Benchmark Test Review

4 Genetics

Use the information below to review the correct answers on the Chapter Test.

1. A two-factor cross with independent assortment will yield a phenotype ratio of about 9:3:3:1 if a large number of offspring are analyzed. Since these are traits with dominant and recessive alleles, the phenotypes will not have equal frequencies, but the dominant phenotype will not be observed in all offspring since they can receive two recessive alleles and express the recessive phenotype. It is unlikely that any cross will yield exactly 9 + 3 + 3 + 1 offspring.

2. If the traits are not independent, the two dominant traits will always appear together, and the two recessive traits will always appear together. If they are independent, the offspring can express the dominant phenotype for one trait and the recessive phenotype for the other trait. In a situation where there is both a dominant and a recessive allele for a trait, there will not be an intermediate phenotype in heterozygotes.

3. In the F_1 generation the recessive trait is masked by the dominant trait, but since gametes are produced that carry only the recessive trait, the recessive phenotype can be expressed in the F_2 generation. Incomplete dominance would not result in a true recessive phenotype, and mutations and chromosomal location do not explain this result.

4. Mendel concluded from his crosses that offspring inherit a copy of a gene from each parent. In sexual reproduction, offspring do not normally inherit two copies from one parent, and offspring do not inherit one copy of every possible allele.

5. When two phenotypes appear blended in the same cells, this is incomplete dominance. In codominance, different phenotypes are expressed in different cells.

6. This is an example of maternal inheritance, which is observed with traits expressed by chloroplast or mitochondrial genes. Chloroplasts and mitochondria are inherited maternally. In this case, leaf color is expressed through the chloroplasts. Maternal inheritance has no meaning in asexual reproduction. The term *dominant trait* does not mean that this trait is the only trait that can be passed to offspring.

7. Homologous chromosomes are not identical, since one came from the paternal gamete and the other from the maternal gamete, and they can carry different alleles. During meiosis, homologous chromosomes pair up, and they may exchange genetic material. Also, the homologous chromosomes will assort

into different cells, such that the resulting gametes will have a mix of paternal and maternal chromosomes. DNA replication occurs before meiosis begins.

8. The genes located farthest apart on a chromosome are most likely to have cross-overs occur between them. A cross-over between two alleles causes the alleles to assort independently as if they were on separate chromosomes. Genes that are closer together are less likely to assort independently. Whether the gene affects appearance or where in the body it is expressed has no effect on how it is inherited.

9. The viruses shown were used in the Hershey-Chase experiment. The sulfur-35-labeled proteins never entered the bacteria, whereas the phosphorus-32-labeled proteins did enter the bacteria, showing that DNA is the genetic material. Franklin's X-ray diffraction work did not use viruses or bacteria.

10. Avery heat-killed bacteria, which prevents them from causing disease in mice. However, extracts from these bacteria transformed harmless bacteria into disease-causing bacteria. Avery then treated the extracts with enzymes to destroy either the protein, lipids, carbohydrates, RNA, or DNA. Only the extracts with the DNA still intact could transform bacteria, showing that DNA was the genetic material. Avery was not trying to prevent infections. Heat killing or enzyme treatment do not cause mutations.

11. Chargaff's rule states that DNA has the same amount of adenine (A) as thymine (T), and the same amount of guanine (G) as cytosine (C). The structure of DNA is double stranded, so the bases are always paired such that A pairs with T and G pairs with C. Base pairing explains why the amount of A equals the amount of T, and G equals C. A does not equal G. Base pairing explains how genetic information is conserved during DNA replication. All four bases appear on both strands.

12. Scientists understood the chemical makeup of DNA before Franklin's work. Her X-ray diffraction located the bases in the center of the molecule and showed the helical structure, but did not show that the strands are antiparallel.

13. In prokaryotes, there is a single starting point for DNA replication, but in eukaryotes, there are multiple starting points. In both prokaryotes and eukaryotes, both strands are replicated, and replication proceeds in both directions from the starting points. Prokaryotes do not have telomeres.

14. Both strands of the double-stranded DNA molecule are replicated by DNA polymerase, which synthesizes new strands that are complementary to each of the original strands. Each of the new strands remains paired with the original strand, so each of the two resulting DNA molecules has a new strand and an original strand. The entire chromosome is replicated, not just the parts that code for proteins. Both strands of every chromosome are replicated in each cell cycle.

15. DNA polymerase joins nucleotides together to form a new strand of DNA. Other enzymes "unzip" the double-stranded DNA template. Telomerase, not polymerase, replicates the telomeres, and although DNA polymerase

“proofreads” the newly synthesized strand, it does not correct preexisting errors that arise from mutagens.

