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生理学基本要点

BASIC CONCEPTS IN Physiology

A STUDENT'S SURVIVAL GUIDE

Charles Seidel

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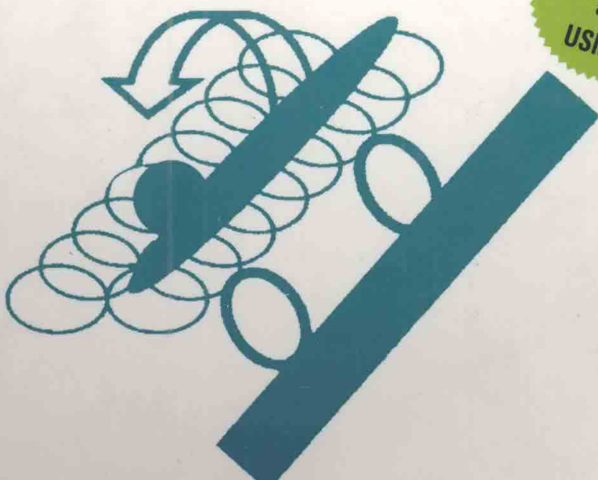

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BASIC CONCEPTS IN Physiology

CHARLES SEIDEL, PhD
Professor
Department of Medicine
Department of Molecular Physiology and Biophysics
Baylor College of Medicine
Houston, Texas

北京大学医学出版社

Charles Seidel
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· C O N T E N T S ·

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CHAPTER · 1 ·

HOMEOSTASIS

DEFINITION OF PHYSIOLOGY

- Physiology is the study of how things work.

Knowing the names of components and how they are assembled into a working system is important so that you can talk about them. For example, to talk about how an automobile engine works and how to fix it, you need a vocabulary describing the components of the engine. You need to be able to identify a carburetor, an air filter, a spark plug, an oxygen sensor, a camshaft and so on. You also need to know their location on the engine in case they are missing or inappropriately positioned. Naming the component parts of the human body is the purview of histology and gross anatomy.

You cannot be a competent mechanic, however, if you do not know what the component parts do and how they interact with one another. Understanding how the parts of the human body work together is the purview of physiology.

BASIC PRINCIPLE OF PHYSIOLOGY

- Homeostasis is the basic principle of physiology.
- Homeostasis is the maintenance of a constant environment.

Homeostasis is the maintenance of a constant environment. What enables us to live, work, and learn under changing conditions of temperature and humidity is to be able to surround ourselves with a hospitable environment generated by systems that heat, cool, and dehumidify the air. Whether in buildings, homes or automobiles, these systems are in constant struggle with the external environment. They are trying to maintain a hospitable internal environment against an inhospitable external environment. The body does the same thing. For the body, the external environment may be the outside physical world or the environment surrounding individual cells or organs.

To understand physiology is to understand how the body's homeostatic systems work. A key to learning physiology is to organize the information into homeostatic systems.

COMPONENTS OF A HOMEOSTATIC SYSTEM

- Regulated variable is a variable to be kept constant.
- Set point is the desired value for the regulated variable.
- Sensors assess current status of the regulated variable.
- Feedback controller compares current conditions with the set point.
- Effector brings current status of regulated variable into line with the set point.

Any homeostatic system has five common components (see Figure 1–1). The first component is the thing that needs to be kept constant. In a house this may be the temperature. This is called the *regulated variable*. Temperature, blood pressure, and the blood content of glucose, oxygen, and potassium ions are examples of regulated variables in the body. The body wants these variables to stay at a certain level. Not everything is a regulated variable. Heart rate, cardiac output, vascular resistance, urine output, and breathing rate are not regulated variables. These things may change, but they usually change in order to keep the regulated variable constant. If you remember what things are regulated variables, you will be a long way toward understanding the details of the homeostatic responses of the body. Once you know the regulated variable, in many cases you will be able to identify intuitively how the body might keep it constant.

