Review for Unit Test #2: Cell Parts, Functions and Protein Synthesis, Answers

Answers to the multiple choice questions are at the bottom of the last page of this document.

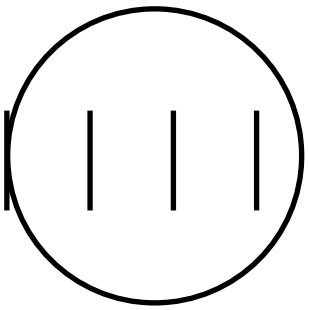
1. Know all of the material on the Review for Cells Quiz #1 (on website).

2. Know and understand the definitions and meanings of the following terms. See notes.

ocular lens	gene	mutation	tRNA
objective lens	chromosome	neutral mutation	transcription
field of view	histones	point mutation	translation
nucleic acids	DNA replication	frameshift mutation	polypeptide
nucleotide	helicase	mRNA	peptide bond
chromatin	DNA polymerase	codon	protein

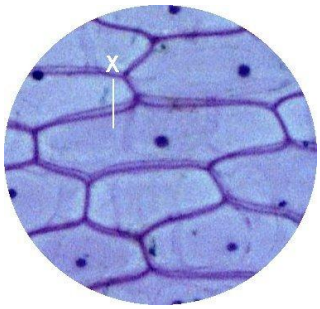
3. Be able to perform microscope calculations for total magnification, FOV and estimate the size of a cell seen under the microscope.

a)



Field of View (Low Power)

FOV low = 3.5 mm
= 3500 µm



Onion Cells (High Power)

Microscope Information:

Ocular lens = 10X

Objective Lenses:

low power = 10X

med. power = 20X

high power = 40X

Because the cell was viewed on high power, use FOV calculation for high

FOV_{low} X magnification $_{low}$ = FOV_{high} X magnification $_{high}$

$$FOV_{high} = \frac{FOV_{low} \text{ X magnification}_{low}}{\text{magnification}_{high}}$$

$$= \frac{3500\ \mu m \quad x \quad 100X}{400X}$$

$$= 875\ \mu m$$

Remember to multiple the ocular x objective lens to get the total magnification

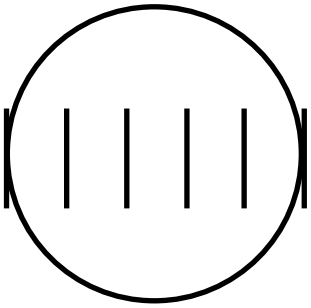
The cell marked "X" (the large centre cell) is about 1/4 to 1/5 of the FOV in width

∴ the cell is **about** 1/5 x 875 µm or 175 µm wide (150 – 225 µm is reasonable)

The cell marked "X" (the large centre cell) is about 2/3 to 3/4 of the FOV in length

∴ the cell is **about** ¾ x 875 µm or 656 µm long (550 – 700 µm is reasonable)

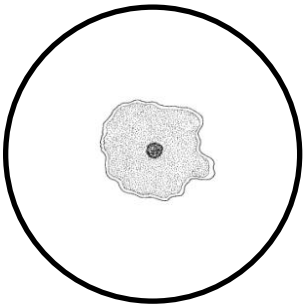
b)



Field of View (Low Power)

FOV = 5 mm

= 5000 μm



Amoeba (Medium Power)

Microscope Information:

Ocular lens = 10X

Objective Lenses:

low power = 5X

med. power = 10X

high power = 20X

Because the cell was viewed on medium power, use FOV calculation for medium

$FOV_{low} \times \text{magnification}_{low} = FOV_{medium} \times \text{magnification}_{medium}$

$$FOV_{medium} = \frac{FOV_{low} \times \text{magnification}_{low}}{\text{magnification}_{medium}}$$

$$= \frac{5000\ \mu m \times 50X}{100X}$$

$$= 2500\ \mu m$$

The amoeba is about 1/3 of the FOV in diameter (length and width are the same)

∴ the cell is **about** 1/3 x 2500 μm or 833 μm in diameter (or close)

4. Compare and contrast the following terms (that is, know the similarities AND differences between the groups of terms):

a) prokaryotic and eukaryotic cells

Similarities:

- both are cells, so they are both types of living things
- both have cytoplasm, a cell membrane, ribosomes and DNA

Differences:

- prokaryotic cells are very small (0.5 – 2.0 μm, about the size of a mitochondria) while eukaryotic cells are much larger, about 10 – 200 μm across
- prokaryotic cells do not have a membrane-bound nucleus or any membrane-bound organelles while eukaryotic cells have both
- prokaryotic cells have their DNA in a simple loop or it may be condensed in a nucleoid region

b) positive and negative mutation

Similarities:

- both involve changes to the order of the nucleotides in a cell's DNA
- both can be either a point mutation or a frameshift mutation
- both may occur spontaneously or be caused by a mutagen (a chemical, or radiation (eg. UV) or a virus that changes the DNA)

Differences:

- a positive mutation is beneficial; it causes a change in a protein that allows the cell to function better than before
- a negative mutation is harmful; it causes a change in a protein that hurts, or maybe kills, the cell

c) frameshift and point mutation

Similarities:

- both involve changes to the order of the nucleotides in a cell's DNA
- both can be either a positive or a negative mutation
- both may occur spontaneously or be caused by a mutagen (a chemical, or radiation (eg. UV) or a virus that causes a change in the DNA)

Differences:

- a point mutation is a change in one single nucleotide base pair so it changes only one codon (and its associated amino acid)
- point mutations are ***less likely*** to cause a problem for the cell, but it some are very harmful. Cystic fibrosis is a serious disease caused by a point mutation
- a frameshift mutation either adds in, or leaves out, one or more nucleotides, so the whole order of the DNA strand is shifted, changing many codons.
- frameshift mutations may change many codons and proteins, so they are ***more likely*** to be negative and very damaging

d) DNA and RNA

Similarities:

- both are nucleic acids made up of nucleotides
- both are involved in protein synthesis and the control of cellular functions

Differences:

- DNA is double stranded so it is much more stable than RNA, which is only single-stranded
- DNA has A, T, C and G while RNA has A, U, C and G
- DNA has deoxyribose as its sugar while RNA has ribose as its sugar

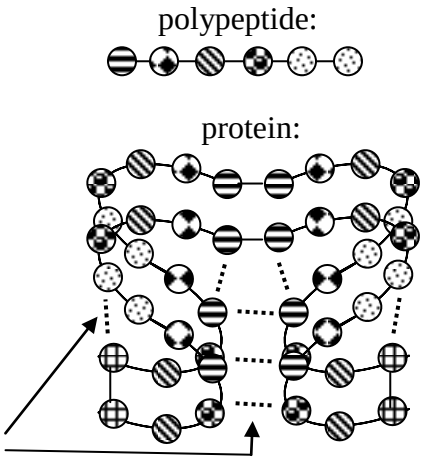
e) polypeptides and proteins

Similarities:

- both are macromolecules made of many amino acids bonded together in a long chain by peptide bonds
- both are made by ribosomes during protein synthesis

Differences:

- polypeptides are simply long chains of amino acids with no particular shape or folding (like a long string of pearls)
- proteins are long polypeptide chains that have been folded and twisted into a specific shape. The shape is maintained (held together) by hydrogen bonds between the amino acids on different parts of the polypeptide chains



f) DNA and chromatin

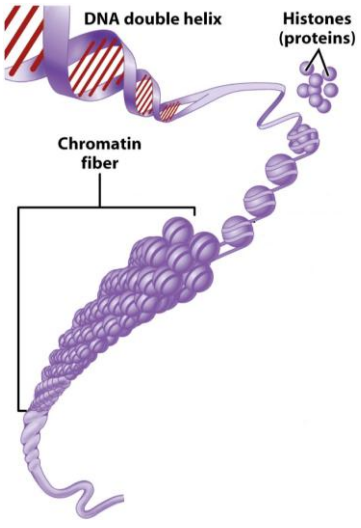
Similarities:

- both are forms of DNA and are involved in storing the information the cell needs in order to make proteins and control cell functions
- both are associated with the nucleus and not with any other organelles

(Note: mitochondria and plastids also contain DNA, but this is considered separately from the DNA and chromatin in the nucleus)

Differences:

- chromatin is the name of the "form" of DNA during interphase, when the cell is between divisions
- chromatin is only slightly coiled, with the DNA wrapped around histone proteins. Chromatin allows the DNA code to be accessed to make proteins or for DNA replication



5. Regarding nucleic acids:

a) What are nucleotides?
- nucleotides are the subunits that make up nucleic acids

b) What three molecules make up nucleotides?
- they contain a phosphate group, a sugar and a nitrogen base

c) What are three significant differences between the structures of DNA and RNA?
- DNA is double stranded so it is much more stable than RNA, which is only single-stranded
- DNA has A, T, C and G while RNA has A, U, C and G
- DNA has deoxyribose as its sugar while RNA has ribose as its sugar

d) Give three reasons why the structure of the DNA molecule is so well suited to its function.
- The function of DNA is store the huge amount of information that a cell needs in order to make its proteins, control all of its functions and to be able to pass a copy of this information along to its daughter cells

The structure of the DNA molecule has three properties which are critical to how it functions:

1. **DNA can be replicated.** Because A always pairs with T and C always pairs with G, DNA can make copies of itself**.** If you pull the two strands apart down the middle, each strand can be used as a pattern (template) to replace its complementary strand and form a complete, new DNA molecule.
2. **DNA can carry information**. The order of the nitrogen bases (A, T, C and G) along a DNA strand is a code for making proteins and controlling cell functions.
3. **DNA can be greatly condensed so it can fit inside the cell's nucleus and not break during mitosis**:
   - the total length of the completely uncoiled DNA in a single human cell is about 6 meters.
   - the total length of human chromatin (DNA coiled around histone proteins) is 28 cm.
   - the total length of human chromosomes (completely coiled DNA during mitosis) is approximately 0.060 cm or just 0.6 millimeters

   (these lengths are provided as an illustration, you do not need to memorize them)

e) Describe the steps in DNA replication. Include the names of two enzymes.
- An enzyme called "helicase" unwinds the DNA double helix and breaks the hydrogen bonds between the complementary strands (like unzipping a zipper).
- The exposed nitrogen bases attract their complementary nucleotides (nitrogen base + sugar + phosphate) that are free in the nucleus.
- An enzyme called "DNA polymerase" chemically bonds the sugar and phosphate on adjacent nucleotides by a dehydration synthesis reaction to form the sugar-phosphate backbone.
- The two new strands of DNA are rewound into helices by another enzyme.

f) A sample of DNA contains 20% cytosine. What are the percentages of the other nucleotides in this DNA?
- if the DNA is 20% cytosine, it must also be 20% guanine because C and G are paired
- therefore, C + G = 20% + 20% = 40%
- the rest of the DNA (60%) is made of equal amounts of A and T
- therefore, there must be 30% of adenine (A) and 30% of thymine (T)

6. Regarding proteins (you may need to look back at your notes on macromolecules):

a) Describe four functions carried out by proteins in living things. Give a specific example for each.
- enzymes to speed up or control the rate of chemical reactions; for example: catalase to break down hydrogen peroxide (H_2O_2) in cells or helicase to unwind and unzip DNA
- transport proteins to carry substances through different parts of the body; for example, channel proteins which allow ions to pass through the cell membrane or hemoglobin to carry oxygen through the blood
- structural proteins which make up the structure of cell or body parts; for example, collagen which makes a network in bone. The bone is hardened by the addition of calcium phosphate.
- antibodies which are proteins that help us fight disease; for example, the antibodies to chicken pox or human papilloma virus (HPV) that people are vaccinated against
- peptide hormones which allow different parts of the body to communicate and work together; for example, insulin which helps glucose move from the blood into the cells

b) Which organelles in plant and animal cells have a role in protein production?
- the nucleus contains the DNA which stores the 'recipes' (genes) to make proteins
- the nucleolus is where ribosomes are made and assembled
- ribosomes are the organelle which actually makes the protein
- the rough endoplasmic reticulum has polypeptide chains secreted inside it. Enzymes on the inner membrane of the rough ER modify the polypeptides/proteins then the rough ER transports and packages the polypeptides/proteins into transport vesicles
- transport vesicles carry the polypeptides/proteins from the rough ER to the Golgi apparatus
- inside the Golgi apparatus, the polypeptides/proteins get their final modifications and then they are packaged into secretory vesicles or lysosomes
- secretory vesicles transport the proteins to the cell membrane where they are released by exocytosis

c) Protein synthesis is anabolic. What does this mean?
- protein synthesis involves joining individual amino acids into a polypeptide chain, so it is taking smaller molecules and combining them or "building them up" to make larger molecules, which is an anabolic process

d) Protein synthesis requires energy. What energy storage molecule supplies this energy? Where is it made?
- protein synthesis forms bonds between amino acids to make a polypeptide chain – forming bonds requires energy
- this energy is provided by ATP
- ATP is produced by cellular respiration in the mitochondria

