Biology 12 **Name:** KEY

Cell Biology **Per:** _____ **Date:** _____

Chapter 4 – DNA Structure & Gene Expression

Complete using BC Biology 12, pages 108 - 153

4.1 DNA Structure pages 112 - 114

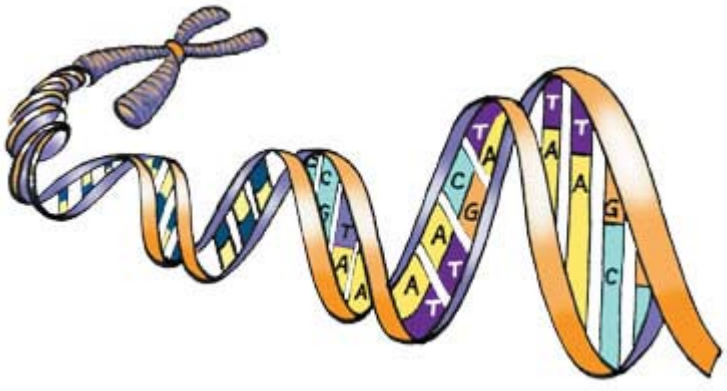
1. **DNA** stands for deoxyribonucleic acid and is the genetic material of life.
2. Researchers knew that the genetic material must be
   (1) able to store information [a] that pertains to the development [b], structure [c], and metabolic [d] activity.
   (2) stable [e] so that it can be replicated with high activity [f] during cell division [g] and can be transmitted [h] from generation to generation.

The Nature of the Genetic Material

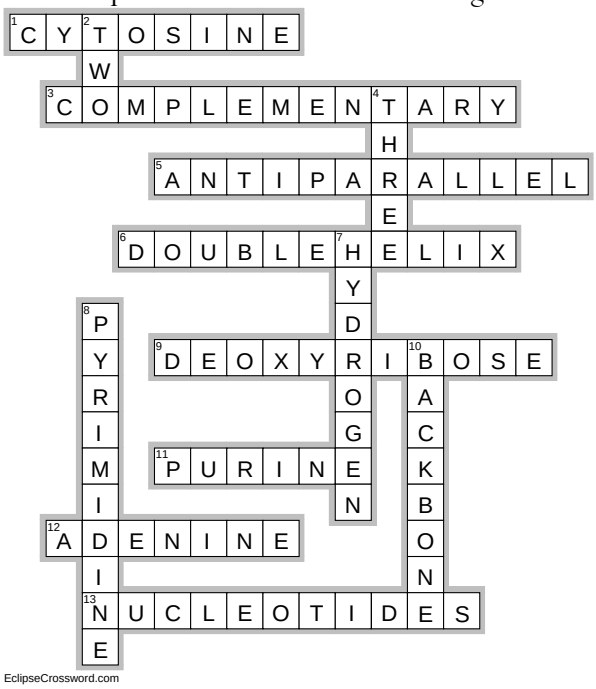
3. Contrast the *phenotype* versus *genotype* of an organism. The "phenotype" is the physical appearance of an organism while the "genotype" is the genetic makeup of that organism.
4. How are DNA, proteins, chromosomes and genes all associated? Genes are segments of DNA found on the chromosomes. Chromosomes are coiled and condensed DNA wrapped around proteins (called histones)
5. By the 1940s, there was scientific debate whether DNA or proteins were the genetic material of the cell. While DNA was proven to be the genetic material, summarize the evidence that supported proteins instead of DNA. Proteins contained 20 possible amino acids rather than only 4 nucleotides of DNA. Therefore, proteins seemed to be the more complex and more likely to contain the code of life.
6. An experiment by Alfred Hershey [a] and Martha Chase [b] in the early 1950s helped to firmly establish DNA as the genetic material of the cell.

