Designer Genes C - MASTER KEY

UT Austin Invitational 2020

October 23, 2020 - October 25, 2020

Team Number: _____

Team Name: _____

Total Points: _____/164 **Rank:** _____/xxxxxx

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Instructions and Clarifications:

- The rules for this event have been adapted for our virtual tournament and follow the **2020-2021 Regional Rules.** Read and follow the rules below.
- You will have access to this exam at **3:30 C.T.** on **October 23, 2020**, and you must upload your answer sheet **before 7:30 C.T.** on **October 24, 2020**.
- You will then **self-report your scores** to ATX Science Olympiad by **3:30 C.T.** on **October 25, 2020**, when keys are made available.
- **Type** your answers on the provided answer sheet, and include your team number and name. Only the answer sheet will be graded.
- If you have any questions or concerns regarding this exam, feel free to contact the authors through the emails below. **Good luck!**

Tiebreaker Order: Part 1: 10, 13, 18, 25, 31, 37, 40, 44, 48; Part 2: 5

I. Multiple Choice (96 pts)

Directions: Choose the most appropriate answer for each question. Each question is worth **2 pts**.

1. **(RK)** The nucleoids of bacteria and most archaea, as well as the nuclear DNA of eukaryotes, are kept _____ supercoiled.
    a. Rarely
    b. Neutrally
    c. Positively
    d. Negatively
    e. Transiently

2. **(RK)** Gene transfer from a parent to progeny is called
    a. Conjugation
    b. Transformation
    c. Horizontal gene transfer
    d. Vertical gene transfer
    e. Two of the above

3. **(RK)** Besides the nucleoid, which of the following are other kinds of DNA molecules that may be present in the cytoplasm of a bacterial cell?
    a. The genomes of bacteriophages
    b. Plasmids
    c. Introns
    d. Exons
    e. Two of the above

4. **(RK)** Bacterial chromosomes can typically be each of the following EXCEPT
    a. Transformable
    b. Supercoiled
    c. Circular
    d. Multi-copy
    e. Linear

5. **(RK)** The Shine-Dalgarno sequence can also be described as
    a. an mRNA sequence that positions the start codon into the P-site of the ribosome.
    b. the sequence 5'-AGGAGGU-3'
    c. a leader sequence upstream of the start codon of an mRNA transcript
    d. complementary to a sequence in the 16S rRNA of the 30S ribosome subunit.
    e. All of the above

6. **(RK)** Both codons and anticodons
    a. are part of tRNA.
    b. are sequences of DNA three nucleotides long.
    c. are identical RNA sequences.
    d. are complementary RNA sequences.
    e. two of the above

7. **(KH)** During which phase of meiosis does crossing over occur?
    a. Prophase I
    b. Metaphase I
    c. Prophase II
    d. Metaphase II
    e. Anaphase II

8. **(KH)** In Meiosis, the genetic content of the daughter cells is reduced from diploid to haploid. When is diploidy re-established?
    a. Metaphase I
    b. Cytokinesis I
    c. Metaphase II
    d. Anaphase II
    e. Fertilization

9. **(KH)** During Oogenesis, how many mature ovums and polar bodies are produced?
    a. 4 mature ovums
    b. 2 mature ovums, 1 polar body
    c. 1 mature ovum, 2 polar bodies
    d. 3 polar bodies
    e. 4 polar bodies

10. **(KH)** Which mechanism(s) are responsible for the reassortment of parental genes? **(TB#1)**
    a. Independent Assortment
    b. Crossing Over
    c. Cytokinesis
    d. Both A and B
    e. Both A and C

11. **(KH)** What term describes phenotypic variation among individuals with the same genotype?
    a. Variable expressivity
    b. Complete penetrance
    c. Incomplete penetrance
    d. Codominance
    e. Incomplete dominance

12. **(KH)** What term describes diseases in which some individuals who have the disease genotype do not display the disease phenotype? **(TB#2)**
    a. Variable expressivity
    b. Complete penetrance
    c. Incomplete penetrance
    d. Codominance
    e. Incomplete dominance

