SUGGESTED SKILL

Concept Explanation

1.C

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

AVAILABLE RESOURCES

- Classroom Resources > From Gene to Protein—A Historical Perspective
- Classroom Resources > Rosalind Franklin: She's Worth Another Look

TOPIC 6.1
DNA and RNA Structure

Required Course Content

ENDURING UNDERSTANDING

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
IST-1.K Describe the structures involved in passing hereditary information from one generation to the next.	**IST-1.K.1** DNA, and in some cases RNA, is the primary source of heritable information. **IST-1.K.2** Genetic information is transmitted from one generation to the next through DNA or RNA— a. Genetic information is stored in and passed to subsequent generations through DNA molecules and, in some cases, RNA molecules. b. Prokaryotic organisms typically have circular chromosomes, while eukaryotic organisms typically have multiple linear chromosomes. **IST-1.K.3** Prokaryotes and eukaryotes can contain plasmids, which are small extra-chromosomal, double-stranded, circular DNA molecules.
IST-1.L Describe the characteristics of DNA that allow it to be used as the hereditary material.	**IST-1.L.1** DNA, and sometimes RNA, exhibits specific nucleotide base pairing that is conserved through evolution: adenine pairs with thymine or uracil (A-T or A-U) and cytosine pairs with guanine (C-G)— a. Purines (G and A) have a double ring structure. b. Pyrimidines (C, T, and U) have a single ring structure.

TOPIC 6.2
Replication

Required Course Content

ENDURING UNDERSTANDING

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE

IST-1.M

Describe the mechanisms by which genetic information is copied for transmission between generations.

ESSENTIAL KNOWLEDGE

IST-1.M.1

DNA replication ensures continuity of hereditary information—

a. DNA is synthesized in the 5′ to 3′ direction.
b. Replication is a semiconservative process—that is, one strand of DNA serves as the template for a new strand of complementary DNA.
c. Helicase unwinds the DNA strands.
d. Topoisomerase relaxes supercoiling in front of the replication fork.
e. DNA polymerase requires RNA primers to initiate DNA synthesis.
f. DNA polymerase synthesizes new strands of DNA continuously on the leading strand and discontinuously on the lagging strand.
g. Ligase joins the fragments on the lagging strand.

EXCLUSION STATEMENT—*The names of the steps and particular enzymes involved—beyond DNA polymerase, ligase, RNA polymerase, helicase, and topoisomerase—are beyond the scope of the course and the AP Exam.*

SUGGESTED SKILL

Visual Representations

2.B.b

Explain relationships between different characteristics of biological concepts, processes, or models represented visually in applied contexts.

AVAILABLE RESOURCES

- Classroom Resources > From Gene to Protein—A Historical Perspective

SUGGESTED SKILL

Visual Representations

2.B.b

Explain relationships between different characteristics of biological concepts, processes, or models represented visually in applied contexts.

AVAILABLE RESOURCES

- Classroom Resources > **From Gene to Protein—A Historical Perspective**

TOPIC 6.3

Transcription and RNA Processing

Required Course Content

ENDURING UNDERSTANDING

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE

IST-1.N

Describe the mechanisms by which genetic information flows from DNA to RNA to protein.

ESSENTIAL KNOWLEDGE

IST-1.N.1

The sequence of the RNA bases, together with the structure of the RNA molecule, determines RNA function—

a. mRNA molecules carry information from DNA to the ribosome.
b. Distinct tRNA molecules bind specific amino acids and have anti-codon sequences that base pair with the mRNA. tRNA is recruited to the ribosome during translation to generate the primary peptide sequence based on the mRNA sequence.
c. rRNA molecules are functional building blocks of ribosomes.

IST-1.N.2

Genetic information flows from a sequence of nucleotides in DNA to a sequence of bases in an mRNA molecule to a sequence of amino acids in a protein.

IST-1.N.3

RNA polymerases use a single template strand of DNA to direct the inclusion of bases in the newly formed RNA molecule. This process is known as transcription.

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LEARNING OBJECTIVE

IST-1.N

Describe the mechanisms by which genetic information flows from DNA to RNA to protein.

ESSENTIAL KNOWLEDGE

IST-1.N.4

The DNA strand acting as the template strand is also referred to as the noncoding strand, minus strand, or antisense strand. Selection of which DNA strand serves as the template strand depends on the gene being transcribed.

IST-1.N.5

The enzyme RNA polymerase synthesizes mRNA molecules in the 5′ to 3′ direction by reading the template DNA strand in the 3′ to 5′ direction.

IST-1.N.6

In eukaryotic cells the mRNA transcript undergoes a series of enzyme-regulated modifications—

a. Addition of a poly-A tail.
b. Addition of a GTP cap.
c. Excision of introns and splicing and retention of exons.
d. Excision of introns and splicing and retention of exons can generate different versions of the resulting mRNA molecule; this is known as alternative splicing.

