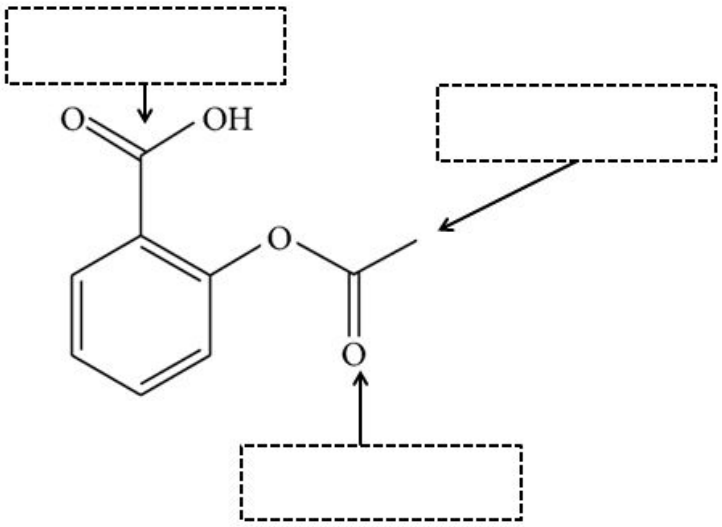
Name:
School:
Total Score: ____/ 50

1. Which nitrogenous bases present in DNA are purines, and which are pyrimidines? What is the main difference between a purine and a pyrimidine? (2 points)

2. To the right is the chemical structure of aspirin, a drug used to relieve pain which you've most likely used at some point in your life. Identify the functional groups that are present by labeling the boxes on the structure. (1.5 points)



3. Suppose you are a geneticist who studies jabberwockies. Two traits that vary in jabberwockies are eye color and claw length. Assume the genes controlling these traits are not found on a sex chromosome. Wild-type jabberwockies have red eyes and long claws (denoted with an "R" and an "L" respectively). The recessive phenotypes are yellow eyes and short claws (denoted with "r" and "l").
    a. Hypothetically, if you crossed a homozygous red eyed, long clawed jabberwocky with a homozygous yellow eyed, short clawed jabberwocky and the offspring all turn out with orange eyes and long claws (the color resulting from combining red with yellow):
        i. What are the genotypes of the parents for the eye color allele?

        ii. What are the genotypes of the offspring for the eye color alle?

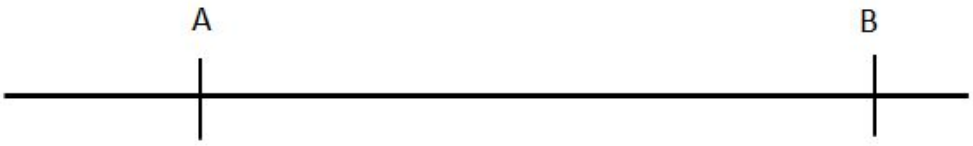
        iii. What would this eye color phenomenon be called?

b. In reality, this phenomenon does not occur and the above offspring would display the dominant phenotype, i.e. they would have red eyes and long claws. Now you take one of these offspring and cross it with a rrll jabberwocky with yellow eyes and short claws.
   i. If eye color and claw length are unlinked and no recombination occurs, predict the percentage of offspring with each phenotype resulting from this cross.

      1. Red eyes, long claws _____
      2. Red eyes, short claws _____
      3. Yellow eyes, long claws _____
      4. Yellow eyes, short claws _____

   ii. At what stage in (circle either mitosis or meiosis) mitosis / meiosis does crossing over typically occur?

c. Consider the linkage map below currently showing two genes, A and B on a jabberwocky chromosome.



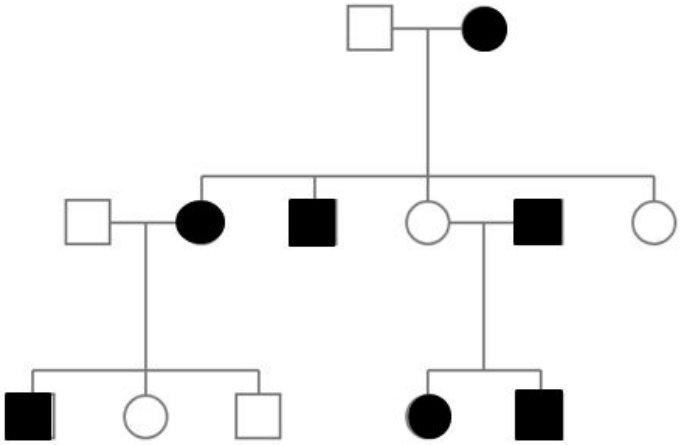
After doing some experiments, you have data on three more genes C, D, and E which are summarized below (the units for distance is cM, centimorgans):

   i. The distance from C to A is 18 cM
   ii. The distance from C to B is 4 cM
   iii. The distance from D to A is 8 cM
   iv. The distance from D to C is 26 cM
   v. The distance from E to C is 12 cM
   vi. The distance from E to A is 6 cM

Based on this information and the diagram, what is the distance (in cM) between B and E?

