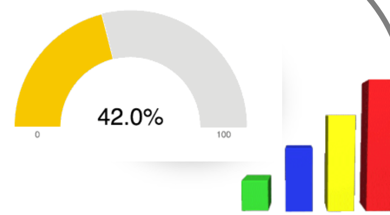
بسم الله الرحمن الرحيم



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Exercise Physiology

Control of the Internal Environment

Objectives

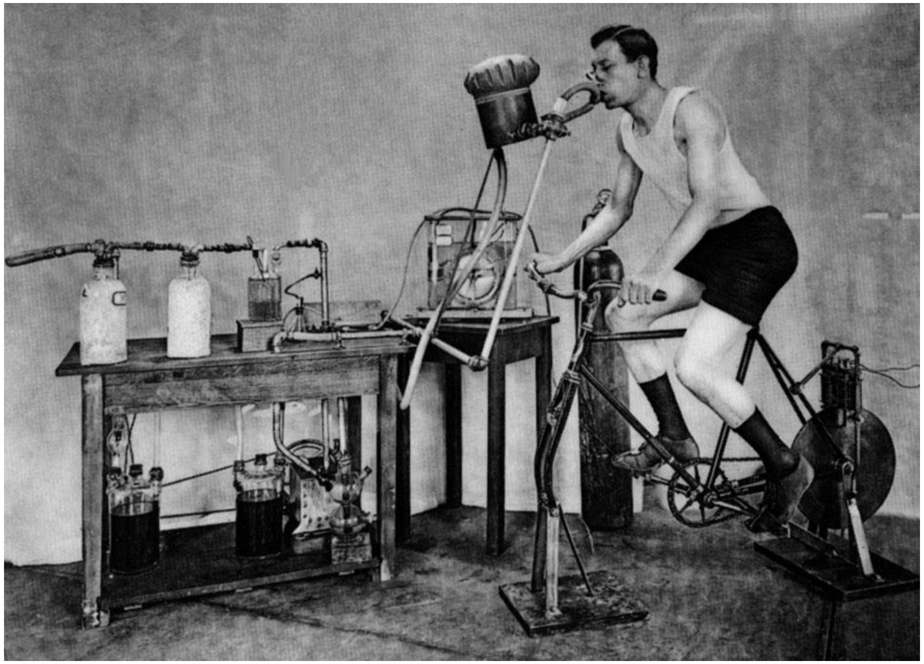
1. **Exercise physiology**
2. **Define the terms *homeostasis* and *steady state*.**
3. **Diagram and discuss a biological control system.**
4. **Give an example of a biological control system.**
5. **Explain the terms *negative feedback* and *positive feedback*.**
6. **Define what is meant by the gain of a control system.**

Exercise Physiology

Exercise Physiology

- Acute **responses** and **chronic adaptations** to a wide range of **exercise** conditions.
- The effect of **exercise** on pathology, and the mechanisms by which **exercise** can reduce or reverse disease progression.

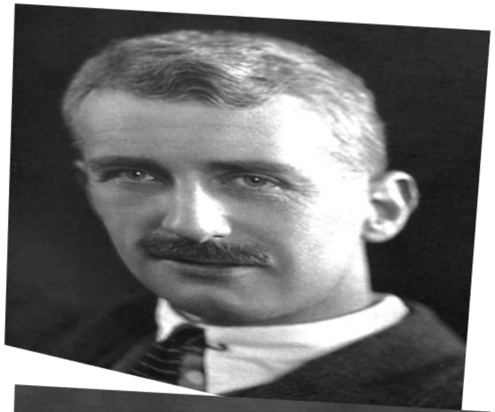
Comparison of Old and New Technology



Nobel Prize

Three Exercise physiologists received the Nobel Prize for work related to muscle or muscular exercise

- A.V. Hill
  - Heat production during muscle contraction and recovery
- Otto Meyerhof
  - Relationship of O_2 consumption and lactic acid in muscle
- August Krogh
  - Function of the capillary circulation



How to Understand Graphs

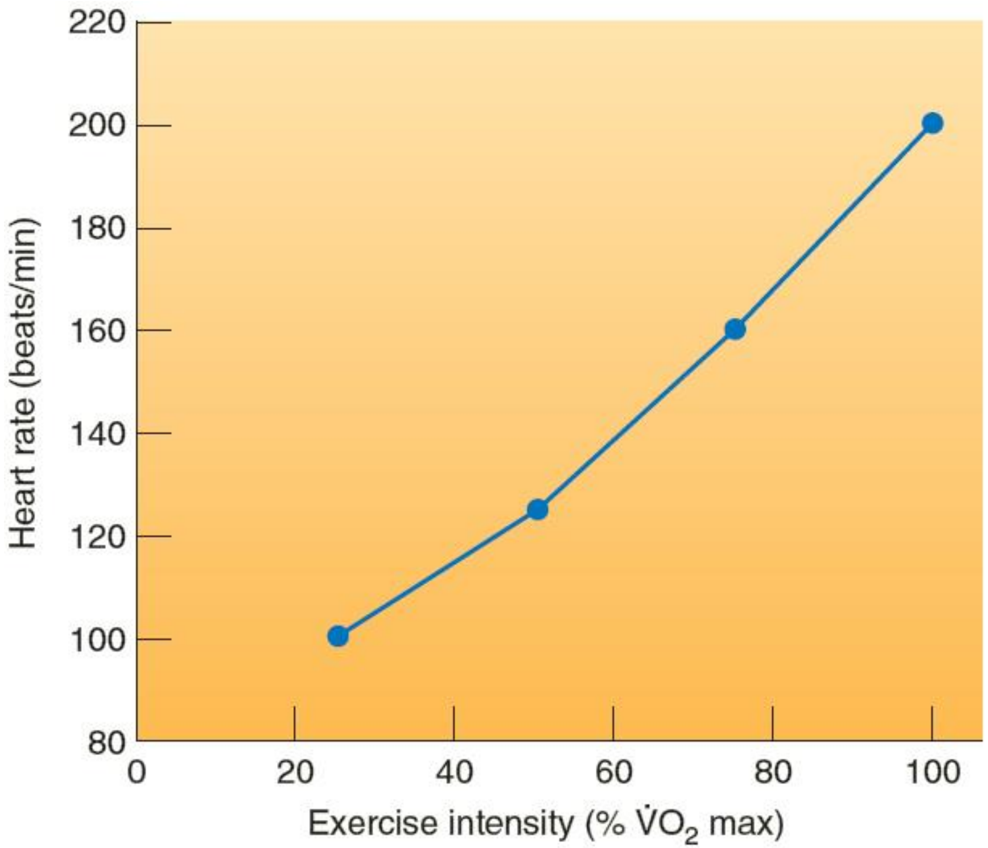
- **Used to illustrate relationships between two variables**
- **Independent variable**
  - On x-axis (horizontal)
  - Manipulated by researcher
- **Dependent variable**
  - On y-axis (vertical)
  - Changes as a function of independent variable

