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**.
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
Desired temp.

House cools
Thermostat circuit closed

House cools, thermostat circuit closes

Desired Temperature

House warms
Thermostat circuit open

Furnace turns off
House cools

Furnace turns on, house warms

House warms
Furnace turns on

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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

Outside cell

Cell membrane

Receptor Protein

Ligand (primary messenger)

Receptor

Inside Cell

CYTOSOL

NUCLEUS

Signal transduction (via second messengers)

Cellular responses

Changes in gene expression
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 Concentration

Meal eaten

Time

Normal
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. Insulin is not produced so glucose levels stay high.
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

<table>
<thead>
<tr>
<th>Disease</th>
<th>Pathogen (bacteria)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth Decay</td>
<td><em>Streptococcus mutans</em></td>
</tr>
<tr>
<td>Lyme Disease</td>
<td><em>Borrelia burgdorferi</em></td>
</tr>
<tr>
<td>Tetanus</td>
<td><em>Clostridium tetani</em></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td><em>Mycobacterium tuberculosis</em></td>
</tr>
<tr>
<td>Salmonella</td>
<td><em>Salmonella enteritidis</em></td>
</tr>
<tr>
<td>Pneumonia</td>
<td><em>Streptococcus pneumoniae</em></td>
</tr>
</tbody>
</table>

**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
- **Yeast**s 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

1. **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

- **Skin surface**
- **Bacteria**
- **Chemical signals**
- **Swelling**
- **Blood vessel**
- **Phagocytes**
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
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 **malfucntion**
- **Personal** behavior (smoking, drinking alcohol, etc.)

Some effects show up **immediately** while others may not show up for **years**
### Biological Research

<table>
<thead>
<tr>
<th>Diagnosing Disease</th>
<th>Preventing &amp; controlling disease</th>
</tr>
</thead>
</table>
| • Culturing bacteria from **infected** person to determine **specific** pathogen  
  • X-rays, CT scans, MRI, genetic testing, ultrasound, etc. | • 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