Endocrine System

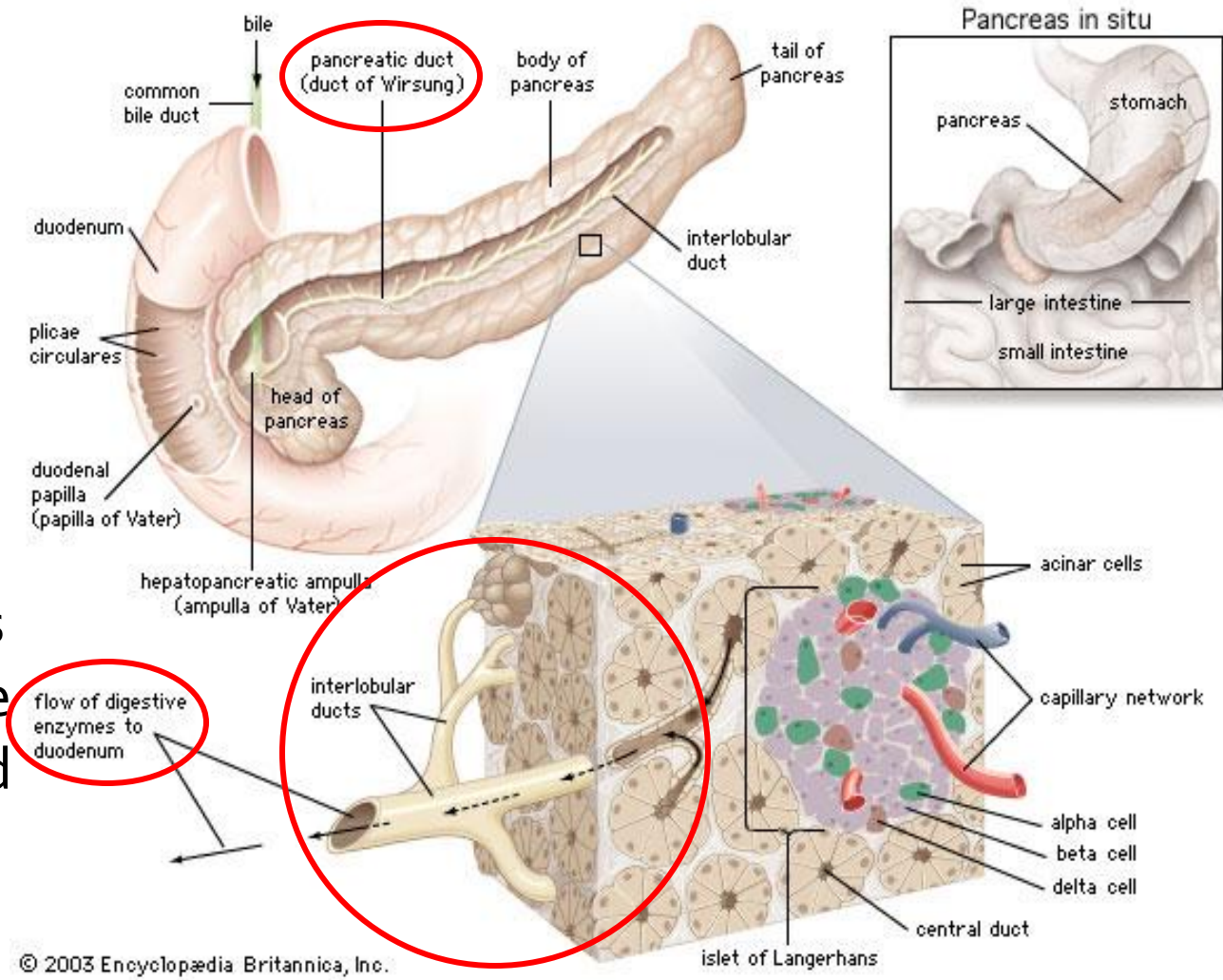
Glucose Regulation

Glucose in Blood

- Glucose is an important fuel for cells
- Pancreas maintains blood glucose levels by secreting hormones

Pancreas

- Exocrine system: secretion of biological molecules through ducts
- Exocrine cells:
  - 98%-99% of pancreas by mass
  - Produce digestive enzymes released into small intestine



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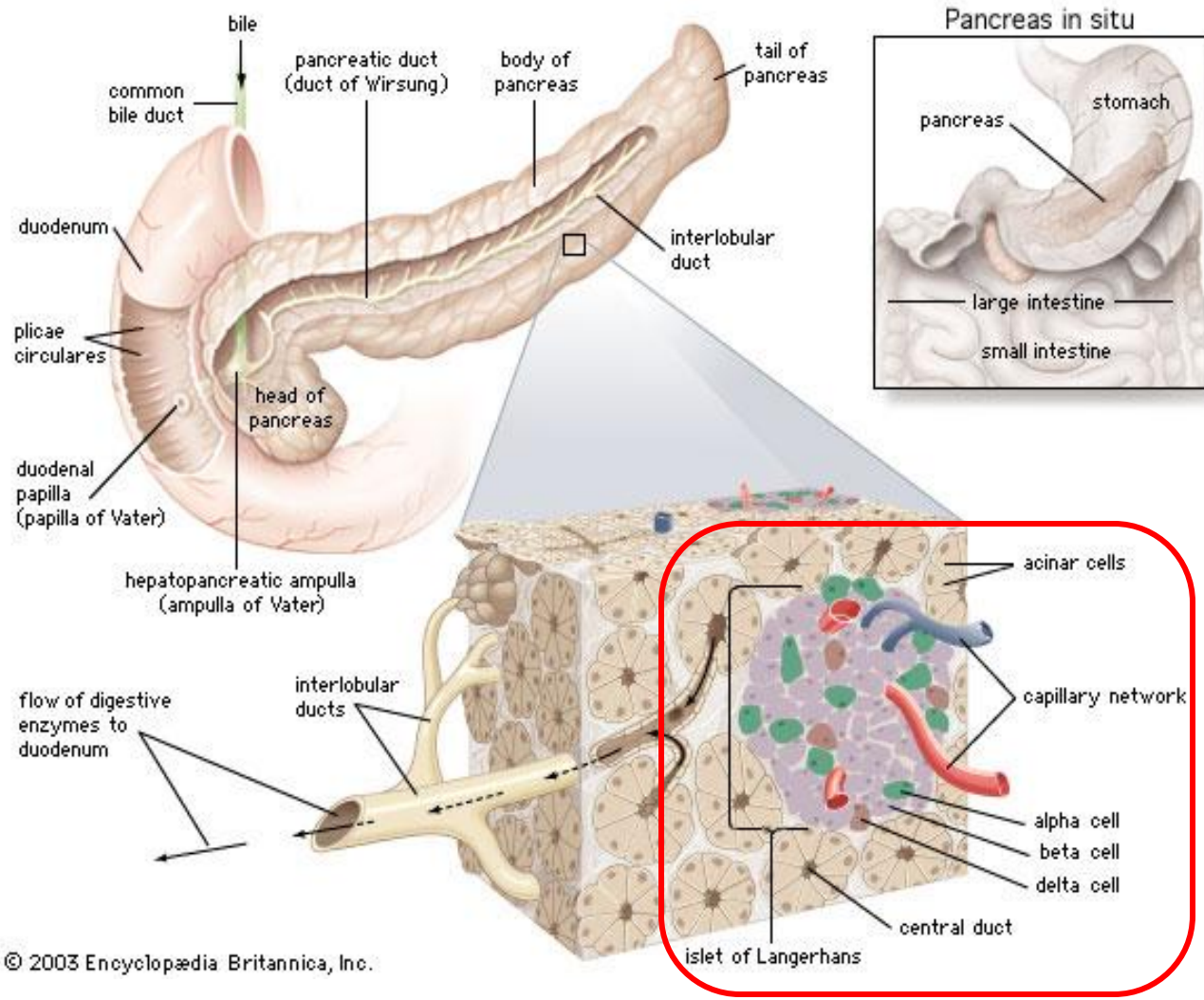
Pancreas

