4 Carbohydrates
Learning Objectives

• Classify carbohydrates according to their chemical composition
• Describe the digestion and absorption of carbohydrates
• Explain the metabolism of glucose
• Describe how muscle glycogen and blood glucose are used to fuel exercise
• Detail and explain carbohydrate recommendations for athletes, including specific guidelines for intake before, during, and after exercise
Introduction

• Carbohydrates
  – Preferred energy source for many of the body’s functions
  – When available, used exclusively by brain as an energy source
  – Should not be avoided when trying to lose weight. Portion size and balance of nutrients is important
Glucose
### The Chemist’s View of Carbohydrates

<table>
<thead>
<tr>
<th>Monosaccharides</th>
<th>Disaccharides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>Sucrose (glucose + fructose)</td>
</tr>
<tr>
<td>Fructose</td>
<td>Lactose (glucose + galactose)</td>
</tr>
<tr>
<td>Galactose (found mostly as part of lactose)</td>
<td>Maltose (glucose + glucose)</td>
</tr>
</tbody>
</table>

*Glycogen in animal muscles rapidly breaks down after slaughter.*
Dietary carbohydrates

- Polysaccharides: chains of monosaccharides
  - **Starch**: hundreds of glucose molecules in either occasionally branched chains or unbranched chains
  - **Glycogen** highly branched polysaccharide?
  - **Dietary** fibers: found in plant-derived foods; non-digestible by human digestive enzymes
A glycogen molecule contains hundreds of glucose units in highly branched chains.

A starch molecule contains hundreds of glucose molecules in either occasionally branched chains or unbranched chains.
Human enzymes can digest starch, but they cannot digest cellulose (fiber).

1α→4 linkage
Can be digested by humans

1β→4 linkage
Cannot be digested – Except termites
The Chemist’s View of Carbohydrate

• Other notes regarding fibers
  – Digestion resistant starches: classified as fibers
  – Some fibers: digested by bacteria in the human digestive tract
  – Fiber groups: soluble and insoluble fibers
Digestion and Absorption of Carbohydrates

- Goal of digestion and absorption of sugars and starches
  - Break them into small molecules that body can absorb and use

The disaccharide maltose splits into two glucose molecules with H added to one and OH to the other (from water).
A sign that you consume too much sugar...

DAVE GRANLUND® www.davegranlund.com
Health Effects of Added Sugars?

• Added sugars
  – Consumption in recent decades
    • Dramatic upward trend
  – Leading source
    • Soft drinks
  – Excessive amounts
    • Linked to obesity, heart disease, nutrient deficiencies, and dental caries
U.S. per capita food consumption
Sugar and sweeteners (individual)

Dry weight, pounds per capita per year

Year

Total selected commodities
Cane and beet sugar
Edible syrups
Honey
HFCS
Glucose
Dextrose

HFCS stands for high fructose corn syrup. Calculated from unrounded data.

Soda, energy drinks, sports drinks 35.7%
Grain-based desserts 12.9%
Fruit drinks 10.5%
Dairy desserts 6.5%
Candy 6.1%
Ready-to-eat cereals 3.8%
Sugars and honey 3.5%
Tea 3.5%
Yeast breads 2.1%
All other food categories 15.4%

*NHANES data, 2005–2006.*

Source: U.S. Department of Agriculture and U.S. Department of Health and Human Services, *Dietary Guidelines for Americans 2010*, available at www.dietaryguidelines.gov. Figure 3-6, p. 29.
Regulation of Blood Glucose

• Blood glucose homeostasis
  – Insulin’s role in regulating blood glucose
    • Facilitates blood glucose uptake by the muscles and adipose tissue
    • Stimulates glycogen synthesis in the liver
  – Glucagon
    • Triggers the breakdown of liver glycogen to single glucose molecules
    • Remember “Starve-feed cycle”
Dietary Requirements:

Absolute Requirement Not Established
However Requires About 50 gm
Or 200Kcal /day

