Exploring the World of Science

University of Michigan Science Olympiad
2021 Invitational Tournament

Designer Genes C

Test length: 50 Minutes

Team name: KEY

Student names: KEY

2021 Designer Genes Exam

Short Answer

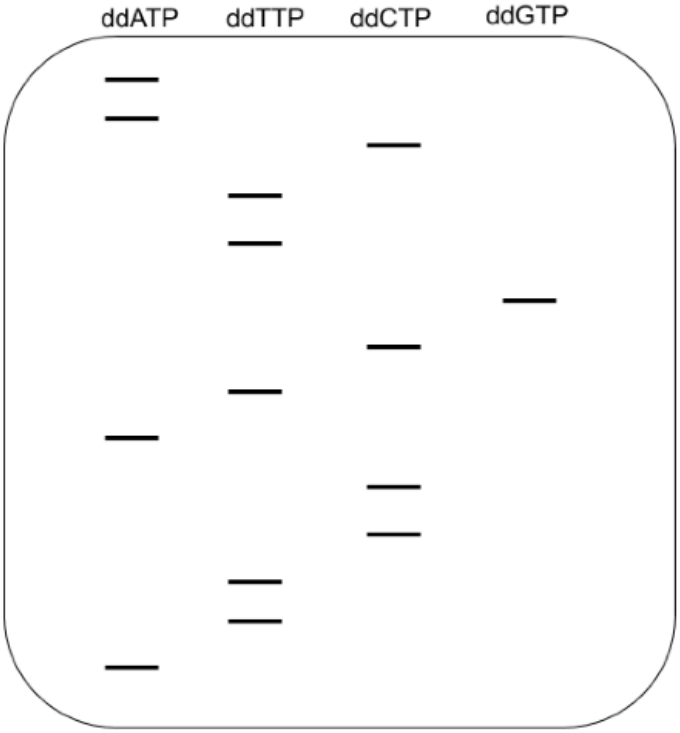
1. Explain how the origin of replication differs between eukaryotes and prokaryotes. (1 pt)

Eukaryotes have multiple origins of replication and prokaryotes have one.

2. A point mutation occurs, changing the third base pair in a codon. The resulting amino acid is tryptophan. What was the wildtype amino acid? (1 pt)

Cysteine. It cannot be the STOP codon because the STOP codon does not code for an amino acid.

3.



What is the 5' -> 3' nucleotide sequence for this strand of DNA?

ATTCCATCGTTCAA

4. You are cloning a gene into *E. coli*. On the plasmid you want to insert, you also include an antibiotic resistance gene. How will you grow only the bacteria that have the desired plasmid? (1 pt)

You grow the bacteria on LB agar/a petri dish containing the antibiotic, so that only resistant bacteria grow.

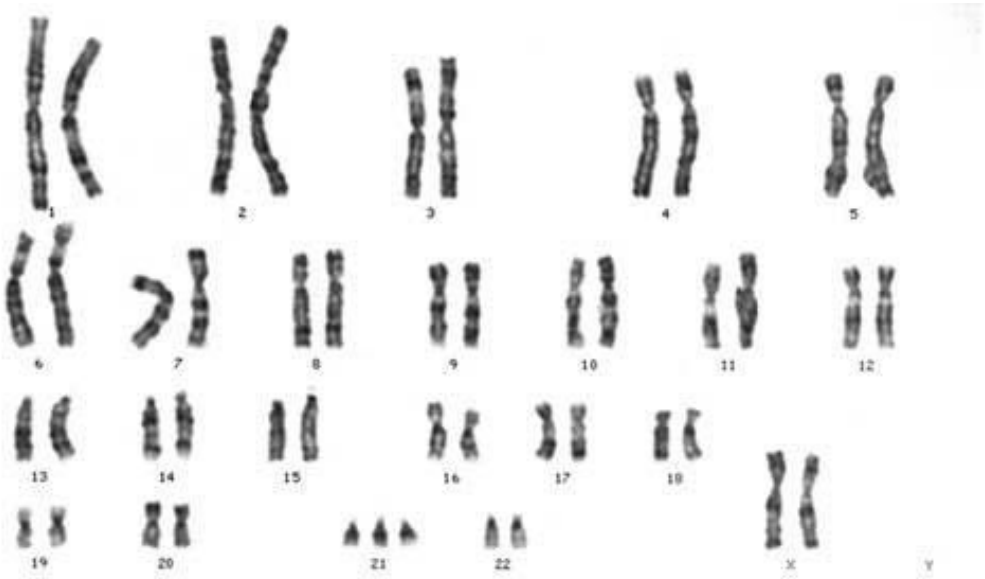
5. [Tie-breaker] “For mitochondrial genes, the phenotype of the offspring is always the same as the phenotype of the mother, but for X-linked genes the phenotype of the offspring can be different than that of the mother.” Is this true? Why or why not? (2 pt)

Yes. Explanation must include:
The mitochondria are only inherited from the mother.

