AP BIOLOGY

UNIT 5

Heredity

8–11%
AP EXAM WEIGHTING

~8–10
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 5

Multiple-choice: ~23 questions
Free-response: 2 questions

- Interpreting and Evaluating Experimental Results with Graphing
- Conceptual Analysis

UNIT 5

8–11% AP EXAM WEIGHTING | **~8–10** CLASS PERIODS

Heredity

BIG IDEA 1
Evolution
- How is our understanding of evolution influenced by our knowledge of genetics?

BIG IDEA 3
Information Storage and Transmission
- Why is it important that not all inherited characteristics get expressed in the next generation?
- How might Mendel's laws have been affected if he had studied a different type of plant?

BIG IDEA 4
Systems Interactions
- How does the diversity of a species affect inheritance?

Developing Understanding

Unit 5 focuses on heredity and the biological concepts and processes involved in ensuring the continuity of life. Students learn that the storage and transmission of genetic information via chromosomes from one generation to the next occur through meiosis. Meiotic division ensures genetic diversity, which is crucial to the survival of a species. In this unit, students gain a deeper understanding of Mendelian genetics and learn how non-Mendelian genetics describes patterns of inheritance that seem to violate Mendel's laws. This unit also covers the roles played by chromosomal inheritance, environmental factors, and nondisjunction on an individual's phenotype. In Unit 6, students move on to learn about gene expression and regulation.

Building Science Practices

1.B 1.C 3.A 5.A 5.C 6.E

Data can convey important information about biological systems. To understand this information, students need to practice describing data and identifying patterns and trends that might make the data meaningful for the researcher. This analysis could lead to the discovery of new information or the development of new concepts. Comparing patterns and trends in data helps students describe biological changes that occur over time, predict short-term and long-term changes, and draw conclusions about the causes or solutions to problems in biological systems.

Students should understand the value and application of the chi-square test in contexts beyond genetics, but also that chi-square hypothesis testing is not always an appropriate statistical test for the data being analyzed. Students should learn how to state a null hypothesis of an experiment, and more importantly, that the null hypothesis is related to the experimental variables in question.

Preparing for the AP Exam

In this unit students need to analyze and construct models of chromosomal exchange, using them to predict the results of a given scenario, such as the haploid results of meiosis or a mistake in crossing over.

Students also need to calculate genotypic and/or phenotypic ratios. Be sure students understand the difference in these two types of ratios, as confusion between them is a common student error on the exam.

Additionally, students can expect to calculate a chi-square value and explain its meaning in a given scenario. On the exam, students commonly fail to identify the null hypothesis rather than an alternate hypothesis. Provide them with multiple and varied opportunities to practice this skill. Building their skills in experimental design throughout the course will help address this misconception. Emphasis should be placed on helping students understand when to reject or fail to reject the null hypothesis.

UNIT AT A GLANCE

Topic	Suggested Skills	Class Periods ~8–10 CLASS PERIODS
5.1 Meiosis	1.B Explain biological concepts and processes.	
5.2 Meiosis and Genetic Diversity	3.A Identify or pose a testable question based on an observation, data, or a model.	
5.3 Mendelian Genetics	5.C Perform chi-square hypothesis testing. 6.E Predict the causes or effects of a change in, or disruption to, one or more components in a biological system.	
5.4 Non-Mendelian Genetics	5.A Perform mathematical calculations, including: i. mathematical equations in the curriculum ii. means iii. rates iv. ratios v. percentages and percent changes 5.C Perform chi-square hypothesis testing.	
5.5 Environmental Effects on Phenotype	1.C Explain biological concepts and processes in applied contexts.	
Go to **AP Classroom** to assign the **Progress Check** for Unit 5. 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	5.1	**Think-Pair-Share** Have students construct simulated chromosomes with pop beads or pipe cleaners and manipulate them through the stages of meiosis. As students model the process, ask them to make a sketch or take a photograph of each stage. They should begin with either a $2n = 4$ or a $2n = 6$ "cell" so that they can build their understanding using a simpler system before applying what they have learned to meiosis in humans. Then, have students turn to a classmate to share their sketches or photographs and discuss what they now understand about meiosis in humans. Conduct a whole-class discussion where one student from each pair shares their collective understanding.
2	5.3	**Construct an Argument** Instruct students that they can use genetically modified corn to apply the chi-square test to a dihybrid cross. First, students should calculate the expected genotypic and phenotypic ratios using a Punnett square. They should then formulate null hypotheses for the cross and perform a chi-square test. Have them conclude the exercise by stating whether they should reject or fail to reject the null hypothesis and ask that they justify their reasoning.
3	5.5	**One-Minute Essay** Direct students to read an article about an organism that exhibits phenotypic plasticity. After reading, provide a prompt about this inheritance process, and ask them to respond to it in one minute or less.

