Designer Genes
Written for the 2021 Scioly Summer Study Session

Team Number: _____

Score: ____/79

Rules:

- You will have **50 minutes** to complete the test.
- The **only** materials allowed during testing are:
    - one 8.5” x 11” sheet of paper containing information on both sides without annotations or labels
    - two non-programmable, non-graphing calculators
- There is **no penalty** for **guessing**.
- Be sure to **answer** each question as **completely as possible**. Partially correct answers may earn **partial credit**.
- **Point values** for each question will be indicated by brackets “{ }” around a number at the end of each question.
- **Tiebreaker questions** will be clearly labeled. These questions will **only** count towards your score in the event of a tie.
- **Good luck!**
- **P.S. -** This test should never be used at an official Science Olympiad tournament!

Part 1

1. Which of the following is **not** a difference between DNA and RNA? {1}
    A. DNA is antiparallel, while RNA is not
    B. DNA is double-stranded, while RNA is single-stranded
    C. DNA has a backbone made of a sugar and a phosphate, while RNA does not
    D. DNA contains thymine, while RNA contains uracil
2. What is the role of topoisomerase in DNA replication? {2}

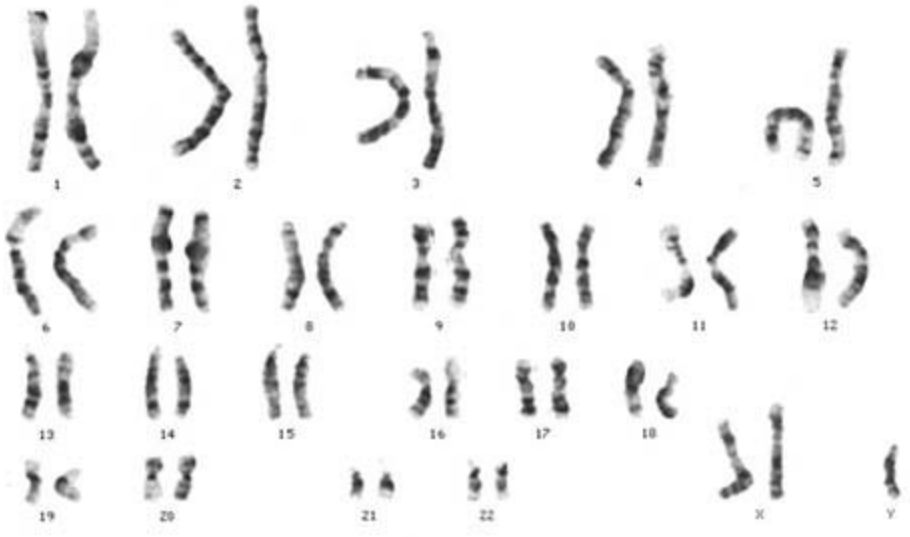
    _____

    _____

3. What is a small-scale mutation? {1}
    A. A mutation where only one cell is affected
    B. A mutation that only affects one or very few nucleotides of a gene
    C. A mutation that does not produce a visible effect on the organism
    D. A mutation that produces a minor effect
4. What is the difference between a somatic and a germline (germinal) mutation? {1}
    A. Somatic mutations cannot be inherited, but germline mutations can
    B. Somatic mutations occur as a result of exposure to mutagens, but germline mutations occur naturally
    C. Somatic mutations are found in gametes, but germline mutations are not
    D. Somatic mutations occur in meiosis, but germline mutations occur in mitosis
5. Fill in the blank: In _____ base pairing, nitrogenous bases are not paired to their Watson-Crick partners. {1}
6. Define linked genes. {1}

    _____

7. Analyze this karyotype.



i. Does this individual exhibit any chromosomal abnormalities? On which chromosomes? {2}

_____

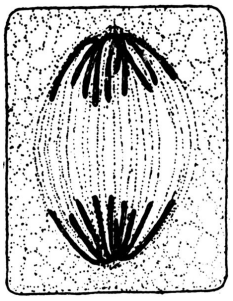
ii. What condition is this indicative of, if any? {1}

