AP BIOLOGY

UNIT 4

Cell Communication and Cell Cycle

10–15%
AP EXAM WEIGHTING

~12–14
CLASS PERIODS

Remember to go to **AP Classroom** to assign students the online **Progress Checks** for this unit.

Whether assigned as homework or completed in class, the **Progress Checks** provide each student with immediate feedback related to this unit's topic and skills.

Progress Check 4

Multiple-choice: ~24 questions
Free-response: 2 questions

- Interpreting and Evaluating Experimental Results (partial)
- Analyze Data

UNIT 4

10–15% AP EXAM WEIGHTING | **~12–14** CLASS PERIODS

Cell Communication and Cell Cycle

BIG IDEA 2
Energetics
- In what ways do cells use energy to communicate with one another?

BIG IDEA 3
Information Storage and Transmission
- How does the cell cycle aid in the conservation of genetic information?
- How do different types of cells communicate with one another?

Developing Understanding

In Unit 4, students continue to learn about the role of cells, focusing on how cells use energy and information transmission to communicate and replicate. Through systems of complex transduction pathways, cells can communicate with one another. Cells can also generate and receive signals, coordinate mechanisms for growth, and respond to environmental cues. To maintain homeostasis, cells respond to their environment. They can also replicate and regulate replication as part of the cell cycle that provides for the continuity of life. In Unit 5, students will move on to learn about heredity.

Building Science Practices

1.A 1.B 4.B 5.A 6.C 6.E

Students build on their abilities to describe and explain biological concepts and processes by detailing the cell cycle regulation. Students should now be able to explain the relationships between structure and function for all organelles and cellular components on both the subcellular and the cellular level.

By performing laboratory investigations focused on the concepts of cell cycle, students should develop an understanding of how to formulate and devise a plan to answer a scientific question—critical skills for scientific inquiry. Students continue to build skills in communicating the results of scientific inquiry. This is a unit where students can be given opportunities to practice their graphing skills.

Preparing for the AP Exam

For the AP Exam, students must have a deep understanding of the significance of the steps in cell signaling, the amplification of the signal, the recycling of relay molecules between activated and inactivated forms to regulate the cellular response, and the multiple roles of the same molecules in providing specificity. Using the principles of cell signaling, students should be able to explain—using claim, evidence, and reasoning—how a drug works or how the symptoms of a chronic disease arise. Students should understand that signal molecules bind to receptors and that gene expression can be stimulated by signal transduction.

Students may be expected to predict the effect on a cell if there is a disruption in the cell cycle. A common error on the exam is failure to explain the purpose and timing of the cell cycle checkpoints. Students should also be prepared to answer a comparative question about mitosis and meiosis.

UNIT AT A GLANCE

Topic	Suggested Skills	Class Periods ~12–14 CLASS PERIODS
4.1 Cell Communication	1.B Explain biological concepts and processes.	
4.2 Introduction to Signal Transduction	1.A Describe biological concepts and processes.	
4.3 Signal Transduction Pathways	6.C Provide reasoning to justify a claim by connecting evidence to biological theories.	
4.4 Feedback	6.E Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.	
4.5 Cell Cycle	4.B Describe data from a table or graph, including: i. identifying specific data points ii. describing trends and patterns in the data iii. describing relationships between variables 5.A Perform mathematical calculations, including: i. mathematical equations in the curriculum ii. means iii. rates iv. ratios v. percentages and percent changes	
4.6 Regulation of Cell Cycle	6.E Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.	
Go to **AP Classroom** to assign the **Progress Check** for Unit 4. Review the results in class to identify and address any student misunderstandings.		

SAMPLE INSTRUCTIONAL ACTIVITIES

The sample activities on this page are optional ways to incorporate varied instructional approaches in the teaching of this course. You do not need to use these activities or instructional approaches and are encouraged to adapt the activities to best support students in your classroom. The following examples were developed in partnership with teachers from the AP community to share ways that they approach teaching some of the topics in this unit. Please refer to the Instructional Approaches section beginning on p. 171 for more examples of activities and strategies.

Activity	Topic	Sample Activity
1	4.1	**One-Minute Essay** Have students conduct online research (provide reputable websites for them to use) to learn about diseases that result from a breakdown in cell communication. Assign students a one-minute essay with a prompt that allows a formative assessment of their understanding, such as, "Describe an example of communication between two cells."
2	4.2	**Ask the Expert** Divide students into three groups and assign them to complete one of the three sections of the Signal Transduction POGIL. After a debrief with each group to clarify misconceptions, students should rotate between groups. Student "experts" can share their understanding of the model they studied and answer any questions from their classmates. Clarify any outstanding misconceptions at the end of class.
3	4.4	**Fishbowl** Share the HHMI case study entitled "The Biochemistry and Cell Signaling Pathway of MC1R" with students. Ask them to read it and answer the questions that accompany the case study. Then set up a fishbowl for students to discuss what they learned from the case study and the applications to real life.