SUGGESTED SKILL

Concept Explanation

1.B

Explain biological concepts and processes.

AVAILABLE RESOURCE

- AP Central > AP Biology Lab Manual > Meiosis Lab

TOPIC 5.1
Meiosis

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

5.1.A

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

ESSENTIAL KNOWLEDGE

5.1.A.1

Meiosis is a process that ensures the formation of haploid gamete cells, sometimes referred to as daughter cells, in sexually reproducing diploid organisms.

5.1.A.2

Meiosis I involves the following steps:

i. Prophase I: Homologous chromosomes pair up and condense, synapsis occurs and then chiasmata may form, meiotic spindle begins to form, centrosomes move to opposite poles of the cell, and the nuclear envelope breaks down.

ii. Metaphase I: Meiotic spindle fibers align homologous pairs of chromosomes along the equator of the cell at the metaphase plate.

iii. Anaphase I: Homologous chromosomes separate, while sister chromatids remain attached, as meiotic spindle fibers pull chromosomes toward poles.

iv. Telophase I: Meiotic spindle breaks down, a new nuclear envelope develops, a cleavage furrow (animal cell) or cell plate (plant cell) forms, and cytokinesis occurs. Two haploid daughter cells are formed (at the end of meiosis I).

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LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
5.1.A Explain how meiosis results in the transmission of chromosomes from one generation to the next.	5.1.A.3 Meiosis II involves the following steps: i. Prophase II: Meiotic spindle forms; sister chromatids connected at the centromere attach to meiotic spindle. ii. Metaphase II: Chromosomes align along the metaphase plate; the kinetochore of each chromatid is attached to a microtubule extending from the poles. iii. Anaphase II: Proteins at the centromeres break down, and sister chromatids are pulled apart and toward opposite poles in the cell. iv. Telophase II: Meiotic spindle breaks down, a new nuclear envelope develops, a cleavage furrow (animal cell) or a cell plate (plant cell) forms, chromatids begin to decondense, and cytokinesis occurs. Four haploid daughter cells are formed, each with an unduplicated chromatid.
5.1.B Describe similarities and differences between the phases and outcomes of mitosis and meiosis.	5.1.B.1 Mitosis and meiosis are similar in the use of a spindle apparatus to move chromosomes but differ in the number of cells produced and the genetic content of the daughter cells.

SUGGESTED SKILL

Questions and Methods

3.A

Identify or pose a testable question based on an observation, data, or a model.

AVAILABLE RESOURCE

- AP Central > AP Biology Lab Manual > Meiosis Lab

TOPIC 5.2
Meiosis and Genetic Diversity

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

5.2.A

Explain how the process of meiosis generates genetic diversity.

ESSENTIAL KNOWLEDGE

5.2.A.1

Correct separation of the homologous chromosomes in meiosis I and sister chromatids in meiosis II ensures that each gamete receives a haploid (1n) set of chromosomes that comprises an assortment of both maternal and paternal chromosomes. When incorrect separation occurs (nondisjunction), gametes are no longer haploid.

5.2.A.2

During prophase I of meiosis, non-sister chromatids exchange genetic material via a process called crossing over (recombination), which increases genetic diversity among the resultant gametes.

5.2.A.3

Sexual reproduction in eukaryotes increases genetic variation, including crossing over, random assortment of chromosomes during meiosis, and subsequent fertilization of gametes.

EXCLUSION STATEMENT—*Knowledge of the details of sexual reproduction cycles in various plants and animals is beyond the scope of the AP Exam.*

TOPIC 5.3
Mendelian Genetics

SUGGESTED SKILLS

Statistical Tests and Data Analysis

5.C

Perform chi-square hypothesis testing.

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 1

Evolution: The process of evolution drives the diversity and unity of life.

BIG IDEA 3

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

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
5.3.A Explain the inheritance of genes and traits as described by Mendel's laws.	**5.3.A.1** Mendel's laws of segregation and independent assortment can be applied to genes that are on different chromosomes.
	5.3.A.2 In most cases, fertilization involves the fusion of two haploid gametes, restoring the diploid number of chromosomes and increasing genetic variation in populations by creating new combinations of alleles in the zygote.

i. Rules of probability can be applied to analyze the passing of single-gene traits from parent to offspring.

ii. Monohybrid, dihybrid, and test crosses can be used to determine whether alleles are dominant or recessive.

iii. An organism's genotype is the set of alleles inherited for one or more genes by an individual organism. An organism's genotype can be homozygous or heterozygous for each gene.

iv. An organism's phenotype is the observable expression of the inherited traits.

