Teacher's Guide

What do AP Biology students need to know to be ready for the AP Biology Exam? The Enduring Understandings and Essential Knowledge standards!

My AP Biology students benefited tremendously from having quick access to the Essential Knowledge standards and these guiding questions. After going through each set, they feel confident they are ready for the Test!

These open ended questions can be used…

- While going through a Unit as a working document, to add to as they learn
- Before a Unit test as a study guide
- At the end of the semester to prepare for the AP Biology Exam

It is helpful to have them begin by going through the Essential Knowledge itself, highlighting key vocabulary. This gives them a good foundation to grow from, they know what to look for and what is important as they learn about or review for the Unit.

When my students use these as review, I put them into small groups of three or four. They work together to each complete the questions. Then students get into new groups and review their answers. I help guide them and help with questions that they can not come to an agreement on.

Here is a link to a digital copy of this document. Open it in Google Docs and then make a copy for your own Google Drive to edit as needed!

Explore the list of extra resources - arranged and organized for each Essential Standard. These are resources I use myself, so if you have questions about any of them, just ask!

Contact me a ScienceOfCuriosity@gmail.com

Looking for more Focused Study Questions for AP Biology?

- **Focused AP Biology Study Questions for Big Idea 1A Natural Selection**
- **Focused AP Biology Study Questions for Big Idea 1B Evolution**
- **Focused AP Biology Study Questions for Big Idea 1C Speciation**
- **Focused AP Biology Study Questions for Big Idea 1.D Origin of Life**

Or get all of Big Idea 1 in this Bundle!

Life Requires Free Energy 2.a.1

Essential knowledge 2.A.1: All living systems require constant input of free energy.

a. Life requires a highly ordered system.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Order is maintained by constant free energy input into the system.
2. Loss of order or free energy flow results in death.
3. Increased disorder and entropy are offset by biological processes that maintain or increase order.

b. Living systems do not violate the second law of thermodynamics, which states that entropy increases over time.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Order is maintained by coupling cellular processes that increase entropy (and so have negative changes in free energy) with those that decrease entropy (and so have positive changes in free energy).
2. Energy input must exceed free energy lost to entropy to maintain order and power cellular processes.
3. Energetically favorable exergonic reactions, such as cellular respiration, that have a negative change in free energy can be used to maintain or increase order in a system by being coupled with reactions that have a positive free energy change.

Highlight Important Terms and Ideas First!

Explain why free energy is necessary to living things. Include the word ‘entropy’ and ‘homeostasis’ in your answer.

What is the first law of thermodynamics?

What is the second law of thermodynamics?

What is the formula for Gibbs Free Energy? _____
Define each part:

Circle the correct term to complete each sentence:

- For a process to occur spontaneously, it must (increase/decrease) the entropy of the system and therefore have a (positive/negative) change in free energy
- **Anabolic** reactions like (photosynthesis/cellular respiration) take (small/large) molecules and make (smaller/larger) molecules and (release/require) energy - thus (increasing/decreasing) entropy of the system. These reactions are (endergonic/exergonic) and therefore (spontaneous/nonspontaneous).

c. Energy-related pathways in biological systems are sequential and may be entered at multiple points in the pathway. [See also 2.A.2] *To foster student understanding of this concept, instructors can choose an illustrative example such as:* Krebs cycle, Glycolysis, Calvin cycle, Fermentation d. Organisms use free energy to maintain organization, grow and reproduce. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Organisms use various strategies to regulate body temperature and metabolism. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* ● Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) ● Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) ● Elevated floral temperatures in some plant species 2. Reproduction and rearing of offspring require free energy beyond that used for maintenance and growth. Different organisms use various reproductive strategies in response to energy availability.	● **Catabolic** reactions (like photosynthesis/cellular respiration) take (small/large) molecules and make (smaller/larger) molecules and (release/require) energy - thus (increasing/decreasing) entropy of the system. These reactions are (endergonic/exergonic). These reactions are (endergonic/exergonic) and therefore (spontaneous/nonspontaneous). How can the organized systems of living organisms occur if all systems are going towards greater disorder? Explain using these words: ATP, energy coupling, endergonic reactions and exergonic reactions Earth gets a constant supply of free energy from the _____ What do plants (autotrophs) do with free energy? _____ How do we (heterotrophs) get free energy? Eventually all energy used by living things ends up as _____ What can organisms do with extra free energy (beyond what it takes to just stay alive)? What happens when organisms get less free energy than is required to stay alive?

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Seasonal reproduction in animals and plants
- Life-history strategy (biennial plants, reproductive diapause)

3. There is a relationship between metabolic rate per unit body mass and the size of multicellular organisms — generally, the smaller the organism, the higher the metabolic rate.

4. Excess acquired free energy versus required free energy expenditure results in energy storage or growth.

5. Insufficient acquired free energy versus required free energy expenditure results in loss of mass and, ultimately, the death of an organism.

e. Changes in free energy availability can result in changes in population size.

f. Changes in free energy availability can result in disruptions to an ecosystem.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Change in the producer level can affect the number and size of other trophic levels.
- Change in energy resources levels such as sunlight can affect the number and size of the trophic levels.

What happens to the food chain if there is a decrease in the amount of free energy available to the producer level of an ecosystem? Explain.

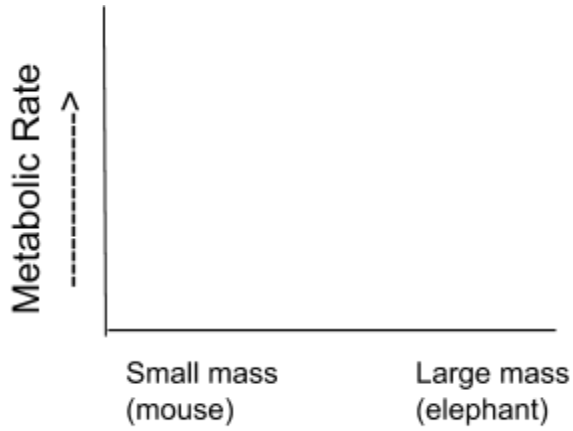
What is glycolysis? What is accomplished by glycolysis? Where does it happen?

What happens when you break down ATP to ADP? Why does it cost ATP to do glycolysis?

How is it that different types of sugars can use glycolysis though they all don't contain glucose?

Complete the graph to show the general relationship between metabolism and size.

Why do mice have such a high metabolism?



