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Molecules of Life

Diabetes and Insulin

The primary role of insulin is to regulate blood sugar, which has a huge influence on fat usage. It accomplishes this by:

- Increasing rate of glucose uptake by cells.
- Increasing rate of sugar storage (primarily in the liver and muscles).
- Decreasing rate of glycogen breakdown.
- Increasing rate of fat uptake by adipose tissue (fat cells).
- Decreasing rate of fat uptake by muscle.
- Decreasing rate of fat release by adipose tissue.

Key molecules

- **Glucose**
  Blood sugar. Too high concentrations in cells and/or bloodstream harmful

- **Triglycerides**
  Large “fat” molecules. Unable to move into or out of adipose tissue (fat cells)

- **Fatty acids**
  Building blocks of triglycerides. Able to enter and leave adipose tissue

- **Insulin**
  An enzyme responsible for lowering blood sugar

- **Glucagon**
  An enzyme that is active when blood sugar is low

Role of Insulin

Biochemistry of Metabolism

Metabolism: Locations

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Biochemistry of Metabolism

Metabolism

Fed State - Pathways

- Insulin and Fat

Fasting State - Pathways

- Fasting State
- Starvation

Sugar, Diabetes, and Diet
Insulin and Blood Sugar

Insulin can bind to receptors on the surface of cells, which allows glucose to enter cells. This directly lowers blood sugar.

Insulin Receptors and Glucose

**Insulin Receptor Sensitivity**
High levels of glucose inside cells is harmful. If cells are regularly ‘overloaded’ with glucose, the receptors become less sensitive to glucose, resulting in less glucose uptake by cells (and higher blood sugar).

**Pancreas**
In response to high blood sugar, pancreas releases more insulin.

Sugar and Fat Regulation

- Insulin ‘activates’ LPL receptors on adipose tissue to increase absorption of fat by these cells.
- Insulin ‘deactivates’ LPL enzymes on surface of muscle cells so that muscle will NOT absorb fat and will preferentially burn carbohydrates for fuel.
- Insulin ‘deactivates’ HSL enzymes so that fat molecules NOT released by adipose tissue.

Fed State - Pathways

Fed State- Pathways
Metabolism after Eating

Assume that a meal is consumed that contains both fats and carbohydrates. Insulin is released that causes the following changes:

- Carbohydrates absorbed by muscle cells: Converted into glycogen (storage) and burned for energy.
- Carbohydrates absorbed by liver: Converted into glycogen and fat (both for energy storage).
- Fats absorbed by fat cells (adipose tissue): Converted into triglycerides for energy storage.
- Carbohydrates absorbed by adipose tissue: Used for formation of triglycerides.

Fasting State - Pathways

Several hours after eating, carbohydrate in blood stream is much lower, and insulin levels also drop.

- Increase in amount of fats released by adipose tissue into blood stream and transported to cells to be used for energy.
- Liver also converts glycogen into glucose to help maintain blood sugar levels.
- When glucose levels drop below a certain level, hunger signal sent to brain.

Fasting State

Starvation

Diabetes

Untreated diabetes similar (from a metabolism perspective) to starvation.

- Blood sugar is high (especially after eating) because either insulin is not formed (Type I) or insulin receptors broken (Type II). Insulin is responsible for bringing glucose from bloodstream into cells.
- Since cells think glucose concentration is low, hormones released to produce more glucose.
- Cell concentration of glucose is low, so metabolism of fats primary fuel source.
- High metabolism of fat can lead to ketone bodies (acetone smell on breath).

Sugar, Diabetes, and Diet

Sugar, Diabetes, and Diet
Diabetes - Pathways

Blood sugar and food

“Normal”, fasting blood glucose ≈ 90 mg/dL

Calculate effect of 1 can of Coke on blood sugar.

- One 12 fl. oz. can Coke Classic contains 39 grams sugar
- Average adult has ≈ 5 liters of blood
- If all sugar in Coke added to bloodstream as glucose:

\[
\frac{39000 \text{ mg glucose}}{5 \text{ L blood}} = 780 \text{ mg/dL}
\]

Sugar Profile

Glycemic Index

Carbohydrates are “all” converted into glucose

- **Glycemic Index**: Estimate of how quickly different foods are converted into glucose.
- **Glycemic Load**: Estimate of how much different foods affect blood sugar
  - Related to G.I. and amount of sugar present in food.

Foods with a higher glycemic load predicted to cause larger spikes in blood sugar.

<table>
<thead>
<tr>
<th>Food</th>
<th>Glycemic Index</th>
<th>Glycemic Load</th>
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</thead>
<tbody>
<tr>
<td>White Bread</td>
<td>70</td>
<td>10</td>
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<tr>
<td>Ice Cream</td>
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<td>4</td>
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<tr>
<td>Boiled Carrots</td>
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<td>2</td>
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<tr>
<td>Raw Carrots</td>
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<td>1</td>
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</tbody>
</table>

High Blood Sugar

If blood sugar is too high, body tries to reduce it:

- Releases insulin so cells can pick up sugar
- Causes Thirst: Drinking water will dilute sugar
- Sends excess sugar to kidneys for elimination (spilling)
- Glucose attaches to proteins (A1C measures sugar on hemoglobin)
- Water can be ‘sucked out’ of cells

Low Carb Diets

Paleo Diets, the Atkin’s Diet, Protein Power Plan, and other related diets require:

- Very low carbohydrate intake
- High fat intake (for fuel)
- High protein (to avoid muscle degradation)

Claim is that we consume too much simple sugar, which gives rise to diabetes.
This is basically the same diet recommended before 1960’s.
American Heart Association warned that these diets can be dangerous.