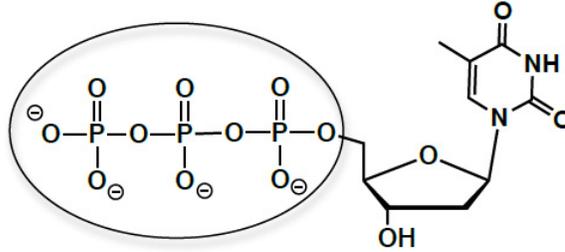


Solution Key- 7.016 Problem Set 2

Question 1

The following diagram represents a nucleotide that serves as a monomer for nucleic acids.



a) Would you classify the nitrogenous base in this nucleotide as Purine or Pyrimidine?

It is a pyrimidine base since it has one ring structure unlike purine bases that have two carbon rings as a part of their structure.

b) Would you classify this nucleotide as a monomer for DNA or RNA? **Explain.**

It is a DNA monomer since it has deoxyribose sugar i.e. its sugar lacks the -OH group at the 2'C position.

c) Assume that this monomer is added to the growing end of a nucleic acid polymer.

i. **Circle** the group(s) of this monomer that participates in forming a covalent bond with the end of the polymer.

ii. Name the **covalent bond** that will be formed between the nucleic acid polymer and the incoming nucleotide. *Phosphodiester bond*

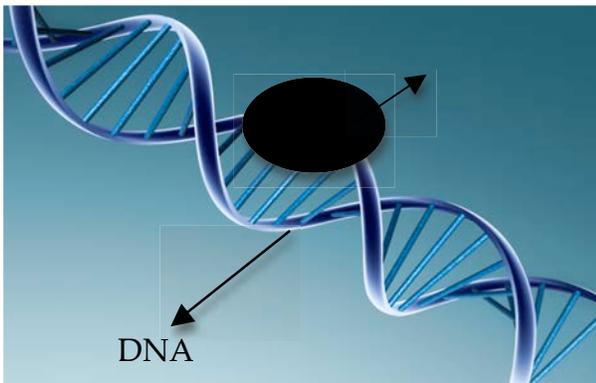
d) If the monomer drawn above comprises 28% of a double-stranded nucleic acid, predict the percentages of each of the three remaining nucleotides present in the double stranded nucleic acid.

As per Chargaff's complementary base pairing rule, dTTP pairs with dATP by forming 2 hydrogen bonds and dCTP pairs with dGTP by forming three hydrogen bonds. Since the base shown in the schematic above is dTTP (28%), the % of remaining bases in the DNA duplex will be: dATP (28%), dGTP (22%) and dCTP (22%).

e) You compare the double-stranded nucleic acid containing 28% of this monomer to another double-stranded nucleic acid that is of the same length but contains 10% of this monomer. Which double-stranded nucleic acid would denature at a lower temperature, the one containing 28% or the one containing 10% of this monomer? **Explain.**

The DNA duplex with 10% dTTP will have 10% dATP, 40% dGTP and 40% dCTP. Therefore the number of hydrogen bonds in the DNA duplex will be more and it will denature at a much higher temperature compared to the DNA duplex that has 28% dTTP and therefore has fewer hydrogen bonds.

f) The following is a schematic of a DNA– protein complex.



Circle the amino acid residue within this DNA binding protein that can potentially form ionic bonds with DNA. **Explain** why you selected this option. *Please note: A chart of amino acids was given on the last page of Problem set 1.*

Serine
Glutamic acid

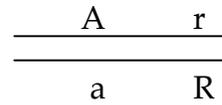
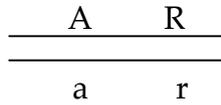
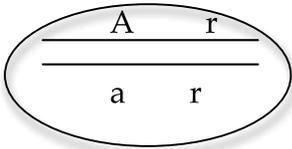
Tryptophan
Lysine

Lysine has a positively charged side-chain that can form ionic bonds with the negatively charged phosphates of the sugar phosphate backbone of DNA duplex.

