PHYSIOLOGY LECTURE 2

# CONTROL SYSTEMS OF THE BODY

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# Lecture Objectives:

- Define and describe the components of homeostatic control system.
- List the factors that are homeostatically regulated.
- Compare and contrast negative and positive feedback and explain the importance of these processes to homeostasis.
- Understand the gain of the control system and its physiological significance.
- Explain the feed forward concept and its importance for initiation of responses in anticipation of a change in internal environment.

# Factors homeostatically regulated:

Factors of the internal environment that must be homeostatically maintained are:

1. Concentration of nutrient molecules.
2. Concentration of oxygen and carbon dioxide.
3. Concentration of waste products.
4. pH (hydrogen ion concentration).
5. Water volume and osmolality (essential electrolyte concentrations).
6. Plasma volume and pressure.
7. Core body temperature.

# Control systems of the body

- Control systems of the body are in thousands. Starting from the cellular level and ending in throughout the entire body control systems.
- To maintain homeostasis, the control system must be able to:
  1) Detect deviations from normal in the internal environmental factor that needs to be held within narrow limits.
  2) Integrate this information with any other relevant information.
  3) Make appropriate adjustments in the activity of the body parts responsible for restoring this factor to its desired value
- Examples are $Na^+$-$K^+$ pump, genetic control, pH regulation, and thermal regulation of the body.
- Homeostatic regulation of a single physiologic factor often involves several cooperating control systems (mechanisms) activated at the same time or in succession.

# Control systems of the body (Cont.)

- The more important a variable, the more numerous and complicated are the mechanisms that operate to maintain the steady-state at the desired value.
- The efficiency of the homeostatic mechanisms varies over a person's lifetime, with some homeostatic mechanisms not being fully developed at birth and others declining with age.
- For example, a newborn infant cannot concentrate urine as an adult. Older adults are less able to tolerate stresses, such as exercise or changing weather, than are younger adults.
- The control systems are characterized by their:
  1. *Negative feedback nature (the majority)*
  2. *Positive feedback nature*

# *Negative feedback:*

When some factors becomes excessive or deficient, series of changes occur that move the factor in the opposite direction of its initial change. That is, a corrective adjustment opposes the original deviation from the homeostatic steady-state.

The components of a simple negative-feedback control system include:

- Regulated variable
- The receptor (sensor or detector)
- The control center (comparator or integrator)
- The effector (acts to oppose change)