13. **(KH)** Mitochondrial diseases often demonstrate variable expression in a population or within a family due to heteroplasmy. Heteroplasmy is the random distribution of normal and mutated mitochondria between daughter cells during which phase of the cell cycle?
    a. G1
    b. S
    c. G2
    d. Mitosis
    e. Cytokinesis

14. **(SV)** Some viruses like HIV have the ability to transcribe RNA into DNA in a process called reverse transcription. Which of the following statements correctly describe this process?
    a. Minus-strand DNA synthesis is initiated using the 5’ end of a partially unwound transfer RNA that is annealed to the PBS in genomic RNA as a primer.
    b. RNase-H mediates the degradation of a DNA strand.
    c. RNase H removes the primer mRNA, which exposes sequences in the +sssDNA.
    d. Minus-strand DNA synthesis ceases once -sssDNA has been transferred to the 3’R segment on viral RNA.
    e. None of the above

15. **(SV)** Which type of mutation changes one codon for an amino acid into another codon for the same amino acid?
    a. Silent
    b. Missense
    c. Nonsense
    d. B and C
    e. None of the above

16. **(SV)** Which DNA repair mechanism(s) is considered to be the pathway of choice to remove bulky lesions such as CPDs and (6 - 4)PP from UV radiation, benzo[a]pyrene adducts, or damage from chemotherapeutic agents?
    a. Nucleotide Excision Repair
    b. Mismatch Repair
    c. Interstrand Crosslink Repair
    d. A and B
    e. All of the above

17. **(SV)** Double-strand DNA breaks are common events that occur in eukaryotic cells. Nonhomologous DNA end joining (NHEJ) is one of the major pathways that repair these DNA breaks. Choose the statement that correctly describes NHEJ. **(TB#3)**
    a. NHEJ does not require a nuclease to resect damage DNA.
    b. NHEJ is described as “non-homologous” since the break ends are indirectly ligated and require a homologous template.
    c. Microhomologies are nonhomologous DNA sequences that typically guide NHEJ.
    d. The inactivation of the NHEJ pathway may lead to a more error-prone pathway called microhomology-mediated end joining (MMEJ).
    e. None of the above

18. **(SV)** How many MMR proteins work together in sequential steps to initiate repair of DNA mismatches in humans?
    a. 5
    b. 7
    c. 9
    d. 10
    e. None of the above

19. **(JG)** Most bacterial promoter regions can be broken down into two functional sites. Where are these consensus sites located?
    a. -35 and -10 bases upstream of the translation start site
    b. -35 and -10 bases upstream of the transcription start site
    c. -30 and -15 bases upstream of the transcription start site
    d. -30 and -15 bases upstream of the translation start site

20. **(JG)** Which of the following is **not** a difference between Eukaryotic and Prokaryotic promoter structure?
    a. Eukaryotic promoters typically contain a TATA box and prokaryotic promoters do not
    b. Eukaryotic promoter regions interact with enhancers and prokaryotic promoters do not
    c. Sigma factor proteins bind to prokaryotic promoters but not eukaryotic promoters
    d. Eukaryotic promoters are more complex than prokaryotic promoters

21. **(LX)** Heterozygous yellow (genotype Yy) and homozygous green (genotype yy) pea plants are crossed in a monohybrid cross. What is the ratio of yellow : green peas from the resultant cross if yellow pea color is a dominant trait and green pea color is a recessive trait?
    a. 3 : 1
    b. 1 : 1
    c. 1 : 3
    d. 1 : 0

22. **(LX)** Homozygous round (genotype RR) and homozygous wrinkled (genotype rr) pea plants are crossed in a monohybrid cross. What is the genotype and phenotype of the resultant plants if roundness is a dominant trait and having wrinkles is a recessive trait?
    a. Rr (round)
    b. Rr (wrinkled)
    c. Half RR (round), half rr (wrinkled)
    d. Half Rr (round), half Rr (wrinkled)

