**\*CELL PHYSIOLOGY**

**\*CELLS ARE THE BASIC UNIT OF LIFE**

**\*\*Functional Organization of the Human Body and Control of the “Internal Environment”**

The goal of physiology is to explain the physical and chemical factors that are responsible for the origin, development, and progression of life.

In *human physiology,* we attempt to explain the specific characteristics and mechanisms of the human body that make it a living being.

The basic living unit of the body is the cell. Each organ is an aggregate of many different cells held together by intercellular supporting structures.

Each type of cell is specially adapted to perform one or a few particular functions.

Although the many cells of the body often differ markedly from one another, all of them have certain basic characteristics that are alike.

******

Further, the general chemical mechanisms for changing nutrients into energy are basically the same in all cells, and all cells deliver end products of their chemical reactions into the surrounding fluids.

Almost all cells also have the ability to reproduce additional cells of their own kind.

**\*Extracellular Fluid, The “Internal Environment”**

About 60% of the adult human body is fluid, mainly a water solution of ions and other substances.

Although most of this fluid is inside the cells and is called *intracellular fluid,* about one third is in the spaces outside the cells and is called *extracellular fluid.* This ECF is in constant motion throughout the body.

It is transported rapidly in the circulating blood and then mixed between the blood and the tissue fluids by diffusion through the capillary walls.

In ECF, the ions and nutrients needed by the cells to maintain cell life.

Thus, all cells **live** in essentially the same environment- the ECF. For this reason, the ECF is also called the *internal environment* of the body*.*

Cells are **capable of living, growing**, and **performing** their special **functions** as long as the proper concentrations of oxygen, glucose, different ions, amino acids, fatty substances, and other constituents are available in this internal environment.

**\*\*Differences Between ECF and ICF**

The **ECF** contains **large** amounts of ***sodium, chloride,***and ***bicarbonate ions***plus **nutrients** for the cells, such as ***oxygen, glucose, fatty acids****,* and ***amino acids****.* It **also** contains ***carbon dioxide***that is being **transported** from the cells to the **lungs** to be **excreted**, plus other **cellular waste products** that are being **transported** to the **kidneys** for excretion.

The **ICF** differs **significantly** from the **ECF**; specifically, it contains **large** amounts of ***potassium, magnesium,***and ***phosphate ions***instead of the sodium and chloride ions found in the **ECF**.

**\*\*“Homeostatic” Mechanisms of the Major Functional Systems**

**Homeostasis:**

The term ***homeostasis***is used by physiologists to **mean *maintenance of nearly constant conditions in the internal environment****.*

Essentially **all organs and tissues** of the body **perform** **functions** that help **maintain these constant conditions**.

**\*ECF Transport and Mixing System - The Blood Circulatory System**

**ECF** is **transported** through all **parts** of the body in **two stages**:

The **first** stage is **movement of blood** through the body in the **blood vessels**.

The **second** is movement of **fluid** between the **blood capillaries** and the ***intercellular spaces***between the **tissue cells**.

The **walls** of the **capillaries** are **permeable** to **most molecules** in the **plasma** of the blood, with the **exception** of the **large** plasma protein **molecules**.

Therefore, **large** amounts of **fluid** and **its dissolved** constituents ***diffuse* back** and **forth between** the **blood** and the **tissue spaces**. This **process** of diffusion is **caused** by **kinetic motion** of the **molecules** in both the **plasma** and the **interstitial fluid**.

**\*\*Origin of Nutrients in the ECF**

**\*Respiratory System:**

Each time the blood **passes** through the **body**, it **also** flows through the **lungs**.

The blood **picks up oxygen** in the **alveoli**. The **membrane** between the **alveoli** **and the lumen** of the pulmonary **capillaries**, the ***alveolar membrane****,* is **only 0.4 to 2.0** micrometers thick, and **oxygen diffuses** by molecular motion through **the pores** of this membrane **into the blood** in the **same manner** that **water and ions diffuse** through **walls of the tissue capillaries**.

**\*Gastrointestinal Tract:**

A **large portion** of the **blood** **pumped** by the heart also **passes** through the **walls** of the **GIT**.

Here **different dissolved nutrients**, including ***carbohydrates, fatty acids,***and ***amino acids,***are **absorbed** from the ingested food **into** the **ECF** of the blood.

**\*Liver and Other Organs That Perform Primarily Metabolic Functions:**

**Not all** substances **absorbed** from the **GIT** **can be used** in their absorbed form **by the cells**. The **liver** changes the **chemical compositions** of many of these **substances** to more **usable forms**, and other tissues of the body such as **fat** cells, **GIT** **mucosa**, **kidneys**, and **endocrine** glands **helps modify** the absorbed substances or **store them** until they are needed.

**\*Musculoskeletal System:**

Sometimes the **question** is asked, how does the musculoskeletal system **fit** into the **homeostatic** functions of the body? The answer is obvious and simple: Were it not for the muscles, **the body** **could not move** to the appropriate **place** at the appropriate **time to obtain** the foods **required for nutrition**. The musculoskeletal system **also provides motility** for **protection against adverse surroundings**, **without which** the **entire body**, along with its homeostatic mechanisms, **could be destroyed** instantaneously.

