Feedback Mechanisms

Key terms
- diabetes mellitus
- homeostasis
- negative feedback
- positive feedback
- thermoregulation
- transpiration

Core ideas
Feedback mechanisms maintain an organism's internal environment within certain limits

- 1. **Homeostasis** mechanisms help the body maintain a constant internal environment, even when external conditions are changing.

- 2. The body's systems must maintain homeostasis so essential life processes can be carried out to maintain life.

- 3. During exercise, the circulatory and respiratory systems are mainly responsible for maintaining homeostasis.

Feedback mechanisms can be positive or negative

- 4. **Positive feedback** mechanisms amplify a response, usually to achieve a certain outcome. Labor is an example of a physiological process involving positive feedback.

- 5. **Negative feedback** mechanisms have a stabilizing effect, are self-correcting, and encourage a return to the steady state. Negative feedback regulates most natural systems, e.g. in physiology and ecology.

- 6. **Thermoregulation** (regulation of body temperature) is controlled by negative feedback. Failure to maintain a constant body temperature can be life threatening.

- 7. Blood sugar levels are tightly regulated by negative feedback mechanisms. **Diabetes mellitus** is a life-threatening disease which can occur when normal regulatory controls no longer work.

- 8. Plants lose water by a process called transpiration. They must take up enough water to balance the water loss so they can continue to carry out essential life processes.

Science and engineering practices

- 1. Develop and use a model to show that the hierarchical organization of interacting systems provides specific functions in a multicellular organism.

- 2. Use a model based on evidence to show how negative feedback mechanisms maintain homeostasis.

- 3. Carry out an investigation to show how the body maintains homeostasis, for example, during exercise.

- 4. Carry out an investigation to show how plants maintain water balance in changing environmental conditions.
1. (a) Is the cell on the right an animal or plant cell?

(b) List the features of the cell that support your answer:

(c) What word is used to describe cells that carry out a very specific job?

2. Organelles are the cell’s “organs”; they carry out the cell’s work. Draw a line to match the organelle in the left hand column with its correct description in the right hand column.

<table>
<thead>
<tr>
<th>Cell wall</th>
<th>A lipid bilayered membrane surrounding a cell. It controls the movement of substances into and out of the cell.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroplast</td>
<td>A structure present in plant cells but not animal cells. It is found outside the plasma membrane and gives rigidity to the cell.</td>
</tr>
<tr>
<td>Nucleus</td>
<td>Membrane-bound area within a eukaryotic cell where most of a cell’s DNA is found.</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>These structures are involved in making proteins in a cell.</td>
</tr>
<tr>
<td>Plasma membrane</td>
<td>An organelle found in plants which contains chlorophyll and is the site of photosynthesis.</td>
</tr>
<tr>
<td>Ribosome</td>
<td>This organelle is involved in producing the cell’s energy.</td>
</tr>
</tbody>
</table>

3. Fill in the missing words in the paragraph below. Use the word list below to help you.

Guanine, nucleotides, protein, shape, double-helix, base, DNA, phosphate, denatured, cytosine, base pairing

All living cells contain genetic material called ____________, which stores and transmits the information an organism needs to develop, function, and reproduce. DNA is very large. It is made up of building blocks called ______________ joined together. A nucleotide has three parts, a ____________, a sugar, and a ______________ group. There are four different types of nucleotides in DNA, adenine, ____________, ____________, and thymine. They pair together in a very specific way called the ____________ ____________ rule. This pairing gives DNA its characteristic ________________ shape. Segments of DNA, called genes, code for a specific ____________. Proteins are very important because they control every aspect of an organism’s structure and function. The ____________ of a protein determines its functional role. If the protein loses its shape, becomes ____________, it can no longer perform its role.
Key Idea: Homeostasis is the ability to maintain a constant internal environment despite changes in the external environment.

What is homeostasis?

Homeostasis literally means "constant state". Organisms maintain homeostasis, i.e. a relatively constant internal environment, even when the external environment is changing. This takes energy.