1. Maintain Kreb’s Cycle Intermediates
2. Spare Protein (Gluconeogenesis)
3. Prevent Ketosis

Recommended: 55% Total Calories
EAT NO CHO?
Metabolic Effect Of CHO Free Diet

1. Ketosis
2. Breakdown Of Protein
3. Loss of Na+
4. Dehydration
5. These symptoms appear on the second day of CHO Free Diet.
6. Reversed by 100g of CHO/DAY.
7. Basis for weight loss on low CHO Diet.
Hypoglycemia

- Blood Sugar < 40 mg/dl
  - EFFECTS

- 1. Epinephrine
- 2. Tachycardia
- 3. Sweating, Anxiety
- 4. Hunger
- 5. Weakness
- 6. Confusion, Coma

PROBLEM?:
Not Specific for Hypoglycemia
HYPOGLYCEMIA NOT A COMMON PROBLEM!
TABLE 3-3  Sample Nutrients in Sugars and Other Foods

The indicated portion of any of these foods provides approximately 100 kcalories. Notice that—for a similar number of kcalories and grams of carbohydrate—milk, legumes, fruits, grains, and vegetables offer more of the other nutrients than do the sugars.

<table>
<thead>
<tr>
<th>Foods</th>
<th>Size of 100 kCal Portion</th>
<th>Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Calcium (mg)</th>
<th>Iron (mg)</th>
<th>Vitamin A (µg)</th>
<th>Vitamin C (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk, 1% low-fat</td>
<td>1 c</td>
<td>12</td>
<td>8</td>
<td>300</td>
<td>0.1</td>
<td>144</td>
<td>2</td>
</tr>
<tr>
<td>Kidney beans</td>
<td>½ c</td>
<td>20</td>
<td>7</td>
<td>30</td>
<td>1.6</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Apricots</td>
<td>6</td>
<td>24</td>
<td>2</td>
<td>30</td>
<td>1.1</td>
<td>554</td>
<td>22</td>
</tr>
<tr>
<td>Bread, whole wheat</td>
<td>1½ slices</td>
<td>20</td>
<td>4</td>
<td>30</td>
<td>1.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Broccoli, cooked</td>
<td>2 c</td>
<td>20</td>
<td>12</td>
<td>188</td>
<td>2.2</td>
<td>696</td>
<td>148</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sugars</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar, white</td>
<td>2 tbs</td>
<td>24</td>
<td>0</td>
<td>trace</td>
<td>trace</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Molasses, blackstrap</td>
<td>2½ tbs</td>
<td>28</td>
<td>0</td>
<td>343</td>
<td>12.6</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Cola beverage</td>
<td>1 c</td>
<td>26</td>
<td>0</td>
<td>6</td>
<td>trace</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Honey</td>
<td>1½ tbs</td>
<td>26</td>
<td>trace</td>
<td>2</td>
<td>0.2</td>
<td>0</td>
<td>trace</td>
</tr>
</tbody>
</table>
Sugars Intake

- Recommended sugar intakes
  - Dietary Guidelines for Americans
    - Reduce the intake of kcals from added sugars
  - The USDA Food Patterns
    - Eight teaspoons for 2200 kcal (5 – 10 percent of day’s total energy intake)
  - Recognize sugar in all its forms – e.g., added sugars
Alternative Sweeteners: Nonnutritive Sweeteners

• Minimal or no carbohydrate or energy
• FDA endorsement
  – Safe over a lifetime within Acceptable Daily Intake (ADI) levels
• Do not cause tooth decay
• Safe?
Health Effects: Dietary Fibers

• Carbohydrates: recommended intakes
  – DRI advises 45 to 65 percent of energy requirement
  – Daily Values: 60 percent of kcalories
  – Fiber (a type of Carb)
    • FDA proposes 25 grams per day
    • Adequate Intake (AI): 14 g/1000 kcal/day
Health Effects of Starch and Dietary Fibers

