Valerie Lovelace

Feedback Mechanisms – Who Needs 'em?

The medulla oblongada is considered the autonomic reflex center of the body, and its function is to maintain homeostasis, regulating respiratory, vasomotor, and cardiac functions. It manages these very serious responsibilities through feedback systems. Feedback systems serve to control the production and release of hormones within the body, and as such they are the means by which the body is able to regulate and protect itself – and without the feedback, it would not take too awfully long for the organism to go completely awry. Imagine a large, teeming city without policeman to maintain control and order – things would run amok in a hurry. And so it is with the human body – without feedback mechanisms, virtually all of the functions of the body would swing wildly out of control - body temperature, blood glucose levels, blood calcium levels, water content, and so forth. These mechanisms provide the means to achieve and maintain homeostasis, giving the body the remarkable ability to protect, defend, and repair itself. There are essentially four types of feedback mechanisms:

- Pituitary-Target Gland Axis (secretions of the pituitary gland to directly regulate another gland of the endocrine system, as in the case of TSH to stimulate the Thyroid for production of T_3 and T_4)
- Hypothalamic-Pituitary-Target Gland Axis (the hypothalamus interacts with the pituitary gland to regulate certain pituitary secretions; the hypothalamus can directly affect target glands as well)
- Chemical Regulation (content or concentration of a substance stimulates homeostatic actions, as in the case of blood glucose levels or sodium-potassium ion-pumps)
- Nervous System Regulation (where nerve system stimuli control certain types of hormones (such as the affects of stress on ADH levels).

The flow chart in figure 1 depicts the general workings of an endocrine gland and the affects of a feedback mechanism, starting with a biological need and recognition of that need (as an example, blood glucose level being too high. In this case, the need is to lower the level of glucose):

