Reading: FEEDBACK MECHANISMS

Feedback refers to communication of a state of being in one place back to a place that may have caused or can respond to that state of being. Below are writings describing some of the feedback mechanisms that we are studying. Notice that feedback mechanisms contribute to homeostasis. Feedback may be carried by either nerves or by chemicals (Often hormones carried by the blood)

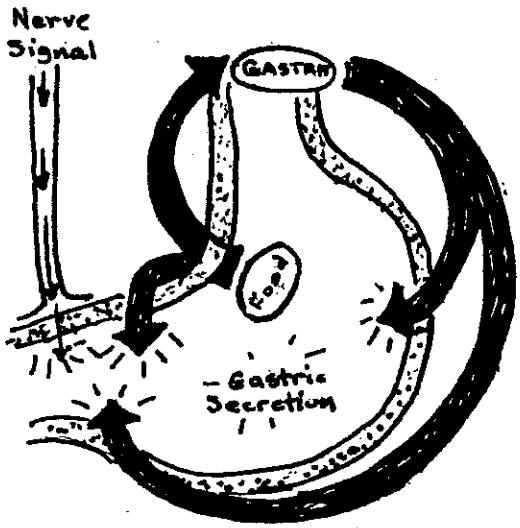
THE STOMACH. The stomach is a muscular bag which expands to store food. Peristaltic contractions mix and mash the food. Gastric juice secreted by the stomach glands carries on chemical digestion that began in the mouth. The stomach principally digests proteins by using enzymes and hydrochloric acid.

The stomach wall is largely made of protein. Why does it not digest itself? A partial and incomplete answer is that the tightly fitting surface cells of the stomach wall form a barrier against the penetration of acid.

When protective mechanisms fail and the stomach does digest itself, an *ulcer* results. Ulcers also occur in the upper small intestine. Tense, active, dynamic people are most susceptible to them. Treatment depends on diet, medication, or surgery.

Actions of the stomach are controlled in several ways. One is a nerve signal initiated by the taste or smell of food. Another way is contact of food with the stomach wall.

Stimulated portions of the stomach wall also release a special chemical, *gastrin*, which travels through the blood to other sections of the stomach and causes them to secrete. Gastrin is an example of a group of regulating chemicals called *hormones*.



Secretion of gastric juice is brought about by three stimuli: food in contact with stomach wall; secretion of hormone, gastrin; and nerve signals

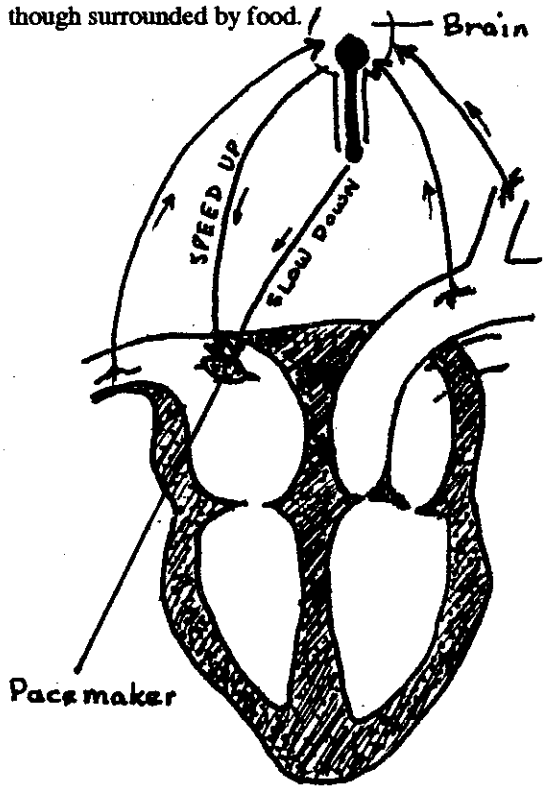
FEEDBACK IN DIGESTION. Homeostasis and feedback are involved in satisfying hunger. *Appetite* is partly inborn, and partly developed from experience in eating different foods. It determines what we want to eat.

Hunger was formerly believed to result only from hunger pangs or stomach contractions. However, complete removal of the stomach does not destroy hunger. Blood glucose is involved.

A low blood glucose level stimulates the hunger nerve in the brain stem, causing the feeling of hunger. Eating raises the blood sugar level and reduces the stimulation to the hunger center. It also stimulates the nearby *satiety center* , which actively counteracts the feeling of hunger.

