2020 Spring Cell Biology Homework (I)

- Your answers are due: **5 pm, Apr. 3rd, 2020.**
- Provide your answers on the answer sheet provided. Be sure to fill in your name and student ID number.
- Select the best answer unless instructed otherwise. (2.5 points each, 105 points in total) The full score is 100. If you got more than 100, your score will still be 100.

1. Imagine a segment of DNA (within a gene) encoding a certain amount of information in its nucleotide sequence. When this segment is fully transcribed into mRNA and then translated into protein, in general, …

   A. the protein sequence would carry more information compared to the DNA and mRNA sequences, because its alphabet has 20 letters.
   B. the protein sequence would carry less information compared to the DNA and mRNA sequences, because several codons can correspond to one amino acid.
   C. the amount of information in the mRNA sequence is lower, because the mRNA has been transcribed using only one of the DNA strands as the template.
   D. the amount of information in the mRNA sequence is higher, because several mRNA molecules can be transcribed from one DNA molecule.

2. Laboratory strains of the model organism *Escherichia coli* that are resistant to antibiotics are very often used in research laboratories as well as in the biotechnology industry. If cultures of such bacteria were allowed to contaminate the environment uncontrollably, it is possible that at some point, pathogenic bacteria such as *Neisseria meningitidis* (which causes meningitis and can cause death, especially in children) could acquire the same antibiotic-resistance gene, causing a meningitis outbreak that is difficult to treat. In this scenario, which of the following mechanisms is a more likely source of the antibiotic-resistance gene in *N. meningitidis*?

   A. Random new gene generation
   B. Intragenic mutation
   C. Gene duplication
   D. DNA segment shuffling
   E. Horizontal gene transfer

3. Which of the following is NOT true regarding the tree of life?

   A. Most bacteria and archaea have 1000 to 6000 genes in their genomes.
   B. Eukaryotes are more similar to archaea than to bacteria with respect to the proteins that act on their DNA.

C. Most bacteria and archaea have genome sizes between one and ten million nucleotide pairs, whereas eukaryotic genomes can be millions of times larger.
D. Archaeal species were thought to belong to the eukaryotic world before sequence analysis placed them in a separate domain of life.
E. Photosynthetic bacteria are thought to be the ancestors of the eukaryotic chloroplasts.

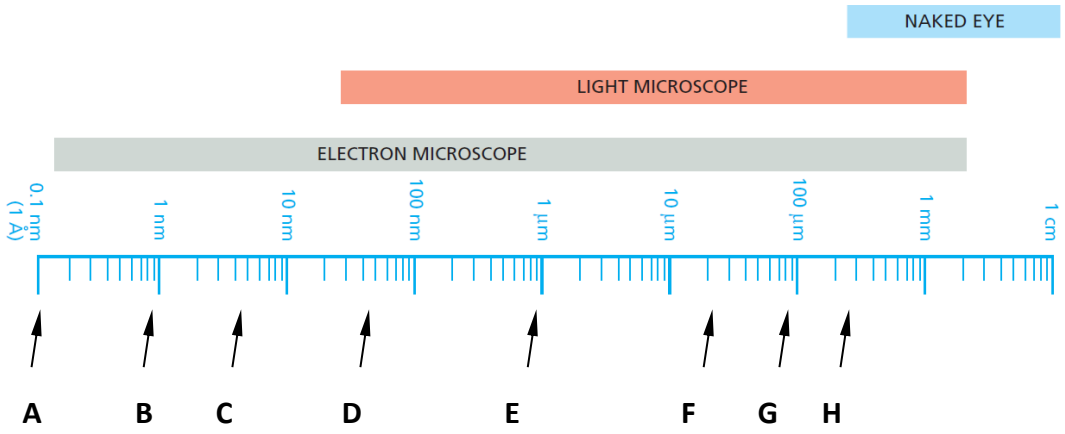
4. Comparing the genomes of present-day mitochondria or chloroplasts with the genomes of their corresponding bacteria reveals that these organelles do not have many of the genes that are essential for their function. For instance, they lack the many genes that are required for DNA replication. What has happened to these genes?

A. They have been lost during evolution, since the organelles no longer rely on DNA replication.
B. The required genes are kept in the nucleus, but many have evolved by gene transfer from the organelle.
C. These genes have undergone mutations and have changed beyond recognition, but are still present in the organelle.
D. The organelles do not replicate their DNA; they import new DNA from the nucleus.
E. The required genes are on plasmids that are separate from the organelle's genome.