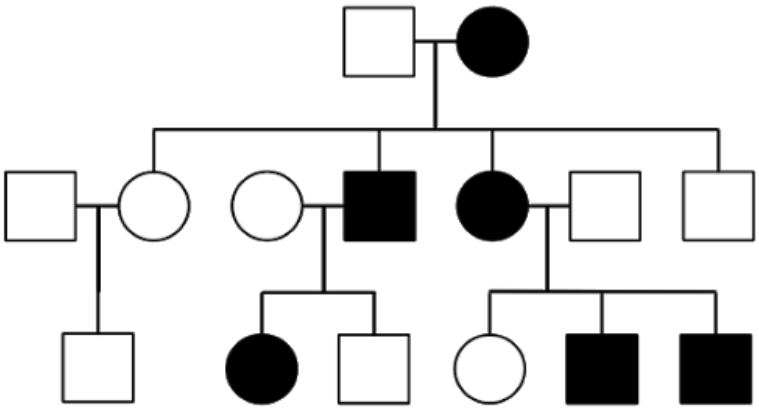
23. **(LX)** Pea plants that are heterozygous for both yellow and round traits (genotype YyRr) are crossed with pea plants that are homozygous for both green and wrinkled traits (genotype yyrr) in a dihybrid cross. What is the ratio of yellow, round : yellow, wrinkled : green, round : green, wrinkled peas from the resultant cross if yellow and round are dominant traits and green and wrinkled are recessive traits?
    a. 9:3:3:1
    b. 3:3:3:1
    c. 1:7:7:1
    d. 1:1:1:1

24. **(LX)** Pea plants that are heterozygous for both yellow and round traits (genotype YyRr) are crossed with pea plants that are also heterozygous for both yellow and round traits (genotype YyRr) in a dihybrid cross. What is the ratio of yellow, round : yellow, wrinkled : green, round : green, wrinkled peas from the resultant cross if yellow and round are dominant traits and green and wrinkled are recessive traits? **(TB#4)**
    a. 9:3:3:1
    b. 3:3:3:1
    c. 1:7:7:1
    d. 1:1:1:1

25. **(LX)** A flower that is heterozygous for 3 traits (genotype XxYyZz) is crossed with itself. What fraction of the resultant flowers is expected to be homozygous for at least 1 (1 or more) of the 3 alleles? (e.i. XXYyZz is homozygous for 1 allele, xxYYZz is homozygous for 2 alleles, XXyyzz is homozygous for 3 alleles, etc.)
    a. 1/16
    b. 1/8
    c. 7/8
    d. 15/16

26. **(LX)** Manx cats carry a gene that can result in a stubby tail. The dominant allele, S, results in a stubby tail but is lethal when homozygous (SS) and the recessive allele, s, results in a normal tail and healthy cat. If 2 Manx cats with stubby tails (genotypes Ss) are crossed, what is the phenotypic ratio of the surviving progeny (normal tail : stubby tail)?
    a. 3 : 1
    b. 1 : 3
    c. 1 : 2
    d. 2 : 1