Another aspect of a homeostatic system is that it must "know" what is normal. "Normal" is where the regulated variable should be. This normal condition is called the *set point*. For example, if the thermostat in your house is set at 76°F, this temperature is the set point that the air conditioning system tries to maintain. For every regulated variable there is a set point. Therefore, the body has set points for temperature, blood pressure, and the blood content of oxygen, glucose, and potassium. You need to know the value of these set points so that you will recognize if something is wrong. If my wife and I don't agree on the set point for the thermostat, I might interpret a temperature greater than 76 as a sign that the air conditioner is broken. However, this may be the set point that my wife has selected. Some diseases involve changes in the body's set point. You shiver when

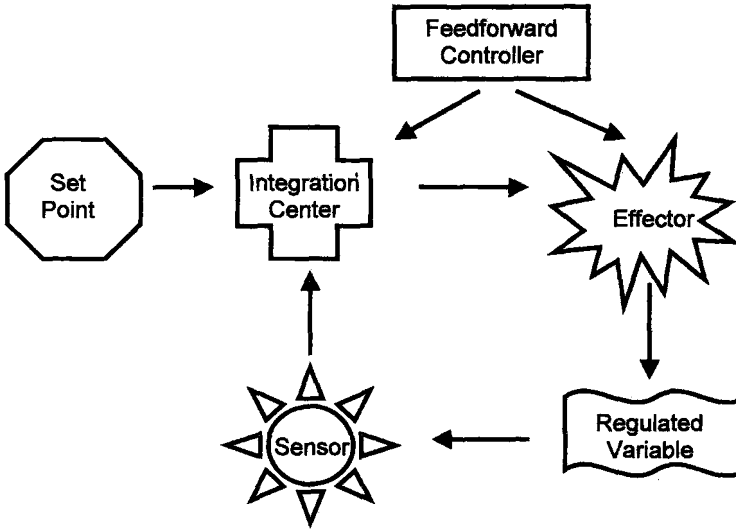

Figure 1–1
A standard homeostatic system consists of five elements: set point, sensor, integration center, effector, and regulated variable. Most homeostatic systems are designed to keep the regulated variable equal to the set point.

you have a fever because the temperature set point of your body has been increased. Your body tries to generate heat to raise its temperature by contracting the skeletal muscles. High blood pressure (hypertension) can be maintained because the set point for blood pressure is increased and the body initiates responses to maintain the blood pressure at this elevated level. So, it is important to know the normal set point and to realize that the set point can be changed as part of a disease process. An illness can result from the use of normal body responses to maintain an abnormal set point.

The third component of a homeostatic system is some mechanism by which the body can "know" the current conditions. There has to be a *sensor* that monitors the internal environment. For example, the thermostat senses the air temperature in your house. For every regulated variable there has to be a sensor. Therefore, the body has sensors for temperature, blood pressure, blood osmolarity, and the blood content of glucose, oxygen, and potassium, to name a few. Part of the study of physiology is the study of these sensors. You will learn where they are located, how they sense, the nature of their response to changes in the regulated variable, and where they send their information.

The information from the sensor about the current value of the regulated variable is useless if there is no way to compare the signals coming from the sensor with the set point. There has to be a *feedback controller* or *integrating center*. The thermostat in your house compares the current air temperature as sensed by the thermometer with the set point temperature you selected. If the thermometer indicates that the air temperature is higher than the set point, the air conditioning will turn on. It will remain on until the thermometer indicates that the air temperature is now equal to the set point, that is, "normal." The body has multiple feedback controllers that are in discrete locations in the brain. You will learn the locations of these controllers, what input they receive, and how they respond under specific circumstances.

In the example of a home air conditioner, the feedback controller had a way to produce change—to alter the internal environment so that the actual air temperature became equal to the set point. A homeostatic system must have an *effector*, that is, some way to produce a change. The home air conditioner is the effector that cools the air and blows the cooled air around inside the house in order to return the temperature to the set point. The body also has effectors and you will be spending a lot of your time understanding them. For example, to maintain temperature, the body uses skin blood flow, sweat production, and skeletal muscle contraction as effectors to either lower or increase body temperature to keep it at the set point. To maintain blood pressure the body alters the pumping action of the heart through changes in its rate of beating and its output per beat (stroke volume), the resistance of the vasculature to blood flow, and the volume of blood.

CHARACTERISTICS OF HOMEOSTASIS

- Effectors may have opposing actions.
- Negative feedback is the process that prevents change.
- Positive feedback is the process that perpetuates change.
- Feedforward control is outside stimuli that alter the normal feedback response.

Returning again to the example of a home air conditioner, notice that if the temperature of the house falls below the set point, nothing happens. The air conditioning system only prevents the house temperature from rising above the set point. It does nothing to actively warm the house if the temperature falls below the set point. For example, the furnace does not turn on if the temperature falls below a set point of 76°F. Few if any systems in the body work this way. The great majority of systems are constructed so that a corrective response is initiated if conditions move above or below the set point. This means that the effectors have opposite or competing actions.