JOGGING

How to Understand Graphs

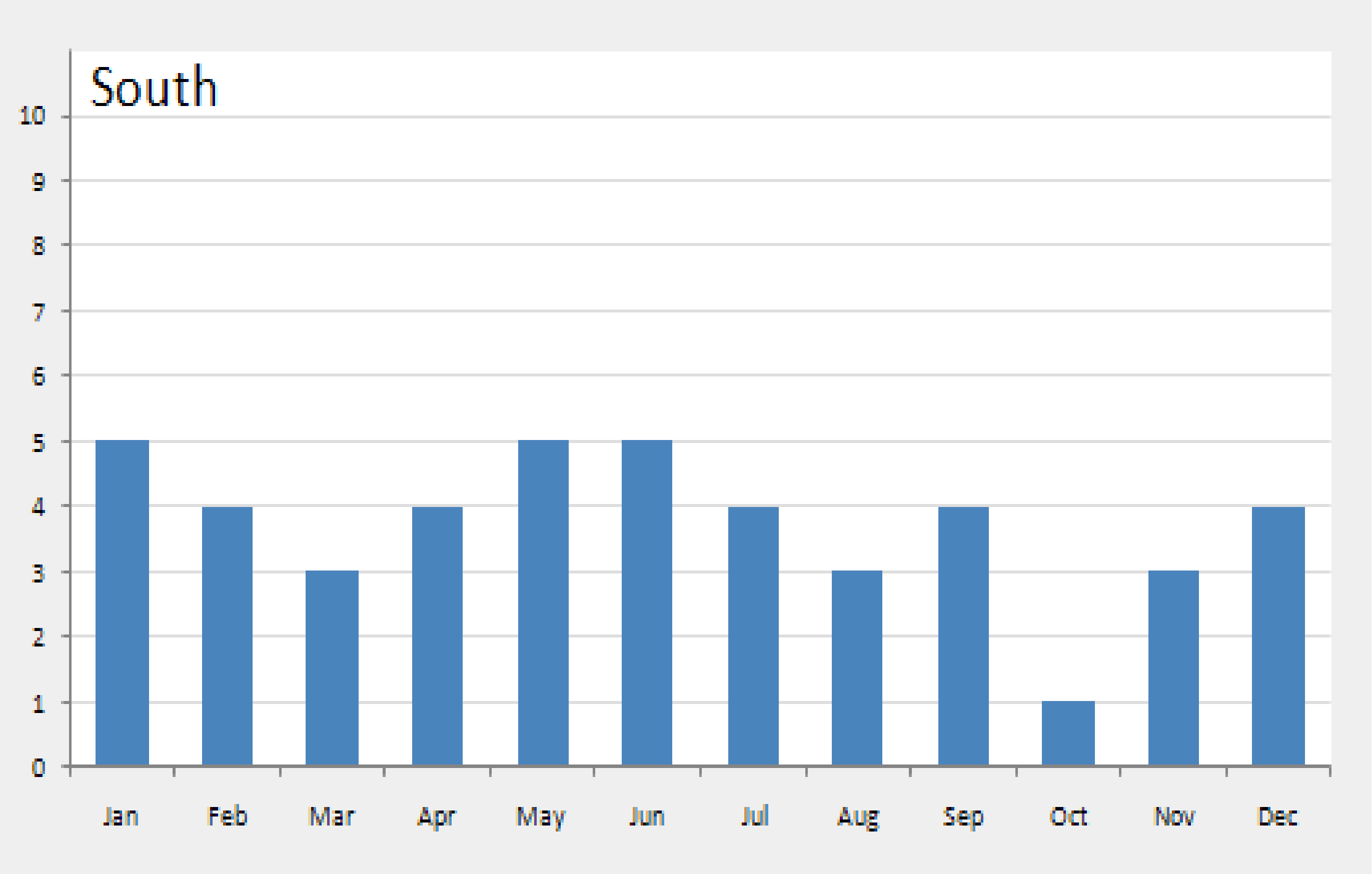
The relationship between heart rate and exercise intensity

Dependent variable, changes as a function of exercise intensity.



Independent variable

Figure 2.1


South
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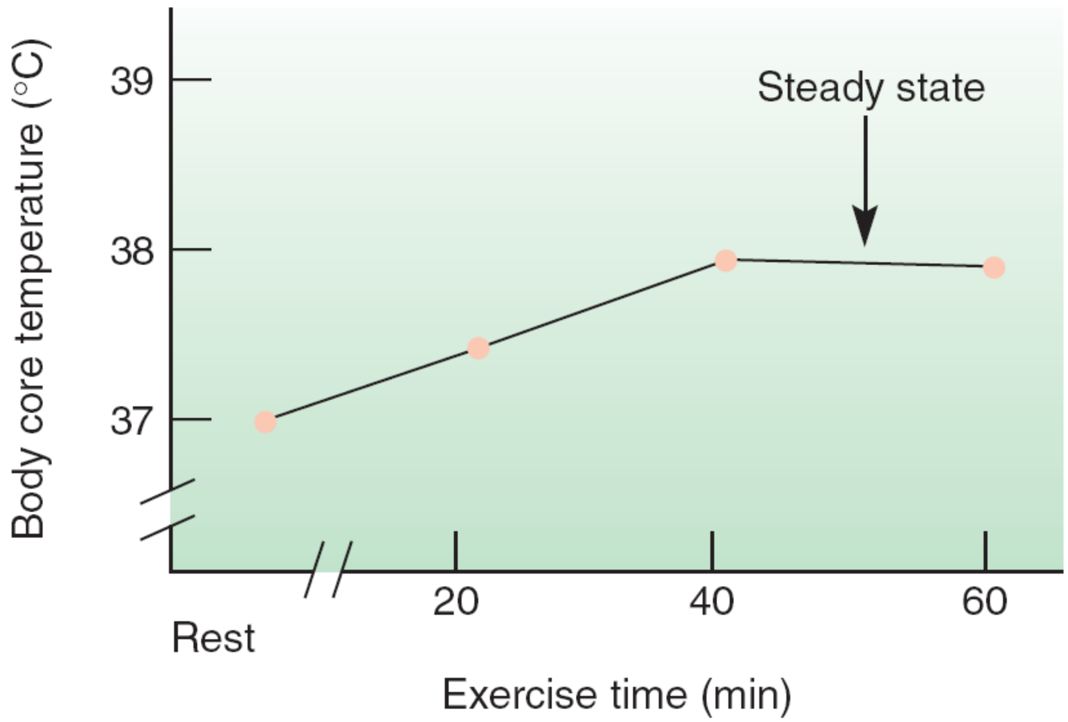
Homeostasis