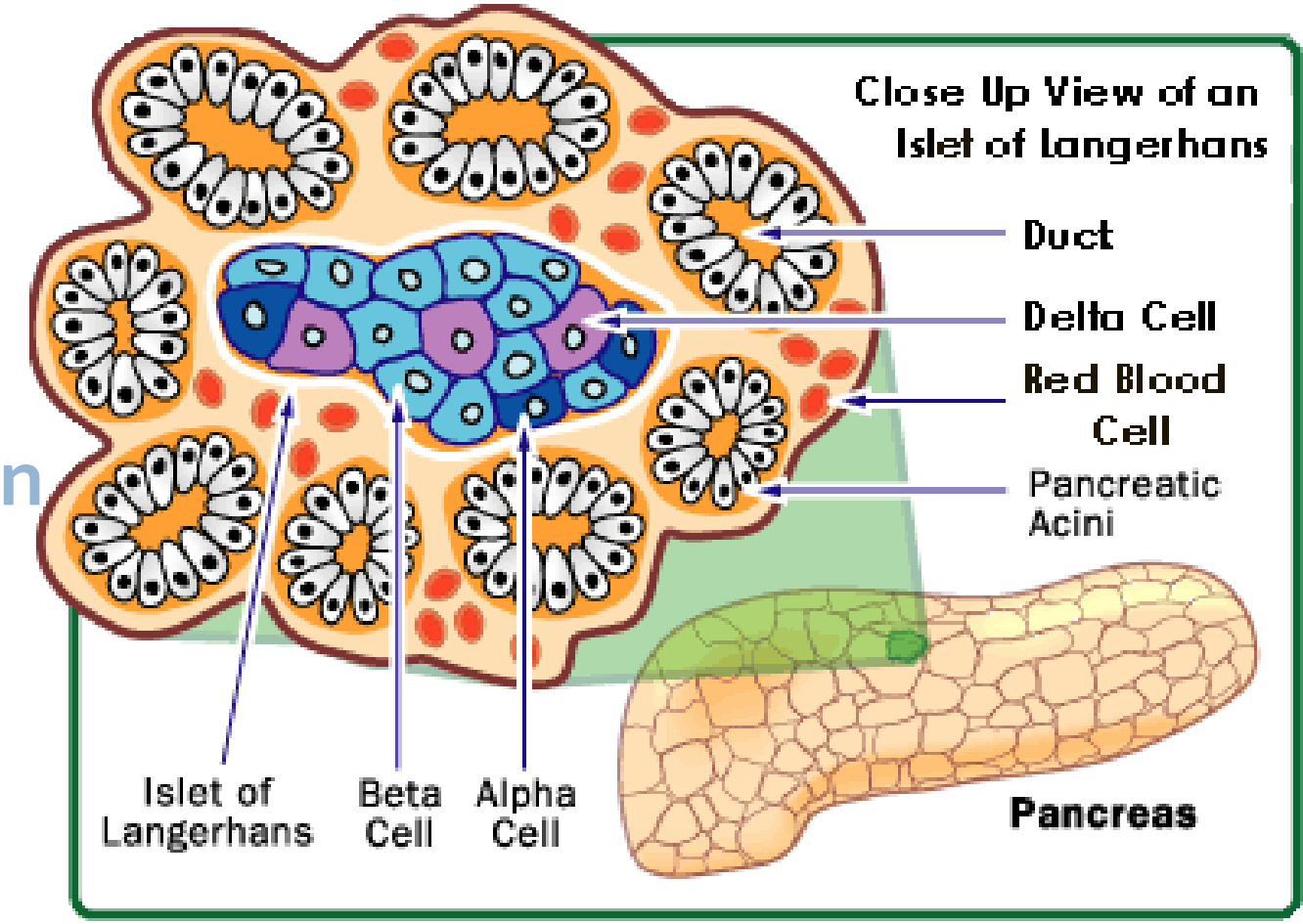
- Endocrine cells:
  - 1%-2% of pancreas by mass
  - Scattered throughout the pancreas
  - Islets of Langerhans



http://media-2.web.britannica.com/eb-media/17/74317-004-9B143D52.jpg

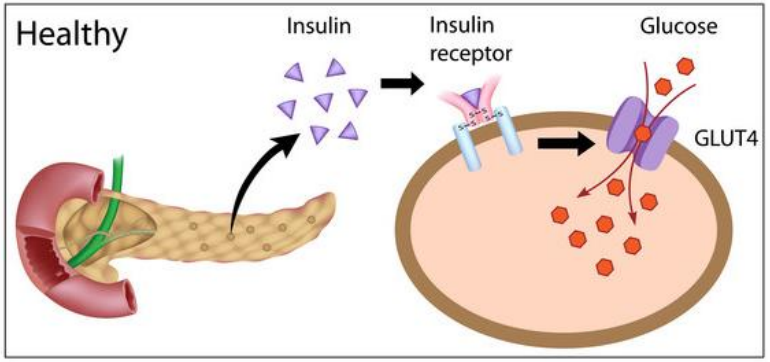
Islets of Langerhans

- **Alpha** cells: secrete **glucagon**
- **Beta** cells: secrete **insulin**
- Insulin and glucagon are **antagonistic** hormones



http://www.rajeun.net/diabetes-pancreas.gif

Insulin



Insulin enters the bloodstream from the pancreas.

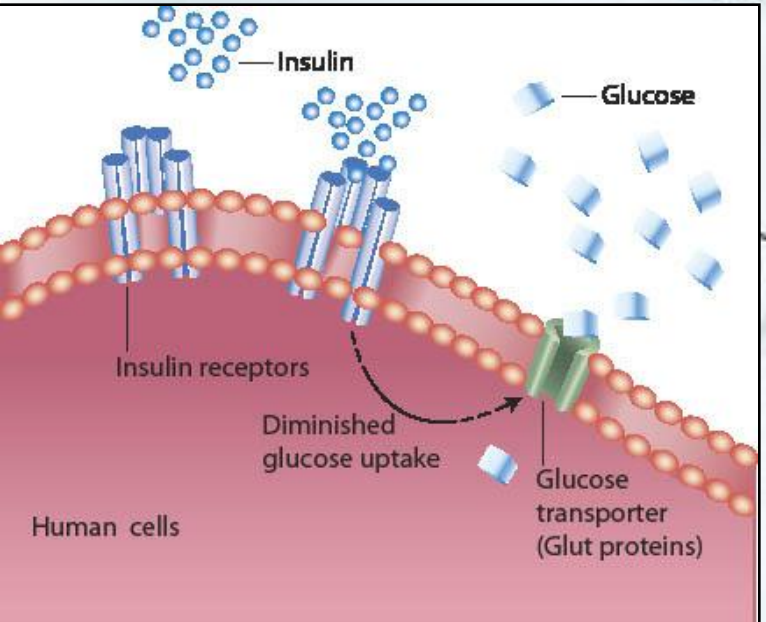
Glucose enters the bloodstream from the digestive system and liver.

Insulin leaves the bloodstream and binds to a cell.

In response to insulin, the cell takes up glucose. The glucose is then used as fuel.