16. In a gene, each group of three consecutive nucleotides forms a codon and specifies one of 20 amino acids, or a “stop.” One amino acid is specified by only one codon, but the other amino acids are specified by two to six codons. There are three stop codons. The genetic code is universal, shared across prokaryotes and eukaryotes with only a few exceptions.

17. DNA is transcribed into mRNA. The codons of the mRNA are “read” by the ribosome, pairing the anticodon of the tRNA with the complementary codon and using the amino acid carried by the tRNA to form a peptide chain. Ribosomes do not read DNA, and tRNA does not come from mRNA.

18. In a gene, each group of three consecutive nucleotides forms a codon and specifies one of 20 amino acids, or a “stop.” All 64 possible codons have meaning. One amino acid is specified by only one codon, but the other amino acids are specified by two to six codons. There are three stop codons. The genetic code is universal, shared across prokaryotes and eukaryotes with only a few exceptions.

19. The anticodon is a three-nucleotide segment of tRNA that is complementary to and pairs with a codon in mRNA. The anticodon is complementary to the codon that specifies the amino acid carried by the tRNA. The anticodon does not block either transcription or translation, and it does not bind to DNA.

20. The protein products of the *lac* operon enable the bacteria to use lactose for energy, if lactose is present. The proteins do not provide energy unless lactose is present. The cell has to expend energy to produce these proteins, so in the absence of lactose, there is no reason for bacteria to produce these proteins, although they would not do any harm to the bacteria. In this case, regulation serves primarily to turn off transcription of the operon. Removal of the repressor allows transcription.

21. Cells must transcribe certain genes to carry out specialized functions. A heart cell does not need to transcribe genes only needed by liver cells. All cells in an organism contain the same genes and tRNAs. Genes are not eliminated. Cells do regulate genes due to environmental changes such as changing nutrient availability, but this does not change the specialized functions of cells such as heart cells, liver cells, skin cells, etc.

22. Transcription factors are proteins that bind to DNA to prevent or allow transcription of a gene. Transcription factors bind DNA in response to changing conditions in the cells. Epigenetic mechanisms involve chemically modifying the DNA of a gene, preventing the expression of a gene or genes. Unlike transcription factors, these chemical modifications persist over long periods of time such as throughout the development of an organism. Both transcription factors and epigenetic mechanisms can affect one gene or multiple genes, and they are important at all stages of development.

23. Changing a single base in a gene may or may not change the amino acid that is specified, since multiple codons can specify the same amino acid. A single base change can also result in a stop codon, which can drastically shorten the protein produced. Inserting a single nucleotide will change the reading frame for all subsequent codons, such that many of the subsequent amino acids in the protein will be changed.

24. Mutations, regardless of how they arise, can be harmful, be beneficial, or have no effect on a cell. A mutation will only be passed on to offspring if the mutation is present in the gametes. If the mutation increases the chance that offspring will survive and reproduce, then it can be beneficial to that species. Changes in chromosome number are usually harmful in animals, although in plants increases in chromosome number can be beneficial.

25. The filled-in circles and squares show which people have red hair. In order to have red hair, the genotype must be *rr,* so this is a recessive trait. Other family members can carry one copy of the *r* allele, but they will not have red hair. If the trait were sex-linked, it would appear in males only, or females only. There is no evidence in this pedigree that multiple alleles are required. There is no evidence that red hair appeared due to a mutation, which is unlikely as it appears in two different generations that do not have a parent-child relationship.

26. A karyotype is an image of all chromosomes in a cell. It is useful for determining whether the expected number of chromosomes is present, and for detecting large-scale changes (mutations) in chromosomes. A human diploid cell (a cell that is not a gamete), normally has 46 chromosomes. This includes 22 pairs of autosomal chromosomes and 1 pair of sex chromosomes.

27. The phenotype of a recessive allele will not be observed if a dominant allele is also present. Therefore, a recessive phenotype can be observed if it is on a sex chromosome in a male. Since males have only one X chromosome and one Y chromosome, there cannot be a second copy of a gene on a sex chromosome. Colorblindness is caused by a recessive allele on the X chromosome, so a male will be colorblind if he has this allele. A female will only be colorblind if she has two copies of the allele. X-chromosome inactivation occurs in females only, and can result in a recessive allele being expressed if the dominant allele is on the inactivated chromosome.

28. A karyotype is an image of all chromosomes in a cell. It is useful for determining whether the expected number of chromosomes is present, and for detecting large-scale changes (mutations) in chromosomes. An extra copy of a chromosome may be present if nondisjunction occurs during meiosis, in which case one daughter cell will receive both copies of a homologous chromosome pair instead of just one member of the pair. Having an extra copy of a chromosome can be fatal or cause disorders such as Down syndrome. A karyotype cannot detect small-scale changes in genes or chromosomes, such as a change in a few base pairs, a point mutation in a gene, or most repeated sequences.

