Endocrine Control of Fuel Metabolism

Once nutrients are processed by digestion:

- Ingested food molecules are broken down through the process of mechanical and chemical digestion into smaller absorbable molecules.
  - Most nutrient absorption occurs in small intestine.
    - Proteins → amino acids
    - Carbohydrates → monosaccharides (mainly glucose)
    - Dietary fats (triglycerides) → monoglycerides and free fatty acids

**Anabolism and Catabolism**

- **Anabolism**
  - Buildup or synthesis of larger organic macromolecules from small organic subunits.
  - Reactions usually require ATP energy.
  - Reactions result in:
    - Manufacture of materials needed by the cell.
    - Storage of excess ingested nutrients not immediately needed for energy production or needed as cellular building blocks.

- **Catabolism**
  - Breakdown or degradation of large, energy-rich organic molecules within cells.
  - Two levels of breakdown:
    - Hydrolysis of large cellular molecules into smaller subunits.
    - Oxidation of smaller subunits to yield energy for ATP production.

**Table 17-3** Summary of Reactions in Fuel Metabolism

<table>
<thead>
<tr>
<th>Metabolic Process</th>
<th>Reaction</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycolysis</td>
<td>Glucose + glycogen → 2 blood glucose</td>
<td></td>
</tr>
<tr>
<td>Gluconeogenesis</td>
<td>Gluconeogenesis</td>
<td></td>
</tr>
<tr>
<td>Amino acids + glucose</td>
<td>2 blood glucose</td>
<td></td>
</tr>
<tr>
<td>Protein Synthesis</td>
<td>Protein + amino acids → 2 blood amino acids</td>
<td></td>
</tr>
<tr>
<td>Protein Degradation</td>
<td>Protein + amino acids + triglycerides</td>
<td></td>
</tr>
<tr>
<td>Fatty acid + glucose + triglycerides</td>
<td>2 blood fatty acids</td>
<td></td>
</tr>
<tr>
<td>Fatty acid + glyceraldehyde + triglycerides</td>
<td>2 blood fatty acids</td>
<td></td>
</tr>
</tbody>
</table>
Endocrine Control of Fuel Metabolism

Once nutrients are processed by digestion:

- **Metabolism**
  - All the chemical reactions that occur within the cells of the body
  - Intermediary metabolism or fuel metabolism is under endocrine regulation
    - Focus is on NUTRIENTS: carbohydrate, fat, protein
      - Degradation (glycolysis, beta oxidation, Krebs Cycle, TCA, ETC → ATP, CO2, HEAT, H2O)
      - Synthesis of storage polymers: glycogen, triglyceride, protein
      - Interconversion of nutrient molecules
  - Aim seems to be primarily support of blood glucose concentration so that there is adequate supply for neural tissue to function
    - Neural tissue requires oxidative phosphorylation
    - Neural tissue does not store either glycogen or triglyceride, it is dependent on obtaining nutrients from circulating blood

Interconversions Among Organic Molecules

- Most interconversion of organic molecules occurs in liver
  - Essential nutrients (certain amino acids and vitamins)
- Food intake is intermittent – nutrients must be stored for use between meals
  - “Excess” circulating glucose
    - Stored in liver and muscle as glycogen
    - Once liver and muscle stores are “filled up”, additional glucose is transformed into fatty acids and glycerol and stored in adipose tissue
  - “Excess” circulating fatty acids
    - Become incorporated into triglycerides
  - “Excess” circulating amino acids
    - Converted to glucose and fatty acids

**Comparison of Absorptive and Postabsorptive States**

**Absorptive Phase** - in this phase digestive endproducts are being absorbed from the gut, oxidized for energy and being sent to storage. The processes occurring during this phase are:

1. **Glycolysis** – glucose oxidized for ATP (insulin)
2. **glycogenesis** - glucose from the blood plasma is moved into the liver and muscle for storage as glycogen. (insulin)
3. protein manufacture - amino acids absorbed from the blood are transaminated and made into proteins. (insulin)
4. Fat synthesis from glucose and transport into the fat reserves of the body. (insulin)