For example, when you exercise (right), your body must keep your body temperature constant at about 37.0 °C despite the increased heat generated by activity. Similarly, you must regulate blood sugar levels and blood pH, water and electrolyte balance, and blood pressure. Your body's organ systems carry out these tasks.

To maintain homeostasis, the body must detect changes in the environment (through receptors), process this sensory information, and respond to it appropriately. The response provides new feedback to the receptor. These three components are illustrated below.

1. What is homeostasis?

2. What is the role of the following components in maintaining homeostasis:

(a) Receptor:

(b) Control center:

(c) Effector:
50 Keeping in Balance

Key Idea: Essential life processes, such as growth, require the body's systems to be kept in balance. Many organ systems work together to maintain homeostasis.

Why is homeostasis important?

- An organism must constantly regulate its internal environment in order to carry out essential life processes, such as growing and responding to the environment. Changes outside of normal levels for too long can stop the body systems working properly, and can result in illness or death.
- Homeostasis relies on monitoring all the information received from the internal and external environment and coordinating appropriate responses. This often involves many different organ systems working together.
- Most of the time an organism's body systems are responding to changes at the subconscious level, but sometimes homeostasis is achieved by changing a behavior (e.g. finding shade if the temperature is too high).

Some examples of how the body keeps in balance

Regulating respiratory gases
All of the body's cells need oxygen to carry out cellular respiration to produce usable energy. Oxygen must be delivered to all cells, and carbon dioxide (a waste product of cellular respiration) must be removed. Oxygen demand and carbon dioxide production change with activity level and changes in the environment. For example, the body needs more oxygen during exercise than when a person is resting quietly, so respiration rates increase to meet the increased demand.

Coordinating responses
The body is constantly bombarded by stimuli from the environment. The brain must prioritize its responses and decide which stimuli are important and require a response, and which ones do not. For example, if a person steps on a sharp object and experiences pain, their body coordinates the responses needed to lift the foot and remove it from the source of pain.

Maintaining fluid balance
Without enough water, the body becomes dehydrated and essential life processes are disrupted. Dehydration quickly results in death if untreated. The amount of water lost in urine, feces, breathing, and sweat, must be balanced by consuming enough water (as food and drink) to cover the losses.

Maintaining nutrient supply
Food and drink provide the energy and nutrients the body needs to carry out its essential life processes. Factors that change the demand for nutrients include activity level (e.g. the body burns more energy while it is active) and environmental factors (more energy is required to maintain homeostasis in cold environments).

Coping with disease-causing organisms
We are under constant attack from disease-causing organisms (pathogens) which can cause damage to the body systems. The body's immune system produces substances and cells to prevent the entry of pathogens and limit the damage they cause if they do enter. The cardiovascular system circulates these components through the body.

Repairing injuries
Damage to the body's tissues triggers responses to repair it and return it to a normal state as quickly as possible. For example, blood clotting stops too much blood from leaving the body from an open wound. If too much blood is lost, a person will go into fatal shock.
The body's organ systems work together to maintain homeostasis

Organ systems work together to maintain the environment necessary for the functioning of the body's cells. A constant internal environment allows an organism to be somewhat independent of its external environment, so that it can move about even as its environment changes. The simplified example below illustrates how organ systems interact to exchange material with each other to maintain a constant internal environment.

1. Why is it important that the body systems are kept in balance? ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________

2. Why is it important that the brain prioritizes the importance of the incoming stimuli? ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________

3. Using an example, briefly explain why homeostasis often involves more than one body system:
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
Negative Feedback Mechanisms

Key Idea: Negative feedback mechanisms detect changes in the internal environment away from the normal and act to return the internal environment back to a steady state.

Negative feedback is a control system which maintains the body's internal environment at a steady state. Negative feedback has a stabilizing effect and acts to discourage variations from a set point. It works by returning internal conditions back to a steady state when variations are detected (right). Most body systems achieve homeostasis through negative feedback. Body temperature, blood glucose levels, and blood pressure are all controlled by negative feedback mechanisms.