5. This model organism is particularly well suited for studying developmental processes in higher animals. It develops from a fertilized egg to an adult in only two to three months, and its body is transparent for the first two weeks, making it easy to observe cell behavior during development. Which of the following describes this organism?

A. It is a vertebrate.
B. It is well suited for genetic analysis.
C. Its early stages of development occur outside of the mother's body.
D. Its genome size is almost half that of humans.
E. All of the above.

6. In the diagram below, a logarithmic scale of sizes is shown. Indicate which of the sizes indicated (A to H) better corresponds to the dimensions of each of the following. Your answer would be a three-letter string composed of letters A to H only, e.g. HCG.



(E) A bacterium
(F) An animal cell
(C) A globular protein

7. In which of the following microscopy techniques are oblique rays of light focused on the specimen?

A. Bright-field microscopy
B. Dark-field microscopy
C. Phase-contrast microscopy
D. Differential-interference-contrast microscopy

8. Indicate whether you would use a fluorescent organic molecule (O), *in situ* hybridization (H), or a coupled fluorescent protein (P) to visualize the cells and their molecules in each of the following cases. Your answer would be a five-letter string composed of letters O, H, and P only, e.g. OHOOO.

(H) You would like to see where in the early *Drosophila* embryo the mRNA encoding a certain transcription regulator is located.
(O) You would like to see the nuclei and count them in an early mouse embryo.
(H) You would like to visualize chromosome 3 in a human cell culture derived from a patient's tissue, based on specific sequences present on this chromosome.
(O) You would like to observe the oscillations in Ca^{2+} ions inside a fertilized frog egg.
(P) You would like to compare the localization of two transcription regulatory proteins in cultured human T cells.

9. Consider an engineered chimeric protein made from fusion of three proteins: a blue fluorescent protein (BFP), a calmodulin-binding peptide, and a green fluorescent protein (GFP). Calmodulin is an abundant calcium-binding protein in eukaryotes. Once bound to calcium ions, it can recognize the calmodulin-binding peptide in the fusion protein, change conformation,

wrap around the peptide, and bring the BFP and GFP components in close proximity. This results in fluorescence resonance energy transfer (FRET) between BFP and GFP. Accordingly, the fusion protein …

A. is a luminescent ion-sensitive indicator that red-shifts its emission wavelength in the presence of calcium.
B. is a luminescent ion-sensitive indicator that increases its emission in the presence of calcium.
C. is a genetically encoded calcium indicator that red-shifts its emission wavelength in the presence of calcium.
D. is a genetically encoded calcium indicator that increases its emission in the presence of calcium.

10. To create cellular factories for monoclonal antibody production, cells derived from an immortalized B lymphocyte cell line (M) are cultured together with antibody-secreting B lymphocytes (B) on a so-called HAT medium. The medium contains an inhibitor of DHFR, an enzyme essential for *de novo* nucleotide biosynthesis. Additionally, it contains substrates for the only alternative nucleotide biosynthetic pathway called the salvage pathway. The enzyme HGPRT is essential for the salvage pathway. One of the cells mentioned above lacks the gene encoding one of the enzymes mentioned. Considering the role of the HAT medium in selecting for *hybrid* cells that are both immortalized and secrete antibodies, which cell (B or M) do you think is missing an enzyme? Which enzyme is missing in this cell?

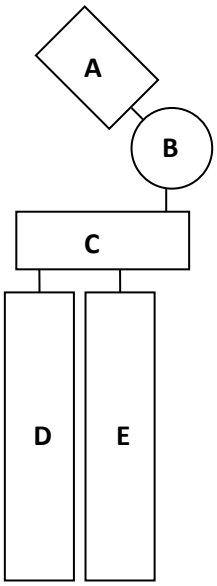
A. M – DHFR
B. M – HGPRT
C. B – DHFR
D. B – HGPRT

11. Sort the following cellular components to reflect the centrifugal force required to sediment them by preparative ultracentrifugation, from low to high force required. Your answer would be a four-letter string composed of letters R, M, L, and N, e.g. LRNM.

