Nutrition, Metabolism & Temperature Regulation

part 3

“You are what you eat!”
Cholesterol

• is insoluble in water & must be transported in the body bound to small lipid-protein complexes called lipoproteins
• The lipoproteins vary considerably in their ratio of fat to protein, but they all contain the same ingredients: triglycerides, phospholipids, cholesterol, and protein
• There are several classes of lipoproteins, based on the “density”, or ratio of fats to proteins
• The higher the percentage of lipid, the less dense the lipoprotein
Major Cholesterol Classes

- **High-density lipoproteins (HDLs)** transports excess cholesterol from peripheral tissues to the liver, where it is broken down and becomes part of the bile.

- **Low-density lipoproteins (LDLs)** transport cholesterol to peripheral tissues, making it available for membrane or hormone synthesis.

- **Very low density lipoproteins (VLDLs)** mainly produced in liver; used to transport triglycerides from the liver to peripheral tissues. When the triglycerides are unloaded, the VLDLs become LDLs, which are cholesterol-rich.
Cholesterol

Figure 24.22

<table>
<thead>
<tr>
<th>From intestine</th>
<th>Made by liver</th>
<th>Returned to liver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chylomicron</td>
<td>VLDL</td>
<td>LDL</td>
</tr>
<tr>
<td>1%–2%</td>
<td>3%–6%</td>
<td>2%–7%</td>
</tr>
<tr>
<td>2%–7%</td>
<td>10%–15%</td>
<td>5%–10%</td>
</tr>
<tr>
<td>3%–6%</td>
<td>15%–20%</td>
<td>25%</td>
</tr>
<tr>
<td>80%–95%</td>
<td>55%–65%</td>
<td>45%</td>
</tr>
<tr>
<td>1%–2%</td>
<td>10%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Key:
- Yellow = Triglyceride
- Orange = Cholesterol
- Purple = Phospholipid
- Pink = Protein
Recommended levels of cholesterol

• Total cholesterol: < _____ mg cholesterol per 100 ml blood
• HDL: > ____ mg per 100 ml blood
• LDL: < _____ mg per 100 ml blood
• Factors Regulating Plasma Cholesterol Levels
• Severe restriction of dietary cholesterol does not lead to a steep reduction in plasma cholesterol levels, because the liver produces a certain basal amount of cholesterol regardless of dietary changes (but it helps!)
Fatty Acids

- Saturated fatty acids
- Unsaturated fatty acids
- Trans-fatty acids
Saturated fatty acids

• stimulate liver synthesis of cholesterol & inhibit its excretion from the body
Unsaturated fatty acids

• enhance excretion of cholesterol from the body (via Bile salts)
Trans-fatty acids

• cause a greater increase in LDL levels & a greater reduction in HDL levels than saturated fatty acids

(Beware of “Hydrogenated” oils & fats!)
Clinical Note

• Smoking, coffee drinking & stress increase LDL levels; regular aerobic exercise appears to reduce LDL levels & increase HDL levels
Energy Balance

• A dynamic exists within the body between the energy intake and energy output.
• Energy intake is the energy liberated during food oxidation.
• Energy output includes energy lost as heat, energy used to do work, and energy that is stored as fat or glycogen.
• We are in “energy balance” when

\[
\text{Energy Intake} = \text{Energy Output}
\]
Energy Balance

- The energy value of foods is measured in kilocalories (kcal, or, C)
- One kcal = amount of heat energy required to raise the temperature of 1 kilogram of water by 1 degree Celsius (when you hear dieters speak of “counting Calories”, this is what they are counting!)
- If Calories In = Calories Burned, then we are in energy balance & weight is neither gained nor lost
Regulation of Food Intake

• When energy intake and energy output are balanced weight remains stable; when not balanced weight is either lost or gained.

