Insulin and Diabetes

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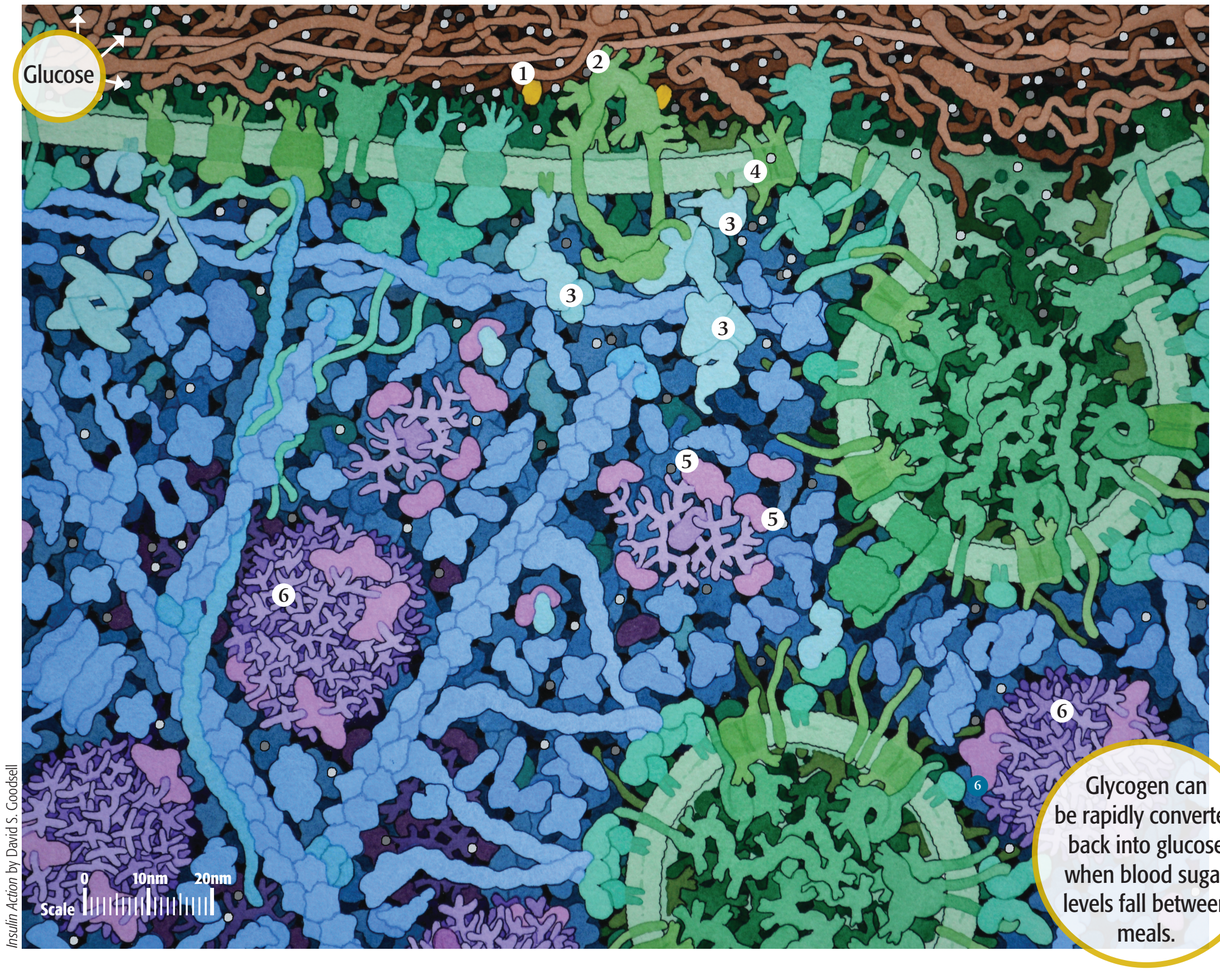
Insulin is one of our most important hormones. It coordinates the action of cells throughout the body, making sure that they are managing uptake, use and storage of blood sugar correctly. After eating, our blood is full of sugar, and special cells in the pancreas release insulin into the blood in response. 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 (1) binds to the **insulin receptor** (2), then the protein kinase domain of the receptor activates a **signaling cascade** (3), mobilizing a number of different systems in the cell.



Insulin Action by David S. Goodsell

Glycogen can be rapidly converted back into glucose when blood sugar levels fall between meals.