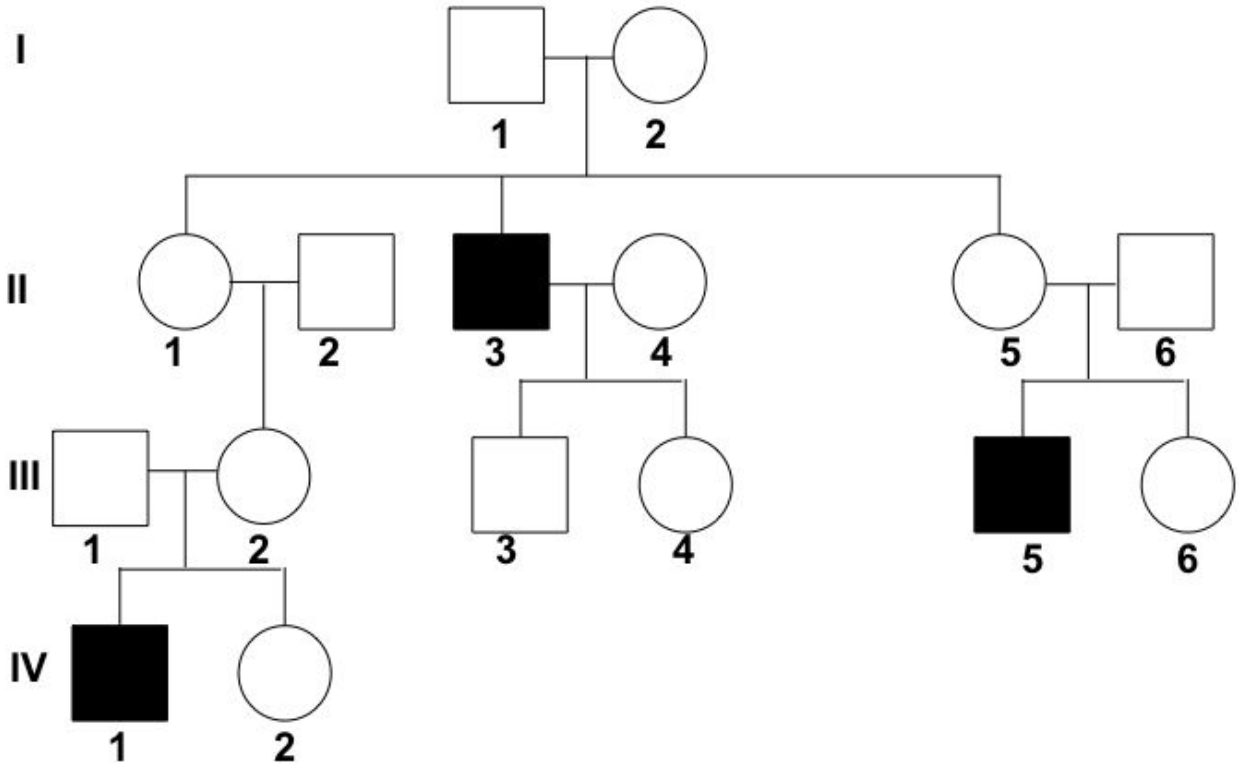
Use the following human pedigree to answer questions 27-28.



27. **(LX)** What pattern of inheritance is depicted in the human pedigree?
    a. Autosomal dominant
    b. Autosomal recessive
    c. X-linked dominant
    d. X-linked recessive

28. **(LX)** Which disease follows this pattern of inheritance?
    a. Hemophilia
    b. Sickle cell anemia
    c. Cystic fibrosis
    d. Polydactyl

Use the following human pedigree to answer questions 29-30.



29. **(LX)** What pattern of inheritance is depicted in the human pedigree?
    a. Autosomal dominant
    b. Autosomal recessive
    c. X-linked dominant
    d. X-linked recessive

30. **(LX)** Which of the individuals in Generation III must be heterozygotes? **(TB#5)**
    a. 1 and 2
    b. 3 and 4
    c. 1, 2, 3, and 4
    d. 1, 2, 3, 4, and 6

31. **(JG)** Which of the following enzymes would be considered an exonuclease?
    a. DNA Polymerase I
    b. Helicase
    c. EcoRI
    d. Primase

32. **(AG)** Mitochondrial and chloroplast genomes are organized similarly to that of most _____, because they consist of _____.
    a. Prokaryotes; multiple linear chromosomes
    b. Eukaryotes; multiple linear chromosomes
    c. Prokaryotes; one circular chromosome
    d. Eukaryotes; one circular chromosome
    e. Viruses; ssRNA

33. **(AG)** In humans, mitochondria exhibit _____ inheritance, so in each cell division, mtDNA segregates _____ into daughter cells.
    a. Cytoplasmic; randomly
    b. Nuclear; randomly
    c. Cytoplasmic; exactly equally
    d. Nuclear; exactly equally
    e. None of the above

34. **(AG)** A fully processed eukaryotic mRNA is 700 bp in length and encodes a single protein. How long is the resulting protein?
    a. Exactly 700 amino acids
    b. > 700 amino acids
    c. > 234 amino acids, but < 700
    d. < 234 amino acids
    e. Cannot tell based on the information provided

