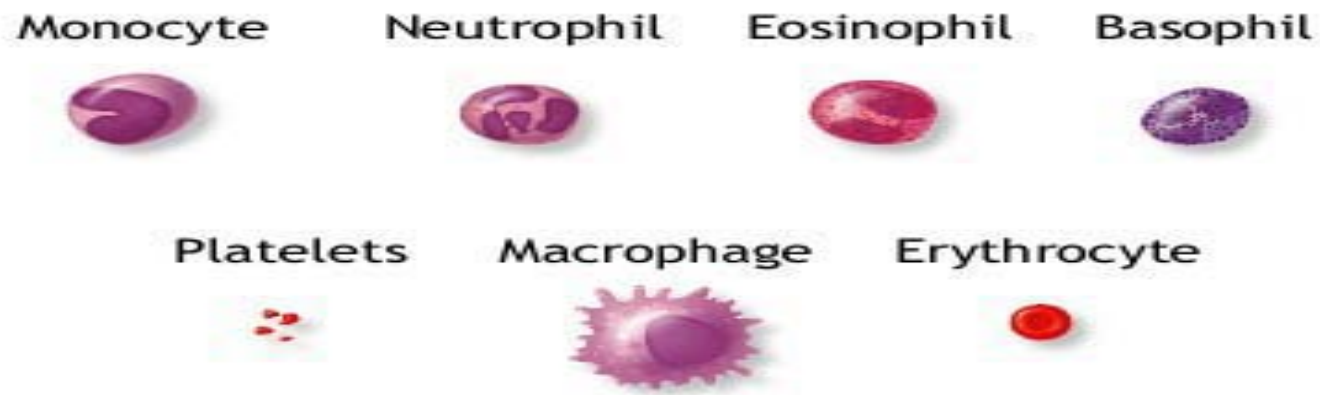
Homeostasis, Feedback Mechanisms & Immunity



Homeostasis

- The steady state of **conditions** inside a living **organism** that allows it to **function** properly
- **Homeostasis** is the dynamic equilibrium of the internal **environment** of the human body
- Achieved by many different internal **control** mechanisms that detect **deviations** and make **corrective** actions
- If there is a **disruption** in any **human** system, there may be a corresponding disruption in **homeostasis**

Homeostasis & Feedback Mechanisms

- **Feedback** mechanisms have **evolved** that maintain homeostasis
- For example:
  - **Changes** in heart rate and respiratory rate in **response** to increased **muscle** activity
  - Involves the **interaction** of multiple body systems
  - Increased muscle activity **requires** muscle cells to use more **oxygen** & **glucose** so that each **cell** can produce enough **ATP** (cell respiration)
  - Circulatory system **responds** with an **increase** in heart rate, which allows **oxygen** and **nutrient** rich **blood** to reach the muscle cells more **quickly**

Homeostasis & Feedback Mechanisms

- Increased **blood** flow also removes **waste** products (CO_2) more **quickly** by bringing the **CO_2** rich blood to the **lungs**
- Respiratory System responds with an **increase** in breathing rate, which allows more **oxygen** to be taken in and more **CO_2** waste to be **released**
- In the lungs, gases are **exchanged.**
- Oxygen **diffuses** into the **blood** and CO_2 diffuses into the **lungs** and is removed from the body during **exhalation**

Homeostasis & Negative Feedback

- **Negative** feedback is a process by which an organism detects, processes and responds to a **change** in a body **constant** so that a **reverse** affect may take place
- This allows the body to stay **constant** (maintain homeostasis)
- **Examples:**

  Temperature Regulation

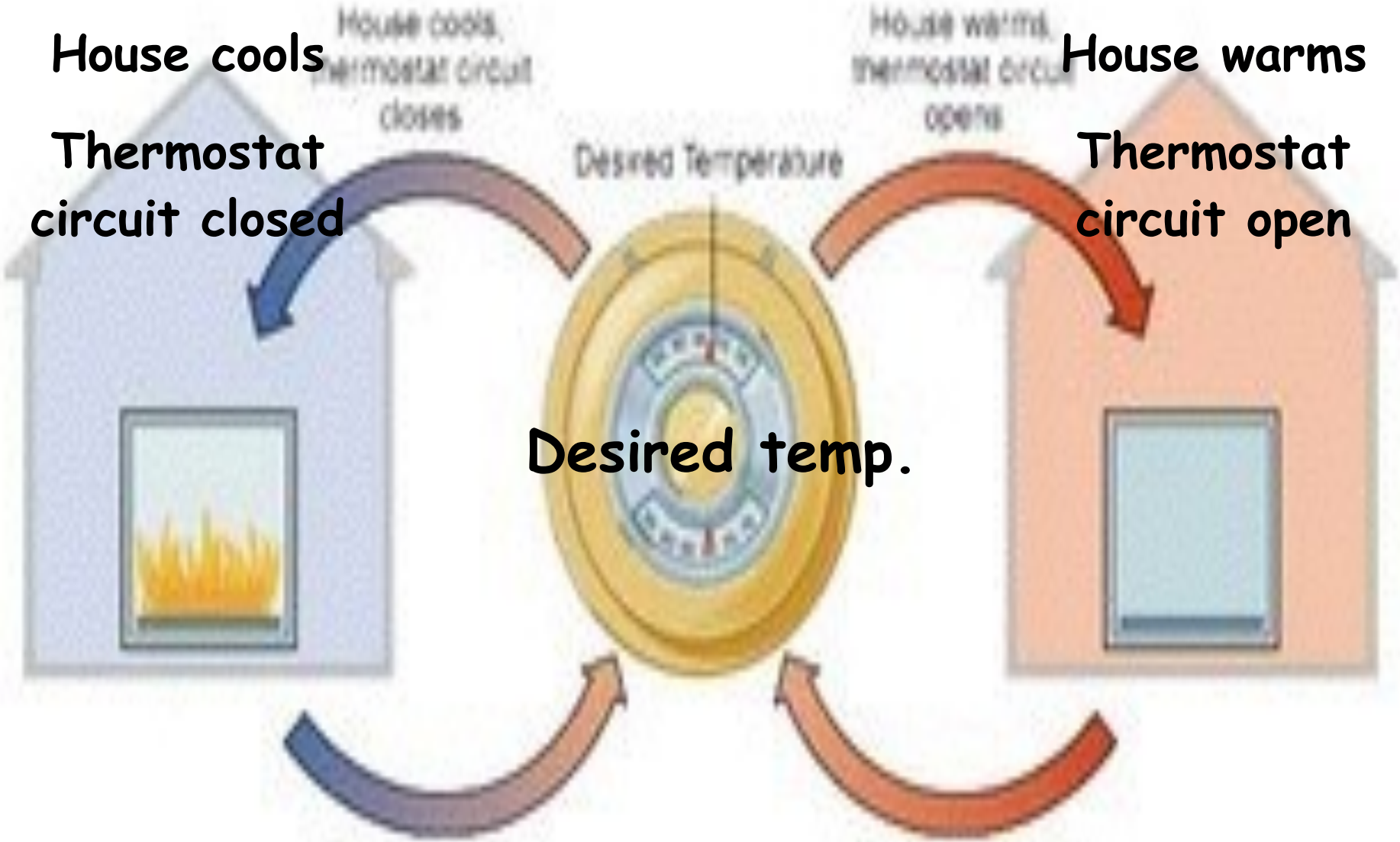
  Regulation of blood sugar levels

  Food and Water Balance

  Regulation of blood calcium levels

Negative Feedback (Home Heating System)

