Montogue

Quiz BI103

Cell and Molecular Biology

Lucas Monteiro Nogueira

PROBLEMS

Problem 1

Regarding various aspects of cell biology, true or false?

Statements 1 to 7 refer to cellular membranes and lipids.

1.( ) Cells make more than 100 major phosphoglycerides using many different fatty acids and esterifying one of five different alcohols to phosphate. The alcohol head groups give phosphoglycerides their names; the two most common mammalian membrane phospholipids are phosphatidylethanolamine (PE, ethanolamine head group) and phosphatidylcholine (PC, choline head group), which together can be gleaned in the *plasmalogens*, a general class of phospholipids found in membranes.

2.( ) Phosphatidylethanolamine (PE) and phosphatidylcholine (PC) stand out from other membrane phospholipids in that they are zwitterionic.

3.( ) Most sugar-containing lipids of biological membranes are derived from sphingolipids. One specific class of these molecules, the *glycosphingolipids*, consist of sphingosine and an attached phosphate group.

4.( ) Triglycerides are simply glycerol with fatty acids sterified to all three carbons. As they feature no polar head group, they are not incorporated into membrane bilayers. Instead, triglycerides form oily droplets in the cytoplasm of cells to store fatty acids as reserves of metabolic energy.

5.( ) Membrane rafts are found in eukaryotic cells. They typically consist of interactions between sphingolipids and triglycerides.

6.( ) Human red blood cells contain no internal membranes other than the nuclear membrane.

7.( ) Although lipid molecules are free to diffuse in the plane of the bilayer, they cannot flip-flop across the bilayer unless enzyme catalysts called phospholipid translocators are present in the membrane.

Statements 8 to 15 refer to cellular organelles and structures.

8.( ) The size of ribosomes can be represented by Svedberg units, which are actually measurements of time for sedimentation but nonetheless offer a relative notion of a microscopic structure's size. Since Svedberg units are additive, a ribosome constituted of a 60S subunit and a 40S subunit will have a total sedimentation coefficient of 100S.

9.( ) In addition to being found free in the cytoplasm, ribosomes are also abundantly found on the outer surface of the smooth endoplasmic reticulum.

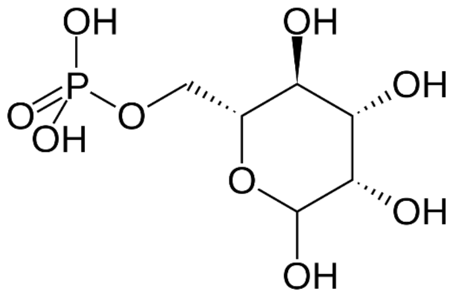
10.( ) The sarcoplasmic reticulum is the smooth endoplasmic reticulum of myocytes. Its main role is to store calcium for muscle contraction.

11.( ) The Nissl bodies are a specialized type of rough endoplasmic reticulum encountered in the pancreatic beta cells. Their main function is to produce insulin.

12.( ) The smooth endoplasmic reticulum is also particularly abundant in cells of tissues that produce sterols and lipids in large quantities, including the adrenal glands and the gonads.

13.( ) Lysosomes process a number of cellular waste materials. The internal medium of lysosomes is highly alkaline (pH $\approx$ 9), which is a requirement for some of its enzymes, such as the *basic hydrolases*, to function properly.

14.( ) I-cell disease is a disease of the lysosomal storage disease family. In the absence of an enzyme named GNPTA (*N*-acetylglucosamine-1-phosphate transferase), proteins in the Golgi apparatus fail to bind to mannose-6-phosphate (shown below) residues, which serve as markers for the proteins to be sent to lysosomes, and instead end up being secreted outside the cell, which is the default pathway for proteins moving through the Golgi apparatus.



15.( ) Proteasomes are barrel-shaped protein complexes that degrade misshaped or misfolded proteins by proteolysis, a chemical reaction that breaks peptide bonds. Proteins to be processed by proteasomes are marked by a small protein called ubiquitin. Proteasomes occur both in the cytoplasm and in the nucleus.

Statements 16 to 24 refer to DNA and RNA.

16.( ) DNA polymerase cannot initiate replication and requires a short nucleotide sequence, called a *primer*, to initiate the process. The primer is in fact a short strand of DNA.

17.( ) DNA replication is directional in nature, which is to say that it always occurs in the 3' to 5' direction.

18.( ) In the G1-S checkpoint of cell division, cyclin-Cdk complexes activate retinoblastoma (Rb) proteins, which bind to DNA promoter regions and activate genes for the S phase, allowing the cell to proceed with genetic material synthesis. At first, Rb proteins are inhibited and bound to E2F proteins, but inhibition is released by G1-S-Cdk phosphorylation of E2F proteins.