35. **(AG)** It is often useful to express a gene of eukaryotic origin in a prokaryotic cell. Which of the following statements is an adjustment that must be made to a eukaryotic gene for it to be successfully expressed in a prokaryotic cell?
    a. Change the start codon
    b. Change the promoter sequence
    c. Remove introns
    d. Change the stop codon
    e. None of the above

36. **(AG)** Why do promoter regions tend to be AT-rich sequences? **(TB#6)**
    a. The double bond between A-T pairs makes denaturing the DNA in that region easier
    b. The double bond between A-T pairs makes spontaneous denaturing of the DNA in that region less likely
    c. The triple bond between A-T pairs makes denaturing the DNA in that region easier makes spontaneous denaturing of the DNA in that region less likely
    d. The original promoter sequence was AT-rich due to random chance, so all subsequent promoters are also AT-rich

37. **(AG)** Which of the following mutations in an mRNA codon would have no effect in the resulting protein? Select all that apply for full credit.
    a. UUA --> UUG
    b. CUC --> CUU
    c. UGU --> UGA
    d. UCG --> UCA
    e. CAC --> UAC

38. **(AG)** Which of the following mutations in an mRNA codon would lead to a truncated protein product? Select all that apply for full credit.
    a. CAG --> UAG
    b. CAA --> UAA
    c. UAA --> UGA
    d. UAA --> UAG
    e. AUG --> AUC

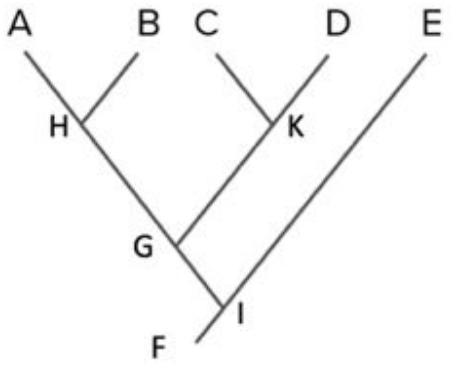
39. **(AG)** How many different mRNA sequences could produce the following polypeptide? **(TB#7)**

    Met-Trp-Gly-Phe

    Hint: Don't worry about the sequence required to terminate translation
    a. 1
    b. 2
    c. 4
    d. 8
    e. 16

40. **(AG)** If a eukaryotic organism encodes 10,000 genes, how many unique proteins can be produced in the cell?
    a. Exactly 10,000
    b. More than 10,000, alternative splicing can produce multiple different proteins from the same coding region
    c. More than 10,000, all genes produce many unique proteins
    d. Less than 10,000, alternative splicing truncates coding regions
    e. Less than 10,000, most of these genes are noncoding

Use the following image of a rooted phylogenetic tree to answer the next three questions



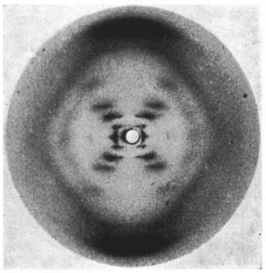
41. **(AG)** A and B are _____
    a. Paraphyletic
    b. Polyphyletic
    c. Monophyletic
    d. Aphyletic
    e. Diphyletic

42. **(AG)** Which gene(s) share(s) the most recent common ancestor with the clade formed by A and B?
    a. C
    b. D
    c. C and D
    d. E
    e. F

43. **(AG)** A and C come from the same organism and B and D also come from the same organism. _____ represents a common ancestor of the clade formed by A,B,C,and D, after which a _____ occurred. **(TB#8)**
    a. G, deletion
    b. K, deletion
    c. I, deletion
    d. G, duplication
    e. I, duplication

44. **(SL)** DNA does not contain which of the following?
    a. Carbon
    b. Hydrogen
    c. Nitrogen
    d. Sulfur
    e. Oxygen
    f. Phosphorus

45. **(SL)** What does this famous image depict?



a. RNA
b. DNA
c. Polypeptide
d. ATP
e. Fatty acid

46. **(SL)** The image in #47 was taken using which method?
    a. DNA microscopy
    b. X-ray crystallography
    c. TEM microscopy
    d. Microarray
    e. Southern blot