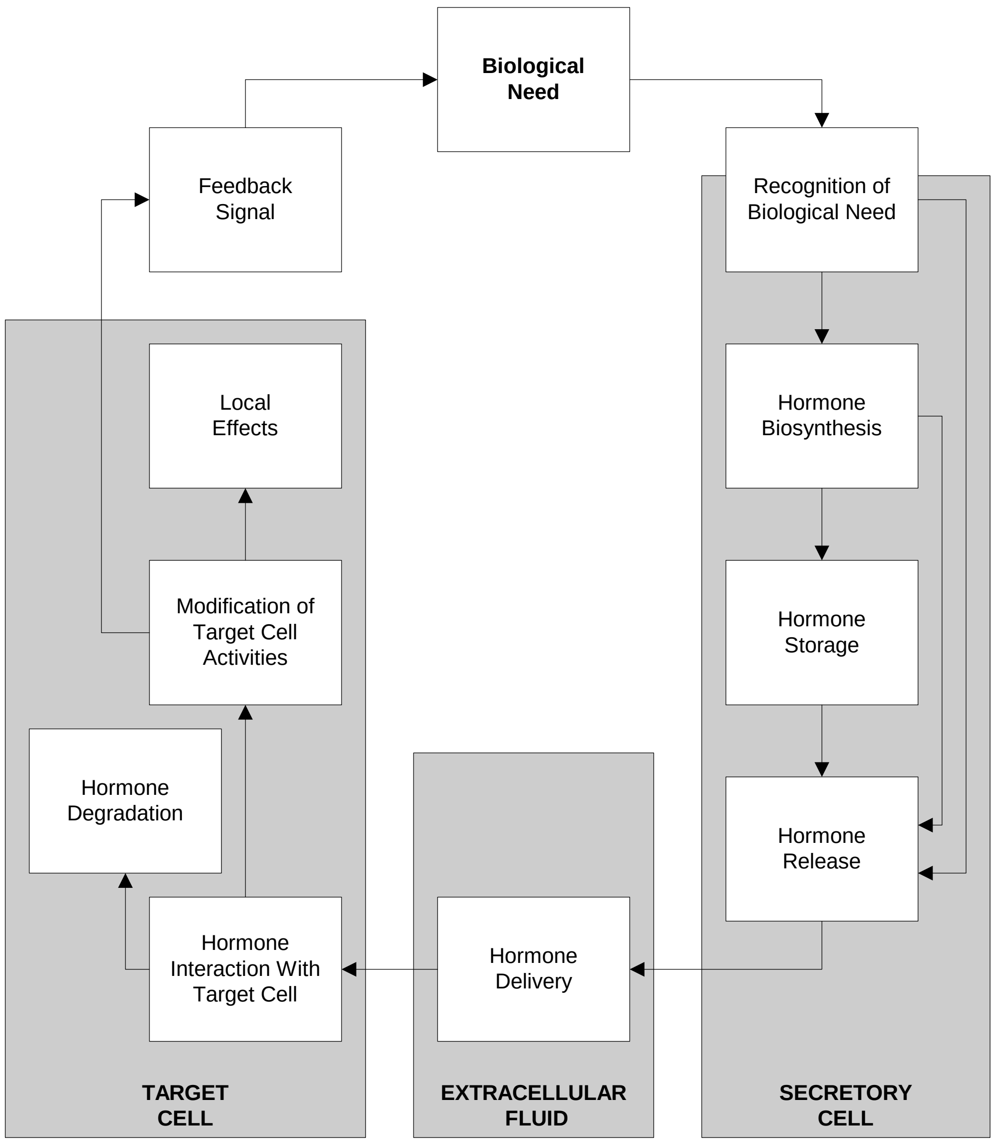

Figure 1: Endocrine Gland Function and Feedback

So, what happens without the feedback? Let's look at body temperature as another example. In order to function properly, the body must be maintained at an internal heat of approximately 37degC. In the absence of some kind of feedback system to indicate internal conditions and then trigger controlling responses (thermoregulation), our bodies would overheat when we eat and exercise and overcool when we sit still (over-exposure notwithstanding). So, let's say we are exercising vigorously. The hypothalamus contains the temperature regulating center of the body, and its sensors can pick up as little as a 0.25degC change in body temperature. As we exercise, our core temperature increases. The regulating center sends signals to stimulate sweat glands in the skin when temperature rises, and notifies the vasomotor center in the medulla oblongata (which is also sensitive to the temperature of its own blood supply). Similar signals from the medulla oblongata then stimulate vasodilation, causing arterioles and capillaries to expand, and more blood flows into the capillary networks, moving heat from the blood into the skin. This results is a rise in skin temperature, and our skin flushes. Sweat on our skin evaporates (better on a dry day than a humid one!), helping to cool our skin. Exposed areas radiate heat away from us, and anything in contact with our skin will take up heat through conduction. Convection will cause the air next to our skin to rise away, and cooler air will replace it, continuing to transfer heat away from us. Thus the body is cooled quite well through a variety of ways after we have exerted ourselves (or suffered a fever, for that matter).

Let's assume, however, that the feedback mechanism is not working well, and at the very moment we need it to respond, it does not. We stop exercising and our core temperature begins to cool. Blood returning from the skin eventually reaches the hypothalamus, which for some reason now cannot pick up on the fact that the temperature has declined. This should lead to vaso-constriction and the sweat glands should stop secreting; any further cooling should prompt heat-promoting shivers and contraction of the arrector pilli muscles (creating "goose-bumps" and trapping warm air). But without the proper feedback to initiate these actions, the body will continue cooling until it reaches a state of hypothermia, where the internal temperature falls below 35degC. Unable to respond to this feedback, the process continues and additional cooling (below approximately 32degC) eventually results in loss of blood pressure, muscle cramping, slower respirations and pulse, disorientation and mental confusion, and ultimately death – all for the want of a properly functioning feedback mechanism. Even if we are indoors, unless the room is heated to about 37degC, our body would continue losing its heat to the environment without the feedback mechanism in place to regulate temperature changes.