SUGGESTED SKILL

Concept Explanation

1.B

Explain biological concepts and processes.

AVAILABLE RESOURCE

- AP Central > Classroom Resources > Cell-to-Cell Communication – Cell Signaling

ILLUSTRATIVE EXAMPLES

EK 4.1.A.1

- Immune cells interact through cell-to-cell contact, antigen-presenting cells (APCs), helper T-cells, and killer T-cells.

EK 4.1.B.1

- Neurotransmitters
- Plant immune response
- Quorum sensing in bacteria
- Morphogens in embryonic development

EK 4.1.B.2

- Insulin
- Human growth hormone
- Thyroid hormones
- Testosterone
- Estrogen

TOPIC 4.1
Cell Communication

Required Course Content

BIG IDEA 3

Information Storage and Transmission: Living systems store, retrieve, transmit, and respond to information essential to life processes.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.1.A Describe the ways that cells can communicate with one another.	**4.1.A.1** Cells communicate with one another through direct contact with other cells or from a distance via chemical signaling.
4.1.B Explain how cells communicate with one another over short and long distances.	**4.1.B.1** Cells communicate over short distances by using local regulators that target cells in the vicinity of the signal-emitting cell. **4.1.B.2** Signals released by one cell type can travel long distances to target cells of another type.

TOPIC 4.2
Introduction to Signal Transduction

SUGGESTED SKILL

Concept Explanation

1.A

Describe biological concepts and processes.

AVAILABLE RESOURCE

- AP Central > Classroom Resources > Cell-to-Cell Communication – Cell Signaling

Required Course Content

BIG IDEA 3

Information Storage and Transmission: Living systems store, retrieve, transmit, and respond to information essential to life processes.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.2.A Describe the components of a signal transduction pathway.	**4.2.A.1** Signal transduction pathways link signal receptions with cellular responses. **4.2.A.2** Many signal transduction pathways include protein modifications and involve phosphorylation cascades.
4.2.B Describe the role of components of a signal transduction pathway in producing a cellular response.	**4.2.B.1** Signaling begins with the recognition of a chemical messenger—a ligand—by a receptor protein in a target cell. i. The ligand-binding domain of a receptor recognizes a specific chemical messenger, which can be a peptide (protein) or a small molecule. ii. G protein-coupled receptors are an example of a receptor protein in eukaryotes. iii. Receptors may be located on the surface of a target cell or in the cytoplasm or nucleus of the target cell.

continued on next page

LEARNING OBJECTIVE

4.2.B

Describe the role of components of a signal transduction pathway in producing a cellular response.

ESSENTIAL KNOWLEDGE

4.2.B.2

Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, resulting in the appropriate responses by the cell. Responses could include cell growth, secretion of molecules, or gene expression.

i. After the ligand binds, the intracellular domain of a receptor protein changes shape, initiating transduction of the signal.

ii. Enzymes and second messengers such as cyclic AMP (cAMP) relay and amplify the intracellular signal.

iii. Hormones are an example of a signaling messenger that can travel long distances in the bloodstream.

iv. The binding of ligands to ligand-gated channels can cause the channel to open or close.

TOPIC 4.3
Signal Transduction Pathways

Required Course Content

BIG IDEA 3

Information Storage and Transmission: Living systems store, retrieve, transmit, and respond to information essential to life processes.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.3.A Describe the different types of cellular responses elicited by a signal transduction pathway.	**4.3.A.1** Signal transduction may result in changes in gene expressions and cell function, which may alter phenotype or result in programmed cell death (apoptosis).
4.3.B Explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway.	**4.3.B.1** Changes in signal transduction pathways can alter cellular responses. Mutations in any domain of the receptor protein or in any component of the signaling pathway may affect the downstream components by altering the subsequent transduction of the signal. **4.3.B.2** Chemicals that interact with any component of the signaling pathway may activate or inhibit the pathway.

SUGGESTED SKILL

Argumentation

6.C

Provide reasoning to justify a claim by connecting evidence to biological theories.

AVAILABLE RESOURCE

- AP Central > Classroom Resources > Cell-to-Cell Communication – Cell Signaling

ILLUSTRATIVE EXAMPLES

EK 4.3.A.1

- Use of chemical messengers by microbes to communicate with other nearby cells and to regulate specific pathways in response to population density (quorum sensing)
- Epinephrine stimulation of glycogen breakdown in mammals

EK 4.3.B.1

- Cytokines regulate gene expression to allow for cell replication and division.
- Mating pheromones in yeast trigger mating gene expression.
- Ethylene levels cause changes in the production of different enzymes allowing fruits to ripen.
- HOX genes regulate animal body plans during embryonic development.