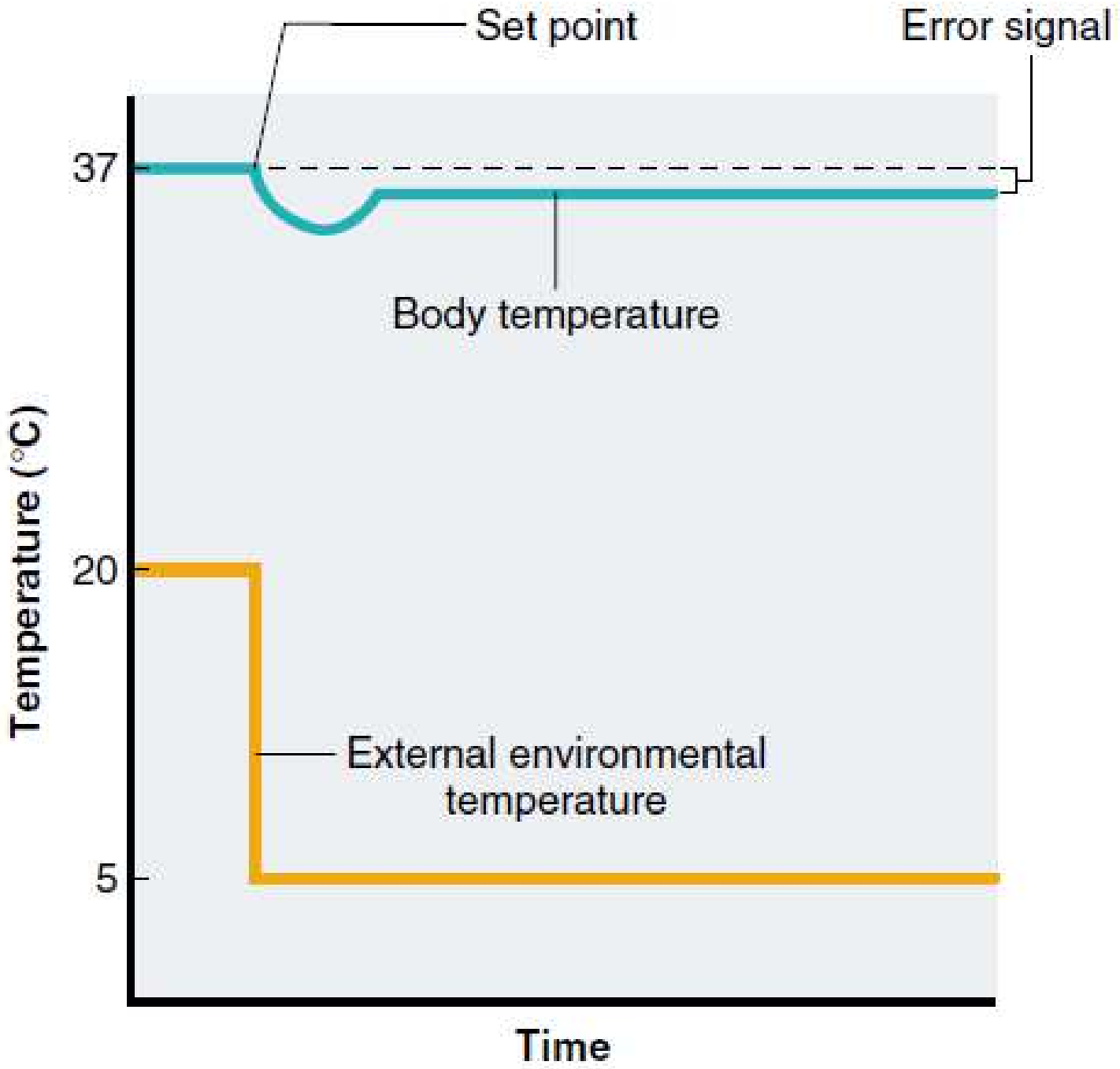
Example: Exercise → ↑ body temperature → stimulation of temperature-monitoring nerve cells in the hypothalamus → activation of cooling mechanisms (sweating) → ↓ body temperature.

# Gain of a Control System:

- The gain is degree of effectiveness with which a control system maintains constant conditions.
- The gain of the control system is calculated by the following formula:

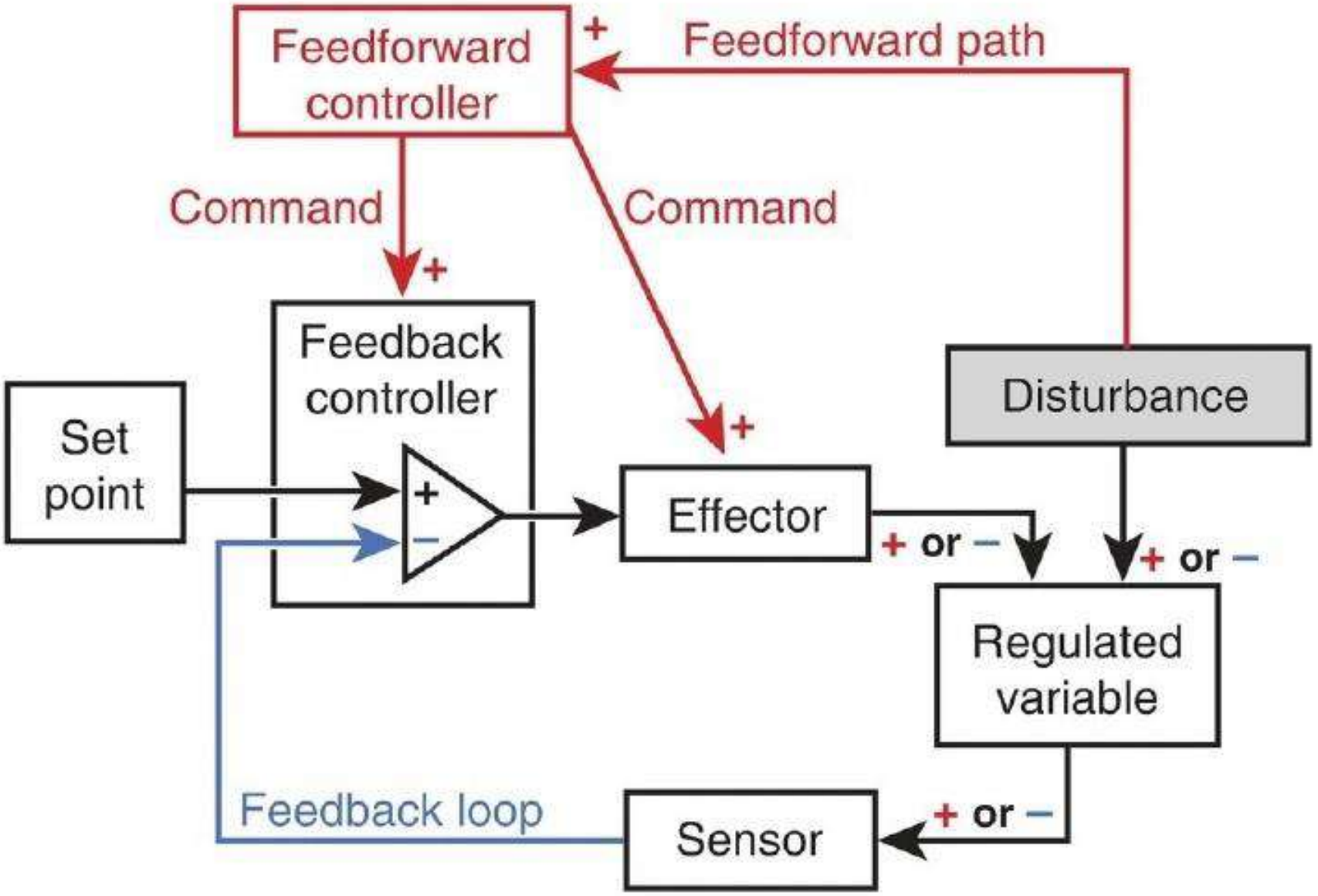
$$The\ \mathbf{Gain}\ of\ a\ control\ system = \frac{Correction}{Error}$$

Where the *Error* is the remaining uncorrected change from normality. The gain of baroreceptors is about -2, whereas the gain of temperature control system is about -33.


Set point
Error signal
37
Body temperature
Temperature (°C)
20
External environmental temperature
5
Time

