AP BIOLOGY

UNIT 5

Heredity

8–11%
AP EXAM WEIGHTING

~9–11
CLASS PERIODS

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

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

Personal Progress Check 5

Multiple-choice: ~25 questions
Free-response: 2 questions

- Interpreting and Evaluating Experimental Results with Graphing
- Conceptual Analysis

UNIT 5

8–11% AP EXAM WEIGHTING | **~9–11** CLASS PERIODS

Heredity

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

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

BIG IDEA 4
Systems Interactions SYI
- 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 learning how non-Mendelian genetics describes those patterns of inheritance that seem to violate Mendel's laws. This unit also teaches the role 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.C 6.E.b 6.E.c

Data can convey important information about biological systems. In order to understand that information, students need to practice describing data and then identifying and describing the patterns and trends that might make the data meaningful for the researcher and possibly 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 and/or solutions to problems in biological systems.

Students should understand the value and application of the chi-square test in additional contexts beyond genetics. Students should learn the difference between null and alternate hypotheses while understanding that the chi-square is not always the most appropriate statistical test to analyze the results of an experiment.

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 a mistake in crossing over or the haploid results of meiosis.

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 should expect to calculate a chi-square value and explain the meaning in context of a given scenario. On the exam, students commonly fail to identify the null hypothesis rather than an alternate hypothesis; thus, they will need 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 on helping students understand when to reject or fail to reject the null hypothesis.

UNIT AT A GLANCE

Enduring Understanding	Topic	Suggested Skill	Class Periods ~9–11 CLASS PERIODS
IST-1	**5.1 Meiosis**	1.B Explain biological concepts and/or processes.	
IST-1	**5.2 Meiosis and Genetic Diversity**	3.A Identify or pose a testable question based on an observation, data, or a model.	
EVO-2, IST-1	**5.3 Mendelian Genetics**	5.C Perform chi-square hypothesis testing. 6.E.c Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on data.	
IST-1	**5.4 Non-Mendelian Genetics**	5.A.b Perform mathematical calculations, including means. 5.C Perform chi-square hypothesis testing.	
SYI-3	**5.5 Environmental Effects on Phenotype**	1.C Explain biological concepts, processes, and/or models in applied contexts.	
SYI-3	**5.6 Chromosomal Inheritance**	6.E.b Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on a visual representation of a biological concept, process, or model.	
	Go to **AP Classroom** to assign the **Personal 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 intended to give you ideas of ways to incorporate varied instructional approaches in the teaching of this course. You do not need to use these activities or approaches and are free to alter or edit them in any way you choose. 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** Students can construct simulated chromosomes with pop beads or pipe cleaners and manipulate them through the stages of meiosis. As students are modeling the process, they can 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. This can be introduced or de-briefed using a Think-Pair-Share approach.
2	5.3	**Construct an Argument** Students can use genetic corn to apply the chi-square test to a dihybrid cross. First, students calculate the expected genotypic and phenotypic ratios using a Punnett square. They then formulate null hypotheses for the cross and perform a chi-square test. They conclude by stating whether they should reject or fail to reject the null hypothesis and justify their reasoning.
3	5.5	**Debate** Students can read a case study about the genetics and evolution of skin color, then answer any questions that may accompany the case study. Alternately, teachers can provide appropriate questions and/or assignments to ensure that students understand the concepts addressed in the case study. Instead of answering the questions on paper, students can be divided into groups to debate possible answers to some or all of the questions. This activity can be augmented by having students read an article about the biology of skin color.

Unit Planning Notes

Use the space below to plan your approach to the unit. Consider how you want to pace your course and your methods of instruction and assessment.

SUGGESTED SKILL

Concept Explanation

1.B

Explain biological concepts and/or processes.

AVAILABLE RESOURCES

- AP Biology Lab Manual > **Meiosis Lab**

TOPIC 5.1
Meiosis

Required Course Content

ENDURING UNDERSTANDING

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE

IST-1.F

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

ESSENTIAL KNOWLEDGE

IST-1.F.1

Meiosis is a process that ensures the formation of haploid gamete cells in sexually reproducing diploid organisms—

a. Meiosis results in daughter cells with half the number of chromosomes of the parent cell.
b. Meiosis involves two rounds of a sequential series of steps (meiosis I and meiosis II).

IST-1.G

Describe similarities and/or differences between the phases and outcomes of mitosis and meiosis.

IST-1.G.1

Mitosis and meiosis are similar in the way chromosomes segregate but differ in the number of cells produced and the genetic content of the daughter cells.

TOPIC 5.2
Meiosis and Genetic Diversity

Required Course Content

ENDURING UNDERSTANDING

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE

IST-1.H

Explain how the process of meiosis generates genetic diversity.

ESSENTIAL KNOWLEDGE

IST-1.H.1

Separation of the homologous chromosomes in meiosis I ensures that each gamete receives a haploid (1*n*) set of chromosomes that comprises both maternal and paternal chromosomes.

IST-1.H.2

During meiosis I, homologous chromatids exchange genetic material via a process called "crossing over" (recombination), which increases genetic diversity among the resultant gametes.

IST-1.H.3

Sexual reproduction in eukaryotes involving gamete formation—including crossing over, the random assortment of chromosomes during meiosis, and subsequent fertilization of gametes—serves to increase variation.