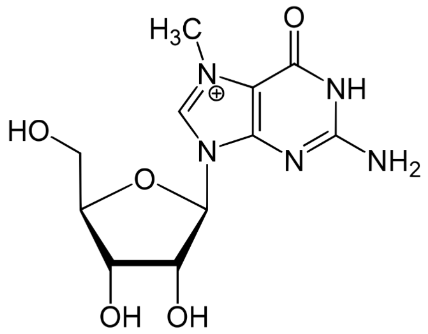
19.( ) In the G1-S checkpoint of cell division, detection of DNA damage activates the ATM and ATR signaling pathways; a major target is the p53 protein, which is phosphorylated and in turn induces transcription of the p21 protein. This latter molecule binds to cyclin dependent kinases (Cdks) and inhibits them, ultimately blocking the cell from proceeding in the S phase. In view of these effects, proteins p53 and p21 are said to be tumor suppressors.

20.( ) Nucleotide excision repair is a mechanism often used to fix "bulky" DNA damage, i.e., damage to multiple bases at once. In eukaryotes, the process involves more than 30 enzymes, including endonucleases, DNA polymerases, and ligases.

21.( ) Unlike nucleotide excision repair, which identifies damaged DNA, mismatch repair identifies not damage to bases, but mainly insertions, deletions, and incorrect matches in DNA sequences. Much like NER, mismatch repair functions mainly during the G1 phase, before genetic material has been replicated.

22.( ) While prokaryotes synthesize RNA by dint of only one RNA polymerase, eukaryotes perform the same function using at least three types of such enzymes. RNA polymerase II mediates the formation of mRNA.

23.( ) A 7-methylguanosine cap (structure shown below) is routinely added to the 5' end of precursor messenger RNA, an important process in the creation of stable and mature messenger RNA able to undergo translation during protein synthesis. Mitochondrial and chloroplastic mRNA are also capped by this modified nucleotide.



24.( ) In addition to five-prime capping, another important modification that mRNA undergoes before leaving the nucleus is intron splicing. As illustrated below, intron segments generally begin with two specific nucleotides, G and U, at the 5' splice site, and end with another two specific nucleotides, A and G, at the 3' splice site.

Statements 25 to 32 refer to amino acids and proteins.
25.( ) Amino acids found in proteins are called α amino acids, because the amino group is bonded to the same carbon as the carboxyl group.

26.( ) Cysteine is an example of amino acid that contains sulfur in its structure.

27.( ) Leucine is an example of amino acid with an aromatic ring in its structure.

28.( ) The only proteinogenic amino acid with a secondary amine group is proline.

29.( ) The side chains of the amino acids serine, asparagine, and glutamine are all endowed with polar side chains, and hence can hydrogen bond with water.

30.( ) Amino acid derivatives play an important role in intercellular communication. One of the most expressive examples comes from tyrosine, which is a precursor of dopamine (a crucial neurotransmitter), γ-aminobutyric acid (GABA, also an important neurotransmitter), and thyroxine (an iodine-containing thyroid hormone that generally stimulates vertebrate metabolism).

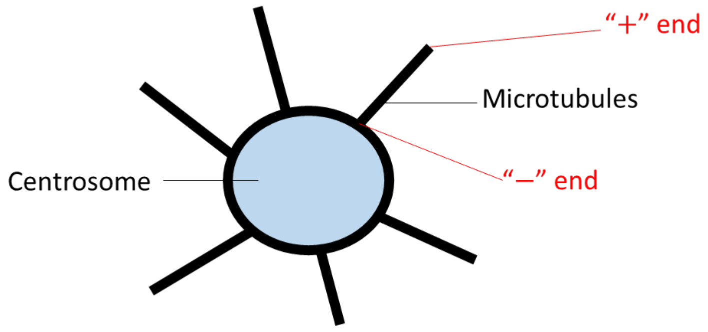
31.( ) Glycosylation of proteins occurs in the Golgi apparatus.

32.( ) Laminins are fibrous proteins of intermediate filaments that occur in the nuclear membrane. They are crucial for the structural properties of the nucleus and have been implicated in the regulation of numerous nuclear processes, including DNA replication, transcription, and chromatin organization.

Statements 33 to 36 refer to the cytoskeleton.
33.( ) Actin filaments determine the shape of the cell's surface, are necessary for whole-cell locomotion, and drive the pinching of one cell into two during cell division.