- Factors that control eating include:
  - Neural signals from the digestive system
  - Bloodborne signals related to body energy stores
  - Hormones
Regulation of Food Intake

- **Hormones**
- **Insulin** depresses hunger
- **Leptin** depresses hunger
- Increased Glucagon increases hunger
- Body temperature – Increased body temp. may depress hunger; this may explain why those in cold climates eat more than those in warm climates.
- Psychological factors – depression, stress
Neural Signals from the Digestive System

• Enteric Nervous System

• Autonomic Nervous System
  – Parasympathetic
  – Sympathetic
Blood-borne signals

• related to body energy stores

  • **Rising blood glucose** levels activate glucose receptors in the brain, which depresses eating; during fasting, the signals are absent

  • **Elevated blood amino acid** levels depress eating, while low amino acid levels stimulate eating

  • **Leptin**, a protein released by adipose tissue cells, may provide the brain with an idea of the status of fat reserves in the body; more leptin = less eating
Metabolic Rate

- The body’s rate of energy output which is the total heat produced by all the chemical reactions and mechanical work of the body.
- The metabolic rate can be measured directly or indirectly:
  - **Direct method**
    - Calorimeter, which measures the change in temperature in water that absorbs body heat
  - **Indirect method**
    - Respirometer, which measures oxygen consumption. Oxygen consumption is directly proportional to heat production. For each liter of oxygen used, the body produces about 4.8 kcal of heat
Basal Metabolic Rate

- (BMR) reflects the energy the body needs to perform only its most essential activities. Factors influencing BMR include:
- **Body surface area** – an increase in surface area result in an increase in BMR
- **Age** – in general, the younger the person, the higher the BMR
- **Gender** – males have higher BMR than females
- **Temperature** – increased temp = increased BMR
- **Stress** – increases BMR by stimulating the sympathetic nervous system
- **Hormones** – Thyroxine (T4) from the thyroid has the greatest effect among hormones on BMR
  - more thyroxine = increased BMR
- ***You can approximate your BMR with the following formula: Body weight in kg x 1 for males or 0.9 for females. (to get weight in kg, divide weight in lbs by 2.2). An average 70 kg adult has a BMR of about 66 kcal/hour, or 1,583 Kcal/day.
Calculating your BMR

- Age in years 34
- 2.54 cm = 1 inch... 69 inches = 175.26 cm
- 1 kg (1000g) = 2.2 pounds (16 oz = 1 lb) ... 200 lbs = 90.71848 Make sure you eat at least 1200 calories each day or you will lose muscle.

- \[ W = \text{weight in kg} \]
- \[ H = \text{height in cm} \]
- \[ A = \text{age in years} \]

- **Male:**
  - \[ 66 + (13.7 \times W) + (5 \times H) - (6.8 \times A) \]
  - \[ 66 + (1242.8431) + (876) - (159.8) = 2025 \]
  - (to lose wt. eat 20-25% less)
  - \[ 2025 \times .20-.25 (405-506) 1514-1620 \]

- **Female:**
  - \[ 655 + (9.5 \times W) + (1.8 \times H) - (4.7 \times A) \]

- One pound of body weight is equal to 3,500 calories
- Eating 500 fewer calories per day will result in a weight loss of 1 pound per week

Total Metabolic Rate

• (TMR)

• the rate of kilocalorie consumption needed to fuel all ongoing activities both involuntary & voluntary
  — (in other words, your metabolic rate over the course of a “typical” day)
Weight gain vs. Weight loss

• Recall that when Kcal in = Kcal burned, we are in energy balance and weight is neither lost nor gained

• When Kcal in < Kcal burned, then the nutrients you take in over that period of time are not sufficient to meet energy demands, so the body must tap into its reserves, especially adipose tissue

• When Kcal in > Kcal burned, then the “excess” energy taken in is stored, usually as adipose tissue
Weight gain vs. Weight loss continued...

• We know that approximately 1 pound of body fat provides 3500 Kcal of energy
• Thus, reducing intake by __________________________
  __________________________ ____________________________ ____________________________ __________________________
  (assuming that all other variables remained the same)
• Or, increasing the expenditure of energy by 500 Kcal per day while eating the same amount would also result in the loss of 1 lb of fat
• (this is the theory behind the “calorie counting” diet method, which is still the most widely recommended, along with a “balanced diet”)
Weight gain vs. Weight loss continued...

