CHAPTER 1
FUNCTIONAL ORGANIZATION OF HUMAN BODY AND HOMEOSTASIS

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About 50 to 70% of adult human body is fluid, mainly a water solution of ions and other substances.

INTRACELLULAR FLUID

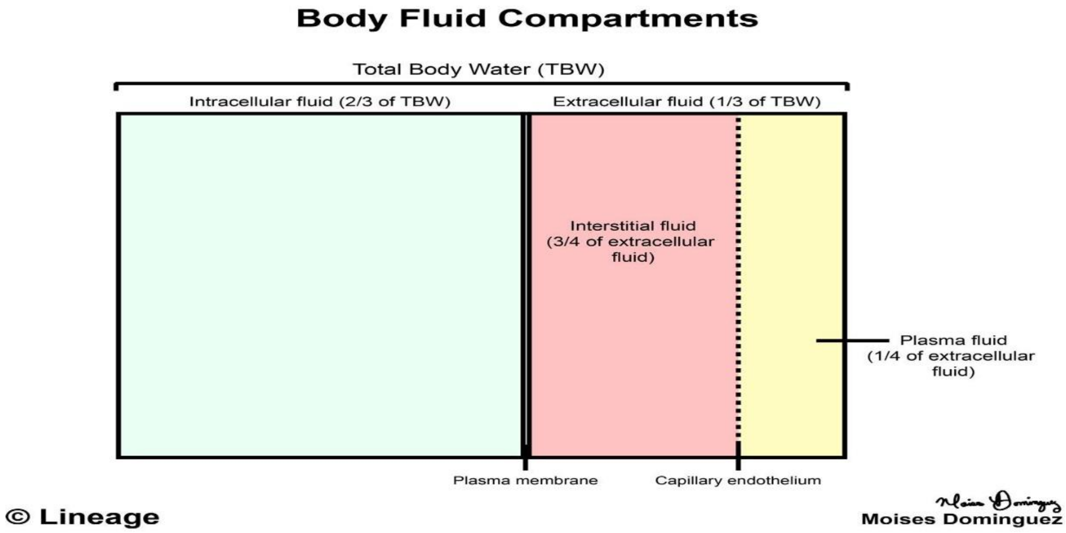
- Fluid inside the cells
- Contains large amount of potassium, magnesium, phosphate ions

EXTRACELLULAR FLUID

- Present in spaces outside the cells
- About one-third of total fluid content
- Also called internal environment of body
- In constant motion throughout the body
- Contains large amount of sodium, calcium, bicarbonate ions, plus nutrients for the cells such as oxygen, glucose, fatty acids, and amino acids.
- It also contains CO_2 and other waste materials to be excreted from body

Extracellular fluid is transported through the body in two stages:

1. Movement of blood through body in blood vessels
2. Movement of fluid between blood capillaries and intercellular spaces between the tissue cells



All the blood in circulation traverses the entire circuit an average of once each minute when the body is at rest and as many as 6 times per minute when person is extremely active.

The plasma proteins suspended in blood cannot move across the semipermeable capillary cell membrane and so they remain in blood plasma.

Number of RBC in each person – about 25 trillion

RBC are the most abundant of any single type of cell in the body.

Thickness of alveolar membrane – 0.4 to 2 micrometer

ORIGIN OF NUTRIENTS IN EXTRACELLULAR FLUID

1. From respiratory system – oxygen
2. From GIT – dissolved nutrients including carbohydrates, fatty acids, amino acids
3. From liver – modified nutrients and waste products

HOW DOES MUSCULOSKELETAL SYSTEM CONTRIBUTE HOMEOSTASIS?

Muscle system performs three functions to help maintain homeostasis:

1. Movement
2. Support
3. Heat production

Were it not for the muscles, the body could not move to obtain the food 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.

Skeletal muscles contribute to maintaining temperature homeostasis in the body by generating heat.

HOMEOSTATIC COMPENSATIONS IN DISEASES

Disease is often considered to be a state of disrupted homeostasis. However, even in the presence of disease, homeostatic mechanisms continue to operate and maintain vital functions through multiple compensations. In some cases, these compensations may themselves lead to major deviations of the body's functions from the normal range, making it difficult to distinguish the primary cause of the disease from the compensatory responses. For example, diseases that impair the kidneys' ability to excrete salt and water may lead to high blood pressure, which initially helps return excretion to normal so that a balance between intake and renal excretion can be maintained. This balance is needed to maintain life, but over long periods of time the high blood pressure can damage various organs, including the kidneys, causing even greater increases in blood pressure and more renal damage. Thus, homeostatic compensations that ensue after injury, disease, or major environmental challenges to the body may represent a "trade-off" that is necessary to maintain vital body functions but may, in the long term, contribute to additional abnormalities of body function. The discipline of pathophysiology seeks to explain how the various physiological processes are altered in diseases or injury

REMOVAL OF METABOLIC END PRODUCTS

1. From lungs – CO_2
2. From kidneys – metabolic waste products
3. From GIT –metabolic waste products
4. Liver – ingested drugs and chemicals

The skin generally comprises about 12-15% of body weight

The constant oxygen concentration in the extracellular fluid is maintained due to presence of hemoglobin in blood and the mechanism is called oxygen-buffering function of hemoglobin.