SUGGESTED SKILLS

Argumentation

6.E.a

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

Visual Representations

2.D.b

Represent relationships within biological models, including diagrams.

AVAILABLE RESOURCES

- Classroom Resources > From Gene to Protein—A Historical Perspective

TOPIC 6.4 Translation

Required Course Content

ENDURING UNDERSTANDING

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE

IST-1.O

Explain how the phenotype of an organism is determined by its genotype.

ESSENTIAL KNOWLEDGE

IST-1.O.1

Translation of the mRNA to generate a polypeptide occurs on ribosomes that are present in the cytoplasm of both prokaryotic and eukaryotic cells and on the rough endoplasmic reticulum of eukaryotic cells.

IST-1.O.2

In prokaryotic organisms, translation of the mRNA molecule occurs while it is being transcribed.

IST-1.O.3

Translation involves energy and many sequential steps, including initiation, elongation, and termination.

EXCLUSION STATEMENT—*The details and names of the enzymes and factors involved in each of these steps are beyond the scope of the course and the AP Exam.*

IST-1.O.4

The salient features of translation include—

a. Translation is initiated when the rRNA in the ribosome interacts with the mRNA at the start codon.

b. The sequence of nucleotides on the mRNA is read in triplets called codons.

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LEARNING OBJECTIVE

IST-1.0

Explain how the phenotype of an organism is determined by its genotype.

ESSENTIAL KNOWLEDGE

c. Each codon encodes a specific amino acid, which can be deduced by using a genetic code chart. Many amino acids are encoded by more than one codon.

d. Nearly all living organisms use the same genetic code, which is evidence for the common ancestry of all living organisms.

e. tRNA brings the correct amino acid to the correct place specified by the codon on the mRNA.

f. The amino acid is transferred to the growing polypeptide chain.

g. The process continues along the mRNA until a stop codon is reached.

h. The process terminates by release of the newly synthesized polypeptide/protein.

EXCLUSION STATEMENT—*Memorization of the genetic code is beyond the scope of the course and the AP Exam.*

IST-1.0.5

Genetic information in retroviruses is a special case and has an alternate flow of information: from RNA to DNA, made possible by reverse transcriptase, an enzyme that copies the viral RNA genome into DNA. This DNA integrates into the host genome and becomes transcribed and translated for the assembly of new viral progeny.

EXCLUSION STATEMENT—*The names of the steps and particular enzymes involved—beyond DNA polymerase, ligase, RNA polymerase, helicase, and topoisomerase—are beyond the scope of the course and the AP Exam.*

SUGGESTED SKILL

Argumentation

6.A

Make a scientific claim.

AVAILABLE RESOURCES

- Classroom Resources > From Gene to Protein—A Historical Perspective

TOPIC 6.5
Regulation of Gene Expression

Required Course Content

ENDURING UNDERSTANDING

IST-2

Differences in the expression of genes account for some of the phenotypic differences between organisms.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
IST-2.A Describe the types of interactions that regulate gene expression.	IST-2.A.1 Regulatory sequences are stretches of DNA that interact with regulatory proteins to control transcription. IST-2.A.2 Epigenetic changes can affect gene expression through reversible modifications of DNA or histones. IST-2.A.3 The phenotype of a cell or organism is determined by the combination of genes that are expressed and the levels at which they are expressed— 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.
IST-2.B Explain how the location of regulatory sequences relates to their function.	IST-2.B.1 Both prokaryotes and eukaryotes have groups of genes that are coordinately regulated— a. In prokaryotes, groups of genes called operons are transcribed in a single mRNA molecule. The *lac* operon is an example of an inducible system. b. In eukaryotes, groups of genes may be influenced by the same transcription factors to coordinately regulate expression.

TOPIC 6.6

Gene Expression and Cell Specialization

SUGGESTED SKILL

Argumentation

6.B

Support a claim with evidence from biological principles, concepts, processes, and/or data.

AVAILABLE RESOURCES

- Classroom Resources > From Gene to Protein—A Historical Perspective

Required Course Content

ENDURING UNDERSTANDING

IST-2

Differences in the expression of genes account for some of the phenotypic differences between organisms.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
IST-2.C Explain how the binding of transcription factors to promoter regions affects gene expression and/or the phenotype of the organism.	IST-2.C.1 Promoters are DNA sequences upstream of the transcription start site where RNA polymerase and transcription factors bind to initiate transcription. IST-2.C.2 Negative regulatory molecules inhibit gene expression by binding to DNA and blocking transcription.
IST-2.D Explain the connection between the regulation of gene expression and phenotypic differences in cells and organisms.	IST-2.D.1 Gene regulation results in differential gene expression and influences cell products and function. IST-2.D.2 Certain small RNA molecules have roles in regulating gene expression.

