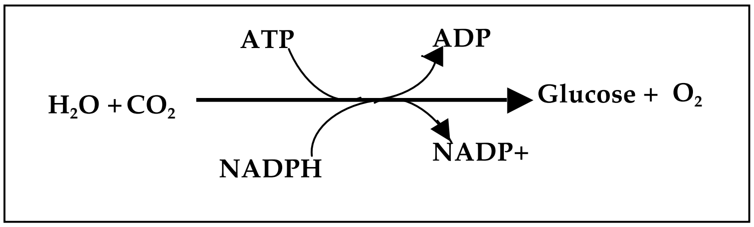
Solutions for 2010 7.012 Problem Set 2

Question 1

E. coli bacteria cells use glucose as an energy source both under aerobic (in the presence of oxygen) and anaerobic (in the absence of oxygen) growth conditions. In the absence of oxygen, these bacteria consume large amounts of glucose. However, their rate of glucose consumption decreases if they are grown in the presence of oxygen.

a) Why do the bacterial cells require less glucose for the same growth rate once oxygen is added?
In the presence of oxygen, the cells can use glucose in aerobic respiration as opposed to fermentation. The net energy yield ***per glucose molecule*** *in respiration is much higher than in fermentation, so less glucose is needed for the same amount of growth under aerobic conditions.*

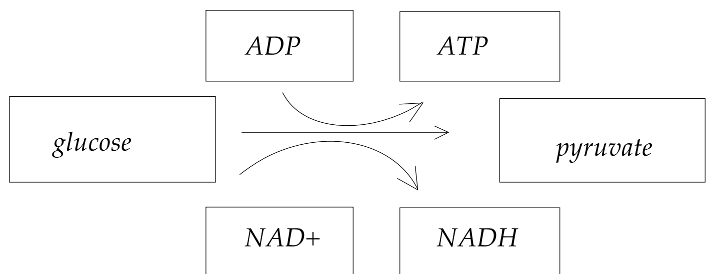
An outline of photosynthesis is shown below.



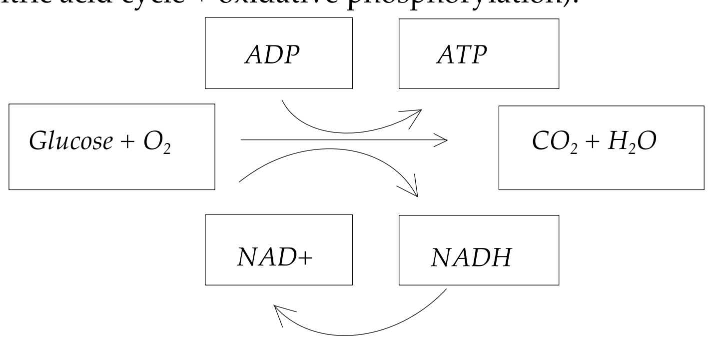
Note: *For part b) include the names of the following molecules where applicable: glucose, pyruvate, CO_2, NAD^+, NADH, O_2 and H_2O, ATP and ADP. You do not need to include any other carbon intermediate or the names of the enzymes that catalyze specific reactions.*

b) In a manner analogous to that shown above,

i. Complete the diagram for glycolysis:



ii. Complete the diagram for the overall process of respiration (respiration = glycolysis + citric acid cycle + oxidative phosphorylation):



iii. Glycolysis occurs in the absence of oxygen. What happens to the carbon containing molecule produced in glycolysis when the cell is undergoing fermentation? Is any additional ATP produced?
The electrons from NADH are given to pyruvate, which is converted into ethanol or lactic acid. This regenerates the NAD^+ needed to continue glycolysis, but does NOT generate any additional ATP.

Question 1, continued

c) Oxidative phosphorylation is a series of oxidation-reduction reactions carried out by the proteins of the electron transport chain (ETC).

i. What molecule donates electrons to the first protein in the ETC? *NADH*

ii. Name the **final** electron acceptor used during oxidative phosphorylation in aerobic conditions. O_2

Question 2

You are studying two true-breeding varieties of plants: one has small yellow flowers **(Parent 1)** and the other has large red flowers **(Parent 2)**. You may assume that flower size and flower color are regulated by two separate genes.

a) You cross the two true-breeding parental plants, and find that **all** the F1 progeny have small red flowers.