REGULATION OF ARTERIAL BLOOD PRESSURE

TERMINOLOGIES

1. **BARORECEPTORS:**

Baroreceptors are mechanoreceptors located in the carotid sinus and in the aortic arch. Their function is to sense pressure changes by responding to change in the tension of the arterial wall.

2. **CAROTID ARTERIES:**

A pair of blood vessels located on both sides of the neck that deliver blood to the brain and head.

3. **BIFURCATION:**

The point at which something divides into two branches

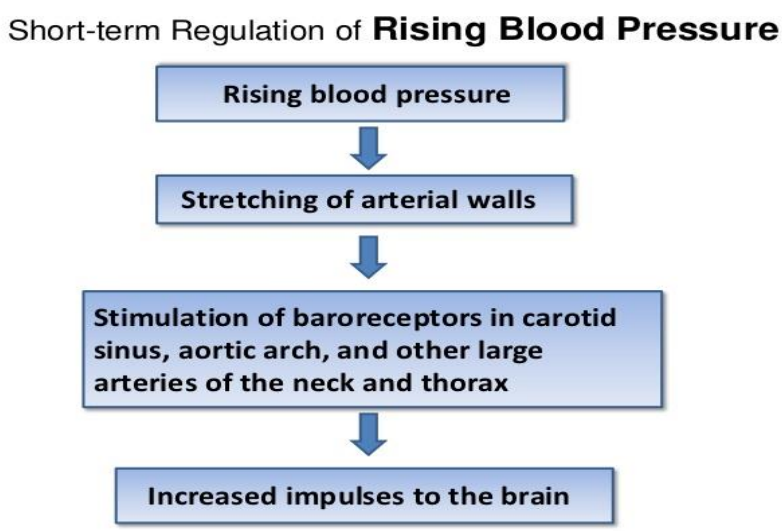
4. **VASOMETER CENTER:**

It is a portion of the medulla oblongata. Together with the cardiovascular center and respiratory center, it regulates blood pressure.

BARORECEPTOR SYSTEM

CONTROL OF HIGH PRESSURE:

1. Stretching of arterial wall stimulates baroreceptors.
2. Baroreceptors send nerve impulses to brain medulla.
3. Vasometer center is inhibited due to which decrease in number of impulses transmitted from the vasometer center through the sympathetic nervous system to the heart and blood vessels take place.
4. Heart pumping activity diminishes and peripheral blood vessels dilate which increase blood flow.
5. Arterial pressure decreases and move back to normal.



CONTROLLING LOW PRESSURE:

1. Decrease in arterial pressure below normal relaxes the stretch receptors.
2. Vasometer center becomes more active.
3. Vasoconstriction and increase heart pumping takes place