How negative feedback works

Internal environment moves away from optimum set point
Corrective mechanisms activated

Return to optimum set point
Corrective mechanisms activated

Optimum set point

Stomach emptying: an example of negative feedback

Response:

Empty stomach
Stomach wall is relaxed.
Stomach returns to steady state.

Stretch receptors are deactivated

Smooth muscle in the stomach wall contracts. Food is mixed and emptied from the stomach.

Receptor:

Food is eaten

Food enters the stomach, causing the stomach wall to stretch.

Effector:

1. How does negative feedback maintain homeostasis? ______________________________________________________

2. (a) On the diagram of stomach emptying, name the receptor, effector, and response in the spaces provided.

(b) What is the steady state for this example? _____________________________
Positive Feedback Mechanisms

**Key Idea:** Positive feedback mechanisms amplify a physiological response in order to achieve a particular outcome.

Positive feedback mechanisms amplify (increase) or speed up a physiological response, usually to achieve a particular outcome. Examples of positive feedback include fruit ripening, fever, blood clotting, childbirth (labor) and lactation (production of milk). A positive feedback mechanism stops when the end result is achieved (e.g. the baby is born, a pathogen is destroyed by a fever, or ripe fruit falls off a tree).

Positive feedback is less common than negative feedback because it creates an escalation in response, which is unstable. This response can be dangerous (or even cause death) if it is prolonged.

---

1. (a) Why is positive feedback much less common than negative feedback in body systems?

   (Your response here)

(b) Why can positive feedback be dangerous if it continues on for too long?

   (Your response here)

(c) How is a positive feedback loop normally stopped?

   (Your response here)

2. (a) Name the regulatory factor in childbirth:

   (Your response here)

(b) What event brings an end to the positive feedback loop in childbirth?

   (Your response here)
Sources of Body Heat

**Key Idea:** An optimal body temperature is required for essential life processes. Ectotherms obtain heat from the environment. Endotherms generate heat from metabolism.

**Where do animals get their body heat from?**

Animals are classified into two groups based on the source of their body heat.

- **Ectotherms** depend on the environment for their heat energy (e.g. heat from the sun).
- **Endotherms** generate most of their body heat from internal metabolic processes.

Many animals fall somewhere between the two extremes.

**Why is body heat important?**

An optimal body temperature is needed for essential life processes. Many ectotherms cannot function optimally until their body temperature has reached a certain level. For example, they cannot move quickly in the early morning and at night when their body temperature is low.

The enzymes involved in metabolic pathways all have an optimal temperature range for activity. Below the optimum temperature, metabolic reactions proceed very slowly. Above the optimum temperature, the enzymes may become damaged and the reaction does not proceed.

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**Source of body heat**

![Illustration of various animals showing their heat sources]

- Most fish are fully ectothermic, they rely wholly on the environment for their body heat.
- Snakes use heat energy from the environment to increase their body temperature for activity.
- Some large insects, such as bumblebees, may raise their temperature for short periods through muscular activity.
- Mammals and birds achieve high body temperatures through metabolic activity and reduction of heat losses.

**Increasingly endothermic**

1. Distinguish between **ectotherms** and **endotherms** in terms of their sources of body heat:

   __________________________________________________________________________

2. (a) Why are the movements of many ectotherms slow in the morning?

   __________________________________________________________________________

   __________________________________________________________________________

(b) Why could this be a disadvantage?

   __________________________________________________________________________

   __________________________________________________________________________
Thermoregulation is a term that describes the regulation of body temperature in the face of changes in the temperature of the external environment. When we look at temperature regulation in animals, we can consider two extremes of body temperature tolerance:

- **Homeotherms** maintain a constant body temperature. They are usually strict thermoregulators.
- **Poikilotherms** allow their body temperature to vary with the temperature of the environment. They usually thermoregulate to avoid overheating.