34.( ) The cilia of respiratory tract cells and the flagella of sperm cells are constituted of closely packed microfilaments surrounded by a thin layer made of tubulin protein. The inherent lightness of microfilaments allows for the swift movement of cilia and flagella in the cells in question.

35.( ) Microtubules grow outward from a central portion of the cell named the centrosome. Using the microtubules to orientate themselves, proteins kinesin and dynein carry membrane vesicles and organelles through the cytoplasm. Movement of material can be towards the "+" end or the "–" end of the tubule, as illustrated below. Most proteins of the kinesin family, including kinesin itself, move along the "–" end direction.



36.( ) In addition to their role in cargo transport, cytoplasmic dyneins also establish the position of the Golgi apparatus in the middle of the cell. Indeed, it has been observed that, when the microtubules are disrupted, the Golgi apparatus breaks up into small vesicles that disperse throughout the cytoplasm.

Statements 37 to 45 refer to cellular energetics.

37.( ) ATP, one of the main energy currencies in cellular activity, is a coenzyme.

38.( ) The final reaction in the glycolysis metabolic pathway is the formation of acetyl-CoA in the cytosol.

39.( ) In beta oxidation, fatty acids are consumed to yield acetyl-CoA, NADH, and $FADH_2$.

40.( ) In the following reaction, the oxidizing agent is pyruvate.

$$\text{Pyruvate} + \text{NADH} + \text{H}^+ \rightarrow \text{Lactate} + \text{NAD}^+$$

41.( ) The reaction introduced in the previous statement has a standard potential ΔE^0 = +0.13 V. Assuming the reaction occurs at 37°C and the concentrations of all reactants and products are 1 M, the change in Gibbs free energy for the reaction has an absolute value greater than 30 kJ/mol.

42.( ) Reconsider the reaction introduced in statement 40. Under normal conditions in vascular smooth muscle (at 37°C), the concentration ratio of NAD^+ to NADH is 1000, the concentration of pyruvate is 0.15 µmol/g, and the concentration of lactate is 0.75 µmol/g. Under these conditions, the change in Gibbs free energy has an absolute value greater than 2.5 kJ/mol.

43.( ) In cellular respiration, most CO_2 from catabolism is released during the citric acid cycle.

44.( ) During cellular respiration, ATP passes through the outer mitochondrial membrane by simple diffusion.

45.( ) The final electron acceptor of the electron transport chain that functions in aerobic oxidative phosphorylation is water.

▶ Problem 2

Choose the alternative that associates the cell division phases (left column) to the corresponding events (right column).

P. Prophase/Prometaphase	**I.** Chromosomes separate
Q. Metaphase	**II.** Spindle breaks down, cells divide
R. Anaphase	**III.** Chromosomes condense, mitotic spindle begins to form
S. Telophase/Cytokinesis	**IV.** Chromosomes line up on metaphase plate

A) P.I, Q.III, R.II, S.I
B) P.IV, Q.III, R.I, S.II
C) P.III, Q.IV, R.I. S.II
D) P.III, Q.IV, R.II, S.I

▶ Problem 3

Suppose an oxygen molecule, starting in the stroma of a chloroplast, diffuses out of one plant cell and into the interior of the Golgi apparatus in a neighboring cell. In doing so, the O_2 molecule will have crossed a minimum of:

A) Three membranes.
B) Four membranes.
C) Five membranes.
D) Six membranes.

▶ Problem 4

Rank the following molecules and ions according to their ability to diffuse through a lipid bilayer, beginning with the one that crosses the bilayer most readily.

I. Water (H_2O)
II. Carbon dioxide (CO_2)
III. Calcium ions (Ca^{2+})
IV. RNA
V. Glucose ($C_6H_{12}O_6$)
VI. Ethanol (C_2H_5OH)

A) H_2O > Ethanol > Ca^{2+} > RNA > CO_2 > Glucose
B) H_2O > RNA > Ethanol > CO_2 > Glucose > Ca^{2+}
C) H_2O > CO_2 > Ca^{2+} > Ethanol > Glucose > RNA
D) CO_2 > Ethanol > H_2O > Glucose > Ca^{2+} > RNA
E) CO_2 > H_2O > Ethanol > Ca^{2+} > Glucose > RNA

▶ Problem 5

To convert a nucleoside to a nucleotide, it would be necessary to:
A) Remove the pentose from the nucleoside.
B) Add phosphate to the nucleoside.
C) Replace purine with pyrimidine.
D) Replace ribose with deoxyribose.