Structure of DNA

7. James Watson [a] and Francis Crick [b] determined the structure of DNA in the early 1950s.



8. Complete the crossword below using the terms found on page 114.



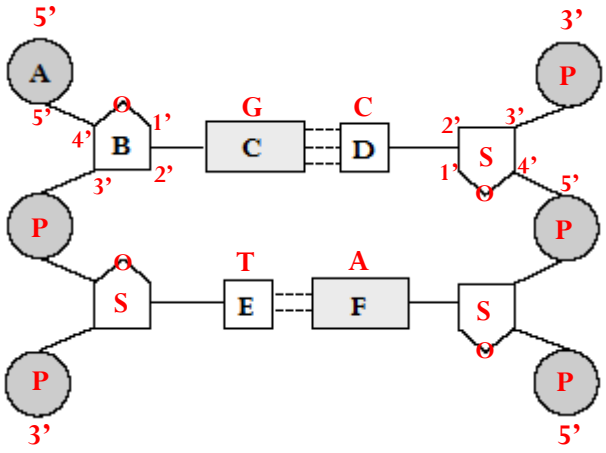
Across

1. The complementary base for guanine.
3. A purine always binds to a pyrimidine (A-T and C-G) is described as "_____ base pairing"
5. Refers to the two DNA strands being oriented in opposite directions.
6. Term used to describe the overall structure of DNA (2 words).
9. The specific type of sugar in each DNA nucleotide.
11. Nitrogen-containing base with a double ring.
12. The complementary base for thymine.
13. DNA is made of chains of these.

Down

2. A is bonded to T by ____ (#) bonds.
4. C is bonded to G by ____ (#) bonds.
7. Two strands of DNA are held to each other with ___ bonds between the nitrogenous bases.
8. Nitrogen-containing base with a single ring.
10. The phosphoric acid and pentose sugar make up the _____ of DNA.

9. Use Figure 4.3 to label the diagram below.



A phosphate

B pentose sugar (deoxyribose)

C guanine (G)

D cytosine (C)

E thymine (T)

F adenine (A)

10. In the above molecule, on one sugar molecule on each strand label the carbons as 1', 2', 3', 4' and 5'.
    a) Label each of the ends of the strands as 3' or 5'

11. Fill in the complementary strand of DNA

G	C	T	A	T	A	T	C	T	G	T	C	T	A	T	A	G	C	T	C
C	G	A	T	A	T	A	G	A	C	A	G	A	T	A	T	C	G	A	G

12. When the body grows [a] or heals [b] itself, cells divide. Each new cell requires an exact copy of the DNA contained in the chromosomes [c].

13. Match the terms with the descriptions.

B DNA polymerase	A. made in one continuous piece
E DNA helicase	B. creates the daughter strands by positioning and joining new nucleotides
C DNA ligase	C. connects fragments on lagging strand and seals any breaks in backbone
A leading strand	D. term for the short segments of DNA found on the lagging strand
F lagging strand	E. unwinds and unzips the double-stranded DNA
D Okazaki fragments	F. made of pieces that need to be bound together

14. Explain why DNA replication is said to be semiconservative. Each new strand of DNA has one old (parent) strand and one new (daughter) strand

