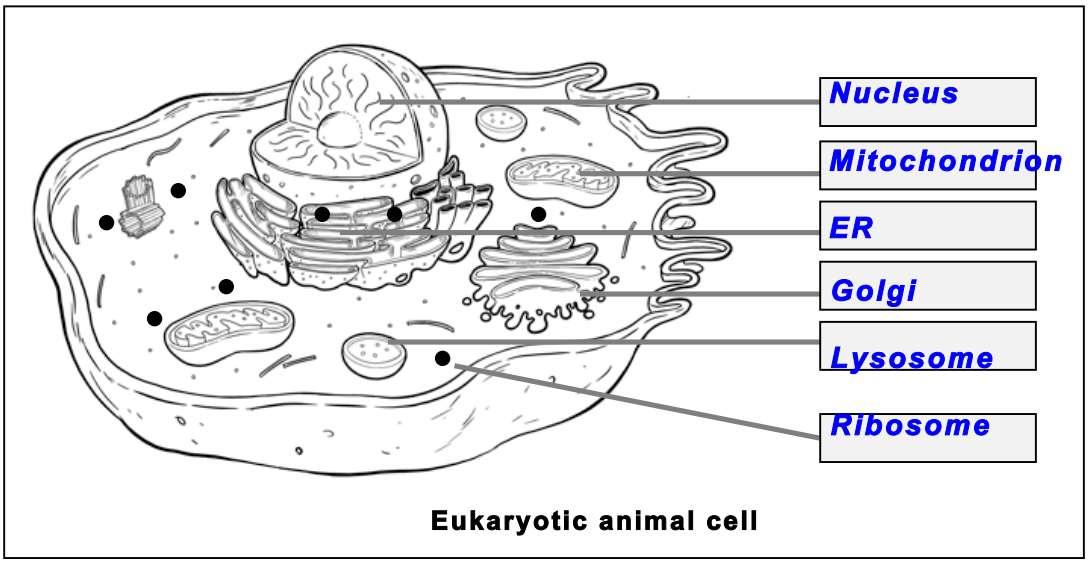
Solution key- 7.016 Problem Set 3- 2018

Question 1 (6pts)

a) The following is the schematic of a **eukaryotic animal cell**. Use the following keywords to fill in the boxes**:** *Ribosome, Nucleus, Lysosome, Endoplasmic reticulum (ER), Golgi apparatus, mitochondrion. (3pts or 0.5 each)*



Eukaryotic animal cell

b) The human microbiome is a collection of different bacteria, viruses and other microorganisms that inhabit us and form a micro ecosystem. Circle **ALL** correct for options for each of the following.

i. Which of the given options are self-replicating cells: **Bacteria/ viruses/ skin cells**? *(0.5 or 0.25 each)*

ii. Which of the given options are prokaryotic cell: **Bacteria/ viruses/ skin cells**? *(0.5)*

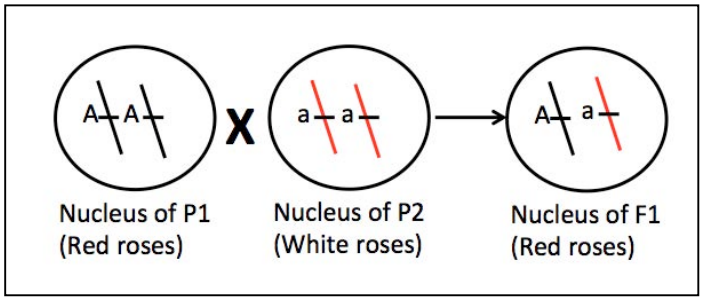
iii. Which of the given options contain membrane bound subcellular organelles: **Bacteria/ viruses/ skin cells**? *(0.5)*

c) Identify the organelle within a human cell that generates energy in the form of ATP: **Mitochondrion** *(0.5)*

d) According to the endosymbiotic theory, the organelle that you identified in part (c) is often regarded as a prokaryotic cell that was engulfed by a eukaryotic cell during the course of evolution. List **two features** of this organelle that characterize it as likely to have been derived from a prokaryotic cell.
Note: *Your answers may vary.*
Mitochondria have a double membrane and they have a circular genome just like bacteria. This reflects that they arose from symbiosis where one small cell was engulfed by a bigger cell and both cells persisted in a symbiotic relationship. Mitochondria also have their own ribosomes, which are similar to bacterial ribosomes. Furthermore, the size of a mitochondrion is almost the same as the size of bacteria. (1pt or 0.5 for each reason)