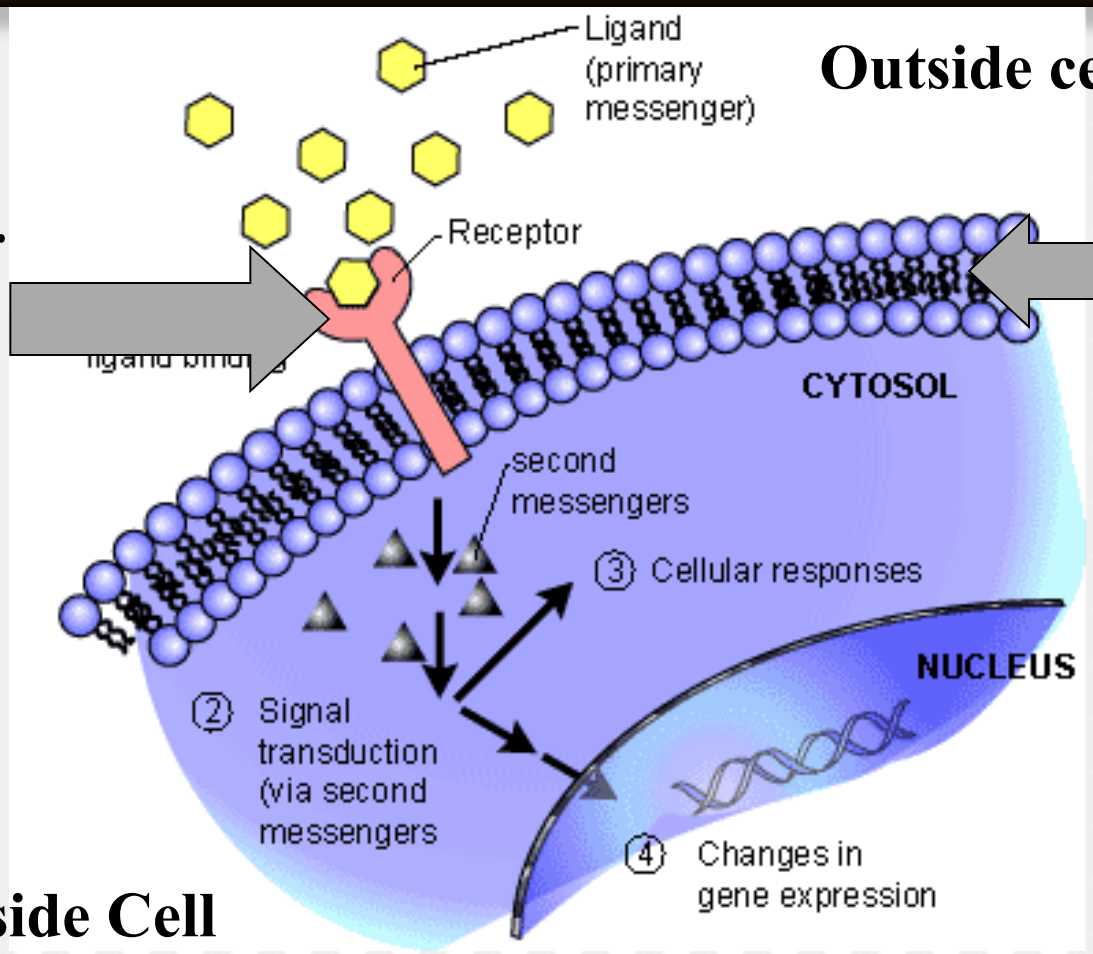
- Thermostat is set at the **desired** temperature
- Furnace turns on and **heats** the house to the desired temp.
- Desired temperature is **reached** and the furnace turns off
- House **cools** & temp. drops **below** the desired temp.
- Furnace turns on and the house **warms** back up to the **desired** temp



Receptor Proteins

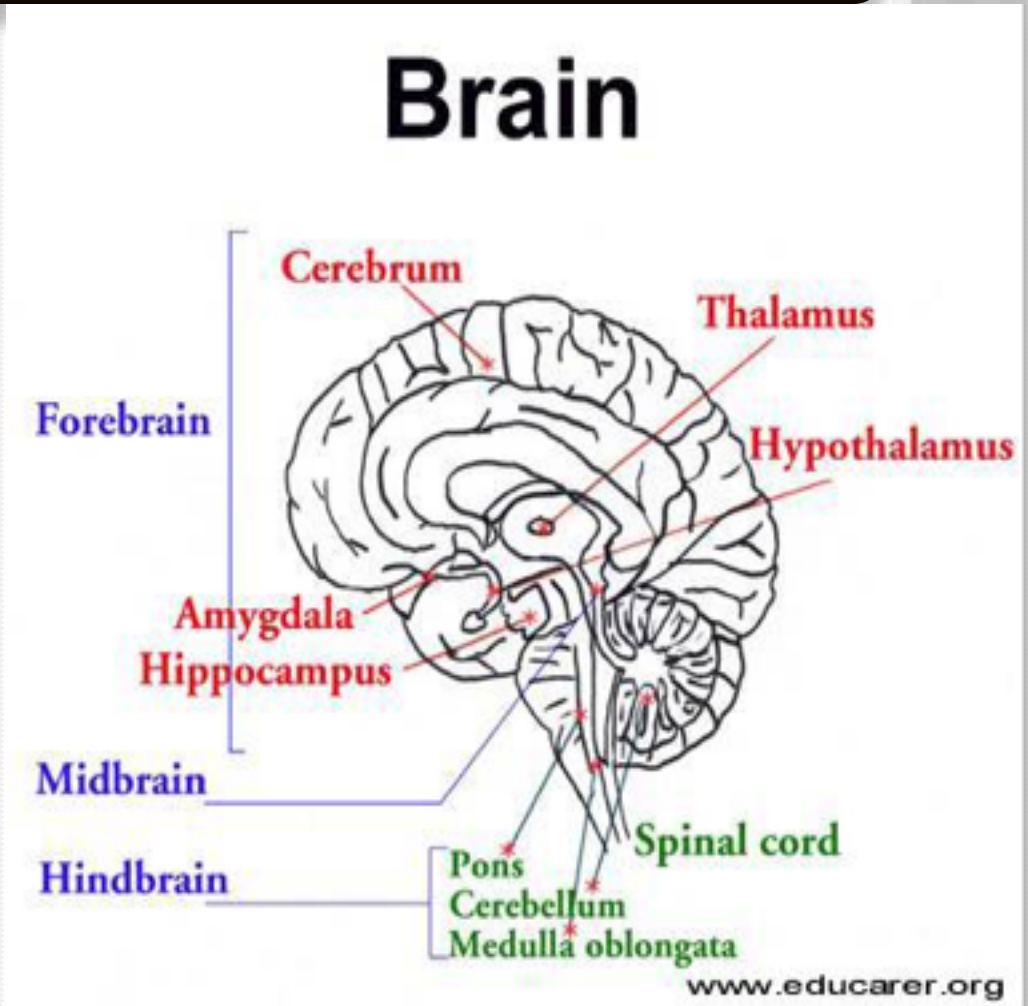
- **1st** part in a negative feedback loop.
- Found on every **cell** in every organ and tissue.
- Send nerve impulses to the **brain** as a result of **environmental** stimulants.
- **For example:** receptor proteins on skin cells detect changes in **temperature** and send that information to the brain
- If nerve or hormone signals are **blocked**, cellular **communication** is disrupted and homeostasis is **affected**

