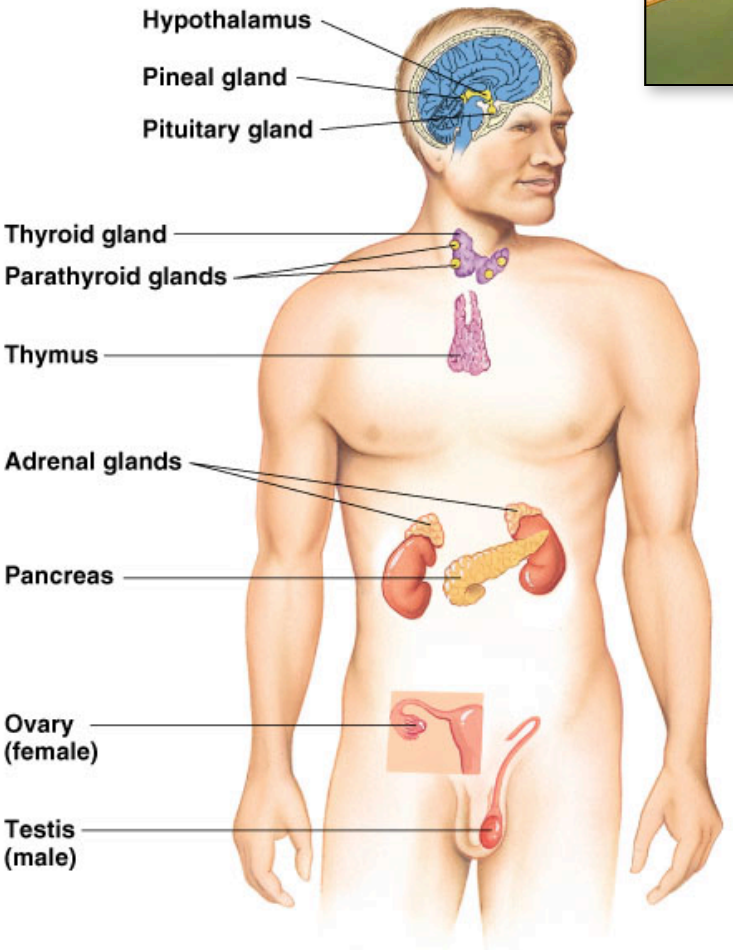


The Endocrine System plays a large role in maintaining homeostasis & coordinating bodily functions

How do multicellular organisms' cells communicate & regulate activities?

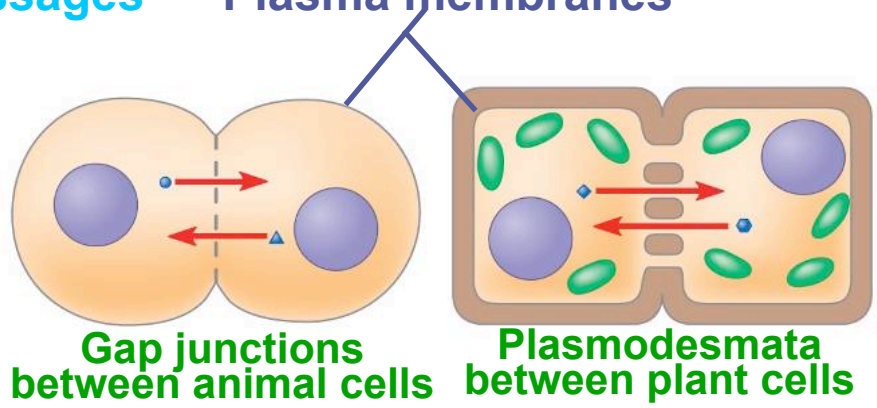
Multicellular organisms' cells must communicate in order to coordinate behavior.

- They communicate by local & long-distance signaling
  - Both involve chemical messages

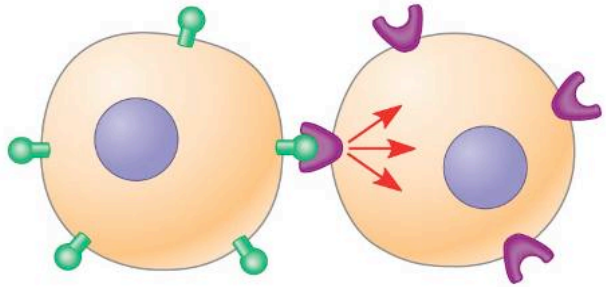
- Local communication:

1. Animal and plant cells have cell junctions that directly connect the cytoplasm of adjacent cells

2. In local signaling, animal cells may communicate by direct contact, or cell-cell recognition

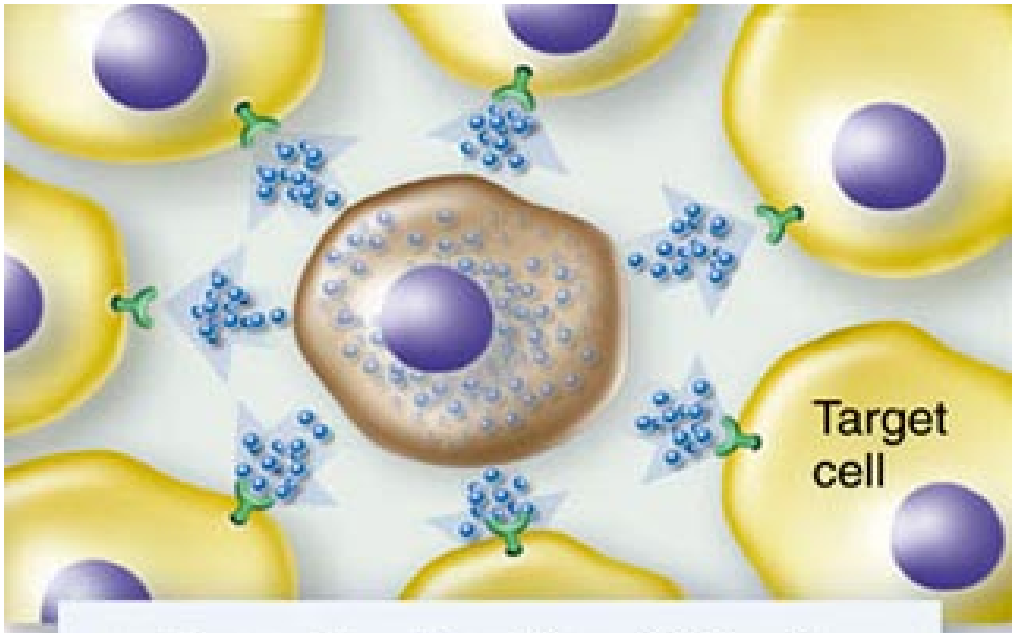


(a) Cell junctions


(b) Cell-cell recognition

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

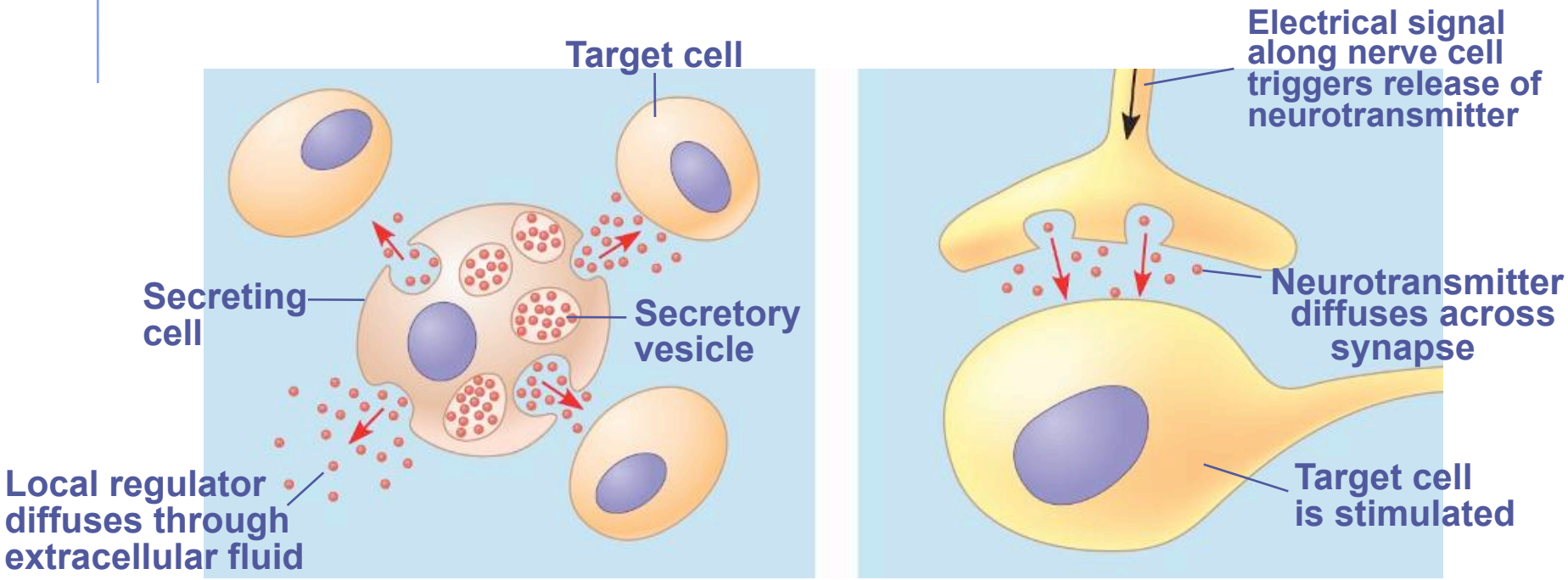
Local Regulators - **secreted molecules that act over short distanced and reach their target cells by diffusion alone**



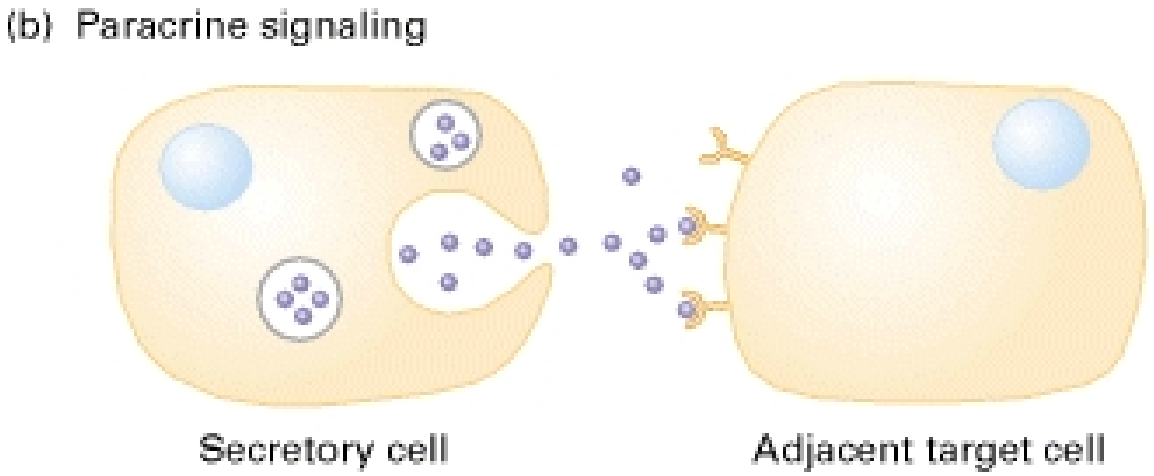
Paracrine signaling: Cells release signals that affect nearby target cells.

Additional local communication…

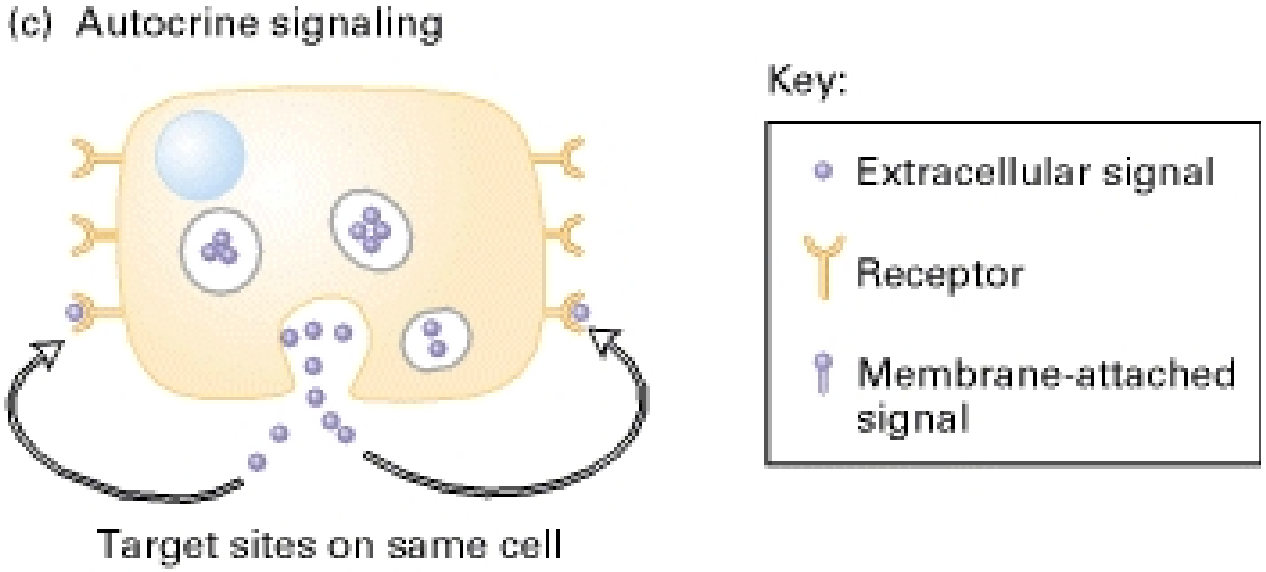
- **Local communication between somatic cells and between neurons in the nervous system and their target cell.**
  - **3. In many other cases, animal cells communicate using local regulators, messenger molecules that travel only short distances**
    - **Regulators do not exist for long in the interstitial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



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



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



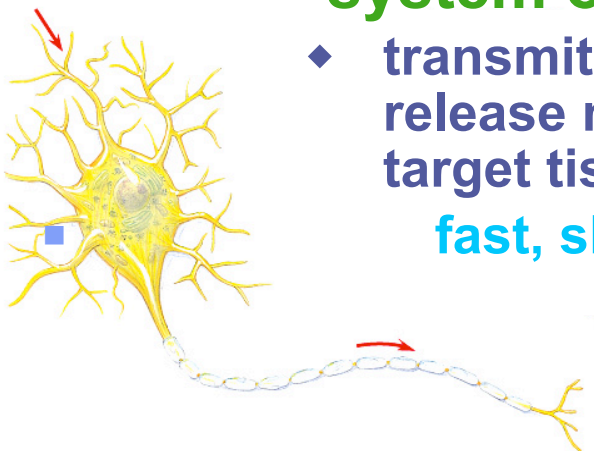
Autocrine signaling
= secreted molecule diffuses and triggers response in the cell that secreted them

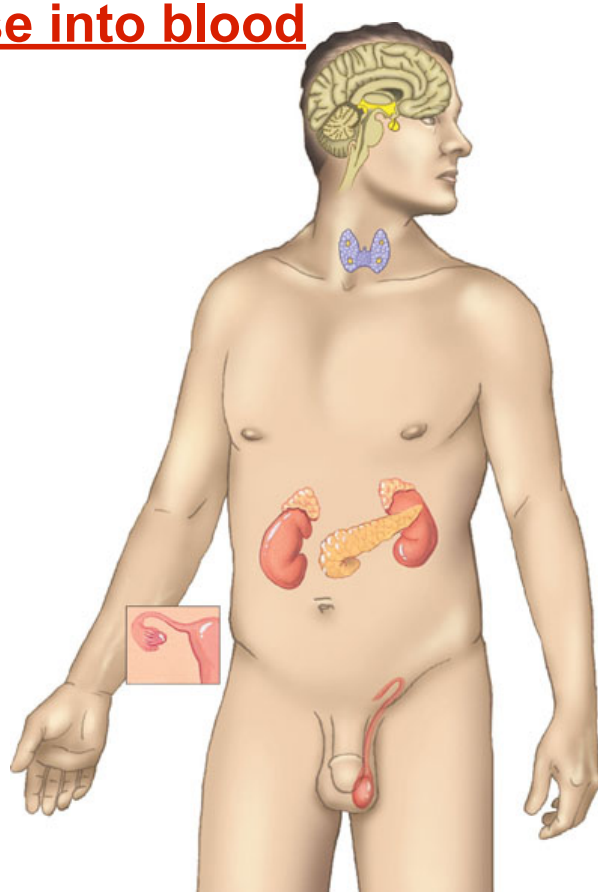
What about long distance Communication?

