AP® BIOLOGY
2007 SCORING GUIDELINES (Form B)

Question 3

A molecule of messenger RNA (mRNA) has just been synthesized in the nucleus of a human cell.

(a) What type of modifications may occur to this RNA before it leaves the nucleus?

One point for each of the following explanations/identifications (3 points maximum):

- Difference between introns and exons
- Description of splicing
- 5′ cap added or description of function
- 3′ poly A tail added or description of function

(b) Once in the cytoplasm, how is the mRNA translated to a protein?

One point for each of the following explanations/identifications (6 points maximum):

- Description of the role of tRNA in the transport of amino acids
- Description of the ribosome/rRNA
- Peptide bond formation (or the connecting of amino acids into a polypeptide chain)
- Concept of codon-anticodon binding
- Concept of the role of the genetic code (e.g., mRNA bases determine the sequence of amino acids)
- Description of stages (initiation, elongation, and termination)
- Elaboration point for a detailed explanation—examples of acceptable answers include, but are not limited to, the following:
  - Description of 40S and 60S ribosomal subunits
  - Role of aminoacyl-tRNA synthetase
  - Structure of tRNA
  - Use of GTP as energy source

(c) If the cell is a secretory cell, how is the protein from part (b) eventually targeted, packaged, and secreted to the exterior of the cell?

One point for each of the following explanations/identifications (3 points maximum):

- Role of chaperones in folding a polypeptide into the protein
- Modification of the protein or addition of sugars and/or phosphate
- Concept of the endomembrane system (description of protein moving from ER to Golgi to vesicles)
- Exocytosis through the fusion of the vesicle with the cell membrane

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In eukaryotes, mRNA is modified in the nucleus before it can become functional. First, special molecules are added on the tips. On the 5' end, a special guanosine cap is added. On the 3 side, a poly-A tail is added. These molecules mainly protect mRNA from damage. If the actual message is destroyed then ~~eprotein~~ the protein it codes for would probably not function.

Another modification is the removal of introns. Introns are non-codeable. Molecules called snRNPs remove the introns, leaving only exons, or codeable segments, in the mRNA. The mRNA now leaves the nucleus through ~~pores~~ pores in the nuclear envelope and enters the cytoplasm to code a protein.

In the cytoplasm, the mRNA is surrounded by a ribosome. The ribosome can only function with the mRNA because that is what brings its smaller and larger subunits together. The mRNA attaches to the smaller subunit. In the larger subunit are the P and A sites. The first codon (set of 3 nucleotides that codes for a specific amino acid) is always AUG, which codes for methionine. A tRNA molecule with the anticodon UAC and a methionine attached to its 3' end comes to the A site. The anticodon forms weak hydrogen bonds with the codon and the mRNA molecule, with the attached tRNA molecule and methionine, is pushed down so that the start codon (AUG) is in the P

site. This process is called initiation. A new codon is now exposed in the A site. This codon attracts a tRNA molecule with the matching anticodon and the associated amino acid. This amino acid forms a peptide bond with the methionine. The tRNA with the methionine exits the ribosomal complex as the ribosome moves down one codon. This process is called elongation and continues for all the remaining codons. The amino acids form peptide bonds with each other, resulting in a polypeptide. When one of the three stop codons (ex. UGA), protein translation stops. The ribosome falls off the mRNA. This is called termination. The mRNA can be reused to form another ribosomal complex and make another peptide. More than one ribosome can code a single mRNA molecule simultaneously. This is called polysome.

Depending whether a polypeptide is made by a free ribosome or one attached to endoplasmic reticulum determines its fate. If made by a ribosome attached to endoplasmic reticulum, the polypeptide is tagged within the lumen. (The polypeptide also folds and becomes a functional protein.) A tag, like mannose-6-phosphate, would transport the protein to the Golgi body, where it is modified, stored, and packaged. Parts of the Golgi body's new membrane breaks, enclosing the protein within. This is a secretory vesicle if it moves to the cell membrane. The vesicle's membrane becomes part of the cell's membrane and its contents are pushed out of the cell.

Split

3 B1

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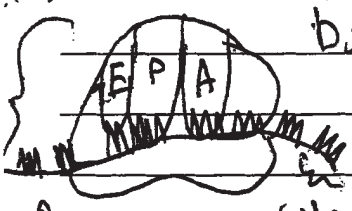
A special feature in eukyrotic DNA is the presence of etons, as well as introns. Exons, the sequences that code for protien, is actually a small portion of the eukyrotic genome. Most of it is fluff, introns. This reduces the chance that random Mutations will effect protien expression. However, these areas must be cut out, or excised, from the final mRNA strand before it leaves the nucleus. A spliciosome is an enzyme that removes the intron from the mRNA. Once mRNA is processed, it leave the nuclear and enters the cytoplasm where its start codon, AUG binds with a large ribosomal unit which is then bound to a small ribosomal unit, forming a ribosome. The process known as translation involves transfer RNA (tRNA) with a specific ammino acid binding to the 3 letter code known as a codon, on the mRNA strand. TRNA enters the A site, exits in the E site, and releases its AA to form a peptide bond with the existing growing chain. the cycle continues until a Stop codon is reached, then a water is added to the



A Ribosome is synthesized in the nucleolus and is an example of a ribozyme, an RNA enzyme.

