AP® BIOLOGY
2009 SCORING GUIDELINES

Question 4

The flow of genetic information from DNA to protein in eukaryotic cells is called the central dogma of biology.

(a) **Explain** the role of each of the following in protein synthesis in eukaryotic cells. **(5 points maximum)**

	Description (1 point each)
RNA polymerase	DNA → RNA
Spliceosomes (snRNPs)	Removes the introns and connects (splices) the exons in RNA
Codons	Codes for amino acids/signals
Ribosomes	RNA → protein or site of protein synthesis
tRNA	Transports amino acids

(b) Cells regulate both protein synthesis and protein activity. **Discuss** TWO specific mechanisms of protein regulation in eukaryotic cells. **(4 points maximum)**

Idea of the mechanism (1 point)	**Discussion (1 point)**	
Promotor	increases RNA polymerase binding	**Protein Synthesis**
Enhancer	increases transcription	
Methylation	adding methyl group inhibits transcription	
Acetylation	adding acetyl group promotes transcription	
DNA packaging	loosening/tightening chromatin promotes/inhibits transcription	
RNA processing	GTP cap or Poly-A tail	
RNA editing	removing of introns	
Alternative splicing	editing in different ways to get new/different RNA/polypeptides	
mRNA degradation	targets RNA for destruction (miRNA or siRNA)	
Protein processing	polypeptide → protein modifications (folding, chaperonins, cleavage, etc.)	
Protein degradation	proteases break down proteins	
Feedback: negative/positive	correct explanation of the identified feedback loop	**Intracellular Protein Activity**
Allosteric/noncompetitive	conformational change/binding to alternative site	
Competitive	binding to (or blocking) active site	
Environmental conditions	**intracellular** control by pH/temperature/substrate/enzyme concentration	
Phosphorylation	protein kinase/phosphorylase activating enzyme/altering 3-D shape	
Hormones	correct action for steroid or protein hormone	
Coenzymes/Cofactors	presence/absence controls reactions	

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Question 4 (continued)

(c) The central dogma does not apply to some viruses. **Select** a specific virus or type and **explain** how it deviates from the central dogma. **(3 points maximum)**

Names a specific RNA virus or type of RNA virus (HIV, flu virus, etc.)	**(1 point)**
Deviation from the central dogma (RNA → DNA or RNA → protein or RNA → RNA)	**(1 point)**
More **detailed explanation** of the deviation from the central dogma	**(1 point)**

4. The flow of genetic information from DNA to protein in eukaryotic cells is called the central dogma of biology.

   (a) **Explain** the role of each of the following in protein synthesis in eukaryotic cells.

   - RNA polymerase
   - Spliceosomes (snRNPs)
   - Codons
   - Ribosomes
   - tRNA

   (b) Cells regulate both protein synthesis and protein activity. **Discuss** TWO specific mechanisms of protein regulation in eukaryotic cells.

   (c) The central dogma does not apply to some viruses. **Select** a specific virus or type of virus and **explain** how it deviates from the central dogma.

a) RNA polymerase ~~begins translation~~ is an enzyme that attaches to a DNA sequence and begins transcribing it to mRNA. ~~The mRNA then leaves the nucleus to be translated.~~ Before the mRNA can leave the nucleus, it undergoes RNA splicing by the spliceosomes. These enzymes cut out the introns & part of the DNA that isn't going to be translated, and leaves the exons to be translated.

The ~~final~~ final mRNA then leaves the nucleus and is partitioned into codons. Codons are the mRNA subunits consisting of 3 nucleotides each. A ribosome attaches itself the the mRNA to stabalize it. Ribosomes are where proteins are made.

Protein making is done by tRNA anticodons (the units of 3 nucleotides) attaching itself ~~to~~ to their respective complementary mRNA codons. When tRNA attaches, it brings with it an amino acid. These amino acids combine to the next amino acid brought by the next tRNA until the stop codon tells the tRNA

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

to stop coming. Then the collected amino acids ~~become a polypeptide and~~ form a protein and are released.

b) Protein regulation includes histone acetylation and DNA methylation. Histone acetylation brings acetyl groups that are positively charged and cause the H1 histones to not bind to the each other as tightly. This loose packaging of DNA allows the DNA polymerase better access to the DNA to transcribe for that protein.