In reality, many animals fall somewhere on a continuum between these two extremes. We have seen in the previous activity that animals are classed as ectotherms or endotherms depending on their sources of heat energy. Most, but not all, endotherms are also homeothermic and most, but not all, ectotherms allow their body temperatures to vary somewhat. Thermoregulation relies on physical, physiological, and behavioral mechanisms.

**Mechanisms of thermoregulation**

**Homeothermic endotherm (mammal)**
- Wool, hair, or fur traps air next to the skin, providing an insulating layer to reduce heat loss and slow heat gain.
- Heat can be generated by shivering.
- In cold weather, many mammals cluster together to retain body heat.
- Panting and sweating cool through evaporation. Mammals usually sweat or pant but not both.

**Poikilothermic ectotherm (reptile)**
- Basking in the sun is common in lizards and snakes. The sun warms the body up and they seek shade to cool down.
- Increasing blood flow to the surface can help lose heat quickly.
- Some lizards reduce points of contact with hot ground (e.g., standing on two legs instead of four) reducing heat uptake via conduction.

1. What is thermoregulation?

2. The graph (top of page) shows temperature regulation in a homeothermic endotherm and a poikilothermic ectotherm. Describe how each responds to changes in environmental temperature:

3. Thermoregulation can be aided by both physical features and behavior. Give an example of each:
   (a) Behavior:
   (b) Physical features:
**Key Idea:** The hypothalamus regulates body temperature in humans. It coordinates nervous and hormonal responses to keep the body temperature within its normal range.

### The hypothalamus regulates temperature

In humans, the temperature regulation center of the body is a region of the brain called the **hypothalamus**. It has a 'set-point' temperature of 36.7°C (98.6°F).

The hypothalamus acts like a thermostat. Changes in the core body temperature or in the skin temperature are registered by the hypothalamus, which then coordinates the appropriate nervous and hormonal responses to counteract the changes and restore normal body temperature. When normal temperature is restored, the corrective mechanisms are switched off. This is an example of a negative feedback regulation.

**Counteracting heat loss**

- The hypothalamus monitors blood temperature and receives input from thermoreceptors in the skin. The heat promoting center in the hypothalamus detects a fall in skin or core temperature below 35.8°C and coordinates responses that generate and conserve heat.
- Increased metabolic rate produces heat.
- Body hairs become raised and increase the insulating air layer around the body.
- In extreme cold, two hormones (epinephrine and thyroxine) increase the energy-releasing activity of the liver.
- The flow of blood to the skin decreases, keeping warm blood near the core (where the vital organs are).
- Shivering (fast contraction and relaxation of muscles) produces internal heat.

**Factors causing heat loss**

- Wind
- Cold external temperature
- Not wearing enough clothing
- Being wet or in cold water
- Dehydration or being in "shock"

**Counteracting heat gain**

- The heat losing center in the hypothalamus monitors any rise in skin or core temperature above 37.5°C and coordinates responses that increase heat loss.
- Sweating occurs. This cools the body by evaporation.
- Decreased metabolic rate. This reduces the amount of heat generated by the body.
- Body hairs become flattened against the skin. This reduces the insulating air layer around the body and helps heat loss.
- The flow of blood to the skin increases. Warm blood from the body core is transported to the skin and the heat is lost from the skin surface.

**Factors causing heat gain**

- Warm external temperature
- High humidity
- Excessive fat deposits
- Wearing too much clothing

Infection can reset the set-point of the hypothalamus to a higher temperature. The body temperature then increases above the normal range, resulting in a **fever**. Fever is an important defense against infection.
Thermoregulation in newborns

Newborn babies cannot fully thermoregulate until six months of age. They can become too cold or too hot very quickly.