47. **(SV)** There are two types of transcriptional termination in prokaryotes: rho-independent (intrinsic) termination and rho-dependent termination. Determine which transcriptional termination type described in the following statements is **rho-dependent**. **(TB#9)**
    a. Hairpin formation causes RNA polymerase to pause due to the interaction of associated Nus A protein with stem-loop structure.
    b. mRNA molecule contains a sequence of base pairs with a high proportion of C and G bases capable of forming an RNA duplex.
    c. Hexameric rho protein recognizes and binds to a specific recognition sequence in the growing mRNA strand.
    d. Frequent mechanism in cis-acting RNA regulatory elements (e.g. riboswitches).

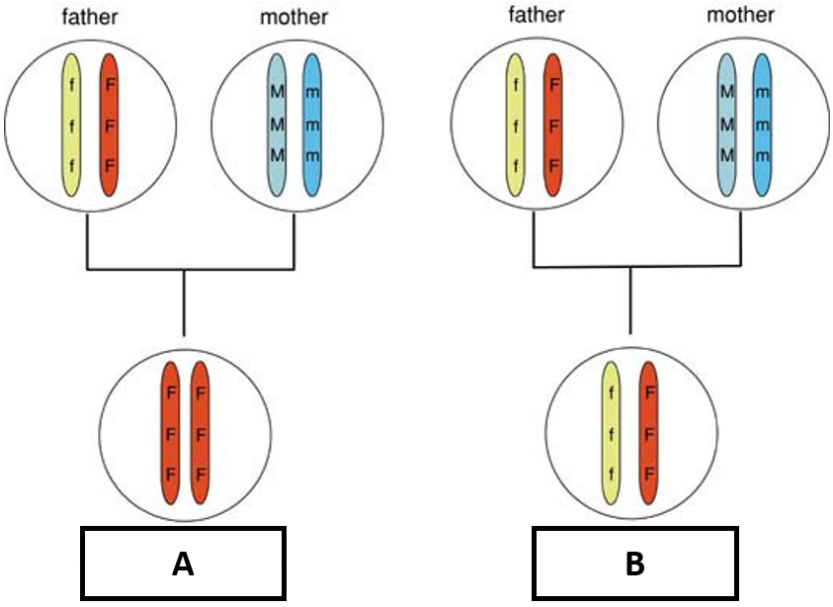
II. Short Answer (68 pts)

Directions: Answer the following questions in the most concise and specific way possible. Complete sentences are **not** required for this section. Point values will be designated for each question.

1. **(SV)** Base excision repair (BER) is an example of a DNA repair mechanism. Answer the following questions regarding BER. **(6 total)**
    a. This repair process is mainly active in which phase of the cell cycle? **(1)** G1
    b. **True or False:** BER does not correct alkylation and abasic single base damage. **(1)** False
    c. What occurs after chromatin remodeling at the DNA damage site? **(2)** lesion recognition (1) by a DNA glycosylase (1)
    d. In short patch repair, what is the substrate for the AP endonuclease (APE1 in humans)? *(Hint: APE1 generates a -OH residue at the 3'-end and leaves a dRP at the 5'end).* **(2)** abasic site

2. **(SV)** Due to the characteristics of CRISPR-Cas systems, they are utilized in genetic editing and engineering. Answer the following questions regarding CRISPR-Cas technologies. **(10 total)**
    a. There are different types of CRISPR-Cas systems. Which type(s) use(s) multiprotein interference modules to facilitate target recognition? **(2)** I (1) and III (1)
    b. What complex, when paired with appropriately spaced target sites, can mimic targeted double-stranded breaks through cooperative nicks? **(2)** Cas9 nickase complexes
    c. Infer why truncating sgRNAs by 2-3 nt increases SpCAs9 targeting specificity. **(2)** greater mismatch sensitivity
    d. Infer how dCas9 represses transcription when binding to DNA elements. **(4)** sterically hindering RNA polymerase machinery (2), stalling transcriptional elongation (2)

3. **(KH)** Chromosomal abnormalities in germ cells commonly result from errors during meiosis. **(8 total)**