In reverse, DNA methylation attracts methyl groups that induce tighter packaging of the DNA. This DNA is less likely to be transcribed and have its proteins synthesized.

In addition operons can be activated or inactivated to have its protein that it codes for synthesized. Repressible operons (like tryptophan) are always having its proteins synthesized unless an enzyme binds to its active site, stopping the RNA molecule from being able to transcribe the genes. Inducible operons are always turned off and not transcribed until the enzyme that is bound to its active site is stimulated to let go, granting access by the DNA polymerase.

c) A retrovirus (like HIV) deviates from the central dogma because ~~instead of~~ instead of creating proteins from DNA, it uses its host cell to create DNA from the virus's own RNA.

4. The flow of genetic information from DNA to protein in eukaryotic cells is called the central dogma of biology.

   (a) **Explain** the role of each of the following in protein synthesis in eukaryotic cells.

   - RNA polymerase
   - Spliceosomes (snRNPs)
   - Codons
   - Ribosomes
   - tRNA

   (b) Cells regulate both protein synthesis and protein activity. **Discuss** TWO specific mechanisms of protein regulation in eukaryotic cells.

   (c) The central dogma does not apply to some viruses. **Select** a specific virus or type of virus and **explain** how it deviates from the central dogma.

RNA polymerase runs along a DNA strand and constructs the RNA translation. Spliceosomes cut and paste together the interpretable sections of RNA, leaving out the intron sections which don't code for anything. Codons are sequences of nucleotides along the strand of completed RNA, and each codon codes for a specific amino acid. RNA is read and translated into a polypeptide in the ribosome; each amino acid is carried by tRNA, where it is matched to the proper codon, and then linked into the chain of amino acids that is forming.

Two methods of regulation are feedback inhibition and allosteric regulation. The former is when too much of a substrate will clog the enzyme or operon that forms it. The latter is when multiple activation sights in an enzyme need to be filled before it can operate, yielding very specific conditions that the ~~substrate~~ product is formed under.

Viruses do not follow the dogma, because they have no regulation. HIV!

4C,

4. The flow of genetic information from DNA to protein in eukaryotic cells is called the central dogma of biology.

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   (b) Cells regulate both protein synthesis and protein activity. **Discuss** TWO specific mechanisms of protein regulation in eukaryotic cells.

   (c) The central dogma does not apply to some viruses. **Select** a specific virus or type of virus and **explain** how it deviates from the central dogma.

Gene expression takes the information from DNA and produces proteins. It all begins when transcription factors (TF) bind to the DNA at certain locations. They then have RNA polymerase create mRNA from the DNA template. Now, the mRNA has its introns, which don't code for any genetic material, cut out leaving the exons. Spliceosomes then splice the remaining exons together. A Me-7 G-Cap is added the the 5' end and a Poly-A tail to the 3' end and the mRNA leaves the nucleus in search of a ribosome. The ribosome is where the mRNA is translated to create the final amino acid sequence. So, the mRNA locates the ribosome at the A-site and waits for tRNA to arrive. The tRNA has the complementary base pairs (anticodons) to match the mRNA's base pairs (codons). These codons bond together and begin the process of translation after the start codon is reached. Each codon has three base pairs and is matched by the anticodon's three base pairs, which code for a certain amino acid. After an amino acid is created the ribosome moves down one codon, translocation, and connects the previous amino acid to the new amino acid with a peptide bond. Once the stop codon is reached the final amino acid is complete and is in its primary structure.

The central dogma of biology does not apply to retroviruses.

4C2

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An example of a retrovirus in the HIV/AIDS virus. It uses a method called reverse transcriptase to insert its genetic material into the host's cell. First, the virus' genetic material is in the form of RNA. Then, it uses an enzyme called reiverse transcriptase to insert the RNA seqverce into the host's DNA sequence. Now, when gene expression occurs it codes for the virus' genetic code also.