- **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

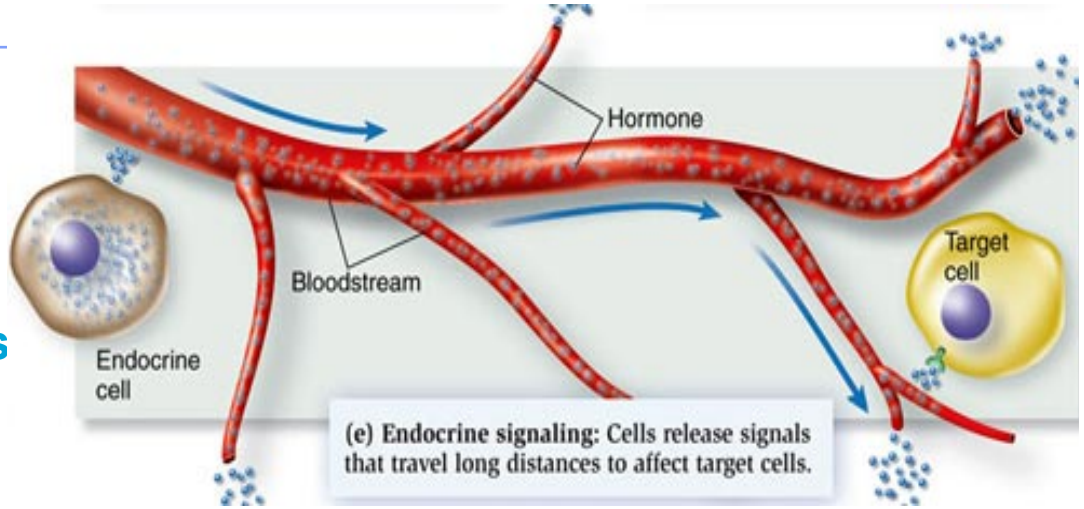
2. **nervous system**
   - system of neurons
     - transmits "electrical" signal & release neurotransmitters to target tissue
   - fast, short-lasting response





Long Distance Regulation & Communication

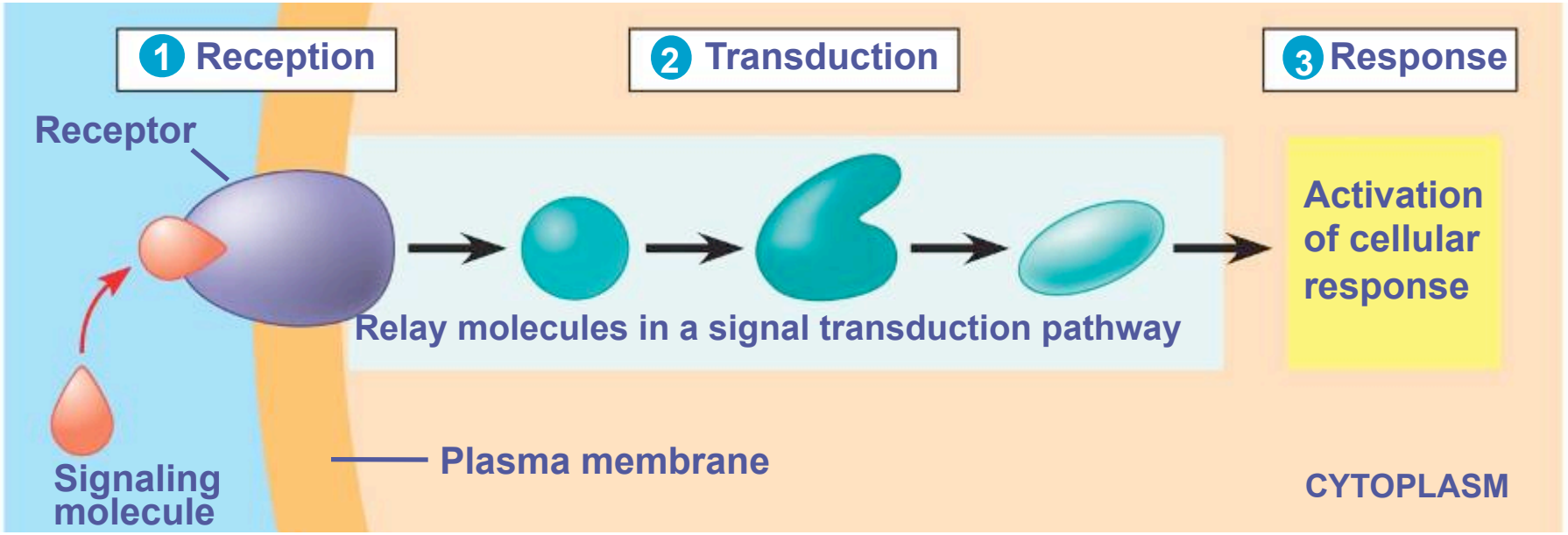
- Duct = A tubular bodily canal or passage, especially one for carrying a glandular secretion. Ex: pancreatic duct carries digestive enzymes from pancreatic cells to small intestines



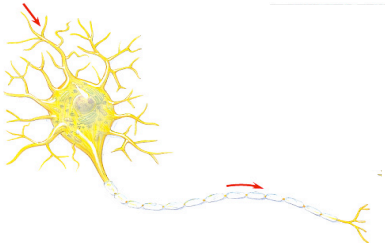
1. **Endocrine system**
   - system of ductless glands
     - secrete chemical signals into extracellular fluids that then diffuse into blood
     - chemical travels to target cells which have receptor proteins
       - ✓ Slow acting
       - ✓ Effects often long-lasting
       - ✓ Hormones may remain 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.

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

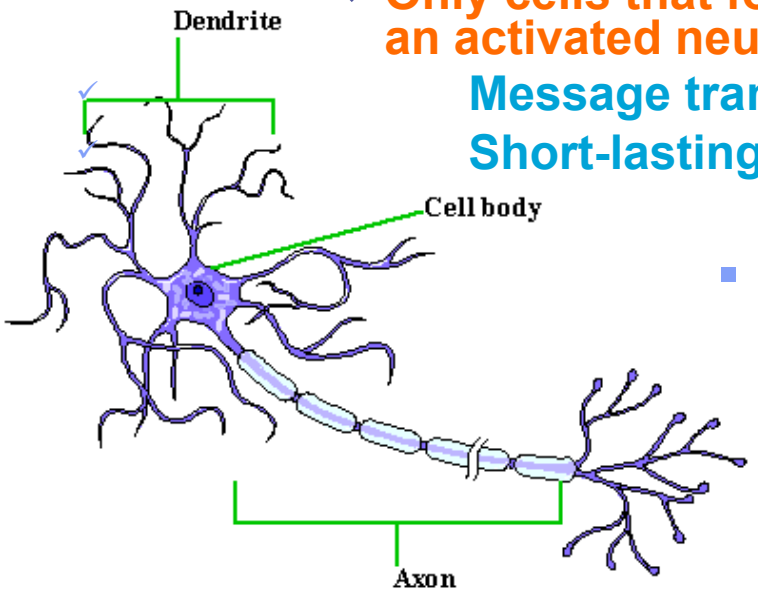


Long Distance Regulation & Communication



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



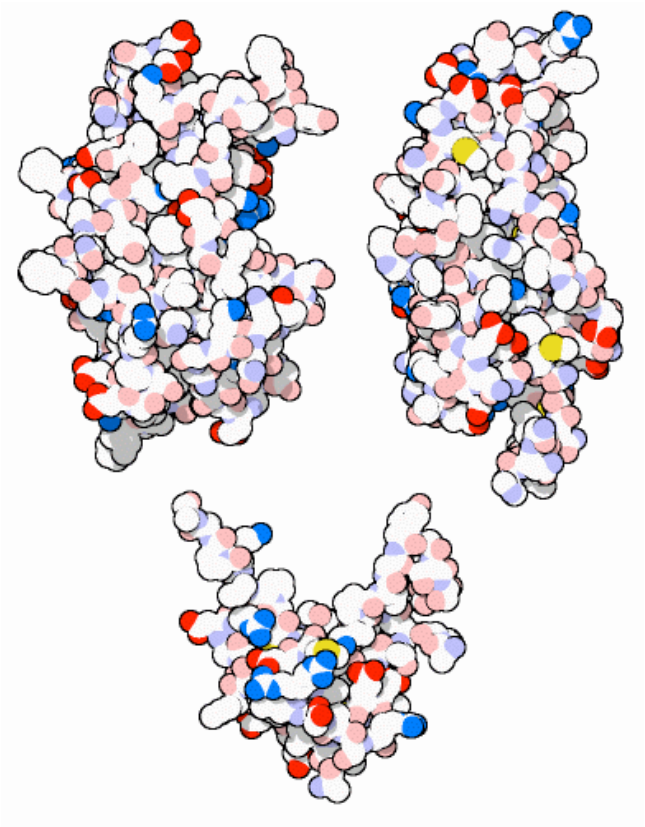
- Well-suited for directing immediate and rapid responses to the internal and external environment
  - ✓ Ex: controlling fast locomotion and animal behaviors

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

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.**
    - **H_2O & 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

Table 45.1 Major Human Endocrine Glands and Some of Their Hormones (Hypothalamus–Parathyroid glands)

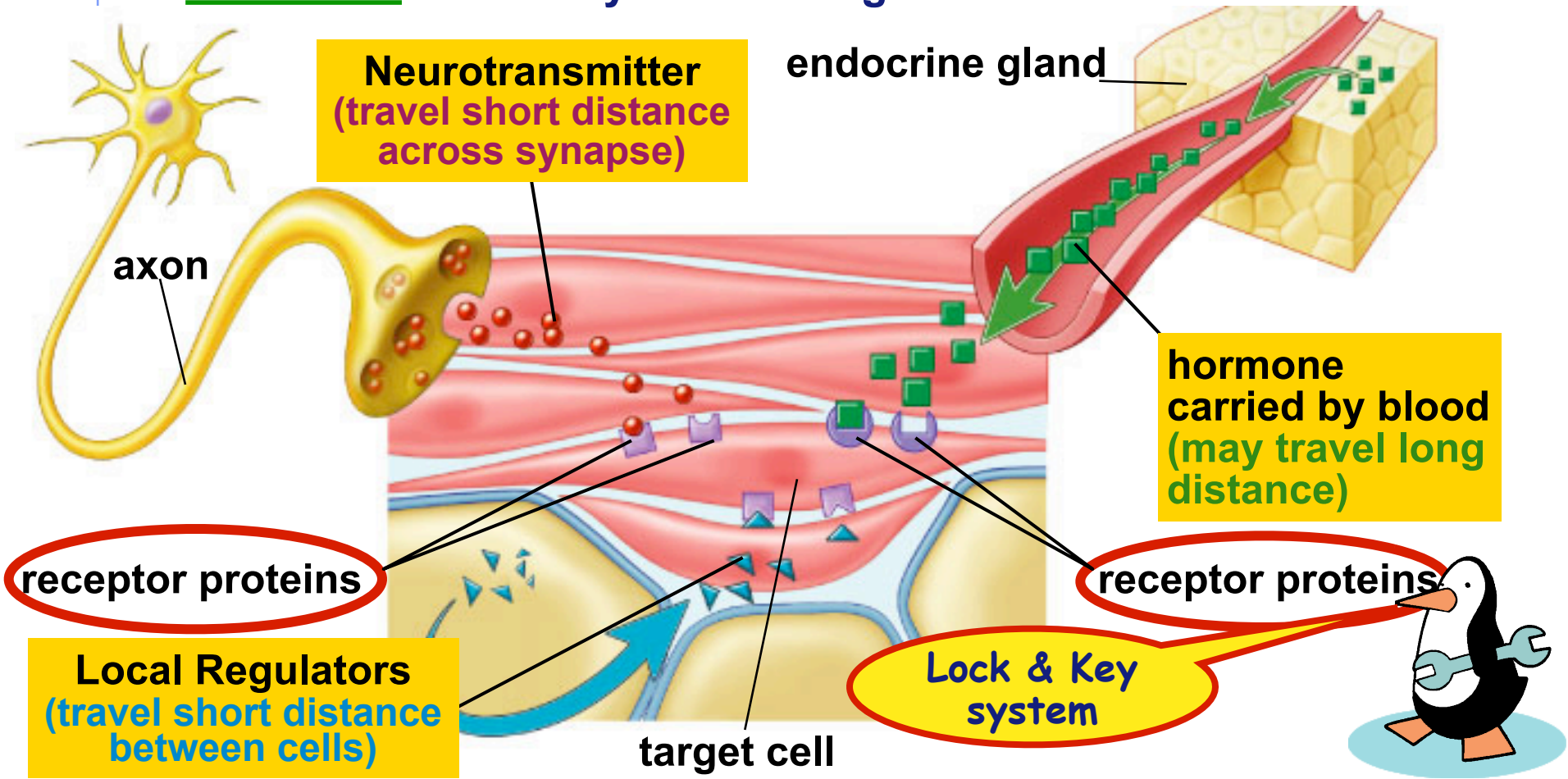
Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus 	Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Pituitary gland 				
Posterior pituitary (releases neuro-hormones made in hypothalamus)	Oxytocin	Peptide	Stimulates 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

