

The Endocrine System plays a large role in maintaining homeostasis & coordinating bodily functions

How do multicellular organisms' cells communicate & regulate activities?

Multicellular organisms' cells must communicate in order to coordinate behavior.

- They communicate by **local & long-distance signaling**
 - Both involve **chemical messages**
- Local communication:**
 - Animal and plant cells have **cell junctions that directly connect the cytoplasm** of adjacent cells
 - In local signaling, animal cells may communicate by **direct contact**, or **cell-cell recognition**

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Local Signaling can also involve the secretion of molecules stored in vesicles by **exocytosis**.

Local Regulators - secreted molecules that act over short distances and reach their target cells by diffusion alone

Paracrine signaling: Cells release signals that affect nearby target cells.

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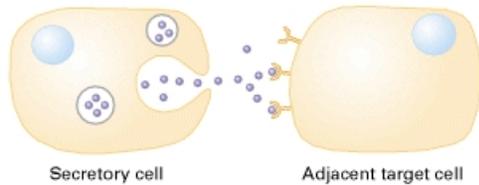
Additional local communication...

- Local communication between somatic cells and between neurons in the nervous system and their target cell.
 - In many other cases, animal cells communicate using **local regulators**, messenger molecules that travel only **short distances**
 - Regulators do not exist for long in the interstitial fluid or the message would keep being sent repeatedly.

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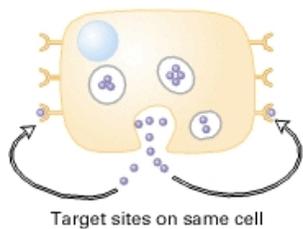
Local Regulators - secreted molecules that act over short distances and reach their target cells by diffusion alone

(b) Paracrine signaling

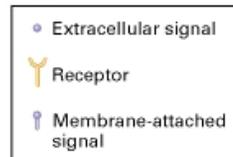


Paracrine signaling
= secreted molecule diffuses locally affecting nearby cells that have the right receptor

(c) Autocrine signaling



Key:



Autocrine signaling
= secreted molecule diffuses and triggers response in the cell that secreted them

What about long distance Communication?

Animals rely on 2 systems for regulation

1. **endocrine system**

▪ **system of ductless glands**

♦ secrete chemical signals that **diffuse into blood**

♦ chemical travels to target tissue

♦ **target cells** have receptor proteins

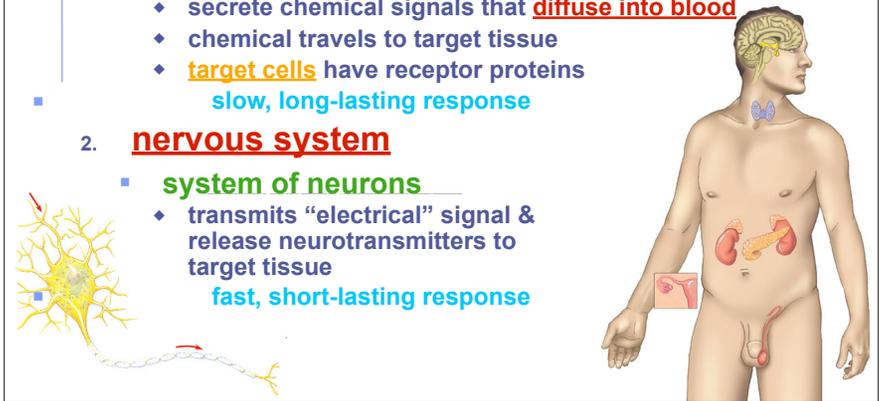
slow, long-lasting response

2. **nervous system**

▪ **system of neurons**

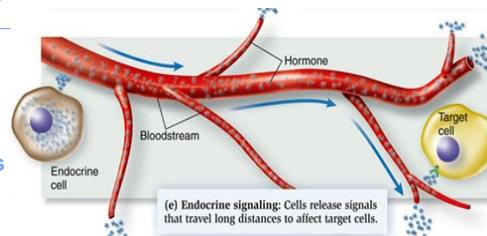
♦ transmits “electrical” signal & release neurotransmitters to target tissue

fast, short-lasting response



Long Distance Regulation & Communication

▪ **Duct** = A tubular bodily canal or passage, especially one for carrying a glandular secretion. Ex: pancreatic duct carries digestive enzymes from pancreatic cells to small intestines



1. **Endocrine system**

♦ **system of ductless glands**

- secrete chemical signals into extracellular fluids that then **diffuse into blood**
- chemical travels to **target cells** which have receptor proteins
 - ✓ Slow acting
 - ✓ Effects often long-lasting
 - ✓ Hormones may remain in blood or target tissue for seconds, minutes, or hours.

▪ **Well-suited for coordinating gradual changes that affect the entire body**

▪ Ex: Growth, development, reproduction, metabolism, digestion, blood glucose level control, response to stress and dehydration.

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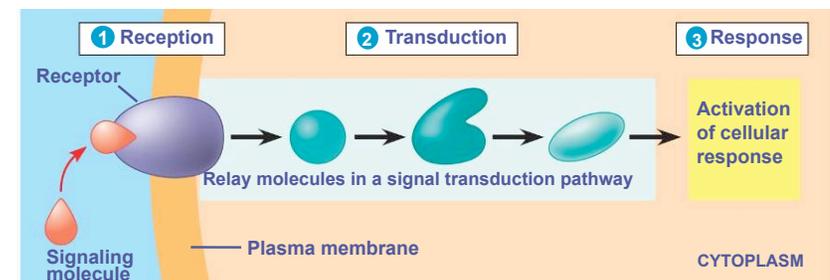
How do cells translate information from the exterior to the interior?

▪ Through **SIGNAL TRANSDUCTION PATHWAYS**.