Receptor Protein



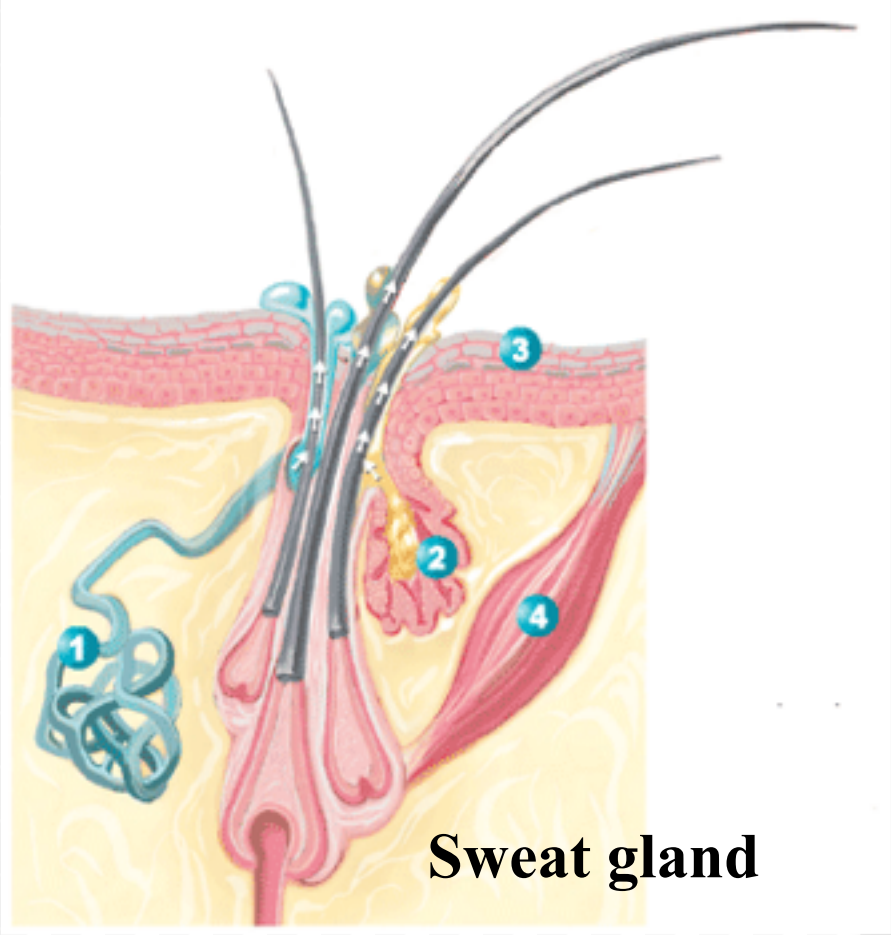
The Brain

- **2nd** part of a negative feedback loop
- Sends **messages** to glands, muscles and/or organs
- **For example:** The brain receives information from the **receptor proteins** and sends a **message** to either the sweat glands or the muscle cells.