Cell

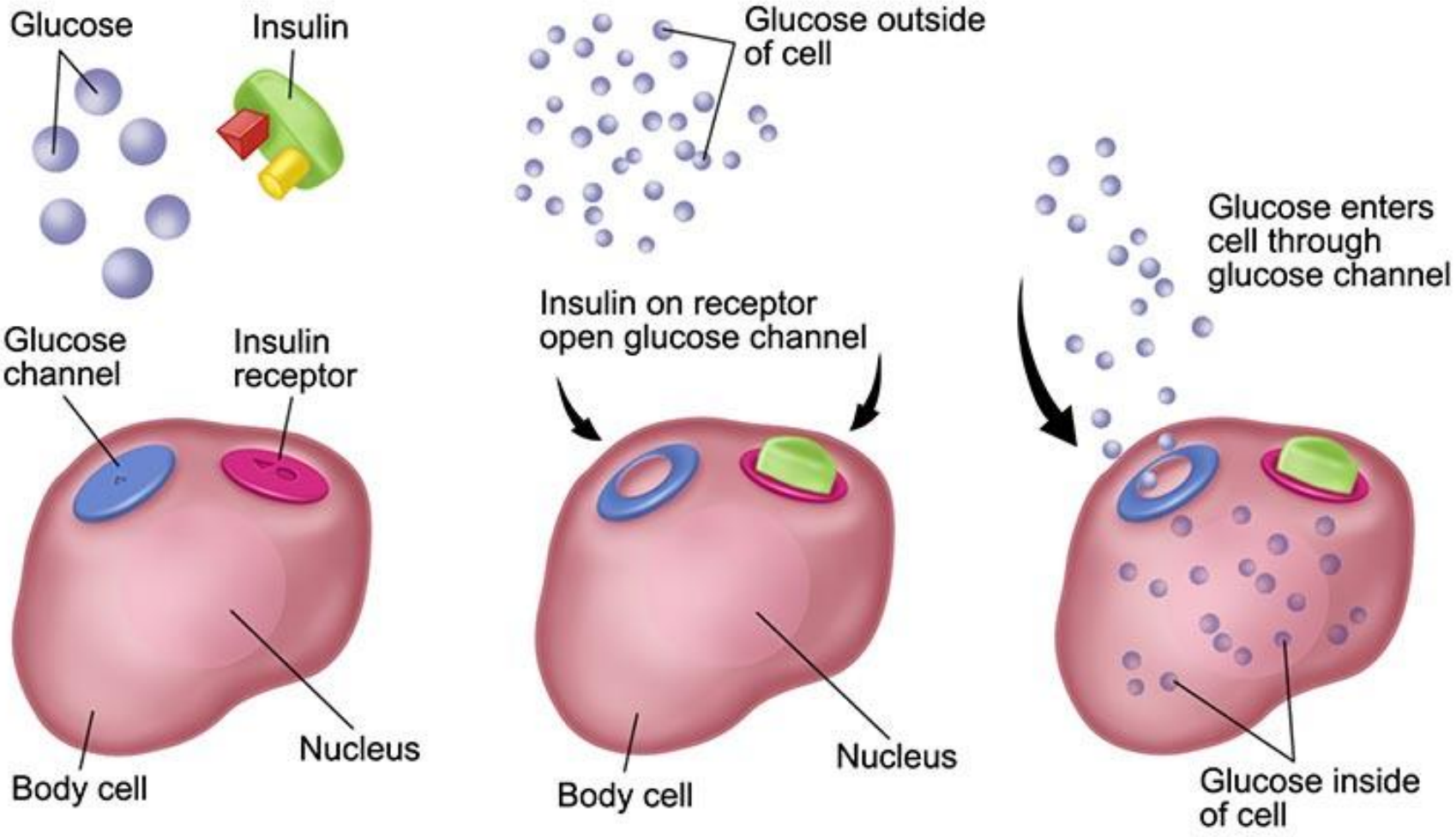
Cell nucleus



Insulin

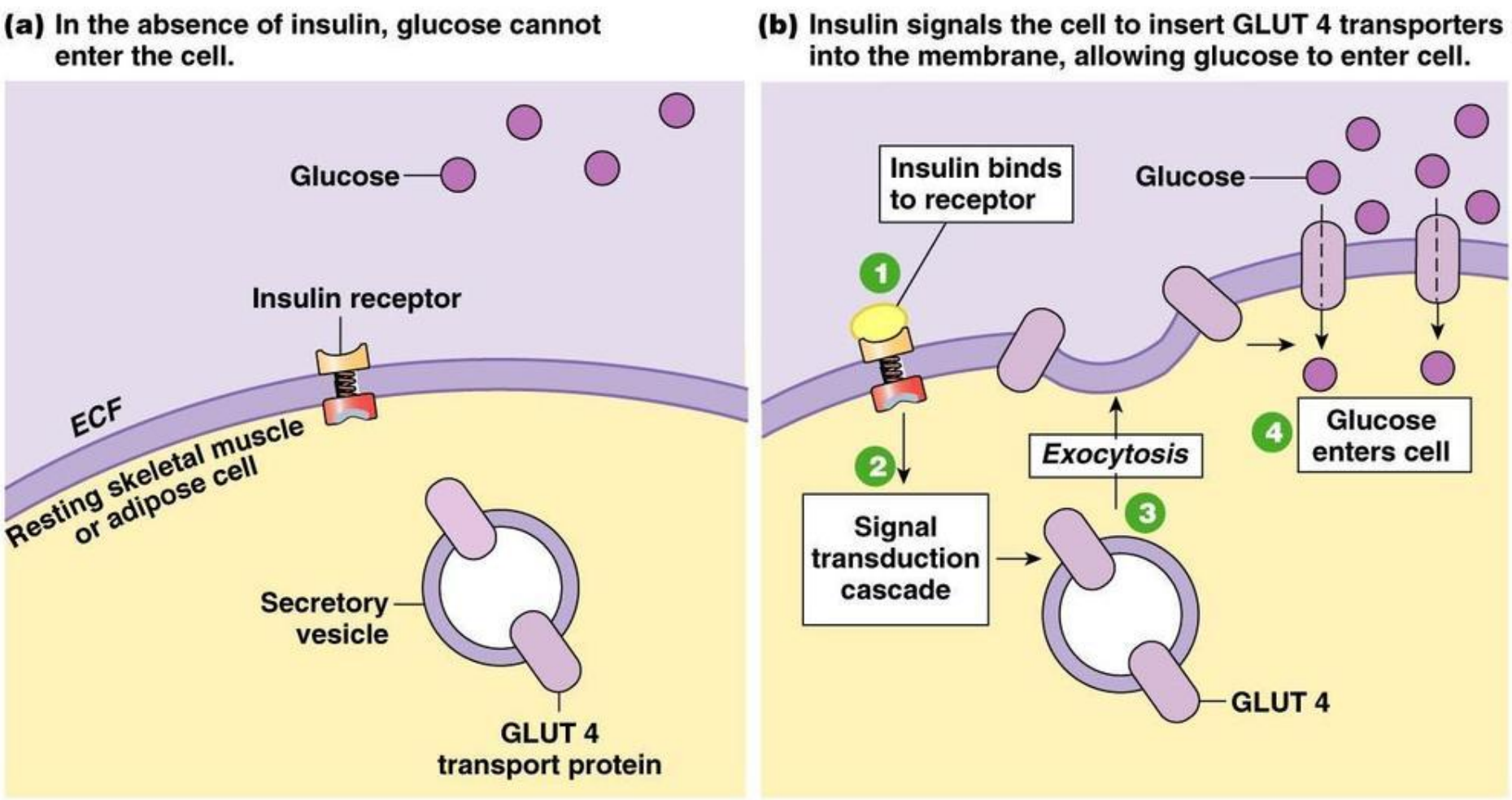
- Stimulant:
  - **Hyperglycemia: Blood glucose level rises** above a set point
  - Observed naturally after eating a meal
- Effect:
  - **Uptake of glucose by body cells** through facilitated diffusion by $GLUT_4$ (glucose transporter)
  - Liver to convert glucose to glycogen for storage
- Result:
  - lowering blood glucose level
  - decrease stimulus for insulin release

Insulin



http://ncc-college.com/wp-content/uploads/2017/03/type-2-diabetes.jpg

Insulin's Mechanism



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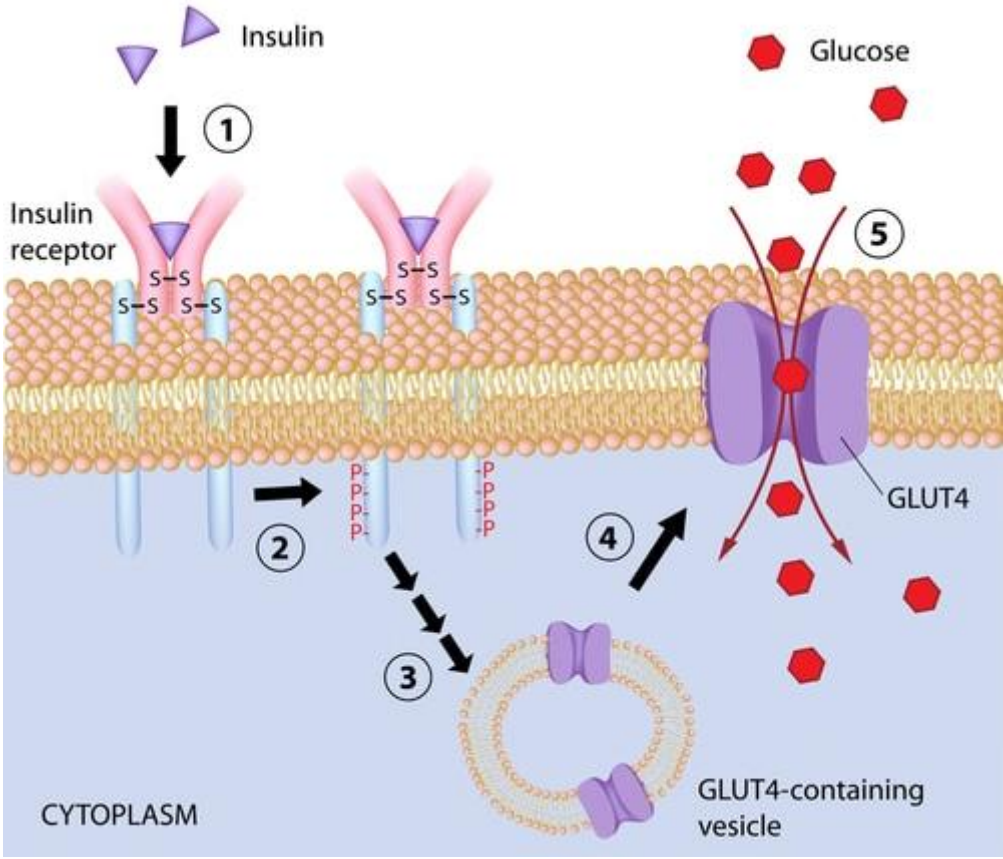
Insulin's Mechanism