Thus feedback occurs between the blood and the nerve centers. It induces us to eat enough to maintain blood sugar concentrations within the range the cells need.

Experiments show the homeostatic role of the nerve centers. Electrically stimulating the hunger center makes a rat overeat and become enormously fat. When the satiety center is stimulated, the animal refuses to eat and starves, though surrounded by food.



Blood flow & heartbeat. Increased flow to right atrium starts reflex (~~black~~) which speeds pacemaker. Reflexes from arteries to the body (~~gray~~) slow pacemaker. Heart also has other feedback systems.

HOMEOSTASIS IN CIRCULATION. The reaction of blood vessels in the skin to temperature changes is one example of homeostasis in circulation. Other aspects of circulation are also under feedback control.

Let us examine feedback control of heartbeat. The pacemaker is specialized heart tissue, which times the heartbeat. It responds to signals from heart rate centers in the medulla of the brain. The autonomic nervous system is in charge of these actions. A pair of sympathetic nerves stimulates the pacemaker and speeds up the heart. Another parasympathetic pair of nerves, the vagus nerves, inhibits the pacemaker and slows the heartbeat.

The heart-rate centers in turn respond to feedback from the blood vessels. A rush of blood to the heart stimulates sense organs near the right atrium, which signal a speed up of heartbeat. An out rush of blood from the heart similarly sparks slowdown signals.

The pacemaker also responds to chemical stimuli. These include oxygen and CO_2 concentration, and pH. Stimulants such as caffeine and nicotine increase heart rate while depressants such as alcohol and barbituates slow heart rate.

Blood is distributed unevenly throughout the body depending upon where blood should be circulated to best maintain homeostasis. This is accomplished by circular muscles in arterioles and the nerves that stimulate them. If more blood is required by leg muscles, nerves to the blood vessels that supply leg muscles will dilate allowing more blood to flow through them. Meanwhile blood vessels to the stomach may be constricted reducing the flow of blood to the stomach so that the leg muscles may be served. Vasoconstriction and vasodilation control distribution of blood to various parts of the body under the direction of nerve messages from the brain.

TEMPERATURE CONTROL. Mammals and birds are often called warm-blooded. *Endothermal* is a more accurate term. This means that the animals control their own body temperature, whether it is warm or cold outside.

Fish, amphibians, and reptiles are cold-blooded or *ectothermal*. They have less control over body temperature, which tends to match the outside temperature. An ectothermal reptile may at times be warmer than an endothermal animal.

Let us see how human temperature is controlled. Various organs differ in heat output. Muscles and the liver produce more heat than they need; the brain less. The blood carries heat from one organ to another. The body as a whole produces heat in excess of its needs. The skin disposes of the excess to the outside.

When we are too warm, heat loss increases in two ways. The skin arterioles relax, causing the skin to flush as its circulation increases, and more heat radiates away. Also we perspire more. The evaporating sweat absorbs heat. We feel cooler.

In the cold the reverse happens. Skin arterioles contract, the skin bleaches, perspiration is reduced, and heat is conserved. Also, shivering and muscular tension increase heat output by the muscles. The heat warms the body.

If the core of the body becomes too cool another set of reactions begins to occur in order to save vital functions. In this more serious case, circulation of blood to the limbs and skin is reduced keeping the heat at the core of the body so that the brain, heart and diaphragm can continue to function. Frost bite and death of skin tissues may occur. The body will sacrifice the health of limbs to preserve life of the core of the body.

Other endothermal animals have different methods of temperature control. The enormous, slowly flapping ears of elephants are a temperature-regulating adaptation.

HORMONES. Hormones are chemical messengers which help in controlling and coordinating the activities of the body. They are produced by *endocrine glands*. All glands in the body may be classified either as duct glands (salivary, sweat, and tear glands) or as endocrine or ductless glands (pituitary, thyroid, and adrenal).

BLOOD SUGAR REGULATION. Let us examine the interaction of hormones using blood sugar regulation. The sugar, glucose, enters blood when we eat. The liver can also release glucose into blood when it is under the influence of *glucogon*. *Glucogon* is produced by the pancreas whenever there is a low concentration of glucose in blood. Glucagon causes the liver to convert glycogen into glucose. It can also cause the liver to convert amino acids into glucose..