• ***If you read food labels, you might see “based on a 2000 cal. diet”

• This refers to a TMR of 2000 Kcal/day, and it is used as an average

• Obviously, if you really want to use the calorie-counting method of weight loss, you need to know YOUR specific TMR
Preferred Fuels

• Brain ➔ Glucose
• In times of starvation ➔ Ketones
• Cardiac & Skeletal Muscle ➔ Fatty Acids
• Liver ➔ Amino Acids, Glucose & Fatty Acids
Chylomicrons

- Resynthesized water soluble coated triglyceride, phospholipid and cholesterol structure produced in the intestine & released into lymphatic system thru lymphatic capillaries “Lacteals”
- Processed by Golgi Apparatus/Bodies
Absorption

- **Water soluble vitamins**
  transported by diffusion (__________)

- **Fat soluble vitamins**
  transported by fat molecules into cells (__________)

- **Amino acids, dipeptides & tripeptides**

- **Electrolytes**

- **Water & Alcohol**- throughout the AC
Thermoregulation

• Balance between heat production & heat loss
• The body’s core (organs within the skull, thoracic and abdominal cavities) has the highest temperature & its shell (the skin) has the lowest temperature in most circumstances
• The core temperature is the most precisely regulated

• Heat-promoting mechanisms
• Heat-loss mechanisms
Regulation of Body Temperature

**Heat production**

- Basal metabolism
- Muscular activity (shivering)
- Thyroxine and epinephrine (stimulating effects on metabolic rate)
- Temperature effect on cells

**Heat loss**

- Radiation
- Conduction/convection
- Evaporation
Heat-promoting mechanisms

- are triggered when the external temperature is low, or blood temperature falls and the heat-promoting center is activated
- Vasoconstriction of cutaneous blood vessels
- Increase in metabolic rate, due to the release of norepinephrine by sympathetic nerve fibers
- Shivering
- Enhanced thyroxine release
- Behavioral modifications
Heat-promoting mechanisms

- Protect the body from excessively LOW temperatures
- Vasodilation of cutaneous blood vessels allows the body to lose heat through radiation, conduction, and convection.
- Enhanced sweating is used if the environment becomes so hot it cannot be lost by other means than evaporation.
- Fever is controlled hyperthermia, usually resulting from an infection somewhere in the body.
Heat-promoting mechanisms

• Chemicals known as Pyrogens are released by leukocytes and injured tissue cells which act on the hypothalamus, causing release of prostaglandins.

• Prostaglandins reset the “thermostat” in the hypothalamus to a higher-than-normal setting, causing heat-promoting mechanisms to kick in.
Heat-promoting mechanisms

- In a sense, the body “thinks” its temperature is too low because the new “normal” is higher.
- Shivering & “chills” occur as the body tries to generate heat & reach the new set-point.
- Sweating & flushed skin are a sign that body temperature is falling back to normal levels following a fever.
Mechanisms of Heat Loss

- **Radiation**
  - the loss of heat in the form of infrared waves (thermal energy)
  - Heat “radiates” from a warmer object to surrounding cooler objects, even when the objects are not in contact

- **Evaporation**
  - removes large amounts of body heat when water absorbs heat before vaporizing
  - For every gram of water evaporated from the body, 0.6 Kcal of heat is removed
  - The Hypothalamus is the main integrating center for thermoregulation
  - It contains the heat-loss center & the heat-promoting center
Mechanisms of Heat Loss

- **Conduction**
  is the transfer of heat from a warmer object to a cooler one when the 2 are in direct contact with each other

- **Convection**
  occurs when the warm air surrounding the body expands & rises and is replaced by cooler air molecules
  Forced convection occurs when air enhances the movement of heat away from a surface (which is why a breeze on a hot day feels so nice & why a “convection” oven cooks food more quickly)
Mechanisms of Body Temperature Regulation

Figure 24.27

- Skin blood vessels dilate: capillaries become flushed with warm blood; heat radiates from skin surface.
- Activates heat-loss center in hypothalamus.
- Blood warmer than hypothalamic set point.
- Stimulus: Increased body temperature (e.g., when exercising or the climate is hot).
- Imbalance.
- Homeostasis = normal body temperature (35.6°C–37.8°C).
- Stimulus: Decreased body temperature (e.g., due to cold environmental temperatures).
- Blood cooler than hypothalamic set point.
- Body temperature increases: blood temperature rises and hypothalamus heat-promoting center “shuts off.”
- Skin blood vessels constrict: blood is diverted from skin capillaries and withdrawn to deeper tissues; minimizes overall heat loss from skin surface.
- Activates heat-promoting center in hypothalamus.
- Skeletal muscles activated when more heat must be generated; shivering begins.
Metabolic & Nutritional Disorders

- Genetic disorders
- Metabolic disorders
- Endocrine disorders
- Eating disorders
- Nutritional disorders
Genetic Disorders