Either: The X-linked gene carried by the mother could be a recessive allele and thus not expressed. Or: In females, one X chromosome is inherited from the father so one allele is not from the mother.

Must include explanations for both the mitochondrial genes and X-linked genes.

6. What genetic condition does this person have? (1 pt)



Down’s Syndrome

7. Explain what is incorrect about this sentence: “In eukaryotes, enhancers are short fragments of DNA that can bind with proteins to promote the expression of genes that are nearby.” (1 pt)

Enhancers can promote genes that are either nearby or far away.

8. The gene for hairlessness is epistatic to the gene for hair color. What does it mean to be epistatic? (1 pt)

The effects of one gene (hairlessness) masks the effects of another gene (hair color).

9. Name two differences in structure between DNA and RNA. (2 pt)

Must include two of these : RNA is single stranded, DNA is double stranded. RNA has ribose, DNA has deoxyribose. RNA has Uracil, DNA has Thymine.

10. Order these steps in the correct order of translation: (1 pt)

I. Addition of amino acids one by one by tRNAs
II. The ribosome dissociates.
III. mRNA enters the cytoplasm
IV. mRNA becomes associated with rRNA
V. tRNA anticodons base pair with mRNA codons
VI. The ribosome hits a stop codon.

III, IV, V, I, VI, II

11. In DNA fingerprinting, after the DNA sample has been cut into fragments by restriction enzymes, name the method used to separate these fragments by size. (1 pt)

DNA/Gel electrophoresis

12. A scientist attempts to clone a gene into *E. coli*. First, he isolates the desired gene from the original organism. Then, he cuts the DNA at a specific point using a restriction enzyme. Then, he cuts a plasmid at a specific point using a different restriction enzyme. The plasmid he uses contains an antibiotic resistance gene. He adds the plasmid to *E. coli*. Why doesn't his experiment work? (1 pt)

He added two different restriction enzymes.

13. In the Polymerase Chain Reaction, what extends the primers? (1 pt)

Taq polymerase

14. In the Polymerase Chain Reaction, what is the purpose of denaturation and does it occur at a low or high temperature? (2 pt)

Denaturation separates the DNA strands. It occurs at a high temperature.

15. What is the purpose of the poly-A tail added to mRNA?

The poly-A tail protects mRNA from degradation as it exits the nucleus.

<u>Multiple Choice</u>

1. In dragonflies, the allele for fragile wings (W) is dominant lethal. The allele for strong wings (w) is recessive. You find a dragonfly with fragile wings that has survived into adulthood. What is most likely its genotype? (1 pt)

a. ww
b. Ww
c. WW
d. b or c
e. a or b

2. Continuing from question 1, in dragonflies, the allele for fragile wings (W) is dominant lethal. The allele for strong wings (w) is recessive. Two heterozygous dragonflies (Ww) mate and produce offspring. What is the probability that their surviving offspring display the dominant phenotype? (1 pt)

a. 3/4
b. 1/4
c. 1/3
d. 2/3
e. 0

3. You discover a new bacteria species and sequence its genome. Which of the following is not a possible result for the nucleotide frequencies? (1 pt)

a. A: 21%, G: 28%, T: 23%, C: 28%
b. A: 30%, G: 21%, T: 29%, C: 20%
c. A: 21%, G: 29%, T: 20%, C: 30%
d. A: 15%, G: 34%, T: 17%, C: 34%
e. A: 30%, G: 32%, T: 16%, C: 22%

4. What is false regarding introns in DNA?

a. There are more introns than exons in the human genome.
b. They regulate gene expression.
c. It is non-coding DNA.
d. They are not found in prokaryotes.
e. They are the protein-coding part of DNA.