- Fiber-rich carbohydrate foods
  - Lower risk of heart disease
  - Reduce the risk of type 2 diabetes
  - May enhance the health of the large intestine
  - Lower risk for colon cancer
  - Weight control
Carbohydrates: food sources

- Grains
- Vegetables
- Fruits
- Milk and milk products
- Protein foods: limited to nuts and dry beans
BREADS, CEREALS, LEGUMES

FIBER

<table>
<thead>
<tr>
<th>Item</th>
<th>Fiber (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Bread 1 slice</td>
<td>.77</td>
</tr>
<tr>
<td>Whole Wheat Bread 1 slice</td>
<td>2.4</td>
</tr>
<tr>
<td>Rice Krispies 1 oz</td>
<td>1.3</td>
</tr>
<tr>
<td>Granola 1 oz</td>
<td>1.9</td>
</tr>
<tr>
<td>Cornflakes 1 oz</td>
<td>3.1</td>
</tr>
<tr>
<td>Shredded Wheat 1 oz</td>
<td>3.5</td>
</tr>
<tr>
<td>All-Bran 1 oz</td>
<td>7.6</td>
</tr>
<tr>
<td>Peanuts 1 oz</td>
<td>2.6</td>
</tr>
<tr>
<td>Baked Beans 1/2 cup</td>
<td>9.3</td>
</tr>
</tbody>
</table>
Health Effects of Starch and Dietary Fibers

• FDA authorized health claims
  1. Fiber-containing grain products, fruits, and vegetables: reduced risk of cancer
  3. Fruits, vegetables, and grain products that contain fiber: reduced risk of coronary heart disease
  4. Soluble fiber from whole oats and from psyllium seed husk: reduced risk of coronary heart disease
  5. Whole grains: reduced risk of heart disease and certain cancers
### 4.5 Carbohydrate Recommendations for Athletes

#### Table 4.4 General Carbohydrate Recommendations Based on Exercise Intensity and Duration

<table>
<thead>
<tr>
<th>Exercise intensity and duration</th>
<th>Examples of sports</th>
<th>Daily carbohydrate recommendation (energy intake must be adequate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high intensity, very short duration (less than 1 minute)</td>
<td>Field events such as shot put, discus, or high jump Track sprints (50–200 m) Swimming sprints (50 m) Sprint cycling (200 m) Weightlifting Power lifting Bobsled (running start)</td>
<td>5–7 g/kg</td>
</tr>
<tr>
<td>High intensity, short duration (1 to 30 minutes continuous)</td>
<td>Track (200–1,500 m) Swimming (100–1,500 m) Cycling (short distance) Rowing (crew) Canoeing/Kayaking (racing) Skiing (downhill racing) Figure skating Mountain biking</td>
<td>5–7 g/kg</td>
</tr>
<tr>
<td>High intensity, short duration (1 to 30 minutes with some rest periods)</td>
<td>Gymnastics Wrestling Boxing Fencing Judo Tae kwon do</td>
<td>5–8 g/kg</td>
</tr>
<tr>
<td>Moderate intensity, moderate duration (30 to 60 minutes)</td>
<td>10 km running (elite runners finish in &lt;30 minutes)</td>
<td>6–8 g/kg</td>
</tr>
</tbody>
</table>

*m = meter; g/kg = gram per kilogram of body weight; km = kilometer

*Note: Athletes may need to consume near the higher end of the range during periods of rigorous training to ensure adequate muscle glycogen resynthesis.*

# Intake During Exercise Training and Competition

Table 4.6 Examples of Prepackaged Pre-Exercise Products for Athletes

<table>
<thead>
<tr>
<th>Product</th>
<th>Serving size</th>
<th>Energy (kcal)</th>
<th>CHO (g)</th>
<th>Fiber (g)</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Recommended timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatorade G Series, Prime, Sports Fuel</td>
<td>118 mL pouch or 6 chews (30 g)</td>
<td>100</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15 minutes before exercise</td>
</tr>
<tr>
<td>Drink or Energy Chews</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gatorade G Series Endurance, Carb</td>
<td>118 mL pouch</td>
<td>120</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>60 minutes or less before exercise</td>
</tr>
<tr>
<td>Energy Drink</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrament</td>
<td>12 fl oz</td>
<td>360</td>
<td>52</td>
<td>0</td>
<td>16</td>
<td>10</td>
<td>3–4 hours before exercise</td>
</tr>
</tbody>
</table>

