Level 1: Knowledge/Comprehension Questions

1. A couple has six children, all daughters. If the woman has a seventh child, what is the probability that the seventh child will be a daughter?

   (A) 1/2
   (B) 1/2
   (C) 1/36
   (D) 1/49
   (E) 1/2

2. If alleles R and S are on two different chromosomes, and the probability of gamete R segregating into a gamete is 1/4, while the probability of allele S segregating into a gamete is 1/3, what is the probability that both will segregate into the same gamete?

   (A) 1/12
   (B) 1/4
   (C) 1/3
   (D) 1/1
   (E) 1/2

3. In llamas, coat color is controlled by a gene that exists in two allelic forms. If a homozygous yellow llama is crossed with a homozygous brown llama, the offspring have gray coats. If two of the gray-coated offspring were crossed, what percentage of their offspring would have brown coats?

   (A) 100%
   (B) 75%
   (C) 50%
   (D) 25%
   (E) 0%

4. Which of the following is NOT true of meiosis?

   (A) During metaphase, spindle microtubules first come into contact with chromosomes.
   (B) The chromosome number in the newly formed cells is half that of the parent cell.
   (C) The homologous chromosomes line up along the metaphase plate, or equator, of the cell.
   (D) The cytoplasm of the cell and all its organelles are divided approximately in half.
   (E) In anaphase II, the sister chromatids travel to opposite ends of the cell.

5. In rabbits, the trait for short hair (S) is dominant, and the trait for long hair (s) is recessive. The trait for green eyes (G) is dominant, and the trait for blue eyes (g) is recessive. A cross between two rabbits produces a litter of six short-haired rabbits with green eyes, and two short-haired rabbits with blue eyes. What is the most likely genotype of the parent rabbits in this cross?

   (A) ssgg x sgg
   (B) SSGG x SGG
   (C) SsGg x SsGg
   (D) SsGg x SSGg
   (E) sGGG x sGG

6. In humans, hemophilia is an X-linked recessive trait. If a man and a woman have a son who is affected with hemophilia, which of the following is definitely true?

   (A) The mother carries an allele for hemophilia.
   (B) The father carries an allele for hemophilia.
   (C) The father is afflicted with hemophilia.
   (D) Both parents carry an allele for hemophilia.
   (E) The boy's paternal grandfather has hemophilia.

7. Which of the following explains a significantly low rate of crossing over between two genes?

   (A) They are located far apart on the same chromosome.
   (B) They are located on separate but homologous chromosomes.
   (C) The genes code for proteins that have similar functions.
   (D) The genes code for proteins that have very different functions.
   (E) The genes are located very close together on the same chromosome.
8. In the pedigree above, circles represent females and squares represent males; those who express a particular trait are shaded, whereas those who do not are not shaded. Which pattern of inheritance best describes the pedigree for this trait?
(A) X-linked recessive
(B) X-linked dominant
(C) autosomal recessive
(D) autosomal dominant
(E) codominant

Questions 9–10 refer to an individual with type O blood, whose mother has type A blood.

9. The father must have which of the following blood types?
(A) A, B, or O
(B) AB or A
(C) AB or B
(D) AB only
(E) O only

10. If the type O individual were to mate with a person with type AB blood, which of the following is the best calculation of the ratio of the offspring?
(A) 3 A:i:1 B:i
(B) 2 A:i:1 B:i
(C) A:i:2 B:i
(D) 1 A:i:2 B:i:1 B:i
(E) 9 A:i:3 B:i:3 B:i:1 O

11. Two yellow mice with the genotype Yy are mated. After many offspring, 1/3 are yellow and 1/3 are not yellow (a 2:1 ratio). Mendelian genetics dictates that this cross should produce offspring that were 1/4 YY (yellow), 1/2 Yy (yellow), and 1/4 yy (not yellow). What is the most likely conclusion from this experiment?
(A) The mice did not bear enough offspring for the ratio calculation to be specific.
(B) y is lethal in the homozygous form and caused death early in development.
(C) Nondisjunction occurred.
(D) A mutation masked the effects of the Y allele.
(E) A mutation masked the effects of the y allele.

12. All of the following contribute to genetic recombination EXCEPT
(A) random fertilization.
(B) independent assortment.
(C) crossing over.
(D) gene linkage.
(E) random gene mutation.

13. In cucumbers, warty (W) is dominant over dull (w), and green (G) is dominant over orange (g). A cucumber plant that is homozygous for warty and green is crossed with one that is homozygous for dull and orange. The F₁ generation is then crossed. If a total of 144 offspring is produced in the F₂ generation, which of the following is the closest to the number of dull green cucumbers expected?
(A) 3
(B) 10
(C) 28
(D) 80
(E) 111

14. The restoration of the diploid chromosome number after halving in meiosis is due to
(A) synapsis.
(B) fertilization.
(C) mitosis.
(D) DNA replication.
(E) chiasmata.
15. During the first meiotic division (meiosis I),
   (A) homologous chromosomes separate.
   (B) the chromosome number becomes haploid.
   (C) crossing over between nonsister chromatids occurs.
   (D) paternal and maternal chromosomes assort randomly.
   (E) all of the above occur.