- **Homeostasis**
  - Maintenance of a constant and "normal" internal environment
- **Steady state**
  - Physiological variable is unchanging, but not necessarily "normal"
  - Balance between demands placed on body and the body's response to those demands
  - Examples:
    - Body temperature
    - Arterial blood pressure

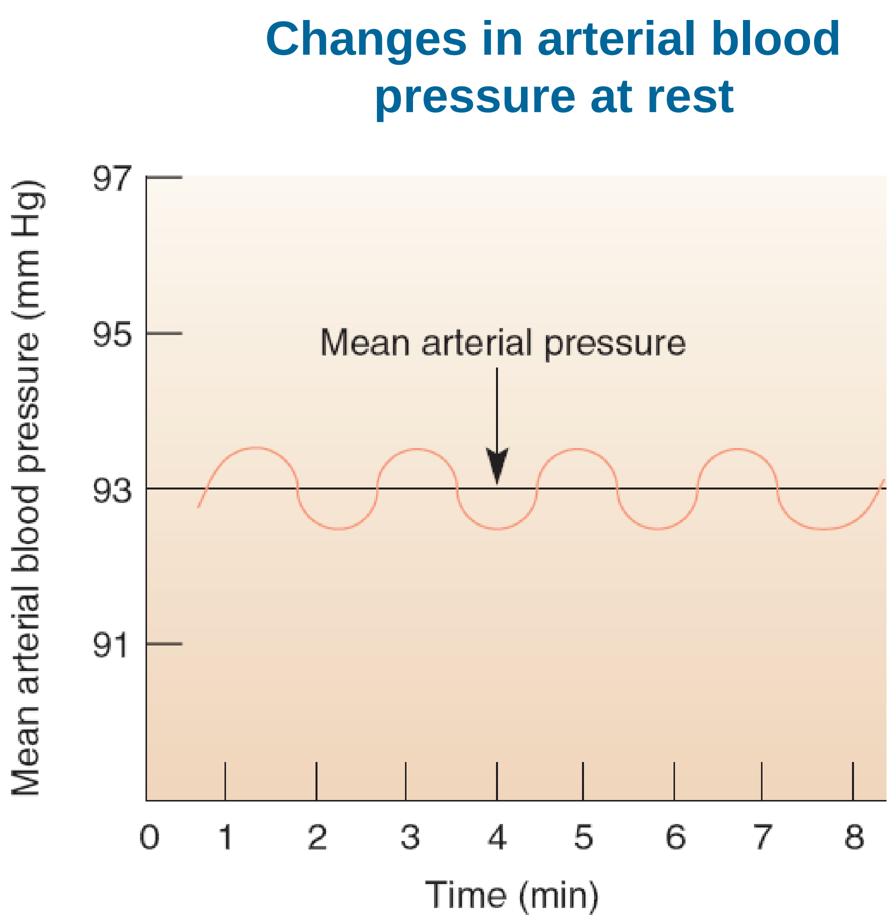
Changes in Body Core Temperature During Exercise

Changes in body core temperature during submaximal exercise



Body temperature reaches a plateau (steady state)