▶ Problem 6

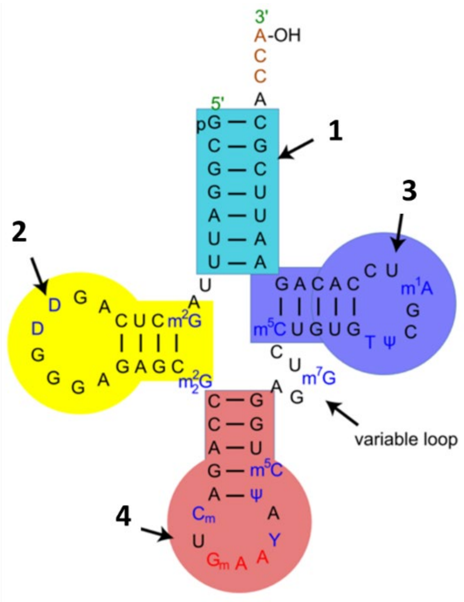
Which of the following eukaryotic DNA polymerases occurs in mitochondria?
A) DNA polymerase α
B) DNA polymerase β
C) DNA polymerase γ
D) DNA polymerase δ

▶ Problem 7

Which of the following enzymes is used by eukaryotic cells to prevent DNA tangling, and has been harnessed by anticancer drugs such as etoposide and irinotecan?
A) DNA polymerase ε
B) DNA gyrase
C) Topoisomerase
D) Primase

▶ Problem 8

The folowing figure is an illustration of typical eukaryote tRNA. Choose the alternative that correctly indicates structures 1 to 4.



A) 1. Acceptor stem, 2. D-loop, 3. TΨC loop, 4. Anticodon loop
B) 1. Acceptor stem, 2. Anticodon loop, 3. TΨC loop, 4. D-loop
C) 1. Acceptor stem, 2. D-loop, 3. Anticodon loop, 4. TΨC loop
D) 1. D-loop, 2. Acceptor stem, 3. TΨC loop, 4. Anticodon loop

▶ Problem 9

Which of the following is the so-called polyadenylation signal?

A) AAAUAA
B) AAUAAA
C) AAAUUA
D) AUUAAA

▶ Problem 10

In bacterial and eukaryotic mRNAs, the normal start codon for protein synthesis is:
A) GAU
B) AGU
C) UAG
D) AUG

▶ Problem 11

In protein biosynthesis, the enzyme the enzyme that catalyzes formation of a peptide bond between two amino acids is:
A) Peptidyl joinase.
B) Peptidyl transferase.
C) Amino acid transferase.
D) RNA polymerase III.

▶ Problem 12

The cytoskeleton is constituted of three types of filaments: microfilaments (actin filaments), intermediate filaments, and microtubules. Which of these are often used as tumor markers?
α) Microfilaments.
β) Intermediate filaments.
γ) Microtubules.

▶ Problem 13

One of the following processes is common to both fermentation and cellular respiration of a glucose molecule. Which one is it?
A) Glycolysis.
B) The citric acid cycle.
C) The electron transport chain.
D) Reduction of pyruvate to lactate.

▶ Problem 14

When electrons flow along the electron transport chains of mitochondria, which of the following changes occurs?
A) NAD^+ is oxidized.
B) The electrons gain free energy.
C) The pH of the matrix increases.
D) ATP synthase pumps protons by active transport.

SOLUTIONS

P.1 ➡ *Solution*

1. False. PE and PC are altogether different from plasmalogens, which are an unusual group of phospholipids found in membranes. Structurally, plasmalogens are distinguished by having a fatty acyl chain attached to glycerol by an ester linkage, and one long hydrocarbon chain attached to glycerol by an ether linkage. These molecules constitute about 20% of the total phosphoglyceride content in humans; in human heart tissue, as much as 40% of choline glycerophospholipids are plasmalogens. The biochemical function of this class of molecules is poorly understood.

2. True. Indeed, PE and PC are zwitterionic and therefore neutral at physiological pH. In contrast, phosphatidylserine (PS), phosphatidylinositol (PI), phosphatidylglycerol (PG) and cardiolipin (CL) have a net negative charge at physiological pH.

3. False. Glycosphingolipids are actually constituted of a ceramide (i.e., a sphingosine molecule linked to a fatty acid) and a carbohydrate.

4. True. Indeed, triglycerides exhibit no polar head group and as such do not occur in membrane bilayers, instead forming compact droplets of cytoplasmic fat to which the cell can resort for metabolic energy. Mitochondria oxidize fatty acids and convert the energy in their covalent bonds to ATP.