_____

8. The TATA box is a sequence of DNA in eukaryotes found in the promoter. What is the prokaryotic equivalent of this sequence? Choose the best answer. {1}
   A. The Chargaff box
   B. The Pribnow-Schaller box
   C. The Putz box
   D. The Goldberg-Hogness box
9. List three organelles that contain DNA. {3}

   1. _____
   2. _____
   3. _____

10. Meiosis must take place in order for reproduction to occur in organisms that sexually reproduce. What is meiosis? {1}
    A. A diploid nucleus divides to form diploid nuclei
    B. A haploid nucleus divides to form diploid nuclei
    C. A haploid nucleus divides to form haploid nuclei
    D. A diploid nucleus divides to form haploid nuclei
11. Fill in the blank: A _____ is a protein that DNA is wrapped around inside a nucleosome. {1}
12. The image to the right shows a phase of mitosis in a plant cell. What phase of mitosis is depicted? {1}
    A. Prophase
    B. Telophase
    C. Metaphase
    D. Anaphase



13. A mRNA sequence AUGACGGCACUGAUUUCGAGGUGA is translated into a protein. List the sequence of amino acids that this mRNA strand produces. {1}

    _____

14. List the three main parts of a eukaryotic promoter. {3}

    1. _____
    2. _____
    3. _____

15. True/False: Most mutations are harmful. {1}
    A. True
    B. False
16. How can a single base substitution (e.g. GAG to GTG) result in a disease like sickle cell anemia? {2}

    _____

    _____

17. What is the difference between nondisjunction occurring in Anaphase I and nondisjunction occurring in Anaphase II? {1}
    A. Nondisjunction in Anaphase II results in two affected daughter cells
    B. Nondisjunction in Anaphase II results in four affected daughter cells
    C. Nondisjunction in Anaphase I results in two affected daughter cells
    D. Nondisjunction only occurs in Anaphase I, it cannot occur in Anaphase II
18. What is a transcription factor? {2}

_____

_____

19. Hershey and Chase discovered that DNA is genetic material. Describe their experiment. {3}

_____

_____

_____

_____

20. **Tiebreaker 1 -** What are the stages of prophase I? {1}
    A. Leptotene, zygotene, pachytene, diplotene, diakinesis
    B. Pachytene, diplotene, diakinesis, zygotene, leptotene
    C. Zygotene, diplotene, leptotene, pachytene, diakinesis
    D. Diplotene, zygotene, leptotene, pachytene, diakinesis

Part 2

21. Define epistasis. {1}

_____

22. A test cross is performed with an organism that exhibits the dominant phenotype. The resulting **phenotypic** ratio is 1:2:1. What is the **genotype** of the unknown organism? {1}
    A. Homozygous dominant
    B. Homozygous recessive
    C. Heterozygous
    D. It cannot be determined with this information
23. In the fancy rat (*Rattus norvegicus domestica*), coat color (R) and tail length (L) are two traits that may be selected for during breeding. Perform a dihybrid cross between a rat that is heterozygous in both traits and a rat that is homozygous dominant for coat color and heterozygous for tail length. {3}

24. Miranda is interested in crossbreeding some of her flowers to see what offspring they produce. If she crosses her red flowers with her yellow flowers, she predicts that they will produce orange flowers. What phenomenon would explain this? {1}
    A. Co-dominance
    B. Incomplete dominance
    C. Mendelian inheritance
    D. None of the above

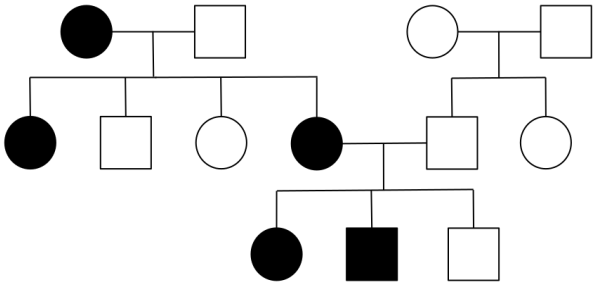
25. A population of 329 foxes live in Hardy-Weinberg equilibrium. Foxes with black-tipped tails have the dominant allele of the A gene, while foxes with white-tipped tails have the recessive allele. If the dominant allele has a frequency of .72 and the recessive allele has a frequency of .28, find the frequency of each genotype in this population. {3}