SUGGESTED SKILL

Argumentation

6.E

Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.

AVAILABLE RESOURCE

- AP Central > Classroom Resources > Cell-to-Cell Communication – Cell Signaling

ILLUSTRATIVE EXAMPLES

EK 4.4.A.1.i

- Blood sugar regulation by insulin/glucagon

EK 4.4.A.1.ii

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

TOPIC 4.4
Feedback

Required Course Content

BIG IDEA 2

Energetics: Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis.

LEARNING OBJECTIVE

4.4.A

Explain how positive and negative feedback helps maintain homeostasis.

ESSENTIAL KNOWLEDGE

4.4.A.1

Organisms use feedback mechanisms to maintain their internal environments in response to internal and external changes.

i. Negative feedback mechanisms maintain homeostasis by reducing the initial stimulus to regulate physiological processes. If a system is perturbed or disrupted, negative feedback mechanisms return the system back to its target set point. These processes operate at the molecular, cellular, and organismal levels.

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

TOPIC 4.5
Cell Cycle

Required Course Content

BIG IDEA 3

Information Storage and Transmission: Living systems store, retrieve, transmit, and respond to information essential to life processes.

LEARNING OBJECTIVE

4.5.A

Describe the events that occur in the cell cycle.

ESSENTIAL KNOWLEDGE

4.5.A.1

The cell cycle is a highly regulated series of events that controls the growth and reproduction of eukaryotic cells.

i. The cell cycle consists of sequential stages of interphase (G1, S, G2), mitosis, and cytokinesis.

ii. G1 phase: The cell is metabolically active, duplicating organelles and cytosolic components.

iii. S phase: DNA is in the form of chromatin and replicates to form two sister chromatids connected at a centromere.

iv. G2 phase: Protein synthesis occurs, ATP is produced in large quantities, and centrosomes replicate.

v. A cell can enter a stage (G0) in which it no longer divides, but it can reenter the cell cycle in response to appropriate cues.

vi. Nondividing cells may exit the cell cycle or be held at a particular stage in the cell cycle.

continued on next page

SUGGESTED SKILLS

Representing and Describing Data

4.B

Describe data from a table or graph, including:

i. identifying specific data points

ii. describing trends and patterns in the data

iii. describing relationships between variables

Statistical Tests and Data Analysis

5.A

Perform mathematical calculations, including:

i. mathematical equations in the curriculum

ii. means

iii. rates

iv. ratios

v. percentages and percent changes

AVAILABLE RESOURCE

- AP Central > AP Biology Lab Manual > Mitosis Lab

LEARNING OBJECTIVE

4.5.B

Explain how mitosis results in the transmission of chromosomes from one generation of cells to the next.

ESSENTIAL KNOWLEDGE

4.5.B.1

Mitosis is a process that ensures the transfer of a complete genome from a parent cell to two genetically identical daughter cells in eukaryotes.

i. Mitosis plays a role in growth, tissue repair, and asexual reproduction.
ii. Mitosis occurs in sequential steps (prophase, metaphase, anaphase, telophase) and alternates with interphase in the cell cycle.
iii. Prophase: Sister chromatids condense, mitotic spindle begins to form, and centrosomes move to opposite poles of the cell.
iv. Metaphase: Spindle fibers align chromosomes along the equator of the cell.
v. Anaphase: Paired sister chromatids separate as spindle fibers pull chromatids toward poles.
vi. Telophase: Mitotic spindle breaks down, a new nuclear envelope develops, and then the cytoplasm divides.
vii. Cytokinesis: A cleavage furrow forms in animal cells or a cell plate forms in plant cells, resulting in two new daughter cells.

TOPIC 4.6
Regulation of Cell Cycle

SUGGESTED SKILL

Argumentation

6.E

Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.

Required Course Content

BIG IDEA 3

Information Storage and Transmission: Living systems store, retrieve, transmit, and respond to information essential to life processes.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.6.A Describe the role of checkpoints in regulating the cell cycle.	4.6.A.1 A number of internal controls or checkpoints regulate progression through the cell cycle. 4.6.A.2 Interactions between cyclins and cyclin-dependent kinases control the cell cycle. **EXCLUSION STATEMENT**—*Knowledge of specific cyclin-CdK pairs or growth factors is beyond the scope of the AP Exam.*
4.6.B Describe the effects of disruptions to the cell cycle on the cell or organism.	4.6.B.1 Disruptions to the cell cycle may result in cancer or apoptosis (programmed cell death).