What is the difference between Endothermy and Ectothermy? Name an organism that uses each strategy.

Why are most organisms born in the spring?

Photosynthesis and Cellular Respiration 2.a.2

Essential knowledge 2.A.2: Organisms capture and store free energy for use in biological processes.

a. Autotrophs capture free energy from physical sources in the environment.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Photosynthetic organisms capture free energy present in sunlight.
2. Chemosynthetic organisms capture free energy from small inorganic molecules present in their environment, and this process can occur in the absence of oxygen.

b. Heterotrophs capture free energy present in carbon compounds produced by other organisms.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Heterotrophs may metabolize carbohydrates, lipids and proteins by hydrolysis as sources of free energy.
2. Fermentation produces organic molecules, including alcohol and lactic acid, and it occurs in the absence of oxygen.

✘ *Specific steps, names of enzymes and intermediates of the pathways for these processes are beyond the scope of the course and the AP Exam.*

c. Different energy-capturing processes use different types of electron acceptors.

Highlight Important Terms and Ideas First!

What are the two types of autotrophs (what two processes)?

Who are the autotrophs making the food for?

Where does chemosynthesis occur (in what conditions)?

Write the equation for photosynthesis:

What is stored in the glucose molecule?

Light Dependant Reaction

Where does the light reaction take place specifically?

What is chlorophyll and what does it do?

What does light do in the light dependant reactions?

As the electrons pass through the _____ they use their energy to pump _____ into the _____ which makes that space very (acidic/basic).

When the protons are concentrated on one side of the membrane, they pass through the _____(name of enzyme) and forms _____

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- NADP in photosynthesis
- Oxygen in cellular respiration

d. The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture free energy present in light to yield ATP and NADPH, which power the production of organic molecules in the Calvin Cycle.

Evidence of student learning is a demonstrated understanding of each of the following:

1. During photosynthesis, chlorophylls absorb free energy from light, boosting electrons to a higher energy level in Photosystems I and II.
2. Photosystems I and II are embedded in the internal membranes of chloroplasts (thylakoids) and are connected by the transfer of higher free energy electrons through an electron transport chain (ETC). [See also 4.A.2]
3. When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of hydrogen ions (protons) across the thylakoid membrane is established.
4. The formation of the proton gradient is a separate process, but it is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase.
5. The energy captured in the light reactions as ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle, which occurs in the stroma of the chloroplast.

How does the plant use the ATP made during the light dependant reactions (where do they go, what is their purpose)?

What is the final electron acceptor in the Electron Transport Chain of the Light Dependant Reaction?

Where did the electron come from that is added NADPH?

Where does NADPH go? What is its purpose?

Calvin Cycle (light independent reaction):

Evolution: What gas was missing in the early Earth atmosphere? _____ What type of organism is thought to have been responsible for filling the Earth with this gas?

Specifically where does the Light Independent Reaction happen?

What is formed during the light independent reaction?

✘ *Memorization of the steps in the Calvin cycle, the structure of the molecules and the names of enzymes (with the exception of ATP synthase) are beyond the scope of the course and the AP Exam.*

e. Photosynthesis first evolved in prokaryotic organisms; scientific evidence supports that prokaryotic (bacterial) photosynthesis was responsible for the production of an oxygenated atmosphere; prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis.

f. Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that harvest free energy from simple carbohydrates.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Glycolysis rearranges the bonds in glucose molecules, releasing free energy to form ATP from ADP and inorganic phosphate, and resulting in the production of pyruvate.
2. Pyruvate is transported from the cytoplasm to the mitochondrion, where further oxidation occurs. [See also 4.A.2]
3. In the Krebs cycle, carbon dioxide is released from organic intermediates ATP is synthesized from ADP and inorganic phosphate via substrate level phosphorylation and electrons are captured by coenzymes.
4. Electrons that are extracted in the series of Krebs cycle reactions are carried by NADH and FADH2 to the electron transport chain.

✘ *Memorization of the steps in glycolysis and the Krebs cycle, or of the structures of the molecules and the names of the enzymes involved, are beyond the scope of the course and the AP Exam.*

Make a simple diagram of a chloroplast. Label the thylakoid, thylakoid membrane, and stroma. Label where the light dependant and light independent reactions are located. Draw in where Water and CO2 enter the process, and where O2 and Glucose are formed.

Cellular Respiration

Name the two types respiration that heterotrophs can do:

Fermentation does not require _____. What type of fermentation do yeast do? What is the product?

What type of fermentation do we do? What is the product?

In **glycolysis,** you start with one glucose and produce two: _____

Glycolysis is considered “highly conserved” across all domains of life. What does this mean, and what does it imply about the evolution of the process?

g. The electron transport chain captures free energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes. *Evidence of student learning is a demonstrated understanding of each of the following:* 1. Electron transport chain reactions occur in chloroplasts (photosynthesis), mitochondria (cellular respiration) and prokaryotic plasma membranes. 2. In cellular respiration, electrons delivered by NADH and FADH2 are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is NADP. 3. The passage of electrons is accompanied by the formation of a proton gradient across the inner mitochondrial membrane or the thylakoid membrane of chloroplasts, with the membrane(separating a region of high proton concentration from a region of low proton concentration. In prokaryotes, the passage of electrons is accompanied by the outward movement of protons across the plasma membrane. 4. The flow of protons back through membrane-bound ATP synthase by chemiosmosis generates ATP from ADP and inorganic phosphate. 5. In cellular respiration, decoupling oxidative phosphorylation from electron transport is involved in thermoregulation.	What electron carrier is produced during glycolysis? Where does it go? Where does the Krebs cycle happen? In the **Kreb's cycle** makes _____ and _____ that go on to the Electron Transport Chain. What happens to these molecules there? **Electron transport chain**. As we transfer electrons down the ETC we are pumping _____ into the _____ which makes that space very (acidic/basic). What is the purpose of the proton gradient? Where do the protons go? What enzyme is involved? What are the substrates? What is produced? Use the word chemiosmosis. The electron that passed through the chain will eventually bind with the terminal electron acceptor _____ forming _____

✘ *The names of the specific electron carriers in the ETC are beyond the scope of the course and the AP Exam.* h. Free energy becomes available for metabolism by the conversion of ATP --> ADP, which is coupled to many steps in metabolic pathways.	Draw a mitochondria - as large as will fit in the space below. Label the inner membrane, outer membrane, cristae, and matrix. Label the location of glycolysis, the Krebs cycle, the Electron Transport Chain, and ATP Synthase. Also show glucose and oxygen go in, and what comes out. Prokaryotes can perform cellular respiration and photosynthesis - but do not have mitochondria or chloroplasts. How do they establish a proton gradient with which to make ATP? What is the difference between oxidative phosphorylation, and substrate level phosphorylation? Where do each occur? How do endotherms generate body heat?