Newborns minimize heat loss by reducing the blood supply to the periphery (skin, hands, and feet). This helps to maintain the core body temperature. Increased brown fat activity and general metabolic activity generates heat. Newborns are often dressed in a hat to reduce heat loss from the head, and tightly wrapped to trap heat next to their bodies.

Newborns lower their temperature by increasing peripheral blood flow. This allows heat to be lost, cooling the core temperature. Newborns can also reduce their body temperature by sweating, although their sweat glands are not fully functional until four weeks after birth.

1. Where is the temperature regulation center in humans located?

2. (a) Why does infection result in an elevated core body temperature?

(b) What is the purpose of this?

3. Describe the role of the following in maintaining a constant body temperature in humans:

(a) The skin:

(b) The hypothalamus:

(c) Sweating:

(d) Shivering:

4. Describe the features of a newborn that can cause it to lose heat quickly:

5. How can newborns control body temperature by altering blood flow to the skin?
Hypothermia and Hyperthermia

Key Idea: Failure of normal thermoregulatory mechanisms can result in hypothermia (low body temperature) or hyperthermia (high body temperature).

Hypothermia

Hypothermia means low body temperature. It occurs when the body cannot generate enough heat and the core body temperature drops below 35°C. In hypothermia, the body loses heat faster than it can produce it.

At temperatures below 35°C, metabolic reactions and body functions are impaired. People with hypothermia experience a loss of coordination, difficulty in moving, and mental fatigue.

Hypothermia is caused by exposure to low temperatures, and results from the body's inability to replace the heat being lost to the environment.

Hyperthermia

Hyperthermia means high body temperature. It occurs when the body cannot dissipate excess heat and the core body temperature exceeds 38.5°C. In hyperthermia, heat is produced more quickly than it can be lost.

Prolonged hyperthermia is potentially fatal and is treated as a medical emergency.

Causes include dehydration, prolonged exposure to excessive heat or humidity, and strenuous exercise. Fever is not hyperthermia because the hypothalamus set-point of a person with hyperthermia has not been reset.

Hypothermia is treated by rewarming the body. However, rewarming the body too quickly can actually cause the body to attempt to remove the sudden excess of heat and cause more heat loss.

Hyperthermia is treated by cooling the body. Mild cases (above) are treated by drinking water, removing excess clothing, and resting in a cool place. Medical treatment is needed for hyperthermia above 40°C.

---

1. (a) What is hypothermia?

(b) How is it treated?

2. (a) What is hyperthermia?

(b) How is it treated?

3. What is the common link in both hypothermia and hyperthermia?

4. On the thermometer (right), mark the normal thermoregulatory set-point, and the temperatures at which hypothermia and hyperthermia occur.
Controlling Blood Sugar Levels

Key Idea: Blood glucose levels are regulated by negative feedback. Two hormones, insulin and glucagon, control blood glucose levels.

The importance of blood glucose
Glucose is the body's main energy source. It is chemically broken down during cellular respiration to generate ATP, which is used to power the chemical reactions of the cell. Glucose is the main sugar circulating in blood, so it is often called blood sugar. Blood glucose levels are tightly controlled because cells must receive an adequate and regular supply of fuel. Prolonged high or low blood glucose causes serious physiological problems and even death. Normal activities, such as eating and exercise, alter blood glucose levels, but the body's control mechanisms regulate levels so that fluctuations are minimized.

Controlling blood glucose levels
Blood glucose (BG) is controlled by two hormones produced by special islet cells in the pancreas. The hormones work antagonistically and levels are tightly controlled by negative feedback.

- Insulin lowers blood glucose by promoting glucose uptake by cells and glycogen storage in the liver.
- Glucagon increases blood glucose by promoting release of glucose from the breakdown of stored glycogen.
- When normal blood glucose levels are restored, negative feedback stops hormone secretion.