• Inborn errors of metabolism

Phenylketonuria (PKU)

• a genetic defect in which tissue cells are unable to use the amino acid phenylalanine, which is in all protein foods

• If this amino acid accumulates, it can become toxic to neurons, resulting in brain damage and retardation within a few months
Endocrine Disorders

- **BMR- Basal Metabolic Rate**
- **Hypothyroidism** In adults it is referred to as Myxedema, and symptoms include low metabolic rate, weight gain, feeling chilled, edema, lethargy and mental sluggishness. In infants it is known as Cretinism, and the child is mentally retarded.
- **Hyperthyroidism** – the most common example is Grave’s disease; symptoms include elevated metabolic rate, sweating, rapid and irregular heartbeat, nervousness and weight loss, exophthalmos
Metabolic Disorders

Diabetes Mellitus

• many types of diabetes
• all types are characterized by increased water loss through urination

• Type 1 Diabetes Mellitus
• Type 2 Diabetes Mellitus
Type 1 Diabetes Mellitus

- **Insulin dependent DM or (IDDM)**
  - 10% of all cases
  - Early onset (usually before age 30)
  - Caused by a lack of insulin production by pancreatic Beta cells of the Islets of Langerhans
  - **Insulin Dependant**
  - Requires patient to take synthetic insulin for remainder of life
  - Cause: autoimmune attack? Viral infection? Unknown?
Type 2 Diabetes Mellitus

- Non-Insulin Dependent DM or (NIDDM)
  - Most common; 90% of all cases
  - Late/Adult onset diabetes (usually occurs after age 40)
  - Insulin is produced by pancreas, there is a problem with the insulin receptors on cells in the body
  - may or may not require synthetic insulin
  - often controlled by diet or drugs to stimulate Beta cells to produce more insulin
Eating Disorders

- Anorexia Nervosa
- Bulimia
- Obesity

(see pp. 980–981, “A Closer Look”)
Nutritional Disorders

- Protein–calorie malnutrition
- Marasmus
  inadequate intake of calories, in any form
  Essentially known as “starvation” Characterized by progressive wasting of the body
- Kwashiorkor Syndrome
  inadequate intake of proteins, even though the total caloric intake may be adequate
  Bloated abdomen due to a lack of plasma proteins necessary to keep fluid in the bloodstream
Nutrition

Fats, Oils, and Sweets
Use Sparingly

Milk, Yogurt, and Cheese Group
2–3 Servings

Meat, Poultry, Fish, Dry Beans,
Eggs, and Nuts Group
2–3 Servings

Vegetable Group
3–5 Servings

Fruit Group
2–4 Servings

Bread, Cereal, Rice,
and Pasta Group
6–11 Servings
Stages of Metabolism
Mechanism of Oxidative Phosphorylation

Figure 24.8
Electronic Energy Gradient

Figure 24.9
Structure of ATP Synthase

A rotor in the membrane spins clockwise when $H^+$ flows through it down the $H^+$ gradient.

A rod connecting the cylindrical rotor and knob also spins, activating catalytic sites in the knob.

A protruding knob contains catalytic sites that join inorganic phosphate to ADP to make ATP.
Summary of ATP Production

Figure 24.11
Interconversion Pathways of Nutrients

Figure 24.17
Control of Feeding Behavior & Satiety

- Choroid plexus
- Ventricles
- Hypothalamus
- Pituitary
- TSH
- ACTH
- Leptin
- Fat tissue

Released signaling molecules affect:
- Feeding behavior
- Muscular activity
- Thermogenesis
- \( O_2 \) use
- Blood glucose levels
- Insulin release
- Glucocorticoid release
Nutrition & Metabolism

Objectives

• Define cachexia, marasmus, kwashiorkor, hypervitaminosis A and identify the effects of excess iron supplements on the liver
• Discuss the absorption of vitamin B12 and relationship to anemia
• Discuss the deficiency of vitamin K in various conditions like stones in common bile duct, cancer head of pancreas of cirrhosis of liver resulting in bleeding
Nutrition & Metabolism

Objectives

• Discuss the relationship of diet and body weight
• Describe the composition of foods- carbohydrates, proteins and fats
• Describe the metabolic pathways for carbohydrates, proteins and fats
• Describe the link between carbohydrate, protein and lipid metabolism
• Define metabolic rate (BMR) and list the factors influencing BMR