15. Put these steps of DNA replication in order from 1 – 3.

3 Fragments of the lagging strand are bonded by the enzyme DNA ligase.

1 Hydrogen bonds between paired bases are broken by enzyme DNA helicase.

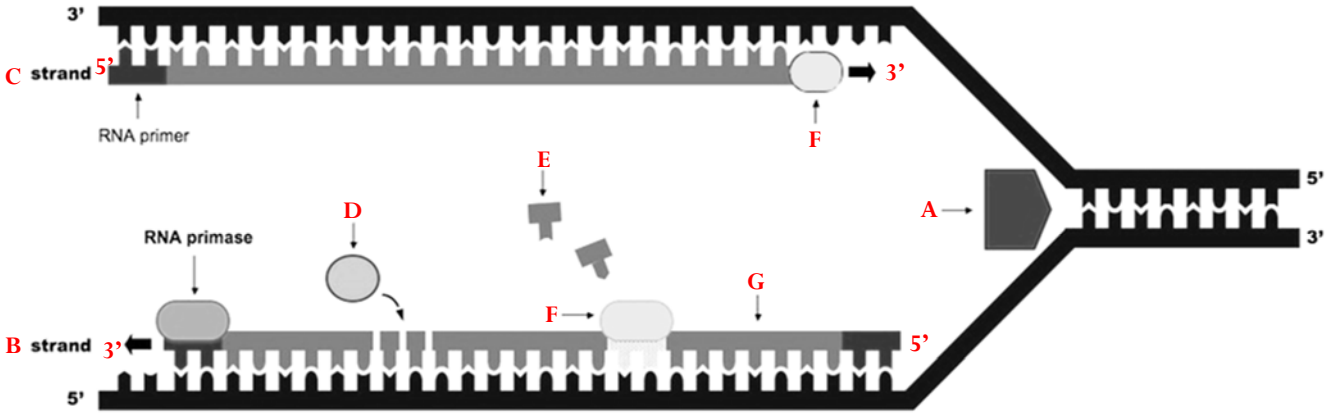
2 Daughter strands form as the enzyme DNA polymerase brings in new nucleotides.

16. Make two identical strands of DNA from the original sequence below.

T	G	C	T	G	A	T	C	G	A	T	C	G	A	T	C	A	G	T	C	(parent)
A	C	G	A	C	T	A	G	C	T	A	G	C	T	A	G	T	C	A	G	(daughter)
T	G	C	T	G	A	T	C	G	A	T	C	G	A	T	C	A	G	T	C	(daughter)
A	C	G	A	C	T	A	G	C	T	A	G	C	T	A	G	T	C	A	G	(parent)

17. Label the diagram below with the terms:

(A) DNA helicase
(B) lagging
(C) leading
(D) DNA ligase
(E) nucleotides
(F) DNA polymerase (x2)
(G) Okazaki fragments



18. The process of using a gene sequence [a] to synthesize a protein [b] is called gene expression [c].
19. Gene expression relies on several different forms of RNA. Briefly describe them below.
    a) **mRNA**: messenger RNA
        i. Role: to carry genetic information from DNA to ribosomes
    b) **tRNA**: transfer RNA
        i. Role: bring amino acids to the ribosomes for protein synthesis
    c) **rRNA**: ribosomal RNA
        i. Role: make up ribosomes (along with many proteins)
20. Give a simple definition for the two main processes of gene expression.
    a) **Transcription**: a portion of the DNA is copied by mRNA; mRNA is processed and sent out to the cytoplasm
    b) **Translation**: sequence of mRNA is "read" by ribosomes and amino acids are put together into a polypeptide

Transcription

21. What does a "gene" code for? "functional products" either RNA or proteins
22. Transcription begins when an enzyme RNA polymerase [a] binds tightly to a region of the DNA called the promoter [b]. This enzyme opens up the DNA helix so complementary base pairing can occur in the same way as in DNA replication. Then, RNA polymerase inserts RNA nucleotides [c] and an mRNA molecule [d] results.
23. Create a strand of mRNA from the DNA strand below.

G	A	T	C	G	A	T	C	G	A	T	C	A	G	T	C	T	G	C	(DNA)
C	U	A	G	C	U	A	G	C	U	A	G	U	C	A	G	A	C	G	(mRNA)

24. Describe the processing of mRNA that must occur before it can leave the nucleus. Ensure you use the terms *primary mRNA*, *mature mRNA*, *introns* and *exons*. Primary mRNA contains segments from DNA that are not coding for genes (introns). These need to be removed to leave only the portions that code for the gene (exons), giving a strand of mature mRNA.