Changes in Arterial Blood Pressure at Rest



Although arterial pressure oscillates over time, mean pressure remains constant

Figure 2.3

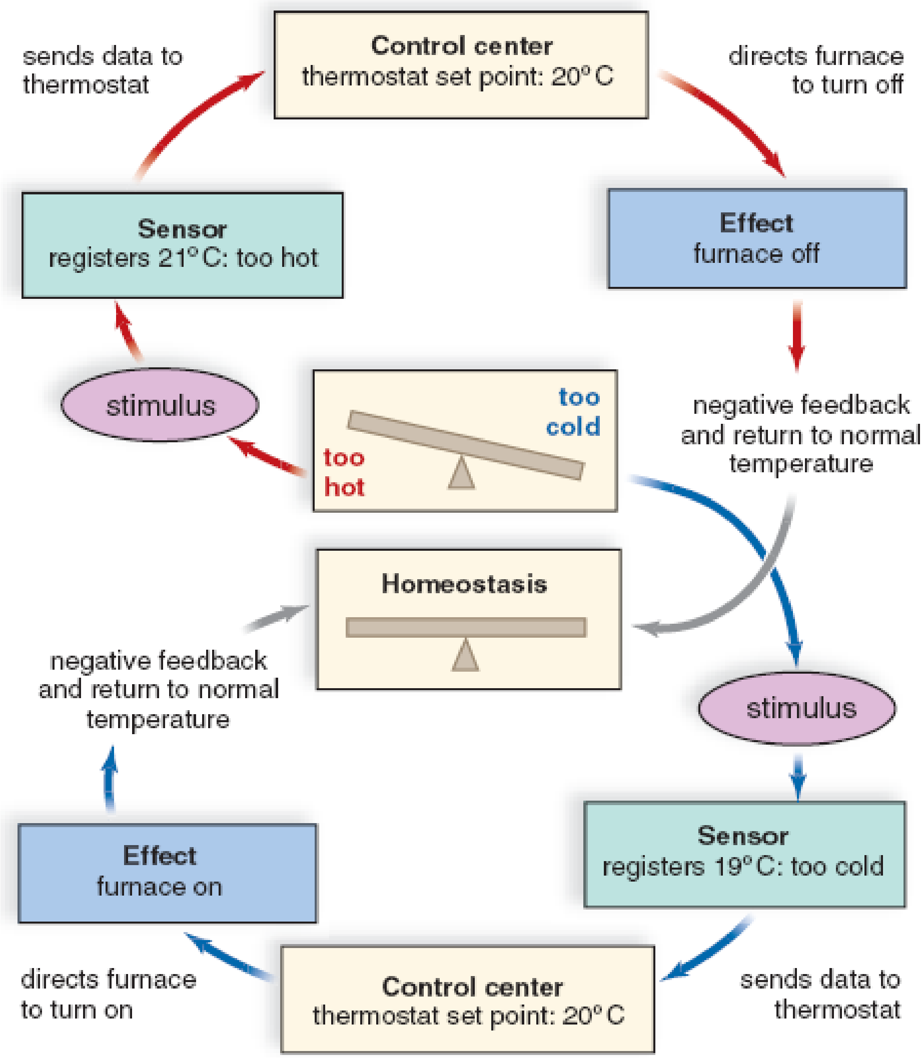
In Summary

- *Homeostasis* is defined as the maintenance of a constant or unchanging "normal" internal environment during unstressed conditions.
- The term *steady state* is also defined as a constant internal environment, but this does not necessarily mean that the internal environment is at rest and normal. When the body is in a steady state, a balance has been achieved between the demands placed on the body and the body's response to those demands.

Control Systems of the Body

- **Intracellular control systems**
  - Protein breakdown and synthesis
  - Energy production
  - Maintenance of stored nutrients
- **Organ systems**
  - Pulmonary and circulatory systems
    - Replenish oxygen and remove carbon dioxide

Non-Biological Control System

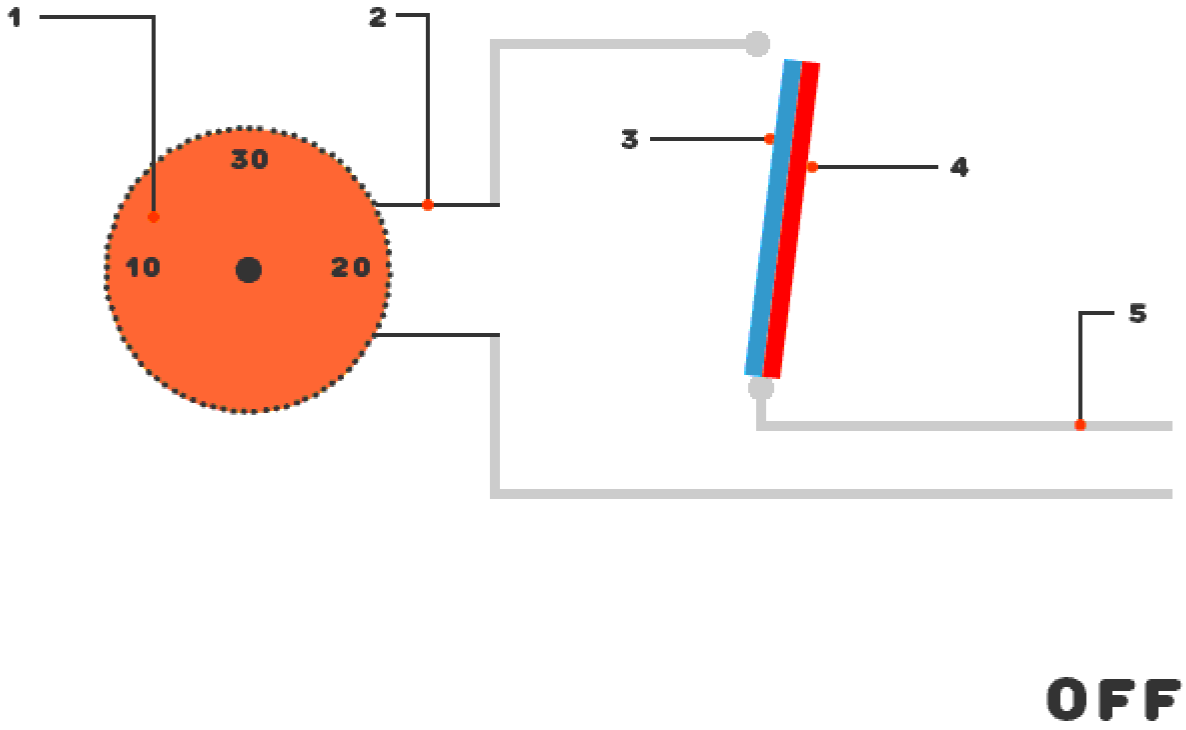


A thermostat-controlled heating/cooling system

An increase in temperature above the set point signals the air conditioner to turn on.

A decrease in room temperature below the set point results in turning on the furnace.

