Name(s): _____ Team Name: _____
_____ Team Number: _____

Captains Test:
Designer Genes
2020
(Division C)

- **You have 50 minutes in which to complete this test.**
- **All answers—both multiple choice and free response—must be recorded on your separate answer packet. No credit will be awarded for any work shown or answers written in the test packet.**
- **For multiple choice questions, simply write the CAPITAL LETTER that corresponds to your answer choice on the appropriate line on your separate answer packet.**
- **For questions involving calculations, show all necessary work in the space provided on your separate answer packet.**
- **The number of points awarded for each question or set of questions may be found in brackets at the end of each question or directions for a set of questions in this test packet.**

Total Score: _____/100

Part I: Mendel & Inheritance Patterns

1) Which of the following is not a correct statement regarding Gregor Mendel's model of heredity? [1].

a) Alternative versions of genes account for variations in inherited characters.
b) If the two alleles at a locus differ, then one determines the organism's appearance; the other has no noticeable effect on the organism's appearance.
c) Many characters of organisms are not one of two discrete characters, but instead vary in the population in gradations along a continuum.
d) The two alleles for a heritable character segregate during gamete formation and end up in different gametes.
e) For each character, an organism inherits two copies of a gene, one from each parent.

2) Which of the following is not a correct statement regarding the testcross? [1].

a) The testcross was devised by Mendel and continues to be used by geneticists.
b) A testcross can reveal the genotype of a resultant organism.
c) The offspring of a testcross will be expected to have a 1:1 phenotypic ratio.
d) A testcross involves breeding an organism of unknown genotype with a recessive homozygote.
e) The need for a testcross arises due to the identical phenotypes of homozygous and heterozygous genotypes.

In questions 3-10, match each scenario described to one of the following genetic terms. Each term may be used more than once.

Complete Dominance
Incomplete Dominance
Codominance
Epistasis
Pleiotropy
Polygenetic Inheritance

3) The main factor in determination of skin color is the pigment melanin that affects much of the skin phenotype. Skin color darkens as the presence of melanin increases. The amount of melanin that is produced is the result of loci on several genes. [1].

4) The ABO blood group is a set of blood antigens with a separate locus that controls the production of these antigens. [1].

5) The human MN blood group is determined by the alleles for the M and N molecules. A single locus, at which two allelic variations are possible. Both M and N phenotypes are exhibited by heterozygotes. [1].

6) In Mendel's pea crosses, the F_1 offspring always looked like one of the two parental varieties. [1].

7) The Rh factor is a type of protein on the surface of red blood cells. It involves three different pairs of alleles located on three different loci on chromosome pair #1. [1].

8) A father with naturally straight hair and a mother with naturally curled hair have a daughter with naturally wavy hair. [1].

9) The expression of a single mutated HBB gene produces both sickle-cell disease symptoms and a degree of resistance to malaria. [1].

10) One gene affects the phenotype of another because the two gene products interact. [1].

For questions 11-15, refer to the following Punnett Square:

a	I^A	I^B
I^A	*b*	*c*
i	*d*	*e*

11) The Punnett square represents which of the following genetic systems? [1].

a) Flower color for pea plants.
b) Classification of human blood based on antigens.
c) Human sex determination.
d) Genetic inheritance of polydactyly.
e) Round versus wrinkled pea seed shape.

12) In the genetic system you identified above, there are ___ possible alleles and ___ possible phenotypes. [1].

a) 2, 4
b) 2, 2
c) 3, 3
d) 3, 4
e) 4, 4

13) In the genetic system you identified above, there are ___ possible genotypes. [1].

a) 2
b) 3
c) 4
d) 5
e) 6

14) Which of the following correctly completes Square (*e*)? [1].

a) I^AI^B
b) I^BI^B
c) I^Ai
d) I^Bi
e) *ii*

15) Which of the following represents the phenotype for Square (*d*)? [1].

a) A group.
b) B group.
c) AB group.
d) O group.
e) *i* group.

For Questions 16-20, consider the following scenario[1]:

You are doing a genetics experiment with the fruit fly. In the "P" generation, you cross two true-breeding flies. The female parent is brown and wingless and the male parent is black with normal wings. All of the flies in the F1 generation are brown and have normal wings. Indicate the alleles associated with dominant phenotypes by uppercase letters and alleles associated with recessive phenotypes by lowercase letters. Assume the genes are not found on a sex chromosome. Indicate the color alleles as "B" and "b" the wing alleles by the letters "N" and "n".