Translation

25. The sequence of bases in DNA is transcribed into mRNA, which ultimately codes for a particular sequence of amino acids [a] to form a polypeptide [b].
26. Mathematically demonstrate how only 4 mRNA bases are able to code for 20 possible amino acids.
    a) If 1 base stood for an amino acid $4^1 = 4$
    b) If 2 bases stood for an amino acid $4^2 = 4 \times 4 = 16$
    c) If 3 bases stood for an amino acid $4^3 = 4 \times 4 \times 4 = 64$
        i. What is the term for a triplet of nucleotides? codon

27. Discuss why the genetic code is said to be degenerate. What is the benefit? Most amino acids are coded for by more than one codon. This offers protection against the possibility of harmful mutations that change the sequence of bases.

28. The universal nature of the genetic code suggests that it dates back to the very first organisms[(a)] on Earth and that all living organisms have a common evolutionary history[(b)].

29. Describe the structure of a tRNA molecule. single stranded polynucleotide that doubles back on itself into a "boot like" shape.

30. On one end of a tRNA is an amino acid[(a)] and on the other end is an anticodon[(b)], a triplet set of three bases complementary to a codon of mRNA[(c)].

31. Complete the table below using Figure 4.8 as reference. *A table like this will always be provided for quizzes and tests.*

Codon (mRNA)	Anticodon (tRNA)	Amino Acid (based on codon)
AUG	UAC	methionine (start)
CCU	GGA	proline
GAC	CUG	aspartic acid
CAG	GUC	glutamine
UGA	ACU	stop

32. Now try completing this more complex table.

DNA Sequence	Codon (mRNA)	Anticodon (tRNA)	Amino Acid
CAT	GUA	CAU	valine
ACC	UGG	ACC	tryptophan
ACT	UGA	ACU	Stop
TAA, TAG, TAT	AUU, AUC, AUA	UAA, UAG, UAU	isoleucine
AAG	UUC	AAG	phenylalanine

33. Ribosomes[(a)] are small structural bodies found in the cytoplasm and on the endoplasmic reticulum where translation also occurs. Ribosomes are composed of many proteins[(b)] and several ribosomes RNAs[(c)]. In eukaryotic cells, rRNA is produced in the nucleolus[(d)] within the nucleus. Then the rRNA joins with proteins manufactured in and imported from the cytoplasm[(e)] to form two[(f)] ribosomal subunits, one large and one small. The subunits leave the nucleus and join together in the cytoplasm to form a ribosome just as protein synthesis[(g)] begins. A ribosome has a binding site for one mRNA[(h)] and three tRNA[(i)] molecules. These binding sites facilitate complementary base paring between tRNA anticodons[(j)] and mRNA codons[(k)]. As the ribosome moves down the mRNA molecule, new tRNA molecules arrive, and a polypeptide[(l)] forms and grows longer.

34. What is the function of a **polyribosome**? Allows multiple copies of protein to be produced simultaneously (speeds up the process)