Question 2 (4pts)
After receiving many bouquets of flowers on your high school graduation day, you become very interested in studying the traits of different plants. You decide to study petal color (red or white) in a variety of rose plants. Gene A regulates this trait.

a) You cross the P1 and P2 plants, which have the following genotypes. You obtain 100 F1 all of which have red roses. On the diagram below, draw the chromosomes and fill in the genotypes of F1 plant.



(1)

b) You cross two **F1 plants** and obtain 100 plants in the F2 generation.

i List the **genotypes and corresponding ratios** of the F2 plants for petal color.

Genotype(s) and corresponding ratios: ***AA (1): Aa(2): aa(1)***
(0.5, 0.25 for genotypes and 0.25 for ratio)

ii List the **phenotypes and corresponding ratios** of the F2 plants for petal color.

Phenotype(s) and corresponding ratios: ***Red roses(3) : White roses(1)***
(0.5, 0.25 for phenotypes and 0.25 for ratio)

c) You want to determine whether a red rose plant is homozygous or heterozygous for the alleles of Gene A. You therefore subject it to a test cross.

i. Give the genotype and the phenotype of the plant you would use in the test cross with the red rose plant.

Genotype: ***aa*** *(0.25)*

Phenotype: ***White roses*** *(0.25)*

ii. If the red rose plant was **homozygous** for the allele A of Gene A, what would be the…

- **Genotype(s) and ratio** of the resulting plants: ***Aa*** *(0.25)*
- **Phenotype(s) and ratio** of resulting plants: ***Red roses*** *(0.25)*

iii. If the red rose plant was **heterozygous** for the allele A of Gene A, what would be the…

- **Genotype(s) and ratio** of the resulting plants: ***Aa (1); aa (1)*** *(0.5)*
- **Phenotype(s) and ratio** of resulting plants: ***Red roses (1): White roses (1)*** *(0.5)*

Question 3 (6pts)
In a variety of tulips, Gene D regulates the leaf shape and Gene H regulates flower color. **Gene D and Gene H are located on different autosomes.**

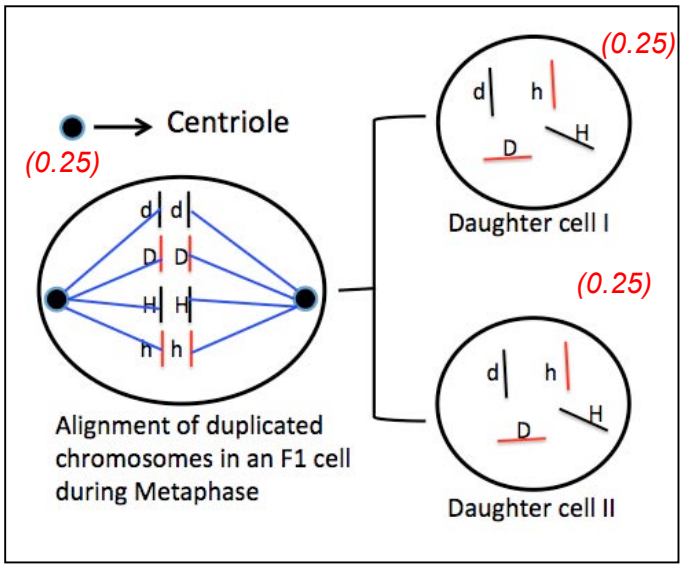
a) You cross **true-breeding** P1 (**narrow leaves/ blue tulips)** and P2 **(wide-leaves/ white tulips)** plants to get the F1 plants (**wide-leaves/ blue tulips)**. Using **"D" or "H"** for the allele for the dominant phenotypes and **"d" or "h"** for the alleles for the recessive phenotype, give the genotypes of…