- Pancreas beta cells secrete insulin
- Insulin bind to insulin receptors on cell surface
- Exocytosis of GLUT4 transporters onto cell membrane
- Uptake of glucose by body cells through facilitated diffusion by GLUT4 (glucose transporter)



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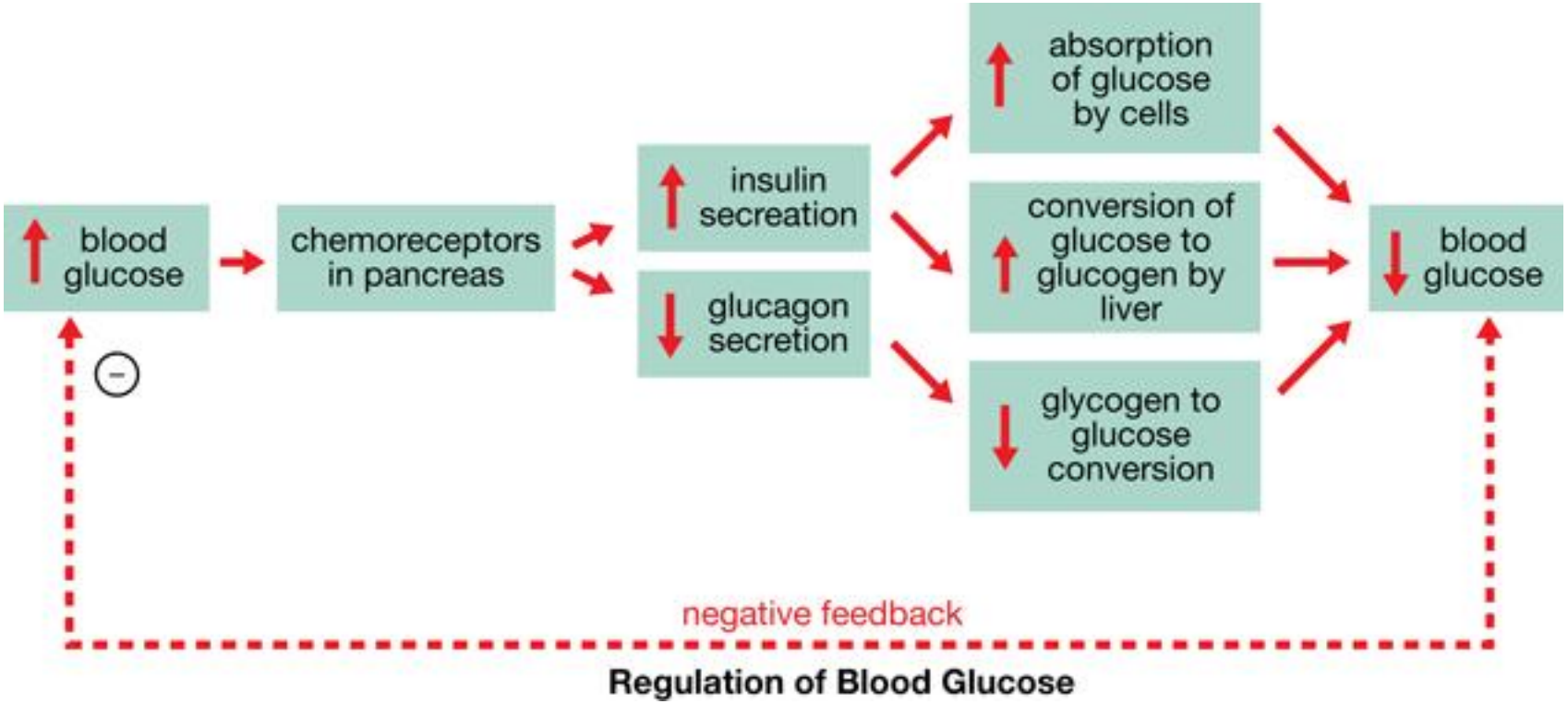
Hyperglycemia



Regulation of Blood Glucose

http://moodle2.rockyview.ab.ca/pluginfile.php/64189/mod_book/chapter/25659/biology_30/images/m2/b30_m2_010_l.jpg

Glucagon

- Stimulant:
  - **Hypoglycemia: Lowered blood glucose**
  - Glucose cleared from the blood stream
- Effect:
  - **Liver to increase breakdown of glycogen**
  - Liver convert amino acids and glycerol to glucose
- Result:
  - Higher blood glucose level
  - Decrease stimulus for glucagon release

Comparing Insulin & Glucagon

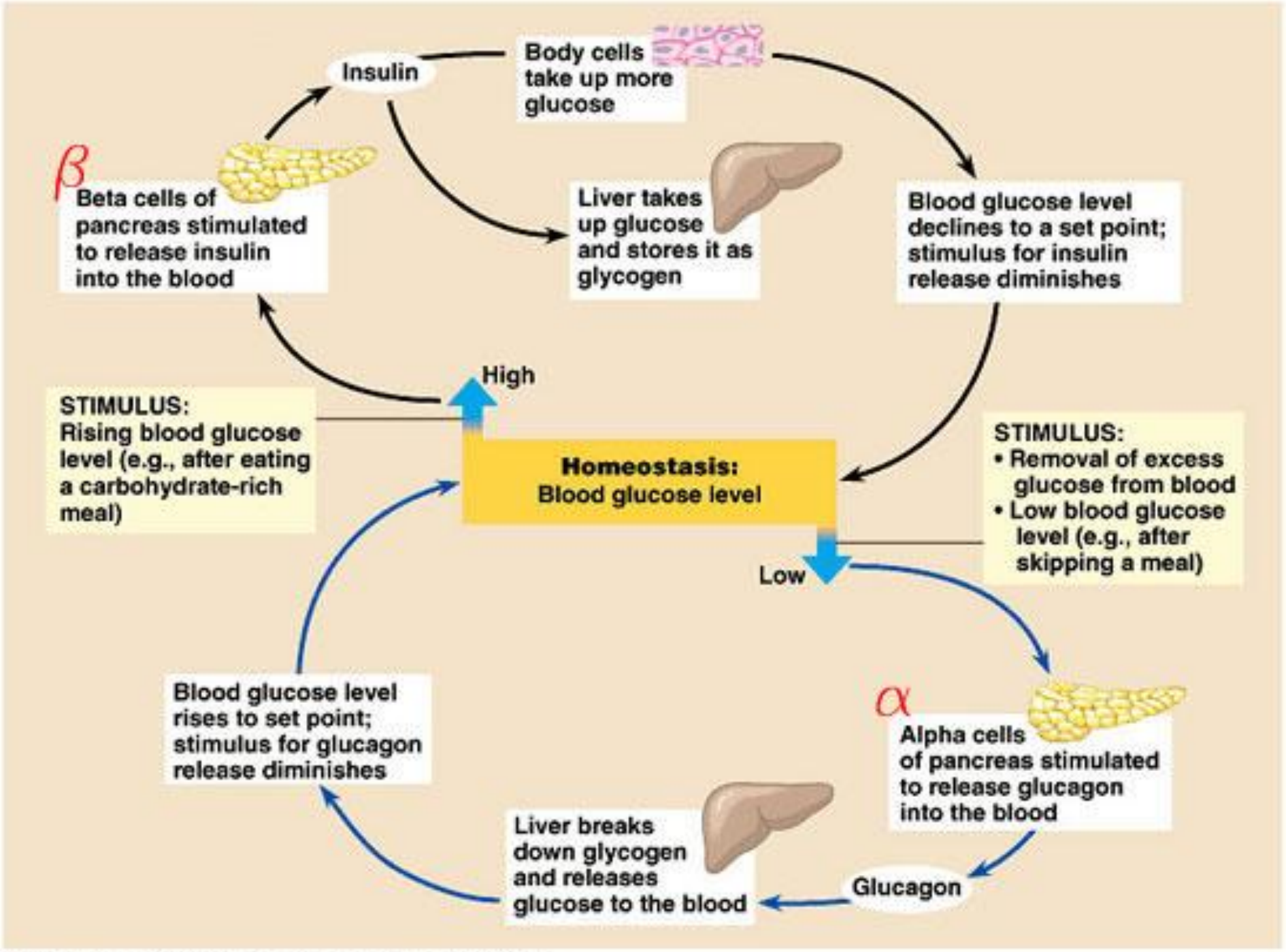
Situation	After a meal	Between meals
Hormone	Insulin	Glucagon
Stimulant: Blood glucose levels		
Effect: Glucose uptake		
Effect: Glycogen breakdown		