5. False. Rafts, small domains in the outer leaflet of plasma membranes, are actually structural interactions between sphingolipids and cholesterol. Special invaginations of the plasma membrane called *caveolae* are the best-characterized example of sphingolipid-cholesterol rafts.

6. False. Human red blood cells contain no internal membranes *at all*; at an early stage in their development, they extrude their nuclei. The lack of any internal membranes is the principal reason they have been used so extensively to investigate the structure of the plasma membrane.

7. True. The hydrophobic interior of the lipid bilayer acts as a barrier to the passage of the hydrophilic head groups that must occur during flip-flop. The energetic cost of this movement effectively prevents spontaneous flip-flop of liquids, so that it occurs extremely rarely in the absence of specific catalysts known as phospholipid translocators.

8. False. Since sedimentation rate is not a direct measurement of mass or volume, Svedberg units are not additive. A Svedberg unit equals 10^{-13} seconds, or 100 femtoseconds; a ribosome constituted of a 60S subunit and a 40S subunit will not necessarily sediment in 100×10^{-13} seconds. Eukaryote ribosomes made of a 60S subunit and a 40S subunit actually have a sedimentation rate of 80S.

9. False. Most ribosomes that are not free are found in the *rough* endoplasmic reticulum and, to a lesser degree, on the outer nuclear membrane (which is continuous with the membrane of the endoplasmic reticulum). Mitochondria and chloroplasts are also endowed with their own ribosomes, but these occur inside the organelles, not on the outer surface.

10. True. The sarcoplasmic reticulum stores Ca^{2+} ions to be used in muscle contraction.

11. False. In actuality, the Nissl bodies are the RER of neurons, and their main function is to produce neurotransmitters.

12. True. Adrenal gland cells rely on the SER to produce cortisol, while the gonads use it to synthesize testosterone and estradiol.

13. False. On the contrary, the lysosome internal medium is highly acidic, with a pH close to 4.8. Fats, carbohydrates and proteins are processed by *acid hydrolases*, of which there are over 40 types.

14. True. Without the molecules that the lysosomes would've received had the correct biochemical processes in the Golgi apparatus taken place, the lysosomes build up substances and lead to the development of the so-called "inclusion cells" seen microscopically.

15. True. Proteasomes degrade proteins that have been tagged by ubiquitin, yielding small peptides that can be further processed into even shorter sequences or employed in the synthesis of new proteins.

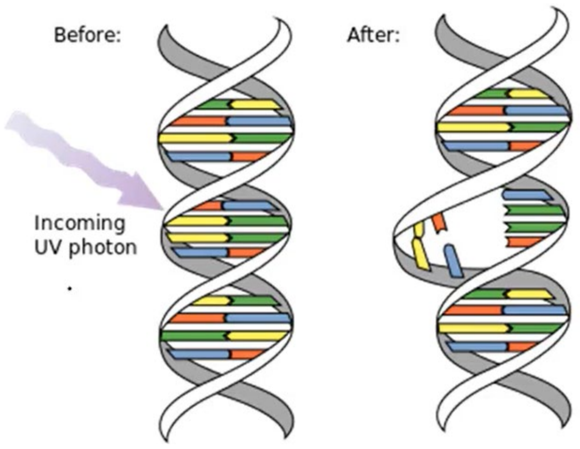
16. False. The primer is a short strand of RNA, not DNA, synthesized by primase, a type of RNA polymerase, before DNA replication can occur. The synthesis of a primer is necessary because DNA polymerases, the enzymes that synthesize DNA, can only attach new DNA nucleotides to an existing strand of nucleotides.

17. False. Nucleotides in the DNA strand are necessarily added to the 3' end of a growing strand.

18. False. The statement would've been flawless were the instances of "Rb protein" replaced with "E2F protein;" it is the latter, not the former, that binds to DNA promoter regions and activates genes for the S phase. E2F proteins are ordinarily inhibited and bound by Rb proteins, but G1-S-Cdk phosphorylation of Rb proteins releases E2F proteins and enable their pro-genetic-synthesis activity.

19. True. Cyclin dependent kinases (Cdks) are always present in cells, but inactive. They are activated by cyclins, another group of proteins, forming Cdk-cyclin complexes, regulatory proteins that allow progression through the cell cycle. If a protein such as p21 produced upon detection of DNA damage binds to Cdk, this enzyme will be inhibited and the cell will ultimately not proceed to the S phase.

20. True. Nucleotide excision repair is especially important in restoration of genetic material damaged by UV light, which, among other effects, may lead to the formation of pyrimidine dimers, as illustrated below. Defects in the NER pathways are linked to human diseases such as xeroderma pigmentosum and Cockayne syndrome.