*Source: Cengage Learning ©*

kcal = kilocalories; CHO = carbohydrate; g = gram; mL = milliliter; fl oz = fluid ounce
# Intake During Exercise Training and Competition

## Table 4.7 Carbohydrate Intake during Exercise to Enhance Performance

<table>
<thead>
<tr>
<th>Exercise intensity and duration</th>
<th>Sport or event</th>
<th>Recommended carbohydrate intake to enhance performance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-intensity exercise less than 45 minutes</td>
<td>Running (sprints up to 10 km); cycling (track cycling, short criteriums); swimming (sprints up to 1500 m); crew (rowing)</td>
<td>None</td>
</tr>
<tr>
<td>High-intensity exercise (continuous or intermittent) approximately 45–60 minutes</td>
<td>Team sports, such as basketball, lacrosse, water polo, or ice hockey; cycling time trials</td>
<td>0–30 g/h</td>
</tr>
<tr>
<td>High-intensity exercise (intermittent) approximately 90 minutes</td>
<td>Team sports, such as soccer; skilled recreational tennis players; team or individual handball, racquetball, or squash</td>
<td>30–50 g/h</td>
</tr>
<tr>
<td>Moderate to vigorous exercise more than 2 hours</td>
<td>Backpacking, hiking; recreational cycling</td>
<td>30–60 g/h**</td>
</tr>
<tr>
<td>High-intensity exercise more than 2 hours</td>
<td>Marathon running; sprint and Olympic distance triathlon; 50 km ski racing; professional tennis match</td>
<td>50–70 g/h**</td>
</tr>
<tr>
<td>Ultraendurance competitions lasting many hours or repeated over days</td>
<td>Ironman length triathlons; cycling stage races, adventure racing</td>
<td>60–90 g/h**</td>
</tr>
</tbody>
</table>

g/h = grams per hour

*Assumes the athlete can tolerate this amount; athletes should experiment with amounts and types of carbohydrates before using in competition.

**The maximal rate of carbohydrate absorption from the gastrointestinal tract is estimated to be 60 g/h. If need approaches or exceeds this amount, it may be helpful to consume sports beverages that contain a variety of sugars, such as glucose, fructose, sucrose, galactose, maltodextrin, isomaltulose, amylose, amylpectin, and/or trehalose.
Muscle Glycogen Stores Can Be Maximized by Diet and Exercise Manipulation

Day 1: Cycle @ 75% to exhaustion
Day 2: Fat + protein diet
Day 3: Cycle @ 75% to exhaustion
Day 4: Hi CHO: 8.2 g/kg/d
Day 5: Cycle @ 75% to exhaustion
Day 6: Hi CHO: 8.2 g/kg/d
Day 7: Cycle @ 75% to exhaustion

CHO = carbohydrate
g/kg/d = grams per kilogram of body weight per day

Muscle Glycogen Stores Can Be Maximized by Diet and Exercise Manipulation


CHO = carbohydrate  
min = minute  
kilometer
Summary

• Carbohydrates are the primary energy source for moderate to intense exercise
• Exercise reduces glycogen stores, which must be replenished on a daily basis
• The general recommendation for carbohydrate intake for athletes in training is 3 to 12 g/kg of body weight daily
• Carbohydrate loading is one technique that endurance athletes and some bodybuilders use before an important competition
Summary

- Sufficient carbohydrate intake is an important element in athletic training and competition.
- Some athletes have lactose intolerance, reactive hypoglycemia, or diabetes, and these conditions influence the choice of carbohydrate-containing foods.
- Proper carbohydrate intake positively affects training, recovery, performance, and health.