_____

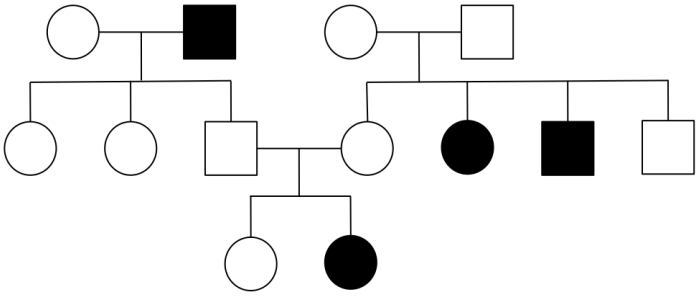
_____

_____

26. Analyze the following pedigrees and state the mode of inheritance for each. {1 point for each correct answer}

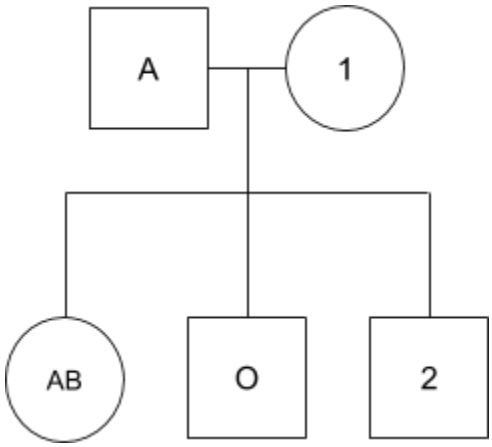


i. _____



ii. _____

27. If an organism with a homozygous recessive genotype is crossed with a heterozygote, what are the odds of an organism in the first generation possessing the homozygous dominant genotype? {1}
    A. 0%
    B. 25%
    C. 50%
    D. 100%
28. Fill in the blank: In _____ traits, the trait will never skip a generation. {1}
29. The pedigree shown below depicts the blood types of select members of a family.



    Which of the following blood types are possible for the individuals with unknown blood types? {1}
    A. Individual 1: AB, Individual 2: B
    B. Individual 1: O, Individual 2: AB
    C. Individual 1: A, Individual 2: O
    D. Individual 1: B, Individual 2: A
30. A trait is controlled by three genes, each possessing two alleles. How many genotypes are possible in the first generation of a cross between a homozygous recessive mother and a homozygous dominant father? {1}

    _____

31. Define polymorphism. {1}

_____

32. What is the difference between a phylogenetic tree and a cladogram? {1}
    A. Phylogenetic trees are vertically aligned, while cladograms are horizontal
    B. Phylogenetic trees show time, while cladograms do not
    C. Phylogenetic trees are based on structural evidence, while cladograms are based on molecular evidence
    D. They are the same
33. What is genetic recombination? {2}

_____

34. Hemophilia is a sex-linked trait, being passed from generation to generation.
    i. Define “sex-linked”. {1}

_____

    ii. Tonya and Evan have three children. One is female (Nikki), and the others are male (Zhen and Carlos). Tonya carries the gene for hemophilia, and passes it on to two of the children (Nikki and Carlos). Unfortunately, Carlos died in childhood but Nikki goes on to marry a man that has hemophilia. They have three children, two boys and a girl. Both boys have hemophilia, and the girl is a carrier. Construct a pedigree for this family, including a key. {5}

35. **Tiebreaker 2 -** How is a chi-square test used to determine whether or not genes are linked? {1}
    A. The genes are likely linked if the difference between the observed and expected frequencies is statistically significant
    B. The genes are likely linked if the difference between the observed and expected frequencies is **not** statistically significant
    C. The genes are likely linked if the difference between the observed and expected frequencies is zero
    D. It cannot be used in this way

Part 3

36. In gel electrophoresis, why do smaller DNA fragments travel farther than longer DNA fragments? {1}
    A. The charge that pulls the DNA has a stronger effect on small fragments
    B. Smaller molecules have a smaller mass and can travel more quickly
    C. The pores of the gel are too small to allow large molecules to travel easily
    D. They don't - the DNA fragments travel the same distance regardless of length
37. Polymerase Chain Reaction (PCR) is performed in lab settings in order to create many copies of a small sample of DNA.
    i. Explain the steps of PCR. {3}