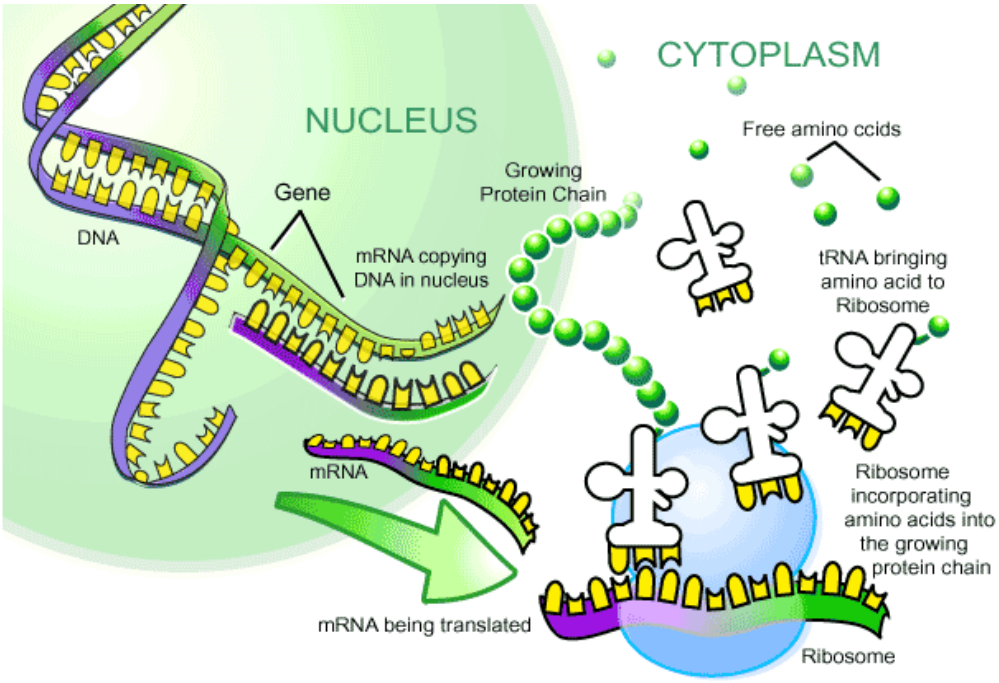
Translation Requires Three Steps

35. Step 1: INITIATION : brings all the translation components together.
    i. Small ribosomal [a] subunit attaches to the mRNA [b] in the vicinity of the start codon which is the triplet code AUG [c] (methionine)
    ii. tRNA start anticodon would therefore be UAC [d]
    iii. Large ribosomal subunit joins to the small subunit.
36. Step 2: ELONGATION : polypeptide increases in length one amino acid at a time.
    i. Amino acids [a] are linked together one at a time through formation of a peptide [b] bond. See Figure 4.13 for a more detailed explanation.
37. Step 3: TERMINATION: ribosome separates into its two subunits, and the polypeptide (protein) [a] is released
    i. 3 possible stop codons = UAA, UAG, UGA
    ii. Once the polypeptide is set free it begins to take on its three dimensional shape. The ribosome dissociates into its two subunits

Review of Gene Expression

38. The genes [a] we receive from our parents determine the proteins [a] in our cells and these proteins are responsible for our inherited traits [c].

Visualizing the Process: create a simplified version of Figure 4.15 on page 123 to display the steps of protein synthesis below.



4.4 Gene Mutations & Cancer — pages 124 - 128

40. A **gene mutation** is a permanent change [a] in the sequence of bases in DNA. The effect on protein activity can range from no effect to complete inactivity [b].
41. Distinguish between a **germ-line mutation** and a **somatic mutation**. "Germ-line" occurs in the gametes and is inherited while "somatic" occurs only in the body cells of one organism.

Causes of Mutations

42. Three causes:
    a) Errors in replication
        i. Extremely rare: DNA polymerase typically only makes one mistake for every 1 billion nucleotide pairs replicated.
    b) Mutagens
        i. Sources of radiation such as radioactive elements, X-rays, and UV radiation.
        ii. Certain organic chemicals such as cigarette smoke and pesticides
    c) Transposons (also known as "jumping genes")
        i. Specific DNA sequences that have the ability to move within and between chromosomes

Effects of Mutations on Protein Activity

43. Define **point mutation**: change in a single DNA nucleotide. May change one amino acid. (also known as a **substitution mutation**).

44. Define **frameshift mutation**: one or more nucleotides are added or removed (may change one or more amino acids) (also known as **insertion** or **deletion mutations**).

45. Complete the tables below to demonstrate various mutations.

a) Regular protein synthesis: use a codon table to determine the sequence of amino acids

DNA	A A T	T G A	A C A	C A T	G C G	C C C
mRNA	U U A	A C U	U G U	G U A	C G C	G G G
amino acids	leucine	threonine	cysteine	valine	arginine	glycine

b) Change the fifth base in the original DNA from a G to a C: determine the new sequence of amino acids

DNA	A A T	T **C** A	A C A	C A T	G C G	C C C
mRNA	U U A	A G U	U G U	G U A	C G C	G G G
amino acids	leucine	**serine**	cysteine	valine	arginine	glycine