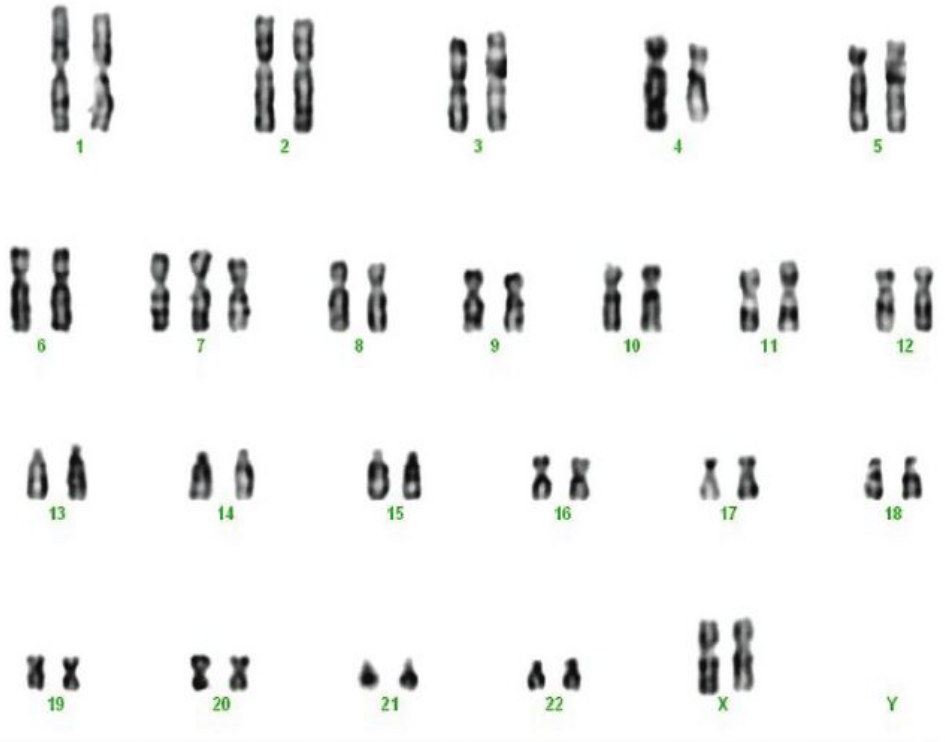
   a. Name the event that occurs when a person receives two copies of a chromosome, or of part of a chromosome, from one parent and no copy from the other parent. Name this event. **(2)** Uniparental Disomy
   b. Name the event that resulted in the gamete labeled "A" in figure 1. **(2)** Uniparental isodisomy
   c. When did nondisjunction occur to produce the gamete in "A"? **(1)** Meiosis II
   d. Name the event that resulted in the gamete labeled "B" in figure 1. **(2)** Uniparental heterodisomy
   e. When did nondisjunction occur to produce the gamete in "B"? **(1)** Meiosis I

4. **(KH)** Suppose that in martians, gene S codes for skin color and gene H codes for hair color. The superscript "R" denotes red, "B" denotes blue, and "Y" denotes yellow. A male martian with genotype $S^RS^RH^RH^B$ and female martian with genotype $S^YS^RH^BH^Y$. Gene S exhibits codominance and gene H exhibits incomplete dominance. Assume mendelian inheritance. **(8 total)**
   a. What color is the male martian's hair? **(1)** Red and blue
   b. What color is the female martian's skin? **(1)** Orange
   c. The male and female have a child. What is the chance that the child's skin is red? **(3)** 75%
   d. What is the chance that the child's hair is only yellow? **(3)** 0%

