Carbohydrates: Simple Sugars and Complex Chains
BIOL 103, Chapter 5

Today’s Topics
• Simple Sugars: Mono and Disaccharides
• Complex Carbohydrates
• Carbohydrate Digestion and Absorption
• Carbohydrates in the Body
• High Blood Glucose: Diabetes Mellitus
• Carbohydrates in your diet
• Carbohydrates and Health

Carbohydrates Capture Energy from the Sun
• Carbohydrates include sugars, starches, and fibers
• Major food sources: ______________
  – Produced during photosynthesis
• Two main carbohydrate types:
  – Simple (sugars)
  – Complex (starches and fiber)

Simple Sugars

<table>
<thead>
<tr>
<th>Monosaccharides</th>
<th>Disaccharides</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Glucose/GLU</td>
<td>1. Sucrose/SUC</td>
</tr>
<tr>
<td>2. Fructose/FRU</td>
<td>2. Lactose/LAC</td>
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</tbody>
</table>
Monosaccharides

• **Glucose/Dextrose**
  – Most __________________
  – Gives food mildly sweet flavor
  – Usually joined to another sugar
  – Provides energy to body cells (Blood sugar)
    • Only fuel source used by brain (unless not enough glucose left in your body)
  – Found in fruits, vegetables, honey

• **Fructose/Levulose**
  – __________________________
  – Tastes the sweetest
  – Present naturally in fruits and vegetables
  – Found in fruits, honey, high fructose corn syrup

• **Galactose**
  – Usually bond to glucose to form ________
    • Primary sugar in milk and dairy products

High Fructose Corn Syrup

• **How is it made?**
  1. Convert glucose → fructose, using isomerase
  2. Add corn syrup, then a specific ratio of glucose
    – Example: HFCS 55

• **Why do we use it?**
  – Before 1970s → U.S. cane sugar → too expensive
  – 1980s, food companies switched to cheaper corn
    • Pepsi/Coke switched in 1984
Why is High Fructose Corn Syrup associated with weight gain?

1. Corn is cheap → cheaper Soda → _________ → drink more → more calories
2. Fructose does NOT release insulin and leptin → does not feel _________ → drink more → more calories

• However, note that overconsumption of ANY forms of sugar will contribute to weight gain.

Disaccharides

• If you link two monosaccharides, they become disaccharides:
  - Sucrose: GLU + _____________
  - Lactose: GLU + _____________
  - Maltose: GLU + _____________

Disaccharides

• Sucrose: glucose + fructose
  - _____________
  - Made from sugar cane and sugar beets
  - Listed as “sugar” on food labels
• Lactose: glucose + galactose
  - _____________
  - Found in milk and milk products

Lactose Intolerance

• Who has it?
  - Anyone who does not have enough ________.
• Why do you get it?
  - Genetics: does not have lactase persistence (can produce lactose into adulthood)
  - Acquired by low lactose diet or injury to intestine usually during infancy
Disaccharides

• **Maltose**: glucose + glucose
  – ____________ sugar
  – Seldom occurs naturally in foods, but usually forms whenever long molecules of starch is broken down
  – Found in germinating cereal grains
  – Fermented in beer

Complex Carbohydrates

• Chains of _____________ sugar molecules
  – Oligosaccharides
    – _____________ sugar molecules
    – In breastfed infants, it plays a similar role to dietary fiber in adults (helps stools to pass by more easily)
    – Examples: dried beans, peas, lentils
  – Polysaccharides
    – Long chains of monosaccharides
    – Digestible (e.g. starch) or non-digestible (e.g. fiber)

Complex Carbohydrates

• **Starch**
  – How plants store energy
  – Long chains of glucose molecules:
    • **Amylose**: _____________ chains
    • **Amylopectin**: _____________ chains
  – Amylopectin is digested more _____________ than amylose.
  – **Resistant starch**: a starch that is not digested.
  – Food sources: grains, legumes, tubers (potatoes and yams)

Complex Carbohydrates

• **Glycogen**
  – Highly branched
  – _____________ form of carbohydrate in our body
  – Mostly stored in our skeletal _____________ and _____________
  – If blood glucose is low: glycogen → glucose
Complex Carbohydrates

- **Fiber:** carbohydrates and lignins
  - **Dietary fiber:** found in plants
    - fruits, vegetables, legumes, whole grains
  - **Functional fiber:** isolated and added to foods
  - **Total fiber:** dietary fiber + functional fiber

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**Complex Carbohydrates**

- **Types of Fibers (Insoluble Fiber):**
  1. **Cellulose:** long, straight chains of glucose units
     - Structural function in plants: forms the woody fibers in trees + strong plant cell walls
  2. **Hemicellulose:** variety of monosaccharides with many branching side chains
     - Usually mixed in with cellulose in plants
  3. **Lignins**
     - Nondigestible substances in vegetables and fruits
     - Examples: strawberry seeds, woody parts of carrots and broccoli