♦ A series of steps by which a signal on a cell's surface is converted into a specific cellular response

▪ **Three processes:**

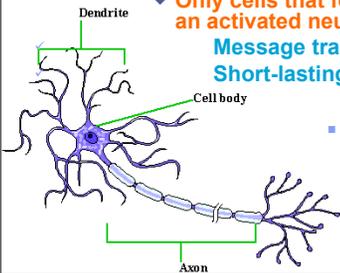
1. **Reception**
2. **Transduction**
3. **Response**



Long Distance Regulation & Communication

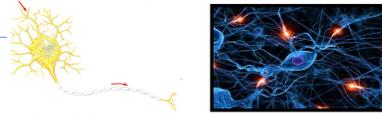
2. nervous system

- ◆ **system of neurons**
 - Nerve cells generate signals that travel along axons
 - ◆ Transmit “electrical” signals - changes in voltage or **Nerve impulses** down each individual nerve cell
 - ◆ Nerve cells release **neurotransmitters** to communicate with target tissues (nerves, muscles, or glands - both endocrine & exocrine)
 - Signaling is **NOT** broadcast throughout the entire body as with hormones
 - ◆ Only cells that form a specialized junction with the axon portion of an activated neuron receive and respond to the signal



Message transmitted very fast
Short-lasting response

- Well-suited for directing immediate and rapid responses to the internal and external environment
 - ✓ Ex: controlling fast locomotion and animal behaviors



Hormones = long distance regulators

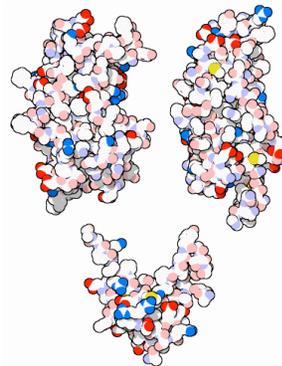
- A lot of homeostasis relies on the functioning of our **endocrine system**
- ◆ The endocrine system is one of two systems used for communication and regulation, throughout the body
 - Nervous system is the other
- ◆ The endocrine system involves the release of **hormones**
 - Regulate reproduction, development, energy metabolism, growth, and behavior



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Hormonal Regulation

- Why are hormones needed?
 - ◆ Send chemical messages from one body part to another
 - Communication is needed to coordinate whole body
 - ◆ Used in daily homeostasis & regulation of large scale changes over time.
 - H₂O & solute levels in blood
 - ◆ osmoregulation
 - ◆ glucose, Ca⁺⁺, salt concentrations etc...
 - metabolism (cellular respiration etc..)
 - growth
 - development
 - maturation
 - reproduction



growth hormones

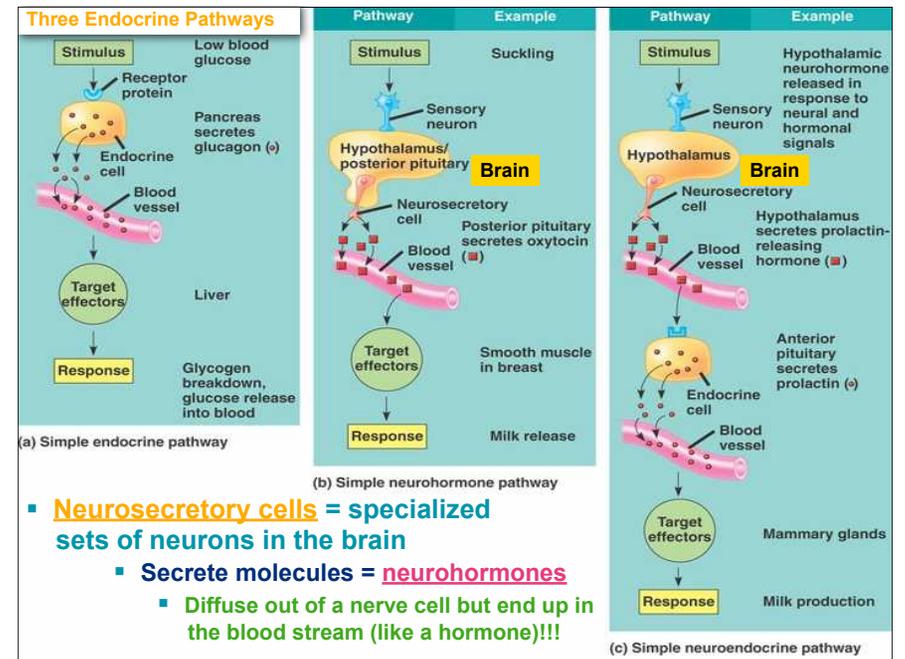
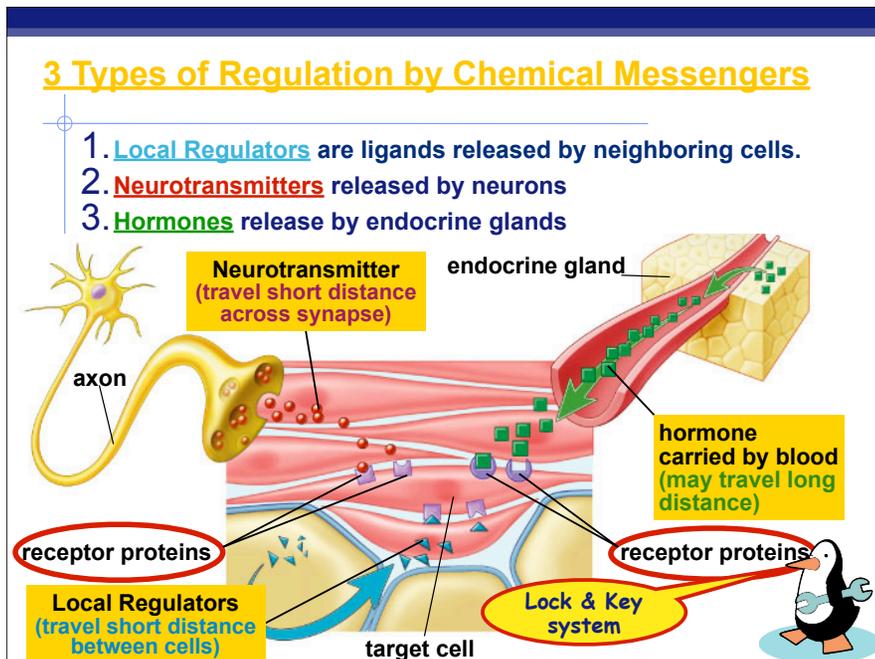
Hormone production