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

SUGGESTED SKILL

Questions and Methods

3.A

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

AVAILABLE RESOURCES

- AP Biology Lab Manual> Meiosis Lab

SUGGESTED SKILLS

Argumentation

6.E.c

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

Statistical Tests and Data Analysis

5.C

Perform chi-square hypothesis testing.

TOPIC 5.3
Mendelian Genetics

Required Course Content

ENDURING UNDERSTANDING

EVO-2

Organisms are linked by lines of descent from common ancestry.

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
EVO-2.A Explain how shared, conserved, fundamental processes and features support the concept of common ancestry for all organisms.	**EVO-2.A.1** DNA and RNA are carriers of genetic information. **EVO-2.A.2** Ribosomes are found in all forms of life. **EVO-2.A.3** Major features of the genetic code are shared by all modern living systems. **EVO-2.A.4** Core metabolic pathways are conserved across all currently recognized domains.
IST-1.I Explain the inheritance of genes and traits as described by Mendel's laws.	**IST-1.I.1** Mendel's laws of segregation and independent assortment can be applied to genes that are on different chromosomes.

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LEARNING OBJECTIVE

IST-1.I

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

ESSENTIAL KNOWLEDGE

IST-1.I.2

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—

a. Rules of probability can be applied to analyze passage of single-gene traits from parent to offspring.

b. The pattern of inheritance (monohybrid, dihybrid, sex-linked, and genetically linked genes) can often be predicted from data, including pedigree, that give the parent genotype/phenotype and the offspring genotypes/phenotypes.

RELEVANT EQUATION

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:

$P(A \text{ and } B) = P(A) \times P(B)$

SUGGESTED SKILLS

Statistical Tests and Data Analysis

5.A.b
Perform mathematical calculations, including means.

5.C
Perform chi-square hypothesis testing.

ILLUSTRATIVE EXAMPLES

- Sex-linked genes reside on sex chromosomes.
- In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits are always expressed in males.
- In certain species, the chromosomal basis of sex determination is not based on X and Y chromosomes (such as ZW in birds, haplodiploidy in bees).

TOPIC 5.4
Non-Mendelian Genetics

Required Course Content

ENDURING UNDERSTANDING

IST-1
Heritable information provides for continuity of life.

LEARNING OBJECTIVE

IST-1.J
Explain deviations from Mendel's model of the inheritance of traits.

ESSENTIAL KNOWLEDGE

IST-1.J.1
Patterns of inheritance of many traits do not follow ratios predicted by Mendel's laws and can be identified by quantitative analysis, where observed phenotypic ratios statistically differ from the predicted ratios—

a. Genes that are adjacent and close to one another on the same chromosome may appear to be genetically linked; the probability that genetically linked genes will segregate as a unit can be used to calculate the map distance between them.

IST-1.J.2
Some traits are determined by genes on sex chromosomes and are known as sex-linked traits. The pattern of inheritance of sex-linked traits can often be predicted from data, including pedigree, indicating the parent genotype/phenotype and the offspring genotypes/phenotypes.

IST-1.J.3
Many traits are the product of multiple genes and/or physiological processes acting in combination; these traits therefore do not segregate in Mendelian patterns.

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LEARNING OBJECTIVE

IST-1.J

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

ESSENTIAL KNOWLEDGE

IST-1.J.4

Some traits result from non-nuclear inheritance—

a. 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.

b. In animals, mitochondria are transmitted by the egg and not by sperm; as such, traits determined by the mitochondrial DNA are maternally inherited.

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

SUGGESTED SKILL

Concept Explanation

1.C

Explain biological concepts, processes, and/or models in applied contexts.

ILLUSTRATIVE EXAMPLES

- 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

TOPIC 5.5
Environmental Effects on Phenotype

Required Course Content

ENDURING UNDERSTANDING

SYI-3

Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

LEARNING OBJECTIVE

SYI-3.B

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

ESSENTIAL KNOWLEDGE

SYI-3.B.1

Environmental factors influence gene expression and can lead to phenotypic plasticity. Phenotypic plasticity occurs when individuals with the same genotype exhibit different phenotypes in different environments.

TOPIC 5.6 Chromosomal Inheritance

Required Course Content

ENDURING UNDERSTANDING

SYI-3

Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

LEARNING OBJECTIVE

SYI-3.C

Explain how chromosomal inheritance generates genetic variation in sexual reproduction.

ESSENTIAL KNOWLEDGE

SYI-3.C.1

Segregation, independent assortment of chromosomes, and fertilization result in genetic variation in populations.

SYI-3.C.2

The chromosomal basis of inheritance provides an understanding of the pattern of transmission of genes from parent to offspring.

SYI-3.C.3

Certain human genetic disorders can be attributed to the inheritance of a single affected or mutated allele or specific chromosomal changes, such as nondisjunction.

SUGGESTED SKILL

Argumentation

6.E.b

Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on a visual representation of a biological concept, process, or model.

ILLUSTRATIVE EXAMPLES

SYI-3.C.3

- Sickle cell anemia
- Tay-Sachs disease
- Huntington's disease
- X-linked color blindness
- Trisomy 21/Down syndrome