5. You are a betta fish breeder who wants fish with a marble pattern. The marble pattern is a recessive trait found on the X chromosome. Solid color is a dominant trait also found on the X chromosome. You breed a male marbled betta fish with a heterozygous female solid color betta fish. Assume sex determination works the same in betta fish as in humans. Which of the following is false? (1pt)

a. A male offspring has a 100% chance of being solid color.
b. A female offspring has a 50% chance of being marbled.
c. 50% of the offspring will be marbled.
d. A female offspring has a 100% chance of inheriting the marbled allele from her father.

e. A female offspring has a 50% chance of inheriting the marbled allele from her mother.

6. Continuing from question 5, you choose a mating pair with the goal of producing male betta fish with a marble pattern. You do not care what the female offspring look like. Which of the following betta (pick one) would be the worst choice to include in the mating pair? (1 pt)

a. A female fish with the marble pattern
b. A female fish with solid color pattern
c. A male fish with a marble pattern
d. A male fish with a solid color pattern

7. In a cat population, there are alleles for white stripes and for black stripes. Both alleles exhibit incomplete dominance. If a cat has one allele for white stripes and one allele for black stripes, what will be its phenotype? (1 pt)

a. The cat will have gray stripes.
b. The cat will have some black stripes, and some white stripes.
c. The cat will have only black stripes.
d. The cat will have only white stripes.
e. Unable to determine.

8. What is incorrect about this sentence? “Each DNA nucleotide is made up of a six-carbon sugar molecule, a phosphine molecule, and one of four nitrogenous bases.” (1 pt)

a. A nucleotide contains a 5-carbon sugar molecule.
b. A nucleotide contains a phosphate molecule.
c. There are six nitrogenous bases.
d. There is nothing incorrect about this sentence.
e. This statement is incorrect for multiple reasons.

9. A human cell is able to replicate its entire genome, about 6 billion nucleotides, in only 6-8 hours. How is it able to accomplish this so quickly? (1 pt)

a. The cell is able to replicate at a rapid pace of about 24,000 base pairs a second.
b. The cell allows for a high rate of error, resulting in humans having a higher mutation rate than other organisms.
c. The use of Okazaki fragments means that “pre-loaded” DNA can be added in fragments.
d. Replication begins at multiple origins of replication along the chromosome.
e. c and d are correct.

10. Which of the following statements is true about polycistronic mRNA? (1 pt)

a. Polycistronic mRNA is present in prokaryotes.
b. Polycistronic mRNA codes for a single protein.
c. Polycistronic mRNA has one termination and one initiation codon.

d. Polycistronic mRNA always codes for xRNAs.
e. Polycistronic mRNA is used by RNA viruses to create DNA.

11. [Tie-breaker] In eukaryotic transcription, where does TFIID bind? (1 pt)
a. TFIID binds to the TATA box at the -10 region before RNA polymerase II binds.
b. TFIID binds to the TATA box at the -30 region before RNA polymerase II binds.
c. TFIID binds to the TATA box at the -35 region after RNA polymerase I binds.
d. TFIID binds to the TATA box at the -10 region after RNA polymerase II binds.
e. TFIID binds to the TATA box at the -30 region after RNA polymerase I binds.

12. How is pre-mRNA converted into mature mRNA in prokaryotes? (1 pt)
a. It is spliced to remove exons.
b. A 5' cap is added.
c. A poly-C tail is added.
d. A, b, and c are correct
e. Pre-mRNA only exists in eukaryotes.

13. Around 1.45 billion years ago, a cell engulfed a bacterial cell through phagocytosis. This created the first cell containing a mitochondrion. Which of the following statements is true about mitochondria? (1 pt)
a. Mitochondria are responsible for energy production.
b. Mitochondrial DNA is circular like a prokaryote.
c. Mitochondrial DNA has an usually high rate of mutation compared to eukaryotes.
d. Mitochondrial DNA is inherited from only the father.
e. a and b are correct

14. You want to insert a gene for producing human insulin into bacteria. However, you cannot insert that gene directly. First, you must produce the gene in cDNA form. Why? (1 pt)
a. The human DNA will have TFIID attached, and it must be removed first.
b. The human DNA must be converted to a form that a virus can insert.
c. The human DNA contains introns, which bacteria do not have a method to remove.
d. You must remove the human polycistronic DNA before it can be inserted into bacteria.
e. There must be multiple copies of the DNA present in order for the cloning to be successful.