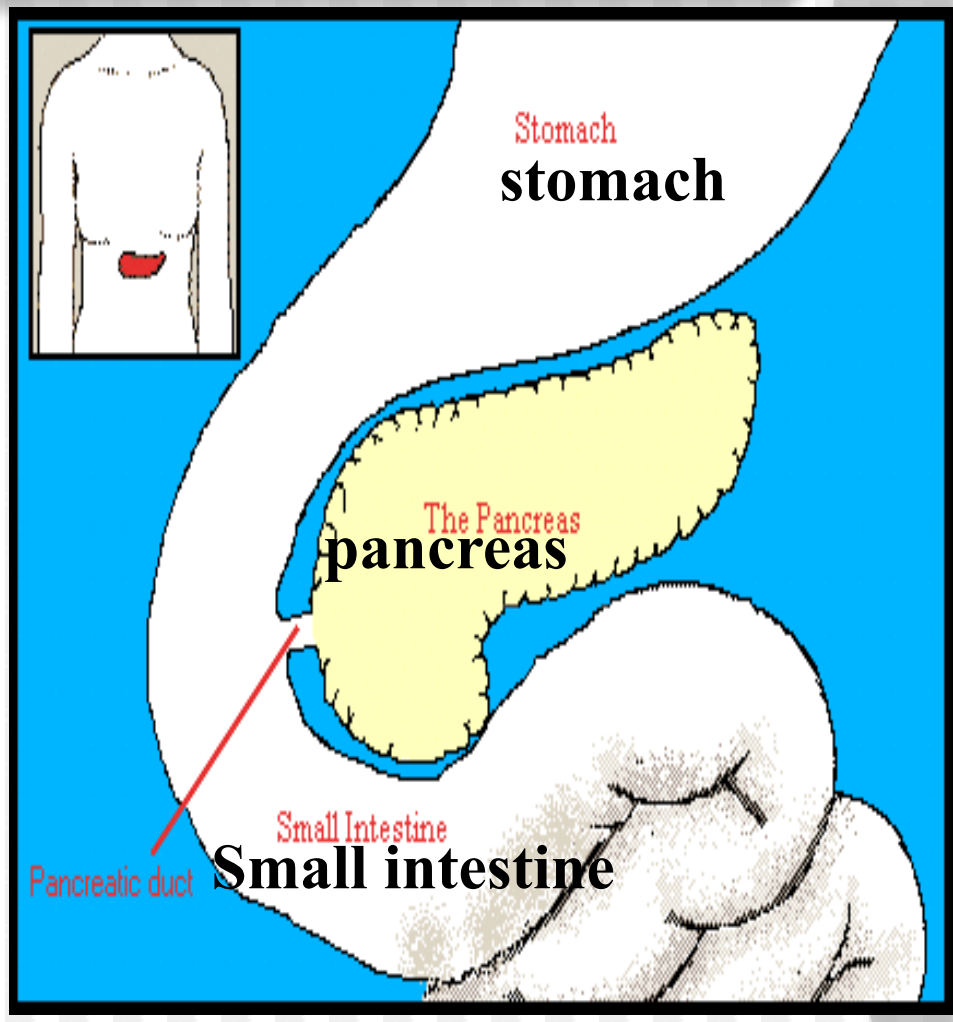
Receptor Proteins

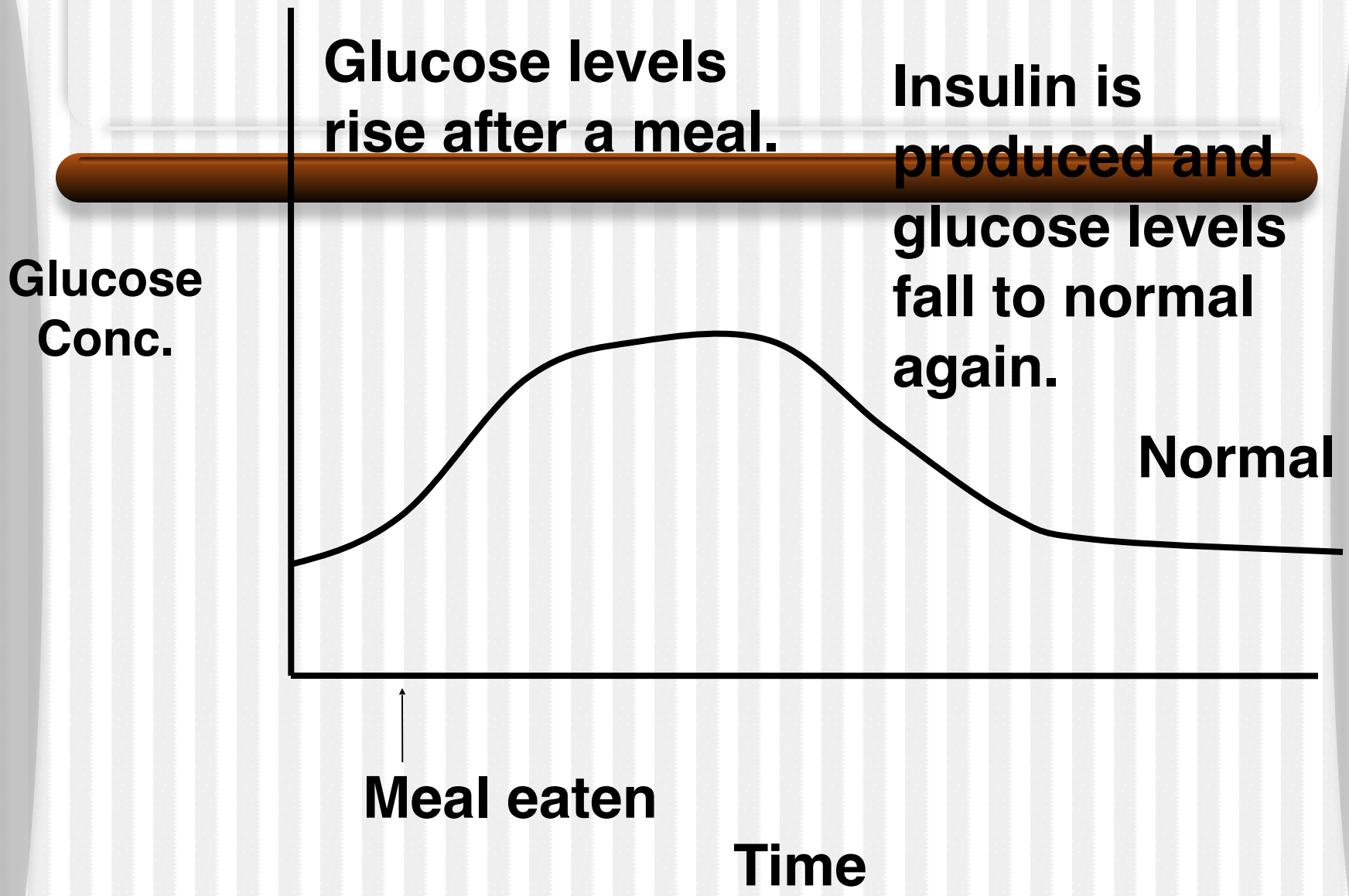
- **3rd** part of a negative feedback loop
- Receptor proteins **receive** info from the brain causing a change in **internal** conditions
- **For example:** Sweat glands enable the body to **cool** off when they produce **sweat** and muscle cells enable the body to **warm** up when they **contract** (shivering)



Negative Feedback: Increase in Blood Glucose Level

- Blood glucose level **increases** (after eating)
- Brain sends message to **pancreas** to release **insulin** into the blood
- Insulin allows body **cells** to absorb **glucose**
- Insulin also **stimulates** the **liver** to convert some glucose into **glycogen** (a form of stored energy)
- Blood glucose level **decreases** & the body returns to **homeostasis**

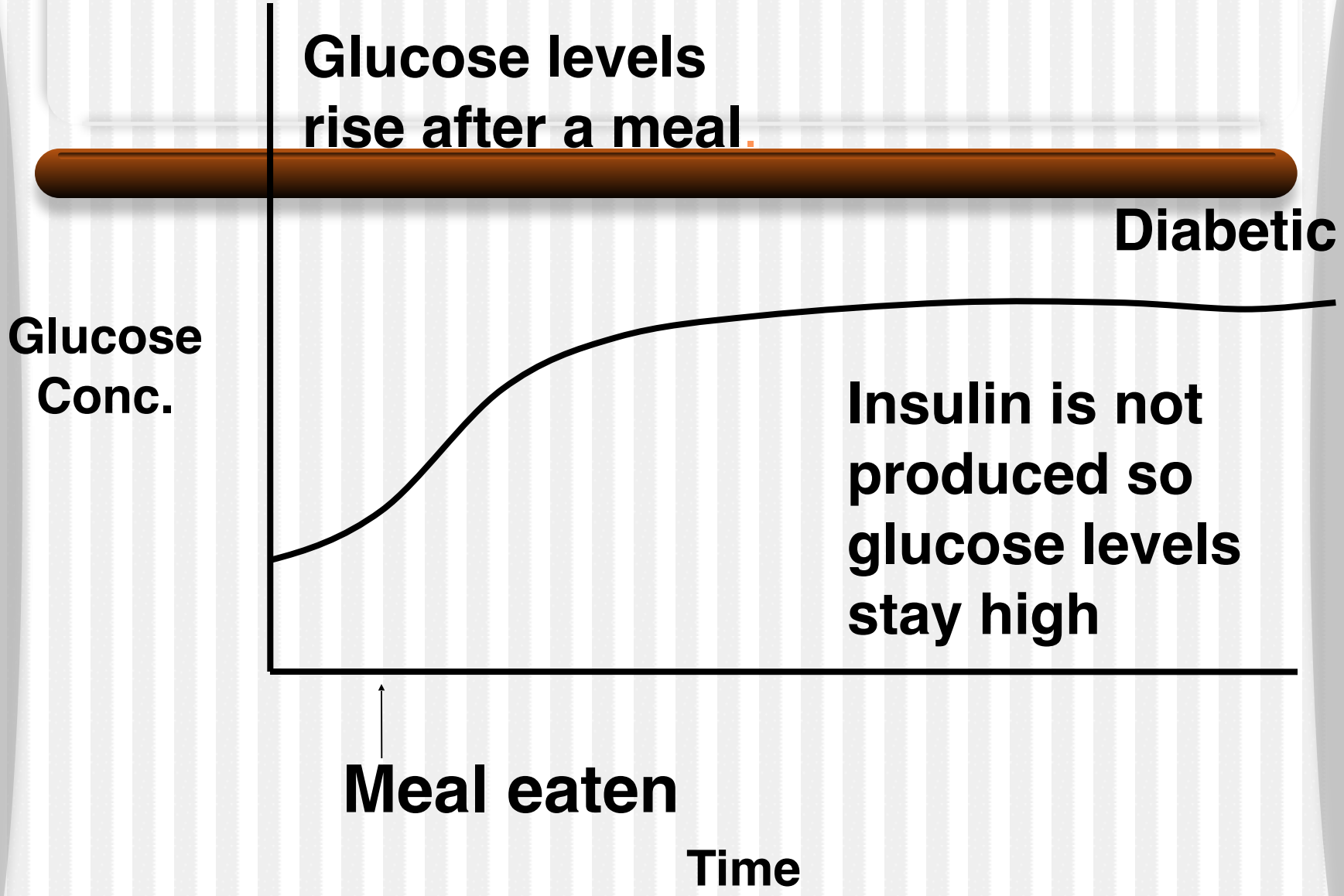



Glucose levels rise after a meal.
Insulin is produced and glucose levels fall to normal again.
Glucose Conc.
Normal
Meal eaten
Time