Table 45.1 Major Human Endocrine Glands and Some of Their Hormones (Pancreas–Pineal gland)

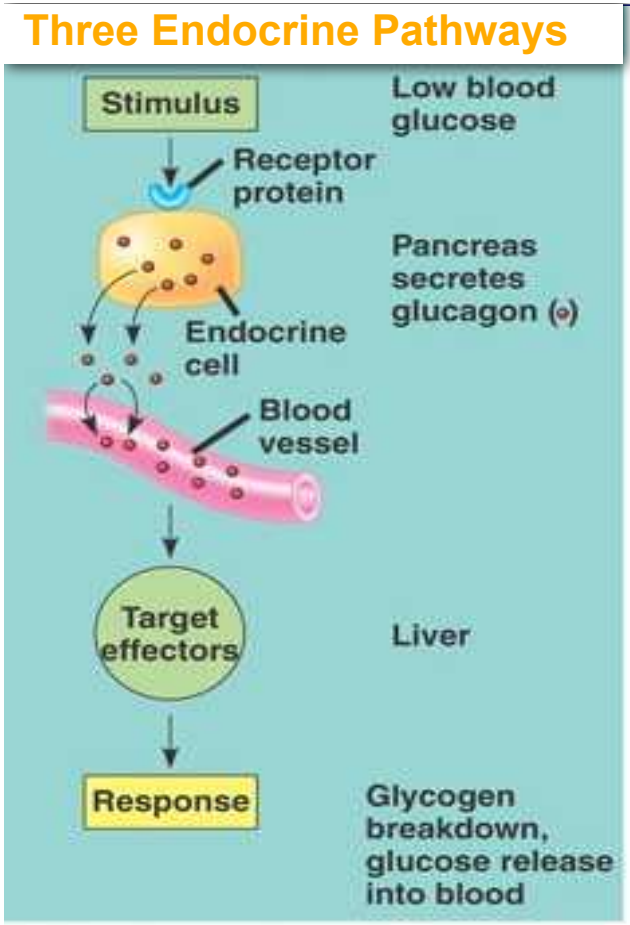
Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Pancreas 	Insulin	Protein	Lowers blood glucose level	Glucose in blood
	Glucagon	Protein	Raises blood glucose level	Glucose in blood
Adrenal glands 				
Adrenal medulla	Epinephrine and norepinephrine	Amine	Raise blood glucose level; increase 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

3 Types of Regulation by Chemical Messengers

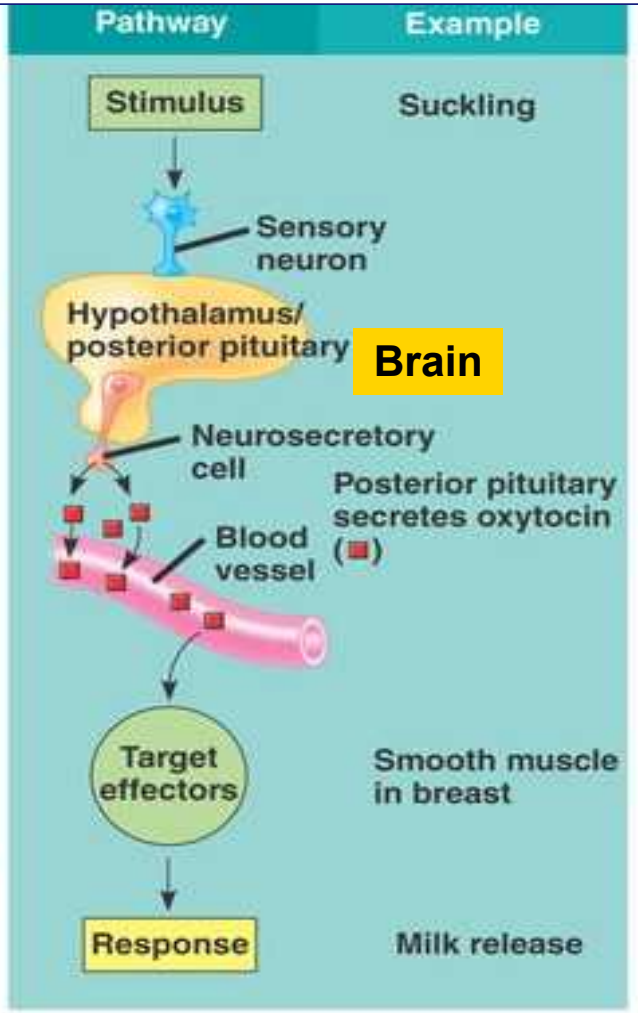
1. Local Regulators are ligands released by neighboring cells.
2. Neurotransmitters released by neurons
3. Hormones release by endocrine glands



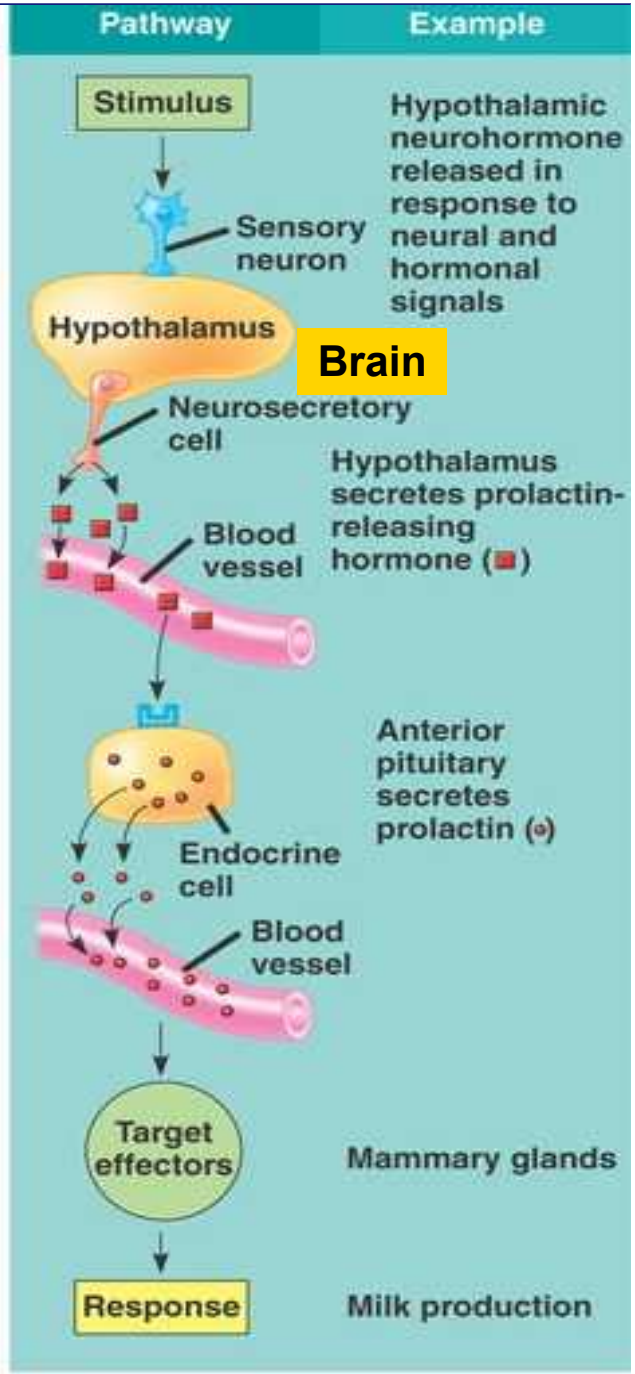
Three Endocrine Pathways



(a) Simple endocrine pathway



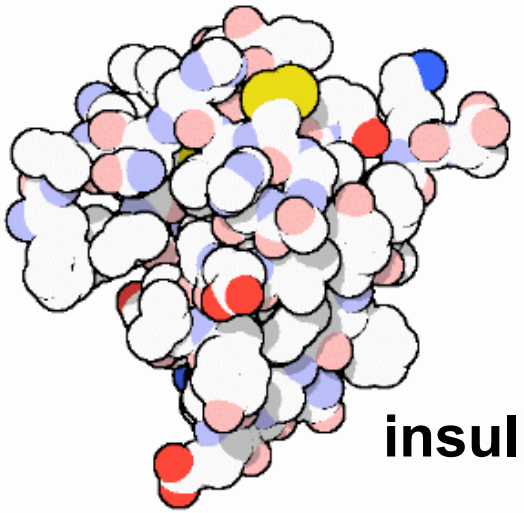
(b) Simple neurohormone pathway



(c) Simple neuroendocrine pathway

- **Neurosecretory cells = specialized sets of neurons in the brain**
  - **Secrete molecules = neurohormones**
    - **Diffuse out of a nerve cell but end up in the blood stream (like a hormone)!!!**

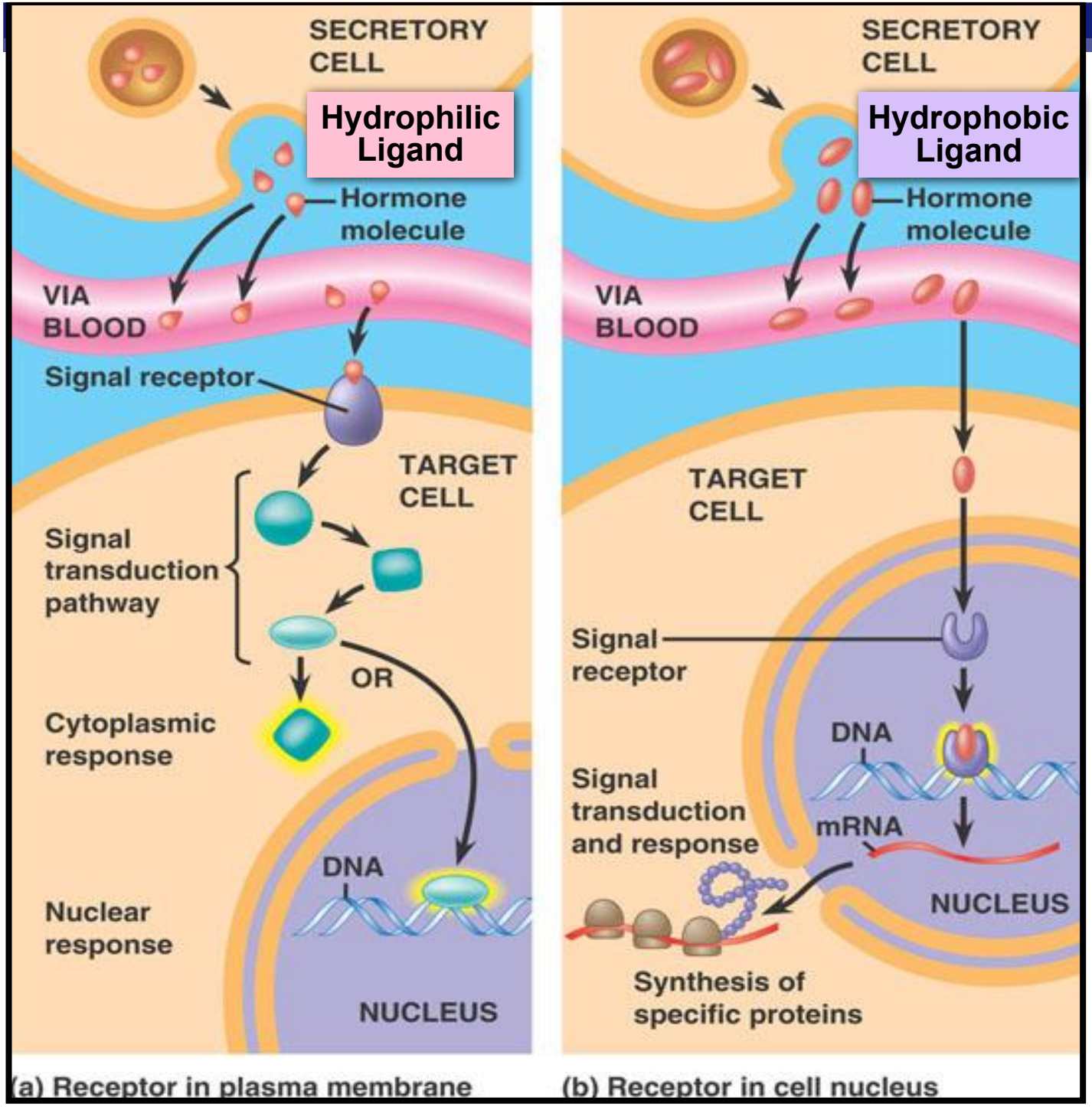
Classes of Hormones


insulin

- 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

How do hormones act on target cells

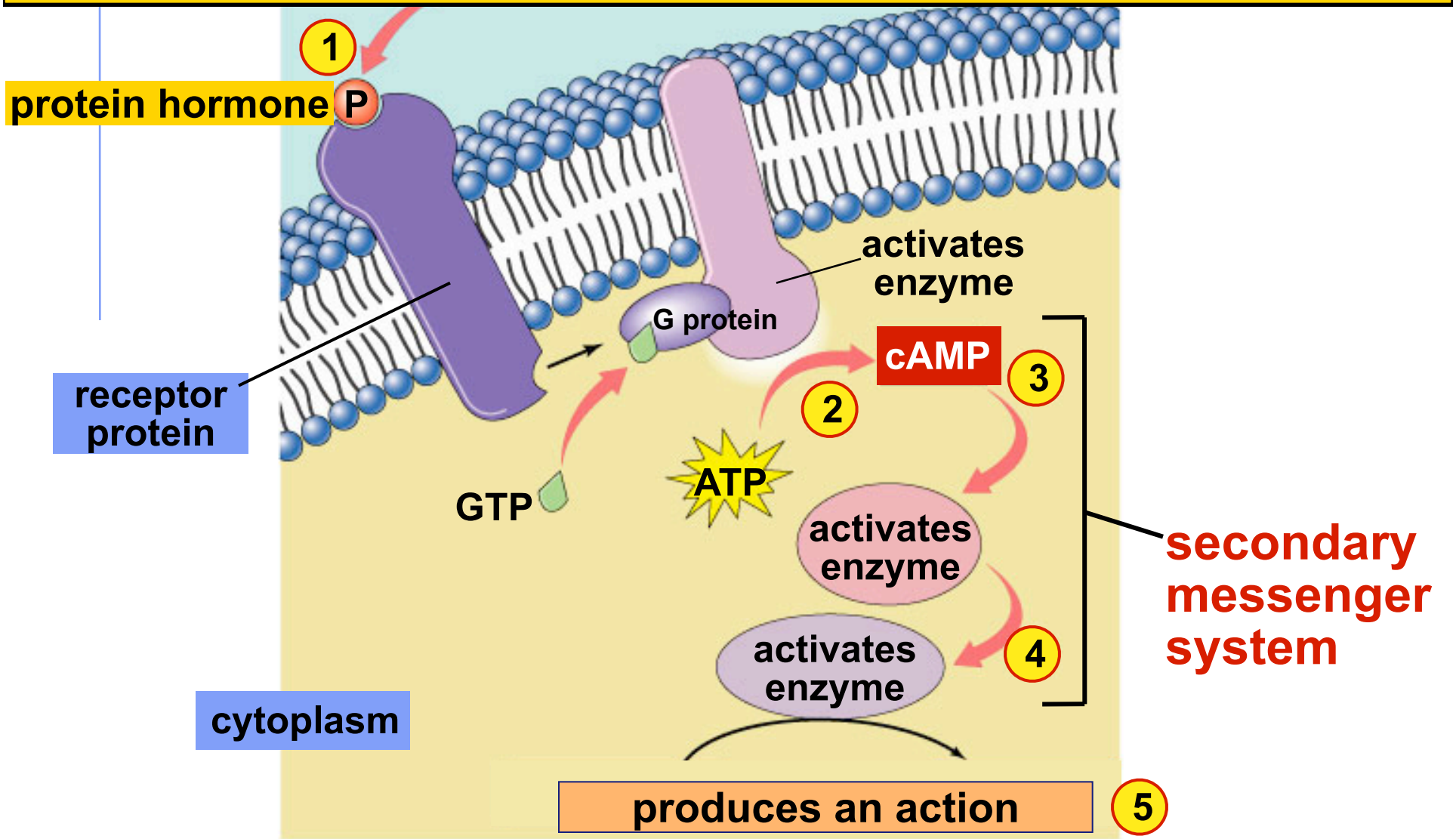
- Lipid-based hormones
  - hydrophobic & lipid-soluble
    - diffuse across cell membrane & enter cells
    - bind to receptor proteins IN cytoplasm or nucleus
      - receptor bind directly or indirectly to DNA as transcription factors = turn on genes
- Protein-based hormones
  - hydrophilic & not lipid soluble
    - can't diffuse across cell membrane
    - bind to receptor proteins embeeded 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…