7. Very briefly outline the steps of protein synthesis that take place in free ribosomes in the cytoplasm.
   a. the cell identifies the protein it needs to make and finds the gene (DNA sequence) for this protein in the chromatin in the nucleus of the cell
   b. an enzyme unwinds and unzips the DNA for this protein
   c. an mRNA copy of the gene is made in the nucleus. Only one side of the DNA strand it copied. Once the mRNA copy is made, the DNA zips and winds back up.
   d. the mRNA travels from the nucleus into the cytoplasm through a nuclear pore
   e. in the cytoplasm, the subunits of a free ribosome attach to the mRNA and start to "read" (translate) the mRNA code
   f. tRNA molecules in the cytoplasm have a codon (a group of 3 nucleotides) and one amino acid. The tRNA codon matches up with its complementary codon on the mRNA and this translates the order of the nucleotides on the mRNA strand into a sequence of amino acids
   g. the ribosome holds the tRNA molecules in place, allowing an enzyme to bond their amino acids together to make the polypeptide chain. The empty tRNA molecules are released from the ribosome to go get another amino acid
   h. eventually there is a 'stop' codon on the mRNA. The ribosome disconnects from the mRNA and the polypeptide chain is released into the cytoplasm

8. What is meant by transcription? Describe what happens during this process.
   a. transcription refers to the process ***in the nucleus*** when mRNA makes a copy of the DNA nucleotide sequence
   b. an enzyme unwinds and unzips the DNA for one protein (one gene)
   c. RNA nucleotides (they have ribose as their sugar) that are floating freely in the nucleus are attracted onto their complementary nucleotide on just ***one side*** of the open DNA strand. C pairs with G, and A pairs with U (instead of T).
   d. an enzyme joins the sugar and phosphate of the RNA nucleotides to make the sugar-phosphate backbone and form the mRNA strand

9. What is meant by translation? Describe what happens during this process.
   - translation refers to the process ***in the cytoplasm*** when mRNA, ribosomes and tRNA read the nucleotide codons and turn this into an amino acid sequence (they translate from nucleic acid into amino acid)
   - in the cytoplasm, the subunits of a free ribosome attach to the mRNA and start to "read" the mRNA code
   - tRNA molecules in the cytoplasm have a codon (a group of 3 nucleotides) and one amino acid. The tRNA codon matches up with its complementary codon on the mRNA and this translates the order of the nucleotides on the mRNA strand into a sequence of amino acids
   - the ribosome holds the tRNA molecules in place, allowing an enzyme to bond their amino acids together to make the polypeptide chain. The empty tRNA molecules are released from the ribosome to go get another amino acid
   - eventually there is a 'stop' codon on the mRNA. The ribosome disconnects from the mRNA and the polypeptide chain is released into the cytoplasm

10. Very briefly outline the roles of the following in protein synthesis:

a) ***chromatin*** is made of long thin threads of DNA wrapped around histone proteins
   - the order of the nucleotides in the DNA contains all of the codes or recipes that the cell needs in order to make its proteins and control cell functions
   - the chromatin is slightly condensed, but it is readily uncoiled in order to access the genes
   - the nucleotide sequence of the DNA is transcribed (copied) to make mRNA

b) ***genes*** are a section of DNA that contains the nucleotide sequence for one protein (ie. a gene is a "recipe" for one protein)

c) ***mRNA*** is the molecule that copies the order of the nucleotides from the DNA in the nucleus and then travels out into the cytoplasm and takes the "recipe" to where the protein is made. mRNA acts as a messenger carrying information between the nucleus and the cytoplasm

d) ***tRNA*** is the molecule in the cytoplasm that has both a codon and an amino acid. The tRNA matches its codon with a complementary codon on the mRNA strand and delivers its amino acid so it can be incorporated into the polypeptide strand

e) ***ribosomes*** provide a platform in which the mRNA, tRNA, amino acids and enzymes all come together in the correct orientation in order for the amino acid chain to form