Diabetes

- Some people cannot produce **insulin**
- When they eat food, the **glucose** levels in their blood cannot be **reduced.**
- This condition is known as **TYPE 1 DIABETES.**
- Diabetics have to **inject** insulin into their **blood**, continually **monitor** their blood glucose levels, and pay close attention to their **diet**
- Diabetes can lead to other **health** complications including, glaucoma & poor **circulation**

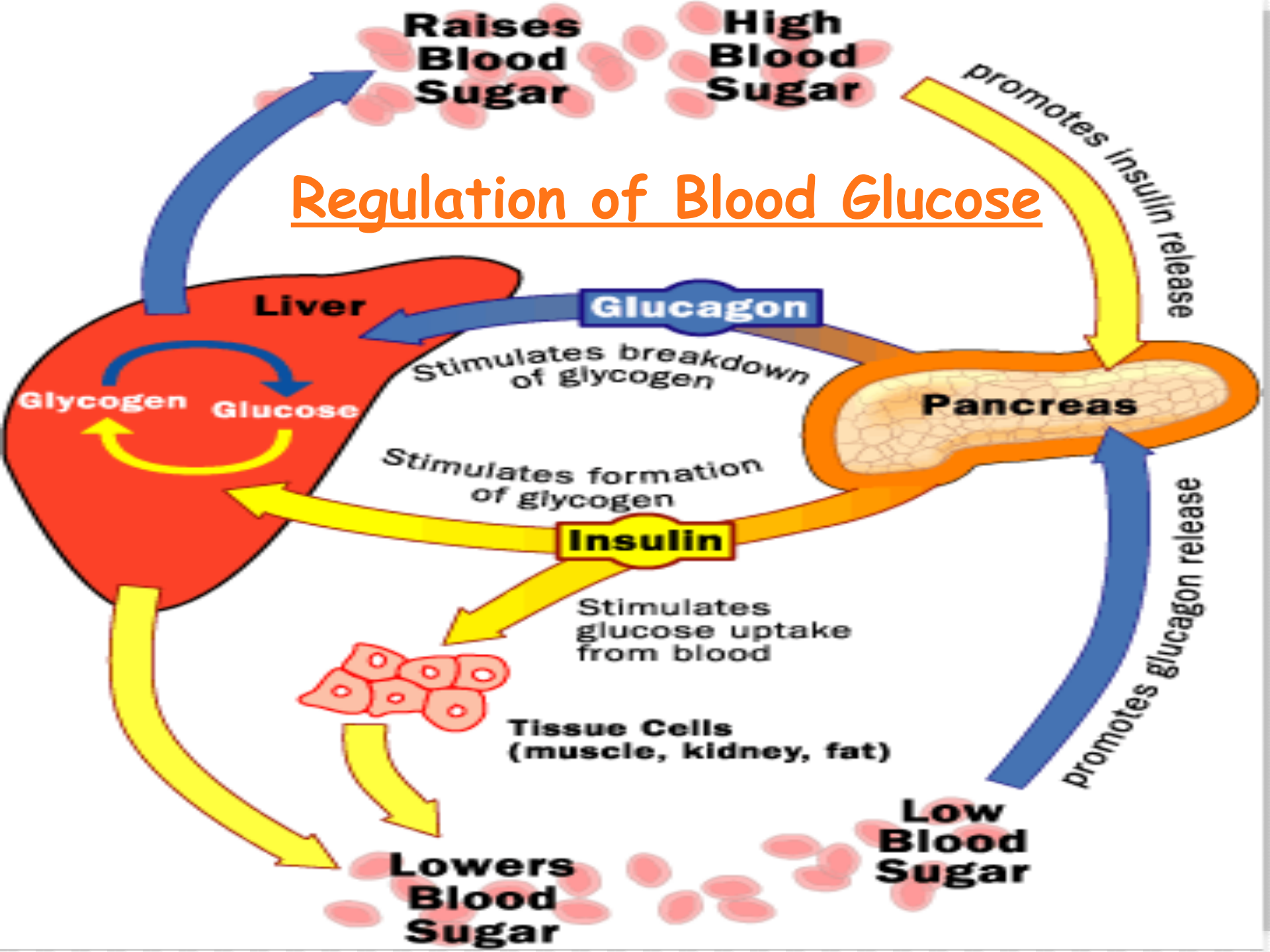
Glucose levels rise after a meal.



Negative Feedback: Decrease in Blood Glucose Level

- Blood glucose level **decreases** (after not eating for awhile)
- **Brain** sends a message to the **pancreas** to release **glucagon** (a type of protein) into the blood
- **Glucagon** stimulates the **liver** to convert glycogen (stored energy) into **glucose**
- Glucose level in the blood **increases** & the body returns to **homeostasis**

Regulation of Blood Glucose



Body Systems Involved in Blood Glucose Regulation

- **Endocrine System** -produces insulin and glucagon (hormones/proteins)
- **Circulatory System** -transports hormones (insulin & glucagon), glucose & glycogen to cells in the body
- **Nervous System** -stimulates a response by sending messages to and receiving messages from cells in the body (blood glucose level increases or decreases as a result)

Immunity & Disease

- **Homeostasis** in an organism is constantly **threatened**
- **Failure** to respond effectively can result in **disease** or **death**
- **Disease:** any **change** (not including injury) that **disrupts** the normal **function** of the body
- Viruses, bacteria, fungi, and other parasites may **infect plants** and **animals** and **interfere** with normal life functions

Pathogens

Defined: **disease** causing organisms

1. **Bacteria:** single-celled organisms that can **interfere** with **normal** life functions resulting in **disease** or **death**
2. Two ways bacteria cause disease

   a. give off **toxins** & **poison** the organism, killing healthy **tissue** (ex. strep throat, food poisoning, etc.)

   b. **invade** cells & **destroy** them from within (ex. Lyme disease)

Common Diseases caused by Bacteria

Disease	Pathogen (bacteria)
Tooth Decay	*Streptococcus mutans*
Lyme Disease	*Borrelia bugdorferi*
Tetanus	*Clostridium tetani*
Tuberculosis	*Mycobacterium tuberculosis*
Salmonella	*Salmonella enteritidis*
Pneumonia	*Streptoccus pneumoniae*

Antibiotics, such as penicillin, are used to treat many bacterial diseases

Viruses

- Particles composed of **nucleic acid** and **protein**
- **Borderline** between living & nonliving
- **Reproduce** when they invade living **cells**
- **Host** cells are **destroyed** in the process

How do they enter the body?