16) The genotypes of the flies in the P generation are _____ female and _____ male. [1].

a) BBnn; bbNN
b) bbnn; BBNN
c) BBNN; bbnn
d) BbNn; BbNn
e) BbNN; BBNn

17) The genotype of the flies in the F_1 generation is _____. [1].

a) BBnn
b) bbnn
c) BBNN
d) BbNn
e) BbNN

18) Cross a true-breeding black, wingless male with an F_1 female. You count 1600 offspring in the F2 generation. If the wing and the color traits were linked and no recombination occurred, you would expect to count which of the following combinations? [1].

---

[1]Adapted from: Eric Lander, Robert Weinberg, Tyler Jacks, Hazel Sive, Graham Walker, Sallie Chisholm, and Michelle Mischke. *7.01SC Fundamentals of Biology.* Fall 2011. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu.

	BbNn	Bbnn	bbNn	bbnn
a)	400	400	400	400
b)	200	600	600	200
c)	0	800	800	0
d)	1600	0	0	0
e)	0	0	0	1600

19) When you count the F2 generation, you really get:

→ 85 brown winged flies
→ 728 black winged flies
→ 712 brown wingless flies
→ 75 black wingless flies

What must be the genetic distance between the color and wing genes? [1].

a) 5 cM
b) 10 cM
c) 15 cM
d) 20 cM
e) 25 cM

20) A series of fruit fly matings shows that the recombination frequency between the gene for wing size and the gene for antenna length is 5% (i.e. the genetic distance between them is 5 centimorgans). Which of the following correctly lists all of the possible genetic distances between the gene for color and the gene for antenna length? [1].

a) 5 cM
b) 5 cM, 10 cM
c) 5 cM, 10cM, 15 cM
d) 5 cM, 15 cM
e) 15 cM

Part II: Meiosis & Mitosis

21) Which of the following occurs at the conclusion of meiosis I? [1].

a) Homologous chromosomes are separated.
b) Four daughter cells are formed.
c) The sperm cells elongate to form a head end and a tail end.
d) Sister chromatids are separated.
e) The chromosome number per cell is conserved.

22) In eukaryotic cells, chromosomes are composed of which of the following? [1].

a) DNA and RNA.
b) DNA and proteins.
c) DNA only.
d) DNA and phospholipid A.
e) RNA and proteins.

23) When the centromeres of all the duplicated chromosomes are on a plane midway between the spindle's two poles, what is the name of this plane? [1].

a) Cleavage furrow
b) Kinetochore plane
c) Metaphase plate
d) Aster
e) Cell plate

24) Which of the following correctly describes a difference between mitosis and meiosis? [1].

a) Mitosis consists of 4 stages in total, while meiosis consists of 5 stages in total.
b) Meiosis increases genetic variation while mitosis decreases genetic variation.
c) Meiosis decreases genetic variation while mitosis increases genetic variation.
d) In meiosis, the chromosome number remains the same, while, in mitosis, the chromosome number is halved in each daughter cell.
e) In mitosis, the chromosome number remains the same, while, in meiosis, the chromosome number is halved in each daughter cell.

In questions 25-29, match the description/definition given to one of the following phases of meiosis' prophase I. Each term may be used more than once.

Diakinesis
Diplotene
Leptotene
Pachytene
Zygotene

25) Chromosomes start to condense. [1].

26) Homologous chromosomes become closely associated to form bivalents consisting of four chromatids (tetrads). [1].

27) Crossing over between pairs of homologous chromosomes forms chiasmata. [1].

28) Homologous chromosomes start to separate but remain attached by chiasmata. [1].

29) Homologous chromosomes continue to separate. Chiasmata move to the ends of the chromosomes. [1].

30) Which of the following statements gives the best evidence for the hypothesis that mitosis evolved from simpler prokaryotic mechanisms of cell reproduction? [1].

a) Mitochondria and chloroplasts within animal cells contain their own DNA similar to prokaryotic DNA.
b) The fossil record illustrates a mitotic process in the Pre-Cambrian period.
c) Some of the proteins involved in bacterial binary fission are related to eukaryotic proteins that function in mitosis.
d) Scientists have observed mitotic cell division in cloned cells of extinct species.
e) Some of the proteins created by modern eukaryotic gene transcription and translation mimic those in simpler prokaryotic cells.