**Removal of Metabolic End Products**

**\*Removal of Carbon Dioxide by the Lungs:**

**At the same time** that **blood picks** up **oxygen** in the lungs, ***carbon dioxide* is released** from the **blood into** the lung **alveoli**; the respiratory movement of **air into and out of the lungs** carries the carbon dioxide **to the atmosphere**.

Carbon dioxide is the most **abundant** of all the end products of metabolism.

**\*Kidneys:**

**Passage** of the blood **through the kidneys removes from the plasma** most of the **other** substances besides **carbon dioxide** that are not needed by the cells. **These** substances **include different end products** of cellular **metabolism**, such as **urea and uric acid**; they **also include excesses of ions and water** from the food **that might have accumulated** in the **ECF**.

The **kidneys** perform their **function** by:

**1-Filtering** large quantities of **plasma** through the **glomeruli** **into the tubules**.

**2-Reabsorbing** **into** the **blood** those **substances needed** by the body, such as **glucose, amino acids, appropriate amounts of water**, and **many of the ions**. Most of the **other substances** that are **not needed** by the body, especially the metabolic end products such as **urea**, are **reabsorbed poorly** and **pass through the renal tubules into the urine**.

**Regulation of Body Functions**

**\*\*Nervous System:**

The nervous system is composed of three major parts:

1 - The ***sensory input portion****.*

2 - The ***central nervous system***(or ***integrative portion***).

3 - The ***motor output portion****.*

**Sensory receptors** **detect the state of the body or the state of the surroundings**. For instance, **receptors** in the **skin apprise** one whenever an **object touches** the skin at any point.

The **CNS** is **composed** of the **brain and spinal cord**. The **brain** can **store information, generate thoughts, create ambition**, and **determine reactions** that the **body performs** in **response** to the **sensations**. Appropriate **signals** are then **transmitted** through the **motor output portion** of the nervous system to **carry out one’s desires**.

A **large segment** of the **NS** is called the ***autonomic system****.* It **operates** at a **subconscious level** and **controls** many **functions** of the **internal organs**.

**\*\*Hormonal System of Regulation:**

There are **eight** major ***endocrine glands***that **secrete chemical** substances called ***hormones****.* Hormones are **transported** in the **ECF** to **all** parts of the **body** to **help regulate** cellular **function**. For instance, **thyroid** hormone **increases the rates** of most **chemical reactions** in all cells, thus helping **to set** the **tempo** of bodily activity. **Insulin** **controls glucose** metabolism; **adrenocortical** hormones control **sodium ion, potassium ion**, and **protein metabolism;** and **parathyroid** hormone controls **bone calcium and phosphate**.

Thus, the **hormones** are a **system of regulation** that **complements** the **NS**. The **NS** **regulates** mainly **muscular and secretory activities** of the body, whereas the **hormonal system regulates** many **metabolic functions**.

Thus, the **hormones** are a **system of regulation** that **complements** the **NS**. The **NS** **regulates** mainly **muscular and secretory activities** of the body, whereas the **hormonal system regulates** many **metabolic functions**.

**\*\*Reproduction:**

Sometimes **reproduction** is **not considered** a **homeostatic** function. It does, however, **help maintain homeostasis** by **generating new beings** to take the place of those **that are dying**.

**Control Systems of the Body**

The human body has **thousands** of **control systems** in it. The **most intricate** of these are **the genetic control** systems that **operate in all cells** to **help control** **intracellular function as well as extracellular function**.

Many **other control** systems **operate *within the organs*** to control **functions** of the **individual parts** of the organs; **others operate** throughout the **entire body** *to* ***control the interrelations between the organs****.*

**Characteristics of Control Systems**

**\*Negative Feedback Nature of Most Control Systems:**

**Most control systems** of the body **act by *negative feedback***. In the **regulation** of **Co2 concentration**, a **high** concentration of **Co2** in the **ECF** increases pulmonary **ventilation**. This, **in turn**, **decreases** the **ECF Co2** concentration **because** the **lungs expire** greater **amounts** of **Co2** from the body.

In other words, the high concentration of **Co2** **initiates events** that **decrease** the concentration **toward normal**, which is ***negative***to the **initiating stimulus**.

**Conversely**, if the **Co2** concentration **falls too low**, this **causes feedback** to **increase** the concentration. This **response** also is **negative** to the initiating stimulus.

Therefore, **in general**, if some **factor** becomes **excessive or deficient**, a control **system initiates *negative feedback,***which **consists** of a **series** of **changes** that **return** the factor **toward a certain mean value**, thus **maintaining homeostasis**.

**((Gain)) of a Control System**

The ***gain***of the **negative feedback is** the **degree** of **effectiveness** **with which** a **control system maintains constant conditions**.

For instance, let us assume that a large volume of blood is transfused into a person whose **baroreceptor** pressure control system is **not functioning**, and the arterial pressure **rises** from the normal level of **100** mm Hg up to **175** mm Hg.