(L) Lysosomes
(M) Microsomes
(N) Nuclei
(R) Ribosomes (free cytosolic)

NLMR

12. In the following schematic drawing of an abundant plasma membrane phosphoglyceride, which part is positively charged?



glycolipids

A. *A*
B. *B*
C. *C*
D. *D*
E. *E*

13. Which of the following is correct regarding the composition of various biological membranes?

A. Bacterial plasma membranes are often composed of one main type of phospholipid and lack cholesterol.
B. Cholesterol in the eukaryotic plasma membrane induces phase transition to the gel state.
C. Inositol phospholipids are the most abundant lipids in the endoplasmic reticulum membrane.
D. The mitochondrial and bacterial membranes are rich in glycolipids.
E. Yeast cells synthesize more fatty acids with *cis*-double bonds when the temperature in the environment rises.

14. Which of the following lipids do you expect to be a canonical scramblase substrate in the plasma membrane?

A. Ganglioside G_{M1}
B. Cholesterol
C. Glycosylphosphatidylinositol
D. Phosphatidylethanolamine
E. Galactocerebroside

15. The permeability of a protein-free lipid bilayer to various molecules depends on their properties. Sort the following in order of low to high permeability from left to right. Your answer would be a six-digit number composed of digits 1 to 6, e.g. 123456.

(A) O_2
(B) ATP
(C) RNA oligonucleotide
(D) Na^+
(E) Glucose
(F) Urea

CBDEFA
621345

EBFCDA

16. Imagine a small synthetic vesicle made from pure phospholipids enclosing an interior lumen containing 1 mM glucose and 1 mM sodium chloride. If the vesicle is placed in pure water, which of the following happens faster?

A. Na^+ diffuses out.
B. Cl^- diffuses out.
C. H_2O diffuses in.
D. Glucose diffuses out.
E. Sodium chloride diffuses out.

17. The lactose permease in *Escherichia coli* is an H^+–lactose symporter that mediates the inward active transport of lactose if this sugar is present in the environment instead of glucose. Which of the following is true about this transporter?

A. It has a twofold pseudosymmetrical structure.
B. Lactose and H^+ bind to two different conformations of the transporter.
C. The transporter goes through an intermediate state in which the bound lactose is open to both sides of the membrane.
D. If lactose and H^+ concentrations are changed sufficiently, the transporter can act as an H^+–lactose antiporter.
E. All of the above.

18. Which of the following normally functions to lower the pH of the cytosol?

A. A Na^+–H^+ exchanger in the plasma membrane.
B. A Na^+-driven Cl^-–HCO_3^- exchanger in the plasma membrane.
C. A Na^+-independent Cl^-–HCO_3^- exchanger in the plasma membrane.
D. A V-type ATPase in the lysosomal membrane.
E. Both answers A and B above.

19. Indicate whether each of the following descriptions matches an ABC transporter (A), a P-type pump (P), or a V-type pump (V). Your answer would be a five-letter string composed of letters A, P, and V only, e.g. PPVVV.

(P) The pumps in this family are phosphorylated at a key Asp residue in each transport cycle.

(A) This family is the largest among membrane transport proteins and includes some channels as well as pumps.

(V) The pumps in this family are responsible for the acidification of synaptic vesicles.

(P) The sodium-potassium pump is a member of this family.

(A) The multidrug resistance protein is a member of this family.

20. Consider a human liver hepatocyte. Among the following membranes, which one has the largest total area?

A. Plasma membrane
B. Nuclear inner membrane
C. Mitochondrial outer membrane
D. Rough ER membrane
E. Smooth ER membrane

21. Indicate true (T) and false (F) statements below regarding the nucleus and nuclear protein transport. Your answer would be a four-letter string composed of letters T and F only, e.g. TTTF.

(T) The inner and outer nuclear membranes are continuous with each other, yet maintain distinct protein compositions.

(T) The outer nuclear membrane is studded with ribosomes engaged in protein synthesis.

(F) The endoplasmic reticulum lumen is continuous with the nuclear interior.

(T) Ribosomal proteins pass through the nuclear pore complexes twice; they are imported into the nucleus after synthesis, and are exported from the nucleus after assembly with ribosomal RNA.

22. Which subset of the following is directly involved in driving protein import into the mitochondrial matrix space? Choose all correct sources. Your answer would be a string composed of letters A to G only, in alphabetical order, e.g. AE.