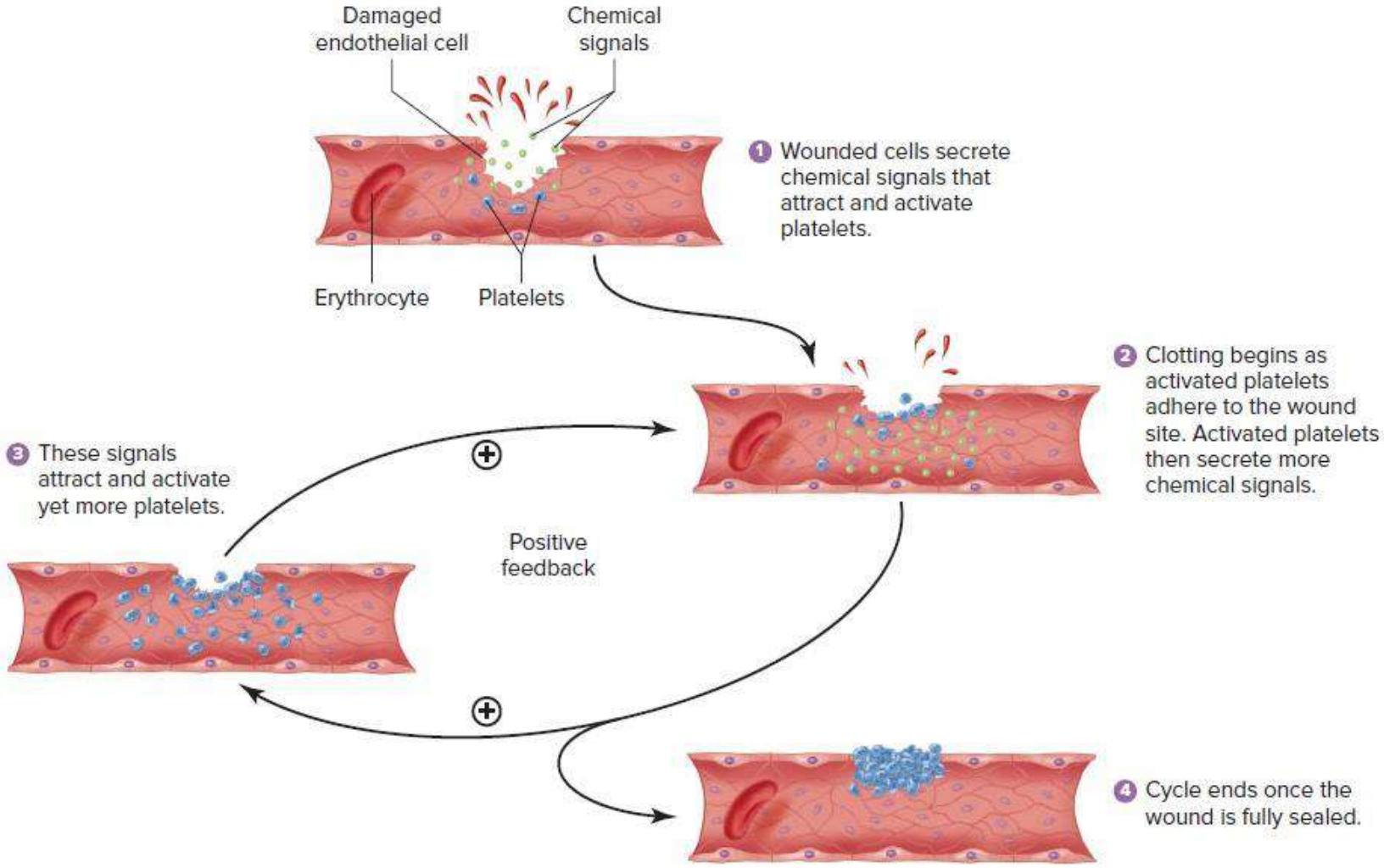
# *Feedforward Regulation:*

- Is another type of regulatory process usually acts in combination with negative-feedback systems
- The feedforward regulation **anticipates** changes in a regulated variable, improves the speed of the body's homeostatic responses, and minimizes fluctuations in the level of the variable being regulated - that is, it reduces the amount of deviation from the set point
- The operation of the controller is "**open loop**"; that is, the regulated variable itself is not sensed
- ***Example***; When outside temperature falls, skin nerve cells immediately detect the change and relay this information to the brain, which then sends out signals to the blood vessels and muscles, resulting in heat conservation and increased heat production even before the internal body temperature falls


Feedforward controller
+
Feedforward path
Command
Command
+
Feedback controller
Set point
+
−
+
Effector
Disturbance
+ or −
+ or −
Regulated variable
Feedback loop
Sensor
+ or −

# *Positive feedback:*

- The change induces further change leading to an amplified effect that ends in **vicious cycle**. It can be useful in some cases; e.g. blood clotting, childbirth (initiation of uterine contraction), generation of action potential in membrane of nerve cell when $Na^+$ ion influx begins, ovarian ovulation, etc.
- The positive feedback may be considered as a part of an overall negative feedback process.
- **Example:** blood clotting, the positive feedback clotting process is a negative feedback process for the maintenance of normal blood volume.




**Positive feedback** as illustrated by the clotting process in blood. Damaged endothelial cells in the lining of a blood vessel secrete chemical signals that attract and activate platelets. As clotting begins, the activated platelets produce chemical signals of their own, attracting and activating **more** platelets to the wound site, which then produce yet **more** chemical signals, and so on. The cycle ends when the wound is fully sealed.

# Test Question:

Q. Which statement about feedback control systems is incorrect?

A. Most control systems of the body act by negative feedback.
B. Positive feedback usually promotes stability in a system.
C. Generation of nerve actions potentials involves positive feedback.
D. Feed-forward control is important in regulating muscle activity.
E. A feedback gain of -3.0 can correct 3/4 of the initial error.