Environmental Matter Exchange 2.a.3

Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

a. Molecules and atoms from the environment are necessary to build new molecules.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Carbon moves from the environment to organisms where it is used to build carbohydrates, proteins, lipids or nucleic acids. Carbon is used in storage compounds and cell formation in all Organisms.

2. Nitrogen moves from the environment to organisms where it is used in building proteins and nucleic acids. Phosphorus moves from the environment to organisms where it is used in nucleic acids and certain lipids.

3. Living systems depend on properties of water that result from its polarity and hydrogen bonding.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Cohesion
- Adhesion
- High specific heat capacity
- Universal solvent supports reactions
- Heat of vaporization
- Heat of fusion
- Water's thermal conductivity

Highlight Important Terms and Ideas First!

List the elements that make up Carbohydrates: _____

Lipids: _____Proteins: _____ Nucleic Acids: _____

What element is the basis for all organic molecules? _____

Where do Autotrophs get carbon from? _____

Where do Heterotrophs get carbon from? _____

Where to Plants get the Nitrogen then need? _____

Where do Animals get the Nitrogen they need? _____

Why is water polar?

Draw a water molecule. Label its charges.

Draw a representation of the cohesion of water molecules

Because water is polar, it can form _____ bonds.

Draw a representation of the adhesion of water molecules

Water is a 'universal solvent' - what does that mean? Why is that important to life?

b. Surface area-to-volume ratios affect a biological system's ability to obtain necessary resources or eliminate waste products.

Evidence of student learning is a demonstrated understanding of each of the following:

1. As cells increase in volume, the relative surface area decreases and demand for material resources increases; more cellular structures are necessary to adequately exchange materials and energy with the environment. These limitations restrict cell size.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Root hairs
- Cells of the alveoli
- Cells of the villi
- Microvilli

2. The surface area of the plasma membrane must be large enough to adequately exchange materials; smaller cells have a more favorable surface area-to-volume ratio for exchange of materials with the environment.

How do you calculate the surface area of a cube? (what is the equation)

How do you calculate the volume of a cube? (what is the equation)

What is the surface area to volume ratio of a cell that is three cm by three cm? Show your work!

What is the surface area to volume ratio of a spherical cell with a 1 cm radius? Show your work!

Which cell is more efficient at exchanging materials with the environment? How do you know?

Draw a root hair cell. What is the purpose of root hairs on a root?

Draw a red blood cell. Why its shape important to its function?

17 Extra Resources for Enduring Understanding 2A

2A1 Life Requires Free Energy

- **Bozeman Gibbs Free Energy** - helpful to watch before Bozeman 12
- **Bozeman 12 -** Life Requires Free Energy
- **Thermodynamics and Free Energy Online Interactive**

2A2 Photosynthesis and Cellular Respiration

Cellular Respiration

- **Bozeman 13 - Photosynthesis and Cellular Respiration**
- **Cellular Respiration animation: Glycolysis**
- **Cellular Respiration animation: Krebs Cycle**
- **Cellular Respiration animation: ETC**

Photosynthesis

- **Photosynthesis Online Interactive activity** for interactive link
- **Plant Pigments and Photosynthesis** LabBench online lab
- **Video clip** with procedure for quick demonstration showing that light is necessary for the production of Starch

2A3 Environmental Matter Exchange

- **Bozeman Science 14 Environmental Matter Exchange**
- **Mr Anderson Explains Water Potential**
- **Water Potential Interactive** - for extra practice, explanation, and help
- **Water Essential to Life** NOVA article

- Easy water experiments: Compare Water, Rubbing Alcohol and Oil in these three challenges:
  - Cohesion: How many drops fit on a penny?
  - How good a solvent - drop a sugar cube into a cup of each liquid
  - Adhesion: Add a drop of each liquid between two slides - which sticks together better?
- Fun activity: Students are assigned a water property to depict as a superhero for a comic strip. They create and draw a five-panel comic strip that illustrates and explains the important role water has in biological systems.
- Use playdoh to make 'cells' of different shapes: square, sphere, long rod. Have students calculate the surface area to volume ratio of each one to determine which shape would be the best for exchanging materials with the environment

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Cell Membranes 2.b.1

Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.

a. Cell membranes separate the internal environment of the cell from the external environment.
b. Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model. [See also 4.A.1]

Evidence of student learning is a demonstrated understanding of each of the following:

1. Cell membranes consist of a structural framework of phospholipid molecules, embedded proteins, cholesterol, glycoproteins and glycolipids.
2. Phospholipids give the membrane both hydrophilic and hydrophobic properties. The hydrophilic phosphate portions of the phospholipids are oriented toward the aqueous external or internal environments, while the hydrophobic fatty acid portions face each other within the interior of the membrane itself.
3. Embedded proteins can be hydrophilic, with charged and polar side groups, or hydrophobic, with nonpolar side groups.

Highlight Important Terms and Ideas First!

Draw the Cell Membrane. Include and label the phospholipids, embedded proteins, cholesterol, glycoproteins and glycolipids. Label the hydrophobic region and hydrophilic regions of the membrane.

Describe the ‘fluid mosaic’ model of the cell membrane.

What are the two roles of cholesterol in the membrane?

Name an important glycoprotein and its role in the body.

What are glycolipids made up of and what is their role in the membrane?

Define the characteristic of being amphipathic. Which molecule in your cell membrane above is amphipathic?

4. Small, uncharged molecules and small nonpolar molecules, freely pass across the membrane. Hydrophilic substances such as large polar molecules and ions move across the membrane through embedded channel and transport proteins. Water moves across membranes and through channel proteins called aquaporins.

c. Cell walls provide a structural boundary, as well as a permeability barrier for some substances to the internal environments. Evidence of student learning is a demonstrated understanding of each of the following:

1. Plant cell walls are made of cellulose and are external to the cell membrane.
2. Other examples are cells walls of prokaryotes and fungi.

What is selective permeability?

By what type of transport do these molecules pass through the cell membrane? Explain the particular characteristic(s) that allow them (or require them) to move through this way.