15. Which is the correct sequence of events of the Polymerase Chain Reaction? (1 pt)
a. Primers attach to the strand -> The DNA is denatured -> A new DNA strand is synthesized -> The number of DNA strands is doubled.
b. Primers attach to the strand -> The DNA is denatured -> A new DNA strand is synthesized -> The number of DNA strands is quadrupled.

c. The DNA is denatured -> Primers attach to the strand -> A new DNA strand is synthesized -> The number of DNA strands is doubled.

d. A new DNA strand is synthesized -> Primers attach to the strand -> The DNA is denatured -> The number of DNA strands is doubled.

16. A botanist wants to grow the brightest pink petunias. She also wants them to be symmetrical so they look good in flower arrangements. The allele for bright pink color has incomplete dominance with the allele for pale pink flowers. The allele for symmetrical petals has complete dominance over the allele for asymmetrical petals. She crosses a true breeding flower having bright pink symmetrical petals with a flower having half pale and half bright pink asymmetrical petals. Which of the following statements about the phenotypes of the offspring is correct? (1 pt)

a. Half of the offspring will have asymmetrical petals.

b. Half of the offspring will have all bright pink petals.

c. A quarter of the offspring will have all bright pink petals.

d. A quarter of the offspring will have all pale pink petals.

e. a and b are correct.

17. The botanist in question 16 also wants her petunias to have vibrant green stems. The vibrant green allele has complete dominance over the dull green allele. She crosses the same two flowers mentioned above, and the true breeding flower having bright pink symmetrical petals also is heterozygous for green stems, and the flower having half pale and half bright pink asymmetrical petals also has dull green stems. Which of the following is true? (1 pt)

a. 1/2 of the offspring will have asymmetrical, all bright pink petals with vibrant green stems.

b. 3/4 of the offspring will have symmetrical, all bright pink petals with dull green stems.

c. 1/8 of the offspring will have symmetrical, all pale pink petals with dull green stems.

d. 1/4 of the offspring will have symmetrical, all bright pink petals with vibrant green stems.

e. 1/2 of the offspring will have asymmetrical, all pale pink petals with partially vibrant green stems.

18. In humans, sometimes nondisjunction results in a person having more than two sex chromosomes. In such cases, what determines the person's biological sex? (1 pt)

a. The number of X chromosomes. (XXY vs XYY)

b. The presence of the Y chromosome. (XXX vs XXY)

c. The number of Y chromosomes. (YYY vs XYY)

d. The ratio of X chromosomes to Y chromosomes. (XXY vs XYY).

e. None of the above.

19. At the end of each round of Meiosis II, in males _____ mature sperm cells are produced and in females _____ mature egg cells are produced. (1 pt)

a. 4; 1

b. 4; 4
c. 1; 4
d. 1; 1
e. 3; 3

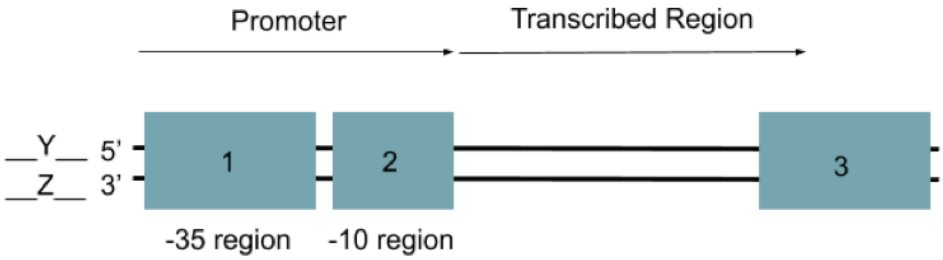
20. [Tie-breaker] Nondisjunction in meiosis II in a male can result in which syndrome? (1 pt)

a. Triple X Syndrome (XXX)
b. Jacob's Syndrome (XYY)
c. Klinefelter Syndrome (XXY)
d. a and b
e. a, b, and c

21. The rare *Flefe* puppy is a diploid organism with 22 pairs of homologous chromosomes. How many dyads are present in its cells? How many dyads would be in a haploid cell of this organism? (1 pt)

a. 22; 11
b. 11; 22
c. 44; 22
d. 22; 44
e. 88; 44

Use this chart of a prokaryotic promoter to answer problems 23 and 24.