- Box **all** the **dominant phenotypes** from the following choices.

  Large $\boxed{\text{Red}}$ Yellow $\boxed{\text{Small}}$

- Write the genotypes of the parental (P) plants and the F1 progeny for genes that regulate flower color and size. *For the flower size gene, use the letter **A** to denote the allele associated with the dominant phenotype and the letter **a** to denote the allele associated with the recessive phenotype. For the flower color gene, use the letter **B** to denote the allele associated with the dominant phenotype and **b** to denote the allele associated with the recessive phenotype.*

  Parent 1: *AAbb* **Parent 2:** *aaBB* **F1 progeny:** *AaBb*

b) You cross an F1 plant with a true breeding plant that has large yellow flowers and obtain 1000 progeny. Assume that the two genes **assort independently.** In the table below, give the expected **phenotypes and genotypes** expected in the progeny. Also give the **approximate number** of each type of progeny.

Genotypes	Phenotypes	Approximate Number of offspring of this type
AaBb	*small red flowers*	*250*
aabb	*large yellow flowers*	*250*
Aabb	*small yellow flowers*	*250*
aaBb	*large red flowers*	*250*

c) In fact, when you do the cross that is given in part (b), you find that the color gene and the size gene are linked. Give the genotype of the plants that represent recombinant progeny.

aabb and AaBb

d) From the cross that is given in part (b), you obtain the following results. Calculate the map distance between the genes that regulate the size and color of flowers.

- 475 plants with large and red flowers
- 25 plants with small and red flowers
- 25 plants with large and yellow flowers
- 475 plants with small and yellow flowers.

Recombination frequency (RF) = # recombinants/ total
RF = 25 + 25/25 + 25 + 475 + 475 = 50/500
RF = 10% or 10 map units or 10 cM

Question 3
You are working with flies that can be broadly categorized as **aggressive** or **mild** and **red** or **black**. You decide to study the genes responsible for these two traits.

Use the letters "A", and "a" for temperament (aggressive or mild) and "B" and "b" for body color (red or black). Use the uppercase letter to represent the alleles associated with the dominant phenotypes and the lowercase letters to represent the alleles associated with the recessive phenotypes.

a) You mate a true breeding **aggressive** and **red** fly with a **mild** and **black** fly. You find that all the flies in the F1 generation are **aggressive** and **black.** You take an F1 generation female fly and **test cross** her with a true breeding male fly and score 1600 progeny.

i. Give the genotype and phenotype of the male fly in the **test cross**.

Phenotype: *mild and red*
Genotype: *aabb*

ii. If the genes for the two characters (traits) are **10cM** apart, write the genotypes and corresponding phenotypes of the different classes of flies that you would expect. Also write the approximate number of flies that you would expect for each class.

Genotypes	Phenotypes	Numbers
AaBb	*aggressive and black*	*80*
aabb	*mild and red*	*80*
Aabb	*aggressive and red*	*720*
aaBb	*mild and black*	*720*

b) You are also interested in the additional following traits for the same flies.
Antennae length, with long antennae being dominant (**N**) over short antennae (**n**).
Wing size, with wings (**D**) being dominant over wingless (**d**).

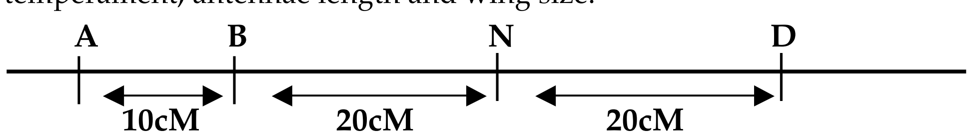
You perform the following crosses.

- You cross a true breeding fly having black body color and long antennae with a true breeding fly having red body color and short antennae. A test cross with a resulting F1 fly gives 320 recombinant progeny from a total of 1600 flies in F2.
- You cross a true breeding aggressive fly having long antennae with a true breeding mild fly with short antennae. A test cross with a resulting F1 fly gives 480 recombinant progeny from a total of 1600 flies in F2.
- You cross a true breeding black fly having wings with a true breeding red, wingless fly. A test cross with a resulting F1 fly gives 640 recombinant progeny from a total of 1600 flies in F2.
- You cross a true breeding aggressive fly having wings with a true breeding mild, wingless fly. A test cross with a resulting F1 fly gives 800 recombinant progeny from a total of 1600 flies in F2.