Glucose	Na+ ions	Water	Oxygen

What is the role of proteins classified as an Aquaporin?

What does “active transport” require to function.

What kinds of cell have cell membranes? _____

What kinds of cells have cell walls (three types), and what material is each cell wall made of?

Name two functions of the cell wall:

Transport Across Cell Membranes 2.b.2

Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

a. Passive transport does not require the input of metabolic energy; the net movement of molecules is from high concentration to low concentration.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Passive transport plays a primary role in the import of resources and the export of wastes.
2. Membrane proteins play a role in facilitated diffusion of charged and polar molecules through a membrane.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Glucose transport
- Sodium/Potassium transport

✘ *There is no particular membrane protein that is required for teaching this concept.*

3. External environments can be hypotonic, hypertonic or isotonic to internal environments of cells.

Highlight Important Terms and Ideas First!

What are the two forms of transport across the membrane?

What is Diffusion? Use the words “concentration gradient” and describe an example of diffusion in living systems.

What is a specific type of diffusion that requires proteins? Name a molecule that diffuses this way.

What substance is needed for Active Transport? Why? Use the words ‘concentration gradient’ in your answer.

Osmosis is the diffusion of _____

Define Hypertonic:

Define Hypotonic:

Define Isotonic:

b. Active transport requires free energy to move molecules from regions of low concentration to regions of high concentration.

Evidence of student learning is a demonstrated understanding of each of the following.

1. Active transport is a process where free energy (often provided by ATP) is used by proteins embedded in the membrane to “move” molecules and/or ions across the membrane and to establish and maintain concentration gradients.
2. Membrane proteins are necessary for active transport.

c. The processes of endocytosis and exocytosis move large molecules from the external environment to the internal environment and vice versa, respectively.

Evidence of student learning is a demonstrated understanding of each of the following:

1. In exocytosis, internal vesicles fuse with the plasma membrane to secrete large macromolecules out of the cell.
2. In endocytosis, the cell takes in macromolecules and particulate matter by forming new vesicles derived from the plasma membrane.

Draw the shape of a red blood cell after being placed into each type of solution. Draw arrows showing the movement of water across the membrane.

Isotonic	Hypertonic	Hypotonic

What is “co-transport”? – describe an example

What is endocytosis? Describe how it takes place. Draw a diagram of the process.

What is exocytosis? Describe how it takes place. Draw a diagram of the process.

Compartmentalization 2.b.3

Essential knowledge 2.B.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.

a. Internal membranes facilitate cellular processes by minimizing competing interactions and by increasing surface area where reactions can occur.

b. Membranes and membrane-bound organelles in eukaryotic cells localize (compartmentalize) intracellular metabolic processes and specific enzymatic reactions. [See also 4.A.2]

To foster student understanding of this concept, instructors can choose an illustrative example, such as:

- Endoplasmic reticulum
- Mitochondria
- Chloroplasts
- Golgi
- Nuclear envelope

c. Archaea and Bacteria generally lack internal membranes and organelles, and have a cell wall.

Highlight Important Terms and Ideas First!

Why do cells need a lot of surface area?

Why are cells small?

Why are Eukaryotes able to be larger than prokaryotes?

What two things do internal membranes (organelles) do for a cell?

Why is the inner membrane of the mitochondria so highly folded? What happens across the inner membrane?

What does the Rough ER do?

List the differences between Prokaryote and Eukaryote cells.

8 Extra Resources for Enduring Understanding 2B

2B1 Cell Membranes

- **Bozeman Science 15 - Cell Membranes**
- Build a paper model of the Cell Membrane - by **Utah Genetics**
- Bubble Membranes Lab **Procedures**: This lab is so much fun!

2B2 Transport Across Membranes

- **Bozeman 16 - Transport Across Cell Membranes 2.b.2**
- **Doodle Notes** for Cell Transport by Science of Curiosity on TPT
- **Instructions** for how to make a game out of the types of Cell Transport

2B3 Compartmentalization

- Bozeman Science video: **Compartmentalization**
- **Read and explore** Utah Genetics- membranes organize cellular complexity

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Positive and Negative Feedback Loops 2.c.1

Essential knowledge 2.C.1: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes.

a. Negative feedback mechanisms maintain dynamic homeostasis for a particular condition (variable) by regulating physiological processes, returning the changing condition back to its target set point.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Operons in gene regulation
- Temperature regulation in animals
- Plant responses to water limitations

b. Positive feedback mechanisms amplify responses and processes in biological organisms. The variable initiating the response is moved farther away from the initial set-point. **Amplification** occurs when the stimulus is further activated which, in turn, initiates an additional response that produces system change.

Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:

- Lactation in mammals
- Onset of labor in childbirth
- Ripening of fruit

c. Alteration in the mechanisms of feedback

Highlight Important Terms and Ideas First!

Describe Negative Feedback in your own words.

Negative Feedback
Define Homeostasis:

Define Ectotherms:

Name an Ectotherm: _____
How do Ectotherms regulate body temperature through negative feedback?

Define Endotherms:

Name an Endotherm: _____
How do Endotherms regulate body temperature through negative feedback?

If too hot we get too hot, what do we do? How does this help?

If we get too cold, what do we do? Why does this help?

Positive Feedback

often results in deleterious consequences. *To foster student understanding of this concept, instructors can choose an illustrative example such as:* ● Diabetes mellitus in response to decreased insulin ● Dehydration in response to decreased antidiuretic hormone (ADH) ● Graves' disease (hyperthyroidism) ● Blood clotting	What plant hormone does ripe fruit give off? Why can one "bad apple" spoil a barrel? How/Why is fruit ripening an example of positive feedback? What is a Positive Feedback example in humans?

Mistakes in Feedback Loops
Besides being in your blood, where else could glucose go to be stored as glycogen? (two places)

Blood sugar goes up when...	Your pancreas makes...	Which leads to...	And brings blood glucose back...

What is wrong when you have type I diabetes?	What is wrong when you have type II diabetes?

Response to External Environments 2.c.2

Essential knowledge 2.C.2: Organisms respond to changes in their external environments.

a. Organisms respond to changes in their environment through behavioral and physiological mechanisms.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Photoperiodism and phototropism in plants Hibernation and migration in animals
- Taxis and kinesis in animals
- Chemotaxis in bacteria, sexual reproduction in fungi
- Nocturnal and diurnal activity: circadian rhythms
- Shivering and sweating in humans

✘ *No specific behavioral or physiological mechanism is required for teaching the above concept. Teachers are free to choose the mechanism that best fosters student understanding.*

Highlight Important Terms and Ideas First!