i. True breeding **P1 plant** (**narrow leaves/ blue tulips): *ddHH*** *(0.5)*

ii. True breeding **P2 plant (wide-leaves/ white tulips): *DDhh*** *(0.5)*

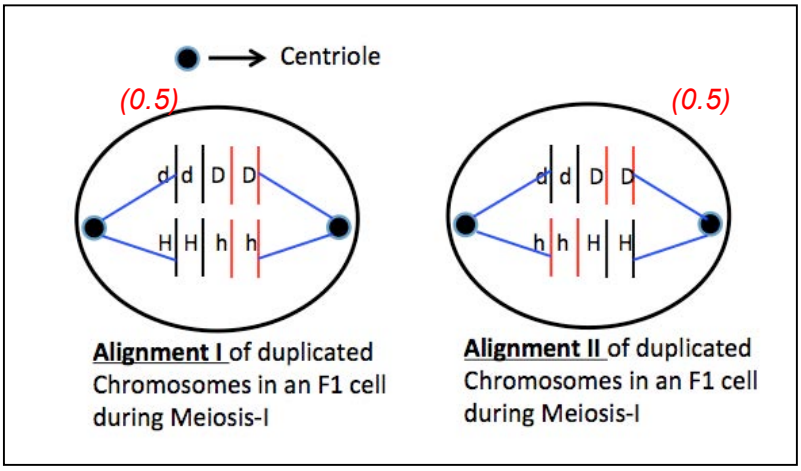
iii. F1 progeny (**wide-leaves/ blue tulips): *dH/ Dh*** *(0.5)*

b) On the schematic below, draw the alignment of replicated chromosomes during **metaphase of MITOSIS** of **an F1 cell** and in the resulting daughter cells and show the arrangement of the alleles of Genes D and H on their corresponding chromatids.



c) If an F1 germ cell (reproductive cell) undergoes **MEIOSIS…**

i. Draw the **TWO** possible alignments of replicated chromosomes **during Metaphase of Meiosis–I** on the schematic below. Only show the chromatids carrying the alleles of Genes D and H.



ii. Give the **genotypes** and the **corresponding ratios** of the gametes produced as per….

Alignment I: *dH, Dh, dH, Dh* *(0.5)*

Alignment II: *dh, dh, DH, DH* *(0.5)*

Question 3 continued

d) You have two plants that have narrow leaves. An enzyme whose normal function is to make wide-leaves regulates the leaf shape. Do you know for certain that the two narrow leafed plants have the same allele of the gene encoding this enzyme? **Why or why not?** How would you determine if they have the same alleles?*An allele is a variant of a gene. So there can be multiple variants/ alleles of the same gene in a population. (0.25)* ***1.*** *If the plants had the same allele they should breed true each time they are crossed* ***2.*** *You can also do recombination test or complementation assay to identify if there are same or different variants of the genes* ***3.*** *You can simply sequence the alleles of the genes to see if there are same or not. (0.25 for a reasonable test)*

e) You cross an F1 plant with another plant that is homozygous recessive for the alleles of both Gene D and Gene H. You obtain 400 F2 progeny. Fill in the table below for F2 progeny based on the assumption that the two genes assort independently. *(0.25 for each row, all or none)*

Genotypes?	Corresponding phenotype?	Corresponding estimated number?
dH/dh	*Narrow leaves/ blue tulips*	*100*
Dh/dh	*Wide leaves/white tulips*	*100*
dh/dh	*Narrow leaves/ white tulips*	*100*
DH/dh	*Wide leaves/ blue tulips*	*100*