Figure 2.4


1
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10
20
3
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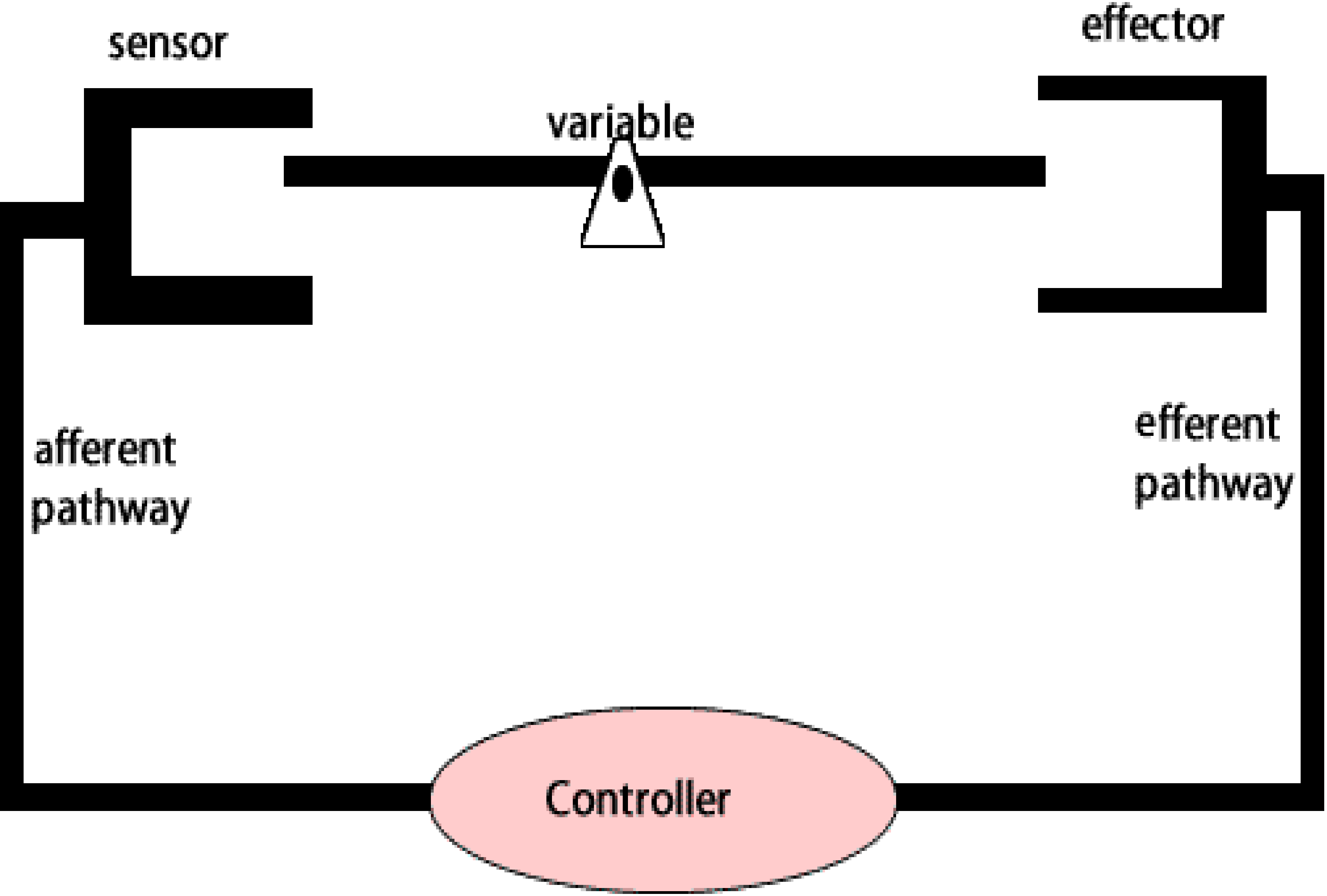
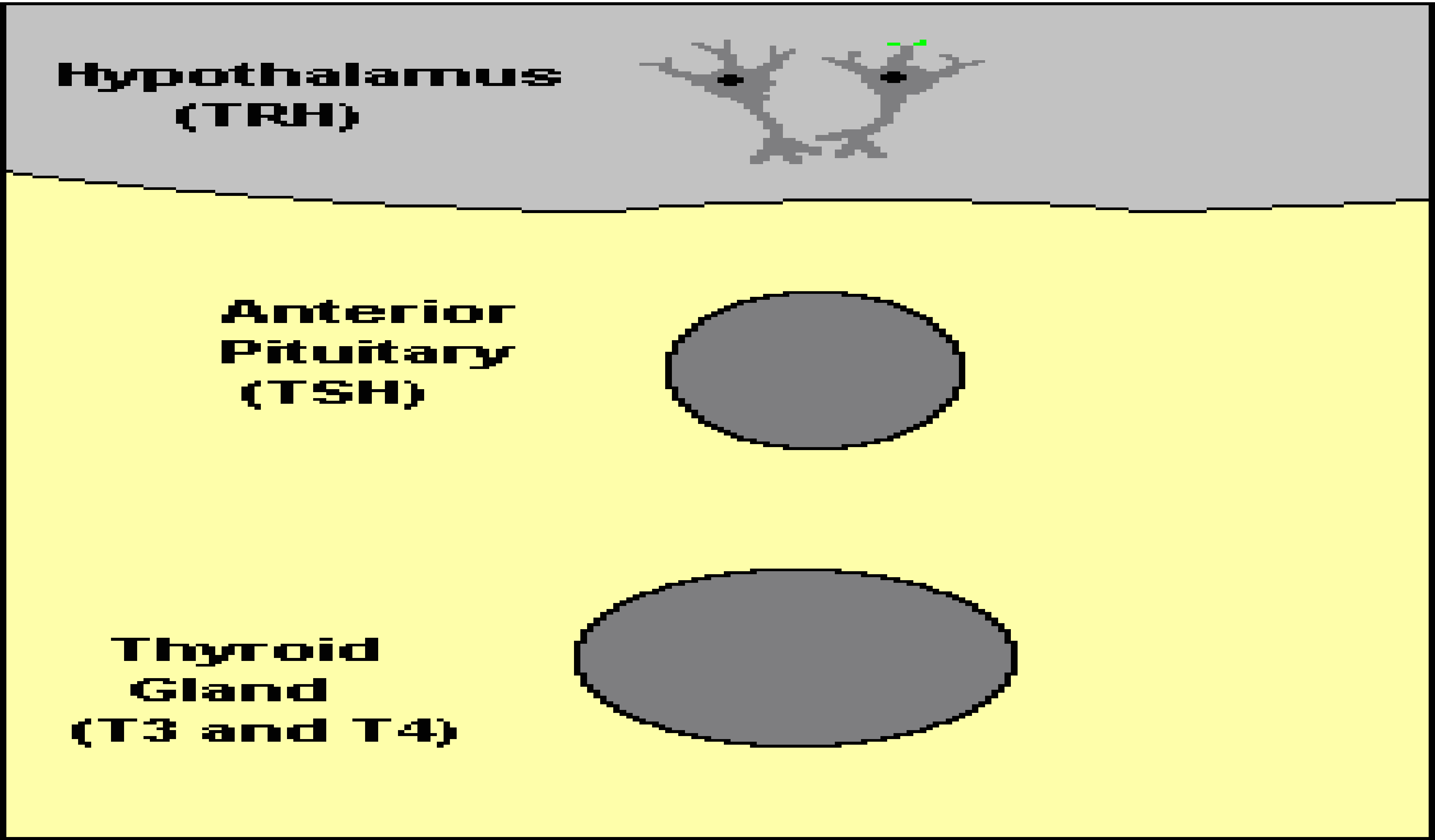
OFF


sensor
effector
variable
afferent pathway
efferent pathway
Controller

Biological Control System

- **Series of interconnected components that maintain a physical or chemical parameter at a near constant value**
- **Components**
  - Sensor or receptor :
    - Detects changes in variable
  - Control center:
    - Assesses input and initiates response
  - Effector:
    - Changes internal environment back to normal


Hypothalamus
(TRH)
Anterior
Pituitary
(TSH)
Thyroid
Gland
(T3 and T4)