Proteins are created because of cell signaling. A signal is received, enters the cell, and then calls for actron to take place. A hormone usually causes cells to start producing proteins, especially anabolic steroids. This can regulate protein synthesis because if more protein needs to be produced then more hormones will be secreted, whereas if proteins don't need to be created the endocrine system won't need to secrete more hormones.

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2009 SCORING COMMENTARY

Question 4

Overview

The question addressed the "central dogma" of biology, the flow of information from DNA to RNA to protein. In the first part of the question, students had to explain the *role* of five specified components—RNA polymerase, spliceosomes, codons, ribosomes, and tRNA—involved in transcription and translation in eukaryotic cells. The second part of the question asked students to describe two specific eukaryotic mechanisms of protein regulation, including protein synthesis and activity. In the third part of the question, students had to explain how the central dogma does not apply to some viruses, selecting a type of virus or a specific virus and explaining how it deviates from the central dogma.

Sample: 4A
Score: 10

The response earned 4 points in part (a). Explanations of the roles of the following each earned a point:

> "RNA polymerase is an enzyme that attaches to a DNA sequence and begins transcribing it to mRNA."
> "[I]t undergoes RNA splicing by the spliceosomes. These enzymes cut out the intron."
> "Ribosomes are where proteins are made."
> "When tRNA attaches, it brings with it an amino acid."

The maximum of 4 points were earned in part (b). Acetylation and methylation are the mechanisms of protein regulation named. These mechanisms each earned a point for a total of 2 points. Each mechanism is also discussed: "Histone acetylation brings acetyl groups that are positively charged and cause the H1 histones to not bind to each other as tightly. This loose packaging of DNA allows the RNA polymerase better access to the DNA to transcribe for that protein," and "DNA methylation attracts methyl groups that induce tighter packaging of the DNA. This DNA is less likely to be transcribed and have its proteins synthesized." These clear explanations of protein regulation mechanisms earned 2 more points. The discussion of operon regulation that follows earned no points since this is not eukaryotic regulation.

A point was earned in part (c) by selection of the "retrovirus (like HIV)" as an example of a virus that deviates from the central dogma. A deviation point was also earned by explaining that "instead of creating proteins from DNA, it uses its host cell to create DNA from the virus's own RNA."

Sample: 4B
Score: 8

The response earned 4 points in part (a). Explanations of the roles of the following each earned a point:

> "Spliceosomes cut and paste together the interpretable sections of RNA, leaving out the intron sections."
> "[E]ach codon codes for a specific amino acid."
> "RNA is read and translated into a polypeptide in the ribosome."
> "[E]ach amino acid is carried by tRNA, where it is matched to the proper codon."

Two mechanism of protein regulation are identified in part (b): "feedback inhibition and allosteric regulation." This earned 2 points: 1 point for each mechanism. However, only 1 point was earned for the correct discussion of the allosteric regulation mechanism: "multiple activation sights [*sic*] in an enzyme need to be filled before it can operate, yeilding [*sic*] very specific conditions that the product is formed under."

Question 4 (continued)

For a point in part (c) the response specifies HIV as a virus that deviates from the central dogma. The response does not explain how this virus deviates from the central dogma, nor does it give a detailed explanation of this deviation.

Sample: 4C
Score: 6

The response earned 4 points in part (a). Explanations of the role of the following each earned a point:

> "RNA polymerase create mRNA from the DNA template."
> "Now, the mRNA has its introns . . . cut out leaving the exons. Spliceosomes then splice."
> "The ribosome is where the mRNA is tranlated [*sic*] to create the final amino acid sequence."
> "Each codon has three base pairs . . . which code for a certain amino acid."

In part (b), which appears in the response after part (c), the identification of a hormone mechanism of protein regulation earned 1 point.

In part (c) the response states that "[t]he central dogma of biology does not apply to retroviruses" and earned 1 point for selection of the correct type of virus. The response then gives an example of a retrovirus. This did not earn an additional point since the question asked for a specific virus or type of virus, not both. The response did not earn a point for the explanation of the deviation from the central dogma because the explanation is incorrect: "Then, it uses an enzyme called reverse transcriptase to insert the RNA sequence into the host's DNA sequence."