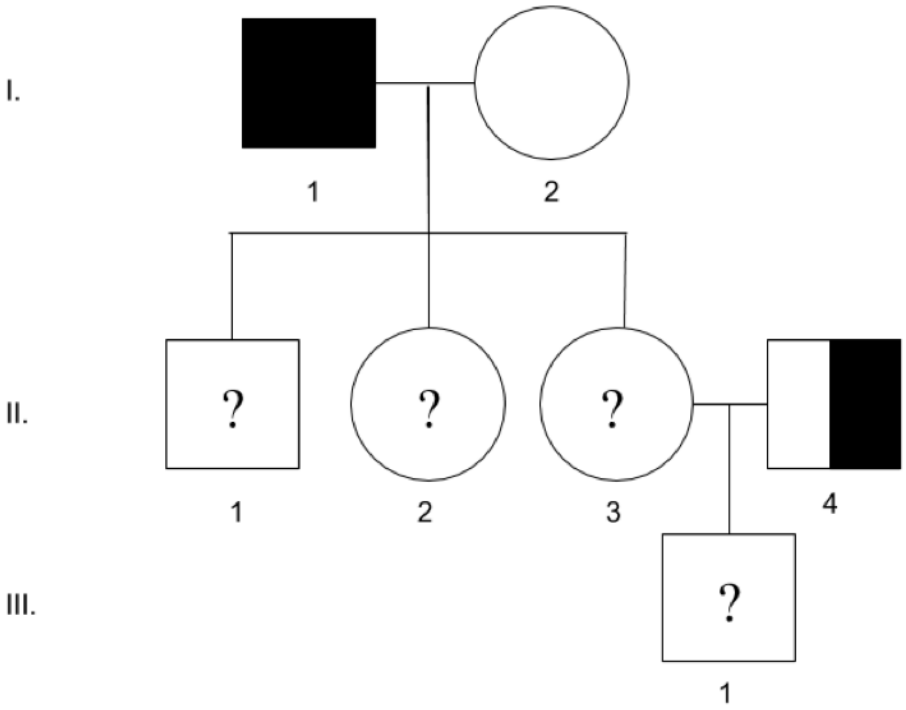
23. What corresponds to boxes 1, 2, and 3?

a. TATA; TGTTGACA; Termination signals
b. Termination signals; TGTTGACA; TATA
c. TGTTGACA; TATA; Termination signals
d. TGTTGACA; Termination signals; TATA
e. TATA; Termination signals; TGTTGACA

24. What corresponds to boxes Y and Z?

a. Coding strand; Template strand
b. Template strand; Coding strand

Use this image to answer questions 25 and 26.



25. What is the genotype of individual 3 of generation II? (1 pt)

a. AA
b. aa
c. Aa
d. unable to determine

26. If individual 3 of generation II mates with individual 4 of generation II, what is true regarding their offspring? (1 pt)

a. There is a 50% chance their offspring has the genotype AA.
b. There is a 50% chance their offspring has the genotype aa.
c. There is a 50% chance their offspring has the genotype Aa
d. There is a 25% chance their offspring has the genotype aa.
e. c and d

27. Blood type is an example of a trait with multiple alleles. The phenotypes of blood type follow this pattern:

Phenotypes	Genotypes
Type A	I_AI_A or I_Ai
Type B	I_BI_B or I_Bi
Type O	ii
Type AB	I_AI_B

Two parents, a mother with blood type B and a father with blood type O, forgot which baby in the maternity ward is theirs. They've narrowed down the possibilities to three babies. Baby I has blood type AB, baby II has blood type A, and baby III has blood type O. Which baby is theirs? (1 pt)

a. Baby I
b. Baby II
c. Baby III
d. Baby I or Baby III
e. None of the above

28. A very advanced person from the future is attempting to build a human cell from scratch. However, he discovers that he cannot fit all the DNA into the nucleus. Then he remembers that the human genome contains 6 billion base pairs. That's 2 meters of DNA per cell. What should he add to make sure all the DNA fits? (1 pt)

a. Methyl groups to wind up and compact the DNA.
b. Histones to wind up and compact the DNA.
c. Telomeres to reduce the space between nucleotides.
d. Chlorine atoms to reduce the space between nucleotides.
e. Make bigger cells.