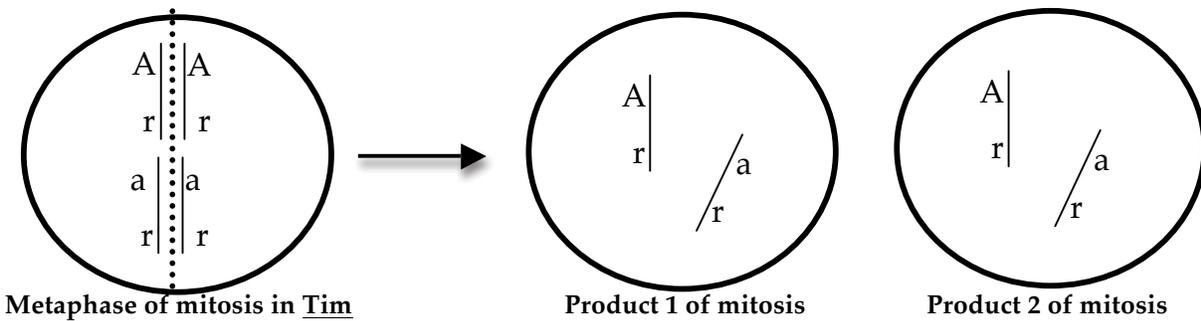
Question 2

Both Tim and his father are carriers for Wilson's disease (Aa) and suffer from Rotor's syndrome (rr). Tim's mother suffered from rotor's syndrome (**Genotype:** AArr). Assume that the genes involved in these disorders are located on chromosome 13.

a) From the following, **circle** the option that gives the correct representation of Tim's genotype.

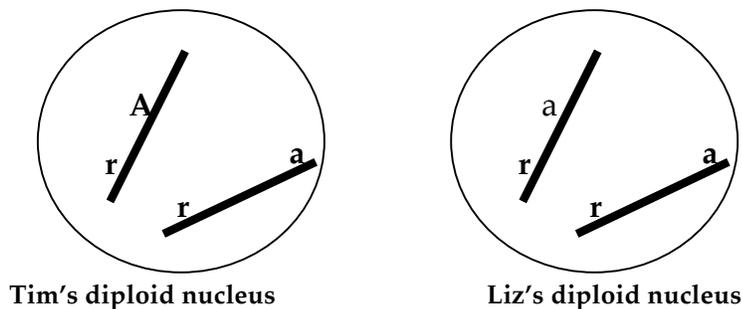


b) If a **somatic cell** from Tim undergoes **mitosis**, draw and align the copies of chromosome 13 as they would be during **metaphase** of the dividing cell. Then draw the copies of chromosome 13 in each of the two products (Product 1 and Product 2) resulting from mitosis. Include the A, a, R, and r alleles on all the chromatids in each drawing below.



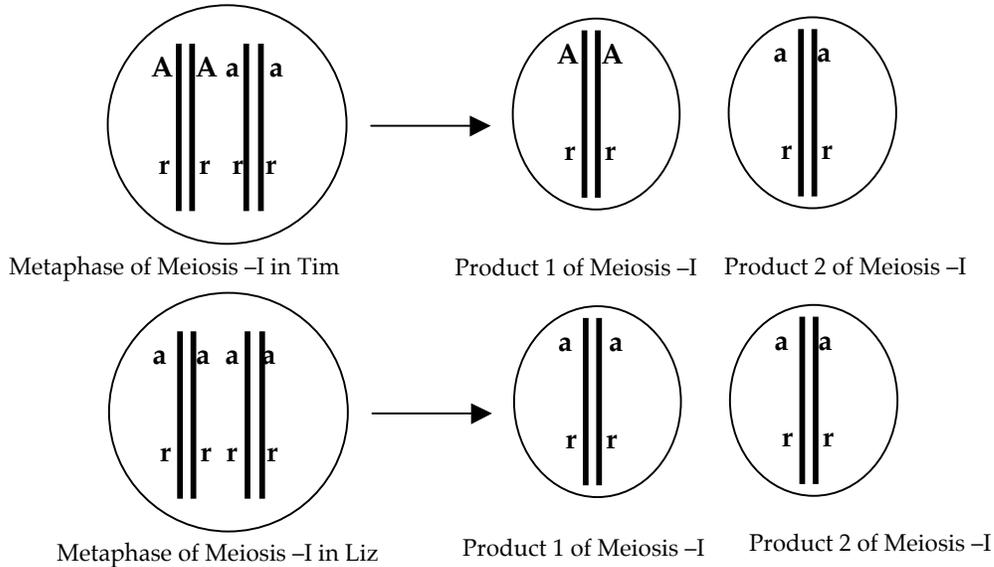
c) Tim meets Liz who suffers both from Wilson's disease (aa) and rotor's syndrome (rr). Together they have a daughter, Amy, who also suffers from both Wilson's disease and Rotor's syndrome.

i. A schematic of two diploid nuclei prior to DNA replication is drawn below. For simplicity, only the two copies of chromosome 13 are shown below. Add the A, a, R and r alleles on the schematics below.