31) Crossing over during meiosis is best attributed to which of the following Mendelian laws? [1].

a) The law of segregation.
b) The law of independent assortment.
c) The law of multiplication.
d) The law of addition.
e) The law of alleles.

32) Crossing over produces _____, or individual chromosomes that carry DNA from two different parents. [1].

a) Random chromosomes
b) Haploid chromosomes
c) Diploid chromosomes
d) Homologous chromosomes
e) Recombinant chromosomes

33) Which of the following is not a correct statement regarding nondisjunction? [1].

a) The members of a pair of homologous chromosomes may not move apart properly during meiosis I.
b) Sister chromatids may fail to separate during meiosis II.

c) One gamete receives two of the same type of chromosome and another gamete receives no copy.
d) Nondisjunction occurs during meiosis, but not during mitosis.
e) Chromosomes not in the homologous pair directly affected are distributed normally.

Part III: DNA & Gene Expression

34) What gives the DNA double helix its uniform shape? [1].

a) All of its components are nitrogenous bases.
b) Two of its bases are purines, while two of its bases are pyrimidines.
c) A purine is always paired with a pyrimidine.
d) Helicase winds the DNA double helix until it is in a uniform shape.
e) Trick question—DNA's double helix does not have a uniform shape.

35) Which of the following correctly pairs a model of DNA replication with its description? [1].

a) Conservative model ⇒ The two strands of the parental molecule separate, and each functions as a template for synthesis of a new, complementary strand.
b) Conservative model ⇒ The two parental strands reassociate after acting as templates for new strands, reforming the parental double helix.
c) Conservative model ⇒ each strand of both daughter molecules contains a mixture of old and newly-synthesized DNA.
d) Dispersive model ⇒ The two parental strands reassociate after acting as templates for new strands, reforming the parental double helix.
e) Dispersive model ⇒ The two strands of the parental molecule separate, and each functions as a template for synthesis of a new, complementary strand.

36) Which of the following is a correct comparison of replication of chromosomal DNA in bacteria and eukaryotes? [1].

a) Bacterial and eukaryotic chromosomal replication extends in both directions from a single origin of replication.
b) Eukaryotic DNA replication proceeds in both directions from an origin of replication, but bacterial chromosomal replication runs in only one direction.
c) In eukaryotes, proteins initiate DNA replication, but, in bacteria, DNA replication occurs spontaneously.
d) Origins of replication on both bacterial and eukaryotic chromosomes are stretches of methylated DNA.
e) In contrast to a bacterial chromosome, a eukaryotic chromosome may have up to a few thousand replication origins to speed up copying of very long DNA molecules.

37) Which of the following is not a correct statement regarding the telomere of eukaryotic chromosomal DNA molecules? [1].

a) Telomeres contain genes that consist of multiple repetitions of one short nucleotide sequence that codes for a stop codon.
b) Specific proteins associated with telomeres DNA prevent the staggered ends of the daughter molecule from activating the cell's systems for monitoring DNA damage.

c) Telomeres DNA acts as a buffer zone that provides protection against the organism's genes shortening.
d) Telomeres become shorter during every round of replication.
e) Normal shortening of telomeres may protect organisms from cancer by limiting the number of divisions that somatic cells can undergo.

38) The term *mosaicism* refers to which of the following scenarios? [1].
a) The creation of a medieval church artwork.
b) The random and independent selection of which X chromosome will form the Barr body.
c) The evolution of an X-linked recessive disorder.
d) The development of a new family of genetic diseases due to a random mutation.
e) The independent assortment of chromosomes.

In questions 39-46, match the description/definition given to one of the following enzymes involved in gene transcription and translation. Each term may be used more than once.

DNA ligase
DNA polymerase I
DNA polymerase III
Helicase
Nuclease
Primase
Telomerase
Topoisomerase

39) This enzyme catalyzes a lengthening process, using self-contained RNA as a template to artificially extend the leading strand, allowing the lagging strand to maintain a given length. [1].

40) This DNA-cutting enzyme excises a segment of an incorrectly-paired nucleotide strand and that will be filled in via DNA polymerase and DNA ligase. [1].

41) This enzyme joins Okazaki fragments of the lagging strand and, on the leading strand, joins the 3' end of DNA that replaces the primer to the rest of the leading strand's RNA. [1].

42) This enzyme uses parental DNA as a template to synthesize a new DNA strand by adding nucleotides to an RNA primer or a pre-existing DNA strand. [1].