Based on the results of the crosses above, answer the following questions.

i. Which pairs of genes are exhibiting classical Mendelian inheritance?
The genes for temperament and wing size

ii. Draw a **chromosomal map** to show the approximate map distance between the genes for body color, temperament, antennae length and wing size.



Question 4

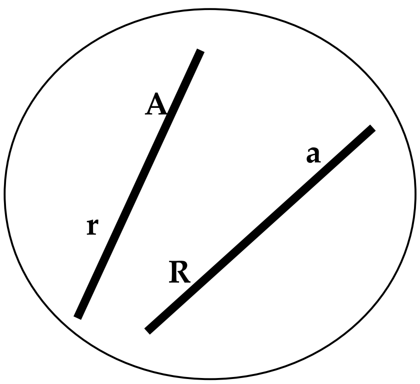
Tim is a carrier for Wilson's disease (Aa) and Rotor's syndrome (Rr). Tim's mother suffered from rotor's syndrome (AArr) and his father had Wilson's disease (aaRR). Assume that the genes involved in these disorders are located on chromosome 13.

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

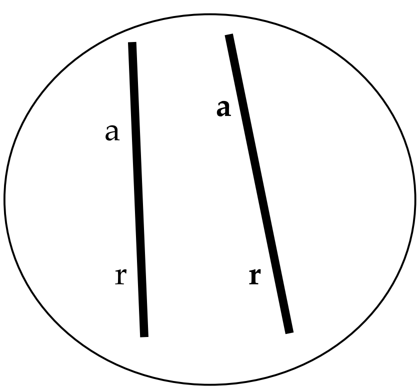
#1	#2	#3
A r	A R	A r
a r	a r	a R

b) Tim marries Liz who suffers from both 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 simplicities sake, only the two copies of chromosome 13 are shown below. Add the A, a, R and r alleles to the schematics below.



Tim's diploid nucleus

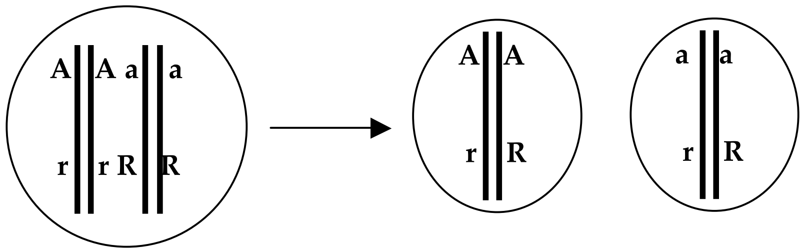


Liz's Diploid nucleus

Question 4, continued

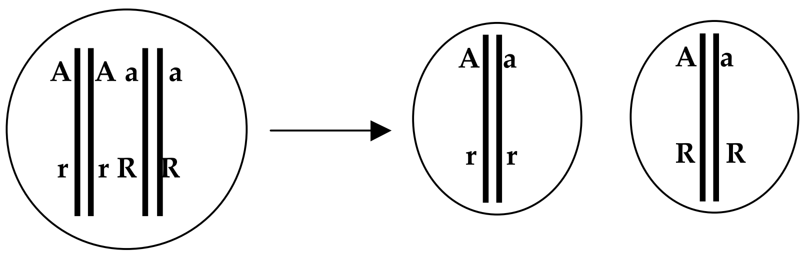
ii. Draw and align the copies of chromosome 13 as they would be during **metaphase of meiosis I** for Tim and Liz. ***Please note that your drawings should reflect the meiotic events that produced Amy's genotype.*** Then draw the copies of chromosome 13 in each of the two products (Product 1 and Product 2) resulting from meiosis I. Include the A, a, R, and r alleles on each drawing below.