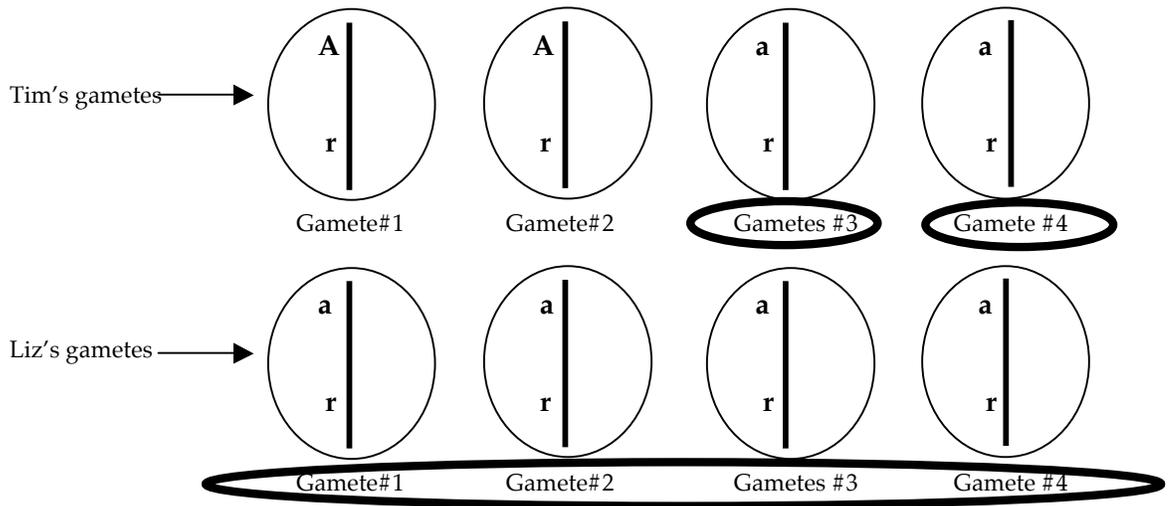


Question 2 continued

- ii. Draw and align the copies of chromosome 13 as they would be during **metaphase of meiosis I** for Tim and Liz. Then draw the copies of chromosome 13 in each of the two products (Product 1 and Product 2) resulting from meiosis I. Include the A, a, R, and r alleles on all the chromatids in each drawing below and assume that **NO recombination** has occurred.



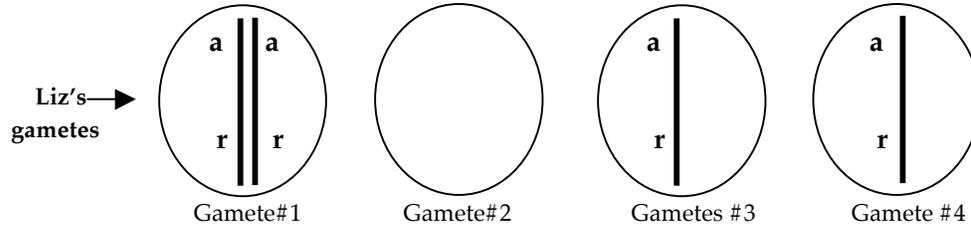
- iii. Based on your drawing and alignment of alleles in part (c) (ii) draw the copies of chromosome 13 in the nuclei of the four gametes that will be produced during meiosis II. Include the respective A, a, R, and r alleles on each drawing below.



- iv. On the schematic in part (iii), circle **any two gametes** that could have fused during fertilization to produce Amy.

Question 2 continued

d) Now assume that **non-disjunction** occurs between the product 1 during meiosis II in Liz. Meiosis 1 proceeds normally with no error. Draw the arrangement of alleles on chromosome 13 in the nuclei of the four gametes that will be produced **after meiosis II** and state their genotypes.



Question 3

As a UROP student working in a genetics lab you are asked to study fur color in hamsters. You do the following mating experiments.

- **Experiment 1:** You mate a female hamster that has black fur (P1) with a male hamster that has white fur (P2). You get 40 hamsters in the F1 generation of which half have black and the other half have white fur.
- **Experiment 2:** You mate two F1 hamsters (obtained from experiment 1) that have black fur. You get 40 hamsters in the F2 generation of which 30 have black fur and 10 have white fur.
- **Experiment 3:** You mate two F1 hamsters (obtained from experiment 1) that have white fur. You get 40 hamsters in F2 generation all having white fur.

a) Give **ALL** the possible genotypes of the **P1 and P2 hamsters** based **only on experiment 1**. *Note: Use the letters "A" and "a" for the alleles that regulate fur color. Use the uppercase letter to represent the allele associated with dominant phenotype and the lowercase letter to represent the allele associated with the recessive phenotype. Assume that this trait is regulated by one gene that is located on an autosome.*

P1 hamsters: *Aa* P2 Hamster: *aa*

b) Give **ALL** the possible genotypes of the **F1 hamsters** based on experiments 1-3.