43) This enzyme unwinds the parental double helix at replication forks. [1].

44) This enzyme removes RNA nucleotides of the primer from the 5' end and replaces them with DNA nucleotides added to the 3' end of an adjacent fragment. [1].

45) This enzyme relieves overwinding strain ahead of replication forks by breaking, swiveling, and rejoining DNA strands. [1].

46) This enzyme synthesizes an RNA primer at the 5' end of the leading strand and at the 5' end of each Okazaki fragment of the lagging strand. [1].

47) In which of the following actions does RNA polymerase differ from DNA polymerase? [1].

a) RNA polymerase can initiate RNA synthesis, but DNA polymerase requires a primer to initiate DNA synthesis.
b) RNA polymerase binds to ssRNA, but DNA polymerase binds to dsRNA.
c) RNA polymerase uses RNA as a template, but DNA polymerase uses DNA as a template.
d) RNA polymerase is much more accurate than DNA polymerase.
e) RNA polymerase does not need to separate the two strands of DNA in order to synthesize an RNA copy, whereas DNA polymerase must unwind the double helix before it can replicate the DNA.

48) As a result of a deleterious mutation, a protein's stabilizing interactions are destroyed, but the protein still functions until it reaches a stability threshold. After this point, further mutations have large effects that prevent proper protein folding. This process leads to which of the following genetic processes? [1].

a) Positive epistasis.
b) Negative epistasis.
c) Sanger sequencing.
d) Transcription.
e) Replication.

49) Which of the following would be the most likely human body systems affected by defects by proteins coded for in extranuclear genes? [1].

a) Nervous system, muscular system
b) Nervous system, digestive system
c) Endocrine system, digestive system
d) Endocrine system, skeletal system
e) Endocrine system, excretory system

50) Approximately how many amino acids comprise a histone, the protein responsible for the first level of DNA packing in chromatin? [1].

a) 25
b) 50
c) 75
d) 100
e) 125

51) More than _____ of a histone's amino acids are positively charged (Lys or Arg) and therefore bind tightly to the negatively-charged DNA. [1].

a) ⅛
b) ⅕
c) ¼
d) ⅓
e) ½

52) Which of the following true statements goes against the central dogma, as explained by Francis Crick in 1956? [1].

a) Genes program protein synthesis via genetic messages in the form of mRNA.
b) Cells are governed by a molecular chain of command with a directional flow of genetic information.
c) In eukaryotic cells, the nucleus provides a separate compartment for transcription.
d) Some enzymes use RNA molecules as templates for DNA synthesis.
e) The basic mechanisms of transcription and translation are similar for bacteria and eukaryotes.

53) Which of the following statements correctly describes a benefit of the bacterial lack of a nuclear membrane? [1].

a) Translation of an mRNA can begin while its transcription is still in progress.
b) Without a membrane, the mutation rate in bacterial DNA is very low.
c) Bacterial cells can produce a primary transcript, while eukaryotic cells cannot.
d) A TATA box can form because it does not have to pass through a nuclear membrane.
e) Transcription of an mRNA can begin while its translation is still in progress.

54) Which of the following statements is a true statement regarding the termination of transcription? [1].

a) Both bacteria and eukaryotes have transcription proceed through a terminator sequence in the DNA.
b) In eukaryotes, RNA polymerase II transcribes the polyadenylation signal sequence.
c) After a bacterial transcript is released, it requires further modification via helicase.
d) In eukaryotes, enzymes start to degrade an RNA transcript starting at its 3’ end.
e) The polyadenylation signal sequence is AAAAAA.

55) Which of the following statements is not a similarity between the 5’ cap and the poly-A tail? [1].

a) They seem to facilitate the export of mature mRNA from the nucleus.
b) They protect mRNA from degradation by hydrolytic enzymes.
c) They help ribosomes attach to the 5’ end of mRNA once mRNA reaches the cytoplasm.
d) The alteration of mRNA ends produce an mRNA molecule ready for translation.
e) As they alter their respective ends of mRNA, they facilitate RNA splicing.

56) Which of the following statements regarding exon shuffling is incorrect? [1].

a) This process is facilitated by the presence of introns in a gene.

b) Introns increase the probability of crossing over between the exons of alleles of a gene.
c) By providing new protein products, exon shuffling is considered, on the whole, a beneficial process.
d) This process might result in new confirmations of exons and proteins with altered structure and function.
e) This process might result in the mixing and matching of exons between completely different genes.