1. Why must blood glucose levels be carefully controlled? ________________________________

   ____________________________________________________________

2. For the following two scenarios, describe how normal blood glucose level is restored:

   (a) Low blood glucose: ________________________________

   ____________________________________________________________

   (b) High blood glucose: ________________________________

   ____________________________________________________________

3. What mechanism regulates the secretion of the hormones controlling BG? ______________

   ____________________________________________________________
Diabetes mellitus is a condition where blood glucose levels are too high. It may be caused by a lack of insulin (type 1) or by resistance to insulin's effects (type 2).

**Key Idea:**

Diabetes mellitus (often just called diabetes) is a condition in which blood glucose is too high because the body's cells cannot take up glucose in the normal way. It is usually detected by glucose appearing in the urine (glucose is normally reabsorbed and does not enter the urine). The two types of diabetes, type 1 and type 2, have different causes and treatments, but both are life threatening conditions if untreated.

**Type 1 diabetes**

No insulin is produced because the insulin-producing cells of the pancreas are damaged.

**Type 2 diabetes**

Insulin is produced. However, either not enough insulin is made, or the body's cells do not react to it.

The beta cells of the pancreatic islets (outlined above) produce insulin.

1. Why does diabetes mellitus result in high blood sugar levels?

2. Discuss the differences between type 1 and type 2 diabetes, including causes and treatments:
Homeostasis during Exercise

**Key Idea:** The circulatory and respiratory systems are primarily responsible for maintaining homeostasis during exercise.

During exercise, greater metabolic demands are placed on the body, and it must work harder to maintain homeostasis. Maintaining homeostasis during exercise is principally the job of the circulatory and respiratory systems, although the skin, kidneys, and liver are also important.

**Increased body temperature**
During exercise, the extra heat produced by muscle contraction must be dispersed to prevent overheating. Thermoregulatory mechanisms, such as sweating and increased blood flow to the skin, release excess heat into the surrounding environment and help cool the body.

**Increased heart rate**
An increased heart rate circulates blood around the body more quickly. This increases the rate at which exchanges can be made between the blood and the working tissues. Oxygen and glucose are delivered and metabolic wastes (e.g., carbon dioxide) are removed.

**Increased glucose production**
During exercise, working muscles quickly use up freely available blood glucose. Glucose is mobilized from glycogen stores in the liver and supplies the body with fuel to maintain ATP production.

1. The graph (right) compares the change in cardiac output (a measure of total blood flow in liters) during rest and during exercise. The color of the bars indicates the proportion of blood flow in skeletal muscle compared to other body parts.

   (a) What percentage of the blood goes to the muscles at rest? ______________________
       ______________________

   (b) What percentage of the blood goes to the muscles during exercise? ______________________
       ______________________

2. (a) What happens to the total blood flow during heavy exercise compared to at rest? ______________________

   (b) Why does this change occur? ______________________

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Exercise and Heart Rate

Key Idea: Heart rate and breathing rate both increase during exercise to meet the body's increased metabolic demands.

In this practical, you will work in groups of three to see how exercise affects breathing and heart rates. Choose one person to carry out the exercise and one person each to record heart rate and breathing rate.

Heart rate (beats per minute) is obtained by measuring the pulse (right) for 15 seconds and multiplying by four.

Breathing rate (breaths per minute) is measured by counting the number of breaths taken in 15 seconds and multiplying it by four.

CAUTION: The person exercising should have no known pre-existing heart or respiratory conditions.

Procedure

Resting measurements
Have the person carrying out the exercise sit down on a chair for 5 minutes. They should not move. After 5 minutes of sitting, measure their heart and breathing rates. Record the resting data on the table (right).

Exercising measurements
Choose an exercise to perform. Some examples include step ups onto a chair, skipping rope, jumping jacks, and running in place. Begin the exercise, and take measurements after 1, 2, 3, and 4 minutes of exercise. The person exercising should stop just long enough for the measurements to be taken. Record the results in the table.

Post exercise measurements
After the exercise period has finished, have the exerciser sit down in a chair. Take their measurements 1 and 5 minutes after finishing the exercise. Record the results on the table.