4. The clutch allele. All the great ones have the ability to elevate their performance when time is winding down. Michael Jordan. Tom Brady. You are a geneticist studying the

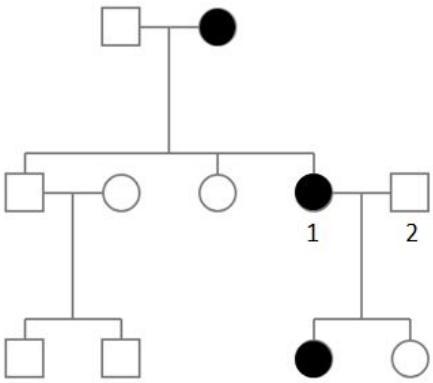
pedigree below representing a family that has “clutchness”. Assume that individuals marrying into the family can carry the clutch allele and that being clutch is completely penetrant, i.e. that any individual with the clutch allele will always produce the clutch trait. (1 point)



Circle the type(s) of inheritance that apply to this pedigree (you may or may not circle more than one)

i. Autosomal recessive
ii. Autosomal dominant
iii. Sex-linked recessive
iv. Sex-linked dominant

5. Now consider the pedigree below, which represents a family in Japan with a rare genetic condition that allows members to swap bodies with another person in their dreams. Again, assume that individuals marrying into the family can carry the body-swapping



allele and that the body-swapping allele is completely penetrant.

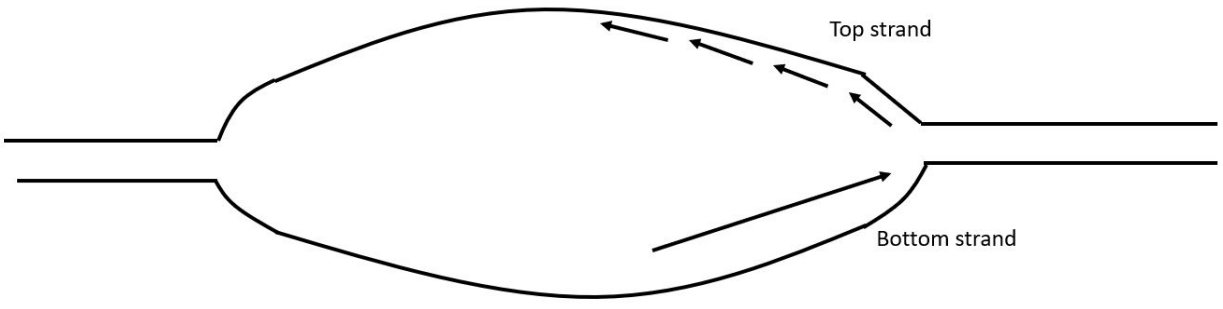
a. Circle the type(s) of inheritance that apply to this pedigree (you may or may not circle more than one)

i. Autosomal recessive
ii. Autosomal dominant
iii. Sex-linked recessive
iv. Sex-linked dominant

b. Suppose individuals 1 and 2 decide to have a son. What is the probability their son will be affected (a number between 0 and 1 inclusive)? If you circled more than one type in part a, then pick one and in your answer give the type of inheritance and the probability (or else it will not be scored), e.g. autosomal dominant, 1

6. Where are the poly-A tail and guanine cap added during RNA processing?
   a. 3' end, 5' end
   b. 5' end, 3' end
   c. Both the poly-A tail and guanine cap are added to the 3' and 5' ends
   d. Neither—this does not occur during RNA processing

7. Which of the following is false?
   a. Introns are removed during RNA splicing
   b. Eubacteria are the only species where introns are not found
   c. "Intron trapping" describes the process that exploits the existence of the intron-exon splicing to find new genes
   d. Spliceosomes are the complex associated with RNA splicing
8. Given the image below, answer the following questions:
   a. Label which strand is the template for the leading strand and which strand is the template for the lagging strand. Also, label the 5' and 3' ends of each template strand.
   b. Which of the following statements is true?
      i. DNA polymerase extends the 5' end of the lagging strand during DNA replication, unlike the synthesis of the leading strand.
      ii. Only lagging strand DNA synthesis requires a primer.
      iii. The leading strand DNA polymerase always synthesizes DNA in the overall direction of replication for the replication fork.
      iv. DNA replication can initiate in the absence of helicase.



9. Shown below is a double stranded bacterial DNA sequence coding for a protein. Note: for this strand, RNA polymerase proceeds from right to left along the DNA.