Behavioural Response examples:
What happens to the metabolism during hibernation?

What is torpor?

_____ is a behavioral response to cold by just leaving a harsh environment.

Photoperiodism is when a plant responds to _____ . What is the difference between a long day plant, and a short day plant?

Describe phototropism and draw a picture of a plant demonstrating phototropism:

What plant hormone is responsible for phototropism?

Physiological Responses:
Examples in Humans- when we get cold we:

When we get too hot we:

13 Extra Resources For Enduring Understanding 2C

2C1 Positive and Negative Feedback

- Bozeman Science 18- **Positive and Negative Feedback**
- Positive feedback (and cell signaling, gene expression) ripe banana with apples **fruit ripening** experiment
- **Whole Body Homeostasis** interactive online activity
- **Clotting video** 15 minutes about how blood clotting works - Positive Feedback
- Blood clotting part of AP Central Module **Cell-to-cell communication, Cell Signaling**
- **Glucose Regulation activity** demonstrating how the negative feedback mechanisms work
- Blood glucose level **stop animation clip**
- Research Activity: Students are self-guided as they research a disease and explain (with justification) which body system the disease impacts as well as how it relates to homeostasis. The students should focus on the specific homeostatic mechanism that is affected by the disease. Students make predictions (with justification) regarding how pharmaceutical companies will need to design drugs that will fight the disease based on the negative feedback mechanisms the organism has.

2C2 Response to External Environment

- Bozeman Science 19- **Response to External Environments**
- **Photoperiodism Interactive** online activity
- **Plant phototropism Interactive Lab** - includes gravity and touch

- Phototropism Investigation - grow seeds in dark for several days. Then treat them in these different ways (see this picture for a visual) cover tops of several, cover middle of several, snip tops of several, leave some alone. Grow in box with side open so gets light from one direction. It will take about three weeks to complete the whole experiment.
- Another phototropism experiment - make a plant maze!

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Biotic and Abiotic Factors 2.d.1

Essential knowledge 2.D.1: All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.

a. Cell activities are affected by interactions with biotic and abiotic factors.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Cell density
- Biofilms
- Temperature
- Water availability
- Sunlight

b. Organism activities are affected by interactions with biotic and abiotic factors. [See also 4.A.6]

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Symbiosis (mutualism, commensalism, parasitism)
- Predator–prey relationships
- Water and nutrient availability, temperature, salinity, pH

Highlight Important Terms and Ideas First!

What does **biotic** mean?	What does **abiotic** mean?
Example of a biotic factor:	Example of an abiotic factor:

Changes in abiotic factors affect cells:
What abiotic factors must be present for bacteria to go from planktonic to forming a biofilm?

What do bacteria do to make the biofilm?

An example of a biofilm in your mouth:

Why do antibiotics not kill bacteria in a biofilm?

Provide an example of each **Symbiotic Relationships**

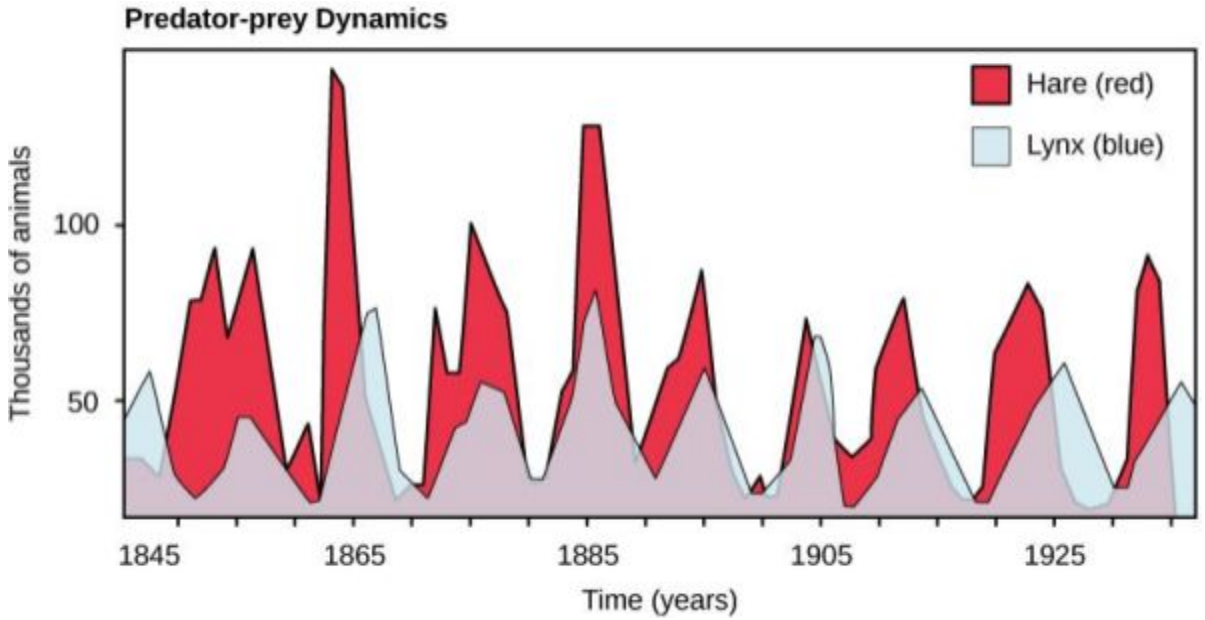
Mutualism	Commensalism	Parasitism

c. The stability of populations, communities and ecosystems is affected by interactions with biotic and abiotic factors. [See also 4.A.5, 4.A.6]

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Water and nutrient availability
- Availability of nesting materials and sites
- Food chains and food webs
- Species diversity
- Population density
- Algal blooms

✘ *No specific example is required for teaching the above concepts. Teachers are free to choose an example that best fosters student understanding.*



For the Predator Prey relationship above, describe how the Lynx population density affects the Hare population density.

How would the Lynx population be affected after a year of drought? Connect all of the dots between water availability and the population of Lynx.

Homeostatic Evolution 2.d.2

Essential knowledge 2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.

a. Continuity of homeostatic mechanisms reflects common ancestry, while changes may occur in response to different environmental conditions. [See also 1.B.1]

b. Organisms have various mechanisms for obtaining nutrients and eliminating wastes.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Gas exchange in aquatic and terrestrial plants
- Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, one-way digestive systems
- Respiratory systems of aquatic and terrestrial animals
- Nitrogenous waste production and elimination in aquatic and terrestrial animals

c. Homeostatic control systems in species of microbes, plants and animals support common ancestry. [See also 1.B.1]

Highlight Important Terms and Ideas First!

