zinc
- Meat, fish, poultry
- Milk and milk products
- Oysters and other shellfish
- Liver
- Ready-to-eat fortified breakfast cereals
- Whole-grain cereals
- Beans, nuts, soy products

Deficiency
- Decreased taste acuity
- Delayed wound healing
- Growth retardation
- Hypogonadism
- Immune deficiencies
- Skin lesions
Fluoride

- Beneficial to tooth enamel and prevention of dental caries
- Found in fluoridated drinking water, fluoridated toothpaste, foods and drinks made using fluoridated water
- Toxicity and fluorosis appear at daily doses of 0.1 mg/kg
Copper

- Component of many enzymes
- Roles in mitochondrial energy production

Sources of copper
- Chocolate
- Nuts
- Cereal grains
- Dried legumes
- Dried fruits
- Shellfish
- Organ meats
- Muscle meats
Iodine

- Synthesis of triiodothyronine ($T_3$) and thyroxine ($T_4$)
- Inhibited by goitrogens
- Selenium is important in iodine metabolism
- Sources
  - Iodized or sea salt
  - Seafood
  - Content of cow’s milk and eggs depends on the animal’s diet
- Content of vegetables depends on soil
- Iodophors used in food processing
Selenium

- Antioxidant and free radical scavenger
- Role in iodine metabolism

Sources
- Brazil nuts
- Seafood
- Kidney, liver
- Meat, poultry
Manganese

- Component of many enzymes, especially in mitochondria
- Activates many other enzymes
- Formation of connective and skeletal tissues
- Growth and reproduction
- Carbohydrate and lipid metabolism
Chromium

- Potentiates insulin action
- Possible glucose tolerance factor
- Possible role in regulation of gene expression
Molybdenum

- Role in enzymes that catalyze oxidation-reduction reactions
- Possible role in response of some people with asthma to sulfites
- Deficiency causes mental changes and abnormalities of sulfur and purine metabolism
Boron

- Essentaility not yet established
- Influences activity of metabolic enzymes and metabolism of several nutrients
- Associated with cell membranes
Cobalt

- Component of vitamin $\text{B}_{12}$ (cobalamin)
- Macrocytic anemia