A. ATP hydrolysis inside mitochondria
B. ATP hydrolysis outside mitochondria
C. GTP hydrolysis inside mitochondria
D. GTP hydrolysis outside mitochondria

E. Light

F. Membrane potential across the inner membrane

G. Membrane potential across the outer membrane

23. Sort the following events as they occur during the peroxisomal protein import cycle, starting with the release of cargo from Pex5. Your answer would be a five-letter string composed of letters A to E only, e.g. ABEDC. BDAEC

(A) Pex5 deubiquitylation

(B) Pex5 ubiquitylation

(C) Docking and translocation of the cargo protein along with Pex5

(D) Pex5 export from the peroxisome with the help of ATPases Pex1 and Pex6

(E) Pex5 binding to a cargo protein containing a C-terminal peroxisomal targeting sequence

24. The signal-recognition particle (SRP) ...

A. is a heterodimeric protein.

B. transiently inhibits translation and polypeptide elongation by binding to and inhibiting the elongation factors.

C. accompanies the nascent polypeptide all the way into the ER lumen.

D. binds GTP.

E. is permanently attached to the cytosolic face of the ER membrane, thus bringing the ribosomes into close proximity of the translocon.

25. Which of the following is NOT a likely ER signal sequence recognized by the signal-recognition particle? All sequences are written with their N-terminus on the left.

A. Met-Lys-Leu-Ser-Leu-Val-Ala-Ala-Met-Leu-Leu-Leu-Leu-Ser-Ala-Ala-Arg-Ala

B. Met-Glu-Met-Phe-Gln-Gly-Leu-Leu-Leu-Leu-Leu-Leu-Leu-Leu-Ser-Met-Gly-Gly-Thr-Trp-Ala

C. Met-Lys-Ala-Lys-Leu-Leu-Val-Leu-Leu-Tyr-Ala-Phe-Val-Ala-Gly-Asn

D. Met-Met-Ala-Ala-Gly-Pro-Arg-Thr-Ser-Leu-Leu-Leu-Ala-Phe-Ala-Leu-Leu-Cys-Leu-Pro-Trp-Thr-Gln-Val-Val

E. Met-Leu-Ser-Leu-Arg-Gln-Ser-Ile-Arg-Phe-Phe-Lys-Pro-Ala-Thr-Arg-Thr-Leu-Ser-Ser-Arg-Tyr-Leu

26. Indicate whether each of the following descriptions better matches the ATF6 (A), the IRE1 (I), or the PERK (P) branch of the ER unfolded protein response. Your answer would be a four-letter string composed of letters A, I, and P only, e.g. APII. IAAI

( ) It involves a noncanonical cytoplasmic splicing process.

( ) Its sensor is a latent transcription regulator.
( ) It involves regulated proteolysis of the sensor protein in the Golgi apparatus.
( ) Its sensor bears both kinase and endoribonuclease activities.

27. Adaptor proteins select cargo proteins that will be incorporated into clathrin-coated vesicles. An adaptor protein such as AP2 …

A. can induce membrane curvature even before clathrin molecules bind.
B. acts as a coincidence detector, assembling only when a number of requirements are met.
C. binds to phosphoinositides in the cytosolic leaflet of the membrane.
D. alternates between a locked cytosolic form and an unlocked membrane-bound form.
E. All of the above.

28. Phosphoinositides mark different cellular membranes and play key roles in protein trafficking inside the cell. Among them, $PI(4,5)P_2$ is involved in receptor-mediated endocytosis as well as phagocytosis at the plasma membrane. This phosphoinositide …

A. is bound by the adaptor protein AP2.
B. is bound by the GTPase dynamin.
C. is depleted from clathrin-coated vesicles to promote their uncoating.
D. All of the above.

29. Sort the following events to reflect the order in which they occur during the formation of vesicles from the ER destined for the Golgi apparatus. Your answer would be a four-letter string composed of letters A to D only, e.g. DACB.

(A) Sar1 GTP hydrolysis
(B) Sar1 GTP binding
(C) Sar1–Sec23 binding
(D) Sar1 membrane association

BDCA

30. If this protein is unable to hydrolyze its bound GTP, invaginated clathrin-coated pits accumulate but fail to pinch off from the plasma membrane. In neurons, long vesicle necks collared by the protein are observed and presynaptic endocytosis is blocked. This protein …

A. contains a $PI(4,5)P_2$ binding domain and a GTPase domain.
B. recruits other proteins to the neck of the vesicle.
C. may change the membrane lipid composition by recruiting lipid-modifying enzymes.
D. may directly distort the membrane using the energy from GTP hydrolysis.
E. All of the above.