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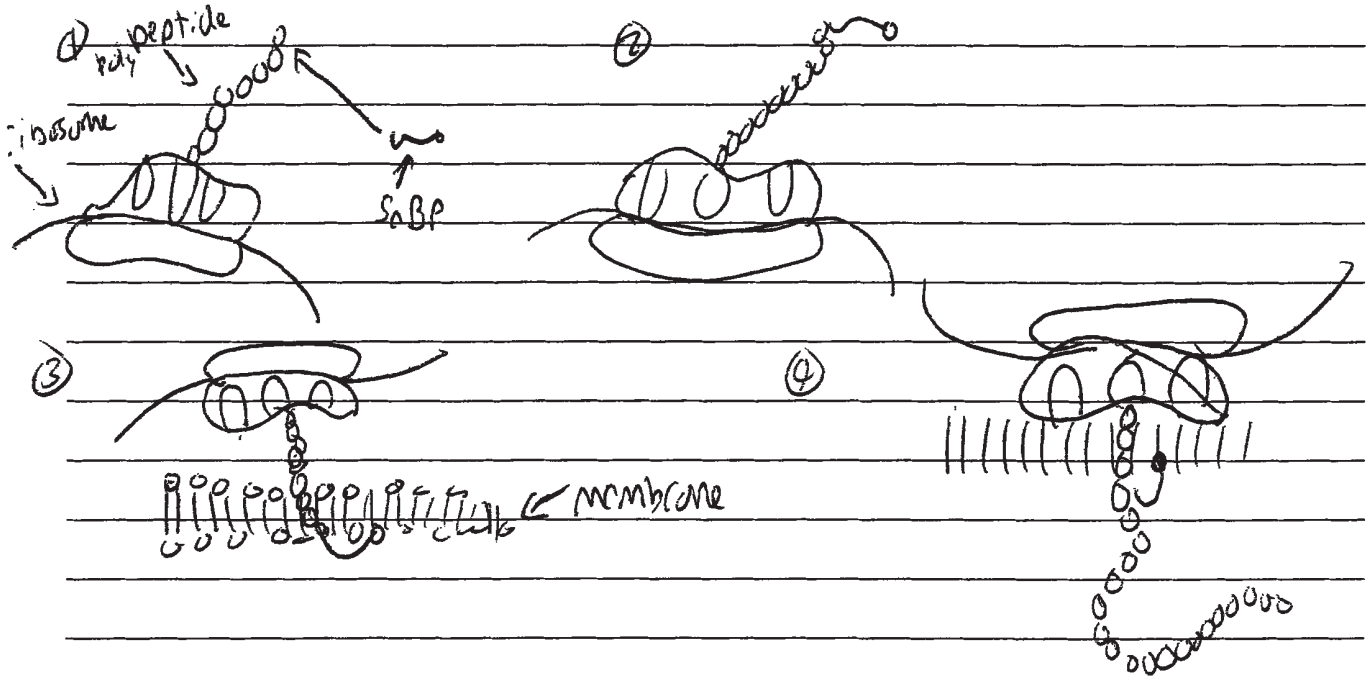
ADDITIONAL PAGE FOR ANSWERING QUESTION 3

peptide chain rather than an AA to release the protein into the cytoplasm.

In cases where the protein is meant to be excreted from the cell, ex: insulin, a signal Binding Particle (SnBP) binds to the protein chain and causes the entire apparatus to bind to a membrane, making the ribosome into a bound ribosome



⑤ protein released inside membrane.

once inside a membrane (ex: rough ER) it is exported via a vesicle.

3C1

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(A) The RNA might have introns cut out off its strands, because this is not vital information. Also a poly cap will be added to the 5' end. The other end is a long tail. Also mutations could ~~be~~ also be made to the RNA. While the RNA polymerase cuts out the introns, a deletion could occur. Other mutations consist of translocation, inversion, and duplication.

(B) After the mRNA leaves the nucleus, it finds a ribosome in the Cytoplasm. The ribosome has three different sites for translation. The mRNA codons are read in ~~[redacted]~~ triplets. The codon is read, and the anti-codon is called with an attached amino-acids. This continues until the ~~[redacted]~~ stop codon has been read. The anti-codon and amino acid are attached by tRNA.

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3C2

ADDITIONAL PAGE FOR ANSWERING QUESTION 3

(C) The protein would be sent to the golgi apparatus. Here its destination would be targeted and it would be shipped out of the cell and through the cell membrane. A tRNA molecule would bind to the protein and take it to its destination out of the cell. The protein could be used for jobs such as facilitated diffusion or active transport

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AP® BIOLOGY
2007 SCORING COMMENTARY (Form B)

Question 3

Sample: 3A
Score: 10

In part (a) the student was awarded 3 points: 1 point for the addition of a 5′ cap; 1 point for the addition of a 3′ poly A tail; and 1 point for the removal of introns. An additional point could have been earned for the action of snRNP in intron removal, but the maximum possible score in part (a) was 3 points.

In part (b) the student earned all 6 points: 1 point for ribosomal structure; 1 point for the genetic code; 1 point for the role of tRNA in transporting the amino acid; 1 point for codon/anticodon binding; 1 point for peptide bond formation; and 1 point for describing the three stages of the process.

In part (c) the student received 1 point for the description of protein modification. Additional points could have been earned for the role of the Golgi apparatus and for exocytosis, but the maximum of 10 points had been reached.

Sample: 3B
Score: 6

In part (a) the student earned 2 points: 1 point for the description of intron removal and 1 point for the role of the spliceosome.

In part (b) the student received 3 points: 1 point for the role of transfer RNA; 1 point for the formation of peptide bonds; and 1 point for an overview of the three stages of the process.

In part (c) 1 point was earned for protein modification. No points were awarded for the insufficient description of transport and secretion.

Sample: 3C
Score: 4

In part (a) the student received 3 points: 1 point for intron removal; 1 point for the addition of a 5′ cap; and 1 point for the addition of a 3′ tail.

In part (b) the description of the translation process was inaccurate, and no points were awarded.

In part (c) 1 point was earned for the function of the Golgi.