16. A cell with a diploid number of 6 could produce gametes with how many different combinations of maternal and paternal chromosomes?
   (A) 6  
   (B) 8  
   (C) 12  
   (D) 64  
   (E) 128

17. The DNA content of a diploid cell is measured in the G1 phase. After meiosis I, the DNA content of one of the two cells produced would be
   (A) equal to that of the G1 cell.
   (B) twice that of the G1 cell.
   (C) one-half that of the G1 cell.
   (D) one-fourth that of the G1 cell.
   (E) impossible to estimate due to independent assortment of homologous chromosomes.

18. A synaptonemal complex would be found during
   (A) prophase I of meiosis.
   (B) fertilization or syngamy of gametes.
   (C) metaphase II of meiosis.
   (D) prophase of mitosis.
   (E) anaphase I of meiosis.

19. Meiosis II is similar to mitosis because
   (A) sister chromatids separate.
   (B) homologous chromosomes separate.
   (C) DNA replication precedes the division.
   (D) they both take the same amount of time.
   (E) haploid cells are produced.

20. Which of the following is NOT true of homologous chromosomes?
   (A) They behave independently in mitosis.
   (B) They synapse during the S phase of meiosis.
   (C) They travel together to the metaphase plate in prometaphase of meiosis I.
   (D) Each parent contributes one set of homologous chromosomes to an offspring.
   (E) Crossing over between nonsister chromatids of homologous chromosomes is indicated by the presence of chiasmata.

21. Given the following recombination frequencies, what is the correct order of the genes on the chromosome? A-B, 8 map units; A-C, 28 map units; A-D, 25 map units; B-C, 20 map units; B-D 33 map units
   (A) A-B-C-D
   (B) D-C-A-B
   (C) A-D-C-B
   (D) B-A-C-D
   (E) D-A-B-C

22. X-linked conditions are more common in men than in women because
   (A) men acquire two copies of the defective gene during fertilization.
   (B) men need to inherit only one copy of the recessive allele for the condition to be fully expressed.
   (C) women simply do not develop the disease regardless of their genetic composition.
   (D) the sex chromosomes are more active in men than in women.
   (E) the genes associated with the X-linked conditions are linked to the X chromosome, which determines maleness.
Level 2: Application/Analysis/Synthesis Questions

1. A black guinea pig crossed with an albino guinea pig produces 12 black offspring. When the albino is crossed with a second black one, 7 blacks and 5 albinos are obtained. What is the best explanation for this genetic situation? Write genotypes for the parents, gametes, and offspring.

2. In pea plants, pod color may be green (G) or yellow (g), while the pod shape may be inflated (I) or constricted (i). Two pea plants heterozygous for the characters of pod color and pod shape are crossed. Draw a Punnett square to determine the phenotypic ratios of the offspring.

3. In some plants, a true-breeding, red-flowered strain gives all pink flowers when crossed with a white-flowered strain: \( C^R C^R \) (red) \( \times C^W C^W \) (white) \( \rightarrow C^R C^W \) (pink). The placement of the flower can be determined by the dominant allele for an axial flower (A), while a terminal flower is determined by the recessive allele (a). What will be the phenotypic ratio of the F₁ generation resulting from the following cross: axial-red (both genes are homozygous) \( \times \) terminal white? What will the phenotypic ratio be in the F₂?
4. If these four cells resulted from cell division of a single cell with diploid chromosome number \(2n = 4\), what best describes what just occurred?

(A) normal meiosis  
(B) translocation  
(C) inversion  
(D) nondisjunction

5. As a genetic counselor, you would explain to the parents that

(A) the eggs must have been accidentally switched, since the baby's blood type has to match one of his parents.  
(B) each parent could have contributed one recessive allele, resulting in type O blood.  
(C) the eggs must have been accidentally switched, since a type A parent and a type B parent can have any type children except O.  
(D) it is possible for the baby to have type O blood, since type O is inherited through a dominant allele.

6. In regard to the baby's color blindness, a sex-linked recessive trait, you explain that

(A) color blindness often appears randomly, even if neither parent is color-blind.  
(B) the baby's father must have a recessive allele for color blindness.  
(C) since color blindness is sex-linked, a son can inherit color blindness if his mother has the recessive color blindness allele.  
(D) the eggs must have been accidentally switched, since males inherit sex-linked traits only from their fathers.