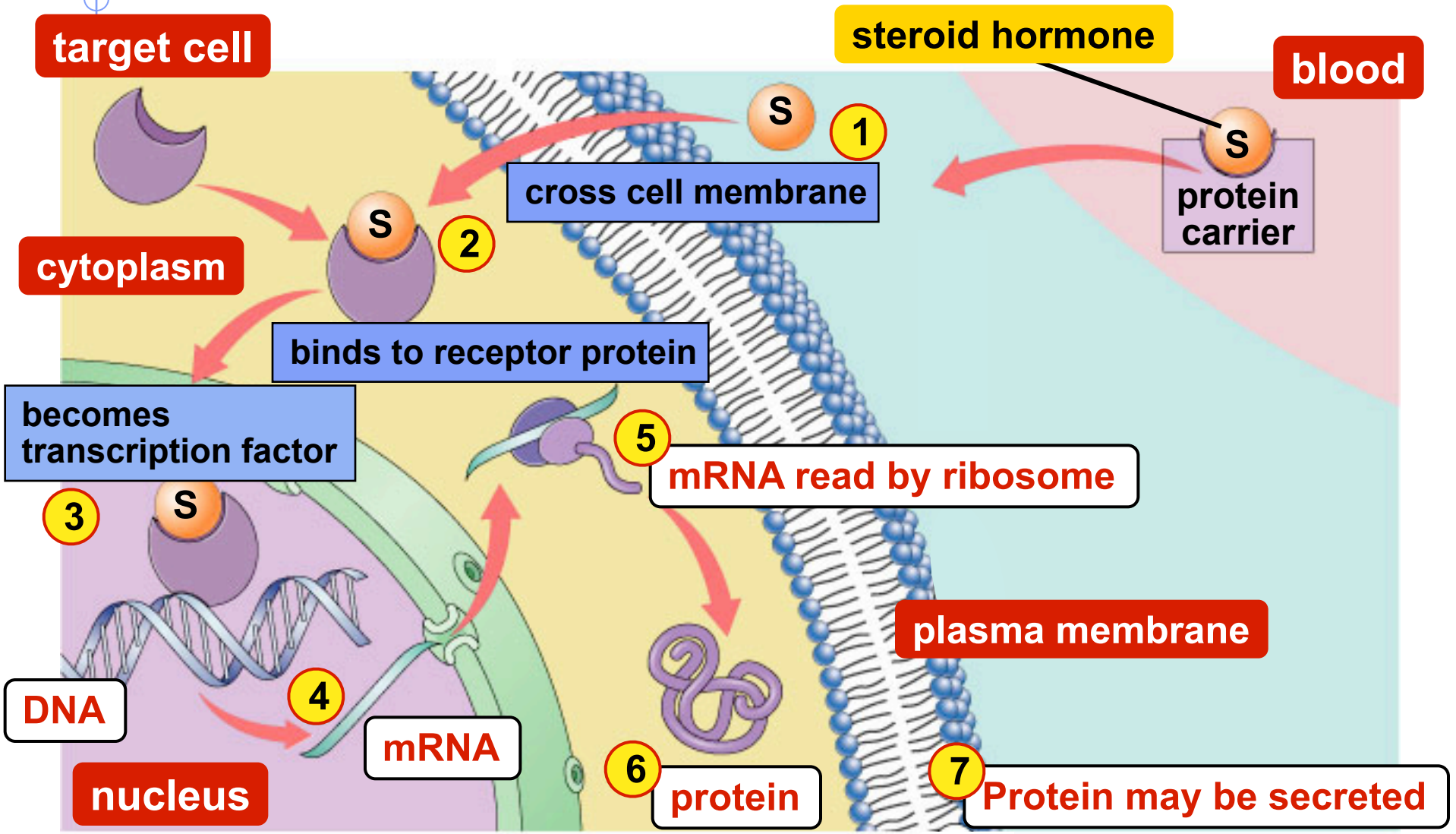
Receptor location varies with hormone type

Water-soluble hormones rely on Signal Transduction Pathways =

series of changes in cellular proteins that converts the extracellular chemical signal to a specific intracellular response



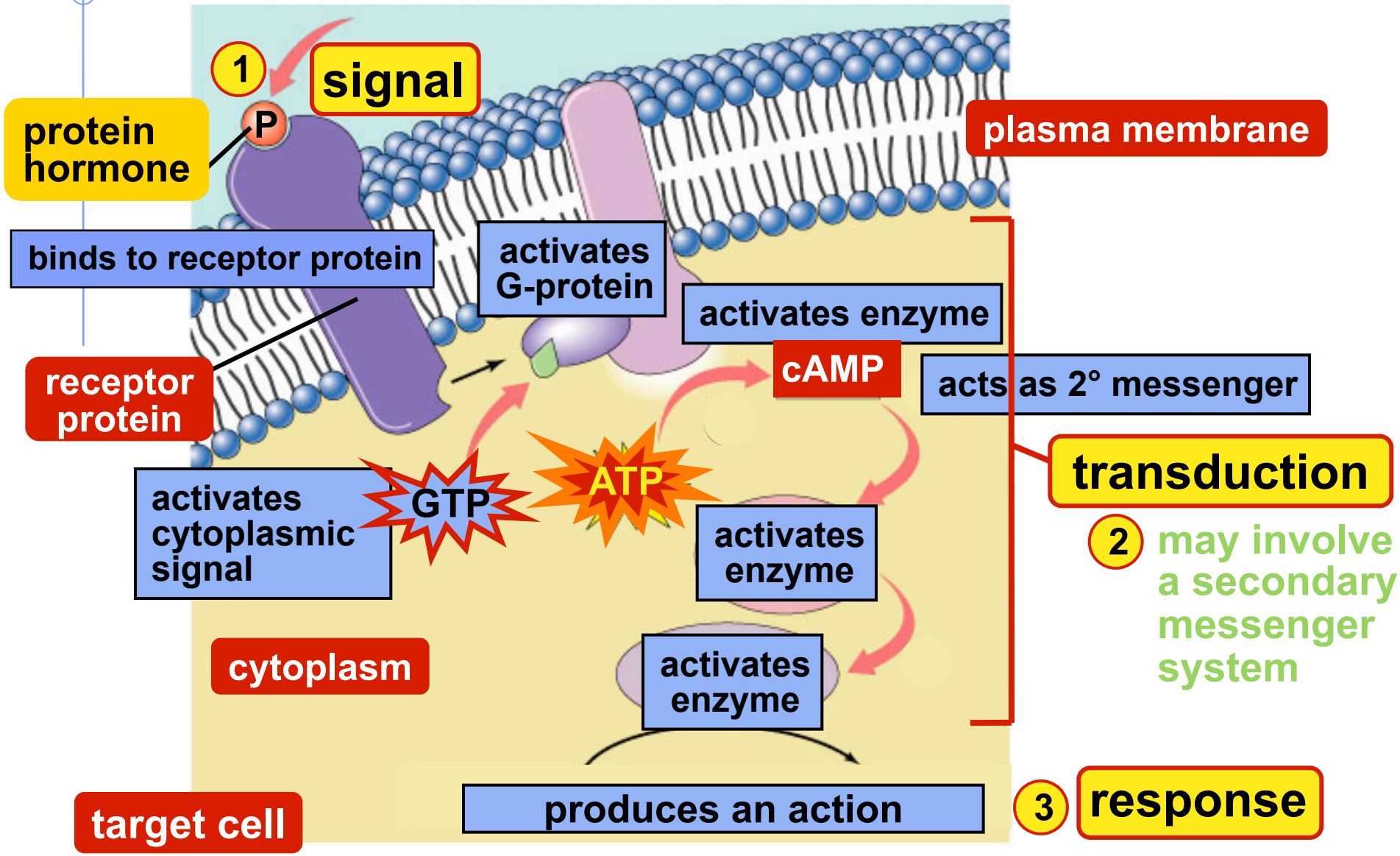
Action of lipid (steroid) hormones



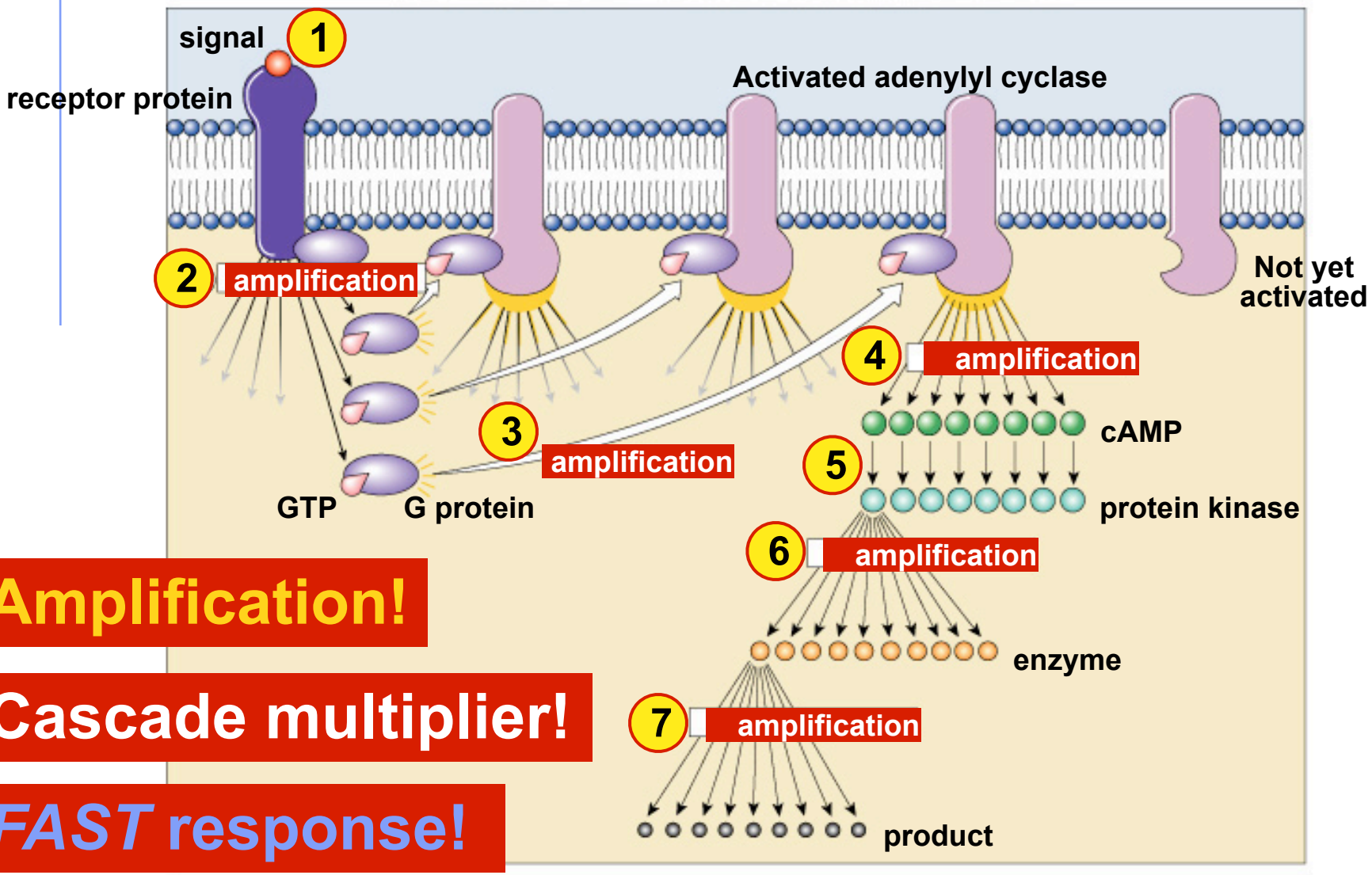
Ex: secreted protein = can be growth factor or other protein like enzyme or ligand