These signaling proteins cause **glucose transporters** (4) to be moved to the surface of the cell, which can then transport glucose into the cell. Some of this glucose is used directly as a source of energy to power the cell.

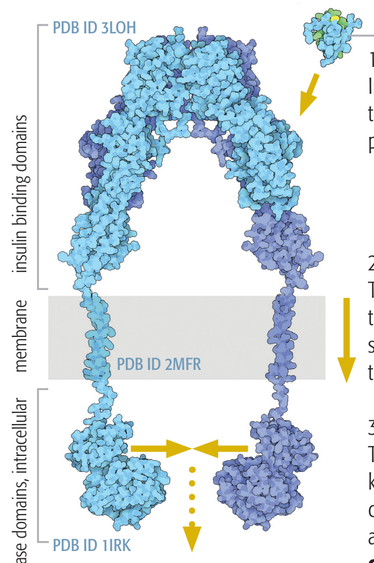
Insulin signaling also activates **a set of enzymes** (5) that build **glycogen** (6) from excess glucose.

Another **set of enzymes** (not depicted) utilize excess glucose to create fatty acids, a longer term way of storing food energy.

Biologists have been studying insulin and insulin signaling since the 1930s.

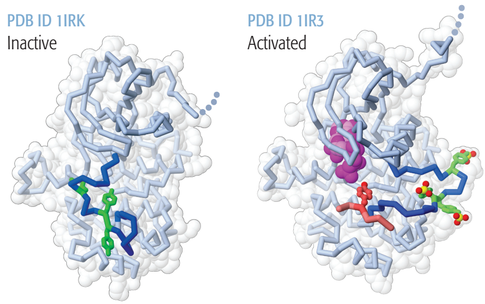
Insulin Signaling

Insulin Receptor



1. Insulin binds to a 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

Kinase Activation



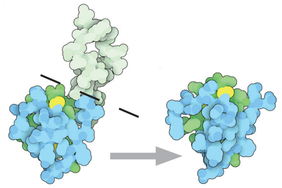
3a. Phosphoryl groups (red and yellow) are added to several tyrosine amino acids (green)

3b. The large activation loop of the kinase (navy) opens up, revealing the active site of the enzyme

3c. The kinase can now bind ATP (magenta) and modify tyrosine amino acids in other signaling proteins (pink)

Insulin Processing

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.



The two polypeptide chains making up insulin are encoded by the same gene, which gives rise to a longer chain **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**.

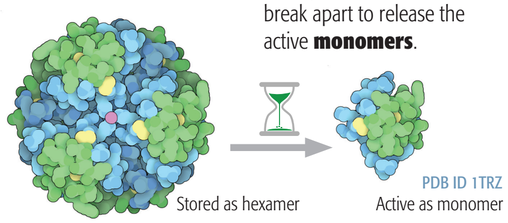
Diabetes Treatment

Left untreated, diabetes can be deadly.

	Causes	Treatment
Type 1	Insulin-producing cells in the pancreas are inappropriately destroyed by the individual's immune system.	The only approved medical treatment is replacement of the body's insulin with an injectable form of the hormone.
Type 2	The body becomes progressively more resistant to the action of insulin at the cell surface.	First line management is behavior modification with diet and exercise. If high blood glucose levels persist, oral medications are used.

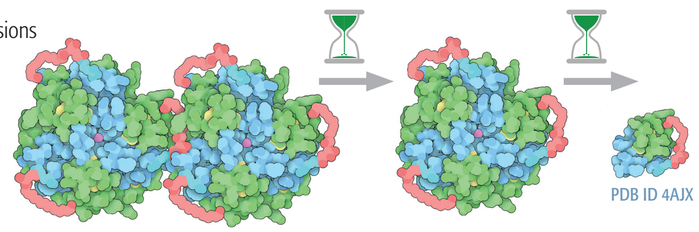
Pioneered in the 1920s at the University of Toronto by **Frederick Banting** and **Charles Best**, early treatments used insulin purified from pig or beef cattle pancreas, each of which differs from human insulin by one amino acid.

Today, genetic engineering is used to produce injectable forms of human insulin, such as **Humulin®**.



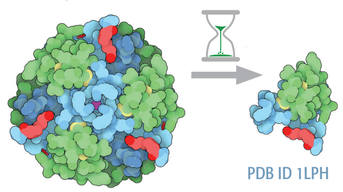
Insulin is normally stored as a **hexamer**, which is stabilized by zinc ions (magenta). When it is injected, the hexamers break apart to release the active **monomers**.

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.



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