A. Print your UA NetID and last name in the space provided for you on the bubble sheet.

B. Take the exam in your exam booklet. When you are certain of your answers, bubble in the scansheet with soft lead pencil, being careful not to have any stray marks on the scansheet.

C. The bubble sheet is your official answer sheet. Circle your answers in this examination booklet, but only the answers on your bubble sheet will be graded. You must turn in your examination booklet and your bubble sheet.

D. Once scoring is complete, exam booklets and answer sheets will be available to download online in the Scansheets and Keys link in the course homepage.
1. Which of the following statements about the enzyme RNA polymerase during the process of transcription is FALSE? (choose ONE)

a. It catalyzes an endergonic reaction.
b. It catalyzes an exergonic reaction.
c. It couples an anabolic reaction to a catabolic reaction.
d. It synthesizes a phosphodiester bond.
e. It synthesizes one or more phosphate-phosphate bonds.
2. Imagine that your lab is synthesizing a new type of cell. One of your colleagues suggests that your synthetic cell should use prokaryotic systems for all the steps of gene expression (transcription and translation) because prokaryotic protein synthesis is faster than eukaryotic protein synthesis. What characteristics of prokaryotic transcription and translation make the overall process faster than in eukaryotes? (choose ALL)
   a. Multiple proteins can be synthesized from a single, polycistronic mRNA molecule.
   b. the primary transcript in prokaryotes does not undergo further processing, so translation can begin immediately.
   c. Unlike in eukaryotes, transcription and translation both take place in the nucleus of prokaryotic cells.
   d. Prokaryotes lack a nuclear envelope, so translation can begin on an mRNA even before transcription of the mRNA is complete.
   e. The smaller ribosomes of prokaryotes can move across the mRNA more quickly.

3. Regarding the 5' G-cap and the poly-A tail that are added to the RNA during processing: (choose ONE)
   a. these processes occur in both prokaryotic and eukaryotic cells.
   b. both facilitate the removal of introns and exons from the primary RNA transcript. both help guide the mRNA out of the nucleus.
   c. both facilitate ribosome in binding to messenger RNA.
   d. both protect the ends of the mRNA from destruction by nucleases.
   e. only the poly-A tail tells the ribosome where to stop translation.

4. Eukaryotic genes consist of exons and introns. Which of the following statements are correct about this topic? (choose ALL)
   a. Introns contain parts of the protein "recipe"; exons do not, and have to be excised (cut out) during RNA processing.
   b. Each exon consists of dozens of nucleotides, and thus specifies several amino acids.
   c. During transcription, both exons and introns are copied by the RNA pol when it synthesizes a primary RNA transcript.
   d. During RNA processing, only introns can be removed.
   e. During RNA processing, only exons can be removed.

5. Alternative splicing means that (choose ALL):
   a. some exons, as well as all introns, are removed from the DNA.
   b. some introns, as well as all exons, are removed from the DNA.
   c. some exons, as well as all introns are removed from the RNA.
   d. differently-spliced mRNAs specify different sequences of amino acids.
   e. multiple different proteins can be synthesized from a single gene.

6. Regarding the levels of protein structure (choose ALL)
   a. the primary structure is the order/sequence of amino acids, held together by covalent bonds.
   b. the secondary structure forms due to interactions between amino acids in the polypeptide, and are stabilized by weak bonds.
   c. the tertiary structure is the folding of a polypeptide into a 3-dimensional shape, and is stabilized by peptide bonds.
   d. secondary and tertiary structures are unaffected by primary structure.
   e. all proteins have quaternary structure.
7. Denaturation, e.g., of a protein (choose ALL)
   a. means that covalent bonds are disrupted by temperature or pH changes.
   b. means that covalent bonds are broken, and the molecule (the protein) separates into individual atoms.
   c. means that the weak bonds that maintain secondary and tertiary structure are disrupted.
   d. results in loss of function.
   e. can expose hydrophobic regions of the protein, and thus result in the loss of solubility in water.