- **inhalation** of airborne viruses
- **consumption** of contaminated food & water
- **direct contact** with infected tissues

Viral Infections

- Viruses must **bind** precisely to **proteins** on the cell's surface
- Once inside the cell it uses the cell's **DNA** to reproduce
- This makes them highly **specific** to the **cells** they **infect**
- Plant viruses only infect **plants**
- Most animal viruses only **infect** certain **species** of animals
- Bacterial viruses (bacteriophages) **infect** only certain types of **bacteria**

Viral Diseases in Humans

- Common cold
- Influenza (flu)
- Measles, mumps, rubella
- Hepatitis
- Polio
- Smallpox
- Rabies
- Herpes
- AIDS
- Etc.

Viruses

- Viral diseases can **spread** quickly
- Antibiotics **cannot** be used to **treat** viral infections
- Most viral infections are **acute**, meaning once they "run their course" you are no longer **infected**
- Others are **chronic**, meaning you are **always** infected, able to **pass** it on to **others**, but may not show **symptoms** (HIV, herpes, HPV)

Fungi

- Organisms made of either one or many **cells**
- Eat by **absorbing** organic substances
- **Yeasts** and **molds** are included in this category
- Examples of fungal infections in humans:

  Athlete's Foot & **Ringworm**
- **Antibiotics** and **fungicides** are used to treat fungal infections

Parasites

- Some animals and single-celled organisms that **survive** by **living** and **feeding** on other **organisms**
- They invade the body through **skin** (insect bites) or through the **consumption** of contaminated **food** & **water**
- Parasites include but are not limited to:

  leeches

  tapeworms

  heartworm (found in dogs & cats)
- **Malaria** is a disease caused by a single-celled **parasite** and is **transmitted** to humans by **mosquitoes**

The Immune System

- the body's primary **defense** against **pathogens.**
- consists of **nonspecific** and **specific** defenses against infection
- the immune system has the **ability** to **distinguish** "self" from "non-self

Non-Specific Defenses

- Guard against **all** infections
- **First** line of defense:

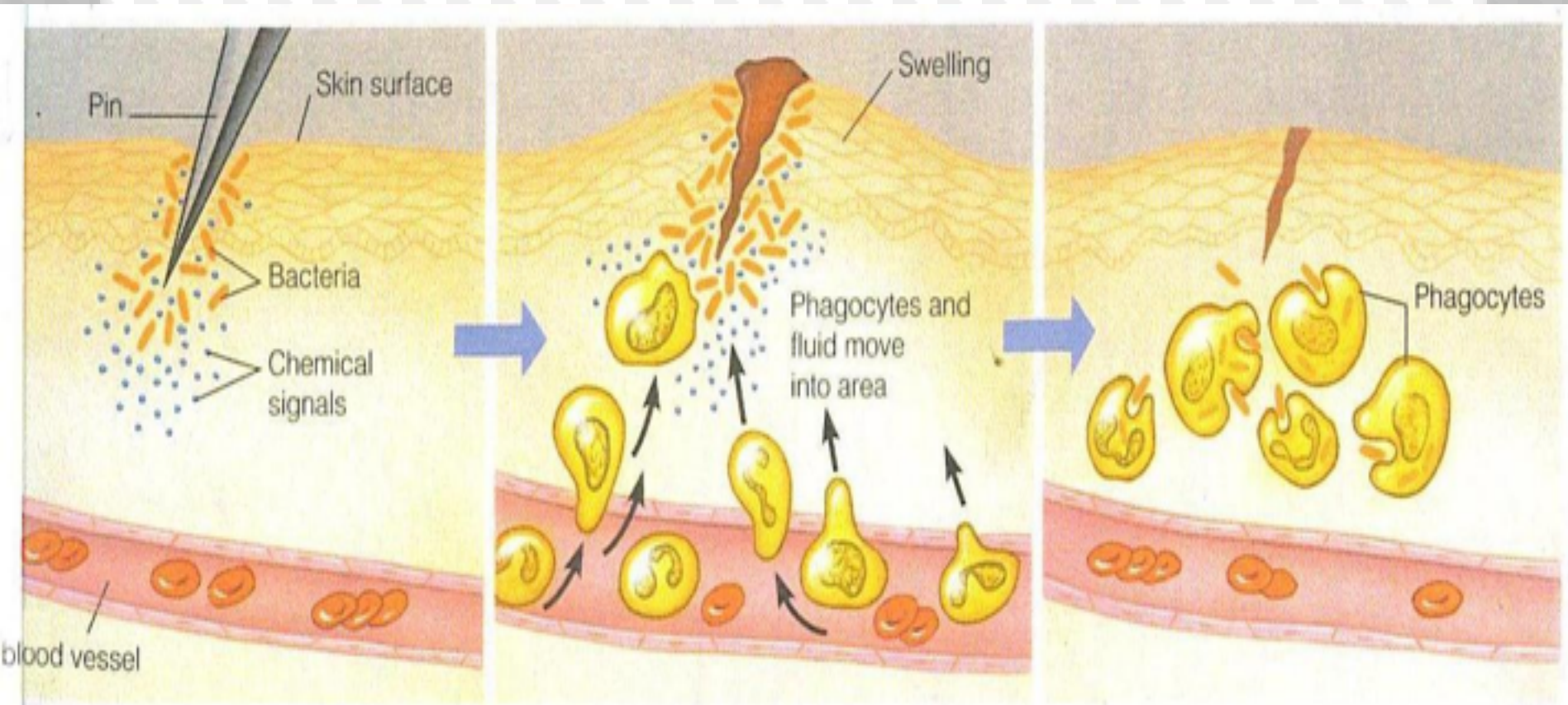
1. **Skin**: most important (acts as a barrier)
2. **Mucus**
3. **Sweat**
4. **Tears**

Mucus, sweat and tears contain **enzymes** that break down the **cell wall** of many bacteria

Nonspecific Defenses

- **2nd** line of defense: **Inflammatory** response
- Body's **reaction** to tissue damage
- Blood vessels **expand** allowing more **blood** to enter the **infected** area
- white blood cells enter the infected **tissue** and **attack** the **foreign** substances
- **Fever** (raise in body temperature) results from the body's attempt to **fight** off **infection**
- Many **pathogens** can only survive within a narrow range of temperature and are killed as a result of a fever

Inflammatory Response



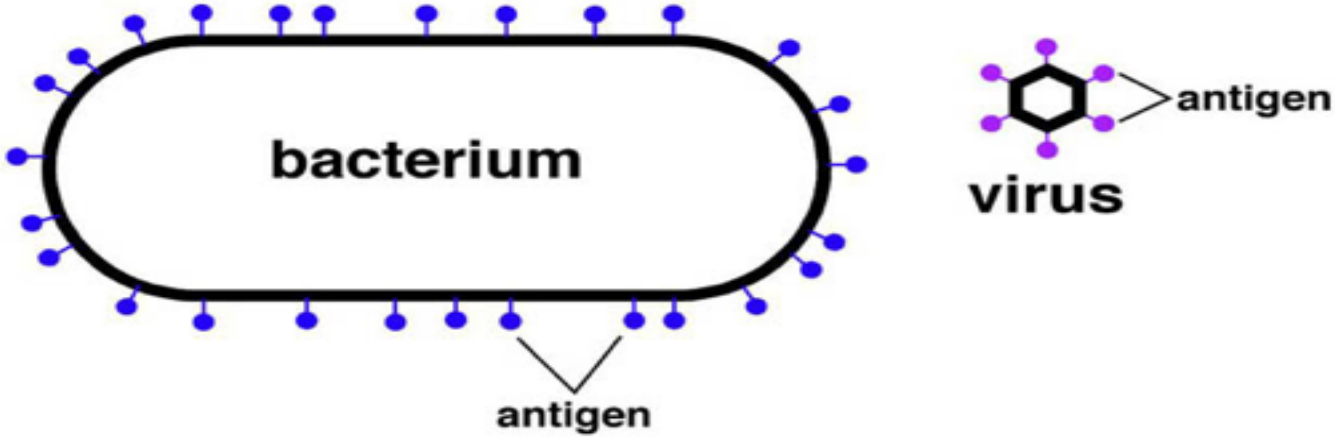
Tissue injury; release of chemical signals such as histamine