57) The rules for base pairing between the third nucleotide base of a codon and the corresponding base of a tRNA anticodon are relaxed compared to those at other codon positions. This flexible base pairing is known as… [1].
a) Bending.
b) Wobble.
c) Genetic drift.
d) Synonymous shift.
e) tRNA flexibility.

58) Which component is not directly involved in translation?
a) tRNA
b) GTP
c) Ribosomes
d) DNA
e) mRNA

59) What is the term for a sequence of nucleotides that reads the same in both directions? [1]
a) Mirror nucleotides.
b) Congruent genes.
c) Even repeats.
d) Barr bodies.
e) Palindromic repeats.

60) Rough estimates about the rate of DNA mutation is both *E. coli* and eukaryotes suggest that about one nucleotide in every _____ is altered, and that change is passed on to the next generation of cells. [1].
a) 10^6
b) 10^8
c) 10^{10}
d) 10^{12}
e) 10^{14}

In questions 61-64, match the description/definition given to one of the following types of mutations. Each term may be used more than once.

Frameshift mutation *Nonsense mutation*
Missense mutation *Silent mutation*

61) A change in a nucleotide pair transforms one codon into another that is translated into the same amino acid. [1].

62) A point mutation changes a codon for an amino acid into a stop codon. [1].

63) A substitution changes a codon for one amino acid into a codon for another amino acid. [1].

64) The number of nucleotides inserted or deleted is not a multiple of 3. [1].

65) Which of the following statements regarding regulatory genes is correct? [1].

a) Regulatory genes are expressed continuously, although at a low rate.
b) At homeostasis, no repressor molecules are present in a given system. The regulatory genes have not directed the production of any.
c) Regulatory genes can produce a repressor protein that functions with the operators of multiple different operons.
d) Regulatory genes are often at the 3' end of the gene they regulate.
e) In prokaryotes, most regulatory genes are positive (they produce proteins that turn "on" functions).

66) Histone acetylation tends to _____ transcription, while histone methylation tends to _____ transcription. [1].

a) Promote; promote
b) Reduce; reduce
c) Promote; reduce
d) Reduce; promote
e) Reduce; have no effect on

67) Which of the following statements about the *trp* operon is incorrect? [1].

a) The *trp* operon is one of many operons in the *E*. coli genome.
b) The *trp* operon is a repressible operon.
c) The *trp* operon is an inducible operon.
d) The *trp* repressor is an allosteric protein, with an active shape and an inactive shape.
e) The *trpR* gene is located some distance from the *trp* operon and has its own promoter.

68) Which of the following statements about the *lac* operon is correct? [1].

a) The *lac* operon is a repressible operon.

b) The repressor for the *lac* operon is allolactose, an isomer of lactose that forms from small amounts of lactose that enter a cell.
c) Without the *lac* repressor bound, the *lac* operon is transcribed into mRNA, and the enzymes for using lactose are made.
d) A specific small molecule, the inducer, activates the repressor.
e) Regulation of the *lac* operon involves the positive control of genes.

69) Which of the following statements about miRNAs is correct? [1].
a) The miRNA-protein complex degrades the target RNA or blocks its translation.
b) miRNAs are small, double-stranded RNA molecules.
c) The miRNA allows an miRNA-protein complex to bind to any mRNA molecule.
d) There are approximately 500 genes for miRNAs in the human genome.
e) At least ¾ of all human genes may be regulated by miRNAs.

70) Which of the following statements about siRNAs is incorrect? [1].
a) If siRNA precursor molecules are injected into a cell, the cell's machinery can process them into siRNAs that turn on expression of genes with related sequences.
b) The blocking of gene expression by siRNAs is RNA interference.
c) RNAi is used in the laboratory as a means of disabling genes via siRNAs.
d) Both miRNAs and siRNAs can associate with the same proteins.
e) siRNA precursors are RNA molecules that are mostly double-stranded.

71) Which of the following is not a correct comparison of heterochromatin and euchromatin? [1].
a) Heterochromatin is a tightly packed form of DNA, while euchromatin is an uncoiled form of chromatin.
b) Heterochromatin is late replication, while euchromatin is early replicative.
c) Heterochromatin is found in eukaryotes only, while euchromatin is found in both eukaryotes and prokaryotes.
d) Heterochromatin is genetically inactive, while euchromatin is genetically active.
e) Heterochromatin contains fewer DNA molecules than euchromatin.