7. Independent orientation of chromosomes at metaphase I results in an increase in the number of

(A) gametes.  
(B) homologous chromosomes.  
(C) possible combinations of characteristics.  
(D) sex chromosomes.
Homeotic genes are master regulatory genes that control placement and spatial organization of body parts by controlling the developmental fate of groups of cells. A homeobox is a widely conserved 180-nucleotide sequence found within homeotic genes. When we say that a sequence is widely conserved, this means that it is found in many groups (e.g., fungi, animals, and plants) with very few differences. This hints at the relatedness and common evolution of all life-forms.

Level 1: Knowledge/Comprehension Questions

1. Which of the following is NOT a potential control mechanism for regulation of gene expression in eukaryotic organisms?
   (A) the degradation of RNA
   (B) the transport of mRNA from the nucleus
   (C) the lactose operon
   (D) transcription
   (E) gene amplification

2. Which of the following exists as DNA surrounded by a protein coat?
   (A) retrovirus
   (B) virus
   (C) eukaryotic cell
   (D) prokaryotic cell
   (E) ampicillin

3. A goat can produce milk containing the same polymers present in the silk produced by spiders when particular genes from a spider are inserted into the goat's genome. Which of the following reasons describes why this is possible?
   (A) Goats and spiders share a common ancestor and, thus, produce similar protein excretions.
   (B) The opposite is true, too—when genes from a goat are inserted into a spider's genome, the spider produces goats' milk instead of silk.
   (C) The proteins in goats' milk and spiders' silk have the same amino acid sequence.
   (D) The processes of transcription and translation in the cells of spiders and goats are fundamentally similar.
   (E) The processes of transcription and translation in the cells of spiders and goats produce exactly the same proteins anyway.

4. Restriction enzymes are generally used in the laboratory for which of the following reasons?
   (A) restricting the replication of DNA
   (B) restricting the transcription of DNA
   (C) restricting the translation of mRNA
   (D) cutting DNA molecules at specific locations
   (E) cutting DNA into manageable sizes for manipulation

Directions: The group of questions below consists of five lettered choices followed by a list of numbered phrases or sentences. For each numbered phrase or sentence, select the one choice that is most closely related to it. Each choice may be used once, more than once, or not at all.

Questions 5-9

   (A) Transcription
   (B) Translation
   (C) Transposon
   (D) DNA methylation
   (E) Histone acetylation

5. A mobile segment of DNA that travels from one location on a chromosome to another, one element of genetic change

6. The addition of groups to certain bases of DNA after DNA synthesis; this is thought to be an important control mechanism for gene expression

7. The synthesis of polypeptides from the genetic information coded in mRNA
8. The synthesis of RNA from a DNA template

9. The attachment of groups to particular amino acids of specific proteins; this is thought to be an important control mechanism for gene expression

10. The figure below shows which of the following processes?
(A) the lytic cycle of a phage
(B) the lysogenic cycle of a phage
(C) transposition
(D) retrovirus infection
(E) mutualism

11. The actions of which of the following enzymes are responsible for ensuring that chromosomes do not decrease in length with every round of replication?
(A) telomerase
(B) DNA ligase
(C) DNA polymerase
(D) helicase
(E) primase

12. PCR (polymerase chain reaction) allows target segments of DNA to be produced quickly because it enables lab technicians to do which of the following?
(A) Isolate gene-source DNA.
(B) Insert DNA into an appropriate vector.
(C) Introduce the cloning vector into a host cell.
(D) Amplify DNA samples.
(E) Identify clones carrying the gene of interest.
Questions 13–14 refer to an experiment that was performed to separate DNA fragments from three samples radioactively labeled with ³²P. The fragments were then separated using gel electrophoresis. The visualized bands are depicted below:

![Diagram of gel electrophoresis with bands labeled as longer and shorter molecules.]

13. When the electric field was applied, the fragments of DNA in each of the three samples migrated to different locations along the gel because
   (A) the fragments differed in their levels of radioactivity.
   (B) the fragments differed in their charges—some were positively charged, whereas others were negatively charged.
   (C) the fragments differed in size.
   (D) the fragments differed in polarity.
   (E) the fragments differed in solubility.

14. How many sites on DNA were cut by the particular restriction enzyme used in Sample 1 (the leftmost sample)?
   (A) 5
   (B) 6
   (C) 7
   (D) 8
   (E) 9

16. RNA viruses require their own supply of certain enzymes because
   (A) host cells rapidly destroy the viruses.
   (B) host cells lack enzymes that can replicate the viral genome.
   (C) these enzymes translate viral mRNA into proteins.
   (D) these enzymes penetrate host cell membranes.
   (E) these enzymes cannot be made in host cells.