Components of a Biological Control System

Components of a biological control system

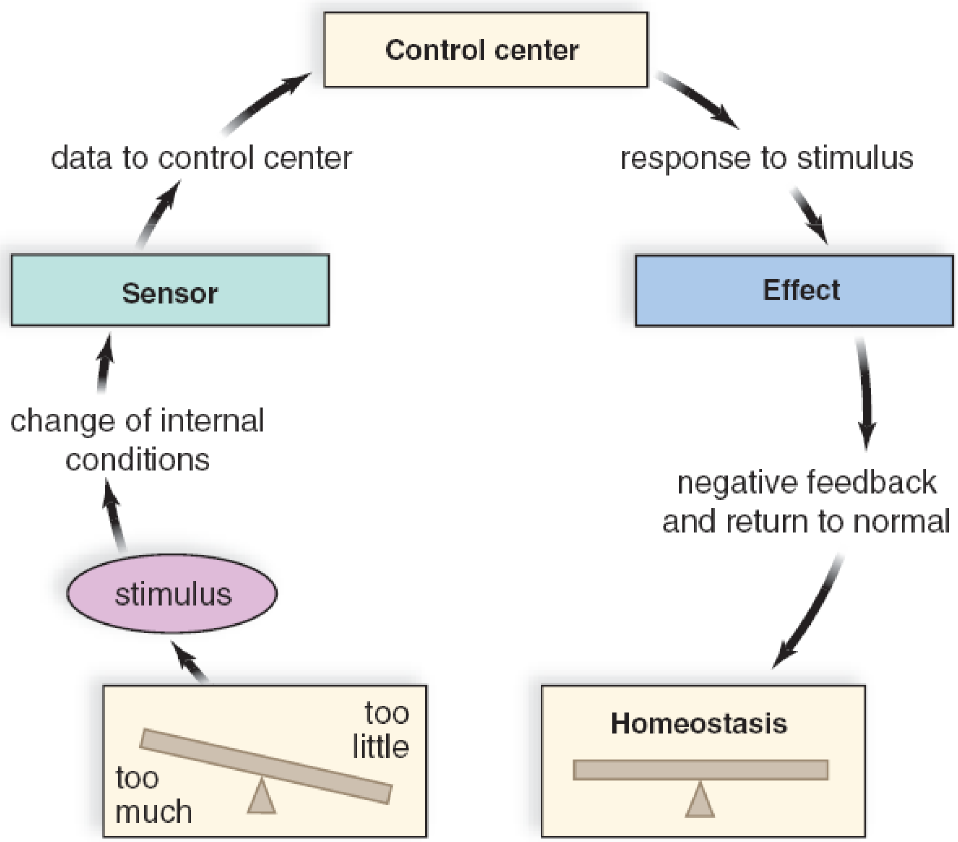


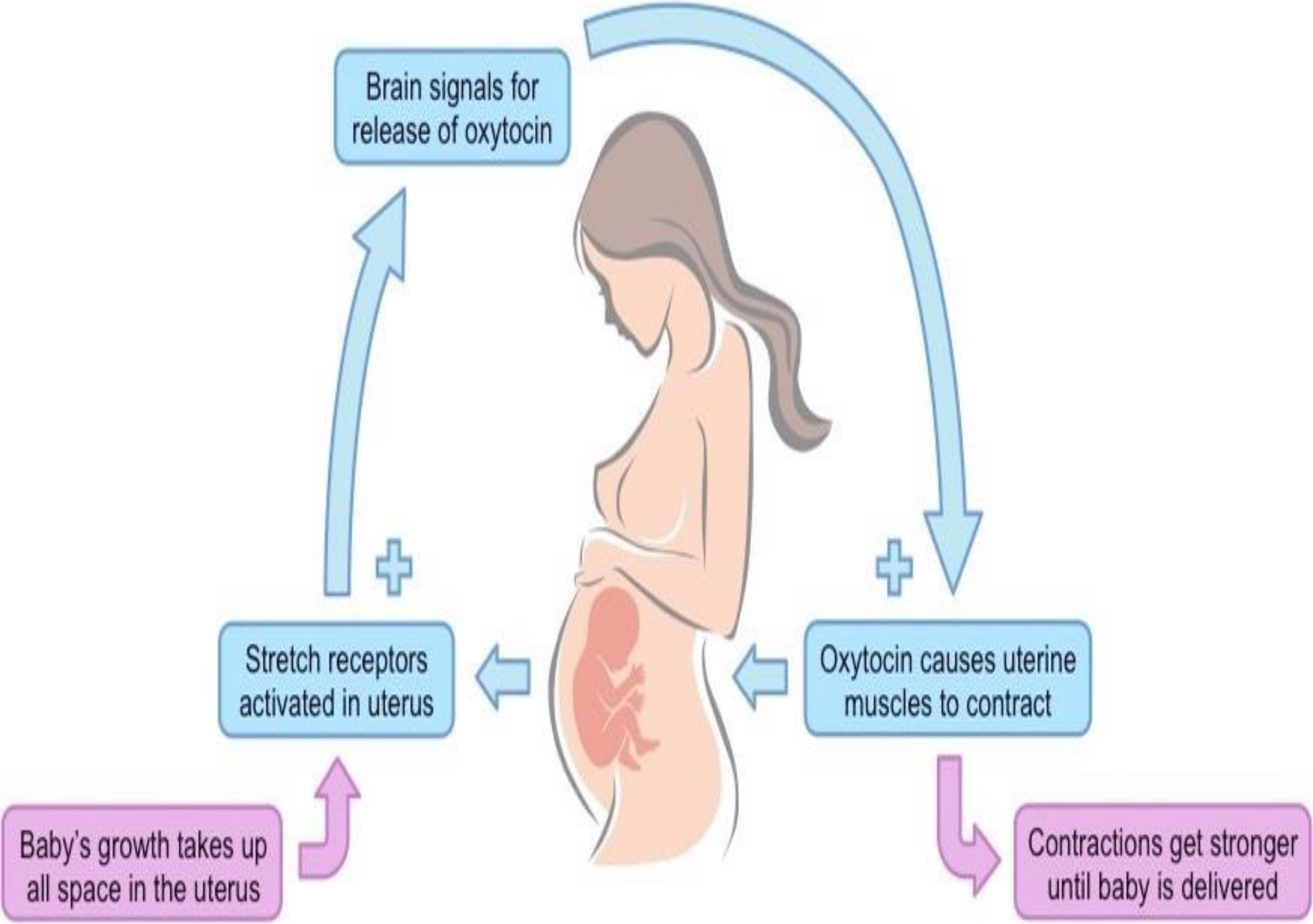
Figure 2.5

Negative Feedback

- **Response reverses the initial disturbance in homeostasis**
- **Example:**
  - Increase in extracellular CO_2 triggers a receptor
  - Sends information to respiratory control center
  - Respiratory muscles are activated to increase breathing
  - CO_2 concentration returns to normal
- **Most control systems work via *negative feedback***