signal-transduction pathway

Action of protein hormones



Benefits of a 2° messenger system

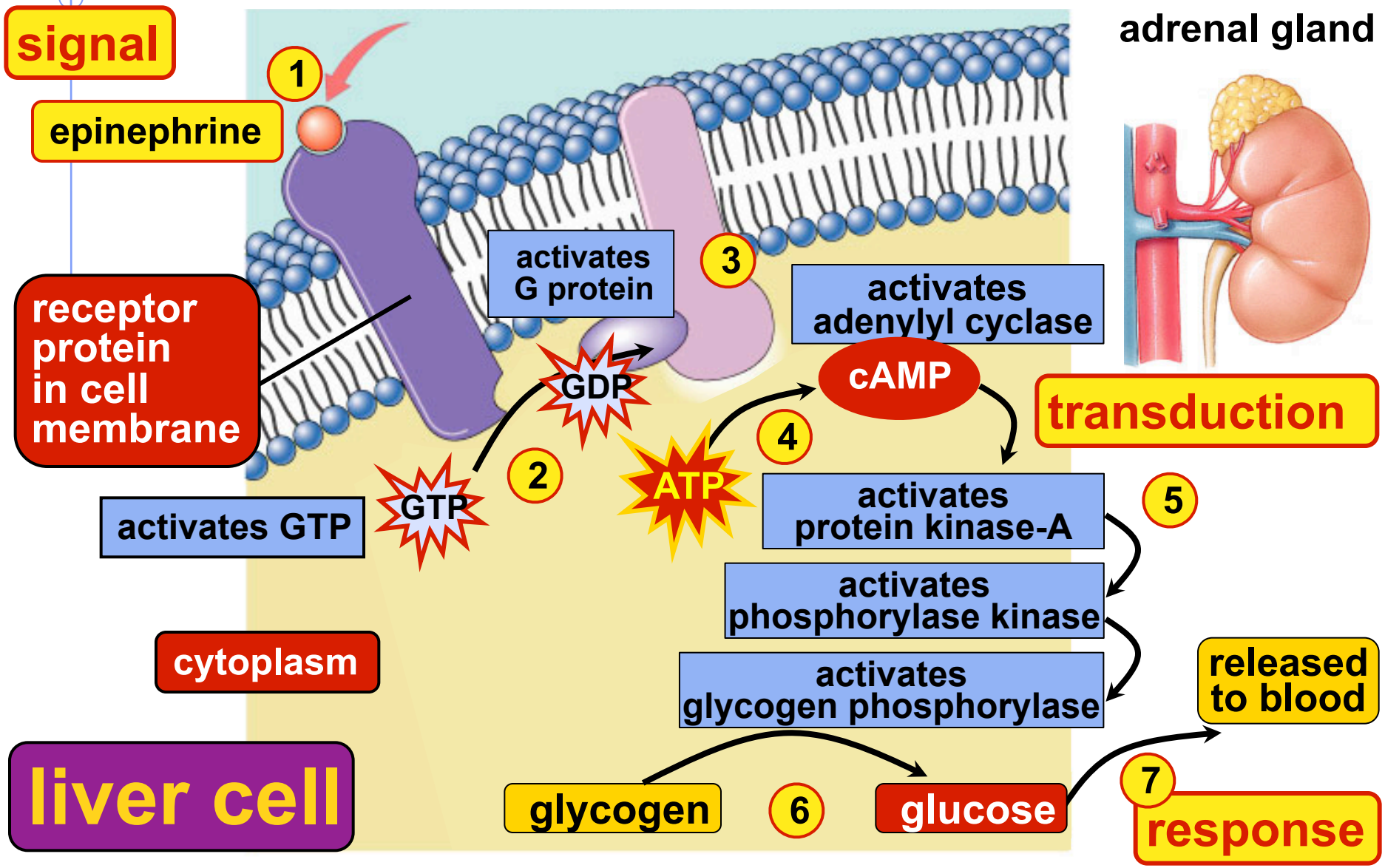


Amplification!

Cascade multiplier!

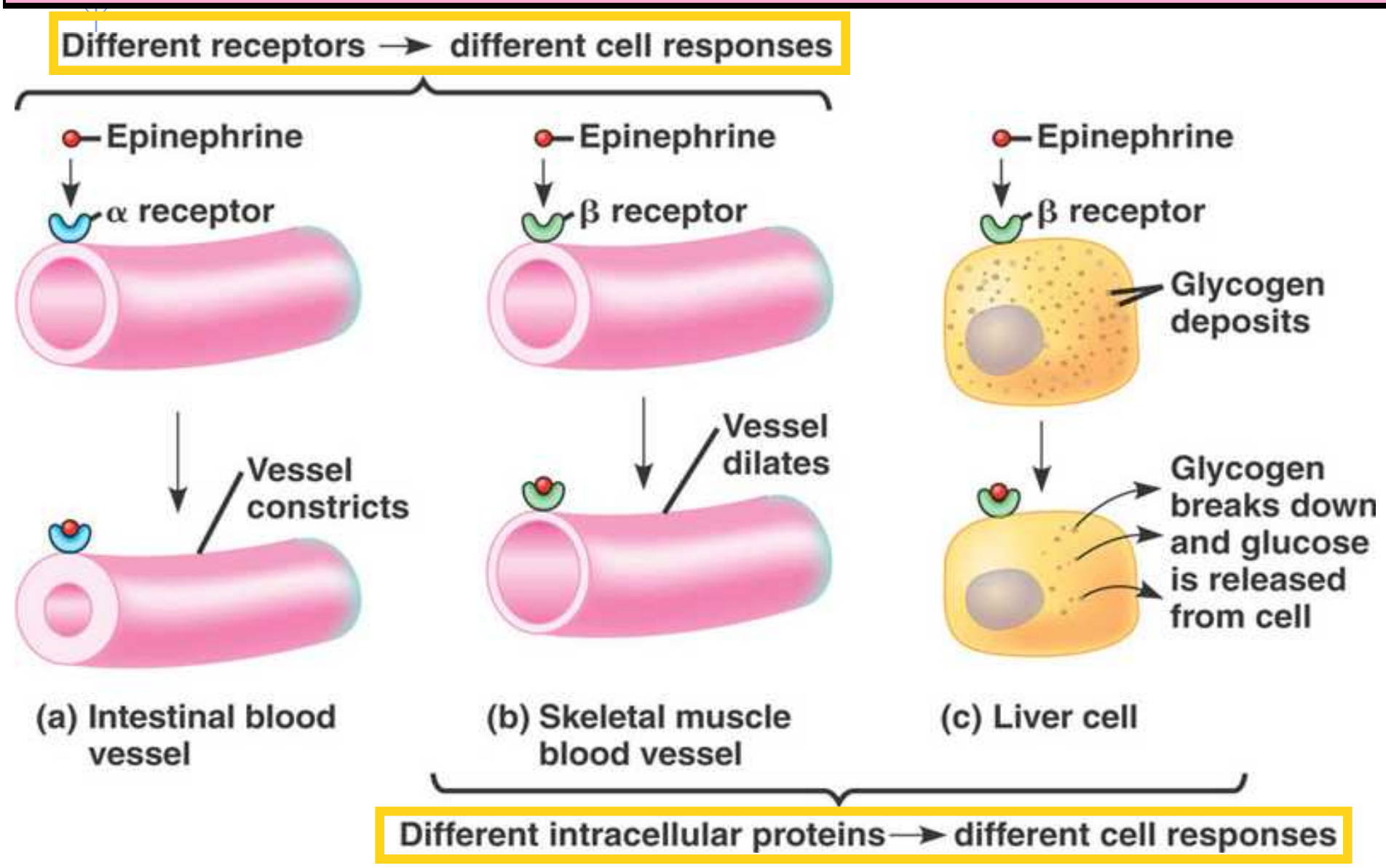
***FAST* response!**

Ex: Action of epinephrine (adrenaline)



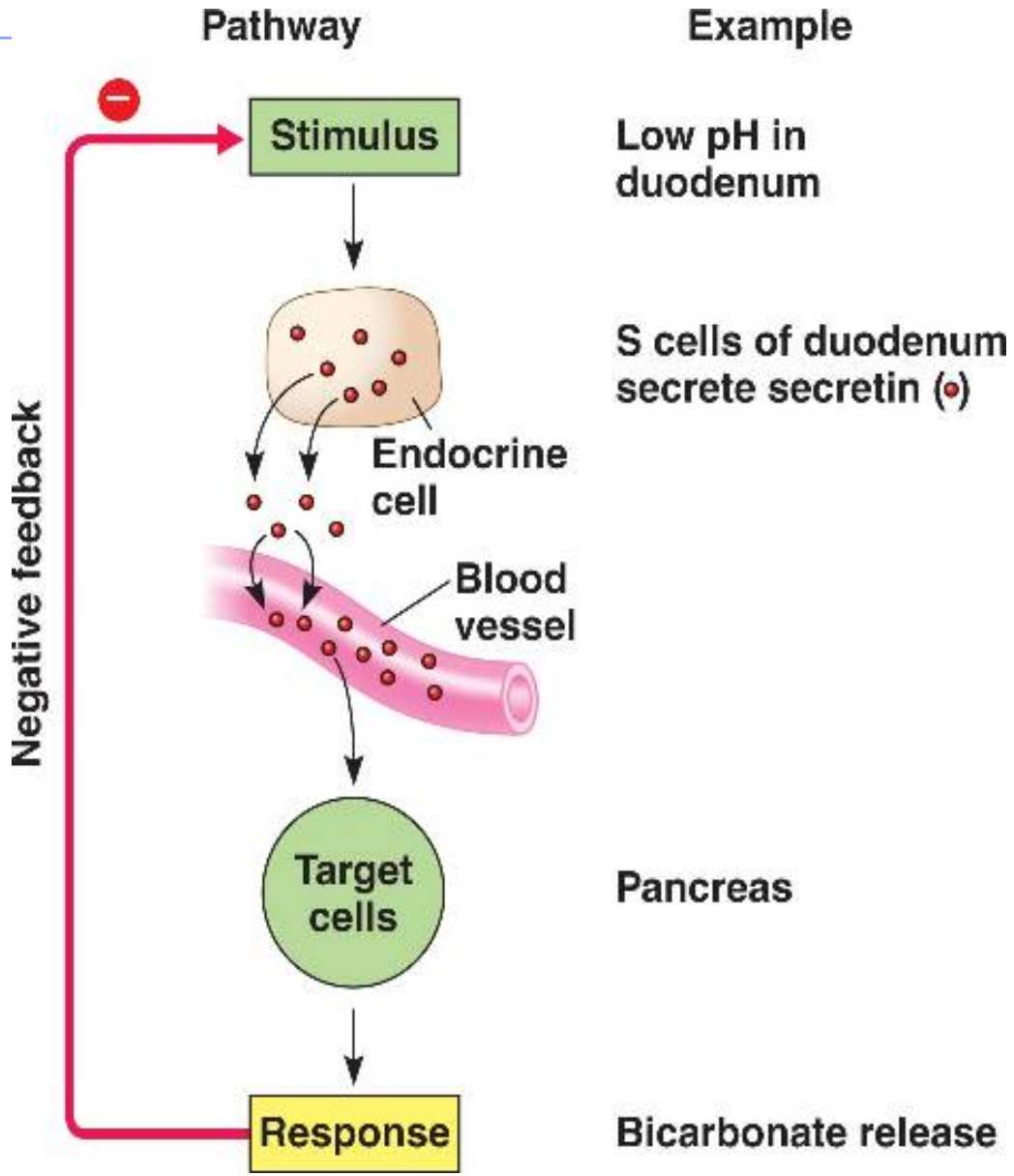
A hormone may cause different effects in different target cells:

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

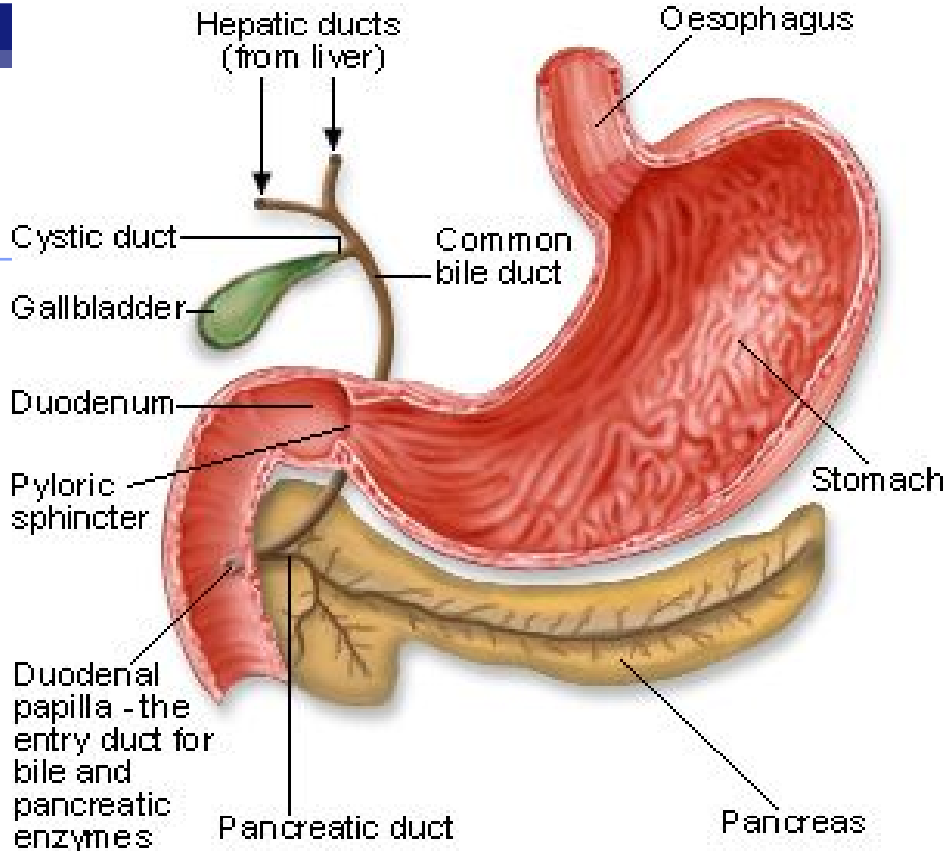


Simple hormone pathways

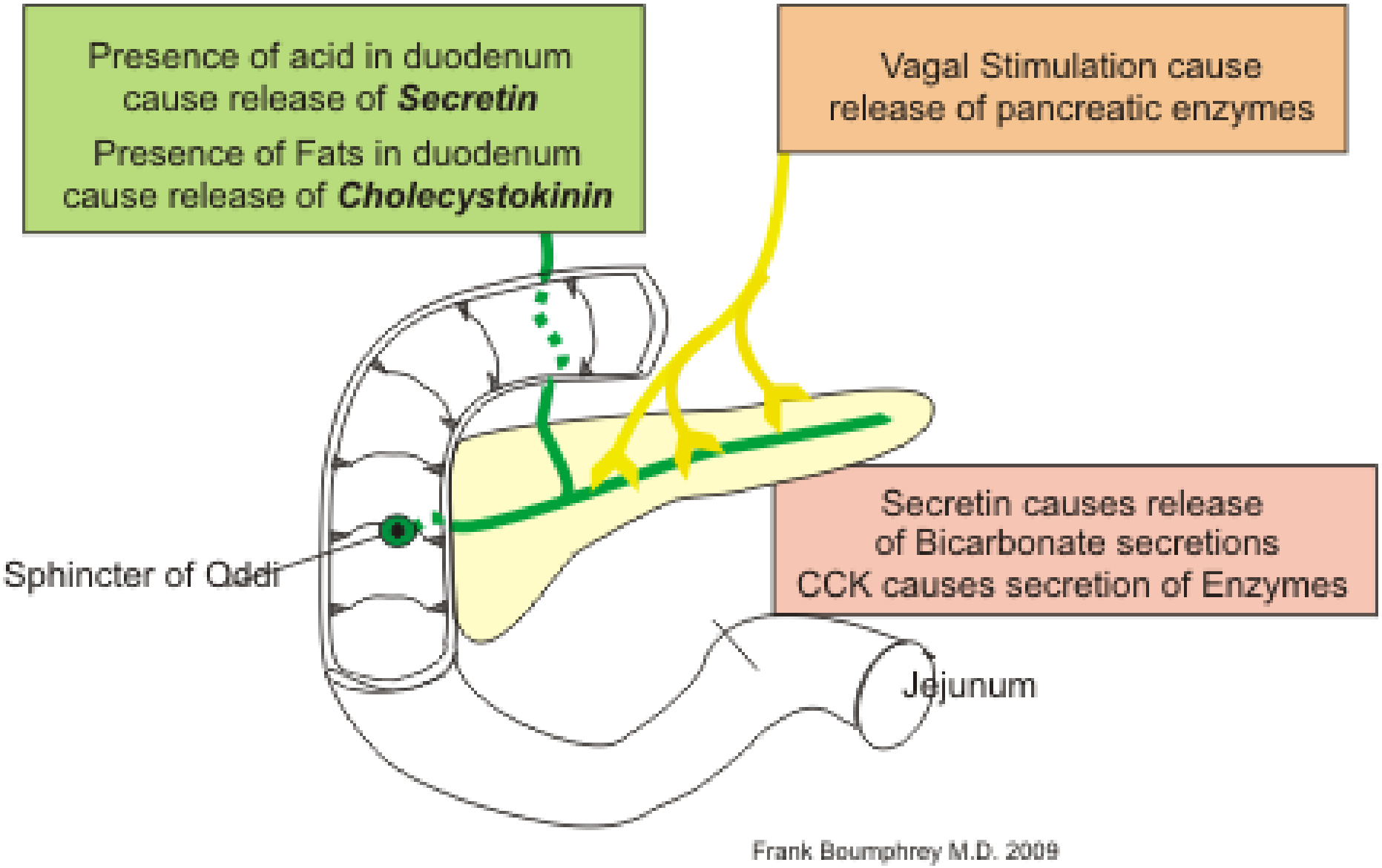
- **Often involves NEGATIVE FEEDBACK**
  - **Response reduces initial stimulus**
    - Internal or environmental stimulus triggers endocrine cell to secrete hormone
    - Hormone travels in bloodstream to target cell receptors
    - Signal transduction within target cell causes physiological response
    - 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**



Control of Pancreatic Secretions

Major Digestive Enzymes

My optimal pH is 2 (deactivate @ 6.5)

My optimal pH is 8

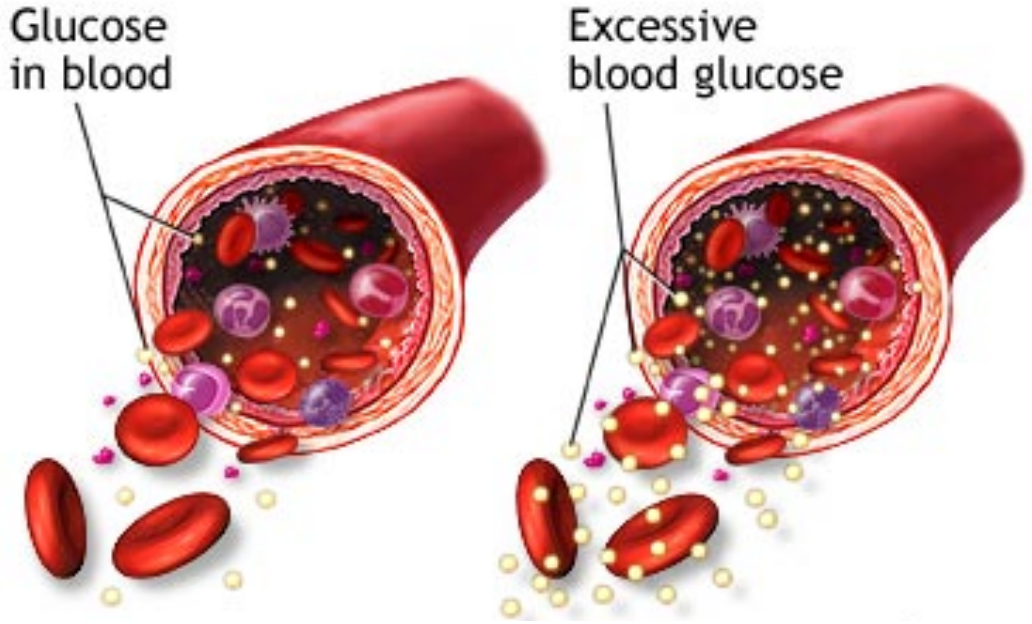
My optimal pH is 8

My optimal pH is 8

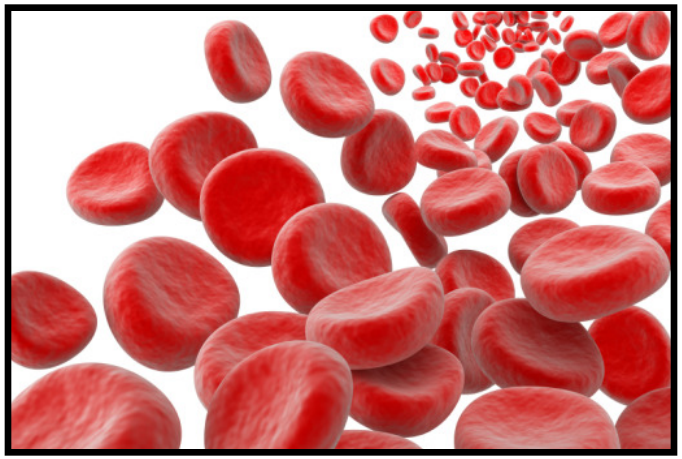
Enzyme	Produced In	Site of Release	pH Level
Carbohydrate Digestion:			
Salivary amylase	Salivary Glands	Mouth	Neutral
Pancreatic amylase	Pancreas	Small Intestine	Basic
Maltase	Small intestine	Small intestine	Basic
Protien Digestion:			
Pepsin	Gastric glands	Stomach	Acidic
Trypsin	Pancreas	Small intestine	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

Your goal is to maintain normal blood glucose levels

Homeostasis:

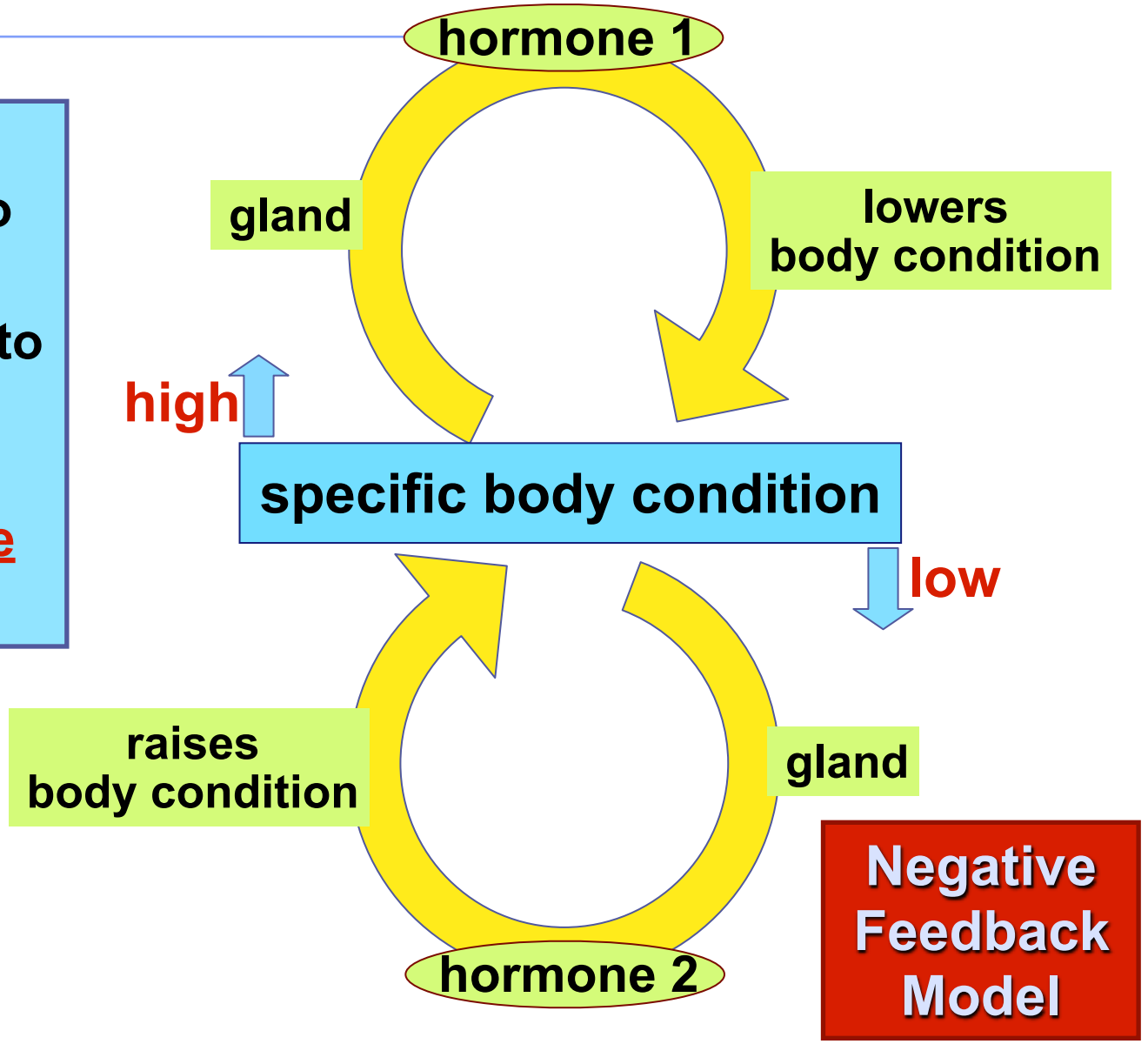


Let's take a closer look at <u>Regulating Blood Glucose Levels</u>



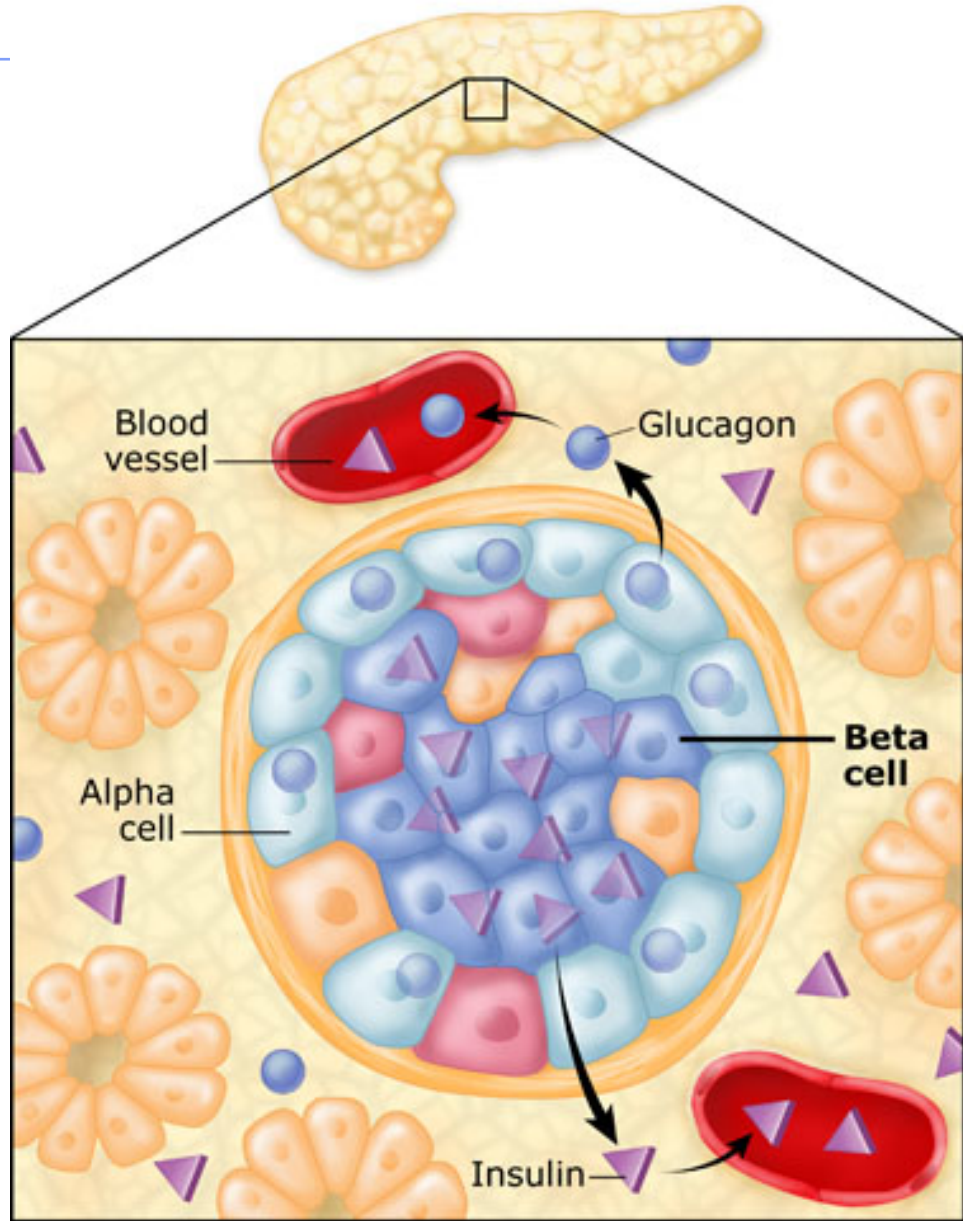
Maintaining homeostasis

A common arrangement to maintain homeostasis is to have a pair of pathways that counterbalance each other.