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**Complex Carbohydrates**

- **Types of Fibers (Soluble Fiber):**
  4. **Gums and viscoses**
     - Gel-forming fibers that hold plant cells together
     - Examples: Xanthan gum, guar gum and carrageenan
  5. **Pectins:** gel-forming polysaccharides
     - Especially in fruits
     - Pectins + acid + sugar = Jam
Complex Carbohydrates

• Types of fibers (cont.)
  6. Beta-glucans: polysaccharides of branched glucose units
     • Help decrease blood cholesterol levels
     • Food sources: barley, oats
  7. Chitin and chitosan
     • Primarily consumed in supplement form
     • Marked as weight-loss supplements
     • May impair absorption of fat-soluble vitamins and some minerals
     • Found in exoskeletons of crabs and lobsters

Carbohydrate Digestion: Carbohydrates to Single Sugars

• Mouth:
  — Salivary amylase
• Stomach:
  — HCl’s acidity stops the action of salivary amylase → stops carbohydrate digestion
• Small intestine
  — Pancreatic amylase: continues starch digestion
  — Bruch border enzymes: digest disaccharides
  — Other digestive enzymes:
    • Maltase, sucrase, and lactase

Carbohydrate Digestion

• Glycosidic bonds: bonds that link glucose molecules
  — Alpha bonds
    • Broken down by human enzymes (e.g. starch, glycogen)
  — Beta bonds
    • Are not broken down by human enzymes (e.g. cellulose, lactose for some people)

Carbohydrate Digestion and Absorption

• Enzymes
  — Highly specific in working with certain reactions and specific molecules
    • Commercial product: Beano
  — Some carbohydrates remain intact, such as fiber and resistant starch
    • Bacteria in colon digests them to gas + few short chain fatty acids → energy supply for colon cells
Carbohydrate Digestion and Absorption

- Absorption: in the small intestine
  - End products of carbohydrate digestion:
    - (Travel to Liver through the Portal Vein):
      - Glucose
      - Galactose $\rightarrow$ __________________
      - Fructose $\rightarrow$ __________________
    - __________________ stores and releases glucose to maintain blood glucose levels.

Carbohydrates in the Body

- Glucose is your primary fuel
- Storing Glucose as Glycogen
  - __________________ glycogen (~1/3)
    - Maintain normal blood glucose
  - __________________ glycogen (~2/3)
    - Fuel muscle activity

Carbohydrates in the Body

- Glucose is your primary fuel (cont.)
- Using Glucose for Energy
  - To obtain energy....
    - Cells must take up glucose from blood $\rightarrow$ glucose goes into cell $\rightarrow$ breaks down into CO2, water, and energy; OR
    - Breakdown ______________ or __________ using energy
Carbohydrates in the Body

• Glucose is your primary fuel (cont.)
  – Sparing Body Protein
    • Order of Energy usage by body:
      – ________ → ______ → _______
    • Adequate carbohydrates prevent body from breaking down proteins to make glucose.

• PrevenHng Ketosis
  – Low glucose + high acetyl CoA → ________ → ketosis → dehydration
  • Body needs a minimum of 50-100g of carbs/day to prevent ketosis

Regulating Blood Glucose Levels

• Why?
  – To maintain an adequate supply of energy for cells

• Controlled by hormones:
  – Insulin
    • High blood glucose → pancreatic beta cells release insulin into blood:
      1. Insulin signals cells to take in glucose
      2. Insulin signals liver and muscle cells to store glucose to glycogen

• Controlled by Hormones (cont.)
  – Glucagon
    • Low blood glucose → pancreatic cells release glucagon to blood → glucagon stimulates liver cells to break down glycogen to glucose and to make glucose from amino acids
  – Epinephrine/Adrenaline: “fight or flight”/sympathetic NS
Regulating Blood Glucose Levels

Glycemic Index measures effect of food on blood _______ levels
  Different foods vary in their effect on blood glucose levels
  Foods with High Glycemic Index cause faster and higher rise in blood glucose

Glycemic Index

High Blood Glucose: Diabetes Mellitus

What is diabetes? Disorder of carbohydrate metabolism
  Normally:
  • Eat food with glucose \(\rightarrow\) blood and cells
  • If too much blood glucose \(\rightarrow\) pancreas releases insulin \(\rightarrow\) blood glucose decreases
  If you have diabetes:
  • Pancreas: little or no insulin OR cells do not respond appropriately to insulin \(\rightarrow\) hyperglycemia
High Blood Glucose: Diabetes

• Consequences of Diabetes
  – Hyperglycemia:
    – “Starvation in the midst of plenty”
    – “Sweet urine”
  – Body breaks down fat and protein for energy sources → ketosis and acidosis
  – Over time, damage to body proteins and tissues