Suppose we cannot generate a fever when our bodies are invaded by unfriendly micro-organisms? Our tissues become damaged, pyrogens are released, but the hypothalamus does not respond – no resetting of the body's 'thermostat', no shivering, no vasoconstriction, no corresponding increase in body temperature, and no flushing or sweating. No fever. The micro-organisms multiply like crazy because the body is still a cozy, comfortable 37degC; they destroy healthy body cells, generate all kinds of toxic waste – and the body eventually dies, overcome and unable to defend itself against the invasion. Again, all for the want of a simple mechanism that says, "For now, it's okay to raise the body temperature to 40degC to kill these little buggers."

The flowchart in Figure 2 illustrates the blood-glucose feedback mechanism:

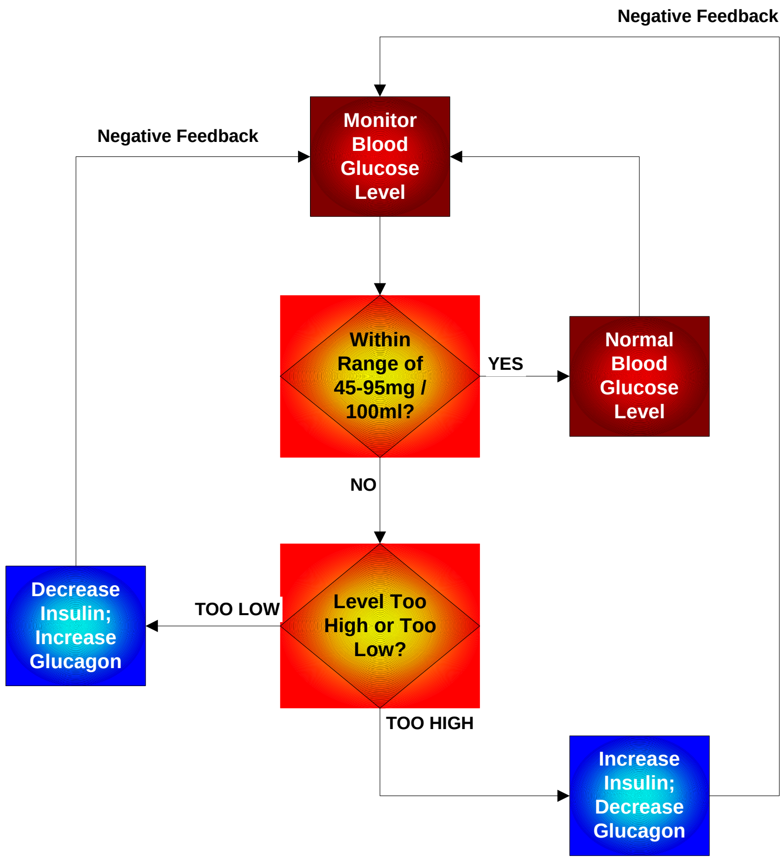

Figure 2: Blood Glucose Level Regulation

Monitored and controlled by cells of the Islet of Langerhans within the pancreas, blood glucose levels are managed through a negative feedback system. Insulin acts to control the level of absorbed nutrients in the blood when they rise too high:

- stimulates uptake and use of glucose.
- increases glycogenesis (conversion of glucose to glycogen for storage in the liver and skeletal muscles)
- decreases glycogenolysis (conversion of glycogen to glucose)
- prevents breakdown of protein and fat, thus preventing gluconeogenesis (formation of new sugar)

On the other hand, glucagon acts to increase glucose blood levels by stimulating glycogenolysis and gluconeogenesis.

This highly tuned and very sensitive chemical feedback system maintains blood glucose levels by constantly monitoring and instantly responding whenever the levels are disturbed (whether we are sleeping, exercising, eating a big Thanksgiving dinner with an extra helping of homemade pumpkin pie, fasting, or being scared out of our wits).

The numerous feedback systems regulating a variety of functions within the body are absolutely critical to achieving and maintaining homeostasis, in order that the body regain or maintain its balance and defend itself against the typical stressors we encounter in our lives. Without proper functioning, our susceptibility increases and the likelihood of developing serious chronic conditions increases over the long-term.

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