11. Use the mRNA codon chart in your notes to translate the following DNA strands into mRNA strands and then into a polypeptide chain:

a) DNA: T A C G G G T T A T C G A A A T G T C G A C T G A T C

mRNA : A U G | C C C | A A U | A G C | U U U | A C A | G C U | G A C | U A G

polypeptide: methionine (start) – proline – asparagine – serine – phenylalanine – threonine – alanine – aspartic acid - stop

b) DNA: T A C G C G A C A G T C C A G A C C G G A T T T A C T

mRNA : A U G | C G C | U G U | C A G | G U C | U G G | C C U | A A A | U G A

polypeptide: methionine (start) – arginine – cysteine – glutamine – valine – tryptophan – proline – lysine - stop

12. If the ninth nucleotide in the mRNA from question b) was changed from 'A' to 'U', this would change the codon to UGA, which is a stop codon. When the mRNA was being translated into a protein, this would tell the ribosome that the polypeptide was complete before it was finished. The ribosome would make incomplete proteins from this mutated mRNA and the cell would not have the protein it needed.

13. Regarding proteins that are manufactured by ribosomes found on the rough endoplasmic reticulum:

a) Why are some polypeptide chains inserted directly into the endoplasmic reticulum and not released into the cytoplasm?
- if a protein is intended for secretion outside of the cell, then the cell keeps the protein contained by inserting inside the ER as it is made (the polypeptide is not allowed to escape into the cytoplasm because then the cell would have to collect it again to put it into a vesicle for secretion)
- if a protein is an enzyme that could damage parts of the cell (eg. a lysosomal enzyme), it is kept out of the cytoplasm by inserting it inside the ER as it is made

b) A cell is making the polypeptide hormone "insulin" to be secreted outside of the cell. Very briefly outline the steps that happen AFTER the polypeptide chain is manufactured and inserted into the centre of the rough ER and BEFORE the insulin can leave the cell.
- the polypeptide chain inside the ER is modified by enzymes on the inner membrane of the ER
- the polypeptide moves along the ER until it is finished being modified
- the ER containing the polypeptide pinches off to form a transport vesicle with the polypeptide inside
- the transport vesicle travels to the cis face of the Golgi apparatus where it fuses (joins) with the Golgi and empties the polypeptide inside the Golgi
- the polypeptide moves along and through the Golgi and is further modified by enzymes on the inner membrane until it is the finished protein
- the Golgi containing the finished protein pinches off to form a secretory vesicle which travels through the cytoplasm to the cell membrane where it is secreted out of the cell by exocytosis

14. What are the functions of these enzymes:

- ***helicase*** unwinds the DNA double helix in preparation for DNA replication
- ***DNA polymerase*** is the enzyme that forms the bonds between sugar and phosphate groups to connect the sugar-phosphate backbone of DNA

15. Regarding mutations:

a) Define or explain what is meant by a mutation.
- a mutation is a change in the order of the nucleotides in a DNA or RNA strand
- the mutation may change the order of the amino acids in a polypeptide chain and this may change the shape and function of a protein

b) What are two common types of mutations? Describe what happens in each type of mutation.
- a point mutation is a change in one single nucleotide base pair so it changes only one codon (and its associated amino acid)
- point mutations are ***less likely*** to cause a problem for the cell, but it some are very harmful. Cystic fibrosis is a serious disease caused by a point mutation
- a frameshift mutation either adds in, or leaves out, one or more nucleotides, so the whole order of the DNA strand is shifted, changing many codons
- frameshift mutations usually change many codons and proteins, so they are ***more likely*** to be negative and very damaging

c) If a mutation occurs during mRNA transcription, how will this affect the cell?
- a mutation during transcription means that the mRNA is not copied properly from the DNA gene
- this changes the order of the nucleotides so it will change the codons and this will change the order of the amino acids in the protein
- different amino acids mean that the protein will not fold properly and it may not be able to perform its function in the cell