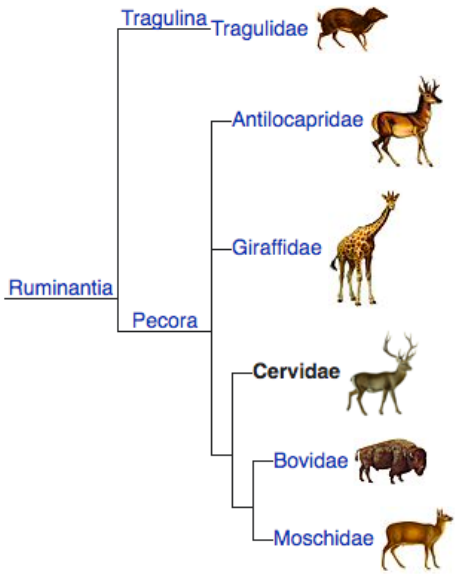
29. Which of the below is a function of DNA Polymerase I? (1 pt)

a. It proofreads the newly synthesized DNA strand
b. It unzips the DNA helix
c. It protects the 3' overhang.
d. It extends the template strand.
e. It rezips the DNA helix.

30. What would be the effects on DNA replication if DNA Polymerase III lost its 3' -> 5' exonuclease activity? (1 pt)

a. There would be more mutations because it wouldn't be able to repair DNA.
b. There would be no DNA replication.
c. The single stranded binding proteins wouldn't be able to prevent the helix from rewinding.
d. The Okazaki fragments wouldn't be able to form.
e. a and b

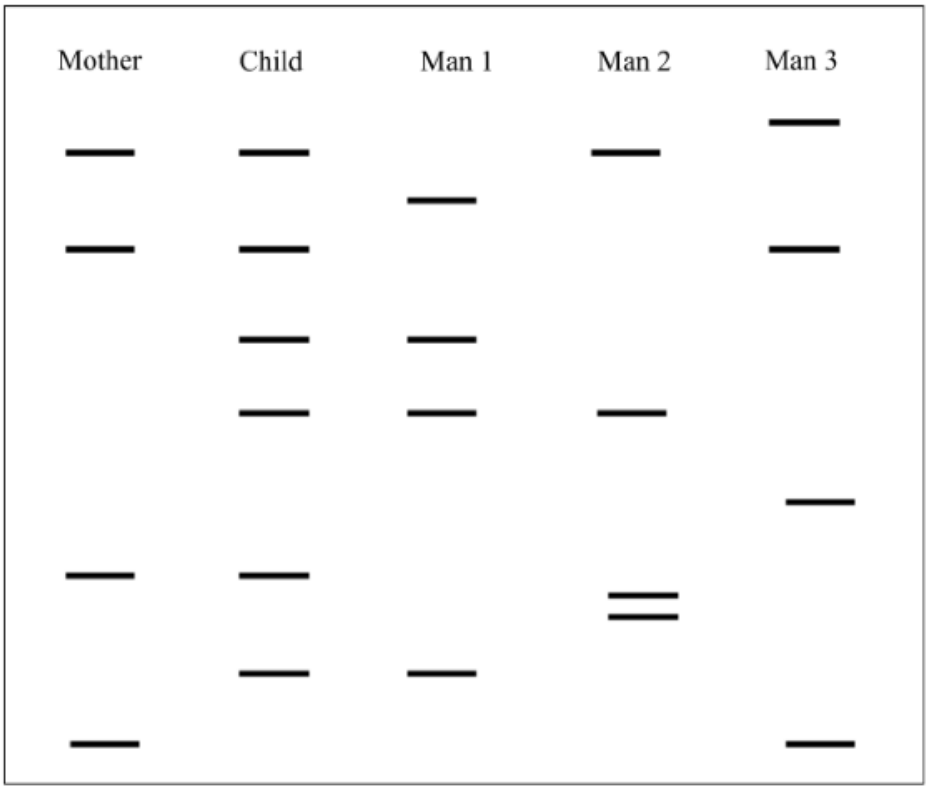
Use this chart to answer questions 31 and 32.



31. Which two species are most closely related? (1 pt)
    a. Giraffidae and Antilocapridae
    b. Tragulidae and Antilocapridae
    c. Cervidae and Bovidae
    d. Bovidae and Moschidae
    e. Tragulidae and Bovidae

32. What is the most recent common ancestor of Giraffidae and Tragulidae? (1 pt)
    a. Ruminantia
    b. Cervidae
    c. Bovidae
    d. Tragulina
    e. Pecora

33. What man is the father of the child? (1 pt)



a. Man 1
b. Man 2
c. Man 3
d. None of the above

34. A molecular biologist wants to know if an individual has a mutation in the gene she is studying. What is the quickest method she should use to test this? (1 pt)

a. She should use Sanger sequencing to sequence their genome.
b. She should construct a pedigree to see if they pass the mutation to their offspring.
c. She should insert the gene into *E. coli* via cloning.
d. She should use a DNA microarray to see if the individual's DNA differs from the wildtype sample.
e. She should study the epigenetic factors affecting their illness.