All excretory systems do what two things?

Nitrogenous waste is the result of breaking down _____ which tends to make this toxic molecule: _____

It takes a lot of water to dilute ammonia. Why is this NOT a problem for aquatic organisms? How do aquatic organisms get rid of nitrogenous waste?

Most terrestrial animals convert ammonia into _____ while birds and insects expend a lot of energy to convert ammonia into _____, which allows them to save more _____

Flatworms: have to get rid of (form of nitrogenous waste) _____ . They use protonephridia – which consists of a _____ cell that collects urine

Earthworms use metanephridia – have added in the (what organ system) _____ system, which wraps around a tube to get rid of wastes.

Vertebrates: we use _____ (functional unit) in our kidneys and the circulatory system wrapped around it in order to get rid of urea waste

To foster student understanding of this concept, instructors can choose an illustrative example such as the comparison of: ● Excretory systems in flatworms, earthworms and vertebrates ● Osmoregulation in bacteria, fish and protists ● Osmoregulation in aquatic and terrestrial plants ● Circulatory systems in fish, amphibians and mammals ● Thermoregulation in aquatic and terrestrial animals (countercurrent exchange mechanisms)	Explain in your own words how the excretory system shows signs of common ancestry between flatworms, roundworms, and vertebrates. What does the respiratory system do? (two things) What respiratory organ is used for gas exchange in water? What respiratory organ is used for gas exchange on land? Lungfish have both gills and _____, Explain how this shows evolutionary transition.

Homeostatic Disruptions 2.d.3

Essential knowledge 2.D.3: Biological systems are affected by disruptions to their dynamic homeostasis.

a. Disruptions at the molecular and cellular levels affect the health of the organism.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Physiological responses to toxic substances
- Dehydration
- Immunological responses to pathogens, toxins and allergens

b. Disruptions to ecosystems impact the dynamic homeostasis or balance of the ecosystem.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Invasive and/or eruptive species
- Human impact
- Hurricanes, floods, earthquakes, volcanoes, fires
- Water limitation
- Salination

✘ *No specific system is required for teaching the above concepts. Teachers are free to choose the system that best fosters student understanding*

Highlight Important Terms and Ideas First!

Dehydration:
About how much of our body is water? _____

If we don't have water, how is the excretory system impacted?

How is the circulatory system impacted?

How long can a human live without water on average? _____

Invasive Species:
Invasive species have greatest impact on (small/large) ecosystems.

List the ways invasive species can impact an ecosystem. Consider predator prey relationships, competition relationships, and spread of disease.

Plant and Animal Defenses 2.d.4

Essential knowledge 2.D.4: Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.

a. Plants, invertebrates and vertebrates have multiple, nonspecific immune responses.

Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:

- Invertebrate immune systems have nonspecific response mechanisms and may possess pathogen-specific defense responses.
- Plant defenses against pathogens include molecular recognition systems with systemic responses; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects.
- Vertebrate immune systems have nonspecific defense mechanisms against pathogens.

b. Mammals use specific immune responses triggered by natural or artificial agents that disrupt dynamic homeostasis.

Evidence of student learning is a demonstrated understanding of each of the following:

Highlight Important Terms and Ideas First!

What is a pathogen?

In your own words, define each type of immune response. Then put these words into their proper category.
Skin, Mucus, B Cells, Tears, Inflammation, Antibodies, Macrophages, Memory B Cell, First line of defense, Natural Killer Cells, T Cells, Cell Mediated Response, Humoral Response, Innate, Acquired

Nonspecific	Specific
Define:	
Categorize:	

Cell-Mediated response: targeting cells in our body that are _____, and kills them. Cell mediated response involves (T Cells / B Cells)

1. The mammalian immune system includes two types of specific responses: cell mediated and humoral.

2. In the cell-mediated response, cytotoxic T cells, a type of lymphocytic white blood cell, “target” intracellular pathogens when antigens are displayed on the outside of the cells.

3. In the humoral response, B cells, a type of lymphocytic white blood cell, produce antibodies against specific antigens.

4. Antigens are recognized by antibodies to the antigen.

5. Antibodies are proteins produced by B cells, and each antibody is specific to a particular antigen.

6. A second exposure to an antigen results in a more rapid and enhanced immune response.

Humoral response: finds antigens in the _____ and _____ (two types of fluids). (B Cells / T Cells) then generate antibodies that bind to pathogens, which stimulates _____ (big eaters) to destroy them

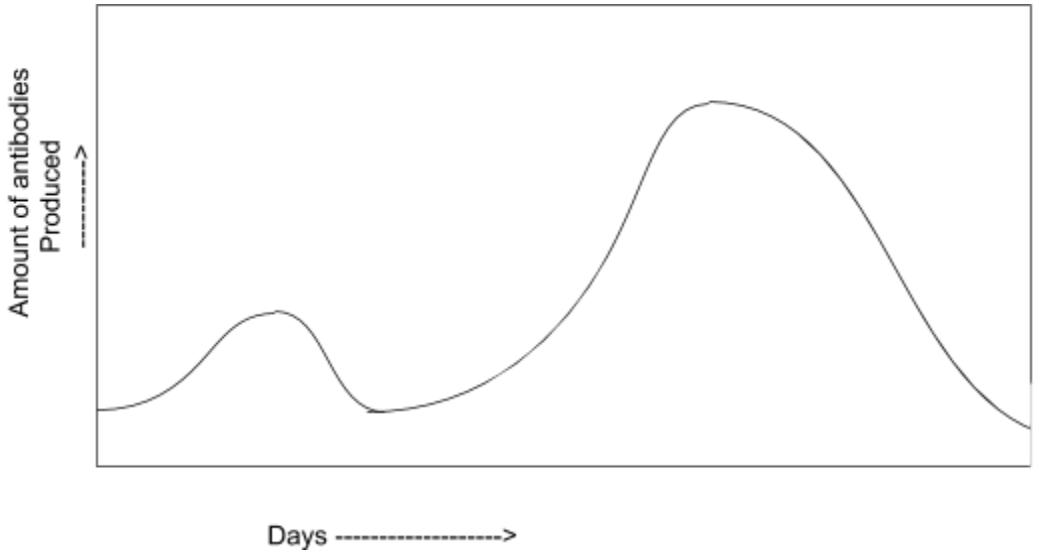
What general shape are all antibodies? Draw an antibody that would bind specifically to this pathogen:

Which type of response also recognizes and destroys cancer cells and transplant cells? (Cell mediated or Humoral)?