8. In your lab, you are doing a series of experiments on a tetramer (a protein with multiple subunits, one if which is illustrated below) using variations in both temperature and pH to disrupt various aspects of bonding. Which of the following is a likely outcome of your experiments? (choose ALL)
   a. High temperature will break weak bonds in the secondary, tertiary, and quaternary level structure.
   b. High pH will result in denaturation of the polypeptide because the increased kinetic energy will cause it to vibrate violently.
   c. Low pH will disrupt all of the labeled bonds (A-E).
   d. A significant change in temperature will interfere with secondary and tertiary structure only (not primary or quaternary).
   e. A significant change in pH would disrupt bond E only.
9. Which of the following amino acid substitutions would LEAST disrupt the structure (and thus the function) of the short polypeptide shown below? (choose ONE) See amino acid table at end of exam.

<table>
<thead>
<tr>
<th></th>
<th>Gly</th>
<th>Pro</th>
<th>Ser</th>
<th>Asp</th>
<th>Phe</th>
<th>Val</th>
<th>Tyr</th>
<th>Cys</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H-N-C-C</td>
<td>N-C-C</td>
<td>N-C-C</td>
<td>N-C-C</td>
<td>N-C-C</td>
<td>N-C-C</td>
<td>N-C-C</td>
<td>N-C-C</td>
</tr>
<tr>
<td></td>
<td>H-H</td>
<td>H-C-CH_2</td>
<td>CH_2-CH_2</td>
<td>CH_2-CH_2</td>
<td>C-CH_3</td>
<td>CH_2</td>
<td>CH_2</td>
<td>CH_2</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>C-CH_3</td>
<td>OH</td>
<td>CO</td>
<td>H-C-CH_3</td>
<td>CH_2-CH_3</td>
<td>SH</td>
<td></td>
</tr>
</tbody>
</table>

a. phenylalanine (Cys) to tyrosine (Tyr)
b. cysteine (Cys) to serine (Ser)
c. valine (Val) to aspartate (Asp)
d. glycine (Gly) to isoleucine
e. aspartate (Asp) to histidine

10. The enzyme aminoacyl tRNA synthetase “charges” each tRNA with the proper amino acid. This means that each enzyme (choose ALL)

a. delivers amino acids to the ribosome for use during translation.
b. “charges” each tRNA with the proper amino (i.e., the one that is specified by the tRNA anticodon).
c. has an active site complementary to the alpha carbon, amino group and carboxyl group on the amino acid.
d. must distinguish between the tRNAs based on their anticodons.
e. has some part of its structure that is complementary to only one amino acid R-group.
11. Which of the following statements about translation is INCORRECT? (choose ONE)
   a. The small subunit of the ribosome is recruited to the 5' cap; it then scans for the first AUG codon.
   b. The large subunit and the UAC tRNA with its methionine join the small subunit.
   c. The ribosome catalyzes the formation of a peptide bond between amino acids delivered by the tRNAs, and continues until it comes to one of the stop codons.
   d. A particular tRNA (e.g., one with the anticodon UUU) may be complementary to more than one codon.
   e. A particular amino acid may be specified by multiple codons and anticodons.

Essay #1: Please confine your answer to the space provided. MAKE A TABLE exactly like the one below, in which you will compare gene transcription and translation.

<table>
<thead>
<tr>
<th>Where in the eukaryotic cell does this take place?</th>
<th>What enzyme or molecular “machine” does this job?</th>
<th>What is the template for this process?</th>
<th>What is the product?</th>
<th>How does the enzyme/machine know where to start and stop?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transcription</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Translation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For the following question, please transcribe and translate the following DNA template: (genetic code dictionary and amino acid table are at end of exam)