- Hormones are secreted into extracellular fluids (interstitial fluid) by endocrine cells
 - ◆ Reach **target cells** by diffusing into **bloodstream or in hemolymph**
 - Only a target cell has receptors for a hormone
 - Cells without receptors **cannot** respond to a hormone
- Some endocrine systems cells are found in organs
 - ◆ Ex: Stomach or kidneys contain endocrine cells
- Other endocrine cells are grouped into **DUCTLESS** organs called **endocrine glands**
 - ◆ Ex: Thyroid gland
 - Exocrine glands (ex: salivary gland) have ducts and carry secretions onto body surface or into body cavities

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Gland	Hormone	Chemical Class	Representative Actions	Regulated By	
Hypothalamus	Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)				
Pituitary gland Posterior pituitary (releases neuro-hormones made in hypothalamus)	Oxytocin	Peptide	Stimulates contraction of uterus and mammary gland cells	Nervous system	
	Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance	
	Anterior pituitary	Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
		Prolactin (PRL)	Protein	Stimulates milk production and secretion	Hypothalamic hormones
		Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates production of ova and sperm	Hypothalamic hormones
	Luteinizing hormone (LH)	Glycoprotein	Stimulates ovaries and testes	Hypothalamic hormones	
	Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid gland	Thyroxine in blood; hypothalamic hormones	
	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Glucocorticoids; hypothalamic hormones	
Thyroid gland	Triiodothyronine (T ₃) and thyroxine (T ₄)	Amine	Stimulate and maintain metabolic processes	TSH	
	Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood	
Parathyroid glands	Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood	

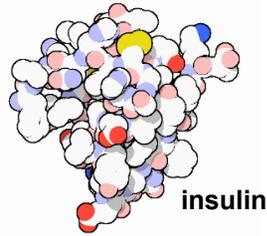
Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Pancreas	Insulin	Protein	Lowers blood glucose level	Glucose in blood
	Glucagon	Protein	Raises blood glucose level	Glucose in blood
Adrenal glands				
Adrenal medulla	Epinephrine and norepinephrine	Amine	Raise blood glucose level; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex	Glucocorticoids	Steroid	Raise blood glucose level	ACTH
	Mineralocorticoids	Steroid	Promote reabsorption of Na ⁺ and excretion of K ⁺ in kidneys	K ⁺ in blood
Gonads				
Testes	Androgens	Steroid	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries	Estrogens	Steroid	Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics	FSH and LH
	Progesterone	Steroid	Promotes uterine lining growth	FSH and LH
Pineal gland	Melatonin	Amine	Involved in biological rhythms	Light/dark cycles



Classes of Hormones

Protein-based hormones

- ◆ polypeptides
 - small proteins: **insulin, ADH**
- ◆ glycoproteins
 - large proteins + carbohydrate: **FSH, LH**
- ◆ amines
 - modified amino acids: **epinephrine, melatonin**



Lipid-based hormones

- ◆ steroids
 - modified cholesterol: **sex hormones, aldosterone**

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How do hormones act on target cells

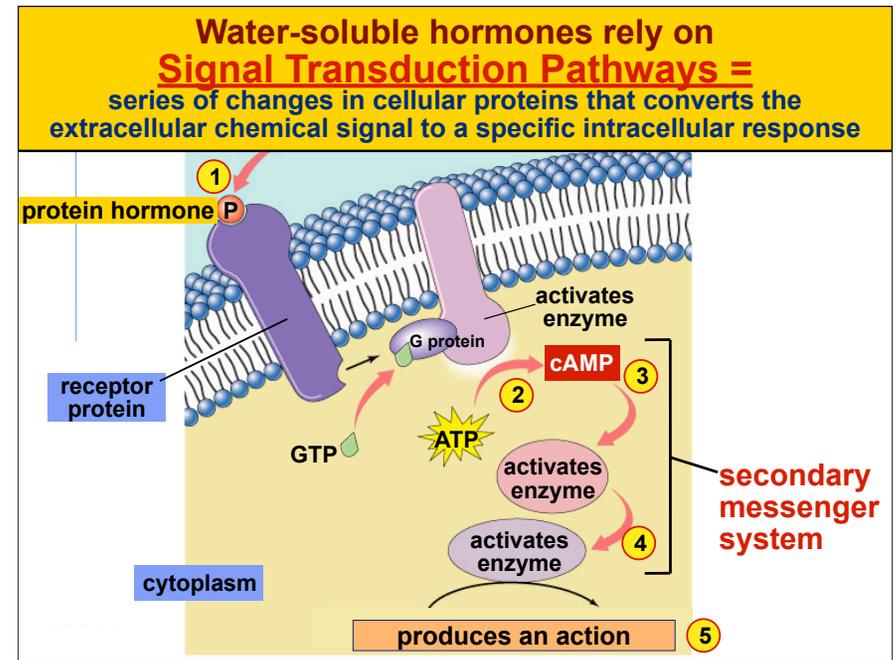
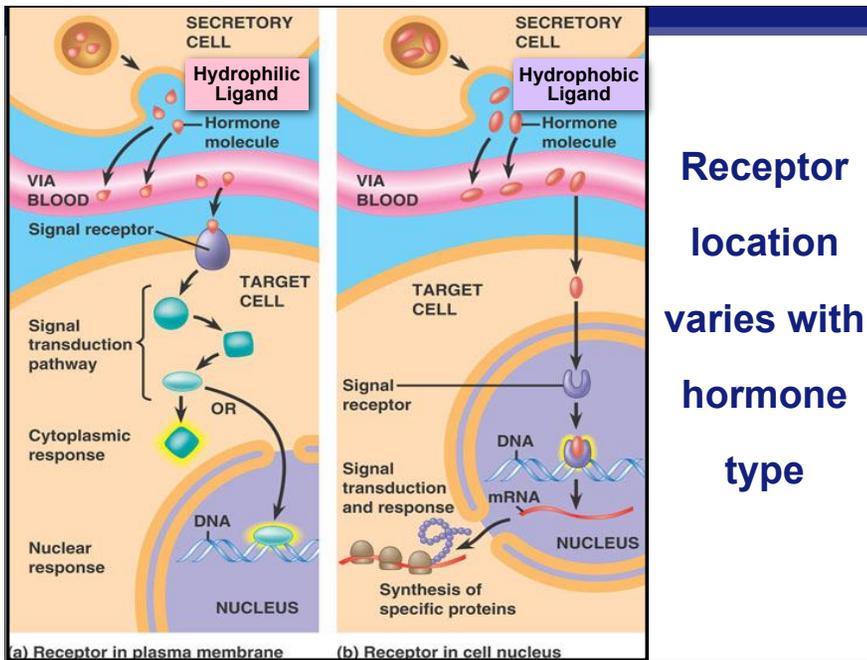
Lipid-based hormones