21. False. While it is true that NER mainly functions in the G1 phase, the same cannot be said of mismatch repair mechanisms; these act in the S or G2 phases, after DNA has been synthesized and the cell will soon begin to divide.

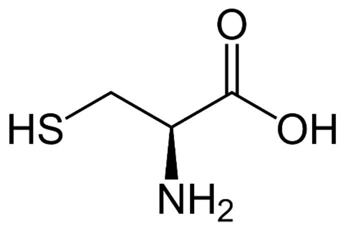
22. True. RNA polymerase I mediates the synthesis of most ribosomal RNA (sizes 5.8S, 18S, and 28S), RNA polymerase II mediates the synthesis of messenger RNA, and RNA polymerase III mediates the synthesis of 5S-sized RNA and other subtypes of RNA.

23. False. Five-prime capping does not occur in mitochondrial and chloroplastic RNA.

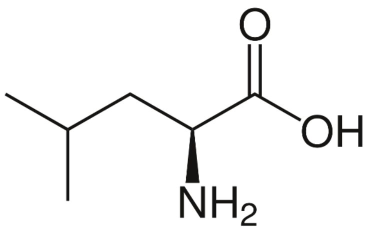
24. True. Indeed, introns are bounded by a GU pair at the 5' splice site and a AG pair at the 3' splice site.

25. True. Amino acids in which the amino group are located in the same carbon as the carboxyl group are named α amino acids.

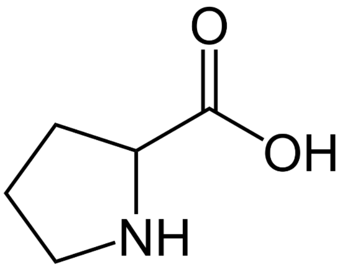
26. True. Methionine, cysteine (shown below), homocysteine, and taurine are the four common amino acids that contain sulfur in their structures, although only the first two are incorporated into proteins.



27. False. Leucine (shown below) has an aliphatic structure. Phenylalanine and tyrosine are amino acids with aromatic rings in their structures.



28. True. Proline (shown below) is indeed the only proteinogenic amino acid with a secondary, rather than a primary, amine group.



29. True. The three amino acids mentioned in the statement are indeed hydrophilic.

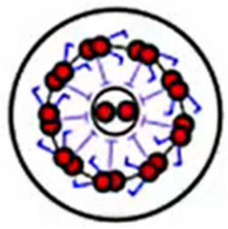
30. False. While dopamine and thyroxine are both derived from tyrosine, GABA is actually a product of the decarboxylation of glutamate.

31. False. Glycosylation of proteins occurs in the endoplasmic reticulum.

32. False. All of the definitions and functions cited in the statement refer to *lamins*, not *laminins*, which are high-molecular weight proteins of the extracellular matrix.

33. True. Actin filaments do perform the functions mentioned in the statement.

34. False. Cilia and flagella in the abovementioned cells are actually constituted of microtubules and the motor protein dynein. The microtubules in these motility structures are organized in a so-called "9×2" pattern, wherein nine doublet microtubules form a ring around a central pair of microtubules, as illustrated below. The blue segments are axonemal dyneins, which serve to link microtubules.



35. False. In actuality, most proteins of the kinesin family, kinesin included, move along the "+" end direction. Different members of the kinesin family vary in the sequences of their carboxy-terminal tails and in the types of cargo they transport, which may include vesicles, chromosomes, and organelles.

36. True. As mentioned in the statement, when the structure of the microtubules is disturbed, be it by a drug or when the cell enters mitosis, the Golgi apparatus breaks up and scatters in the cytoplasm. When the microtubules re-form, the Golgi apparatus also reassembles, with the Golgi vesicles apparently being transported to the center of the cell (i.e., towards the "–" end of the microtubules) by cytoplasmic dynein. Accordingly, one may surmise that movement along the microtubules of eukaryotic cell is responsible not only for vesicle transport, but also for establishing the positions of membrane-enclosed organelles within the cytoplasm.

37. True. A coenzyme is a molecule that acts as a second substrate for many enzymes; ATP is one such molecule, interacting in this manner with a number of enzymes, including polynucleotide kinase, hexokinase, and glycogen phosphorylase kinase.

38. False. Glycolysis generates pyruvate. Pyruvate can then be converted to acetyl-CoA, but this takes place in the mitochondria, not the cytosol, and is not regarded as being part of the glycolysis pathway.