35. Where was CRISPR-Cas9 gene editing discovered? (1 pt)

a. It was discovered in yeast, which use it to resist high salinity.
b. It was discovered in bacteria, which use it to protect from bacteriophages (viruses).
c. It was discovered in bacteria, which use it to counteract high temperatures.
d. It was discovered in human cancer cells, which use it to elongate their telomeres.

e. It was discovered in human cancer cells, which use it to grow in higher densities.

36. Why might a molecular biologist choose to use Next Generation Sequencing (NGS) instead of a DNA microarray to measure a set of RNA levels? (1 pt)

a. NGS has more hybridization artifacts.
b. NGS has a narrower range of expression levels.
c. NGS is more environmentally friendly.
d. NGS is not dependent on a known genome.
e. All of the above.

37. How many restriction sites should plasmids used for cloning have? (1 pt)

a. 1
b. 2
c. 3
d. 4
e. many

38. Why are restriction enzymes used in DNA cloning? (1 pt)

a. They hybridize the desired DNA sequences.
b. They add topoisomerase to aid in DNA replication.
c. They recognize and cut the target DNA sequence.
d. They link fragments with matching ends together.
e. They resist the Polymerase Chain Reaction

39. In gel electrophoresis, the _____ fragments travel the fastest. They are attracted to the _____ end of the gel because DNA is _____. (1 pt)

a. largest; negative; positively charged
b. largest; positive; negatively charged
c. largest; negative; negatively charged
d. smallest; negative; positively charged
e. smallest; positive; negatively charged

40. When a bacterial chromosome is cut by a restriction enzyme once, it results in one fragment. Why is this true? (1 pt)

a. The bacterial chromosome cannot be cut by restriction enzymes.
b. The restriction enzyme only cuts one strand of DNA.
c. The bacterial chromosome is a circle.
d. The bacterial chromosome is immediately repaired.
e. The bacterial chromosome does not contain introns.

41. [Tie-breaker] Black bear cells are diploid, with a haploid number of 74 chromosomes. If each chromosome has exactly 10 genes, how many alleles are present in the black bear cells in the G1 phase of the cell cycle? (1 pt)

a. 740
b. 1480

c. 370
d. 2960
e. 185

42. What is a Barr body and where can it be found? (1 pt)
a. A Barr body is an inactivated X chromosome found in male cells.
b. A Barr body is an inactivated X chromosome found in female cells.
c. A Barr body is an inactivated X chromosome found in sperm cells.
d. A Barr body is an inactivated Y chromosome found in female cells.
e. A Barr body is an inactivated Y chromosome found in male cells.

43. Congenital night blindness is an X-linked trait. If a man has night blindness, but neither of his parents do, which family member is most likely to be a carrier for night blindness? (1 pt)
a. Paternal grandfather
b. Paternal grandmother
c. Maternal grandfather
d. Father
e. Mother

44. 5'…CCCAGCCTAGCCTTTGCAAGAGGCCATATCGAC…3'

3'…GGGTCGGATCGGAAACGTTCTCCGGTATAGCTG…5'

What is the polypeptide sequence for this gene? (1 pt)

a. Met-Ala-Ser-Cys-Lys-Gly
b. Met-Ala-Ser-Cys-Lys-Gly-Ile
c. Met-Gly-Arg-Gly-Phe-Ala
d. Met-Gly-Arg-Gly-Phe-Ala-Ile
e. Met-Ala-Ser-Cys-Phe-Gly

45. Which is not a part of the pre-initiation complex? (1 pt)
a. elongation factor
b. mRNA
c. small subunit of the ribosome
d. large subunit of the ribosome
e. a and d

46. A molecular biologist wants to reduce the expression of a gene in a eukaryote. They disable an enhancer for a gene, but the expression of the gene is not reduced. Why? (1 pt)
a. Enhancers are only found in prokaryotes.
b. One gene can have many enhancers.
c. They disabled the enhancer for the wrong gene.
d. They accidently chose an enhancer that is upstream of the gene.
e. Some enhancers reduce the expression of genes.