SUGGESTED SKILLS

Visual Representations

2.C

Explain how biological concepts or processes represented visually relate to larger biological principles, concepts, processes, or theories.

Questions and Methods

3.D

Make observations or collect data from representations of laboratory setups or results.

AVAILABLE RESOURCES

- Classroom Resources > **From Gene to Protein—A Historical Perspective**

ILLUSTRATIVE EXAMPLES

IST-2.E.1

- Mutations in the *CFTR* gene disrupt ion transport and result in cystic fibrosis.
- Mutations in the *MC1R* gene give adaptive melanism in pocket mice.

IST-4.B.1

- Antibiotic resistance mutations
- Pesticide resistance mutations
- Sickle cell disorder and heterozygote advantage

TOPIC 6.7 Mutations

Required Course Content

ENDURING UNDERSTANDING

IST-2

Differences in the expression of genes account for some of the phenotypic differences between organisms.

LEARNING OBJECTIVE

IST-2.E

Describe the various types of mutation.

ESSENTIAL KNOWLEDGE

IST-2.E.1

Changes in genotype can result in changes in phenotype—

a. The function and amount of gene products determine the phenotype of organisms.
   i. The normal function of the genes and gene products collectively comprises the normal function of organisms.
   ii. Disruptions in genes and gene products cause new phenotypes.

IST-2.E.2

Alterations in a DNA sequence can lead to changes in the type or amount of the protein produced and the consequent phenotype. DNA mutations can be positive, negative, or neutral based on the effect or the lack of effect they have on the resulting nucleic acid or protein and the phenotypes that are conferred by the protein.

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ENDURING UNDERSTANDING

IST-4

The processing of genetic information is imperfect and is a source of genetic variation.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
IST-4.A Explain how changes in genotype may result in changes in phenotype.	**IST-4.A.1** Errors in DNA replication or DNA repair mechanisms, and external factors, including radiation and reactive chemicals, can cause random mutations in the DNA— a. Whether a mutation is detrimental, beneficial, or neutral depends on the environmental context. b. Mutations are the primary source of genetic variation. **IST-4.A.2** Errors in mitosis or meiosis can result in changes in phenotype— a. Changes in chromosome number often result in new phenotypes, including sterility caused by triploidy, and increased vigor of other polyploids. b. Changes in chromosome number often result in human disorders with developmental limitations, including Down syndrome/ Trisomy 21 and Turner syndrome.
IST-4.B Explain how alterations in DNA sequences contribute to variation that can be subject to natural selection.	**IST-4.B.1** Changes in genotype may affect phenotypes that are subject to natural selection. Genetic changes that enhance survival and reproduction can be selected for by environmental conditions— a. The horizontal acquisitions of genetic information primarily in prokaryotes via transformation (uptake of naked DNA), transduction (viral transmission of genetic information), conjugation (cell-to-cell transfer of DNA), and transposition (movement of DNA segments within and between DNA molecules) increase variation. b. Related viruses can combine/recombine genetic information if they infect the same host cell. c. Reproduction processes that increase genetic variation are evolutionarily conserved and are shared by various organisms.

SUGGESTED SKILL

Argumentation

6.D

Explain the relationship between experimental results and larger biological concepts, processes, or theories.

AVAILABLE RESOURCES

- AP Biology Lab Manual > Gel Electrophoresis Lab
- AP Biology Lab Manual > Transformation Lab
- Classroom Resources > Visualizing Information

ILLUSTRATIVE EXAMPLES

- Amplified DNA fragments can be used to identify organisms and perform phylogenetic analyses.
- Analysis of DNA can be used for forensic identification.
- Genetically modified organisms include transgenic animals.
- Gene cloning allows propagation of DNA fragments.

TOPIC 6.8 Biotechnology

Required Course Content

ENDURING UNDERSTANDING

IST-1

Heritable information provides for continuity of life.

LEARNING OBJECTIVE

IST-1.P

Explain the use of genetic engineering techniques in analyzing or manipulating DNA.

ESSENTIAL KNOWLEDGE

IST-1.P.1

Genetic engineering techniques can be used to analyze and manipulate DNA and RNA—

a. Electrophoresis separates molecules according to size and charge.
b. During polymerase chain reaction (PCR), DNA fragments are amplified.
c. Bacterial transformation introduces DNA into bacterial cells.
d. DNA sequencing determines the order of nucleotides in a DNA molecule.

EXCLUSION STATEMENT—*The details of these processes are beyond the scope of this course. The focus should be on the conceptual understanding of the application of these techniques.*