39. True. In beta oxidation, fatty acids are converted to acetyl-CoA, with NADH and $FADH_2$ being produced in the process.

40. True. In this reaction, which may be part of a lactate fermentation process, pyruvate is reduced to lactate and serves as the oxidizing agent of NADH.

41. False. The reaction potential is given by the Nernst equation,

$$\Delta E = \Delta E'^0 - \frac{2.303RT}{nF}\log\frac{[\text{lactate}][\text{NAD}^+]}{[\text{pyruvate}][\text{NADPH}]}$$

With all concentrations at 1 M, the logarithm on the right-hand side becomes zero and the equation reduces to $\Delta E = \Delta E'^0$, i.e., the reaction voltage equals the standard voltage. Knowing that the reduction of pyruvate involves 2 electrons, ΔG is determined to be

$$\Delta G = -nF\Delta E = -2\times 96,500\times 0.13 = -25.1 \text{ kJ/mol}$$

42. True. Noting that $[NAD^+]/[NADPH] = 1000$ and [lactate]/[pyruvate] = 0.75/0.15 = 5, we appeal to the Nernst equation to obtain

$$\Delta E = \Delta E'^0 - \frac{2.303RT}{nF}\log\frac{[\text{lactate}][\text{NAD}^+]}{[\text{pyruvate}][\text{NADH}]}$$

$$\therefore \Delta E = 0.13 - \frac{2.303\times 8.314\times 310}{2\times 96,500}\log(5\times 1000) = 0.0162\text{ V}$$

It remains to compute the change in Gibbs free energy,

$$\Delta G = -nF\Delta E = -2\times 96,500\times 0.0162 = -3.13 \text{ kJ/mol}$$

43. True. Two carbon atoms come into the citric acid cycle from each acetyl group, representing four out of the six carbons of one glucose molecule. Two carbon dioxide molecules are released in each turn of the cycle; however, these do not necessarily contain the most recently-added carbon atoms. The two acetyl carbon atoms will eventually be released on later turns of the cycle; thus, all six carbon atoms from the original glucose molecule are eventually incorporated into carbon dioxide.

44. False. ATP, being a highly charged ion, cannot cross the mitochondria by simple diffusion; instead, it crosses the outer mitochondrial membrane through porin.

45. False. The final electron acceptor is actually oxygen, O_2.

P.2 ➡ *Solution*

In prophase/prometaphase, the chromosomes begin to condense and the mitotic spindle begins to form; in metaphase, the chromosomes line up on the metaphase plate; in anaphase, the chromosomes separate; lastly, in telophase/cytokinesis the spindle breaks down and the cells divide.

- ♦ The correct answer is **C**.

P.3 ➡ *Solution*

Beginning in the stroma, the oxygen molecule will have crossed the inner chloroplast membrane, the outer chloroplast membrane, the plasma membrane of the first cell, the plasma membrane of the second cell, and the membrane of the Golgi apparatus; accordingly, the O_2 molecule will have traversed five membranes in total.

- ♦ The correct answer is **C**.

P.4 ➡ *Solution*

The correct order is CO_2 (small and nonpolar) > Ethanol (small and slightly polar) > H_2O (small and polar) > Glucose (large and polar) > Ca^{2+} (small and charged) > RNA (very large and highly charged). This sequence of entities illustrates the two basic properties that govern the capacity of molecules to diffuse through a lipid bilayer, namely size (small molecules/ions diffuse faster than small ones) and polarity (nonpolar molecules/ions diffuse faster than polar ones, which in turn diffuse faster than charged entities).

- ♦ The correct answer is **D**.

P.5 ➡ *Solution*

A nucleoside consists of a nitrogenous base covalently attached to a sugar (ribose or deoxyribose), but without the phosphate group. A nucleotide, in turn, consists of a nitrogenous base, a sugar, and one to three phosphate groups.

- ♦ The correct answer is **B**.

P.6 ➡ *Solution*

DNA polymerase γ is encountered in the mitochondria, while at least four other types – α, β, δ and ε – mainly occur in the nucleus.

♦ The correct answer is **C**.