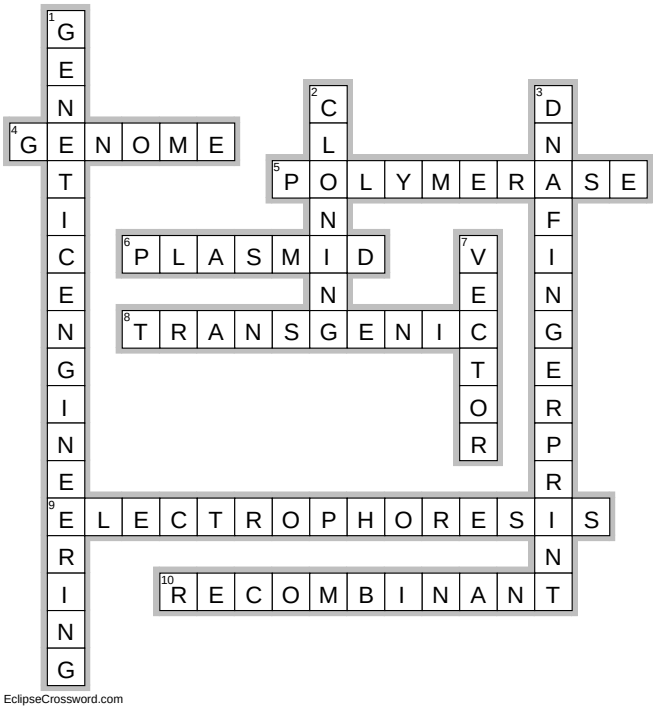
c) Add a G to the original DNA strand after the third base: determine the new sequence of amino acids

DNA	A A T	**G** T G	A A C	A C A	T G C	G C C
mRNA	U U A	C A C	U U G	U G U	A C G	C G G
amino acids	leucine	**histidine**	**leucine**	**cysteine**	**threonine**	**arginine**

46. Based on question #45, which type of mutation is likely more harmful and why? Frameshift will likely change all amino acids from the mutation point and on, BUT pointshift will only change one (or potentially none)

4.5 DNA Cloning — pages 128 - 131

47. Read through the section, then complete the crossword.



Across

4. The complete genetic makeup of an organism.
5. A _____ chain reaction (PCR) can create billions of copies of a segment of DNA in a test tube in a matter of hours.
6. One common vector used to make rDNA is a bacterial _____.
8. Organisms with foreign DNA or genes inserted into them are called _____ organisms.
9. During a process called gel _____, an electrical current is used to force DNA through a porous gel.
10. _____ DNA (rDNA) contains DNA from two or more different sources.

Down

1. Cloning genes and using them to alter the genome of viruses and cells (2 words).
2. Production of identical copies an organism.
3. A pattern of distinctive DNA bands (2 words).
7. Term for a piece of DNA that researchers can manipulate and add foreign DNA to.

4.6 Biotechnology Products and Gene Therapy — pages 131 - 134

48. Transgenic organisms (bacteria, plants, and animals) are often called genetically modified organisms (GMOs) and the products they produce are called biotechnology products.
49. Name several uses for…
    a) Transgenic bacteria
        i. create products such as insulin, human growth hormone, hepB vaccine
        ii. protect plants from frost, insects
        iii. aid in environmental cleanup by eating oil, removing sulfur from coal
    b) Transgenic plants
        i. dual purpose plants such as the pomato
        ii. create plants that are resistant to insects (pests) and herbicides
        iii. to increase crop yield
        iv. engineered to produce human proteins such as hormones, clotting factors, antibodies
    c) Transgenic animals
        i. many types of animal eggs have acquired the gene for bovine growth hormone to make larger fishes, cows, pigs, rabbits and sheep
        ii. Gene pharming, the use of transgenic farm animals to produce pharmaceuticals
        iii. Genes that code for theraputic and diagnostic proteins that will appear in the animal's milk.
        iv. Studying a gene's function by eliminating a gene and can be used to test new drugs for the treatment of the disease.