Comparing Insulin & Glucagon

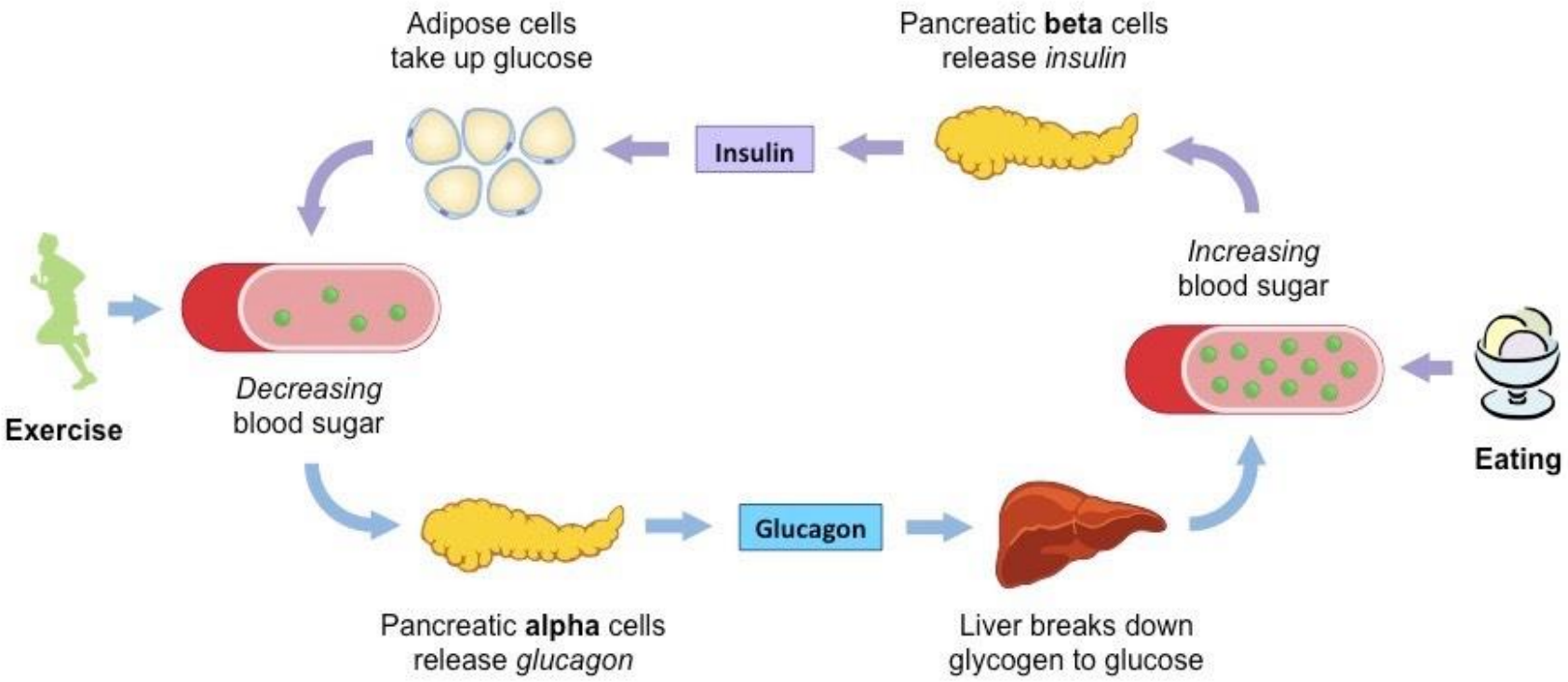
Situation	After a meal	Between meals
Hormone	Insulin	Glucagon
Stimulant: Blood glucose levels	Increased	
Effect: Glucose uptake	Increase	
Effect: Glycogen breakdown	Decrease	

Comparing Insulin & Glucagon

Situation	After a meal	Between meals
Hormone	Insulin	Glucagon
Stimulant: Blood glucose levels	Increased	Decreased
Effect: Glucose uptake	Increase	Decrease
Effect: Glycogen breakdown	Decrease	Increase