Positive Feedback

- **Response increases the original stimulus**
- **Example:**
  - Initiation of childbirth stimulates receptors in cervix
  - Sends message to brain
  - Release of oxytocin from pituitary gland
  - Oxytocin promotes increased uterine contractions


Brain signals for release of oxytocin
Oxytocin causes uterine muscles to contract
Stretch receptors activated in uterus
Baby's growth takes up all space in the uterus
Contractions get stronger until baby is delivered

Gain of a control system

- **Degree to which a control system maintains homeostasis**
- **System with large gain is more capable of maintaining homeostasis than system with low gain**
  - Pulmonary and cardiovascular systems have large gains

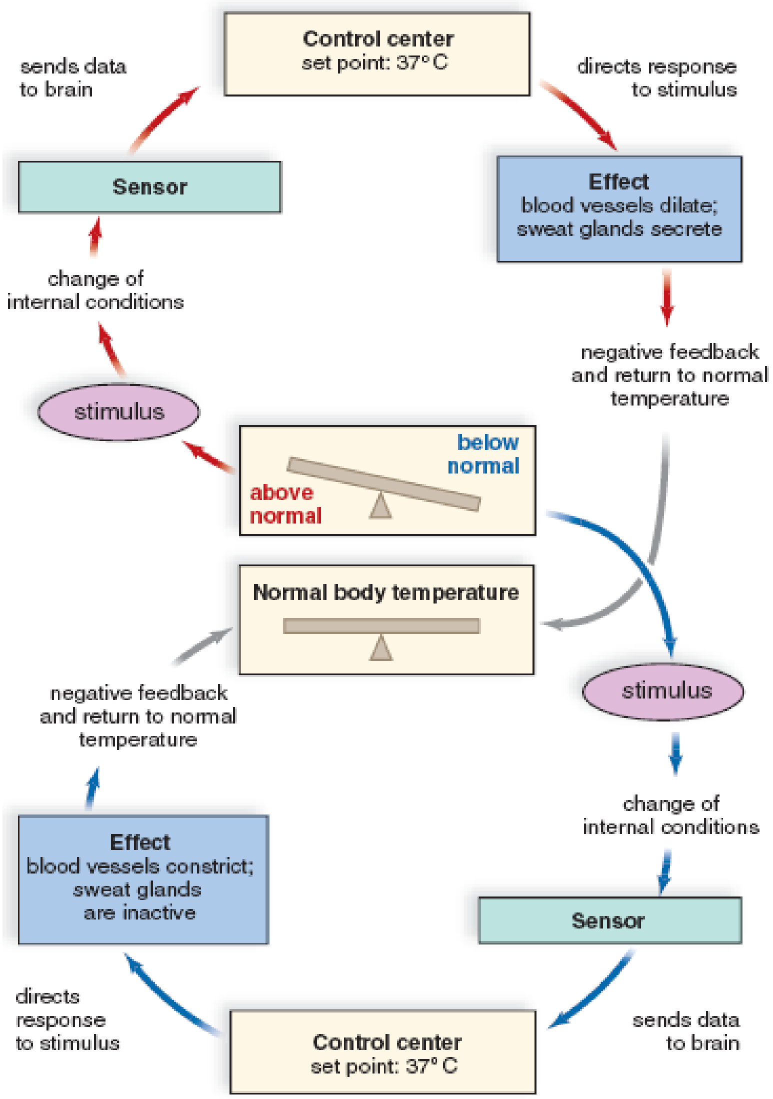
In Summary

- A biological control system is composed of a sensor, a control center, and an effector.
- Most control systems act by way of negative feedback.
- The degree to which a control system maintains homeostasis is termed the *gain of the system*. A control system with a large gain is more capable of maintaining homeostasis than a system with a low gain.

Examples of Homeostatic Control

- **Regulation of body temperature**
  - Thermal receptors send message to brain
  - Response by skin blood vessels and sweat glands regulates temperature
- **Regulation of blood glucose**
  - Requires the hormone insulin
  - Diabetes
    - Failure of blood glucose control system
- **Regulation of cellular homeostasis**
  - Stress proteins (heat shock proteins)
    - Repair damaged proteins to restore homeostasis in response to changes in temperature, pH, and free radicals

Regulation of Body Temperature



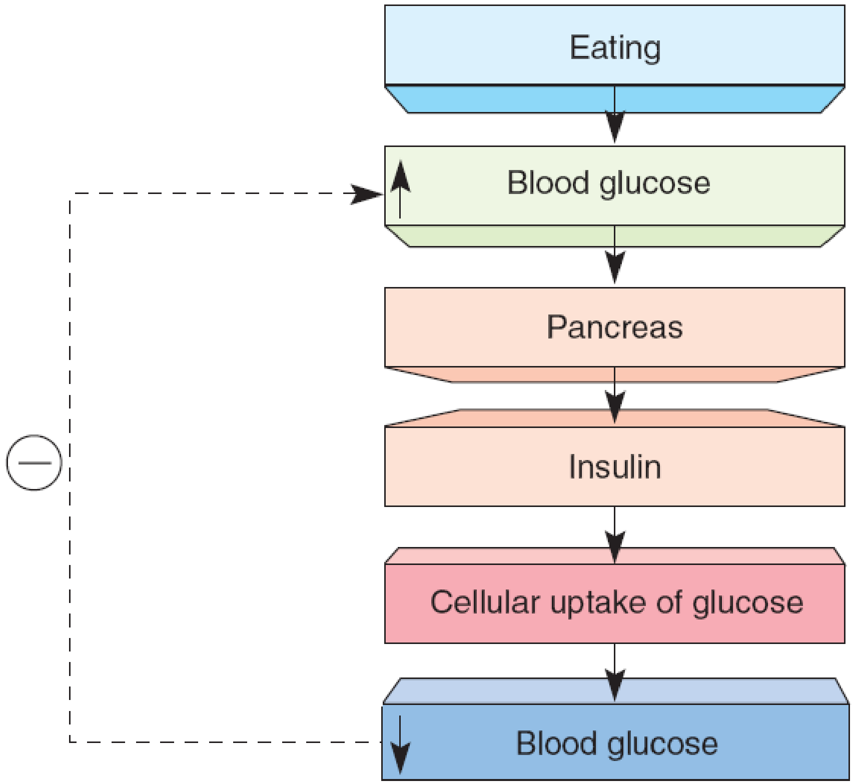
Negative feedback mechanism to regulate body temperature

