Insulin is one of our most important hormones. It coordinates the action of cells throughout the body, making sure that they are managing uptake, use and storage of blood sugar correctly. After eating, our blood is full of sugar, and special cells in the pancreas release insulin into the blood in response. This signal tells cells to take the sugar out of the blood for direct conversion into energy or storage as glycogen or fatty acids. Later, as blood sugar levels drop, another pancreatic hormone, glucagon, manages the release of sugar from the cellular glycogen stores.

Insulin in Action

Insulin binds to the insulin receptor, then the protein kinase domain of the receptor activates a signaling cascade, mobilizing a number of different systems in the cell.

Glucose

1. Insulin binds to the receptor
2. The receptor transmits the signal into the cell
3. The tyrosine kinase domains come together and activate each other
4. The active kinase domains activate downstream signaling proteins
5. Another set of enzymes (not depicted) utilize excess glucose to create fatty acids, a longer term way of storing food energy
6. Glycogen can be rapidly converted back into glucose when blood sugar levels fall between meals
7. Insulin signaling also activates a set of enzymes that build glycogen from excess glucose

Diabetes Treatment

Causes
Insulin-producing cells in the pancreas are inappropriately destroyed by the individual’s immune system.

Treatment
The only approved medical treatment is replacement of the body’s insulin with an injectable form of the hormone.

Type 1
The body becomes progressively more resistant to the action of insulin at the cell surface.

Type 2
First line management is behavior modification with diet and exercise. If high blood glucose levels persist, oral medications are used.

Today, genetic engineering is used to produce injectable forms of human insulin, such as Humulin®. Insulin is normally stored as a hexamer, which is stabilized by zinc ions (magenta). When it is injected, the hexamers break apart to release the active monomers.

Biotechnologists have created improved versions of injectable human insulin, like the two shown here, that customize how quickly it acts:

- **Long-Acting Insulin:** Tresiba® insulin has several hydrocarbon chains attached (pink), so it forms larger complexes that dissociate slowly at the injection site, making the treatment last through the night when the liver is breaking down its glycogen energy stores to maintain adequate blood sugar levels.

- **Fast-Acting Insulin:** Humalog® insulin, on the other hand, has the order of two amino acids in the B-chain reversed at positions 28 and 29 (red), which weakens the hexameric assembly of two-chain insulin monomers allowing them to act more quickly after injection at meal times when blood sugar levels rise rapidly.

References
- Banting et al. (1920) Pioneered in the 1920s at the University of Toronto by Frederick Banting and Charles Best, early treatments used insulin purified from pig or beef cattle pancreas, each of which differs from human insulin by one amino acid.
- PDB ID 1IRK
- Proinsulin

Insulin Processing

1. Insulin is a very small protein consisting of two chains: an A-chain of 21 amino acids (green) and a B-chain of 30 (blue). Three disulfide linkages help to stabilize the 3D structure of the protein.
2. The two polypeptide chains making up insulin are encoded by the same gene, which gives rise to a longer proinsulin consisting of the B-chain, a long connecting C-peptide (light green), and the A-chain. During proinsulin processing inside the cell, the C-peptide is excised and the A- and B-chains come together as a tightly folded two-chain monomer.
3. For insulin to work, the insulin binding domains in the receptor protein must come together to activate the signaling pathway.
4. This can happen in one of two ways: either the receptor protein is pre-assembled as a hexamer, or the two chains can assemble into a hexamer after they are separated in the cell.
5. Hexamers, dihexamers, and linear multihexamer structures by the enzyme that catalyzes the reaction.
6. Three disulfide linkages help to stabilize the 3D structure of the protein.

Insulin Binding

Insulin binds to the insulin receptor (not depicted) utilizing excess glucose to create fatty acids, a longer term way of storing food energy.

Insulin Signaling

1. Insulin binds to the receptor protein
2. The receptor transmits the signal into the cell
3. The tyrosine kinase domains come together and activate each other
4. The active kinase domains activate downstream signaling proteins

Insulin and Diabetes

Diabetes is a progressive and chronic disease characterized by high levels of blood glucose. It affects millions of people worldwide and can lead to severe complications if not managed properly.

Insulin is the hormone responsible for regulating blood glucose levels. It acts by stimulating the uptake of glucose into cells, particularly muscle and fat cells, and promoting the storage of glucose as glycogen or fatty acids. Insulin is produced in the pancreas by the β-cells of the islets of Langerhans.

There are two main types of diabetes:

- **Type 1 Diabetes:** This type of diabetes is autoimmune in nature, where the immune system destroys the insulin-producing cells in the pancreas. It is usually diagnosed in children and young adults, and requires daily insulin injections or continuous insulin delivery to maintain blood glucose levels in a normal range.

- **Type 2 Diabetes:** This type of diabetes is largely due to insulin resistance, where the body becomes resistant to the actions of insulin. Type 2 diabetes is more common in adults, especially in overweight or obese individuals, and is often associated with other health conditions such as high blood pressure, high cholesterol, and obesity. Type 2 diabetes can be managed through lifestyle changes, such as diet and exercise, and sometimes requires oral medications or insulin injections.

Both types of diabetes require careful management to prevent complications such as heart disease, stroke, kidney disease, eye problems, and nerve damage. Regular check-ups and blood tests are essential to monitor blood glucose levels and adjust treatment as needed.

Insulin is produced in the pancreas by the β-cells of the islets of Langerhans. It is a hormone that plays a crucial role in regulating blood glucose levels. Insulin is responsible for stimulating the uptake of glucose into cells, particularly muscle and fat cells, and promoting the storage of glucose as glycogen or fatty acids.

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