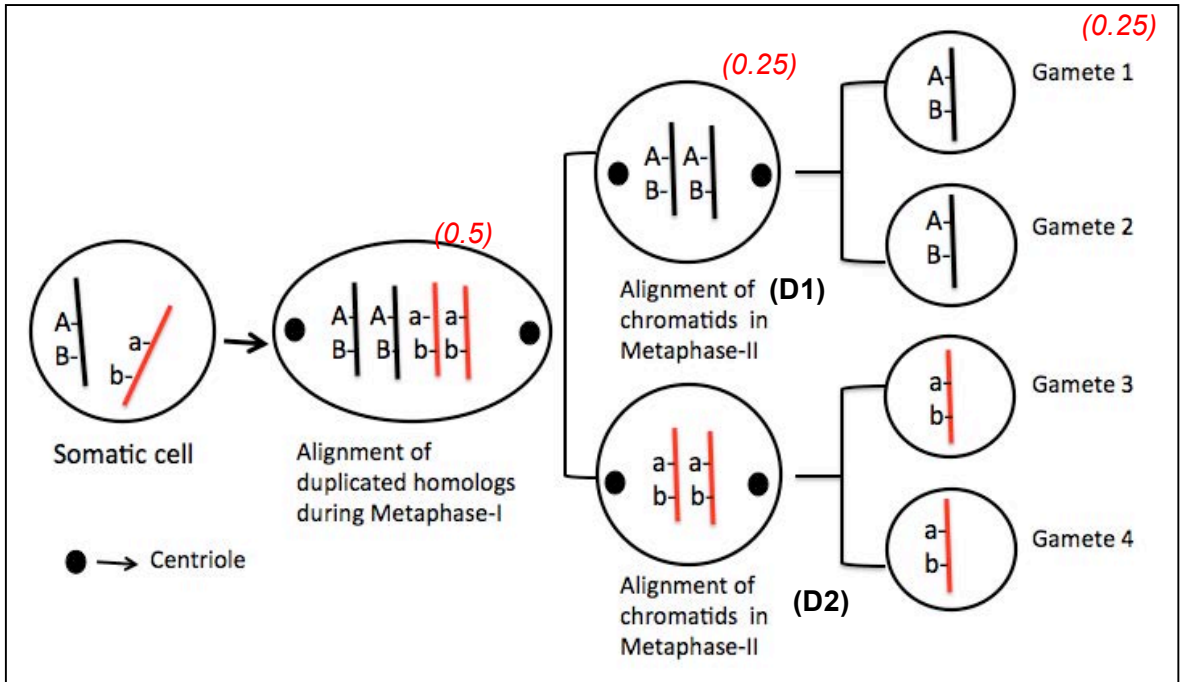
f) You also cross two F1 plants to each other and obtain 1600 F2 plants. How many F2 plants will have **narrow leaves and blue tulips**?

Since the two genes are located on TWO different autosomes they will assort independently as per Mendel's law and the ratio of wide-leaves, blue color/ wide-leaves, white color/ narrow leaves, blue color/ narrow leaves, white color in the ratio of 9: 3: 3: 1. So you will have 3/16X 1600 = 300 F2 that will have narrow leaves and blue tulips. (0.25)

Question 4 (2pts)

The following schematic represents a **F1** germ cell (reproductive cell).

a) If the F1 (germ cell) undergoing **MEIOSIS,** draw the alignment of replicated chromosomes **during Meiosis** on the schematic below. Also show the arrangement of the alleles of Genes A and B on **all** the chromatids. ***Note:*** *Assume NO recombination / NO crossing over.*



Question 4 continued

b) Trisomy of Chromosome 21 in humans can result in Down's syndrome, an inherited genetic disorder. If the "daughter cell 1 (D1)" in part (a) undergoes **nondisjunction** of chromosome 21 during Metaphase II, give the possible genotypes of the gametes that would result if **NO recombination** occurs between the alleles of **genes A and B**. ***Note:*** *Answers may vary based on the drawing in part (a).* *(0.5)*

Gamete 1: ABAB, Gamete 2: Null for the alleles of A and B genes, Gamete 3: ab, Gamete 4: ab