Insulin is produced by the pancreas whenever there is a high concentration of glucose in blood. *Insulin* travels throughout the body and influences every cell. In helping cells use glucose, insulin is effective in very small concentrations. The cells can already absorb and utilize glucose to some extent, but insulin increases the response. Muscle cells in particular, use the glucose in cell respiration and/or store it as glycogen for later use. Liver cells also store glucose in glycogen molecules. Fat tissues can convert glucose to fat for storage under the influence of insulin.

Failure to maintain blood glucose levels within a very narrow range of tolerance results in a coma and death. Diabetes is a condition in which blood sugar is not properly regulated because of the failure of the pancreas to produce insulin.

PARAHORMONES. Hormones interact also with other chemical agents, called *tissue hormones* or *parahormones*, produced by cells generally. For example, CO_2, made by all cells, stimulates the respiratory and other brain centers. Other tissue hormones are vitamin D, serotonin, histamine, and acetylcholine.

The line between true hormones--chemical regulators made by endocrine glands which affect other parts of the body--and parahormones, is not always sharp. Thus gastrin, the "hormone" secreted by stomach cells, stimulates other parts of the stomach to activity. *Histamine* is a parahormone secreted by all irritated cells. It causes much of the discomfort of a cold.

Histamine produces the same effect on t he stomach as gastrin. Is gastrin just another form of histamine rather than a specific hormone? The answer is not clear.

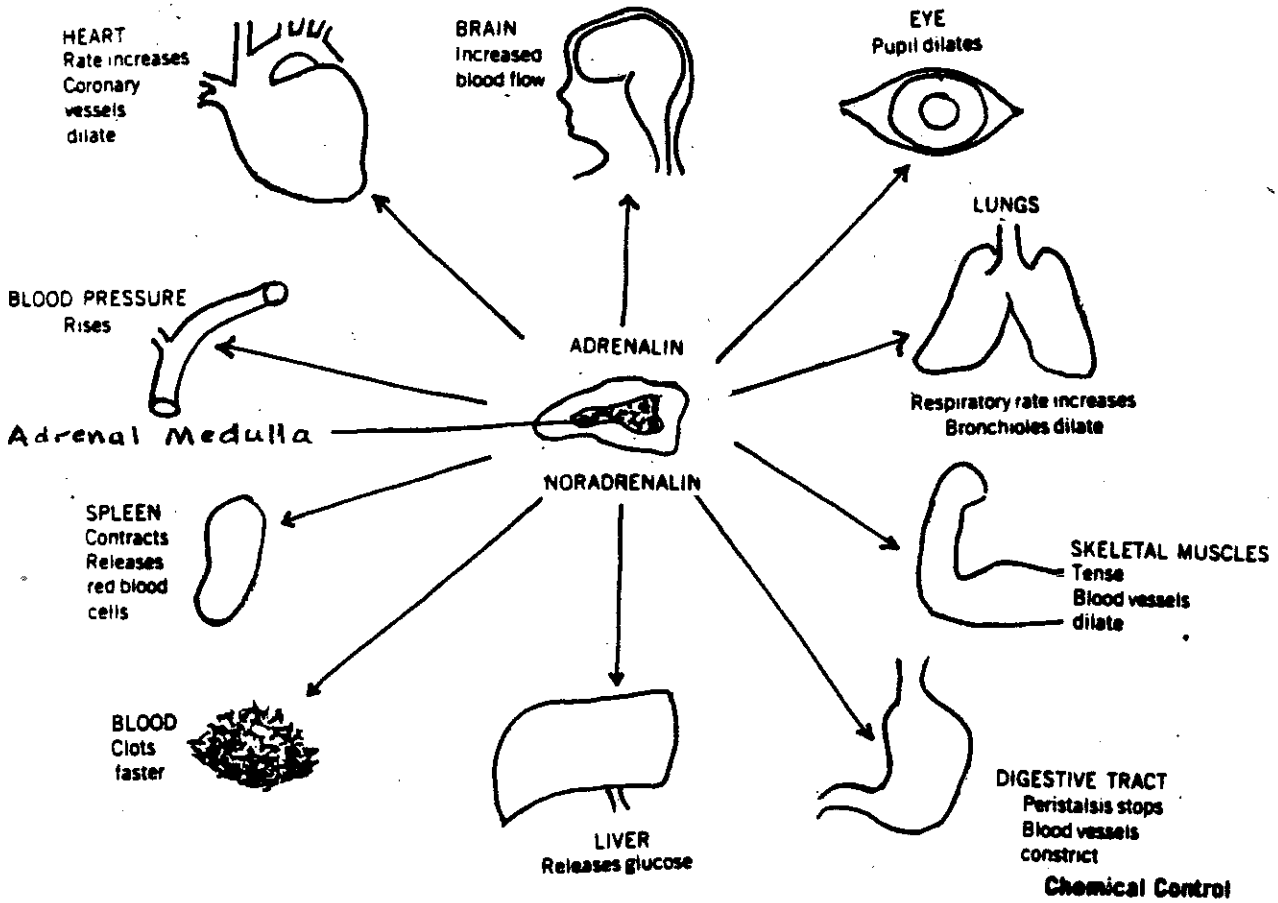
In 1971 Earl Sutherland won a Nobel Prize for discovering the parahormone *cyclic AMP*. This is a chemical relative of ATP. It seems to be present in all cells and to act only within cells. Many hormones produce their effects by stimulating production of cyclic AMP, which then activates specific enzymes.