4. Arterial pressure is raised back to normal.

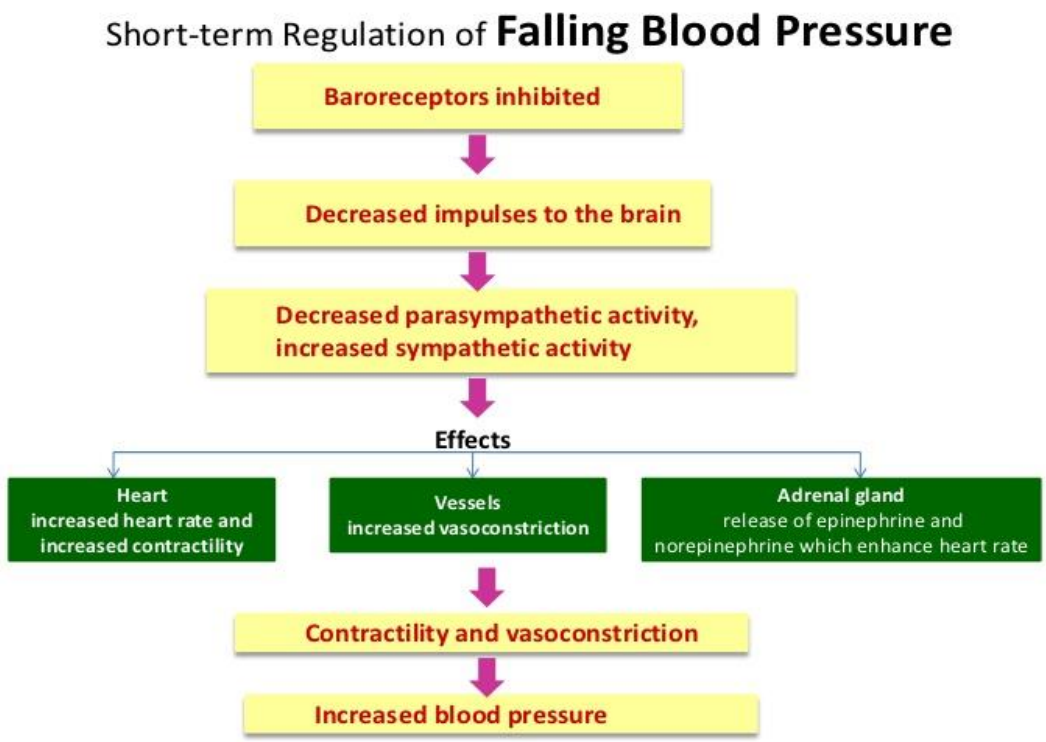


Table 1-1 Important Constituents and Physical Characteristics of Extracellular Fluid

	Normal Value	Normal Range	Approximate Short-Term Nonlethal Limit	Unit
Oxygen (venous)	40	35-45	10-1000	mm Hg
Carbon dioxide (venous)	45	35-45	5-80	mm Hg
Sodium ion	142	138-146	115-175	mmol/L
Potassium ion	4.2	3.8-5.0	1.5-9.0	mmol/L
Calcium ion	1.2	1.0-1.4	0.5-2.0	mmol/L
Chloride ion	106	103-112	70-130	mmol/L
Bicarbonate ion	24	24-32	8-45	mmol/L
Glucose	90	75-95	20-1500	mg/dl
Body temperature	98.4 (37.0)	98-98.8 (37.0)	65-110 (18.3-43.3)	°F (°C)
Acid-base	7.4	7.3-7.5	6.9-8.0	pH

Most important are the limits beyond which abnormalities can cause death. For example, an increase in the body temperature of only 11°F (7°C) above normal can lead to a vicious cycle of increasing cellular metabolism that destroys the cells. Note also the narrow range for acid-base balance in the body, with a normal pH value of 7.4 and lethal values only about 0.5 on either side of normal. Another important factor is the potassium ion concentration because whenever it decreases to less than one-third normal, a person is likely to be paralyzed as a result of the inability of the nerves to carry signals. Alternatively, if potassium ion concentration increases to two or more times normal, the heart muscle is likely to be severely depressed. Also, when calcium ion concentration falls below about one-half normal, a person is likely to experience tetanic contraction of muscles throughout the body because of the spontaneous generation of excess nerve impulses in the peripheral nerves. When glucose concentration falls below one-half normal, a person frequently exhibits extreme mental irritability and sometimes even has convulsions.

DISRUPTIONS FROM NORMAL EXTRACELLULAR FLUID CONCENTATION MAY CAUSE

1. Increase in body temperature – destruction of cell
2. Decrease In potassium to one-third of normal – paralysis due to inability of nerves to carry signals
3. Increase in K+ ions to two times – depression of heart muscle
4. Decrease in Calcium ions to half of normal – tetany
5. Decrease in glucose to half of normal – mental irritability and sometimes convulsions

GAIN OF CONTROL SYSTEM

To understand gain of control system, we'll first clear our concept about control system.

CONTROL SYSTEM

Anything that must be maintained in the body within a normal range must have a control system.

A control system has four components:

1. Stimulus (a physiological variable that changes)
2. Sensor, a sensory receptor
3. Control center is the body structure that determines the normal range of the variable, or set point e.g hypothalamus is the control center for body temperature
4. Effector

PROPERTIES OF CONTROL SYSTEM

1. The direction of correction will always be towards stability.
2. After the error is sensed, there is a delay in onset of correction.
3. There is always some residual error after the correction.

FORMULA FOR GAIN OF CONTROL SYSTEM

Gain = Correction / Residual Error

Higher the gain, more efficient is the system.

CALCULATING GAIN OF CONTROL SYSTEM

Normal BP = 100 mmHg

Some disturbance cause increase in BP = 175 mmHg

Baroreceptor mechanism brings BP down to 125 mmHg

So correction done by baroreceptor mechanism = 125-175 = -50 mmHg

But still error = 125 – 100 = 25

So, Gain = -50/25 = -2

CAN YOU ANSWER?
In an experiment the mean blood pressure of a rabbit was decreases from 100mmHg to 50mmHg. After 5 min the blood pressure come back to 75 mmHg. Calculate the gain of the control system involved.

SOLUTION:

Gain = 75-50/ 75-100

= 25/-25 = -1

POSITIVE FEEDBACK

- Blood clotting is an example of positive feedback
- Generation of nerve signals is also an important use of positive feedback.
- In each case in which positive feedback is useful, the positive feedback 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 the maintenance of normal blood volume.
  Also, the positive feedback that causes nerve signals allows the nerves to participate in thousands of negative feedback nervous control systems.