5. **(CW)** Consider a population of plants with a variety of flower colors: red, yellow, blue, and green. Flower color is controlled at a single locus, with one allele for each possible color: *R*, *B*, and *Y*, respectively. These alleles exhibit a linear dominance hierarchy where *R* > *B* > *Y* (i.e. *R* is dominant to *B* and *Y*, and *B* is dominant to *Y*). **(12 total)**
    a. What is the phenotypic ratio of the offspring when an *R* plant is crossed with an *RY* plant? **(2)** 3 red : 1 blue
    b. Two plants are crossed, and red-flowered, blue-flowered, and yellow-flowered plants are all observed among the offspring. What are the genotypes of the parental plants? **(2)** *RY* and *BY* (order doesn't matter)
    c. Now suppose that the three alleles form a circular dominance hierarchy such that *R* is dominant to *B*, *B* is dominant to *Y*, and *Y* is dominant to *R*. What is the phenotypic ratio of the offspring if a heterozygous red plant is crossed with a homozygous yellow plant? **(4)** 1 blue : 1 yellow
    d. Finally, suppose that none of the alleles are dominant over one another, but rather that a plant with two different alleles has flowers whose colors are a "blend" of the two primary colors. *RB* plants have purple flowers, *BY* plants have green flowers, and *YR* plants have orange flowers. When two plants are crossed, 25% of the offspring have green flowers and 25% of the offspring have blue flowers. What are the phenotypes of the parental plants? **(4)** green and purple (order doesn't matter)

6. **(LX)** Consider a population of plants with a variety of flower colors: white, red, and purple, where flower color is dependent on two pigmentation genes, *A* and *B*, each of which has 2 alleles. If gene A (AA or Aa) encodes an enzyme to turn a white flower red (e.i. aabb is white, and Aabb is red), and if gene B (BB or Bb) encodes an enzyme to turn a red flower purple (e.i. AABB is purple, aaBB is white), determine the phenotypic results of the following flower crosses. **(8 total)**
    a. Cross 1: A white flower line (white1, genotype aaBB) is crossed with a purple flower line (genotype AABB), producing an F1 generation of all purple flowers (genotype AaBB). What is the phenotypic ratio (purple : red : white) of the offspring when these F1 flowers are self-crossed? **(2)** 3 : 0 : 1
    b. Cross 2: A white flower line with a different genotype (white2, NOT aaBB) is crossed with a purple flower line (Genotype AABB), producing an F1 generation of all purple flowers. These F2 flowers are self-crossed, producing an F2 generation with the phenotypic ratio 9 purple : 3 red : 4 white. What is the genotype of the F1 generation of all purple flowers? **(4)** AaBb
    c. Cross 3: If you cross the white flower line in cross 1 (white1, genotype aaBB) and the white flower line in cross2 (white2), what is the resultant genotype of the F1 generation? **(2)** aaBb

7. **(LX)** Answer the following questions pertaining to the image of human chromosomes shown below: **(8 total)**



a. What is the name for this type of image? **(1)** Karyotype
b. Which chromosome has an abnormality? What is the type of abnormality? **(1)** Chromosome 7 trisomy
c. Is the human's sex female or male? **(1)** Female
d. If the human had an additional Y chromosome, what syndrome would they have? **(1)** Klinefelter syndrome
e. If the human had an X chromosome removed, what syndrome would they have? **(1)** Turner syndrome
f. What chromosome is associated with Down syndrome? **(1)** 21
g. What chromosome is associated with Edwards syndrome? **(1)** 18
h. What chromosome is associated with Patau syndrome? **(1)** 13

8. **(SL)** You work at a blood donation center. The nearby hospital is asking for your assistance to supply blood to some of their clients in need of it. **(8 total)**
    a. True or false: A donor with Type AB blood can only donate to clients with AB blood. **(1)** True
    b. True or false: A donor with Type O blood can only donate to clients with O blood. **(1)** False
    c. You have a shortage of Type AB blood and a relatively high demand from clients that are originally Type AB. If it is possible to use another type to supply the remaining clients who don't receive AB blood, what types would you be able to give? **(2)** A, B, and O
    d. There was also a case of a premature birth at the hospital. The baby is severely underdeveloped, so the doctors decided to not attempt a blood test due to the possibility of exsanguination. They determine that the baby may need a blood transfusion as soon as possible, though. The parents' records say they are Type A and Type B. What are all the possible blood types the baby could have? **(2)** All of them - A, B, AB, and O
    e. For the case in part (d), which type of blood would be the best type to bring for the transfusion? **(2)** Type O