Possibility #1:

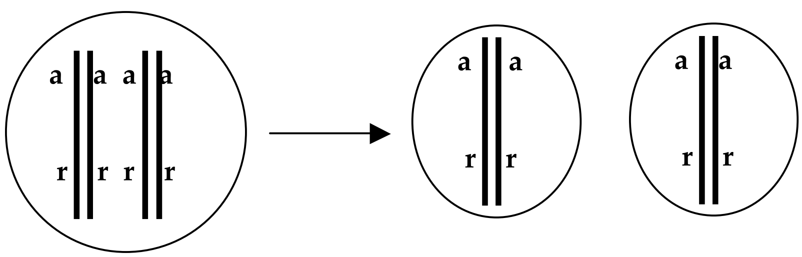


Metaphase of Meiosis –I in Tim | Product 1 of Meiosis –I | Product 2 of Meiosis –I

Possibility #2:



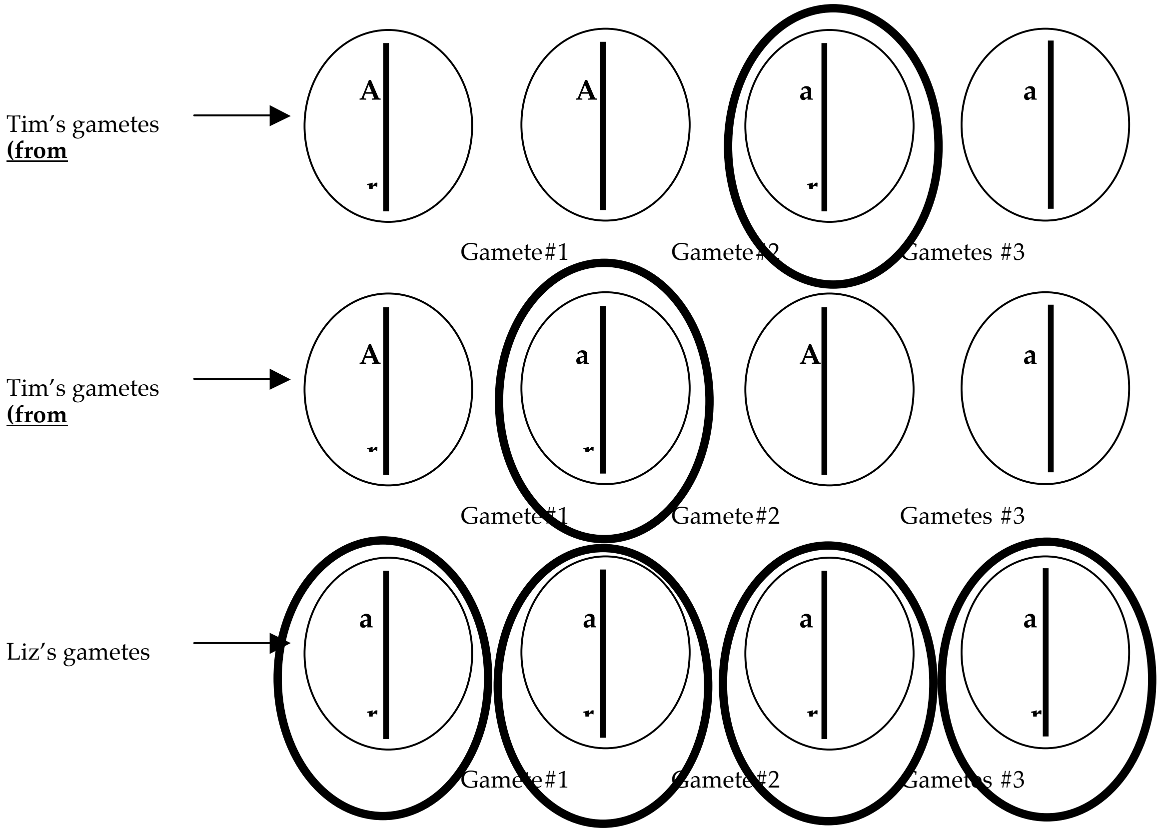
Metaphase of Meiosis –I in Tim | Product 1 of Meiosis –I | Product 2 of Meiosis –I



Metaphase of Meiosis –I in Liz | Product 1 of Meiosis –I | Product 2 of Meiosis –I

Question 4, continued

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



iv. Circle two gametes that could have fused during fertilization to produce Amy.
One of four gametes (genotype = ar) from Liz fused either with gamete #3 (generated from possibility 1) or gamete #2 (generated from possibility #2) to produce Amy.