Hamsters with **black** fur: *Aa* Hamsters with **white** fur: *aa*

c) Give **ALL** the possible genotypes of the **F2 hamsters** based on experiments 1-3.

Hamsters with **black** fur: *AA, Aa* Hamsters with **white** fur: *aa*

d) Give **ALL** the possible genotypes and the corresponding ratios of the F2 hamsters resulting from **Experiment 2**.

Genotypes	Corresponding Ratio
<i>AA</i>	<i>1/4</i>
<i>Aa</i>	<i>1/2</i>
<i>aa</i>	<i>1/4</i>

e) Based on the results of experiments 1- 3, **circle is the dominant trait** for fur color (*black* / *white*).

Question 4

You are studying eye color in a specific variety of fish. You may assume that eye color is regulated by one gene. *Note: In each case, use the uppercase "E" for the allele associated with the blue eye color and the lowercase "e" for the allele associated with white- eye color.*

a) For this part of the question you may assume that the **gene regulating this trait is on an autosome**. For each set of data below, fill in the genotypes of the Fish in F0, F1 and F2 generation.

F0 cross: Blue-eye fish EE X white- eye fish ee



100 pale-blue-eye color fish in F1 Ee

F1 cross: Pale- blue- eye fish Ee X Pale- blue- eye fish Ee



F2: 25 blue eye fish EE , 49 pale-blue eye fish Ee , 24 white eye fish ee

b) For this part of the question you may assume that the **gene regulating this trait is on the X chromosome**. For each set of data below, fill in the genotypes of the Fish in F0, F1 and F2 generation.

F0 cross: Blue-eye male fish $X^E Y$ X white- eye female fish $X^e X^e$



<u>100 Fish in F1</u>	Genotype(s)	Corresponding phenotype(s)	Approximate number(s)
Male	$X^e Y$	White	50
Female	$X^E X^e$	Pale blue	50



F1 male $X^e Y$ X F1 female $X^E X^e$



100 fish in F2

Fish in F1	Genotype(s)	Corresponding phenotype(s)	Approximate number(s)
Male	$X^E Y, X^e Y$	Blue, white	25 each
Female	$X^E X^e, X^e X^e$	Pale blue, white	25 each

c) Choose the **best option** from the choices below.

- Blue eye color is dominant to white eye color
- White- eye color is dominant to blue eye color.

- Eye color is an example of incomplete dominance.
- Eye color is an example of co-dominance.

Question 5

As you wait for the train at Kendall Square, you notice a peculiar pair of flies. You bring these flies back to your lab, observe them under the microscope and find that one of these flies is male and the other is female. Both flies have **light brown** body color and are **wingless**. You put these flies in a vial and few days later, you return to find that this vial is full of flies that are **light brown** and **wingless (P1)**. The two flies have mated and it turns out that they are **true breeding** for the alleles that determine these two traits i.e. body color and wing development!

You know that the genes regulating these two traits are located on autosomes. You decide to further characterize these genes. You mate a **P1** female fly with a **true breeding** male lab fly (**P2**) that is **dark brown** and has **normal wings** and find that **all F1 flies** are **light brown** and have **normal wings**.

a) Circle the **dominant phenotypes**. *Your choices are: light Brown, wingless, normal wings, dark brown.*

b) Give the genotypes of the following flies for the genes that regulate body color and wing development. *Indicate the alleles associated with dominant phenotypes by uppercase letters and alleles associated with recessive phenotypes by lowercase letters. Assume the genes for the two traits **assort independently**. Indicate the alleles for the body color by the letters "A" and "a" and the alleles for the wing development as "B" and "b."*

Genotype of P1 Fly: *AAbb* **Genotype of P2 Fly:** *aaBB* **Genotype of F1 Fly:** *AaBb*

c) You now take an F1 female fly and cross her with a true breeding **wingless** male fly that is **dark brown**. You then score **400** progeny. Assuming that the genes, which regulate these two traits **assort independently**, complete the table below for each type of progeny.