A group of parahormones called *prostaglandins*, are not yet well understood. They seem to protect against asthma, infection and cell injury. In conditions of stress they stimulate inflammation, fever, intensification of pain and allergic reaction. All of these reactions may be viewed as contributing to the body's defense by sounding an alarm that something harmful is going on. Aspirin may reduce these symptoms of injury or infection by inhibiting the synthesis of prostaglandins.

THE ADRENAL GLANDS. Adrenalin and *noradrenalin* are hormones of the adrenal medulla. The emotional stress of anger, fear, or depression causes their quick release. Between them they produce the effects shown in the diagram.

Walter B. Cannon developed the hypothesis that the adrenal medullas were emergency glands. In case of danger, and under the spur of strong emotion, they swiftly prepared the body for escape or combat. Increased circulation and respiration, shift of the blood from digestive organs to muscle and brain, more red cells, more blood sugar, faster clotting, all seem like preparations for battle.

Effects of hormones secreted by the adrenal medulla.



Chemical Control

One argument against the hypothesis is that an animal with both adrenal medullas removed can still produce most of these responses. Other tissues must supplement the adrenal medullas. Yet Cannon's idea has value. Doctors keep adrenalin at hand to inject quickly in case of heart failure or shock.

THE MASTER GLAND. The *pituitary gland* is located in the middle of the head, under the brain, to which it is attached. It has three lobes, each functioning as an independent gland.

The posterior lobe secretes two hormones. *Antidiuretic Hormone,* ADH, is a pituitary hormone that affects kidneys. This hormone reduces water loss through the kidneys by increasing the amount of water reabsorbed in nephrons so that it does not leave the body with urine.

Oxytocin, the other posterior pituitary hormone, functions in reproduction. It helps the uterus to contract in childbirth, and stimulates the mammary glands to release stored milk.

The middle lobe secretes a hormone, *intermedin,* which helps control skin color in lower vertebrates, though not in mammals. We do not know whether intermedin is vestigial in mammals, or whether we have not yet discovered its major function.

The anterior lobe is called the *master gland* because of its control over other glands. Some of its hormones, called *tropins,* stimulate other endocrine glands such as the thyroid, adrenal cortex, and gonads. *ACTH,* which stands for *adrenal corticotropic hormone,* stimulates the adrenal cortex. TSH, *thyroid stimulating hormone,* stimulates the thyroid gland which controls metabolism.

The pituitary in turns is controlled by feedback from the glands that it controls. The master gland plays a large part in coordinating the body and in maintaining homeostasis.

Other anterior pituitary secretions include a growth hormone. Over-secretion or under-secretion of the growth hormone produce spectacular results in the form of giants, dwarfs, and other abnormalities of bodily proportions. Pituitary giants usually result from tumors of the gland. The giants are tall without being particularly strong or hardy.

GONADS. Testes and ovaries are gonads. Besides functioning in the production of gametes, gonads produce hormones. Testes produce *testosteron e* which stimulates secondary sex characteristics. Ovaries produce *estrogen,* and *progesterone,* which stimulate female secondary sex characteristics and regulate the menstrual cycle with feedback from the anterior lobe of the pituitary gland.