- ◆ hydrophobic & lipid-soluble
 - diffuse across cell membrane & enter cells
 - bind to **receptor proteins IN cytoplasm or nucleus**
 - ◆ receptor bind directly or indirectly to DNA as **transcription factors** = turn on genes

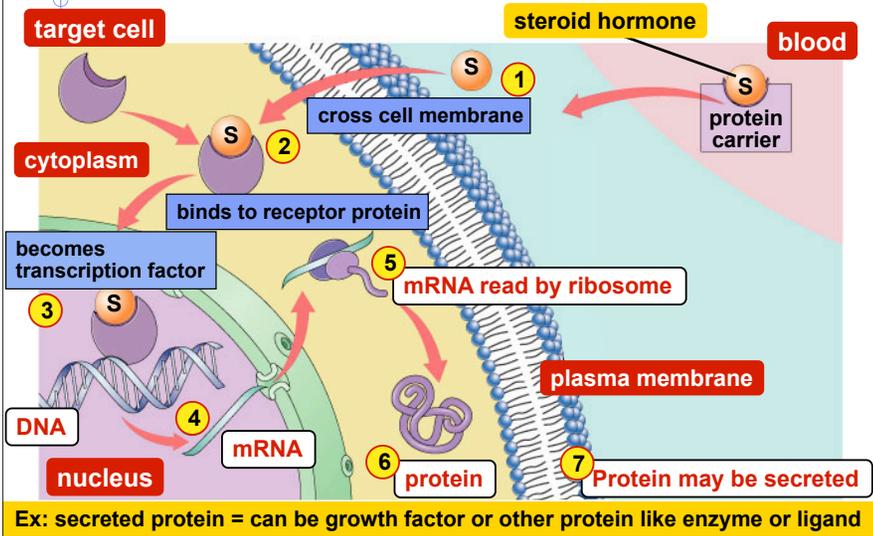
Protein-based hormones

- ◆ hydrophilic & not lipid soluble
 - can't diffuse across cell membrane
 - bind to **receptor proteins embedded in cell membrane**
 - Triggers **signal transduction pathway** and often use a **secondary messenger pathway**
 - activate internal cellular response
 - ◆ Alter enzyme action, cause uptake or secretion of molecules or other solutes by altering transport protein conformation etc...

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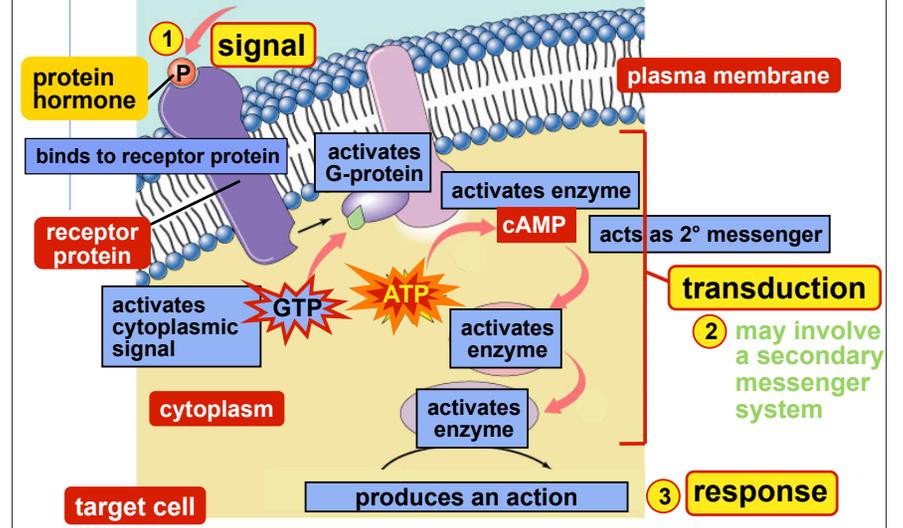