After being infected, _____ stay in the blood stream so that if you are ever infected again because...

On the graph, label the moment that this person was first infected, then label where he was infected a second time.

Explain why there are so many more antibodies made during the second infection. Why is this helpful to the organism?



Unlike animals, plants don't have a _____ so a can be infected again by the same pathogen.

What type of cells does HIV infect? How does this impact the immune system's ability to fight HIV?

27 Extra Resources for Enduring Understanding 2D

2D1 Biotic and Abiotic Factors

- Bozeman Science 20- **Biotic and Abiotic Factors**
- **Case Study- Bullfrog Invasives**
- **Case Study:** PBS lesson plans for the impact of the reintroduction of wolves in Yellowstone
- TedEx Video on **Parasite mind control**
- **Article and questions about mutualism** - fly and the flower: review of evolution and selection
- **Virtual Lab - Population Biology with Paramecium**
- **Quick review and mini quiz on properties of water**
- **Transpiration Interactive** - online activity, compare data for water loss in different types of plants

2D2 Homeostatic Evolution

- Bozeman Science 21- **Homeostatic Evolution**
- Bozeman **Osmoregulation**
- **Prezi** by AP Bio Teacher Julia Colton - excretory system of flatworms, earthworms, and vertebrates
- Bozeman **Homeostasis Hugs** and heat exchange
- **Resources and ideas** for building a model of countercurrent exchange of for thermoregulation

2D3 Homeostatic Disruptions

- Bozeman Science 22- **Homeostatic Disruptions**
- **Case Study:** Invasive Brown Tree Snakes in Guam
- **Invasive Species Database**
- Research Activity: Students choose two types of environmental disasters (e.g., hurricanes, floods, fire, droughts, oil spills, earthquakes, tsunamis, disease epidemics) to explain how the distribution of changes in

the ecosystem over time may affect changes in the future. Each student then makes a visual representation with annotation of one of those disasters, showing the before and after effects related to evolution.

2D4 Plant and Animal Defenses

- Bozeman Science 23 - **Plant and Animal Defenses**
- **HHMI Immune System** - click through and learn
- **Immune System animation** with mini-quiz below
- HHMI **Click and Learn** Cells of the Immune System with downloadable worksheet
- **Using Balloons to teach Immunity** - classroom activity
- **Immunity interactive** online activity by BioMan
- **Click and learn** about types of cells involved in Specific and Nonspecific immune response
- Simple **video clip** about B and T cells
- Research Activity: Students create posters that describe the immune system. Each poster should show examples of how plants or animals use chemical defenses against infectious diseases
- **TedTalk Plant Immunity**

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Timing and Coordination 2.e.1

Essential knowledge 2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.

a. Observable cell differentiation results from the expression of genes for tissue-specific proteins.

b. Induction of transcription factors during development results in sequential gene expression.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Homeotic genes are involved in developmental patterns and sequences.

2. Embryonic induction in development results in the correct timing of events.

3. Temperature and the availability of water determine seed germination in most plants.

4. Genetic mutations can result in abnormal development.

5. Genetic transplantation experiments support the link between gene expression and normal development.

6. Genetic regulation by microRNAs (RNAi) plays an important role in the development of organisms and the control of cellular functions.

Highlight Important Terms and Ideas First!

Cell Differentiation: Stem cells can become…

What is the difference between a muscle cell and a nerve cell? Use the words Tissue Specific, Differentiation, Gene Expression, and Proteins in your answer.

Once a stem cell has become something specific, .it can never _____

What do **transcription factors** do? What is their role in cell differentiation?

What does this SRY gene do? Explain in terms of transcription factors.

What do you suppose would happen if SRY protein was added to a female embryo?

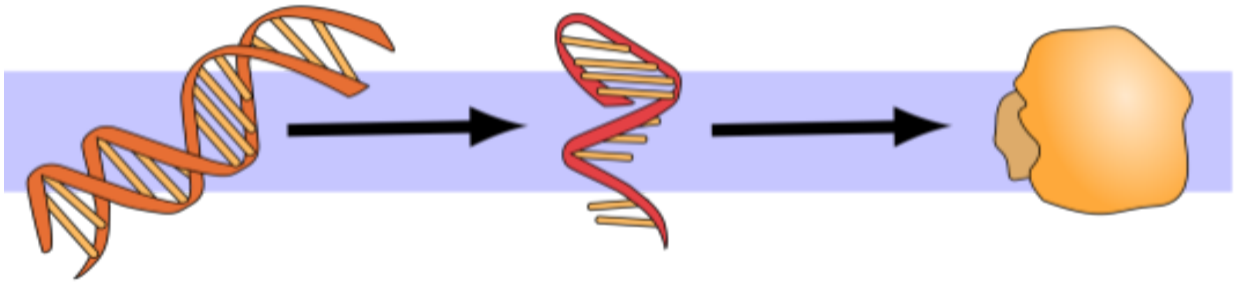
c. Programmed cell death (apoptosis) plays a role in the normal development and differentiation. **Ch 11.5**

Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:

- Morphogenesis of fingers and toes
- Immune function
- C. elegans development
- Flower development

✘ *Names of the specific stages of embryonic development are beyond the scope of the course and the AP Exam.*

Define microRNA: What does microRNA do?



On the diagram, label where transcription factors work, and where microRNA (RNAi) works to regulate gene expression.

Define Embryo **Induction**:

What is apoptosis? How does apoptosis play a role in the development of fingers and toes?

Homeotic genes: In what organisms are homeotic genes found in?

What do homeotic genes do in a fruit fly:

What have scientists done with these genes to make a leg grow out of a fly's head?

Seed Germination: what two things does a seed need to germinate?

Mechanisms of Timing and Control 2.e.2

Essential knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.

a. In plants, physiological events involve interactions between environmental stimuli and internal molecular signals. [See also 2.C.2]

Evidence of student learning is a demonstrated understanding of each of the following:

1. Phototropism, or the response to the presence of light

2. Photoperiodism, or the response to change in length of the night, that results in flowering in long-day and short-day plants

✘ *Memorization of the names, molecular structures and specific effects of all plant hormones are beyond the scope of the course and the AP Exam.*

b. In animals, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues
- Diurnal/nocturnal and sleep/awake cycles

Highlight Important Terms and Ideas First!