High Blood Glucose: Diabetes Mellitus

• Risk Factors:
  – Genetics
    • Type I (Caucasians)
    • Type II (Native Americans, Hispanic Americans, and African Americans)
  – Increased risk with “Westernized diet”, body fat around midsection
• Best Prevention:
  – Healthful diet (Well balanced meals, Exchange List)
  – Regular exercise

High Blood Glucose: Diabetes

• Forms of diabetes mellitus
  – Type 1: _________ of insulin production
    • “juvenile diabetes”
  – Type 2: cells are ____________________ to insulin
    • “adult-onset diabetes”
    • Pre-diabetes
  – Gestational diabetes: occurs during pregnancy

Low Blood Glucose: Hypoglycemia

• Low blood glucose: hypoglycemia
  – Symptoms:
    • Nervousness, irritability, hunger, headache, shakiness, rapid heart rate, weakness
    • Really low blood glucose → coma, death
  – Results from:
    • Too much insulin, missed meals, and vigorous exercise
Low Blood Glucose: Hypoglycemia

• Types of hypoglycemia:
  – **Reactive hypoglycemia**: body produces too much insulin in response to food
    • What to do?
  
  – **Fasting hypoglycemia**: body produces too much insulin (even without food)
    • Why?

Carbohydrates in Your Diet

• Choosing Carbohydrates wisely
  – Increase fruit, vegetables, whole grains, low-fat milk

• Strategies
  – Eat peel of fruits/veggies
  – Eat legumes
  – Choose brown rice, high fiber cereal
  – Gradually increase fiber intake and drink plenty of water to allow your body to adjust
  – Question: Why is it important to eat fiber to manage blood sugar?

Carbohydrates in Your Diet

• Moderating Sugar intake
  – Use less added sugar
  – Limit soft drinks, sugary cereals, candy, ice cream, and sweet desserts
  – Choose fresh fruits or canned in water or juice

Carbohydrates in Your Diet

• **Nutritive Sweeteners**: substances that sweeten food and can be absorbed and yield energy in the body.
  
  • Examples: honey, white sugar, brown sugar, maple syrup, fructose, glucose, xylitol, etc.
Carbohydrates in Your Diet

• Nutritive Sweeteners by types:
  1. **Natural**: mono + di-saccharides
  2. **Refined**: mono + di-saccharides extracted from plant food
  3. **Sugar Alcohol/Polyols**: may be sugar/sucrose free, but not always calorie free

Carbohydrates in Your Diet

• **Non-nutritive sweeteners**
  – “Artificial sweeteners”
  – Mostly sweeter than nutritive sweeteners, not much energy
  1. **Saccharin** (1970s bladder cancer)

Carbohydrates in Your Diet

• Non-nutritive sweeteners (cont.):
  2. **Aspartame** (combination of two amino acids: phenylalanine + aspartic acid)
      • Very sweet, but ~0 calories in diet
      • __________x sweeter than table sugar
      • ___________ destroys products → thus cannot be used in cooking
      • *NutraSweet, Equal, Sugar Twin, Spoonful, and Equal-Measure*
      • **PKU**: phenylketonuria

Carbohydrates in Your Diet

• Non-nutritive Sweeteners (cont.)
  3. **Acesulfame K**
      • __________x sweeter than table sugar
      • Provides NO Energy because body can’t digest it
      • Used in cooking, nondairy creamers, gelatins, chewing gum, powdered beverage mixes

  4. **Sucralose**
      • “Splenda”
      • Made from sucrose, ___________x sweeter
      • Used in baked goods, beverages, gelatin, etc.
Sugar-Free Candies

- **Maltitol** = sugar alcohol
  - From plants
  - Benefits:
    - No tooth decay
    - Safe for diabetics
    - Nearly as sweet as sugar → "I can eat more"

Carbohydrates and Health

- **Pros**: high fiber foods keep GI tract healthy, may reduce risk for heart disease and cancer
- **Cons**: excess sugar → weight gain, poor nutrient intake, tooth decay
- Sugar and dental caries (cavities) promoted by:
  - Sugar eaten by bacteria in teeth → acids → tooth decay → cavities
  - Chocolate or Candy?
  - "Natural toothbrushes"

Carbohydrates and Health

- **Fiber and Obesity**
  - Fiber rich food:
    - Low in fat and energy
    - Attract water → more filling
- **Fiber and Type 2 Diabetes (pg 162)**
  - Better control of blood glucose
- **Fiber and cardiovascular disease (pg 162-163)**
  - Can lower blood cholesterol levels
- **Fiber and GI disorder (pg 163)**
  - Healthier GI functioning

Carbohydrates and Health

- **Negative effects of excess fiber (pg 163)**
  1. Gradual intake and increased water consumption to prevent your stool from becoming hard and impacted
  2. Can bind small amounts of minerals → prevent some mineral absorption
    - Examples: Zn, Ca, Fe
    - Fiber has no UL