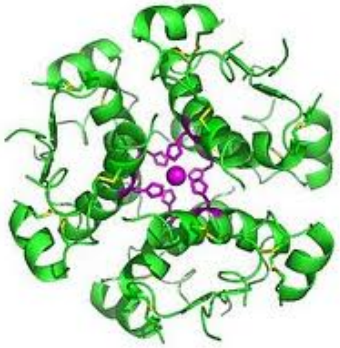
Regulation of Blood Glucose

- **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



Big Picture - Insulin Hormone

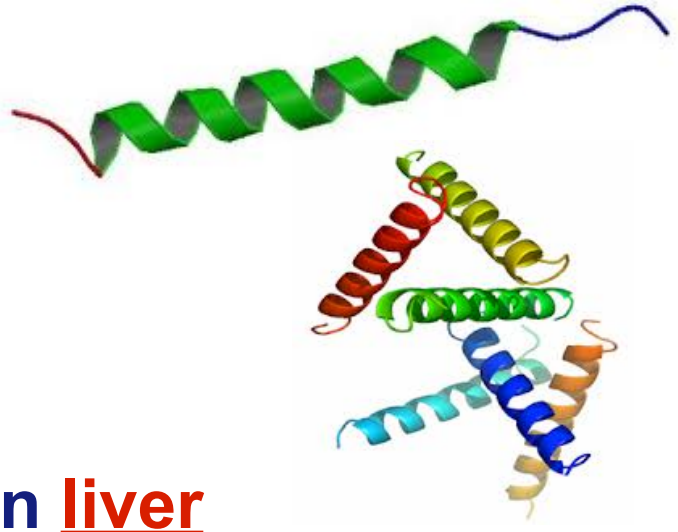
- Glucose is the major fuel for cellular respiration and key source of a carbon skeleton for biosynthesis



- 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

Big Picture - Glucagon Hormone

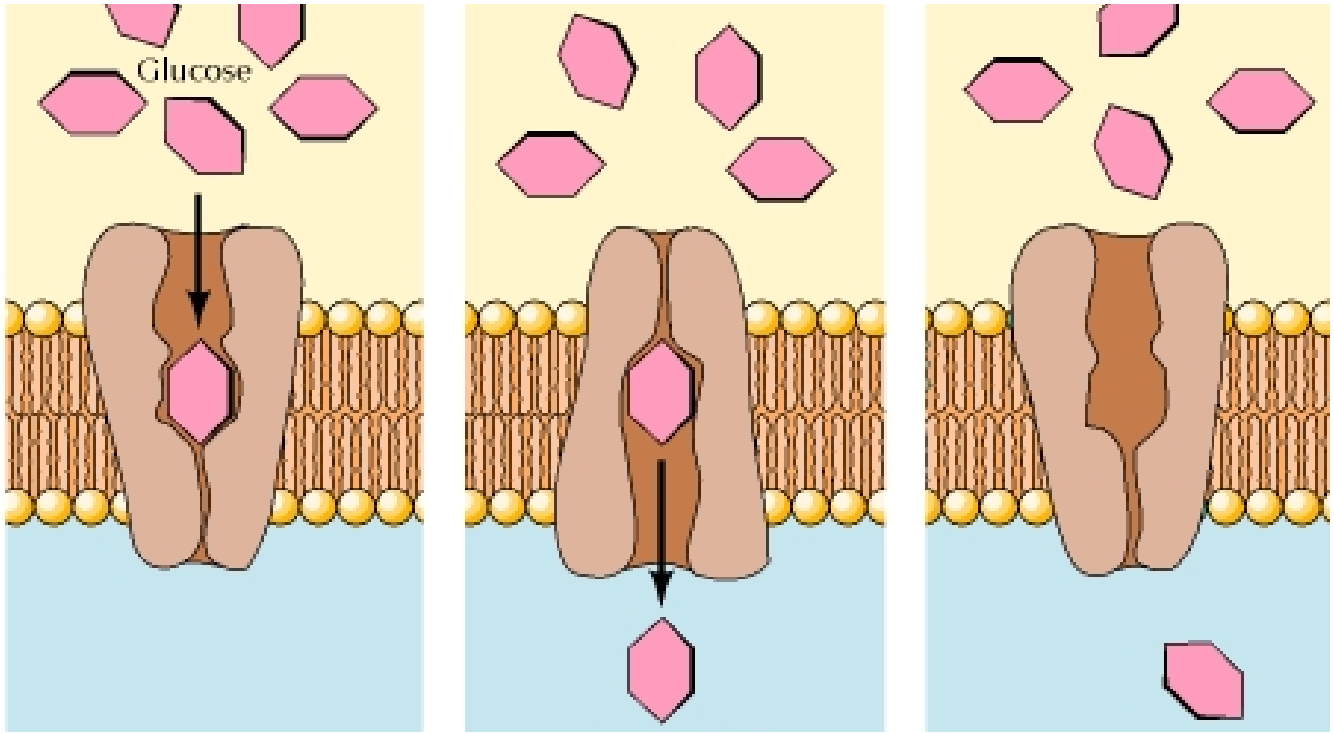
- Glucose is the major fuel for cellular respiration and key source of a carbon skeleton for biosynthesis



- 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

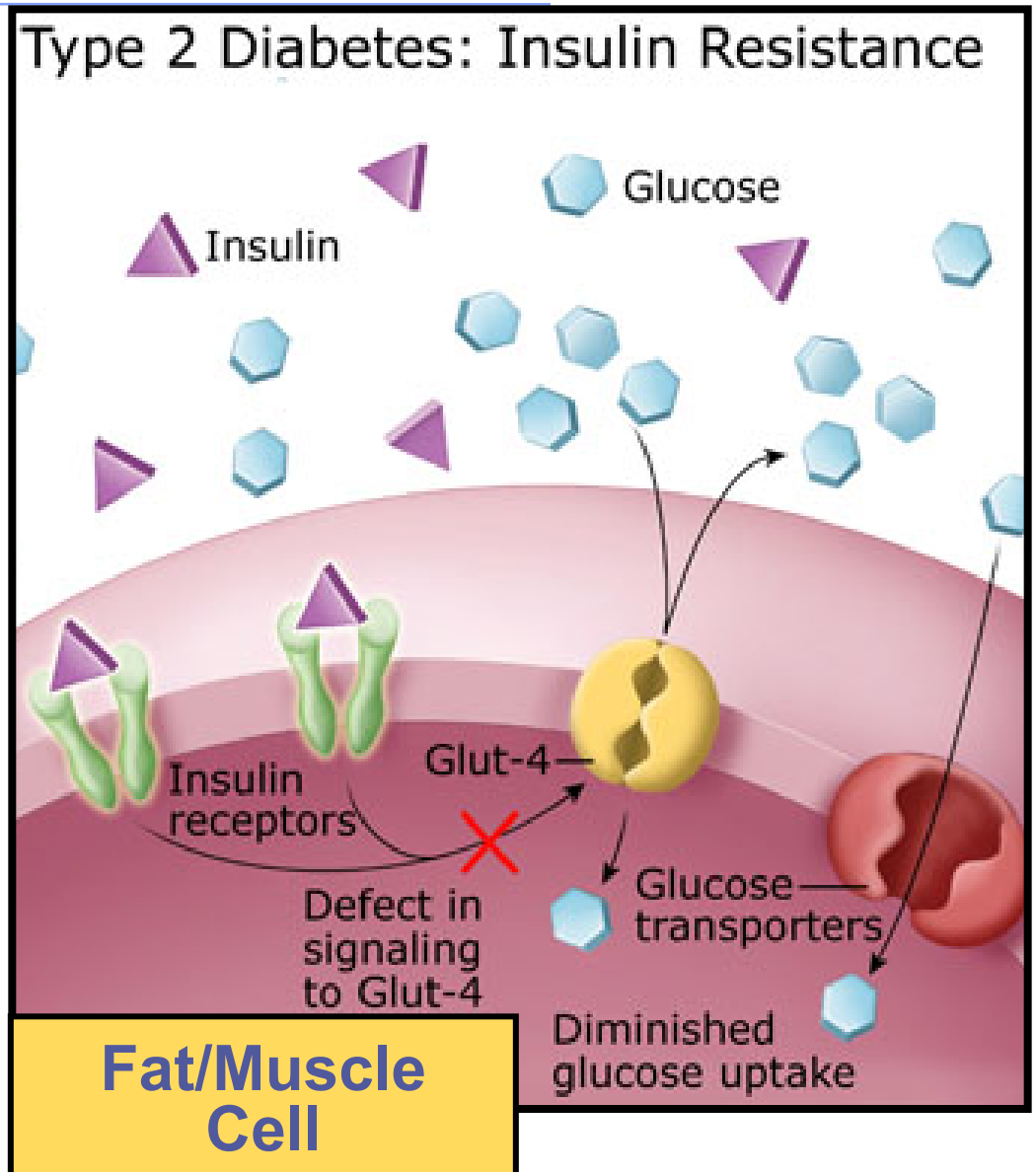
Glucose Transporters

- 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

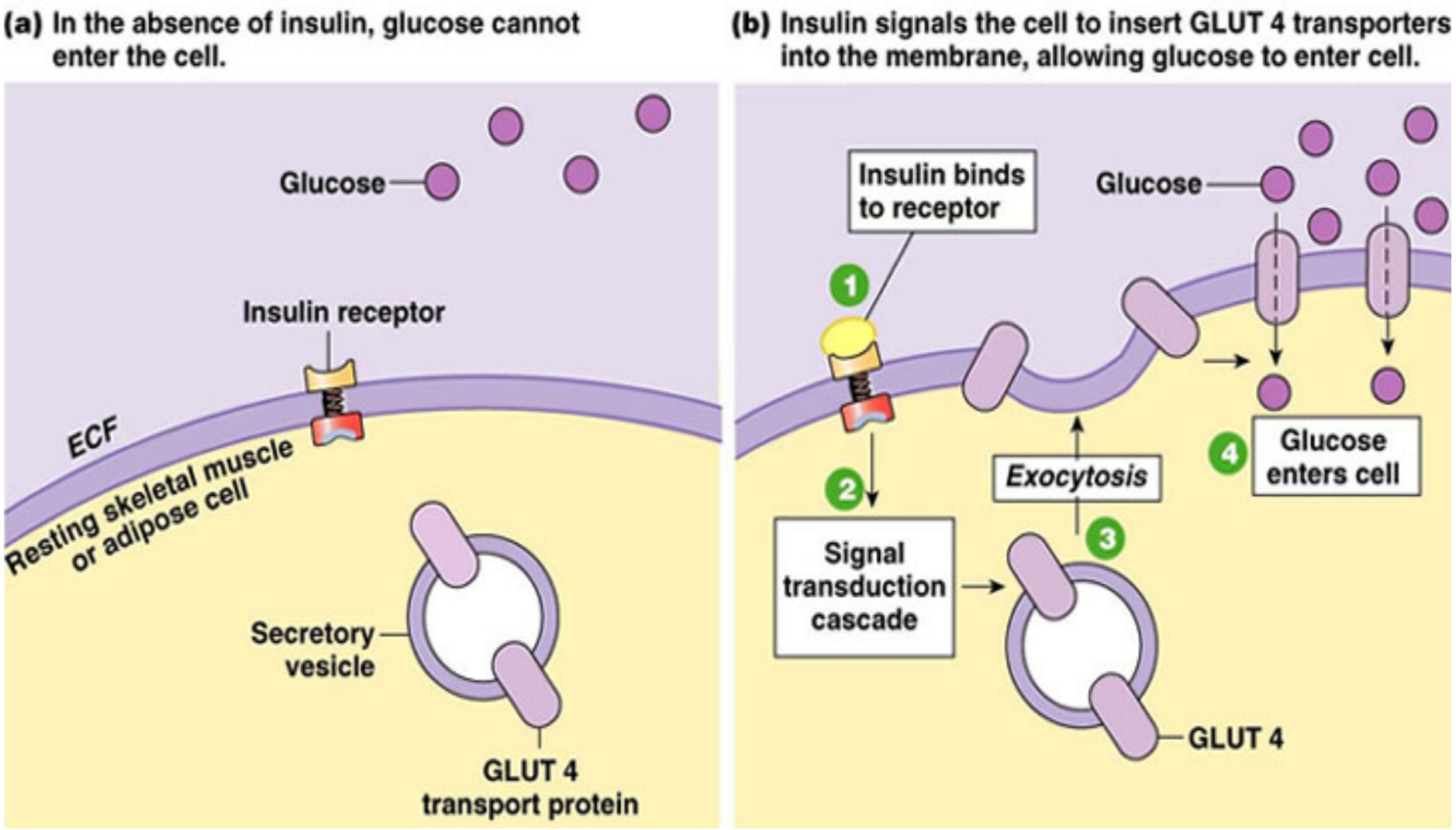


Glucose Transporters

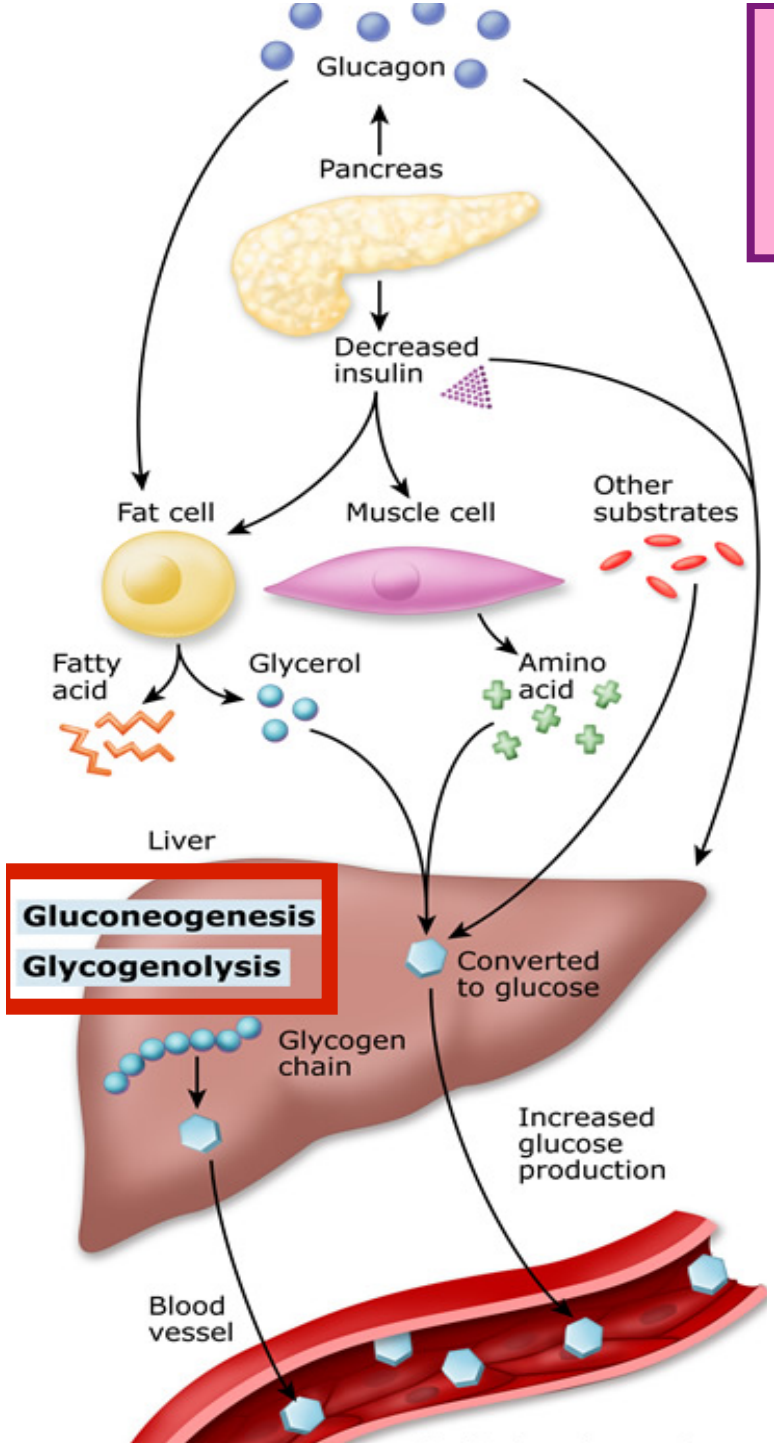
2. **Glut-4 transporters**
   - Kept inside the cytoplasm in the membrane of vesicles
     - Insulin ligands bind to tyrosine kinase receptors in the plasma membrane that initiate a signal transduction pathway
     - Leads to fusion of vesicles carrying additional Glut-4 glucose transporters with the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