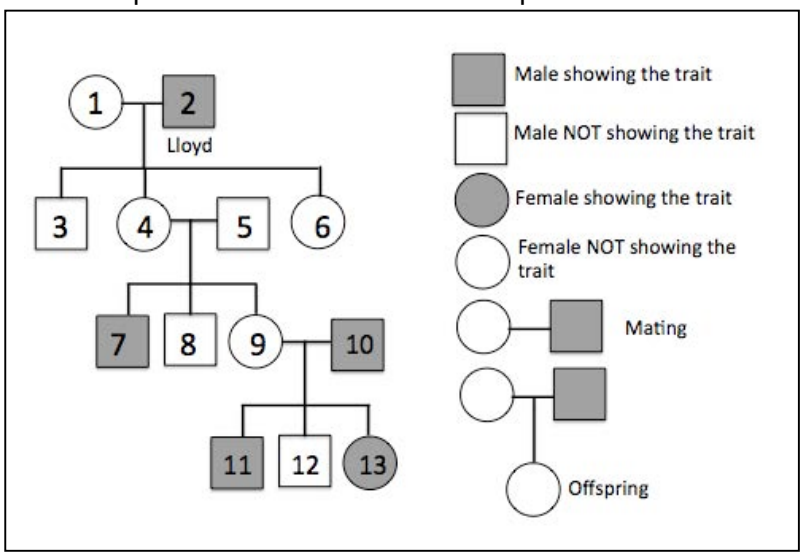
c) Could the nondisjunction events such as the one described in part (b) account for genetic disorders such as Trisomy 21? **Why or why not?**

Yes, if the gametes (such as Gamete 1 above) that have disomy of chromosome 21 fuse with a normal male gamete, the resulting fertilized ovum will show trisomy of chromosome 21 resulting in Downs syndrome. *(0.5)*

Question 5 (2pts)

During your trip from Boston to San Francisco you realize that you are sitting next to Charlie Bean, the Director of Ninjago movie. Being a big Ninjago fan you start chatting with the director who surprisingly enough is willing to answer your questions!

During the conversation the director says the upcoming movie will have the next generation of spinjitzu masters (the trait) starting with Lloyd and his wife. He shows you the following pedigree for which more than one specific mode of inheritance is possible.



If this pedigree is true, does the inheritance of spinjitzu (trait) show an….

a) Autosomal dominant mode of inheritance? If not, give one possible explanation. *(0.25 for explanation)*
No, since 7 has the trait but his parents don't. For a pedigree to show this inheritance, each affected child should have at least one affected parent.

b) Autosomal recessive mode of inheritance? If not, give one possible explanation. *(0.25 for explanation)*
Yes, assuming 4, 5 and 9 are carriers (genotype= Aa), you can explain the genotype of 7, 11, and 13 (genotype= aa)

c) X-linked dominant mode of inheritance? If not, give one possible explanation.
No, for this mode of inheritance the daughters of each affected father should be affected since they get one X chromosome from each parent. This is not the case here since #2 is affected but his daughter (#4) is not. *(0.25 for explanation)*

d) X-linked recessive mode of inheritance? If not, give one possible explanation.
Yes, assuming both 4 and 9 are carriers (genotype = X^AX^a) you can explain the genotype of number 7, 11 and 13. *(0.25 for explanation)*

Question 5 continued

e) Using uppercase **"A or X^A"** as the allele for the dominant phenotype and **"a or X^a"** as the allele for the recessive phenotype give the genotype of **Individual 9** for each possible mode of inheritance for this pedigree.

Per the autosomal recessive mode the genotype for Individual 9 is "Aa". (0.25)

Per the X-linked recessive mode the genotype for Individual 9 is "X^AX^a". (0.25)

f) Give **two reasons** why you use model animals such as plants, fruit flies, worms or yeast as opposed to humans to study if a specific gene is inherited as per Mendel's laws of inheritance. ***Note:*** *Your answers may vary. (0.5)*

Multiple possible answers: The model organisms are easy to manipulate, they give faster results so many generations can be studied to track the inheritance pattern, there are fewer ethical concerns.

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