31. Rab5 and Rab7 constitute a Rab cascade in the process of endosome maturation. One of the Rab5 effectors is a Rab7-GEF, while one of the Rab7 effectors is a Rab5-GAP. Which of these proteins would you expect to find in early endosomes? Write down Rab5 or Rab7 as your answer. Rab5

32. Indicate whether each of the following descriptions better applies to t-SNAREs (T) or v-SNAREs (V). Your answer would be a three-letter string composed of letters T and V only, e.g. TVV.

(T) They are usually located on the target membrane.
(V) They are composed of a single polypeptide chain.
(T) They are usually associated with inhibitory proteins that can be released by Rab proteins.

33. Indicate whether each of the following descriptions better applies to *N*-linked (N) or *O*-linked (O) glycosylation. Your answer would be a four-letter string composed of letters N and O only, e.g. OONO. ONOO

( ) It is abundant in proteoglycans.
( ) It involves the attachment of a preassembled block of oligosaccharide onto a protein.
( ) It is attached to a serine or threonine residue in the protein.
( ) It involves heavily sulfated sugars.

34. Lysosomes are the principal site of cellular digestion. They …

A. normally maintain a pH of about 2.0 to 2.5.
B. contain F-type ATPases that pump protons into the organelles.
C. contain heavily glycosylated membrane proteins.
D. are homogeneous in size and shape.
E. All of the above.

35. Which of the following is NOT correct regarding M6P receptors and KDEL receptors?

A. They both shuttle back and forth between different membrane-enclosed compartments.
B. They are both transmembrane proteins.
C. They both release their soluble binding targets at lower pH.
D. They both prevent the escape of proteins to the cell exterior by the "default" pathway.

36. Indicate whether each of the following descriptions better applies to receptor-mediated endocytosis (R), phagocytosis (F), pinocytosis (P), or macropinocytosis (M). Your answer would be a four-letter string composed of letters R, F, P, and M only, e.g. MMPF.

(P) This pathway depends on caveolin and cavin proteins.

(P) Pathogenic particles such as SV40, papillomavirus, and cholera toxin enter the cell via this pathway.

(F) In animals, this pathway is normally limited to professional cells such as neutrophils.

(M) This pathway proceeds by the formation of highly ruffled regions in the plasma membrane which then collapse, resulting in fluid uptake.

37. During maturation of early endosomes to late endosomes, …

A. the vacuolar domain of the endosome is shed, whereas the tubular domain is retained.
B. the endosome migrates along actin filaments away from the cell interior.
C. the lumen of the endosome becomes more acidic.
D. intralumenal vesicles disappear.
E. All of the above.

38. Indicate whether each of the following membrane proteins releases its protein ligand (R), remains bound to its protein ligand (B), or is degraded in the lysosome along with its protein ligand (D) following receptor-mediated endocytosis. Your answer would be a three-letter string composed of letters R, B, and D only, e.g. RBD.

(R) LDL receptor

(B) Transferrin receptor

(D) EGF receptor

39. Which of the following would you NOT expect to find in a bacterial cell?

A. Swimming using flagella
B. Having a cell wall around the plasma membrane
C. ATP production in mitochondria
D. Protein production on the ribosome
E. Sexual exchange of DNA with other bacteria

40. Which of the following changes would you expect to increase the phase transition temperature of a synthetic bilayer composed of phosphatidylserine?

A. Incorporation of phospholipids with longer fatty acid chains.
B. Introduction of double bonds in the fatty acids.
C. Addition of cholesterol.

D. Removal of serine from the head group.
E. None of the above.

41. Which of the following is a pump that hydrolyzes two ATP molecules per transport cycle?

A. The cystic fibrosis transmembrane conductance regulator protein
B. The multidrug resistance protein
C. The Na^+-K^+ pump
D. The Ca^{2+}-pump
E. The V-type ATPase

42. Compared to the cytosol, which of the following is generally true about the lumen of the endoplasmic reticulum in our cells?

A. It has a higher pH.
B. It has a more reducing environment.
C. It has a much higher calcium ion concentration.
D. It has a higher density of ribosomes.
E. All of the above.