2 Dilation and increased leakiness of local blood vessels; migration of phagocytes to the area

3 Phagocytes (macrophages and neutrophils) consume bacteria and cell debris; tissue heals

Specific Defenses-Immune Response

- track down **pathogens** that have gotten through the body's **nonspecific** defenses
- **Antigen:** on the outer **surface** of **pathogens**; trigger an **immune** response

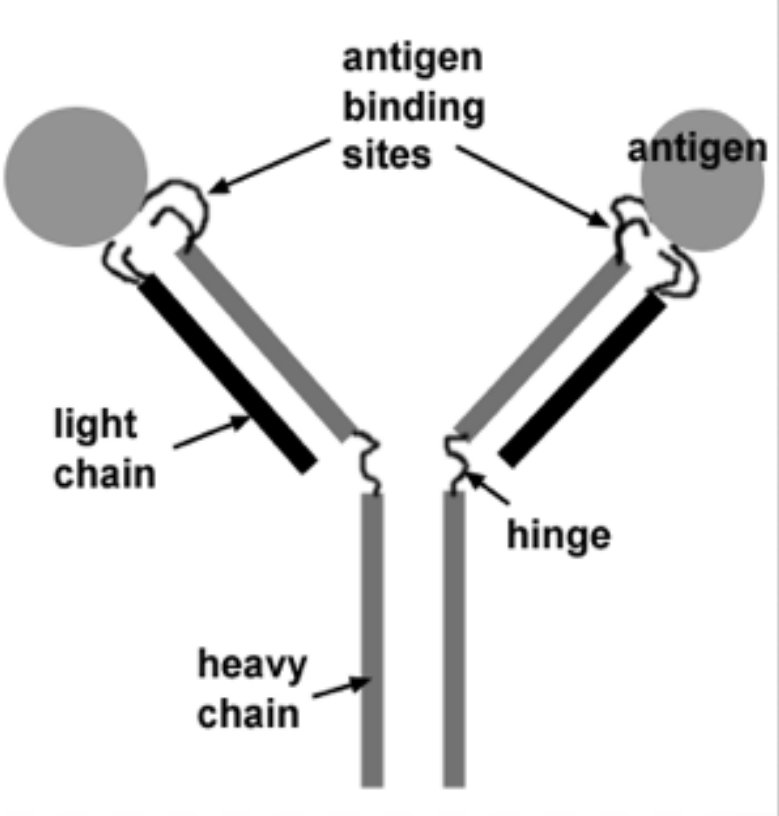


Immune Response

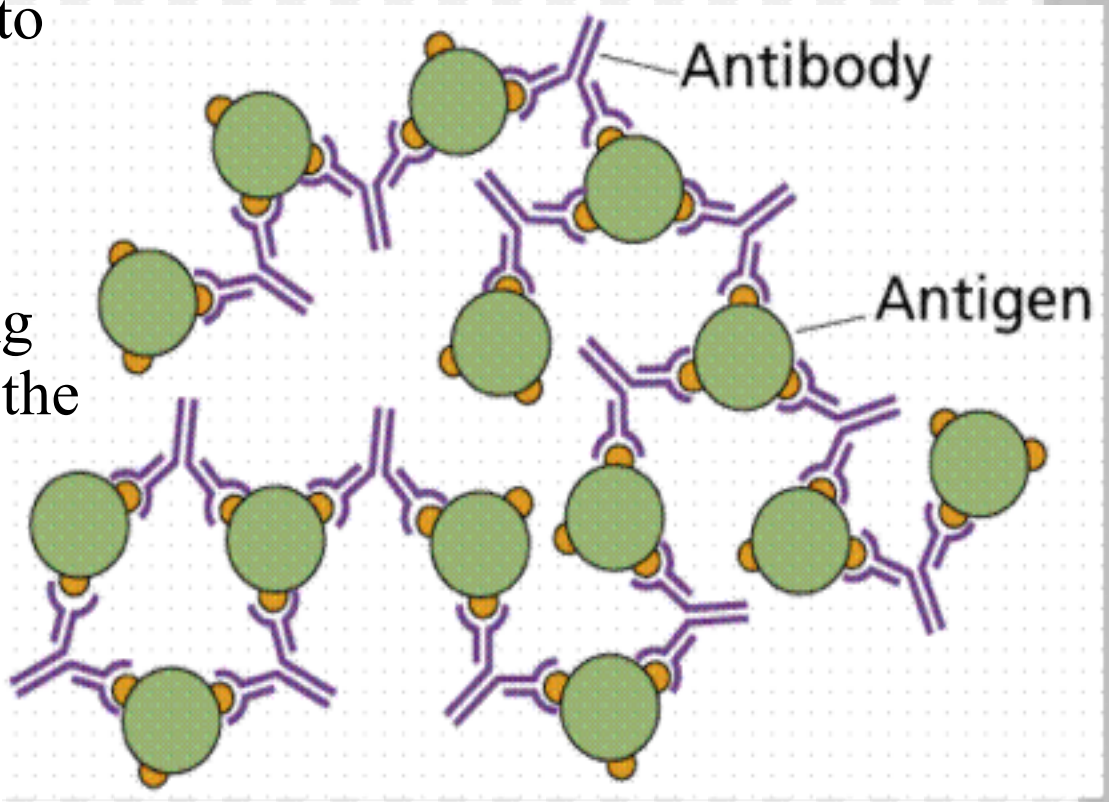
1. Some white blood cells produce **antibodies** to destroy **pathogens** (B-cells)

   - **Antibody: proteins** that bind to **antigens** & either **destroy** the pathogen or **mark** pathogens for **destruction** by other white blood cells

   - **Memory cells remain** in the body and are **capable** of quickly **producing** more **antibodies** to fight off later invasions of the **same** pathogen



- Pathogens are being **destroyed** by **antibodies**
- Antibodies are **attaching** to the antigen's **marker-receptors**
- Notice the **shape** of the **antibody's** antigen binding site **matches** the shape of the **antigen**
- These **pathogens** are no longer able to **enter** other cells or **reproduce.**