Action of lipid (steroid) hormones

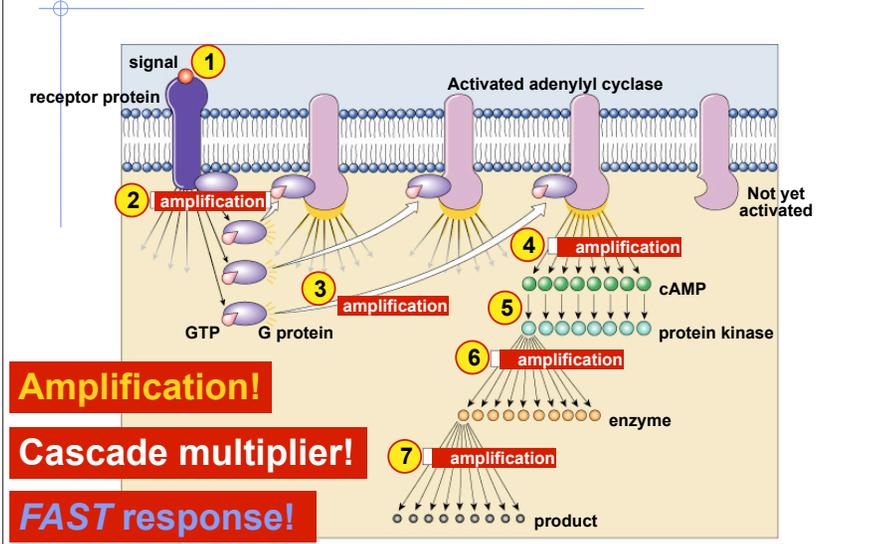


signal-transduction pathway

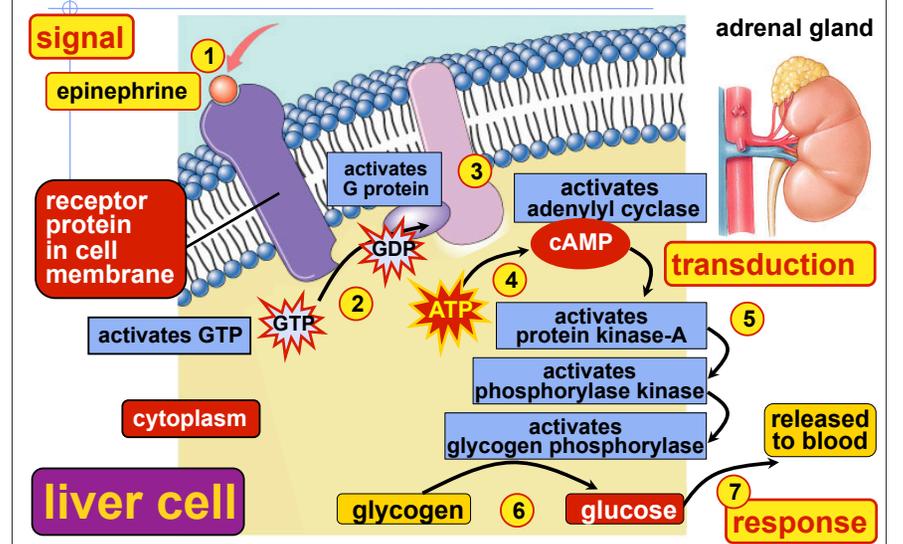
Action of protein hormones



Benefits of a 2° messenger system



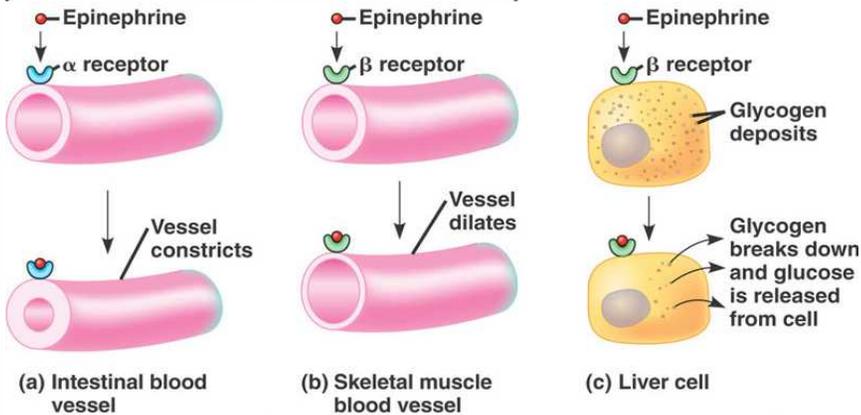
Ex: Action of epinephrine (adrenaline)



A hormone may cause different effects in different target cells:

- May cause different signal transduction pathways
- May bind different receptors all together

Different receptors → different cell responses

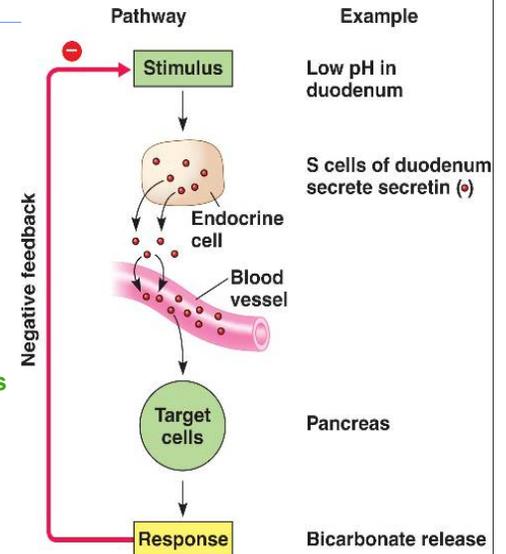


Different intracellular proteins → different cell responses

Simple hormone pathways

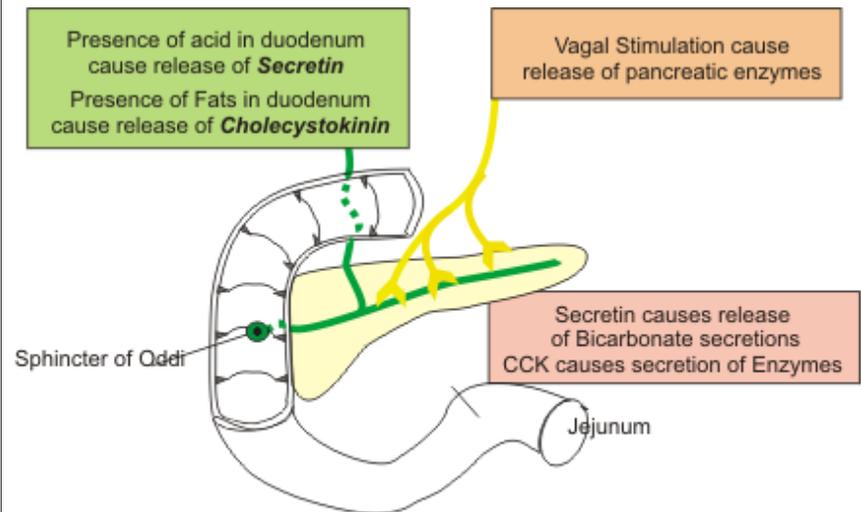
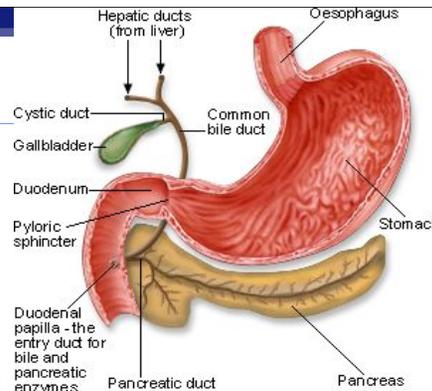
Often involves **NEGATIVE FEEDBACK**