**Table 17-4 Stored Metabolic Fuel in the Body**

<table>
<thead>
<tr>
<th>Metabolic Fuel</th>
<th>Circulating Form</th>
<th>Storage Form</th>
<th>Major Storage Site</th>
<th>Percentage of Total Energy Content (proof Calories)</th>
<th>Reservoir Capacity</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>Glucose</td>
<td>Glycogen</td>
<td>Liver, muscle</td>
<td>10%</td>
<td>Less than a day's worth of energy</td>
<td>The energy source essential for the brain.</td>
</tr>
<tr>
<td>Fat</td>
<td>Free fatty acids</td>
<td>Triglycerides</td>
<td>Adipose tissue</td>
<td>70%</td>
<td>About a month's worth of energy</td>
<td>Primary energy reserve. Source of glucose for the brain during fasting.</td>
</tr>
<tr>
<td>Protein</td>
<td>Amino acids</td>
<td>Body proteins</td>
<td>Muscle</td>
<td>2% (4,380 Calories)</td>
<td>2.5 years</td>
<td>Meets structural and functional repair of the body.</td>
</tr>
</tbody>
</table>

*Refers to insulin-related, emp. *ads.
Comparison of Absorptive and Postabsorptive States

**Post-absorptive Phase** - in this phase glucose is moved back into the blood to supply what is used in metabolism.

1) **glycogenolysis** - the first source of glucose is the breakdown of glycogen. The primary hormone for this is **glucagon**.

2) **lipolysis** - fat is broken down into glycerol and fatty acids. Glycerol is used to make glucose or in glycolysis. Fatty acids can be catabolized by many cells, especially aerobic muscle fibers.

This is said to be "**glucose sparing**" because it leaves glucose available for those cells, e.g. neurons, which rely on glucose exclusively. Glucagon and (epinephrine) trigger lipolysis.

Lipolysis begins when glycogen reserves fall to about 1/3 of maximum.

3) **gluconeogenesis** - **Amino acids** are made into glucose under two conditions:
   a) when they are in abundance as in a high protein, low carbohydrate diet, an action mediated by glucagon
   b) when other fuel reserves are low or when severe stress causes release of cortisol.

**Table 17-5**

<table>
<thead>
<tr>
<th>Metabolic Fuel</th>
<th>Absorptive State</th>
<th>Postabsorptive State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>Glucose providing the main energy source</td>
<td>Glucose sparing to conserve glucose for the brain</td>
</tr>
<tr>
<td></td>
<td>Glycogen synthesis and storage</td>
<td>Glucose production through gluconeogenesis</td>
</tr>
<tr>
<td></td>
<td>Fatty acids converted and stored as triglycerides</td>
<td>Fatty acids providing the major energy source for non-glucose-dependent tissues</td>
</tr>
<tr>
<td>Protein</td>
<td>Protein synthesis</td>
<td>Proteins catalyzed</td>
</tr>
<tr>
<td></td>
<td>Glucose converted and stored as triglycerides</td>
<td>Amino acids used for gluconeogenesis</td>
</tr>
</tbody>
</table>
Roles of Key Tissues in Metabolic States

• Liver
  – Primary role in maintaining normal blood glucose levels
  – Principal site for metabolic interconversions such as gluconeogenesis

• Adipose tissue
  – Primary energy storage site
  – Important in regulating fatty acid levels in the blood

• Muscle
  – Primary site of amino acid storage
  – Major energy user

• Brain
  – Normally can only use glucose as an energy source
  – Does not store glycogen
    • Mandatory blood glucose levels be maintained

Pancreatic Hormones

• Pancreas
  – Endocrine cells – Islets of Langerhans
    • B (beta) cells
      – Site of insulin synthesis and secretion
    • A (alpha) cells
      – Produce glucagon
    • D (delta) cells
      – Pancreatic site of somatostatin synthesis
    • PP cells
      – Least common islet cells
      – Secrete pancreatic polypeptide

• Insulin and glucagon
  – Most important in regulating fuel metabolism
Pancreatic Hormones

- Insulin
  - Anabolic hormone
  - Promotes cellular uptake of glucose, fatty acids, and amino acids and enhances their conversion into glycogen, triglycerides, and proteins, respectively
    - Lowers blood concentration of these small organic molecules
  - Secretion is increased during absorptive state
    - Primary stimulus for secretion is increase in blood glucose concentration

- Glucagon
  - Mobilizes energy-rich molecules from storage sites during postabsorptive state
  - Secreted in response to a direct effect of a fall in blood glucose on pancreatic α cells
  - Generally opposes actions of insulin
  - No known clinical abnormalities caused by glucagon deficiency or excess