29. Sickle cell disease is caused by a recessive allele, so people will only have the disease if they have two copies of the sickle cell allele. However, persons with one copy of the sickle cell allele are healthy and are also resistant to acquiring the disease malaria. Therefore, inheriting two copies of the allele is extremely disadvantageous, but inheriting one copy is advantageous if living in an area where there is a risk of malaria. Mosquitoes carry the parasite that causes malaria but do not have sickle cell disease, which cannot be passed between individuals. Sickle cell trait has no effect on typhoid, and does not increase the number of offspring.

30. Although the overwhelming majority of the human genome is identical in all people, people have unique genomes due to the many different alleles and mutations present. If a person has alleles that increase his or her risk for disease, others may use this information to discriminate against him or her. There is little reason for someone to publish another person's genome online, and that information would be difficult to use to create a clone given current technology.

31. Farmers have used hybridization, crossing different types of plants and animals, for thousands of years in order to combine the best features of dissimilar individuals. Polymerase chain reaction, recombinant plasmids, and CRISPR are all recent technologies that have arisen in the last 50 years as a result of biotechnology.

32. A recombinant plasmid must contain a start signal for DNA replication in order for it to persist as the bacteria grow and divide. It must also contain a selectable marker, such as a gene for antibiotic resistance, so that by growing the bacteria in the presence of the antibiotic, only bacteria with the plasmid can survive. The plasmid does not have to carry sequences complementary to the host genome, and Cas9 is only needed for the CRISPR gene-editing procedure.

33. Option 3 describes the CRISPR technique. Polyploidy is an increase in the number of chromosomes in a cell, not a change in gene sequence. Option 2 describes polymerase chain reaction. Option 4 describes cloning.

34. Animals are cloned by fusing a cell from an animal with an egg cell from the same species that has had its nucleus removed (enucleated). Injecting plasmids, or editing genes with CRISPR, will not create a clone. Polymerase chain reaction is used to copy pieces of DNA, not entire organisms.

35. Many restriction enzymes cut DNA so that one strand is longer than the other. These are called "sticky ends" since the longer strand is available to pair with another DNA strand with complementary bases. Therefore, two DNA fragments cut with the same restriction enzyme will have complementary sticky ends, and can pair with each other. DNA ligase can be used to join such complementary fragments into a single DNA molecule. Restriction enzymes can also be used to cut DNA for analysis on gels, but this is not a critical step in producing recombinant DNA. Restriction enzymes do not generally cause mutations in DNA. DNA can be cut in such a way that genes are removed, but

removing a gene is not necessary to the formation of all recombinant DNA molecules.

36. DNA fingerprinting for crime uses DNA isolated from suspects or crime scenes. The DNA is double stranded, not single stranded. The DNA is cut into fragments, and the fragments are separated by gel electrophoresis and labeled with probes. Microarray plates are not used, and the probes are not specific for expressed genes. The pattern of fragments is unique to each individual due to differences in genomes.

37. The pattern of fragments observed in DNA fingerprinting is unique to each individual, and can thus be used to identify living or deceased individuals. Also, the patterns in related individuals will be more similar than the patterns in unrelated individuals. Likewise, DNA fingerprinting can be used to identify the species of an animal. DNA fingerprinting cannot be used to identify personality traits or predict what career would be best for a person.

38. Genetically modified plants are beneficial because they help to sustain the large population on our planet. However, the seeds of GM plants can be expensive to buy for small farmers. It is not possible for plants to transfer plant diseases to humans, and there are many safeguards in place to ensure that chemical residues do not enter the food supply. Also, corporations cannot patent naturally occurring plant genes.

39. Radiation can damage DNA, leading to mutations. A beneficial mutation may lead to increased food production. Radiation can also kill bacteria, but this is unlikely to be beneficial as bacteria are still present in the environment. Radiation does not cause all things to grow larger or increase gene transcription, unless it causes a mutation that has that effect.

40. Polyploidy is usually fatal in animals. However, it often results in larger and stronger plants.

41. A karyotype is an image of all the chromosomes in a cell. A normal cell has 46 chromosomes; 22 pairs of autosomes, and 1 pair of sex chromosomes. If a karyotype has 47 chromosomes, and an extra on the 21st pair, the diagnosis is Down syndrome. This child will have developmental delays. This error was caused by nondisjunction of the 21st chromosome during meiosis of either parent.

42. Using biotechnology, scientists are able to clone certain organisms such as sheep or bacteria. Scientists are also able to insert genes into plants and animals, such as a glowing gene into a fish, or an insecticidal gene into a plant. They can easily identify the parents of an individual using gel electrophoresis and DNA fingerprinting, but the technology does not yet exist that could give entire chromosomes to an individual.