This can be seen at two levels. At the level of a given regulated variable, such as temperature, some effectors raise temperature and some decrease temperature. They compete with or oppose each other to keep temperature constant. Around each regulated variable there is a constellation of effectors each exerting an action. These effects balance, keeping the temperature constant. A steady state is established because of these competing actions. On a more global scale, conflicts can develop between effectors interacting to maintain different regulated variables. For example, when you run in a hot, humid environment, there is a conflict between the effectors that are trying to maintain body temperature and those that are trying to maintain blood pressure. As your body temperature rises, more blood is directed to your skin to try to lower body temperature. However, this means that there is less blood to supply exercising muscle. Something has to give. In this example, temperature wins. The body does not want to "cook" the brain, so skeletal muscle blood flow is sacrificed to preserve appropriate temperature. So there is a hierarchy to the regulated variables. This is a very important point, which, if forgotten, can lead to confusion.

A term used to describe the process by which a regulated variable is maintained constant is *negative feedback*. Discrepancies between the set point and the regulated variable set into motion processes that attempt to return the regulated variable to the set point. If blood pressure rises, actions are taken to lower blood pressure. The initial response elicits an opposite response. This is a closed system that is self-correcting. Sometimes, however, there are situations where the initial response produces further change in the same direction. This is self-perpetuating and is called *positive feedback*. Changes in ion flux that initiate an action potential, blood coagulation, and ovulation are examples of positive feedback systems. There are not many such systems in the body because they do not keep things constant.

There are also situations when information comes from outside the negative feedback loop, information not detected by the sensor, that initiates change. This information usually comes from the brain as it responds to input from sensors outside the feedback loop. A good example is the response to a frightening experience. Your heart rate, blood pressure, and breathing rate increase because of central stimulation, not because of some change in a regulated variable. This type of input is called *feedforward control*. The intrinsic negative feedback systems would antagonize feedforward control unless the set point is changed.

COMMUNICATION IS AN ESSENTIAL ELEMENT OF A HOMEOSTATIC SYSTEM

- Two languages of communication are chemical and electrical.
- Characteristics of communication are distance, speed, distribution.

The sensor has to communicate with the feedback controller and the feedback controller has to communicate with the effector. There are essentially two languages of communication. One is chemical and the other is electrical. These will be developed in later chapters.

Communication has several characteristics: (1) distance: short vs. long; (2) speed: fast vs. slow; and (3) distribution: focused vs. diffuse. Communication occurs over distances as short as the environment surrounding a single cell. Cells can stimulate themselves, called *autocrine stimulation*, or their neighbor, called *paracrine stimulation* through the release of chemical agents. Communication can also occur over long distances, such as a nerve cell located in the spinal cord sending a process out to the end of the finger to stimulate a muscle cell. Communication can be fast, again like nerve stimulation of a muscle cell or the electrical communication between cells during the heartbeat. And it can be slow. Slow communication occurs when the transmission of the chemical is determined by its distribution in the blood. The response to a hormone is intrinsically slower than that to nerve stimulation. Finally, communication can be very focused, such as the activation of single muscle cells in the eye in order to focus on an object. And it can be diffuse, such as when epinephrine, released from the adrenal medulla when blood pressure falls, acts on the heart and the vasculature throughout the whole body.

C H A P T E R · 2 ·

CELL PHYSIOLOGY

MOVEMENT OF MOLECULES ACROSS CELL MEMBRANES

General Properties

- Lipid composition of the cell membrane limits transmembrane movement of molecules.
- The cell membrane is semipermeable because channel and carrier molecules enable some molecules to cross the membrane.
- Channels are proteins that form holes in the cell membrane enabling specific water-soluble molecules to pass in and out of the cell.
- Carriers are proteins that physically move specific molecules across the cell membrane.

The mammalian cell membrane is composed of two layers of lipids (fat) in which protein molecules are embedded. The water-loving (hydrophilic) ends of the lipids face either the exterior or interior of the cell while the water-hating (hydrophobic) ends of the lipid face the interior of the membrane. The protein molecules embedded in this sea of lipids may be large enough to completely span the thickness of the membrane, or they may be confined to one side or the other of the membrane. These proteins form structures such as chemical receptors, attachment points to the extracellular matrix, and transport molecules.

Because of the lipid composition and molecular organization of the cell membrane many molecules cannot cross without assistance. The cell membrane is therefore, said to be selectively permeable or *semipermeable.* Some of the proteins in the cell membrane form structures that permit transmembrane movement of such molecules. There are two ways that the cell gets molecules through the