Then, let us assume that the **same volume** of blood is injected into the **same person** when the **baroreceptor system** is **functioning**, and this time the pressure **increases only 25** mm Hg.

Thus, the feedback control system has caused a “correction” of –50 mm Hg—that is, from 175 mm Hg to 125 mm Hg. There remains an increase in pressure of +25 mm Hg, called the “error,” which means that the control system is not 100% effective in preventing change. The gain of the system is then calculated by the following formula:

 Correction

Gain = ---------------- Error

Thus, in the baroreceptor system example, the correction is –50 mm Hg and the error persisting is +25 mm Hg. Therefore, **the gain** of the person’s **baroreceptor** system for **control** of **arterial pressure** is –50 divided by +25, or **–2**. That is, a **disturbance** that **increases or decreases** the arterial pressure **does so only one third** as much as would occur **if this control system were not present.**

**The gains** of some other physiologic **control systems** are much **greater** **than** that of the **baroreceptor** system. For instance, **the gain** of the system **controlling internal body** **temp** when a person **is exposed to** moderately **cold** weather **is about –33**.

**\*\*Positive Feedback Can Sometimes Cause Vicious Cycles and Death**

**One** might **ask** the question, **why do** essentially **all control** systems of the body **operate by negative** feedback rather than positive feedback? If one considers the nature of positive feedback, one immediately sees that **positive** feedback **does not lead to stability** but **to instability** and **often death**.

Figure 1–3 shows an example in which death can ensue from positive feedback.



This figure depicts the pumping effectiveness of the heart, showing that the heart of a healthy human being pumps about 5 liters of blood per minute. If the person is suddenly bled 2 liters, the amount of blood in the body is decreased to such a low level that not enough blood is available for the heart to pump effectively.

As a result, the arterial pressure falls, and the flow of blood to the heart muscle through the coronary vessels diminishes. This result in weakening of the heart, further diminished pumping, a further decrease in coronary blood flow, and still more weakness of the heart; the cycle repeats itself again and again until death occurs.

Note that each cycle in the feedback results in further weakening of the heart. In other words, the initiating stimulus causes more of the same, which is *positive feedback.*

**Positive** feedback is **better known as a (vicious cycle),** but a **mild** degree of **positive** feedback can be **overcome** by the **negative** feedback control mechanisms of the body, and the **vicious cycle fails to develop**.

For instance, if the person in the same example were bled only 1 liter instead of 2 liters, the normal negative feedback mechanisms for controlling cardiac output and arterial pressure would overbalance the positive feedback and the person would recover, as shown by the dashed curve of Figure 1–3.

**Positive Feedback**: **Positive Feedback Can Sometimes Be Useful**. For examples:

Blood clotting is an example of a valuable use of positive feedback. When a blood vessel is ruptured and a clot begins to form.

Childbirth is another instance in which positive feedback plays a valuable role. When **uterine contractions** become **strong enough** for the baby’s **head** to begin pushing through the cervix, **stretch of the cervix** sends **signals** through the **uterine muscle back** to the **body of the uterus**, causing even more powerful contractions.

Another important use of positive feedback is for **the generation of nerve signals.** When the **membrane** of a **nerve** fiber is **stimulated,** this causes slight **leakage of sodium ions** through **Na** **channels** in the nerve membrane **to** the **fiber’s interior**. **Na** ions entering the fiber then **change** the membrane **potential**, which in turn **causes** more **opening of channels**, more change of potential, still more opening of channels, **and so forth**.

Thus, a **slight leak** **becomes an explosion** of sodium entering the interior of the nerve fiber, **which creates the nerve action potential**. This action potential in turn **causes electrical** **current** to flow along both the **outside and the inside** of the **fiber** and **initiates additional** action potentials. This process **continues** again and again **until the nerve signal goes all** the way **to the end** of the fiber.

**In each case** in which **positive feedback is useful**, the **positive** feedback itself is **part of an overall negative** feedback process.

For example, in the case of blood clotting, the positive feedback clotting process is a negative feedback process for maintenance of normal blood volume.

**\*\*More Complex Types of Control Systems (Adaptive Control):**

The **nervous system** contains great numbers of **interconnected control mechanisms**. **Some are simple** **feedback** systems similar to those already discussed. **Many are not**. For instance, **some movements** of the body **occur** so **rapidly** that there is not **enough time** for **nerve signals to travel** from the **peripheral parts** of the body all the way **to the brain** and **then back** to the periphery again to control the movement.

Therefore, **the brain uses** a principle called ***feed-forward control***to cause **required muscle contractions**. That is, **sensory nerve signals** from the **moving parts apprise** the **brain** whether the **movement is performed correctly**. If **not**, **the brain corrects** the **feed-forward** signals that it sends to the **muscles the *next*** time the movement is required. Then, **if still further correction is needed**, this will be done again for subsequent movements. **This is called *adaptive control****.* Adaptive control, in a sense, **is delayed negative feedback**.