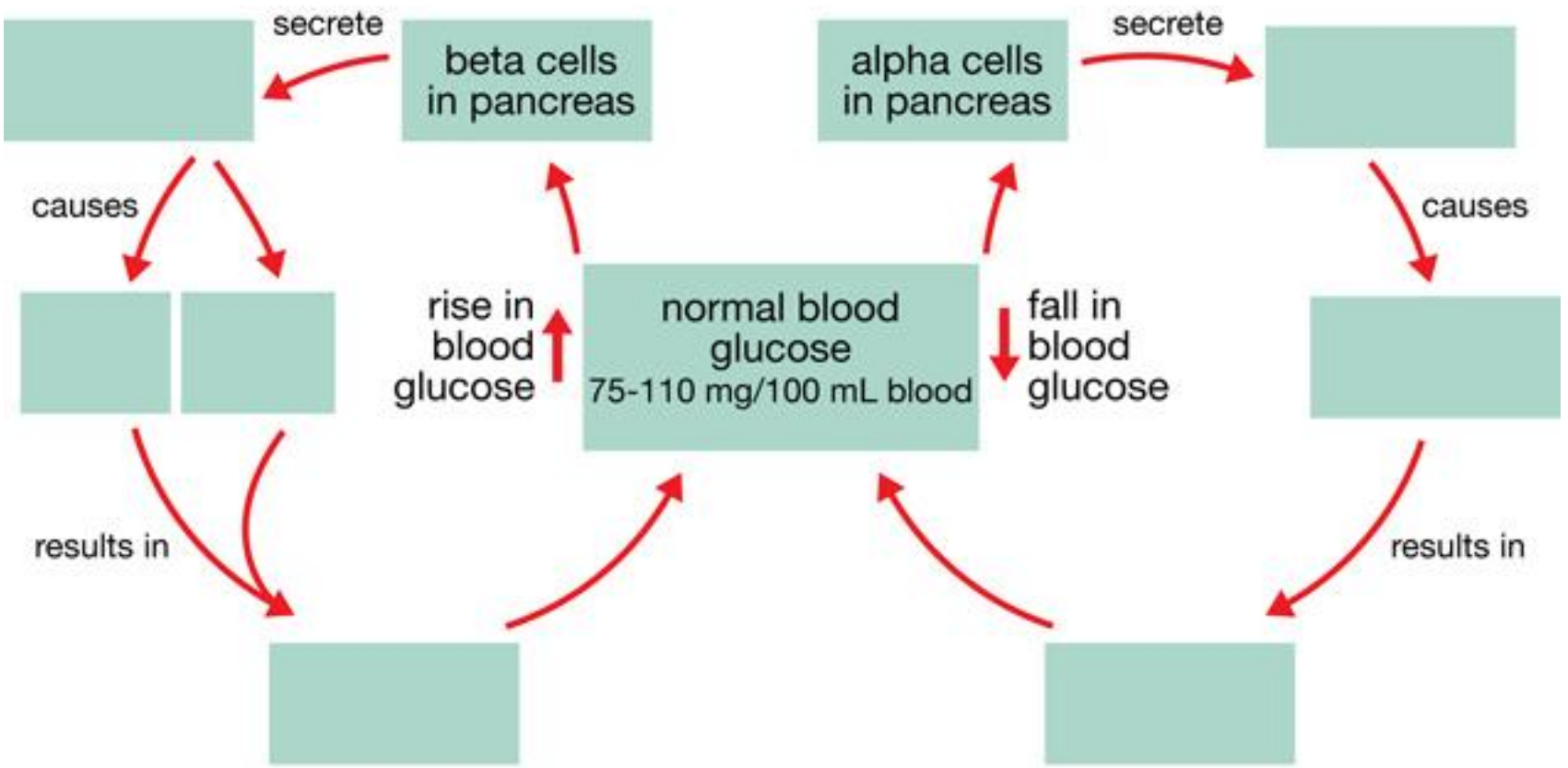


Glucose Regulation Feedback Loop

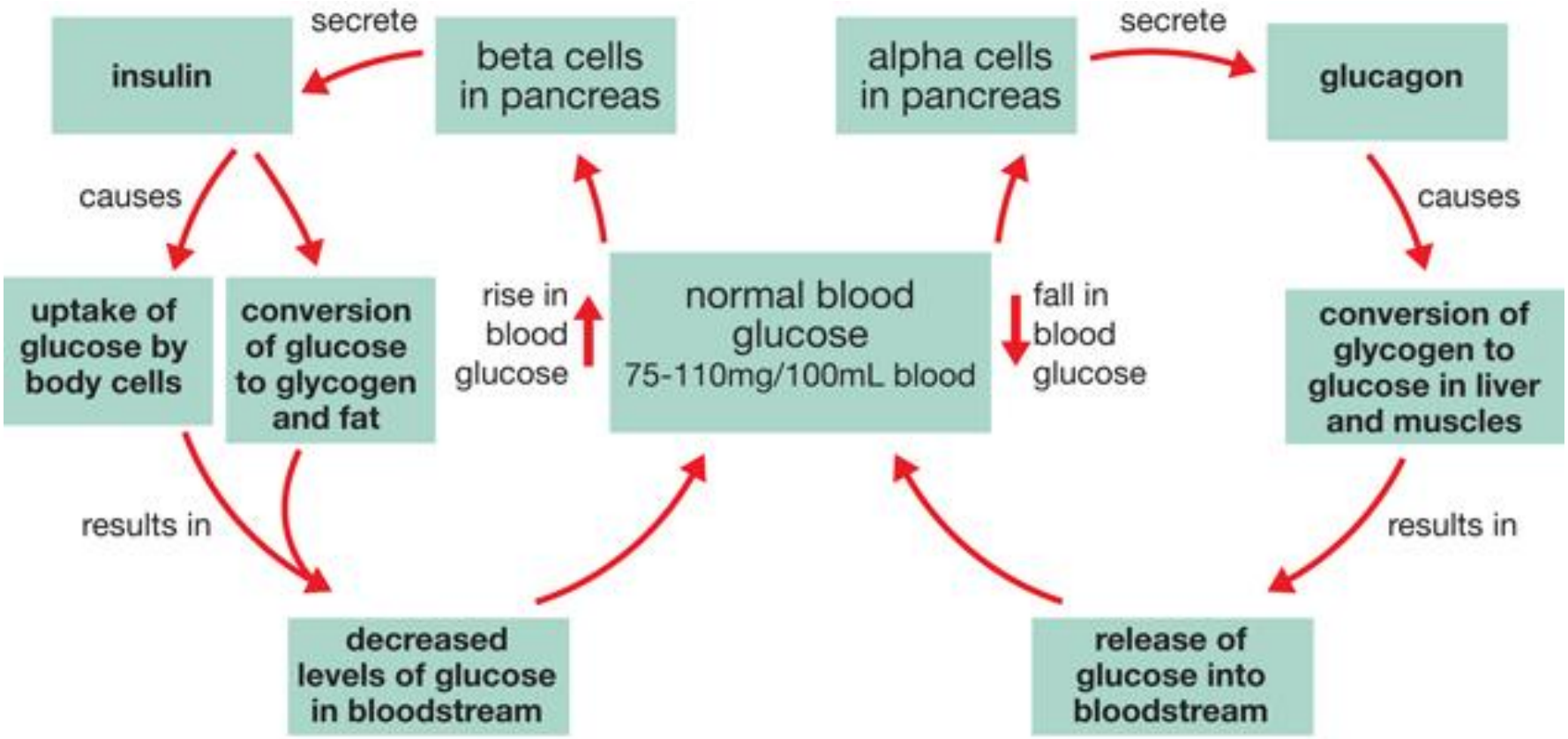


http://ib.bioninja.com.au/_Media/blood-glucose_med.jpeg

Glucose Regulation Feedback Loop



Glucose Regulation Feedback Loop



Glucose Regulation Feedback Loop

Blood glucose levels rise.

Liver takes up glucose and builds glycogen.

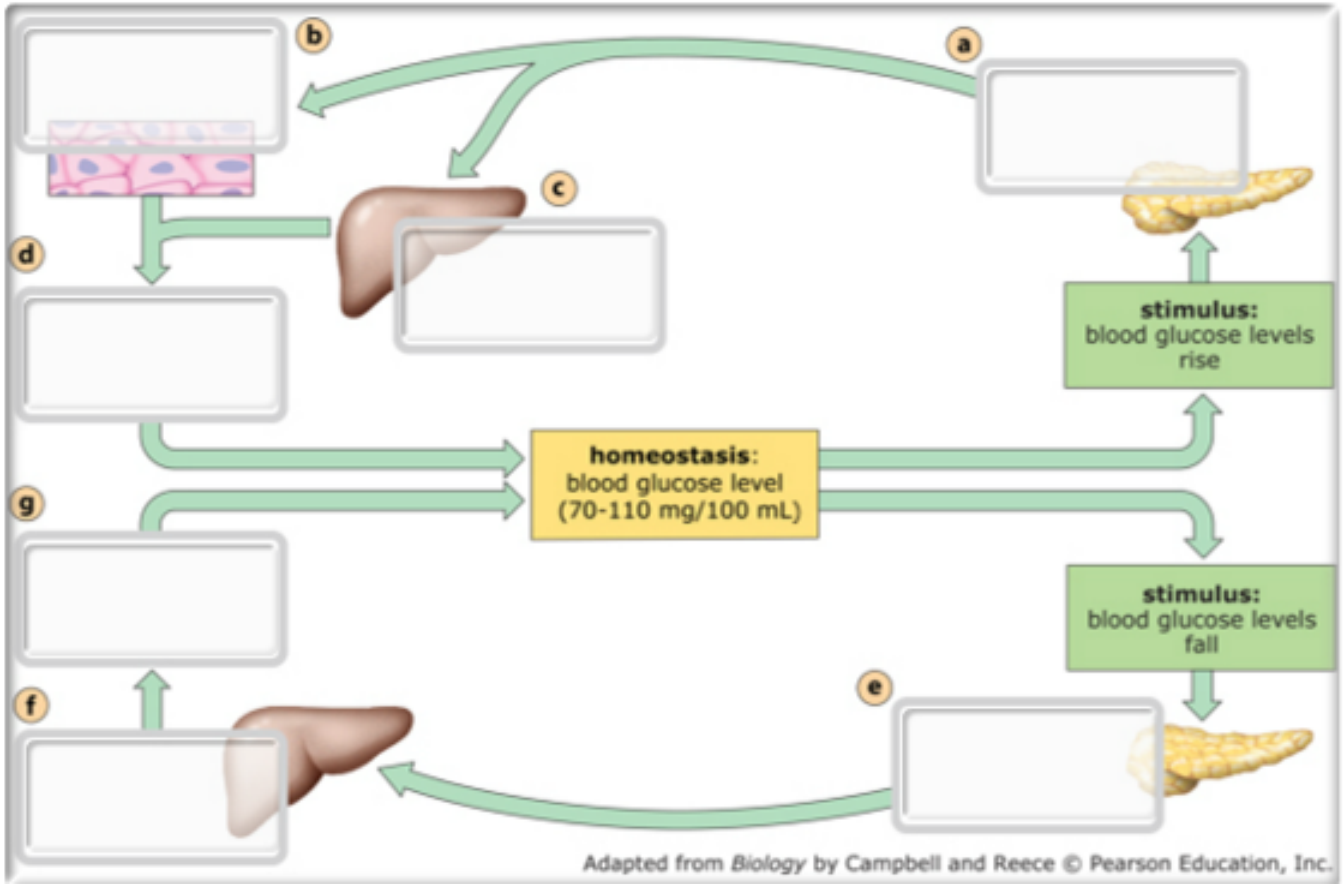
Body cells take up more glucose.

Beta cells of pancreas release insulin.