4.7 Genomics, Proteomics, and Bioinformatics — pages 134 - 137

50. Define **genomics**: study of complete genetic sequence of humans and other organisms

Sequencing the Genome

51. Describe the "Human Genome Project" and its importance, or benefit, to humanity. "Mapping" the base sequence (3.2 billion) and genes (25000) of humans. It took 13 years to complete and opened many possibilities for biomedical research and treatment such as screening for diseases. Identified small regions that vary among individuals which may affect phenotypes and potentially affect their susceptibility to disease and their response to medical treatements.

Chapter 4 Review Questions — pages 148 - 153

1. B
2. A
3. C
4. C
5. A
6. B
7. A
8. B
9. A
10. A
11. C
12. B
13. B
14. A *
15. C
16. A *
17. C
18. A *
19. A
20. B
21. D
22. C
23. D
24. B
25. D
26. A
27. A
32. D
34. A
36. B
37. D
38. C
39. B
42. C

* key is wrong for the above questions

43. base sequence, amino acid, 3° structure of protein, protein function, expression of trait.

44. (a) I (b) II, III, IV (c) I (d) all (e) I
(f) I (g) II (h) III (i) IV (j) all

45. Complete the table

	DNA	RNA
Subunit	nucleotide	nucleotide
Sugar	deoxyribose	ribose
Nitrogenous bases	A, T, G, C	A, U, G, C
# of strands	2	1
Base pairings	A-T and G-C	A-U and G-C
Process that produces this nucleic acid	replication	transcription

46. Semi-conservative replication

47. DNA polymerase, helicase, ligase

48. Parent DNA is unzipped by helicase, polymerase adds new nucleotides to leading and lagging daughter strands, ligase binds any breaks in the backbone of the lagging strand

49. Nucleus

50. (a) purine nitrogenous base (b) pyrimidine nitrogenous base
(c) deoxyribose sugar (d) phosphate group

51. RNA, ATP

52. RNA has a ribose sugar instead of a deoxyribose like DNA

53. Hydrogen bonds; covalent bonds

54. 2-3-4 or 1-3-4

55. (amino acids) iso – seri – arg – asp.acid – pro – threo - phenyl
(mRNA) AUU – AGU – CGU – GAU – CCU – ACU – UUU
(DNA) TAA – TCG – GCA – CTA – GGA – TGA – AAA
Because there is more than one codon for each amino acid, of course there is more than one right answer

56. Gene mutation

57. As the primary sequence is altered, the overall 3D tertiary shape may be changed which would alter the shape and therefore the function of the protein

58. A different sequences means a different protein. Red blood cells won't be able to efficiently carry O_2

59. Protects them against malaria so it has an advantage or benefit for those people

60. Higher number as those individuals have an evolutionary advantage that helps them survive.

61. Frameshift (specifically a deletion) mutation

62. First amino acid is changed and it will be missing the

65. Complete the table

DNA	GCA	ATG	TCA	GTT
mRNA	CGU	UAC	AGU	CAA
tRNA	GCA	AUG	UCA	GUU
Amino acid	arginine	tyrosine	serine	glutamine

66. High level of accuracy. Reduces the changes of errors occurring which could result in harmful mutations

67. GCA → CGU (arginine) but ACA → UGU (cysteine) which changes the first amino acid!

68. Will change the whole 3D shape

69. $4^3 = 4x4x4 = 64$ codons

72. Complete the table

Species W: amino acids	valine	threonine	glycine	histidine
Species Z: mRNA sequence	GUU	AGC	GCA	CAU

These codes could vary as there is more than one possibility for the amino acids

74. W & Y

76. CAU → GUG valine. Still codes for the same amino acid

79. Could alter or fix genetic disorders; manipulate genes to change an organism's characteristics

80. May cause other portions to be accidentally altered if the splicing enzyme wasn't so specific

81. Some would argue that it's like "playing God", human population increases make it hard to support with enough food, etc.

84. Restriction enzyme and gel electrophoresis

86. C as it shares the highest number of marks.

Mark the review questions using the answer key on pages 530 - 532