Genotypes	Phenotypes	Approximate Number of progeny of this type
<i>Abab</i>	<i>Light brown/ wingless</i>	<i>100</i>
<i>aBab</i>	<i>Dark brown/ normal wings</i>	<i>100</i>
<i>ABab</i>	<i>Light brown/normal wings</i>	<i>100</i>
<i>abab</i>	<i>Dark brown/wingless</i>	<i>100</i>

d) Now you mate two F1 flies and obtain 1600 F2 flies. If the genes for the two traits **assort independently**, in the table below, give the different phenotypes and their approximate number, which you would expect to obtain in F2.

Phenotypes	Approximate Number of progeny of this type
<i>Light brown/ normal wings</i>	<i>900</i>
<i>Dark brown/ normal wings</i>	<i>300</i>
<i>Light brown/ wingless</i>	<i>300</i>
<i>Dark brown/wingless</i>	<i>100</i>

Question 6

You are studying two characteristics in a specific variety of fish: color (*gray or blue*) and fin length (*short or long*). You may assume that each trait is regulated by one gene that has an autosomal location. You mate a **true-breeding** gray fish that has long fins (P1) with a **true-breeding** blue fish that has short fins (P2). All of the resulting fish in F1 are Gray and have short fins. *Note: In each case, use the uppercase letter for the allele associated with the dominant phenotype and the lowercase letter for the allele associated with the recessive phenotype. For the fish color (i.e. gray or blue) use D or d to designate the alleles. For fins length (i.e. long or short) use G or g to designate the alleles.*

a) Circle the **dominant traits** (Gray, Blue, Long fins, Short fins).

b) You then mate an F1 fish with a **true breeding** fish that is blue and has long fins. You obtain 1000 fish in F2.

- i. Assuming that the genes regulating these two traits are **absolutely linked**, give all possible genotypes, phenotypes and approximate number of the fish in each class that you obtain in F2.

Phenotype of the fish in F2	Genotype of the fish	Approximate Number
<i>Gray color and long fins</i>	<i>Dgdg</i>	500
<i>Blue color and short fins</i>	<i>dGdg</i>	500

- ii. Assuming that the genes regulating these two traits are **10 centimorgans (cM)** apart, give all possible genotypes, phenotypes and approximate number of fish in each class that you will obtain in F2.

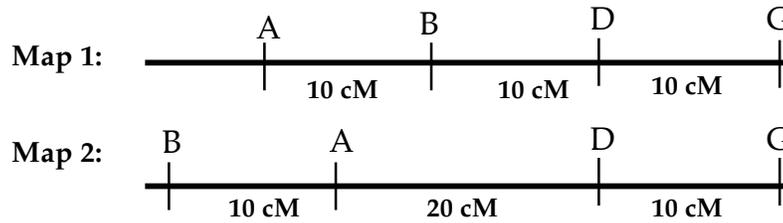
Phenotype of the fish in F2	Genotype of the fish in F2	Approximate Number
<i>Golden color and long fins</i>	<i>Dgdg</i>	450
<i>Blue color and short fins</i>	<i>dGdg</i>	450
<i>Golden color and short fins</i>	<i>DGdg</i>	50
<i>Blue color and long fins</i>	<i>dgdg</i>	50

Question 6 continued

c) You also want to study the following genes in the same fishes.

- A gene that regulates the eye color, which is either black (dominant trait represented by allele A) or white (recessive trait represented by allele a). **The map distance between this gene and the gene that regulates body color is 20cM.**
- A gene that regulates swimming rate, which is either fast (dominant trait represented by the letter B) or slow (recessive trait, represented by the letter b). You find that the **map distance between this gene and the gene that regulates eye color is 10cM.**

On the maps below, draw the two possible locations of genes that regulate eye color and swimming rate and give the map distance between the genes.



d) Propose a mating experiment based on which you can decide which chromosomal map (1 / 2) provides the correct location of the genes that regulate eye color, swimming rate, body color and fin length. **Explain** your results.

You can set up one of the following two mating experiments:

Experiment #1: Mate a true-breeding fish that has the genotype BBgg with another true-breeding fish that has genotype bbGG to obtain F1 fish that have genotype BgbG. Now mate an F1 fish with a true-breeding fish that has genotype bbgg. You will get 20% recombinants if map 1 is correct or 40% recombinants if map 2 is correct.

Experiment #2: Mate a true-breeding fish with genotype BBGG with another true-breeding fish that has genotype bbgg to obtain F1 fish that have genotype BGbg. Now mate an F1 fish with a true-breeding fish that has genotype bbgg. You will get 20% recombinants if map 1 is correct or 40% recombinants if map 2 is correct.

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