17. In genetic engineering, DNA ligase is used for which of the following purposes?
   (A) to act as a probe for locating cloned genes
   (B) to create breaks in DNA in order to allow foreign DNA fragments to be inserted
   (C) to seal up nicks created in newly created recombinant DNA
   (D) to ensure that “sticky ends” of like DNA fragments do not re-anneal
   (E) in Southern blotting

Directions: The group of questions below consists of five lettered choices followed by a list of numbered phrases or sentences. For each numbered phrase or sentence, select the one choice that is most closely related to it. Each choice may be used once, more than once, or not at all.

Questions 18–22
   (A) tRNA
   (B) mRNA
   (C) Poly-A tail
   (D) RNA polymerase
   (E) rRNA

18. An example of a post-transcriptional modification

19. Binds to the promoter on DNA to initiate transcription

20. Along with proteins, comprises ribosomes

21. Binds to free amino acids in the cytoplasm
22. Travels out of the nucleus and into the cytoplasm, where it serves as a template in translation.

23. The expression of eukaryotic genes can be controlled at all the following stages of protein synthesis EXCEPT:
(A) initiation of transcription.
(B) RNA processing.
(C) DNA unpacking.
(D) degradation of protein.
(E) acetylation of DNA.

24. After eukaryotic transcription takes place, mRNA undergoes several modifications before leaving the nucleus to take part in translation. One of these is the cutting out of nonessential sections of mRNA and the subsequent splicing together of stretches of mRNA necessary for the final functional molecule. Which of the following mRNA sections are spliced together into the finished mRNA molecule?
(A) introns
(B) exons
(C) genes
(D) coding sequences
(E) ribozymes

26. Which of the following is an example of a missense mutation?
(A) A nucleotide and its partner are replaced with an "incorrect" pair of nucleotides, which destroys the function of the final protein.
(B) A nucleotide pair is added into a gene, destroying the reading frame of the genetic message.
(C) A nucleotide pair is lost from the gene, destroying the reading frame of the genetic message.
(D) A frameshift mutation occurs, ultimately causing the production of nonfunctional proteins.
(E) A nucleotide pair substitution occurs, which causes the codon to code for an amino acid that may not be the "correct" one, although translation continues.

27. In analyzing the number of different bases in a DNA sample, which result would be consistent with the base-pairing rules?
(A) A = G
(B) A + G = C + T
(C) A + T = G + T
(D) A = C
(E) G = T

28. At the end of DNA replication, each of the daughter molecules has one old strand, derived from the parent strand of DNA, and one strand that is newly synthesized. This explains why DNA replication is described as
(A) conservative.
(B) largely conservative.
(C) nonconservative.
(D) semiconservative.
(E) unconservative.
29. The segment of DNA shown below has restriction sites I and II, which create restriction fragments a, b, and c. Which of the following gels produced by electrophoresis would represent the separation and identity of these fragments?

30. Which of the following is a difficulty in getting prokaryotic cells to express eukaryotic genes?
   (A) The signals that control gene expression are different and prokaryotic promoter regions must be added to the vector.
   (B) The genetic code differs because prokaryotes substitute the base uracil for thymine.
   (C) Prokaryotic cells cannot transcribe introns because their genes do not have them.
   (D) The ribosomes of prokaryotes are not large enough to handle long eukaryotic genes.
   (E) The RNA splicing enzymes of bacteria work differently from those of eukaryotes.

31. One of the characteristics of retrotransposons is that
   (A) they code for an enzyme that synthesizes DNA using an RNA template.
   (B) they are found only in animal cells.
   (C) they generally move by a cut-and-paste mechanism.
   (D) they contribute a significant portion of the genetic variability seen within a population of gametes.
   (E) their amplification is dependent on a retrovirus.

32. You have affixed the chromosomes from a cell onto a microscope slide. Which of the following would NOT make a good radioactively labeled probe to help map a particular gene to one of those chromosomes? (Assume DNA of chromosomes and probes is single-stranded.)
   (A) cDNA made from the mRNA transcribed from the gene
   (B) a portion of the amino acid sequence of that protein
   (C) mRNA transcribed from the gene
   (D) a piece of the restriction fragment on which the gene is located
   (E) a sequence of nucleotide bases determined from the genetic code needed to produce a known sequence of amino acids found in the protein product of the gene

33. The human genome appears to have only one-third more genes than the simple nematode, *C. elegans*. Which of the following best explains how the more complex humans can have relatively few genes?
   (A) The unusually long introns in human genes are involved in regulation of gene expression.
   (B) More than one polypeptide can be produced from a gene by alternative splicing.
   (C) Human genes code for many more types of domains.
   (D) The human genome has a high proportion of noncoding DNA.
   (E) The large number of SNPs (single nucleotide polymorphisms) in the human genome provides for a great deal of genetic variability.