- ◆ Response reduces initial stimulus
 - Internal or environmental stimulus triggers endocrine cell to secrete hormone
 - Hormone travels in bloodstream to target cell receptors
 - Signal transduction within target cell causes physiological response
 - Response leads to reduction in the stimulus
 - Pathway shuts off



Negative Feedback

- Acidic chyme (*food mixture*) in stomach is released into duodenum (*beginning of small intestines*)
- Low pH in small intestine stimulates endocrine cells of duodenum called **S cell**
 - ◆ **Secrete Secretin**
 - Diffuse through interstitial fluids and enter bloodstream
- Secretin's target cells are cells in **pancreas**
 - ◆ Releases **bicarbonate** into small intestine
 - Binds with free H⁺ protons & raises the pH in duodenum to slightly alkaline pH
- Pathway is self-limited because response to secretin (release of bicarbonate) reduces stimulus (low pH)
 - Example of a negative feedback loop



Frank Bounphrey M.D. 2009

Control of Pancreatic Secretions

Major Digestive Enzymes

Enzyme	Produced In	Site of Release	pH Level
Carbohydrate Digestion:			
Salivary amylase	Salivary Glands	Mouth	Neutral
Pancreatic amylase	Pancreas	Small Intestine	Basic
Maltase	Small intestine	Small intestine	Basic
Protein Digestion:			
Pepsin	Gastric glands	Stomach	Acidic
Trypsin	Pancreas	Small intestine	Basic
Peptidases	Small Intestine	Small intestine	Basic
Nucleic Acid Digestion:			
Nuclease	Pancreas	Small intestine	Basic
Nucleosidases	Pancreas	Small intestine	Basic
Fat Digestion:			
Lipase	Pancreas	Small intestine	Basic

My optimal pH is 2 (deactivate @ 6.5)

My optimal pH is 8

My optimal pH is 8

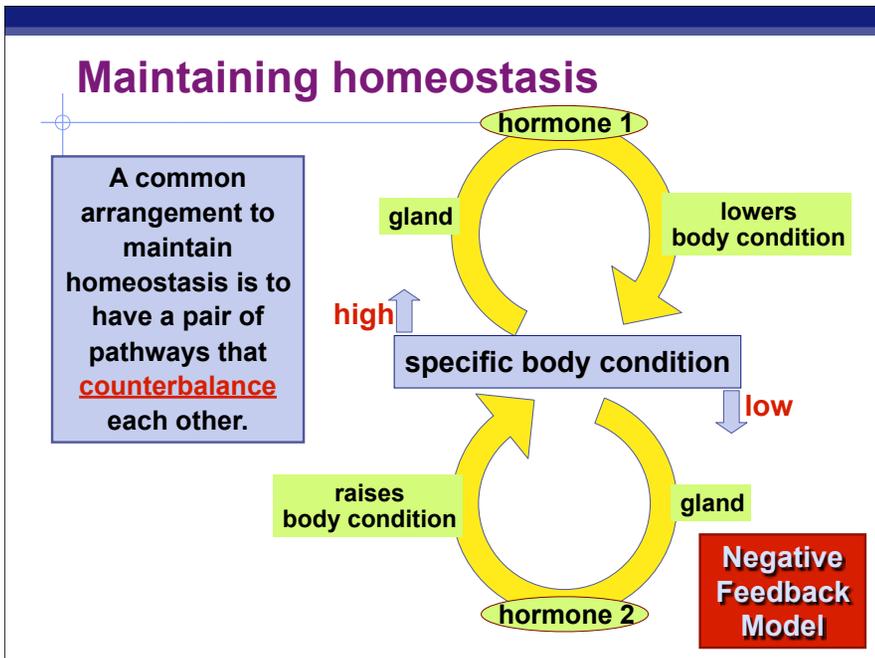
My optimal pH is 8

Your goal is to maintain normal blood glucose levels

Homeostasis:

Let's take a closer look at Regulating Blood Glucose Levels

The image contains several illustrations: a cross-section of a blood vessel with normal glucose levels, a cross-section showing 'Excessive blood glucose' with more glucose molecules, a ball-and-stick model of a glucose molecule, a cluster of red blood cells, and a hand using a digital glucose meter on a finger.



Regulation of Blood Glucose

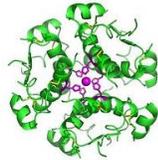
- **Blood Glucose balance**
 - ◆ 80-120(90)mg/100mL
- Pancreas makes **insulin** and **glucagon**, which are antagonistic hormones
 - ◆ Produced in the **pancreas**
 - Within the **Islets of Langerhans**
 - ◆ **Beta cell** make **insulin**
 - ◆ **Alpha cells** make **glucagon**

The diagram shows a cross-section of the pancreas with a callout to the 'Islets of Langerhans'. Inside the islet, there are 'Alpha cells' (orange) and 'Beta cells' (blue). A 'Blood vessel' is shown nearby. Arrows indicate 'Glucagon' being released from alpha cells and 'Insulin' being released from beta cells into the blood vessel.