Immune Response

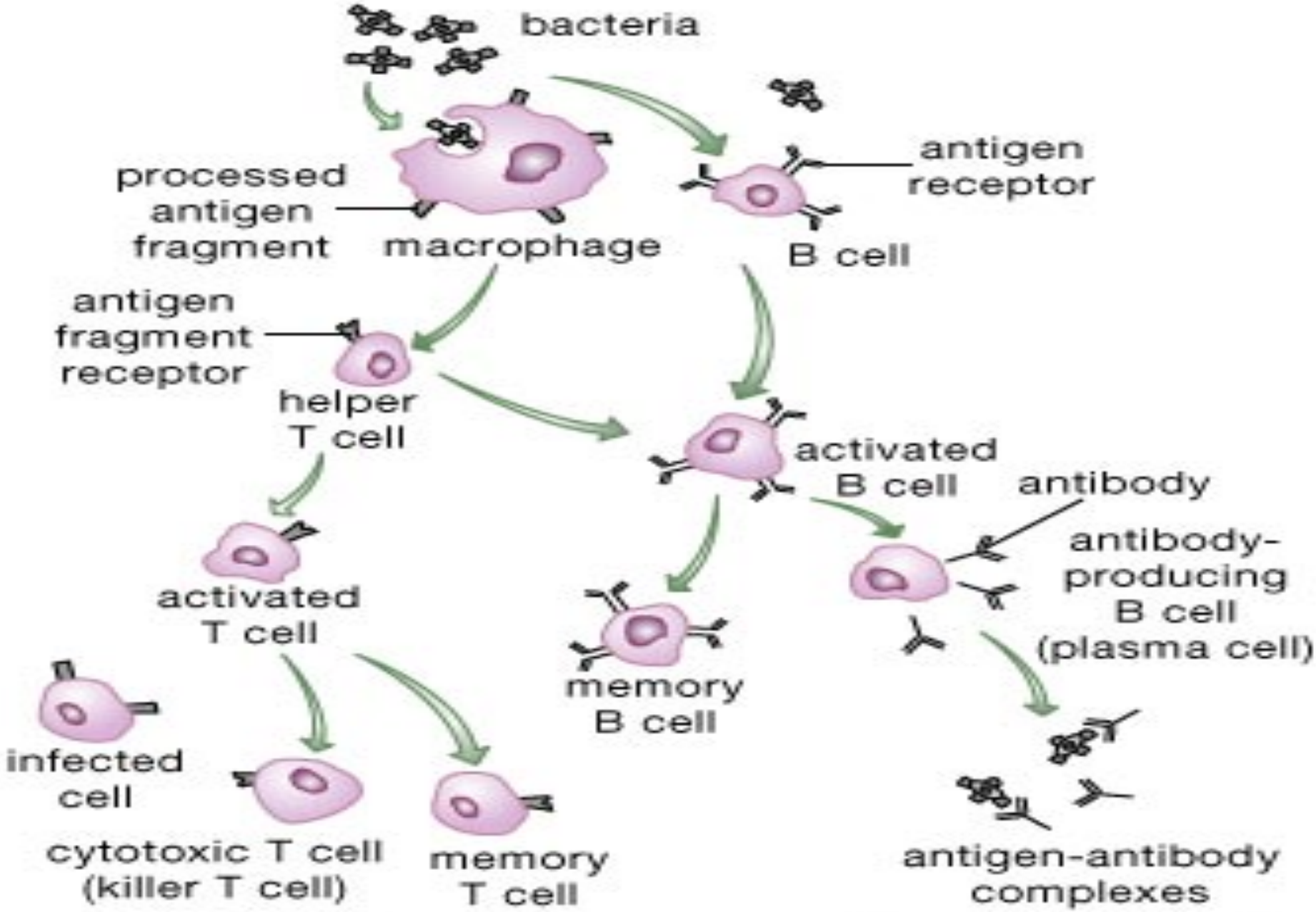
1. Some white blood cells are **specialized** to **surround** and **engulf** invading pathogens that are recognized as a threat (macrophages)
2. Some cells (T-cells) are specialized to **attach** to an **antigen** bearing cell **directly**

   T-cells: bind to **activated** white blood cells (cells that have **engulfed** a pathogen) and become **helper T cells**

   Helper T-cells: **activate** killer T-cells & B-cells

   Killer T-cells: bind to the **infected** cells, **rupturing** their cell membrane and **destroying** them

T-cells make organ transplants difficult by **attacking** the **cells** of the **transplanted** organ. This can lead to organ **rejection.** To avoid organ rejection, transplant patients are given **drugs** to reduce the **effectiveness** of their **immune** system.



Permanent Immunity

- once the body has been **exposed** to a pathogen, millions of **memory** B & T cells remain, capable of producing **specific** antibodies to the **pathogen**
- **For example:** Chicken pox

Active Immunity

- immunity produced by a **vaccine**
- the body makes its own **antibodies** in response to an **antigen** bearing pathogen
- Vaccinations use **weakened** pathogens (or parts of them) to **stimulate** the immune system to **react**
- When **injected** with a vaccine, the body reacts like it had been invaded by a **live** pathogen
- This reaction **prepares** the body to **fight** subsequent invasions by the **same** pathogen by producing **cells** capable of producing **antibodies** against that pathogen (memory cells) that remain in the body for **years**
- **Examples:** MMR, chicken pox, polio, DTAP, etc.

Passive Immunity

- the body is **injected** with **antibodies** that were **produced** by **another** organism
- **Antibodies** that are passed from a **mother** to her **child** through **breast milk**
- This immunity usually lasts **several** weeks, because the body **destroys** the borrowed **antibodies** over **time.**

Autoimmune Disease

- results when the immune system makes a **mistake** and attacks the body's own **cells**

Example:

- **Type I diabetes (juvenile):** the body **attacks** cells in the **pancreas** that produce **insulin** so that the body no longer **produces** insulin

HIV & AIDS

- **Acquired Immune Deficiency Syndrome (AIDS)-** a **viral** infection caused by **HIV** (Human Immunodeficiency Virus)
- HIV **attacks** and **destroys** helper **T-cells** leaving the body **unable** to fight off **infection**
- People with **AIDS** often **die** of **infections** that a **healthy** immune system would easily destroy

Allergies

- A **reaction** caused by the body's immune responses to usually **harmless** environmental **substances**
- Examples include certain **foods**, **pollen,** and chemicals from **insect** bites
- **Allergens** stimulate the immune system to release **histamines**
- **Histamines** are responsible for **symptoms** like a runny nose, sneezing, watery eyes, itching/rash, and swelling
- **Antihistamines** (Claritin, Allegra, Benadryl, etc.) are drugs used to **counteract** the effects of the histamines and **reduce** allergy symptoms

Other Factors that can cause Disease

- Inheritance of specific **genes**
- Gene **mutations** leading to uncontrolled **cell** division (cancer)
- **Exposure** to toxic substances
- Poor **nutrition**
- Organ **malfunction**
- **Personal** behavior (smoking, drinking alcohol, etc.)

Some effects show up immediately while others may not show up for years

Biological Research

Diagnosing Disease	•Culturing bacteria from **infected** person to determine **specific** pathogen •X-rays, CT scans, MRI, genetic testing, ultrasound, etc.
Preventing & controlling disease	•Improved **sanitation** •**Sterilizing** wounds & equipment •Controlling **populations** of disease-carrying organisms •**Treating** food & beverages •**Vaccinations** •Identifying **dangers** of **risky** behaviors

Biological Research

Treating & curing disease	•**Antibiotics** & other **drugs** to kill pathogens •Medical **procedures** including surgery & laser techniques to remove **damaged/diseased** tissue from the body