<table>
<thead>
<tr>
<th>DNA template</th>
<th>mRNA</th>
<th>Amino acid sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>3'- A G T A C A G A A T A C C C G A T C A T A C T -5'</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. Which of the following statements are correct about this transcription/translation exercise? (choose ONE)
   a. The mRNA would consist of 7 amino-acid-specifying codons.
   b. The resulting polypeptide would be 7 amino acids in length.
   c. If the bolded A were mutated such that it is replaced by a T, no polypeptide would be synthesized.
   d. If the bolded A were mutated such that it is replaced by T, a shorter polypeptide would be synthesized.
   e. If we have the amino acid sequence, we can be sure of the mRNA and DNA sequenced that encoded it.
13. The fluid mosaic model of the plasma membrane describes which of the following? (choose ALL)
   a. Membranes are fluid in the sense that lipids diffuse/move freely in water.
   b. The various components of the membrane are not covalently bonded to one another, but are jostling and moving constantly.
   c. The membrane is "mosaic" in the sense that is made from various pieces: lipids, proteins, and carbohydrates.
   d. Membranes are fluid and dynamic in the sense that various membrane components (phospholipids, embedded proteins) move and flow from place to place in the cell: nuclear envelope, RER, vesicles, and plasma membrane.
   e. Membranes are mosaics in the sense that they are sometimes made of DNA, sometimes made of RNA, sometimes made of proteins, as information flows through the central dogma.

14. Phospholipids have the ability to spontaneously form complex structures such as the lipid bilayers that make up cell membranes. Which of the following is a property of phospholipids that explains this phenomenon? (choose ALL)
   a. The phospholipids are initially assembled around a protein scaffold, when then dissociates.
   b. The hydrophobic tails of the phospholipids orient towards the center of the membrane, away from water, due to hydrophobic effects.
   c. Weak bonds, such as H-bonds and ionic attractions between the fatty acid tails of the phospholipids hold them together in the membrane.
   d. Polar covalent bonds between the polar heads of the phospholipids maintain the integrity of the membrane.
   e. The polar heads are arranged so that they associate freely with aqueous solutions on either side of the bilayer.

15. Transmembrane proteins like the one shown below (choose ALL)

   ![Diagram of a transmembrane protein]

   a. have portions of their structures that are polar, and other portions that are nonpolar.
   b. are covalently bonded to the polar heads of the phospholipids in the membrane.
   c. can function as signal receptors, enzymes, channels, and connections to the cytoskeleton.
   d. if removed from the membrane would fold up into compact balls.
   e. can be integral, transmembrane, or peripheral to the membrane.
16. The beaker below is divided into two sections by a semi-permeable membrane that functions very much like a plasma membrane. Which of the following statements about this scenario are correct? (choose ALL)

- Side A is hypotonic to side B.
- Side B is hypertonic to side A.
- Side A is hypertonic to side B.
- Over time, we would expect salt to move from side B to side A until an equal balance of solutes to solvent is reached on both sides of the membrane.
- Over time, we would expect water to move from side A to side B until an equal balance of solutes to solvent is reached on both sides of the membrane.

17. Which of the following statements is correct about the permeability of the plasma membrane to various substances? (choose ALL)

- Molecules like O₂, CO₂, N₂ can diffuse easily because they are nonpolar, and can move freely through the membrane interior.
- Nonpolar molecules are repelled by the polar heads of the phospholipids.
- Small, uncharged polar molecules such as H₂O and glycerol can get past the membrane interior without the aid of transmembrane proteins.
- Ions such as Cl⁻, K⁺, and Na⁺ cannot easily diffuse because they are too big.
- Ions cannot diffuse easily without the aid of transmembrane proteins.
18. Transmembrane proteins (choose ALL)
   a. can be used to allow the flow of polar substances across the plasma membrane with their concentration gradients.
   b. can be used to transport polar substances in (or out) of the cell against their concentration gradients.
   c. always require the expenditure of ATP.
   d. generally bind covalently to the substances they transport across the membrane.
   e. can move more than one type of molecule at the same time—even in opposite directions.