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Big Picture - Insulin Hormone

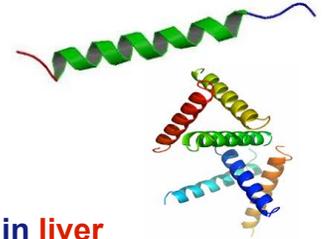
- **Glucose** is the major fuel for **cellular respiration** and key source of a carbon skeleton for **biosynthesis**
- **Insulin**
 - ◆ Stimulates almost **ALL** body cells outside the brain to **take up** excess glucose from blood
 - Brain takes up glucose even without insulin
 - ◆ **Slows** glycogen breakdown in liver
 - No release of glucose into blood
 - ◆ **Inhibits** conversion of amino acids and glycerol (from fats) to glucose



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Big Picture - Glucagon Hormone

- **Glucose** is the major fuel for **cellular respiration** and key source of a carbon skeleton for **biosynthesis**
- **Glucagon** - target cells **ONLY** in **liver**
 - Muscles, like liver, do store glucose as glycogen
 - Muscles do not respond to glucagon though - only the liver
- ◆ **Increases** glycogen hydrolysis in liver
- ◆ **Converts** amino acids and glycerol **into** glucose in liver
- ◆ **Release** glucose into bloodstream from liver



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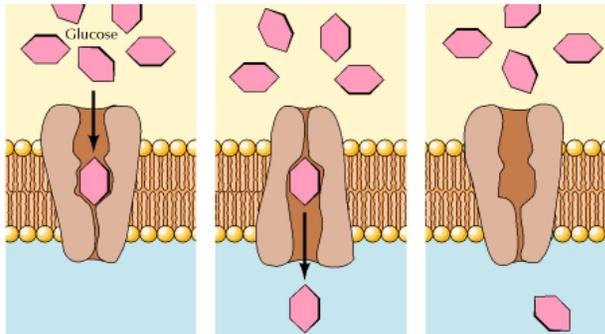
Glucose Transporters

- **Adipose, skeletal muscle, liver cells have two types of glucose transport systems:**

1. Glucose transport proteins function in facilitated diffusion (in the absence of insulin)

- ◆ Glucose moves **down** its concentration gradient

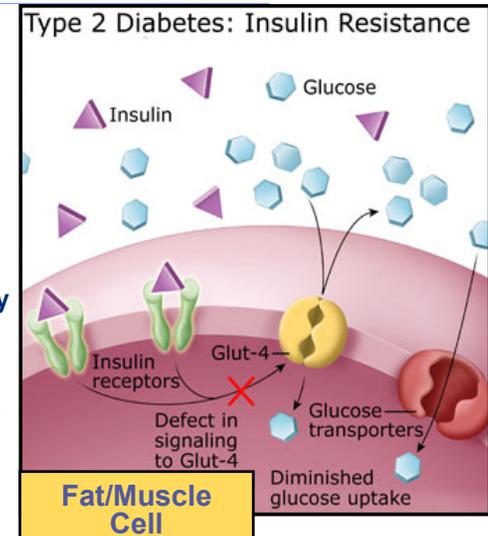
- Glucose transporter reversible
- Glucose can be transported in opposite direction
- **Ex: Liver**