Figure 2.6

Regulation of Blood Glucose

Illustration of the regulation of blood glucose concentration

Negative feedback



The pancreas acts as both the sensor and effector organ

Figure 2.7

Failure of a Biological Control System Results in Disease

- **Failure of any component of a control system results in a disturbance of homeostasis**
- **Example:**
  - Type 1 diabetes
    - Damage to beta cells in pancreas
    - Insulin is no longer released into blood
    - Hyperglycemia results
  - This represents failure of “effector”

Stress Proteins Help Maintain Cellular Homeostasis

- **Cells synthesize "stress proteins" when homeostasis is disrupted**
  - Heat shock proteins
- **Stresses include:**
  - High temperature
  - Low cellular energy levels
  - Abnormal pH
  - Alterations in cell calcium
  - Protein damage by free radicals
- **Exercise induces these stresses**

Example of Homeostatic Control: Cellular Stress Response

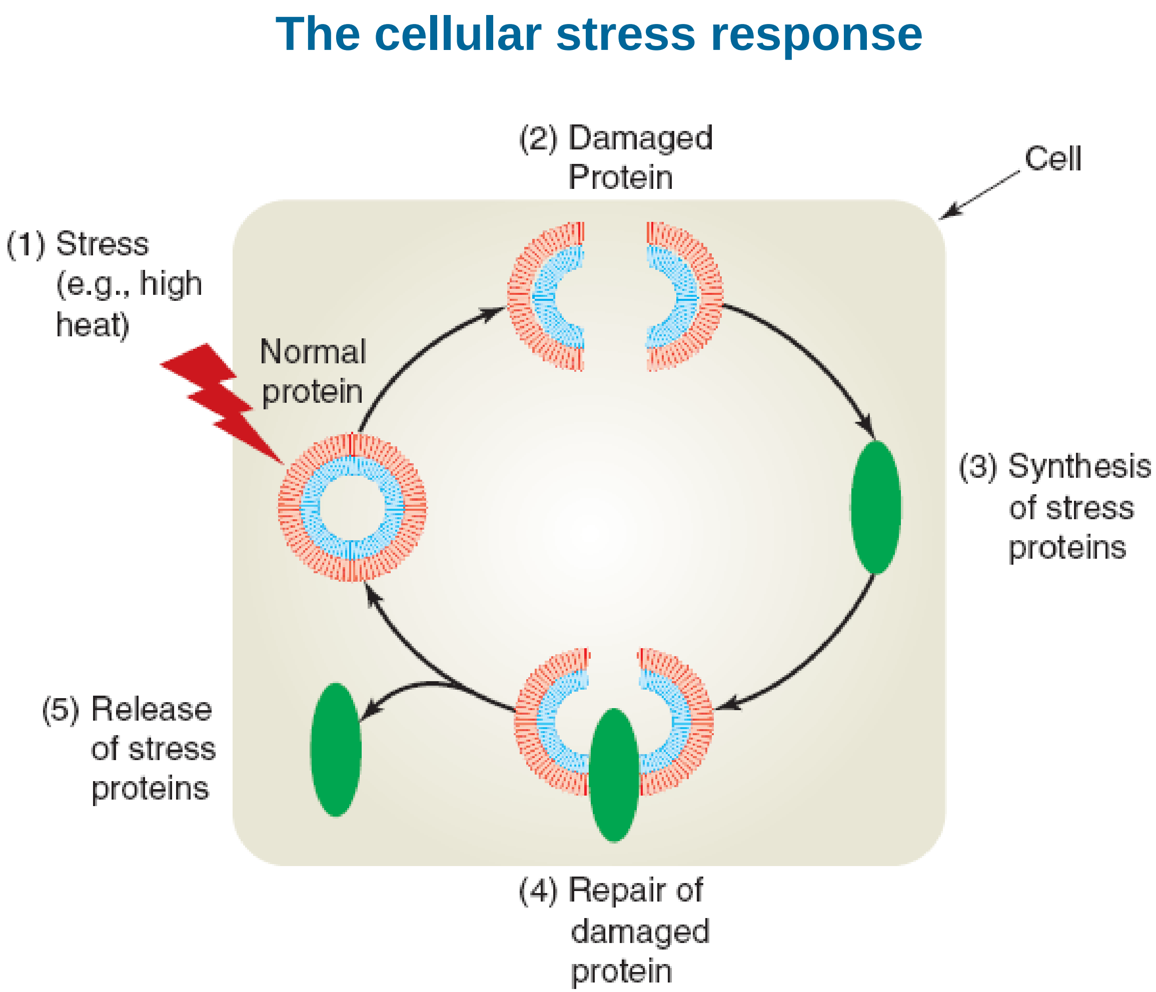


Figure 2.8

Exercise

- **Exercise disrupts homeostasis by changes in pH, O_2, CO_2, and temperature**
- **Control systems are capable of maintaining steady state during submaximal exercise in a cool environment**
- **Intense exercise or prolonged exercise in a hot/humid environment may exceed the ability to maintain steady state**
  - May result in fatigue and cessation of exercise

In Summary

- Exercise represents a challenge to the body’s control systems to maintain homeostasis. In general, the body’s control systems are capable of maintaining a steady state during most types of exercise in a cool environment. However, intense exercise or prolonged work in a hostile environment (i.e., high temperature/ humidity) may exceed the ability of a control system to maintain steady state, and severe disturbances of homeostasis may occur.

Study Questions

1. Define the term *homeostasis*. How does it differ from the term *steady state*?
2. Cite an example of a biological homeostasis control system.
3. Draw a simple diagram that demonstrates the relationship between the components of a biological control system.
4. Briefly, explain the role of the sensor, the integrating center, and the effector organ in a biological control system.
5. Explain the terms *negative feedback* and *positive feedback*. Give a biological example of negative feedback.
6. Discuss the concept of gain associated with a biological control system.