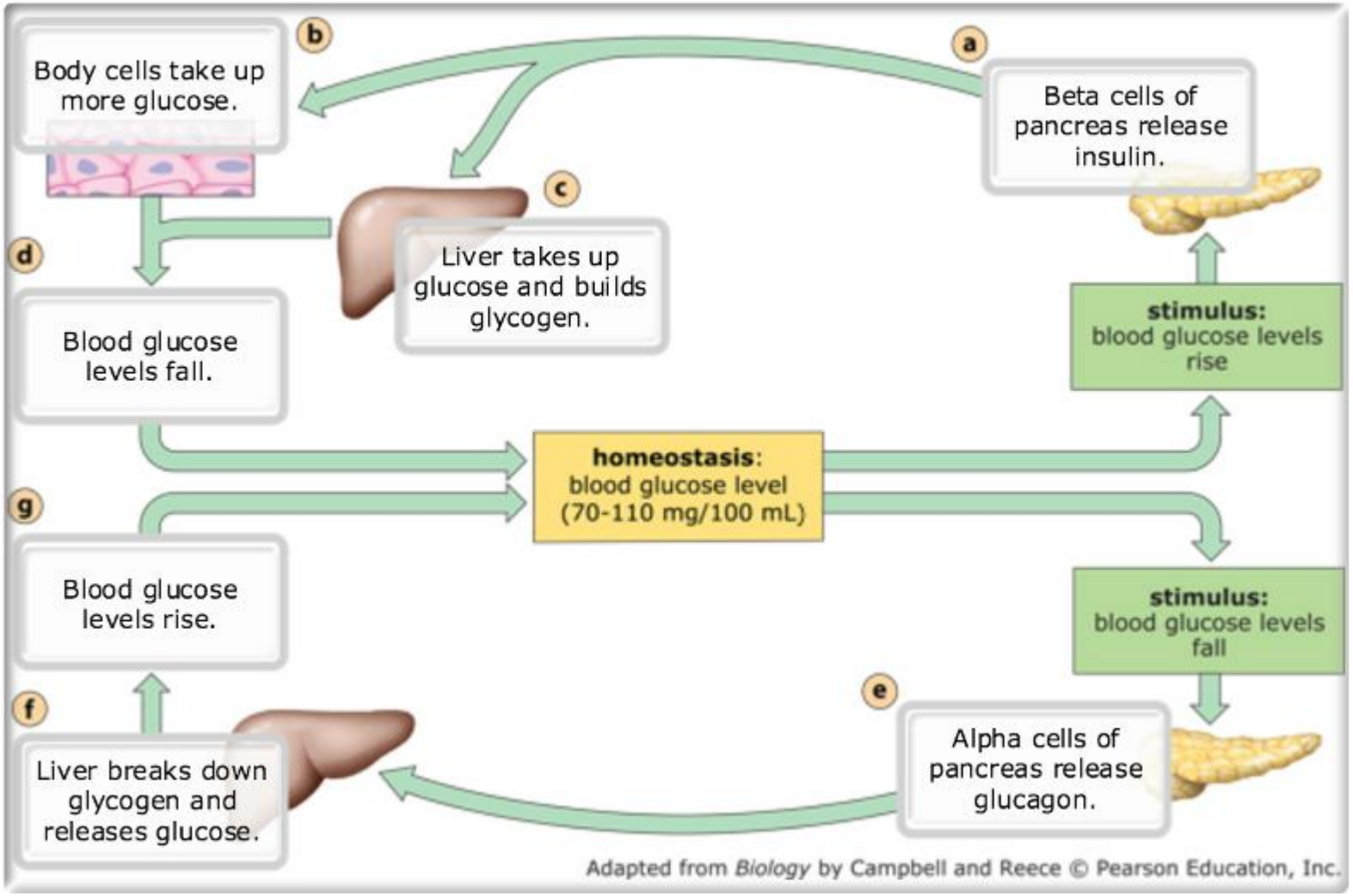
Blood glucose levels fall.

Alpha cells of pancreas release glucagon.

Liver breaks down glycogen and releases glucose.



Glucose Regulation Feedback Loop



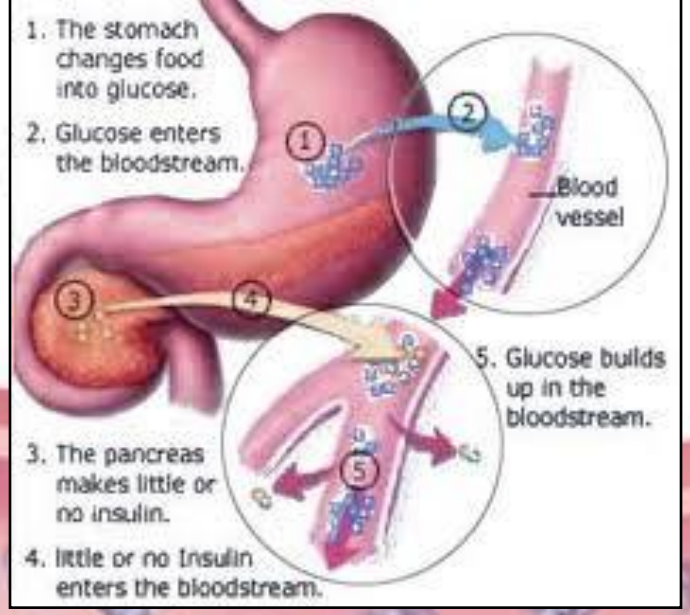
Diabetes

- Common symptoms: frequent urination
- Types of diabetes:
  - Mellitus (related to insulin and glucose)
    - Type 1
    - Type 2
  - Insipidus (related to reabsorption)

Diabetes Mellitus Cause

- **Type 1** diabetes
  - Immune system attacks insulin producing cells
  - **Decreased insulin levels**
- **Type 2** diabetes
  - Reasons not related to autoimmunity
  - **Decreased responsiveness of cells to insulin**
  - Inability of insulin to regulate blood glucose levels
  - Impairment of ability to remove glucose from the bloodstream

Glucose enters bloodstream from digestive system and liver



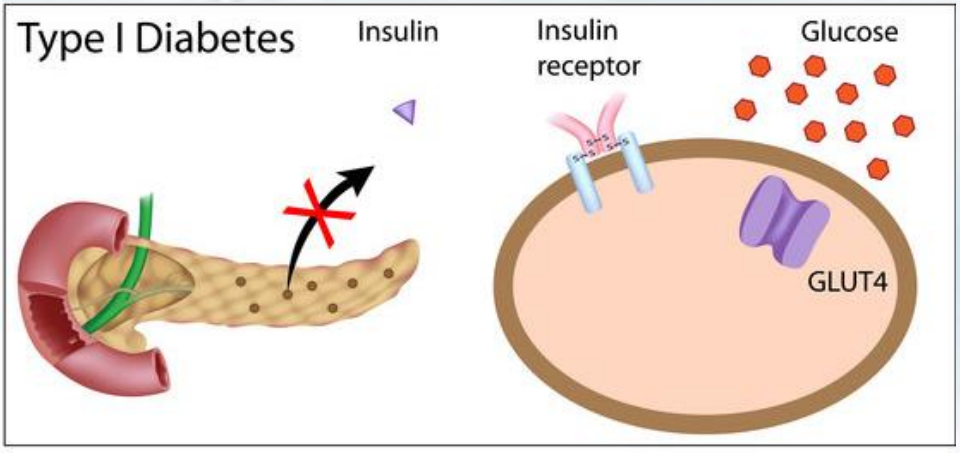
Unhealthy amount of glucose circulates in bloodstream

