How the Body Uses Negative Feedback

Blood glucose, blood pressure, and blood pH

How does your body respond after a meal, when you stand up, or when extra carbon dioxide accumulates? Use AI-assisted coding to explore how negative feedback helps physiological variables return toward their usual levels.

Use the following illustrative values for this educational simulation only.

1 Understand the feedback systems

- Blood glucose: After a meal, pancreatic cells sense rising glucose. Insulin helps lower elevated glucose; glucagon helps raise low glucose.
- Blood pressure: Standing can temporarily lower pressure. Stretch-sensitive receptors detect the change, and signals through the brain adjust heart activity and blood vessel narrowing.
- Blood pH: Extra carbon dioxide tends to lower pH. Chemical sensing helps adjust breathing; exhaling more carbon dioxide helps raise pH toward its usual level.

Before coding: For each example, identify the regulated variable, sensor, controller, and response. Explain why the response is called negative feedback. Connect your answer to the reference, controller, system, and sensor in the lecture slide.

2 Use one simple mathematical model

$$\tau_x \, dx/dt = d(t) - x + u$$

$$\tau_u \, du/dt = -gx - u$$

Start with x = 0 and u = 0. Here x is the scaled deviation from a reference level; d(t) is the disturbance; u is the combined corrective response; and g is feedback strength. The time constants τ_x and τ_u set the response timescales. All of x, d, u, and g are dimensionless; both time constants use the time units of the simulation.

When x is positive, −gx pushes u downward, helping bring x down. When x is negative, the response reverses. The term −x represents background recovery, so some recovery remains even when g = 0.

This is a simplified control model. The response u is not an insulin concentration, heart rate, or breathing rate.

3 Blood glucose after a meal

Question: How do feedback strength and response speed affect the glucose rise after a meal?

$$G(t) = 90 + 20x(t) \quad \text{mg/dL}$$

Use τ_x = 30 minutes. Set d(t) = 2 from minute 10 up to minute 30, and zero otherwise. Simulate 180 minutes. The disturbance represents temporary glucose entry after a meal.

Case	g	τ_u
Baseline	2	10 minutes
Weaker feedback	0.5	10 minutes
Slower response	2	30 minutes

- Plot glucose over time for all three cases. Which has the highest peak and which takes longest to recover?
- Does glucose temporarily fall below its reference level? Explain how a response that persists after the disturbance could cause this.

Interpretation: Weaker feedback represents a smaller corrective effect. This model does not distinguish reduced insulin secretion from reduced insulin sensitivity.

4 Blood pressure when standing up

Question: How does feedback help restore pressure after a sudden drop? Use mean arterial pressure rather than separate systolic and diastolic pressures.

$$P(t) = 90 + 10x(t) \quad \text{mmHg}$$

Use τ_x = 5 seconds. Set d(t) = −2 from second 10 up to second 15, and zero otherwise. Simulate 90 seconds. This brief disturbance represents a simplified pressure-lowering effect of standing.

Case	g	τ_u
Baseline	2	2 seconds
Weaker feedback	0.5	2 seconds
Slower response	2	8 seconds

- Plot pressure and the corrective response u. Which case has the lowest pressure?
- Does u increase or decrease when pressure falls? Can pressure temporarily rise above its reference level during recovery?
- Explain how increased heart activity and blood vessel narrowing can oppose a pressure drop. The model combines these effects into u.

5 Blood pH and extra carbon dioxide

Question: How does a slower respiratory response affect recovery from a temporary acidifying disturbance?

$$\mathrm{pH}(t) = 7.40 + 0.05x(t)$$

Use τ_x = 3 minutes. Set d(t) = −1 from minute 5 up to minute 10, and zero otherwise. Simulate 40 minutes. The negative disturbance represents an acidifying effect associated with extra carbon dioxide.

Case	g	τ_u
Baseline	2	1 minute
Weaker feedback	0.5	1 minute
Slower response	2	4 minutes

- Plot pH over time. Which case produces the largest decrease?
- When pH falls, should the corrective response raise or lower pH?
- Explain how increased carbon dioxide removal can support recovery.

Model limitation: pH is logarithmic. This model approximates small changes near a reference level; it is not a hydrogen-ion mass-balance equation. Real regulation also involves chemical buffers and slower kidney responses.

6 Coding support and checks

You may use this starter prompt in Colab Gemini or another coding assistant:

Implement the two feedback equations provided in this practice using Python. Let me choose the glucose, blood-pressure, or pH example and its parameters. Compare baseline, weaker, and slower feedback on the same graph. Label axes and units, mark the disturbance interval, and plot the corrective response separately. Explain the code and check the results using a smaller numerical time step.

- Confirm that x = u = 0 stays unchanged with no disturbance.
- Check that the initial corrective response opposes the change in x.
- Repeat with a smaller time step and confirm that the curves remain similar. Resolve the beginning and end of each disturbance accurately.
- Explain one important physiological detail the model leaves out.

7 Optional challenge

Does stronger feedback always produce a smoother recovery? Choose one system. Test g = 0.5, 2, and 5, then repeat with a slower response. Compare the largest deviation, overshoot, and recovery time. Define recovery as returning to and remaining within $|x| < 0.05$ after the disturbance ends. If this does not occur within the simulation, report that result.

For your own practice, prepare three comparison plots and a short explanation of what they reveal about homeostasis. Discuss why response timing can matter as much as feedback strength.

Background reading

These optional OpenStax readings explain the physiological mechanisms. The simulation equations and parameter values in this practice are illustrative teaching choices, not calibrated models from these chapters.

The endocrine pancreas

https://openstax.org/books/anatomy-and-physiology-2e/pages/17-9-the-endocrine-pancreas

Homeostatic regulation of the vascular system

https://openstax.org/books/anatomy-and-physiology-2e/pages/20-4-homeostatic-regulation-of-the-vascular-system

Acid base balance

https://openstax.org/books/anatomy-and-physiology-2e/pages/26-4-acid-base-balance