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LEARNING OBJECTIVE

5.3.A

Explain the inheritance of genes and traits as described by Mendel's laws.

ESSENTIAL KNOWLEDGE

v. Patterns of inheritance (autosomal, genetically linked, sex-linked) and whether an allele is dominant or recessive can often be predicted from data, including pedigrees. Punnett squares can be used to predict the genotypes and phenotypes of parents and offspring.

RELEVANT EQUATIONS

Laws of Probability:

If *A* and *B* are mutually exclusive, then:
$P(A \text{ or } B) = P(A) + P(B)$

If *A* and *B* are independent, then:
$P(A \text{ and } B) = P(A) \times P(B)$

TOPIC 5.4
Non-Mendelian Genetics

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

5.4.A

Explain deviations from Mendel's model of the inheritance of traits.

ESSENTIAL KNOWLEDGE

5.4.A.1

Patterns of inheritance of many traits do not follow the ratios predicted by Mendel's laws and can be identified by quantitative analysis, when the observed phenotypic ratios statistically differ from the predicted ratios.

i. Genes located on the same chromosome are referred to as being genetically linked. The probability that these linked genes segregate together during meiosis can be used to calculate the map distance (or map units) between them on a chromosome. This calculation is called gene or genetic mapping.

ii. Codominance occurs when the phenotype from both alleles is expressed such that the heterozygote would have a different phenotype than either homozygote.

iii. Incomplete dominance occurs when neither allele of a gene can mask the other, so the phenotype of the heterozygote is a blended version of the dominant and recessive phenotypes.

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SUGGESTED SKILLS

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

5.C

Perform chi-square hypothesis testing.

ILLUSTRATIVE EXAMPLES

EK 5.4.A.2

- Sex-linked traits (X- or Y-linked) reside on sex chromosomes.
- Sex-linked traits (X- or Y-linked) are inherited at higher rates in XY individuals than they are in XX individuals.
- In certain species, the chromosomal basis of sex determination is not based on X and Y chromosomes (e.g., ZW in birds, haplodiploidy in bees).

LEARNING OBJECTIVE

5.4.A

Explain deviations from Mendel's model of the inheritance of traits.

ESSENTIAL KNOWLEDGE

5.4.A.2

Some traits, known as sex-linked traits (X- or Y-linked), are determined by genes on sex chromosomes. The pattern of inheritance of sex-linked traits can often be predicted from data, including pedigrees, indicating the genotypes and phenotypes of both parents and offspring.

5.4.A.3

Pleiotropy is a phenomenon in which the expression of a single gene results in multiple traits or effects; these traits therefore do not segregate independently.

5.4.A.4

Some traits result from non-nuclear inheritance.

i. Chloroplasts and mitochondria are randomly assorted to gametes and daughter cells; thus, traits determined by chloroplast and mitochondrial DNA do not follow simple Mendelian rules.

ii. In animals, mitochondria are usually transmitted by the egg and not by sperm; thus, traits determined by the mitochondrial DNA are typically maternally inherited.

iii. In plants, mitochondria and chloroplasts are transmitted in the ovule and not in the pollen; as such, mitochondria-determined and chloroplast-determined traits are typically maternally inherited.

TOPIC 5.5
Environmental Effects on Phenotype

Required Course Content

BIG IDEA 4

Systems Interactions: Biological systems interact, and these systems and their interactions exhibit complex properties.

LEARNING OBJECTIVE

5.5.A

Explain how the same genotype can result in multiple phenotypes under different environmental conditions.

ESSENTIAL KNOWLEDGE

5.5.A.1

Environmental conditions influence gene expression and can lead to phenotypic plasticity (e.g., the ability of individual genotypes to produce different phenotypes).

SUGGESTED SKILL

Concept Explanation

1.C

Explain biological concepts and processes in applied contexts.

ILLUSTRATIVE EXAMPLES

EK 5.5.A.1

- Height and weight in humans
- Flower color based on soil pH
- Seasonal fur color in arctic animals
- Sex determination in reptiles
- Effect of increased UV on melanin production in animals
- Presence of the opposite mating type on pheromone production in yeast and other fungi