No insulin available to bind to cell

Glucose returns to bloodstream

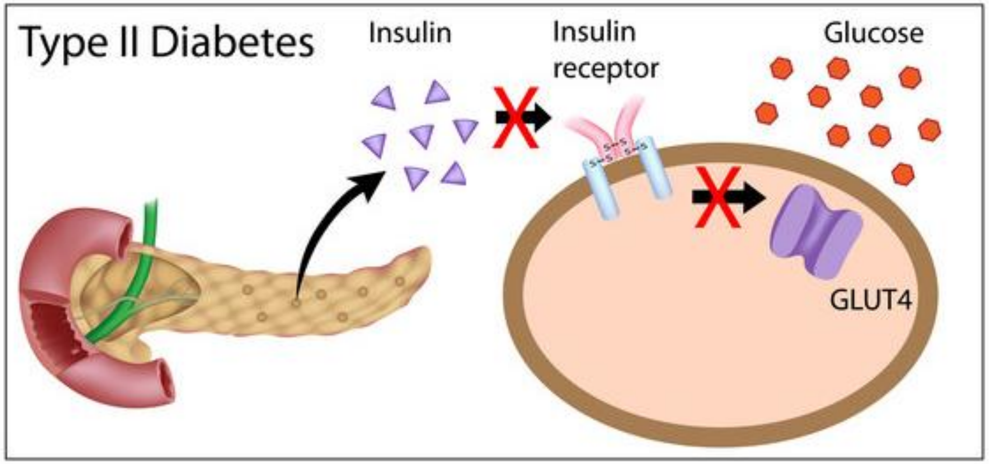
Glucose cannot enter cell

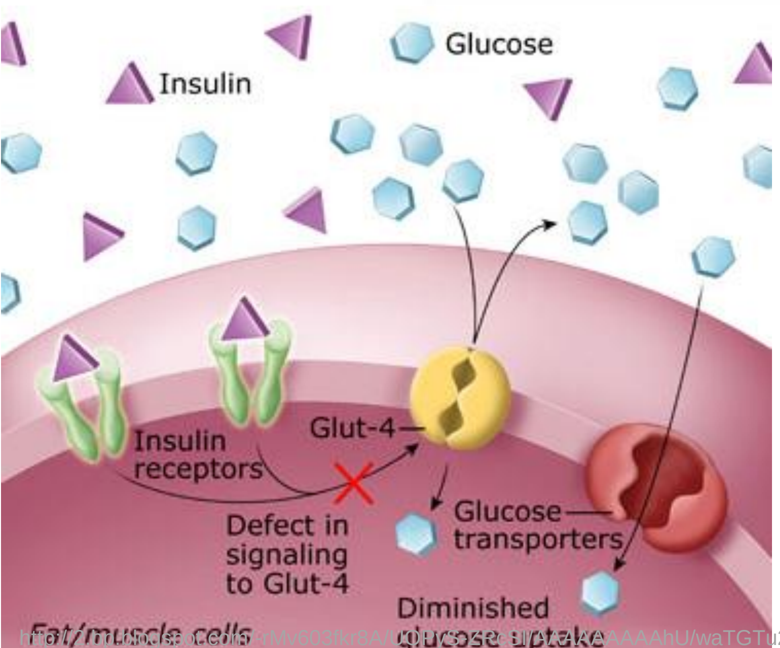
Cell has no glucose for fuel

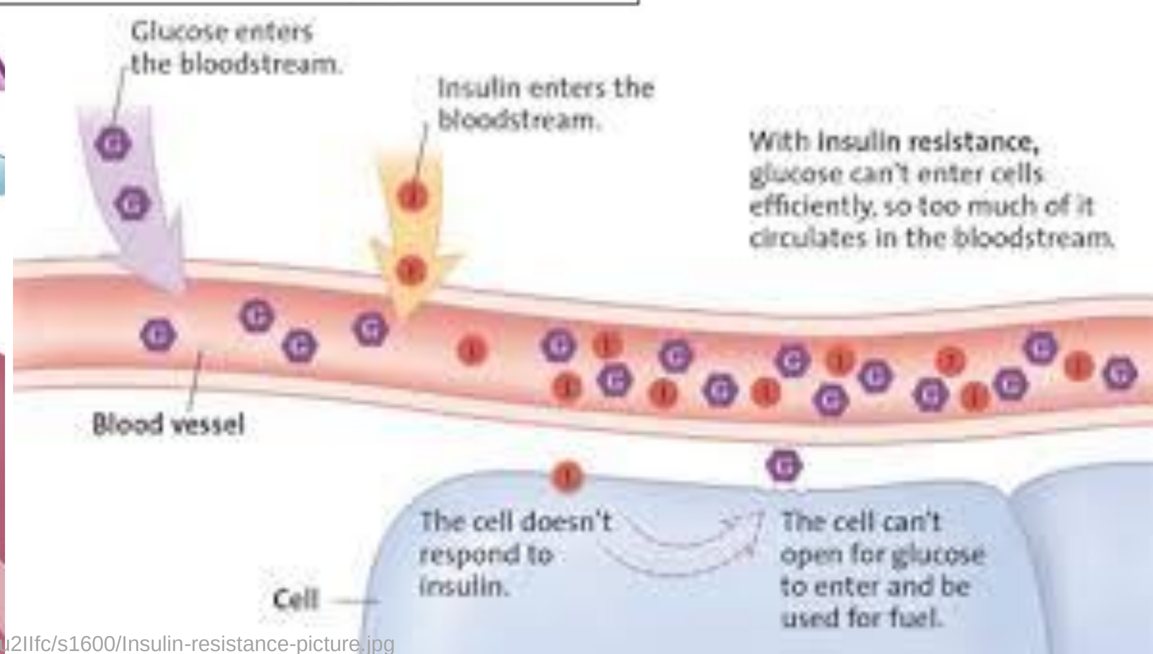


Type I Diabetes

Diabetes Mellitus Type 2

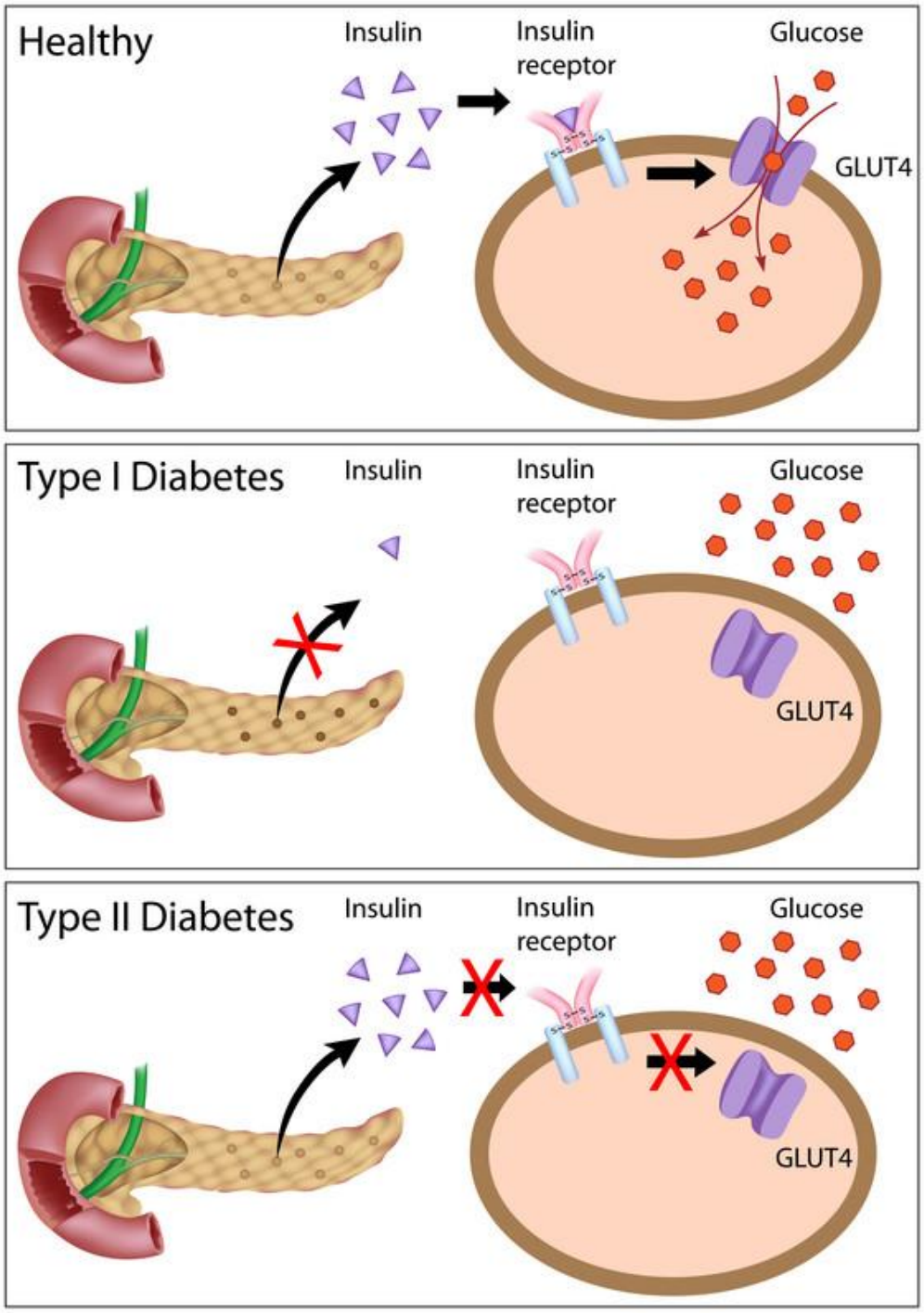






http://2.bp.blogspot.com/-rMv603fkr8A/U0PyS-ZRcSI/AAAAAAAAAhU/waTGTu2IIfc/s1600/Insulin-resistance-picture.jpg

Diabetes Summarized



http://goldsourcelabs.com/wp-content/uploads/2014/04/insulin-resistance.jpg

Diabetes Mellitus Types

	Type 1 (Insulin dependent)	Type 2 (Non-insulin dependent)
Onset	Childhood	Adult (past age 40) Pregnancy
Molecular Cause	Insulin deficiency	Insulin resistance (unresponsive receptors) and deficiency
Cause	Genetic Autoimmune disorder	Obesity
Treatment	Daily insulin injections	Exercise & dietary control drugs

Diabetes Mellitus Effect

- Glucose unavailable to body cells
  - **Hyperglycemia**: high glucose in blood
  - Excessive hunger
  - Fat used for cellular respiration
  - Increased blood viscosity and decreased blood flow
    - leads to blurry vision (poor blood flow in capillaries of retina)
    - foot infections (gravity cause blood to pool in feet)
- Kidneys start to excrete glucose
  - **Glucosuria**: glucose in urine, "sweet" urine
  - Frequent urination
  - Persistent thirst

Canadian Connection

- Frederick Banting & Charles Best
- Nobel Prize – 1923
- Insulin isolation
  - tied off ducts to digestive tract
  - cell producing digestive enzymes shrivelled
  - only islets of Langerhans remained

Banting and Best Experiment

- Removed pancreas from dog
- Effects on dog:
  - Rise in blood sugar
  - Thirsty, drank lots of water
  - Urinated more often
  - Became weaker
  - Developed diabetes
- Injected isolated "insulin" into the dog and seemed to cure it

Leonard Thompson

- first to be successfully treated with insulin injections on January 1922 in Toronto, Canada
- 14-year-old boy, only 65 lbs