Carbohydrates, Lipids & Proteins

- Utilize SAME Cellular Respiration reactions

**METABOLISM of Organic Molecules**

- Carbohydrates, Lipids & Proteins
- Utilize SAME Cellular Respiration reactions

**Carbohydrate Utilization: “Quick Energy”**

- **Storage Form:** GLYCOGEN
  - 75% faster ATP production than fat
  - ~1% of total body energy (350g or 2,000 Kcal)
~Majority glycogen stored in:

- **Liver** - 8% liver mass
- **Muscle** - 1-2% muscle mass

- **Synthesis: GLYCOGENESIS**
  - Link: Glucose-6-phosphate
  - Stimulated by hormone INSULIN
    - Decreases blood sugar:
      - Store cellular glucose
      - Increase cellular GLYCOGEN

- Site of Insulin production: **Pancreas**
  - (Islets of Langerhans)
- **Stimulus: Increasing Blood Glucose**
  - Following a meal: 140–150mg/dl
  - Normal: 65–105mg/dl
- **Effect:** Decrease blood glucose
• Primary Effector Tissue: Liver, Muscle & Adipose
  - Muscle & Adipose: GLUT4 glucose channels are insulin sensitive
  - Insulin receptors activate: Glucose storage: Glycogen or as FAT
    GLUT2 channels are not insulin sensitive

• Effect: Decrease blood glucose

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GLUT 4: Insulin sensitive facilitated channel

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• Glycogen Utilization: GLYCOGENOLYSIS
  - Glycogen breakdown
    a. Muscle: Makes glucose available for glycolysis
    b. LIVER: Releases "FREE" blood glucose
a. **Epinephrine**: Hormone “Adrenaline”
   - **Site of Production**: Adrenal Gland
   - **Stimulus**: Sympathetic Nervous System
     - “Fight or flight hormone”
     - Exercise

b. **Glucagon**: Hormone regulates body sugar
   - **Site of Production**: Pancreas (Islets of Langerhans)
   - **Stimulus**: Decreased blood sugar
     - Fasting

**Overall Effect**: Increase glucose availability
LIPIDS:

- **Storage Form:** Triglycerides
  - *Macromolecule:* Glycerol & Fatty Acids
  - *Approximately 80–85% total body energy* (140,000 Kcal)
  - *Approximately 55% of carbohydrates converted into fat*

- **Synthesis:** LIPOGENESIS
  - *Primary location:* Adipose tissue & Liver
  - *Reaction:* Triglyceride formation

- **Reactants:**
  a. *Glycolysis intermediates*
     - Acetyl CoA link forming ~ Fatty Acids
     - Phosphoglyceraldehyde ~ Glycerol
  b. *Ingested fats*
     - Form: Glycerol & Fatty Acids
Stimulus: **Insulin**

- Stimulated by:
  - a. **Epinephrine**: Exercise
  - b. **Glucagon**: Fasting

**Lipolysis**

- Lipase breaks Ester bonds:
  1. **Glycerol**
  2. **3 Fatty Acid Chains** ("free" - blood)

Overall Effect: **Increase fatty acids**
Fatty Acid Chain Utilization:

- Fatty Acid breakdown: \( \beta \)-Oxidation

- Fatty Acids: "CUT" into 2 carbon units

ATP per C-C:

4 ATP: Per every 2 carbons cut
10 ATP per Acetyl CoA

16 Carbon Chain = 108 ATP:

- 7 cuts

4 ATP: Per every 2 carbons cut
10 ATP per Acetyl CoA

7 cuts (4 ATP) = 28 ATP
8 Acetyl CoA (10ATP) = 80 ATP

~ 28ATP + 80ATP = 108ATP
Electron transport chain required

Fats: ~9 Kcal / gram
Proteins: ~4 Kcal / gram
Carb’s: ~4 Kcal / gram
PROTEINS:

• Account for: \(~15\%-20\%\) stored energy

⇒ **NOT designed as an energy source**

<table>
<thead>
<tr>
<th>Organ</th>
<th>Glucose</th>
<th>Fatty Acids</th>
<th>Ketone Bodies</th>
<th>Lactic Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skeletal muscles</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Liver (fasting)</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Liver</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 5.3  Relative Importance of Different Molecules in the Blood with Respect to the Energy Requirements of Different Organs

1. **Growth & repair**: Children & body builders
   - **Positive Nitrogen Balance**: Ingest more Nitrogen than is excreted

2. **Everyday Protein “Turnover”: Adults**
   - **Nitrogen Balance**: Excretion is balanced by ingestion

(*Negative Nitrogen Balance: Starvation*)
Transamination:
- Inter-conversion of amino acids
  - Transferring amine groups

Transamination uses:
1. Pyruvate
2. AcetylCoA
3. Krebs Cycle intermediates (keto-acids)
**11 Non-essential Amino Acids:**

*Inter-converted by Trans-amination*

**Table 5.2: The Essential and Nonessential Amino Acids**

<table>
<thead>
<tr>
<th>Essential Amino Acids</th>
<th>Nonessential Amino Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lysine</td>
<td>Aspartic acid</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>Glutamic acid</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>Proline</td>
</tr>
<tr>
<td>Threonine</td>
<td>Glycine</td>
</tr>
<tr>
<td>Valine</td>
<td>Serine</td>
</tr>
<tr>
<td>Methionine</td>
<td>Alanine</td>
</tr>
<tr>
<td>Leucine</td>
<td>Cysteine</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>Arginine</td>
</tr>
<tr>
<td>histidine (in children)</td>
<td>Asparagine</td>
</tr>
<tr>
<td>Hydroxylysine</td>
<td>Glutamine</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>Tryptophyline</td>
</tr>
</tbody>
</table>

**9 Essential Amino Acids:**

*NOT inter-converted by trans-amination*

**Oxidative Deamination:**

- Amino acid – Nitrogen removal
Protein Turnover: “Used” amino acid skeletons are excreted

Processed Nitrogen Removal: UREA

Cellular Energy Sources:

- Tissue preferred energy sources:
  - a. Brain: Glucose (Liver)
  - b. Skeletal Muscle (Rest): Fatty Acids (Adipose)
  - c. Skeletal Muscle (Exercising): Glucose (Liver & Muscle)
  - d. Liver: Fatty Acids (Adipose) & Ketone Bodies (Liver)

Ketone Bodies:

- Produced by liver when glucose is scare
  - Starvation / Fasting
  - Diabetes
- Obtained from breaking down Fatty acids
  - Produced from 2 Acetyl CoA
Metabolic Result: Ketosis

- Elevated levels of Ketone bodies
- Ketone Bodies are Acidic:
  - Ketoacidosis
  - Metabolic acidosis

- Glucose can NOT be made from fatty acids!!
- Body needs energy in an alternate fuel:
  - Fatty acids : Ketone bodies
  - Proteins