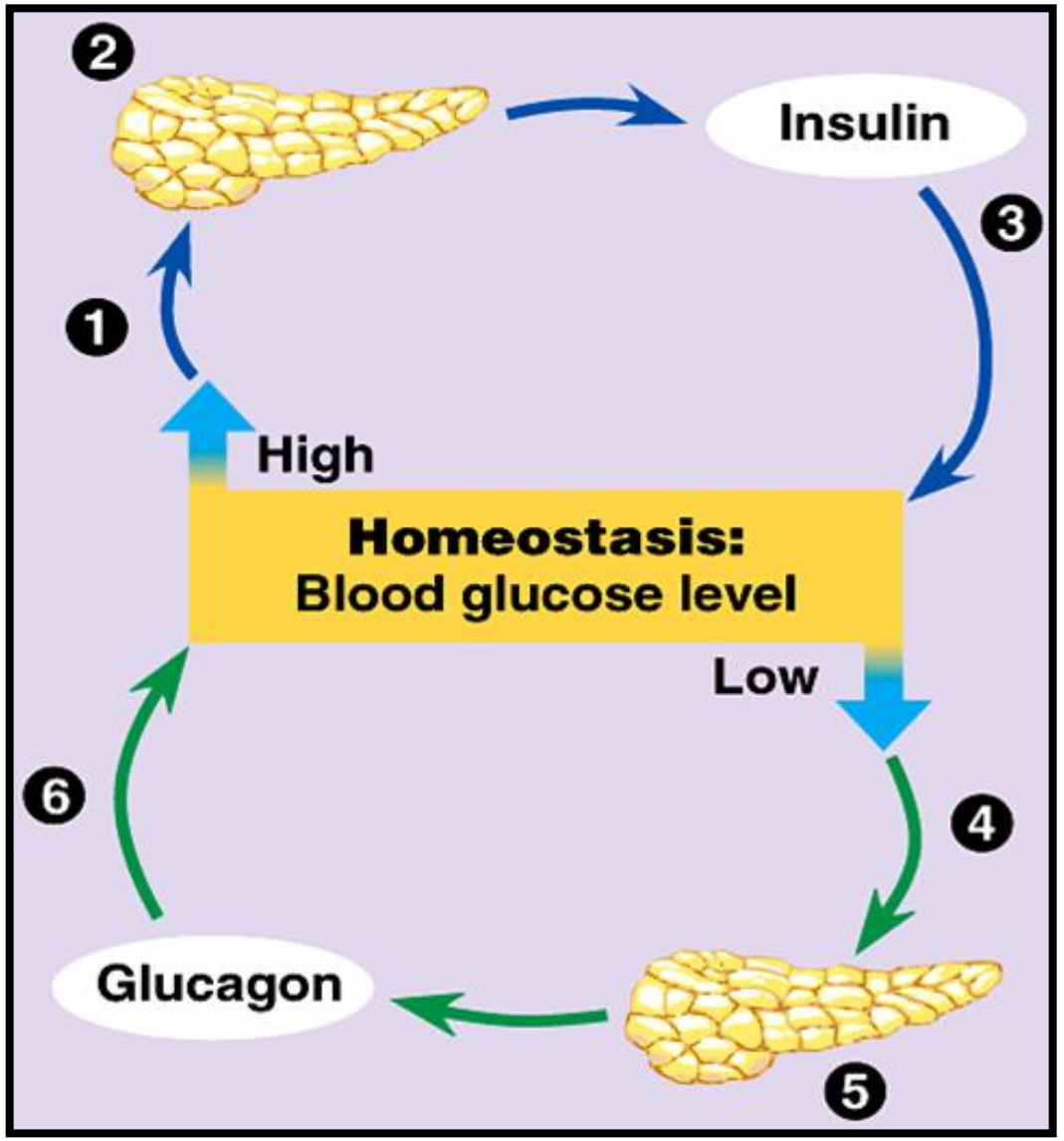


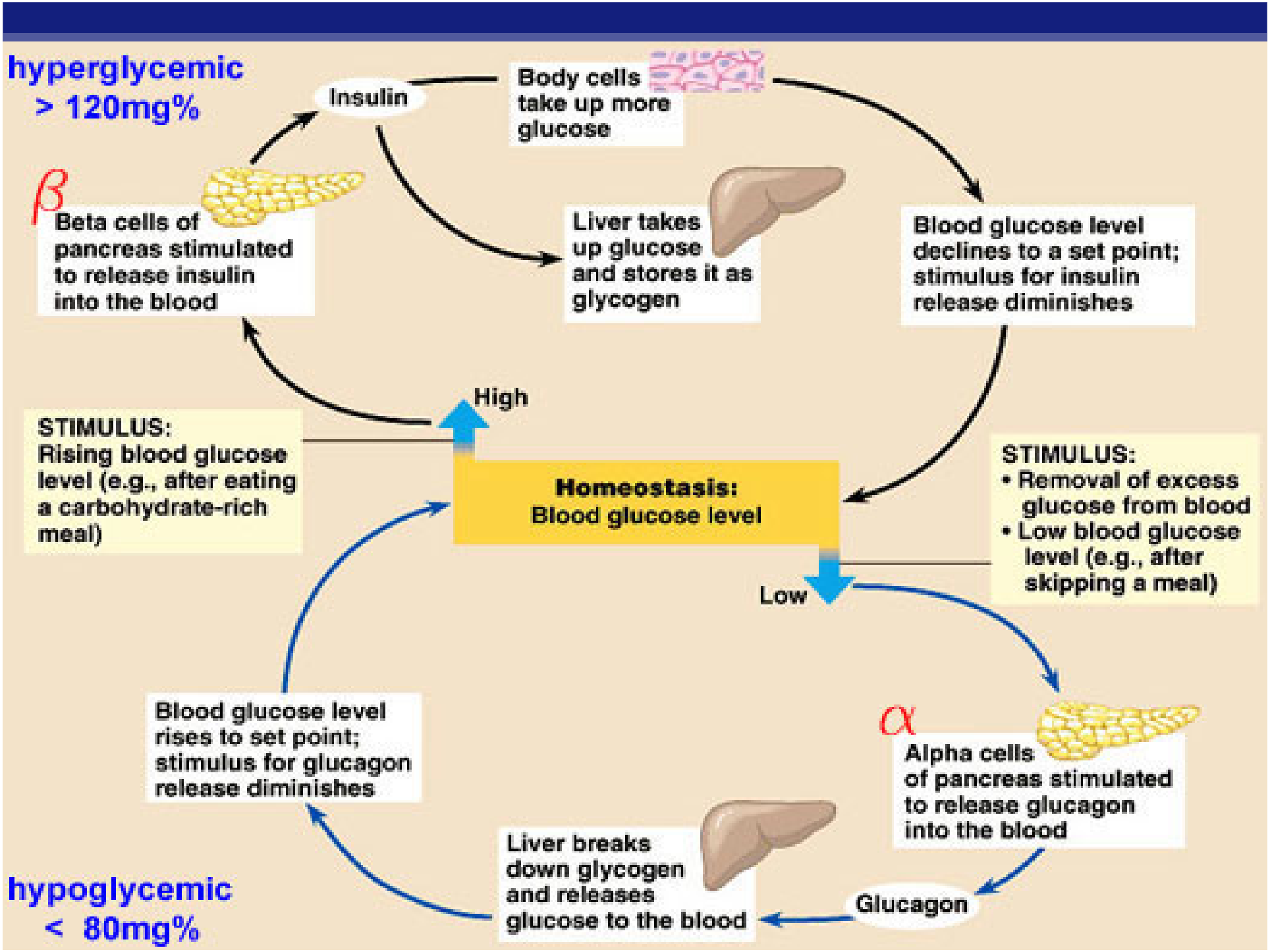
Role of insulin - skeletal muscle & fat cells



Glucagon stimulates the formation of glucose in liver through gluconeogenesis or glycogenolysis

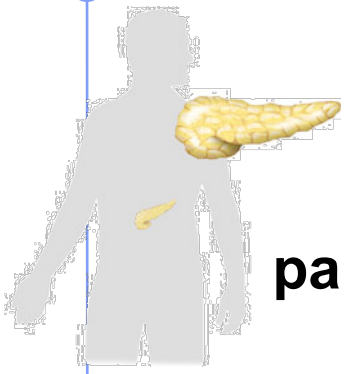





hyperglycemic
> 120mg%
Insulin
Body cells take up more glucose
β
Beta cells of pancreas stimulated to release insulin into the blood
Liver takes up glucose and stores it as glycogen
Blood glucose level declines to a set point; stimulus for insulin release diminishes
High
STIMULUS:
Rising blood glucose level (e.g., after eating a carbohydrate-rich meal)
Homeostasis:
Blood glucose level
STIMULUS:
• Removal of excess glucose from blood
• Low blood glucose level (e.g., after skipping a meal)
Low
Blood glucose level rises to set point; stimulus for glucagon release diminishes
α
Alpha cells of pancreas stimulated to release glucagon into the blood
Liver breaks down glycogen and releases glucose to the blood
Glucagon
hypoglycemic
< 80mg%

Endocrine System Control:
Regulation of Blood Sugar

Feedback



pancreas

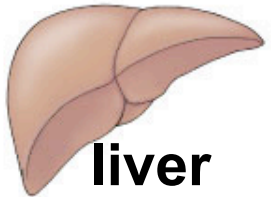
insulin

islets of Langerhans
beta islet cells

body cells take up sugar from blood

liver stores glycogen

reduces appetite



liver

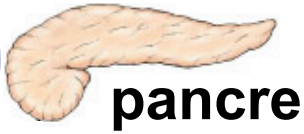
high

blood sugar level
(90mg/100ml)

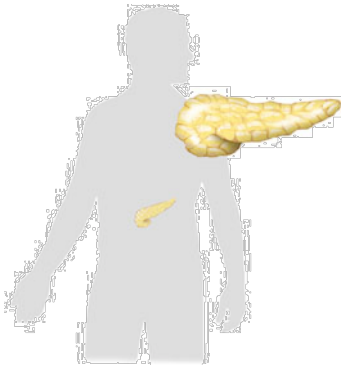
low

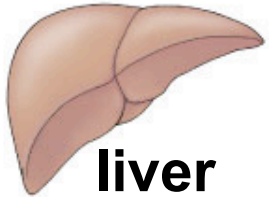
triggers hunger

liver releases glucose



pancreas





liver

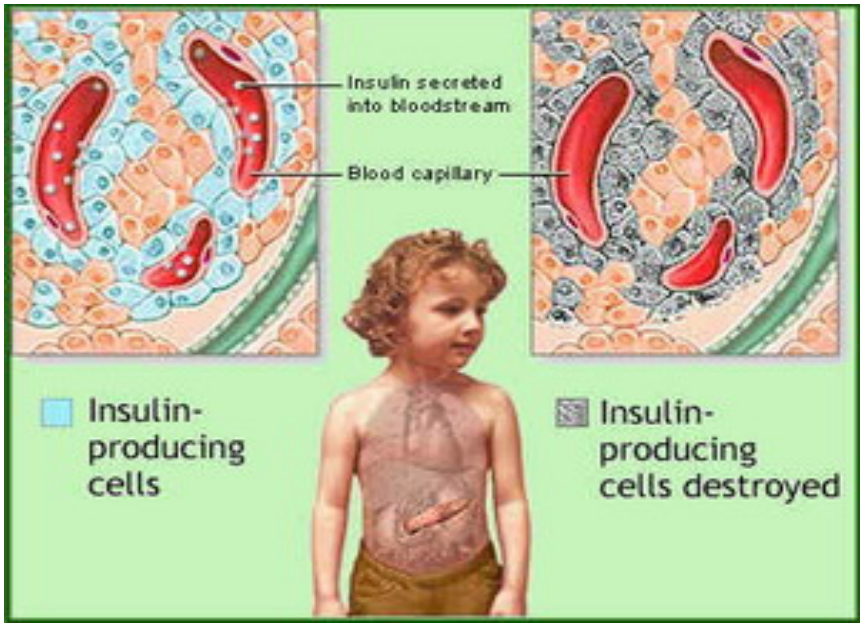
glucagon

islets of Langerhans
alpha islet 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

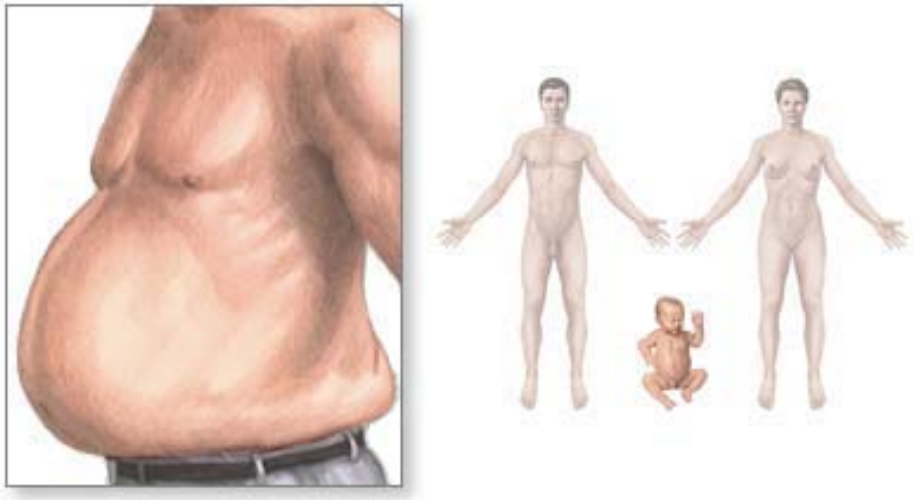
1. **Type I diabetes**
   - Aka juvenile or insulin-dependent diabetes
   - Autoimmune disorder
   - Immune system attacks beta cells of pancreas that produce insulin
   - Artificially inject insulin
   - Stem cell research may provide a cure by replacing destroys beta cells with working ones



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