Fat and Protein Metabolism

Fats and Proteins as Energy Sources

- Fats can be hydrolyzed to glycerol and fatty acids
  - These can be modified to run through Kreb’s!
- Proteins can be broken down to amino acids
  - Which can be deaminated and run through Kreb’s!
- These pathways can be used to interconvert carbohydrates, fats, and proteins

Review

Phase 1: Priming
Phase 2: Cleavage
Phase 3: Oxidation and formation of ATP and release of high energy electrons

2 ADP + 2 NADH + H+ → 2 ATP + 2 NAD

Key:
- ATP
- ADP
- NAD
- NADH
- H+
- ATP
- Inorganic phosphate
- Coenzyme A
- Acetyl CoA
- Pyruvic acid
- Glyceraldehyde phosphate
- Glucose-Dihydroxyacetone phosphate
- Fructose-1,6-diphosphate
- Oxygen

To citric acid cycle and electron transport chain (aerobic pathway)
Acetyl CoA

- Is a common substrate for energy and other pathways

Many are reversible reactions

Energy Storage

- When more energy is taken in than consumed, ATP synthesis is inhibited
- Glucose converted into:
  1) glycogen
  2) fat

Fat Synthesis (Lipogenesis)

- Acetyl CoAs (2Cs) can be linked together to form fatty acids
- Fatty acids + glycerol = Fat (triglycerides)
- Occurs mainly in adipose and liver tissues
- Fat is major form of energy storage in body
  - Yields 9 kilocalories/g
  - Carbs and proteins yield only 4 kc/g
- Body Energy
  - 80-85% energy in a body is stored as fat
    - Some as Glycogen (Muscles mainly & liver)
    - 15-20% protein (not used much)

Lipogenesis and Lipolysis Pathways

Lipolysis

- Is breakdown of fat into fatty acids and glycerol
  - Via hydrolysis by lipase

1. Glycerol produces a few ATP
   - Released into blood
   - Liver converts most to Glucose (gluconeogenesis)
2. Free fatty acids serve as major energy source for many tissues (Acetyl CoA!!)
Lipogenesis and Lipolysis Pathways

- **Glucose**
  - PGAL (phosphoglyceraldehyde)
  - Glucose 6-phosphate

- **Key**
  - Lipogenesis
  - Lipolysis

- **Lipogenesis**
  - Glycerol
  - Fatty acids
  - Acetyl-CoA
  - Stored triglycerides

- **Lipolysis**
  - Beta oxidation
  - Citric acid cycle
  - New triglycerides

**Beta-Oxidation of a Fatty Acid**

- **Beta-oxidation**
  - Clips 2 C acetic acid
  - Leaves CoA to enter Krebs
  - Which can be run through Kreb's giving 10 ATPs each
  - Plus β-oxidation itself yields 4 ATPs

- **16 C fatty acid = 108 ATP!!!!!!!**

**Brown Fat**

- Brown fat is a major site for thermogenesis
  - Brown fat produces an uncoupling protein
    - Causing H⁺ to leak out of inner mitochondrial membrane
  - Less ATP is produced, causing electron transport system to be more active
  - Heat produced instead of ATP!!!!!!!!!

**Ketone Bodies**

- Triglycerides are continually broken down and resynthesized
  - Ensures blood contains fatty acids for aerobic respiration
- If lipolysis exceeds fatty acid use - i.e., fasting (or diabetes)
  - (i.e., lots of fat is broken down very quick)
  - Blood concentration of fatty acids increases
  - Acetyl CoA derived from fatty acids makes ketone bodies
    - 2 acetyl CoA combined to form a 4 C molecule
    - Acetoacetic acid/β-hydroxybutyric acid/acetoacetate acid (3 C)
  - Can be used for E under normal condition
  - High levels cause acidic blood (acidosis)
  - Gives breath an acetone smell
Acetyl CoA - Review

- Break down of large molecules to simple molecules
- Break down simple molecules to Acetyl CoA
- Oxidation of Acetyl CoA to H₂O and CO₂ – produce E and make ATP

Proteins - Peptides

- Short chains of amino acids
  - Amino acids are linked by peptide bonds
  - Formed by dehydration synthesis reactions (condensation)

Amino Acid Metabolism

- Nitrogen (N) is ingested primarily as protein (i.e., amino groups on the amino acids)
- Excess is excreted mainly as urea

Nitrogen (N) Balance

- Nitrogen balance = N ingested minus N excreted
  - Positive N balance: more N ingested than excreted
  - Negative N balance: less N ingested than excreted
- In healthy adults amount of N excreted = amount ingested
- Excess amino acids can be converted into carbs and fat
Essential and Non-essential Amino Acids

- 20 amino acids are used to build proteins

Table 5.3 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></td>
<td>Glutamine</td>
</tr>
<tr>
<td></td>
<td>Tyrosine</td>
</tr>
</tbody>
</table>

Making amino acids (so we can make proteins!)

- New amino acids can be obtained by transamination
- Amine group transferred from one A.A. to another molecule to form a different A.A.
- Catalyzed by transaminase

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Oxidative Deamination – in liver!

- If more A.A. are present than needed to make protein, excess amino acids are eliminated
- -NH2 is removed from glutamic acid, forming keto acid (and ammonia)
- Ammonia is converted to urea and excreted
- Keto acid goes to Krebs or to fat or glucose

Gluconeogenesis

- Occurs when amino acids or other non-carbos are converted to Keto acids, then pyruvate, then glucose
- i.e., making glucose from non-carbohydrates
- Pyruvic acid and acids of Krebs Cycle are keto acids
- They possess a Keto group \( \text{C}=\text{O} \)

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Pathways of Amino Acid Metabolism

Uses of Different Energy Sources

- Different cells have different preferred energy substrates
- Brain uses glucose as its major source of energy

Table 5.4 Relative Importance of Different Molecules in the Blood with Respect to the Energy Requirements of Different Organs

<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 (resting)</td>
<td>+</td>
<td>+++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Liver</td>
<td>+</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Heart</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>