19. Suppose you are studying the transport of a certain polar molecule (similar in size and chemical properties to glucose) across the plasma membrane of cells in culture. Over a period of time, you measure the concentration of a polar molecule inside and outside of the cells. You find that the concentration of the molecule is initially higher outside the cell and is gradually increasing inside the cell. You also measure the ATP concentration inside the cell and find that it remains constant. Which of the following is probably responsible for the transport of this polar substance into the cell? (choose ONE)
   a. endocytosis
   b. active transport
   c. facilitated diffusion
   d. simple diffusion
   e. a gated ion channel

20. This figure shows the secondary active transport of glucose into a cell. Which of the following statements about this scenario are correct? (choose ALL)

![Diagram of secondary active transport]

   a. ATP is hydrolyzed by the glucose importer transmembrane protein to actively transport glucose into the cell.
   b. ATP is spent to build a Na⁺ gradient.
   c. The passive flow of Na⁺ allows for the passive flow of glucose into the cell.
   d. Glucose is brought in against its concentration gradient by the Na⁺ gradient.
   e. The exchange of K⁺ and Na⁺ ions is an example of antiport.
21. Why does active transport require the expenditure of ATP, either directly or indirectly? (choose ONE)
   a. An input of energy is needed to speed up the rate of facilitated diffusion.
   b. An input of energy is needed to maintain the shapes of the transport proteins.
   c. An input of energy is needed because the molecules are polar.
   d. An input of energy is needed to go against the nature of the universe: the tendency towards disorder.
   e. An input of energy is needed to move substances with their concentration gradients.

22. Short, unsaturated fatty acid tails ______ membrane permeability and ______ membrane fluidity. (choose ONE)
   a. enhance; increase
   b. reduce; increase
   c. reduce; decrease
   d. enhance; decrease
   e. both c and d

23. Cells need to change the composition of the membrane fatty acid tails in order to respond to changing environmental conditions, and thus maintain homeostasis (a steady internal state). Which of the graphs below represents the change in membrane fluidity/permeability of a fish in Lake Michigan as it transitions from hot summer to cold winter? (choose ONE)
24. Lake sturgeon live in ponds and lakes in northeast Canada. During the warm summers, they prey on insects in shallow water. In winter, they hibernate deep below the frozen surface. Which of the following statements are correct about this topic? (choose ALL)

- a. In cold winter conditions, the sturgeon cell membranes will have to look like this to maintain proper fluidity and diffusion rates:

- b. In hot summer conditions, the sturgeon cell membranes will have to look like this to maintain proper fluidity and diffusion rates:

- c. As the summer warms up, the sturgeon will need to get rid of cholesterol molecules in its membranes in order to maintain proper fluidity.
- d. As summer heats up, the sturgeon will need more long-tailed phospholipids, and more saturated tails.
- e. There is no way for an organism to make adaptive corrections to its membranes that would accommodate the temperature swings from hot summer to icy winter.

25. The figure below shows red blood cells in a variety of environments. Which of the following statements is correct about this topic? (choose ALL)

- a. Cell A’s cytoplasm is hypotonic to the environment.
- b. Cell B is in a hypotonic environment
- c. Cell C is in a hypertonic environment.
- d. Solutes are diffusing out of cell A.
- e. Water is diffusing into cell C.

26. How do plant, animal, and prokaryotic cells differ from one another? (choose ALL)

- a. Each animal and plant cell has multiple linear chromosomes; each prokaryotic cell has a single circular chromosome.
- b. Any of these types of cells can have a cell wall, depending on the species.
- c. Animal and plant cells both have mitochondria; only plant cells have chloroplasts (prokaryotes have neither).
- d. Only animal cells have an endomembrane system.
- e. Plant and animal cells have a plasma membrane; prokaryotic cells do not.
27. Membrane-enclosed sub-compartments (organelles) in eukaryotic cells (choose ONE)
   a. have pH the same as that of the rest of the cell, so that they are compatible.
   b. are quite similar to those in prokaryotes.
   c. allow cells to be more efficient with lower energy needs.
   d. allow for incompatible reactions to be separated.
   e. are similar in type, number, and size in all cells of a particular organism.