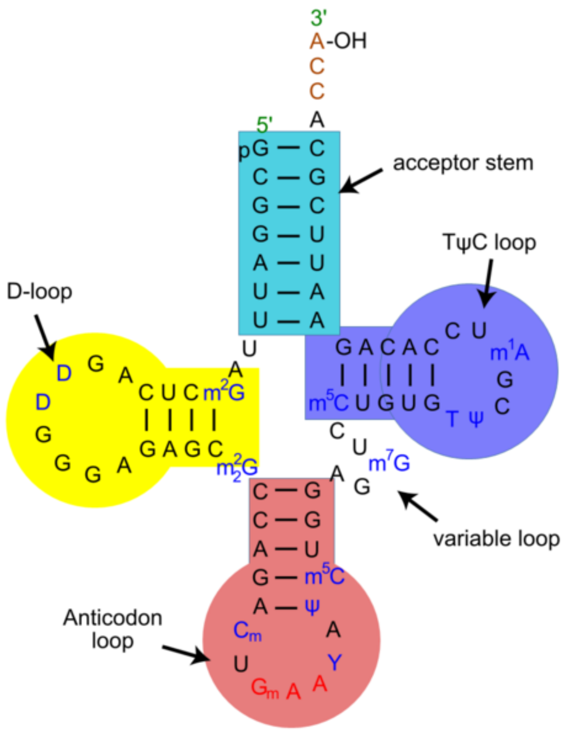
P.7 ➡ *Solution*

Topoisomerase occurs in two forms, I and II. Topoisomerase I is a ubiquitous enzyme whose function *in vivo* is to relieve the torsional strain in DNA, specifically to remove positive supercoils generated in front of the replication fork and to relieve negative supercoils occurring downstream of RNA polymerase during transcription. In addition to these specific roles, topoisomerases have also been implicated in a number of regulatory roles referring to chromosome structure and recombination. Both type I and type II enzymes are the targets of important anticancer agents. The principal drugs acting against type I topoisomerases are the camptothecins, including topotecan and irinotecan. A wider range of agents act against eukaryotic topoisomerase II, including the anthracyclines doxorubicin and daunomycin, as well as the epipodophyllotoxins etoposide and teniposide.

♦ The correct answer is **C**.

P.8 ➡ *Solution*

The regions of the tRNA molecule are indicated below.



♦ The correct answer is **A**.

P.9 ➡ *Solution*

The polyadenylation signal is AAUAAA.

♦ The correct answer is **B**.

P.10 ➡ *Solution*

The start codon for protein synthesis in bacterial and eukaryotic mRNAs is AUG, which codes for the amino acid methionine.

♦ The correct answer is **D**.

P.11 ➡ *Solution*

Peptidyl transferase is the enzyme that forms peptide bonds between adjacent amino acids using tRNAs during the translation process of biosynthesis. Alternatives A and C are made-up enzyme names, and D is an enzyme involved in the transcription of DNA to form small ribosomal RNA.

♦ The correct answer is **B**.

P.12 ➡ *Solution*

Microfilaments are the smallest constituents of the cytoskeleton, with width no greater than 9 nm; intermediate filaments are slightly larger, with a width of 10 nm; finally, microtubules are substantially larger, with a width of about 25 nm. Intermediate filament proteins constitute the largest family of cytoskeletal proteins in metazoans, and are traditionally known for their roles in fostering structural integrity in cells and tissues. Remarkably, individual IF genes are tightly regulated in a fashion that resembles the type of tissue, its developmental and differentiation stages, and biological context. In cancer, IF proteins serve as diagnostic markers, as tumor cells partially retain their original signature expression of IF proteins. However, there are also characteristic alterations in IF gene expression and protein regulation. The use of high throughput analytics suggests that tumor-associated alterations in IF gene expression have prognostic value. Parallel research is also showing that IF proteins directly and significantly impact several key cellular properties, including proliferation, death, migration, and invasiveness, with a demonstrated impact on the development, progression, and characteristics of various tumors.

Reference: Sharma, P., Alsharif, S., Fallatah, A., and Chung, B.M., (2019). Intermediate filaments as effectors of cancer development and metastasis: a focus on keratins, vimentin, and nestin. *Cells*, 8(5):497.

♦ The correct answer is $\boldsymbol{\beta}$.

P.13 ➡ *Solution*

Glycolysis is a process common to fermentation and aerobic respiration.

♦ The correct answer is **A**.

P.14 ➡ *Solution*

As the electron transport chain is carried out, oxygen is reduced to form water and protons are continuously pumped from the mitochondrial matrix to the intermembrane space. The latter process causes the pH of the matrix to increase.

♦ The correct answer is **C**.

ANSWER SUMMARY

Problem 1	**T/F**
Problem 2	**C**
Problem 3	**C**
Problem 4	**D**
Problem 5	**B**
Problem 6	**C**
Problem 7	**C**
Problem 8	**A**
Problem 9	**B**
Problem 10	**D**
Problem 11	**B**
Problem 12	$\boldsymbol{\beta}$
Problem 13	**A**
Problem 14	**C**

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