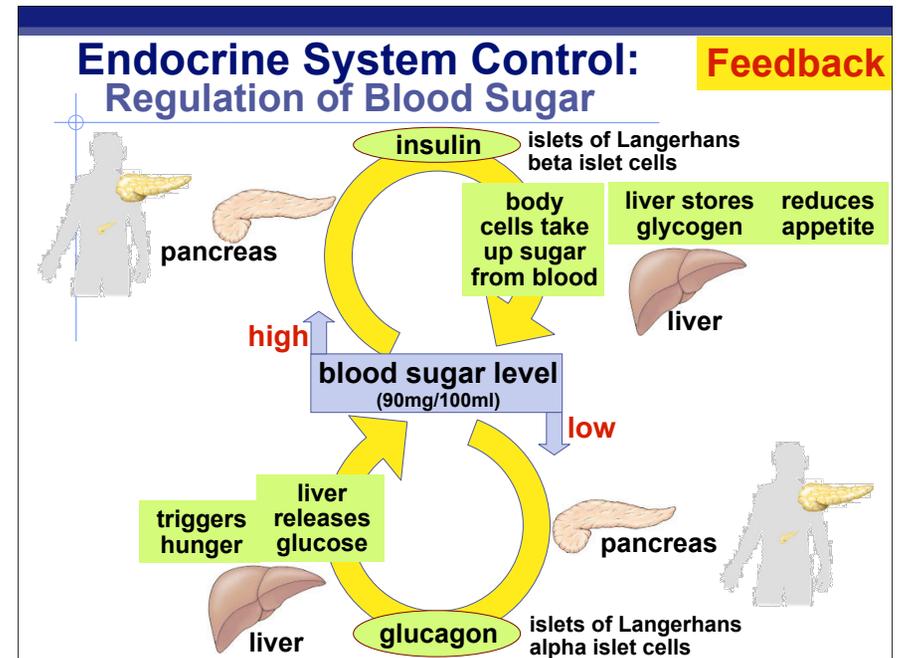
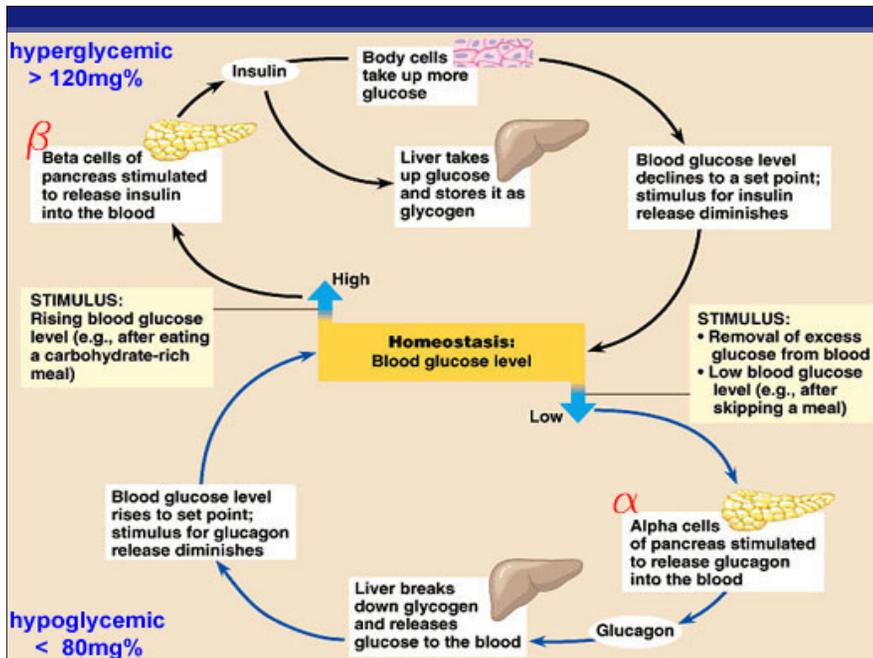
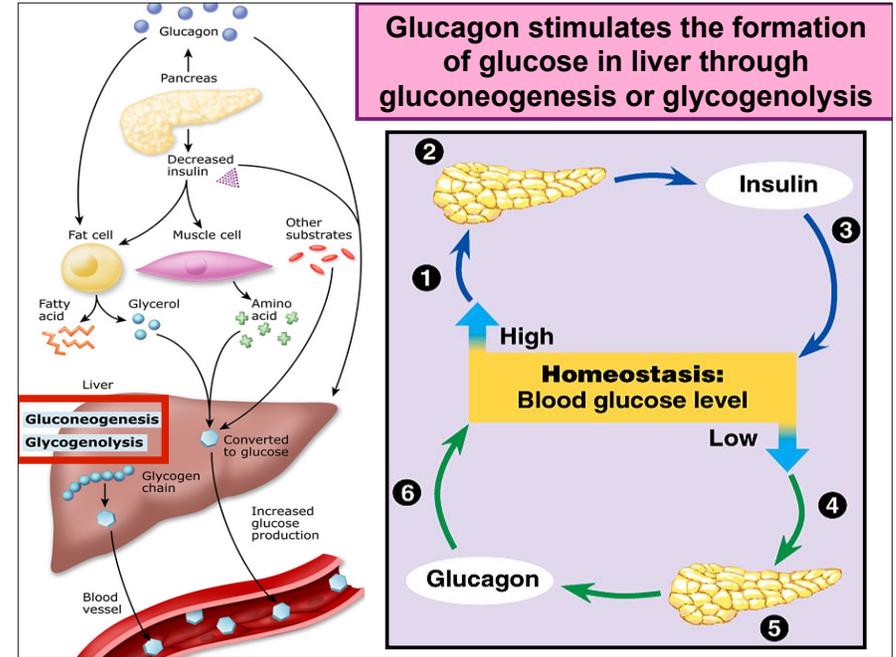
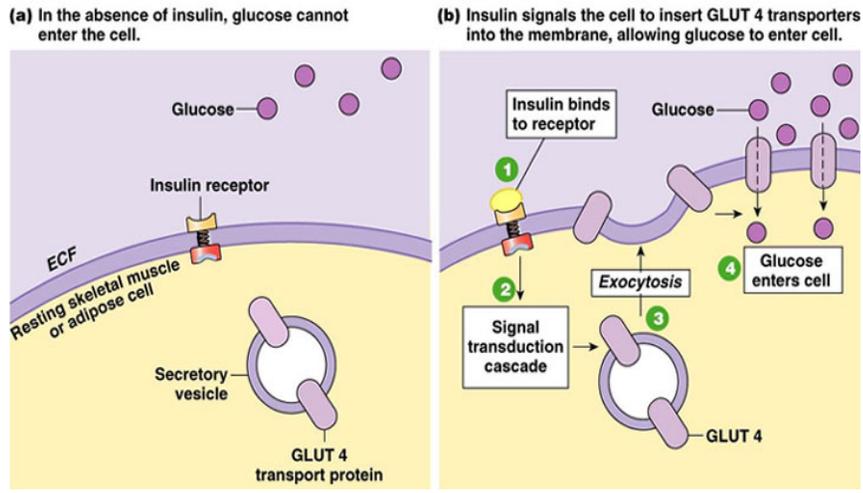
Glucose Transporters

2. Glut-4 transporters

- Kept inside the cytoplasm in the membrane of vesicles
 - ◆ **Insulin** ligands bind to **tyrosine kinase receptors** in the plasma membrane that initiate a signal transduction pathway
 - ◆ Leads to fusion of vesicles carrying **additional Glut-4 glucose transporters** with the plasma membrane
 - **Increases the uptake of glucose**



Role of insulin - skeletal muscle & fat cells



Disruption of glucose homeostasis

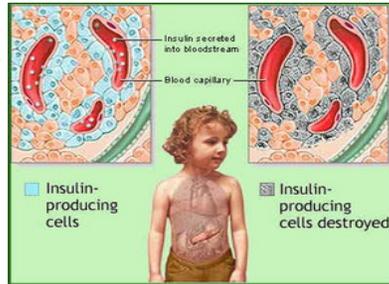
■ **Diabetes mellitus**
(Greek: diabainein for “to pass through” and meli for “honey”)

- ◆ Refers to the concentration of glucose in the urine of someone with untreated diabetes



1. Type I diabetes

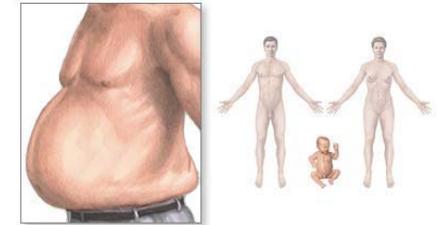
- ◆ Aka juvenile or insulin-dependent diabetes
- ◆ Autoimmune disorder
- ◆ Immune system attacks beta cells of pancreas that produce insulin
- ◆ Artificially inject insulin
- ◆ Stem cell research may provide a cure by replacing destroyed beta cells with working ones



Disruption of glucose homeostasis

2. Type II diabetes

- ◆ Aka non-insulin-dependent diabetes
- ◆ Insulin produced normally
- ◆ Target cells fail to respond normally to insulin
- ◆ 7th leading cause of death
- ◆ Risk factors: Body weight, lack of exercise, heredity



Being overweight and heredity are two risk factors for diabetes

Disruption of glucose homeostasis