_____

_____

_____

    ii. What is the purpose of using a heat-resistant polymerase during PCR instead of a normal polymerase? {1}

_____

38. Sanger sequencing is a form of DNA sequencing that requires the incorporation of special nucleotides. What is the purpose of these nucleotides? {1}
    A. Terminating the replication of DNA
    B. Allowing the primer to bind to the DNA
    C. Allowing the DNA polymerase to replicate the DNA
    D. Terminating the transcription of DNA
39. Identify two potential applications of plasmid cloning. {2}

_____

_____

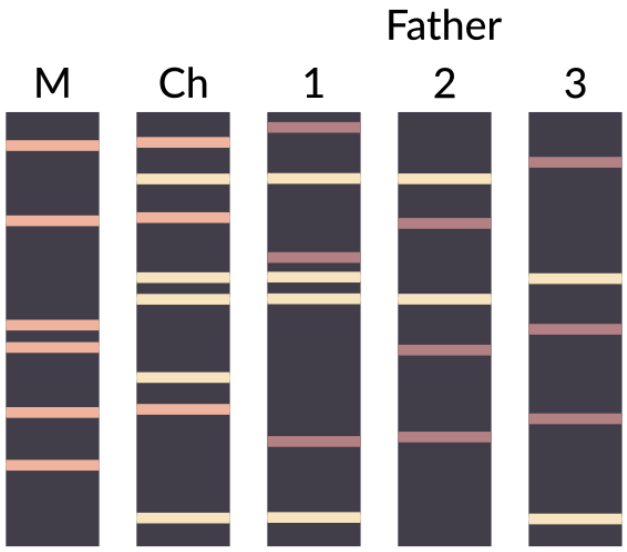
40. What is the difference between southern blotting and northern blotting? {1}
    A. Southern blotting detects RNA and northern blotting detects DNA
    B. Southern blotting detects DNA and northern blotting detects proteins
    C. Southern blotting detects proteins and northern blotting detects DNA
    D. Southern blotting detects DNA and northern blotting detects RNA
41. RFLP is commonly utilized in laboratories to perform what kind of analysis? {1}
    A. DNA profiling
    B. Paternity testing
    C. Genealogical testing
    D. Sequencing
42. CRISPR-Cas9 is a technology that allows for gene editing.
    i. What does CRISPR stand for? {1}

_____

    ii. What was its original purpose? {1}

_____

43. Analyze the following DNA fingerprint.



Which of the three samples most likely corresponds to the father of the child (Ch)? {1}

A. Option 1
B. Option 2
C. Option 3
D. None of the above

44. A DNA microarray can have powerful applications, specifically in the field of cancer research. How can a DNA microarray be used to investigate potential causes of cancer? {1}

_____

_____

45. Restriction enzyme ligation has long been considered the traditional method for cloning DNA despite its many flaws. Why might this method still be used despite newer, easier methods being available? {1}

_____

46. The CRISPR-Cas9 system is most well known for originating in prokaryotic organisms. How is it possible to employ this system in eukaryotic organisms? {1}
    A. Eukaryotes and prokaryotes both store genes in plasmids
    B. Both prokaryotes and eukaryotes produce the same polypeptides
    C. Viruses can infect both prokaryotes and eukaryotes
    D. Both prokaryotes and eukaryotes use the same genetic code
47. What is a DNA ladder? {2}

_____

48. You work in a forensics lab, where part of your job involves analyzing DNA evidence to identify suspects. What technique might you utilize in this position? {1}
    A. DNA microarrays
    B. Sanger sequencing
    C. PCR
    D. Plasmid cloning
49. What is reverse transcription, and what biotechnology technique utilizes it? {2}

_____

_____

50. **Tiebreaker 3 -** What is a northwestern blot? {1}
    A. A blot that detects interactions between DNA and proteins
    B. A blot that detects post-translational modifications
    C. A blot that detects interactions between proteins
    D. A blot that detects interactions between RNA and proteins