Essay #2: Please confine your answer to the space provided on the scansheet, and number your answers. List and describe the functions of ten organelles and molecules that play roles in the synthesis of a protein to be exported from the cell, in the order in which they participate. Specify whether the role is a direct or indirect one. Example:
1. The helium tank is the source of helium gas for inflating party balloons, and thus plays a direct role in producing the party balloon.
2. The latex balloon is the receptacle for the helium gas, and thus plays a direct role.
3. etc, through 10

28. How do newly-synthesized proteins get where they need to go? (choose ALL)
   a. All proteins are initially synthesized in the nucleus, and then delivered by chaperone proteins to their final destinations.
   b. Proteins that are needed in the cytoplasm are usually synthesized by free-floating ribosomes.
   c. Proteins destined for the nucleus, mitochondria, or chloroplasts have signal sequences that direct delivery to those organelles.
   d. Proteins for export from the cell, or to be embedded in the plasma membrane, are synthesized by ribosomes docked with the RER, and are sorted into vesicles by the Golgi.
   e. Proteins that require significant modification or assembly of subunits are synthesized by ribosomes free-floating in the cytoplasm.

29. A cell suffers a mutation that results in a rough endoplasmic reticulum (RER) that does not allow ribosome docking. Such a cell (choose ALL)
   a. would be unable to synthesize new polypeptides.
   b. would be unable to chemically-modify newly-synthesized proteins.
   c. would be unable to assemble proteins with multiple subunits.
   d. would be unable to metabolize or synthesize lipids.
   e. would soon find itself missing essential enzymes and other proteins.

30. If a cell lacked a cytoskeleton, which of the following would likely result? (choose ALL)
   a. The cell would be unable to harness energy.
   b. The cell would be unable to carry out translation.
   c. The shape of the cell would be impacted.
   d. The delivery of proteins to various parts of the cell would be impacted.
   e. The cell would not be able to separate its chromosomes during cell division.
### Genetic Code Dictionary (codons)

<table>
<thead>
<tr>
<th></th>
<th>U</th>
<th>C</th>
<th>A</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>UUU</td>
<td>UUC</td>
<td>UAU</td>
<td>UGU</td>
</tr>
<tr>
<td></td>
<td>UUA</td>
<td>UAG</td>
<td>UAA</td>
<td>UGA</td>
</tr>
<tr>
<td></td>
<td>UUG</td>
<td></td>
<td>UAG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>CUU</td>
<td>CUC</td>
<td>CAU</td>
<td>CGU</td>
</tr>
<tr>
<td></td>
<td>CUC</td>
<td>CCC</td>
<td>CCA</td>
<td>CGC</td>
</tr>
<tr>
<td></td>
<td>CUA</td>
<td>CCG</td>
<td>CCA</td>
<td>CGG</td>
</tr>
<tr>
<td></td>
<td>CUG</td>
<td></td>
<td>CCA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>AUU</td>
<td>ACU</td>
<td>AAA</td>
<td>AGU</td>
</tr>
<tr>
<td></td>
<td>AUC</td>
<td>ACC</td>
<td>AAA</td>
<td>AGC</td>
</tr>
<tr>
<td></td>
<td>AUA</td>
<td>ACA</td>
<td>AAA</td>
<td>AGG</td>
</tr>
<tr>
<td></td>
<td>AUG</td>
<td>ACG</td>
<td>AAA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>GUU</td>
<td>GCU</td>
<td>GAU</td>
<td>GGU</td>
</tr>
<tr>
<td></td>
<td>GUC</td>
<td>GCC</td>
<td>GAC</td>
<td>GGC</td>
</tr>
<tr>
<td></td>
<td>GUA</td>
<td>GCA</td>
<td>GAA</td>
<td>GGA</td>
</tr>
<tr>
<td></td>
<td>GUG</td>
<td>GCG</td>
<td>GAG</td>
<td>GGG</td>
</tr>
</tbody>
</table>

- Phenylalanine
- Leucine
- Serine
- Tyrosine
- Stop codon
- Stop codon
- Cysteine
- Stop codon
- Tryptophan
- Leucine
- Proline
- Histidine
- Glutamine
- Arginine
- Isoleucine
- Threonine
- Asparagine
- Lysine
- Arginine
- Methionine; start codon
- Alanine
- Aspartic acid
- Glutamic acid
- Glycine