5’ AGGGCACCCTGTAGTTCGAAAAGAAATTATTTCGTAAGGC 3’

3’ TCCCGTGGGACATCAAGCTTTTCTTTAATAAAGCATTCCG 5’

   a. Which strand is used as a template for transcription, the top strand or the bottom strand?
   b. The transcription start site is highlighted in red. What are the first 10 nucleotides of the resulting RNA? Please label the 5’ and 3’ ends of the RNA.
   c. Is the promoter located before or after the transcription start site?
   d. Suppose a T/A base pair is inserted after the transcription start site (this does not result in a stop codon). How does this affect the mRNA transcript, and how does it affect the protein?
   e. What is the name of the type of mutation in part d? Be as specific as possible.

10. When you’re doing Sanger sequencing, what special nucleotides are necessary for sequencing?

   a. What’s the main difference between these nucleotides and the nucleotides normally present in your DNA?

   b. If you add too many of these special nucleotides, why does sequencing not work?

11. Place the following steps of DNA replication in order from first to last:
   a. DNA polymerase begins synthesizing in the 5’ to 3’ direction.
   b. DNA primase begins to synthesize RNA primers.
   c. Helicase unwinds the double helix.
   d. DNA ligase joins the Okazaki fragments together.
   e. Single-strand binding protein first binds to single stranded DNA.

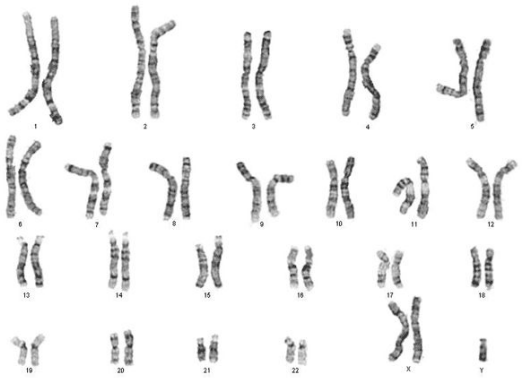
12. In this question you will compare and contrast bacterial and eukaryotic transcription.
   a. Name the DNA sequence where RNA polymerase binds and initiates transcription.

   b. Name this sequence of nucleotides commonly found in eukaryotic promoters approximately 25 nucleotides upstream of the transcription start site.

   c. In both bacteria and eukaryotes, certain proteins must bind to the DNA before RNA polymerase can bind. What are these proteins called, for bacteria and eukaryotes respectively?

d. Which of these is true for termination of eukaryotic transcription? (you may circle more than one answer)
   i. Proteins in the nucleus cut the RNA transcript free from the DNA polymerase.
   ii. Once the terminator sequence in the DNA is transcribed, the corresponding RNA sequence causes the transcript to be released from DNA polymerase.
   iii. Polymerase continues to transcribe for a certain amount of time even after the pre-RNA transcript is released.
   iv. RNA polymerase transcribing a polyadenylation signal in the DNA is the key event that leads to termination of transcription.

13. Which genetic disorder is represented by this karyotype?



14. Indicate which of the steps of translation, starting from the binding of tRNA to its mRNA codon, would be affected in the following scenarios (be as specific as possible):
    a. A sudden decrease in the amount of GTP present.

    b. A sudden decrease in the amount of ATP present.

    c. A mutation in the DNA causes all sequences that would be transcribed into AUG to be AGG instead.

15. The operon is a genetic regulatory system found most commonly in bacteria.
    a. What are the three components of an operon?

    b. In the trp operon, how is gene expression affected when the intracellular tryptophan concentration increases?

i. What type of operon is the trp operon?

c. Suppose there is a mutation that causes cyclic AMP (cAMP) to always be produced, regardless of glucose concentration. Will the the lac operon be on if…
   i. Glucose concentration is low and lactose concentration is high?

   ii. Glucose concentration is high and lactose concentration is high?

16. What is the function of Cas9 in using CRISPR-Cas9 to edit DNA? You may find the components needed for CRISPR-Cas9 useful in answering this question.

17. You're trying to insert a gene for blue protein production into a plasmid and obtain bacteria cells containing this recombinant plasmid. Which component of a vector were you missing?
    a. You successfully ligated your gene into some plasmids. You then introduced these plasmids into bacteria, and cultured the bacteria on a plate containing ampicillin (which kills this bacteria). All your bacteria die.

    b. After performing all the steps for creating a vector and transforming it into your bacteria, you culture your cells on a plate with ampicillin. You notice that after a few days the number of cells on the plate hasn't changed at all.

    c. After transforming the vector into the bacteria and culturing them on a plate containing ampicillin, you notice that they all die and that the plasmids don't contain the blue protein gene.

18. During which phase of the cell cycle does the cell replicate its DNA?
    a. M
    b. S
    c. G1
    d. G2
19. In humans, an AB blood type is the result of
    a. Multiple alleles
    b. Polygenic inheritance
    c. Incomplete dominance
    d. Codominance

20. In a certain population, the dominant phenotype of a certain condition occurs 91% of the time. What's the frequency of the dominant allele?
    a. 0.3
    b. 3%
    c. 0.7
    d. 7%
21. What are three examples of multifactorial inheritance?