Part IV: Genetic Diseases & Disorders

72) Which of the following fields of genetics may explain why one identical twin acquires a genetically-based disease but the other does not? [1].

a) Mendelian genetics.
b) Watson and Crick genetics.
c) Chromatography.
d) Epigenetic inheritance.
e) Pleiotropic inheritance.

73) *The _____ chromosome creates an easily recognizable, much shortened chromosome 22 to cause cancer by creating a newly-fused gene.* Which of the following cities correctly fills in the blank? [1].

a) Pittsburgh
b) Philadelphia
c) Boston
d) Buffalo
e) Detroit

74) Which of the following statements about Patau Syndrome is correct? [1].

a) Patau Syndrome is the result of monosomy 13.
b) Most infants with Patau Syndrome are viable but may require transplant surgery.
c) One potential symptom of Patau Syndrome is cleft palate.
d) Patau Syndrome affects the neurological system but not the cardiovascular system.
e) The physical symptoms of mosaic Patau Syndrome are often more severe than those of full Patau Syndrome.

75) Which of the following statements about Edwards Syndrome is incorrect? [1].

a) Edwards Syndrome is the result of trisomy 18.
b) 5-10% of children with this disease live past their first year.
c) Mosaic Edwards Syndrome occurs as a random event during cell division early in embryonic development.
d) Another name for this disease is trisomy E.
e) Most cases of Edwards Syndrome are inherited from the maternal genome.

76) Which of the following genetic disorders results from mutations in the *FGFR1* or *FGFR2* genes? [1].

a) Tay-Sachs disease
b) Ichthyosis
c) Cooley's anemia
d) Pfeiffer syndrome

e) Hemophilia

77) Because two genes (*BRCA1* and *BRCA2*) have recently been identified as inherited in an autosomal dominant fashion and linked to an increased susceptibility to breast cancer, breast cancer can be considered the result of… [1].

a) X-linked inheritance.
b) Y-linked inheritance.
c) Multifactorial inheritance.
d) Gamete formation.
e) Recessive inheritance.

Part V: Biotechnology

78) In November 2018, the biophysicist He Jiankui of the University of China in Shenzhen announced that his team had used CRISPR technology to disable the CCR5 gene in two babies born that month. Why did Jiankui choose to target the CCR5 gene? [1].

a) People with delta-32 in this gene are immune to the common cold.
b) People with delta-32 in this gene have a 32-DNA letter addition on the CCR5 gene that causes cancer.
c) People with delta-32 in this gene have a 32-DNA letter deletion that provides HIV resistance.
d) People with a mutation in the CCR5 gene are unlikely to survive beyond the age of 6 months.
e) The CCR5 gene is the gene that the Chinese government required him to disable.

79) Affinity chromatography is widely used in Ig purification and in the purification of recombinant proteins. Which of the following amino acid "tags" is most often added to the end of a desired recombinant protein via genetic engineering to allow it to bind to a Ni column and thus be separated out of solution? [1].

a) Lys4
b) Lys6
c) Arg4
d) His4
e) His6

80) Which of the following is not currently a limit of modern DNA microarray technology? [1].

a) Limited dynamic range of measurement.
b) Relatively expensive procedure.
c) Relatively low sensitivity of scanning instruments.
d) Limited intensity of fluorescent dyes.
e) Potential for non-specific hybridization.

Part VI: Free-Response—Genetics and Evolution

81) Hardy-Weinberg equilibrium, named after the British and German scientists who independently published this idea in 1908, is the state of a population in which frequencies of alleles and genotypes remain constant from generation to generation. It requires thinking of Punnett squares as representative of the combination of alleles in all the crosses in a population. It is common for natural populations to be in Hardy-Weinberg equilibrium for specific genes.

To quantify the relationship between two possible alleles in a population, p and q, they developed the following equation: $p^2 + 2pq + q^2 = 1$.

a) It has been determined that there are five (5) environmental conditions that must exist for a population to be in Hardy-Weinberg equilibrium. Name each of the 5 conditions in the space provided on your answer sheet. [2 pts. per correct answer, for a possible total of 10 points].
b) For each of the conditions you have named above, describe the consequence(s) if the condition does not hold in the space provided on your answer sheet. [2 pts. per correct answer, for a possible total of 10 points].

NB: This question will also be used as a tiebreaker if necessary. Thus, is the same score is achieved on the whole of the test, the test with the higher score on this free-response section will receive the higher ranking.