<table>
<thead>
<tr>
<th>Heart rate (beats minute⁻¹)</th>
<th>Breathing rate (breaths minute⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting</td>
<td></td>
</tr>
<tr>
<td>1 minute</td>
<td></td>
</tr>
<tr>
<td>2 minutes</td>
<td></td>
</tr>
<tr>
<td>3 minutes</td>
<td></td>
</tr>
<tr>
<td>4 minutes</td>
<td></td>
</tr>
<tr>
<td>1 minute after</td>
<td></td>
</tr>
<tr>
<td>5 minutes after</td>
<td></td>
</tr>
</tbody>
</table>

1. (a) Graph your results on separate piece of paper. You will need to use one axis for heart rate and another for breathing rate. When you have finished answering the questions below, attach it to this page.

   (b) Analyze your graph and describe what happened to heart rate and breathing rate during exercise:

   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________

2. (a) Describe what happened to heart rate and breathing rate after exercise:

   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________

   (b) Why did this change occur?

   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
1. Test your vocabulary by matching each term to its definition, as identified by its preceding letter code.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>diabetes mellitus</td>
<td>A mechanism in which the output of a system acts to oppose changes to the input of the system. The net effect is to stabilize the system and dampen fluctuations.</td>
</tr>
<tr>
<td>homeostasis</td>
<td>B The loss of water vapor by plants, mainly from leaves via the stomata.</td>
</tr>
<tr>
<td>negative feedback</td>
<td>C A destabilizing mechanism in which the output of the system causes an escalation in the initial response.</td>
</tr>
<tr>
<td>positive feedback</td>
<td>D Regulation of the internal environment to maintain a stable, constant condition.</td>
</tr>
<tr>
<td>thermoregulation</td>
<td>E A condition in which the blood glucose level is elevated above normal levels, either because the body doesn’t produce enough insulin, or because the cells do not respond to the insulin that is produced.</td>
</tr>
<tr>
<td>transpiration</td>
<td>F The regulation of body temperature.</td>
</tr>
</tbody>
</table>

2. Test your knowledge about feedback mechanisms by studying the two graphs below, and answering the questions about them. In your answers, use biological terms appropriately to show your understanding.

**A**

Type of feedback mechanism: ____________

Mode of action: ____________

Biological examples of this mechanism: ____________

**B**

Type of feedback mechanism: ____________

Mode of action: ____________

Biological examples of this mechanism: ____________

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ISBN: 978-1-927173-84-8

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Core ideas

Organisms grow and develop through mitosis

- 1. Multicellular organisms develop from a single cell (a fertilized egg) called a zygote.
- 2. The cell cycle describes the events in a cell leading to its division into two daughter cells. The cell cycle consists of two main phases, interphase and the mitotic or M phase (mitosis and cytokinesis).
- 3. During mitosis (cell division) a cell divides to produce two genetically identical cells.
- 4. Mitosis has three functions: growth of an organism, replacement of damaged cells, and asexual reproduction (in some organisms).
- 5. DNA replication must take place before a cell can divide. DNA replication produces two identical copies of DNA. A copy goes to each new cell produced during mitosis.
- 6. DNA replication is semi-conservative. Each replicated DNA molecule consists of one ‘old’ (parent) strand of DNA, and one ‘new’ (daughter) strand of DNA.

Cells become differentiated to carry out specialized roles

- 7. A multicellular organism is made up of many different types of specialized cells. Specialized cells have specific roles in the organism. They arise through cellular differentiation, a process involving the activation of specific genes within a cell.
- 8. Stem cells are unspecialized cells that can give rise to many different cell types.
- 9. Differentiation and specialization of cells produces tissues and organs, which work together to meet the needs of the organism.

Science and engineering practices

- 1. Use a model to illustrate the role of mitosis and cellular differentiation in producing and maintaining a multicellular organism.
- 2. Use a model to show how the components of blood (a liquid tissue) are produced through cellular differentiation from stem cells.