Timing and Control In Plants –
Phototropism:
What is the difference between negative and positive phototropism.

What hormone do plants use for phototropism? What does it do on a cellular level?

Photoperiodism:
In order to flower, long day plants need:

In order to flower, short day plants need:

Timing and Control for Animals- **Circadian rhythm:**

We are set on a _____ hour schedule that is influenced by the presence of _____ but will continue even in the absence of external cues.

Explain how jet lag relates to your circadian rhythm?

- Jet lag in humans
- Seasonal responses, such as hibernation, estivation and migration
- Release and reaction to pheromones
- Visual displays in the reproductive cycle

c. In fungi, protists and bacteria, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues.

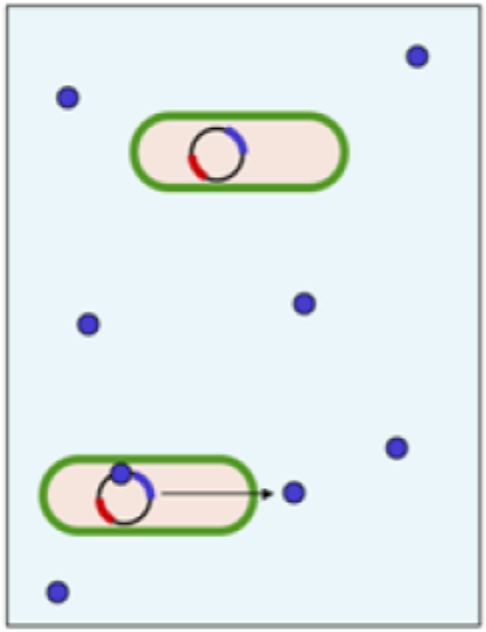
To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Fruiting body formation in fungi, slime molds and certain types of bacteria
- Quorum sensing in bacteria

✘ *Memorization of the names, molecular structures and specific effects of hormones or features of the brain responsible for these physiological phenomena is beyond the scope of the course and the AP Exam.*

Define **Quorum Sensing** in bacteria**:**

On the left, a low density of bacteria make small amounts of autoinducers. Autoinducers bind to the plasmid shown inside and, when bound, cause the transcription and translation of a triangle shaped protein.
On the right, draw a large density of bacteria and change in gene expression.



Behaviour and Natural Selection 2.e.3

Essential knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.

a. Individuals can act on information and communicate it to others.

Evidence of student learning is a demonstrated understanding of each of the following

1. Innate behaviors are behaviors that are inherited.

2. Learning occurs through interactions with the environment and other organisms.

b. Responses to information and communication of information are vital to natural selection. [See also 2.C.2]

Evidence of student learning is a demonstrated understanding of each of the following:

1. In phototropism in plants, changes in the light source lead to differential growth, resulting in maximum exposure of leaves to light for photosynthesis.

2. In photoperiodism in plants, changes in the length of night regulate flowering and preparation for winter.

3. Behaviors in animals are triggered by environmental cues and are vital to reproduction, natural selection and survival.

Highlight Important Terms and Ideas First!

Innate means...

Learned means...

Phototropism: Explain how phototropism is an adaptation for plants.

What would happen to a plant that had a mutation preventing it from being able to perform phototropism? Compare to a plant with a mutation that allows it to do phototropism more quickly than other plants. Explain in terms of natural selection.

Photoperiodism: Explain how photoperiodism is an adaptation for plants. What would happen to a plant with a mutation that prevented it from performing photoperiodism?

Students should be able to demonstrate understanding of the above concept by using an illustrative example such as: ● Hibernation ● Estivation ● Migration ● Courtship	How will global climate change impact plants that strictly respond to their environment through photoperiodism? Explain!
4. Cooperative behavior within or between populations contributes to the survival of the populations. *Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:* ● Availability of resources leading to fruiting body formation in fungi and certain types of bacteria ● Niche and resource partitioning ● Mutualistic relationships (lichens; bacteria in digestive tracts of animals; mycorrhizae) ● Biology of pollination	**Courtship:** Describe how courtship behavior drives sexual selection. Use the peacock as an example. How are bright tail feathers (or loud sounds, or the ability to fight off other suitors) a good indication of general fitness and health of a male sutor? How does this influence the next generation? **Cooperative Behavior:** Describe the cooperative relationship between plants and their pollinators. What is the name of this symbiotic relationship? What is coevolution? How would it relate to flowers and pollinators?

18 Extra Resources for Enduring Understanding 2E

2E1 Timing and Coordination of Development

- Bozeman Science 24 - **Development: Timing & Coordination**
- Genes Control Body Segments **PBS video 14 min**
- Research Activity: Students create PowerPoint presentations to distinguish between embryonic versus adult stem cells. Students work in small groups to explain (with justification) their arguments for and against stem cell research.

2E2 Mechanisms of Timing and Control

- Bozeman Science 25- **Mechanisms of Timing and Control**
- **Plant hormone lab** - procedures
- **Termites follow pen lines** as they smell like pheromones - turn into an investigative lab: which pens will they follow? What types of paths or shapes will they follow?
- **Clockwork Genes lecture HHMI** - holiday lecture
- **Circadian Rhythms and Your Health** TedTalk
- **There is a Clock in every cell of your Body** TedTalk
- **Documentary What Plants Talk About**
- Research Activity: Students research and analyze articles that include data on the effects of hormone replacement drugs. Students complete an article analysis focusing on the evaluation of collected data that supports the claim that timing and coordination of physiological events are regulated by multiple mechanisms.
- Bonnie Bassler Ted Talk - **Quorum Sensing**

- Role-playing and using materials available in the classroom, students in small groups demonstrate the details of timing and coordination of physiological events. Groups choose either a plant or animal example. Examples of plant physiological events are phototropism and photoperiodism. Examples of animal physiological events are circadian rhythms, diurnal/nocturnal cycles, jet lag, seasonal responses, and the effect of pheromones.

2E3 Behavior and Natural Selection

- Bozeman Science 26- **Behaviour and Natural Selection**
- Aggression in crickets - **lab**, **article**, and **detailed article with picture of behavior**
- **From molecules to ecosystems - locusts article**
- **Fire Ant Behavioral Evolution** click and learn
- **Fly Fight Club** aggressive flies

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