47. After cytokinesis of meiosis I in female cells, the resulting daughter cells have: (1 pt)

a. two copies of each chromosome
b. one copy of each chromosome
c. one chromatid corresponding to each chromosome
d. a and b
e. b and c

48. A mouse breeder notices that mice with gray fur often also have brown ears. He wonders if these two traits are linked. He asks a geneticist how to determine this. She knows these traits are autosomal, and she suggests that he: (1 pt)

a. uses Sanger sequencing to determine if the traits have similar DNA sequences.
b. uses a DNA microarray to determine if the traits both have high expression.
c. creates a karyotype of the gray mice with brown ears and compare it to gray mice without brown ears.
d. uses CRISPR-Cas9 to create a point mutation in the gray fur allele.
e. performs a test cross and records the frequencies of gray fur and brown ears among the offspring

49. Which of the following is not a component of transcriptional gene expression control? (1 pt)

a. promoters
b. enhancers
c. silencers
d. transcription factors
e. all of the above are involved in transcriptional gene expression control

50. An evolutionary biologist discovers two new species of monkeys that share similarities to the Rhesus Macaque. How should he determine which is more closely related to the Rhesus Macaque? (1 pt)

a. determine which one has more physical similarities to the Rhesus Macaque.
b. determine which one lives the closest to the natural habitat of the Rhesus Macaque.
c. use genetic analysis to determine which one shares a most recent common ancestor the Rhesus Macaque.
d. determine which one is able to produce viable offspring with the Rhesus Macaque
e. all of the above.

51. A double-stranded break in DNA is catastrophic for a cell if it is not repaired. There are two methods the cell uses to repair this damage: nonhomologous end joining, and homologous recombination. What is the benefit of using nonhomologous end joining instead of homologous recombination? (1 pt)

a. Nonhomologous end joining can be performed at body temperature.
b. Nonhomologous end joining uses undamaged DNA as a template.

c. Nonhomologous end joining can be done much quicker.
d. Nonhomologous end joining can take place when the nucleus is damaged.
e. b and c are correct.

True or False

1. Telomeres protect the ends of chromosomes in prokaryotes. T/**F** (1/2 pt)

2. A mutation that a mother passes to 100% of her offspring is located in the mitochondria and is considered X-linked. T/**F** (1/2 pt)

3. In plant cells, DNA is found in the nucleus and chloroplasts *only*. T/**F** (1/2 pt)

4. In methylation, a methyl group attaches to a gene, causing expression to be reduced. **T**/F (1/2 pt)

5. Adenine and guanine are purines. **T**/F (1/2 pt)

6. Gene regulation occurs most often at the level of translation, via translation factors. T/**F** (1/2 pt)

7. A bacterial plasmid is called a vector when used in genetic engineering. **T**/F (1/2 pt)

8. Crossing over occurs in prophase of meiosis I. **T**/F (1/2 pt)

9. The lagging strand requires more primers than the leading strand. **T**/F (1/2 pt)

10. CRISPR-Cas9 is no longer considered a reliable, fast, and cheap way to create alterations in single genes. T/**F** (1/2 pt)

11. In Sanger Sequencing, the primer used must begin and end with the same nucleotide. T/**F** (1/2 pt)

12. The Polymerase Chain Reaction is most similar to the cellular process of mitosis. T/**F** (1/2 pt)

13. Epigenetic factors are changes in gene activity that do not change the DNA sequence and cannot be inherited from parent to child. T/**F** (1/2 pt)

14. Non-homologous end joining is a highly error prone method of DNA repair. **T**/F (1/2 pt).

15. If the proteins that make mRNA used the sense strand of DNA to make a strand of mRNA, the resulting mRNA would be anti-sense. **T**/F (1/2 pt)

16. Sister chromatids undergo recombination during meiosis. T/**F** (1/2 pt)

17. A CAAT box is found in many eukaryotic promoters upstream of the initial transcription site. **T**/F (1/2 pt)

18. Transfer of the SRY gene during recombination between the X and Y chromosome can result in biological males with two X chromosomes. T/**F**(1/2 pt)

19. The Shine-Dalgarno sequence aligns the start codon and ribosome, initiating protein synthesis. **T**/F (1/2 pt)

20. In order for a gene to be expressed, all parts of the Kozak sequence must be perfectly conserved. T/**F** (1/2)