Note: a mutation during transcription only changes ***the mRNA*** for one protein in one cell

d) If a mutation occurs during DNA replication, how will this affect the cell?
- a mutation during DNA replication means that one, or both, copies of the DNA will be incorrect
- the incorrect DNA will be passed to the daughter cells, and passed to their daughter cells, etc.
- all future cells will now have changed genes for protein synthesis or the control of a cell function
- the effect on the cell depends on whether the mutation is a positive, negative or neutral mutation

Note: a mutation during DNA replication changes ***the gene*** for one protein and this will be passed to all generations of cells that are produced from this cell

16. A common theme in biology is that "structure dictates function" which means that how a structure or organism is made (its anatomy) influences how it works (its physiology). Describe how the structure of the following organelles affects their function:

a) mitochondria: mitochondria have two membranes – an inner membrane (similar to a bacterial cell) and an outer membrane that is similar to the cell membrane

i) the inner membrane
- is deeply folded so it has a very large surface area
- the enzymes for cellular respiration are found on this inner membrane
- the large surface area of the inner membrane allows mitochondria to have many sets of enzymes for cellular respiration

ii) mitochondria have their own DNA and ribosomes
- this allows mitochondria to divide on their own, independently of the cell
- if cells require more energy, they can increase the number of mitochondria without waiting for the cell to divide

b) nuclear membrane: the nucleus has a double membrane which completely surrounds the DNA
- the membrane keeps the DNA in the nucleus, where it is less likely to be damaged
- the nuclear membrane is a phospholipid bilayer, which controls the movement of substances through the nuclear membrane, into and out of the nucleus
- the nuclear membrane has nuclear pores which allow ribosomes and mRNA (which are made inside the nucleus) to pass out into the cytoplasm where they can be used

c) rough endoplasmic reticulum
- the endoplasmic reticulum is a series of membranes which have a huge surface area to hold the enzymes which modify proteins
- the surface of the rough ER has special binding sites for ribosomes, so ribosomes can make proteins and insert them directly into the ER so these proteins won't damage the organelles
- the ER forms channels which can move proteins through the cell
- finally, bits of the ER can pinch off to form transport vesicles to carry proteins to the Golgi apparatus for further processing and packaging

d) lysosomes
- these are small membrane-bound vesicles which contain powerful digestive enzymes; the lysosome membrane keeps the enzymes separate from the cytoplasm so they can't damage the cell or its organelles
- lysosomes are small so they can move through the cytoplasm and digest any worn out organelles
- the lysosome's membrane allows lysosomes to join with other vesicles, especially vesicles formed by endocytosis that contain food or bacteria. The lysosome joins its membrane with the other vesicle and the lysosome's enzymes digest whatever was in the endocytotic vesicle

17. Cells are the smallest unit of life. What are the characteristics of living things? (MRS GREN)
Living things are capable of:
- movement (changing their position)
- respiration (obtaining and using chemical energy)
- sensing and responding to their environment
- growth
- reproduction
- excretion to get rid of wastes, and
- nutrition to obtain food as a source of nutrients and energy

18. State one way in which the following organelles are related or work together:

a) Golgi apparatus and lysosomes: Golgi apparatus make lysosomes. Lysosomes are tiny vesicles full of digestive enzymes that pinch off from the Golgi

b) microtubules and vesicles: microtubules provide a structure for the cell and also a pathway along which vesicles can be moved by motor proteins

c) ribosomes and nucleolus: ribosomes are made and assembled in the nucleolus region of the nucleus.

Answers to the multiple choice:

1. c	9. d	17. d	25. c	33. c	41. c	49. c	57. a
2. a	10. b	18. a	26. a	34. b	42. d	50. d	58. a
3. c	11. c	19. b	27. b	35. c	43. d	51. b	59. b
4. b	12. d	20. d	28. b	36. d	44. a	52. a	60. b
5. a	13. a	21. a	29. d	37. a	45. b	53. d	61. d
6. c	14. b	22. b	30. a	38. c	46. b	54. c	62. a
7. b	15. b	23. a	31. b	39. a	47. a	55. d	63. c
8. c	16. a	24. b	32. b	40. c	48. a	56. d	64. b