

Montogue

Quiz BI104

# BASIC GENETICS

Lucas Monteiro Nogueira

## ►► PROBLEM DISTRIBUTION

Problem range	Subject
1 → 8	Mendel's first law and blood types
9 → 14	Independent segregation
15 → 18	Linkage
19 → 27	Sex-linked inheritance

## ►► PROBLEMS

### ► Conversation Starter

In a population of moths, individuals may have either black or brown color. It is known that crossing black individuals with one another produces black individuals and brown individuals, while crossings of brown individuals produce brown offspring only. This information suggests that the color of these moths is determined by:

- A)** A pair of alleles, with the allele for brown color being dominant over the allele for black color.
- B)** A pair of alleles, with the allele for black color being dominant over the allele for brown color.
- C)** Two linked genes with a high recombination rate.
- D)** Environmental factors, such as the coloration of tree trunks on which the moths land.

### ► Problem 2

If an angiosperm with genotype  $aa$  for a certain trait fertilizes a plant with genotype  $AA$  for the same trait, the embryo and endosperm of the ensuing seed will have genotypes, respectively:

- A)**  $Aa$  and  $Aaa$
- B)**  $Aa$  and  $AAa$
- C)**  $AA$  and  $Aaa$
- D)**  $AA$  and  $AAa$

### ► Problem 3

Consider a gene that can take the form of three alleles, which we name *alpha*, *beta*, and *gamma*. *Alpha* and *gamma* are codominant and *gamma* is recessive relatively to both. This gene must determine:

- A)** Two phenotypes and four genotypes.
- B)** Three phenotypes and four genotypes.
- C)** Four phenotypes and four genotypes.
- D)** Four phenotypes and six genotypes.
- E)** Four phenotypes and nine genotypes.

### ► Problem 4

A blood bank had the following amounts of blood available. True or false?

<b>O</b>	20 liters
<b>A</b>	12 liters
<b>B</b>	10 liters
<b>AB</b>	4 liters

1. ( ) There are 46 liters available of blood compatible with individuals of type O.
2. ( ) There are 32 liters available of blood compatible with individuals of type A.
3. ( ) There are 30 liters available of blood compatible with individuals of type B.
4. ( ) There are 26 liters available of blood compatible with individuals of type AB.

### ► Problem 5

Genetic inheritance in the ABO system is determined by multiple alleles, namely  $I^A$ ,  $I^B$ , and  $i$ , which combine to yield the following phenotypes. True or false?

$ii$	Blood type <b>O</b>
$I^A I^A$ or $I^A i$	Blood type <b>A</b>
$I^B I^B$ or $I^B i$	Blood type <b>B</b>
$I^A I^B$	Blood type <b>AB</b>

1. ( ) Alleles  $I^A$  and  $I^B$  are dominant relatively to  $i$ .
2. ( ) Individuals of blood type B have anti-B agglutinins and A agglutinogens.
3. ( ) Individuals with blood type A may exhibit one type of genotype and two types of phenotype.
4. ( ) Individuals with blood type AB, when crossed with one another, have a 25% probability of producing descendants with blood type AB.
5. ( ) Individuals with blood type O can donate blood to individuals with any type of blood in the ABO system.
6. ( ) Individuals with blood type O, when crossed with one another, can only yield individuals with blood type O; they offspring will contain no descendants of blood type A, B, or AB.

### ► Problem 6

A woman has recently given birth to her second son, who sadly died from Rh-system hemolytic disease of the newborn (HDN). Considering that the woman was never subjected to a blood transfusion procedure and had a first child with no abnormalities, choose the alternative that correctly identifies the Rh-system phenotypes of the mother, the first child, and the second child.

	<b>Mother</b>	<b>First child</b>	<b>Second child</b>
<b>A)</b>	Rh-negative	Rh-negative	Rh-positive
<b>B)</b>	Rh-negative	Rh-positive	Rh-negative
<b>C)</b>	Rh-negative	Rh-positive	Rh-positive
<b>D)</b>	Rh-positive	Rh-negative	Rh-positive
<b>E)</b>	Rh-positive	Rh-positive	Rh-negative

### ► Problem 7

The following table lists the results of the ABO and Rh typing of a couple and their son. A sign “+” indicates a positive reaction and a sign “-” denotes a negative reaction.

	<b>Anti-A serum</b>	<b>Anti-B serum</b>	<b>Anti-Rh serum</b>
Father	+	-	+
Mother	-	+	-
Son	-	-	+

Consider the following statements.

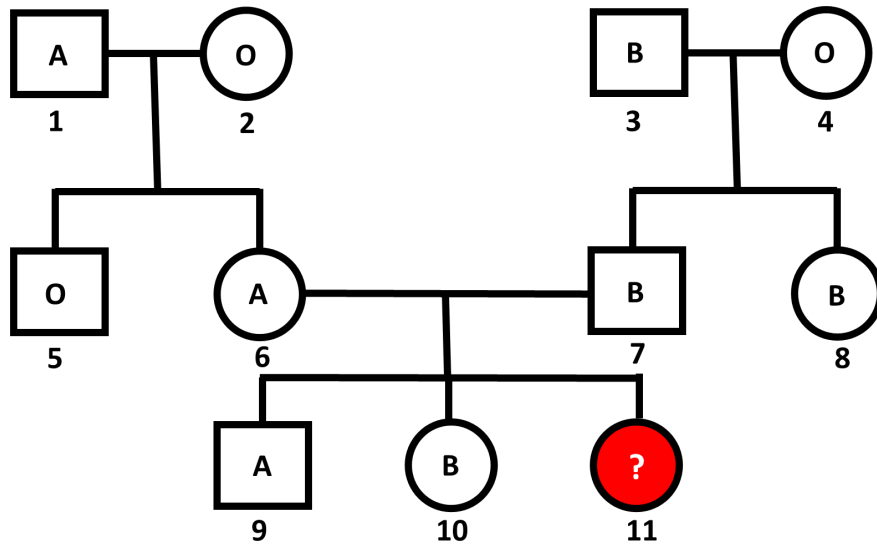
- I. In the future, the mother may have a child with HDN.
- II. If at one point the son requires blood transfusion, he can safely receive blood from either parent.
- III. The genotype of the father might be  $I^A I^A RR$ .

The correct statements are:

- A)** I only.
- B)** II only.
- C)** I and II only.
- D)** I and III only.
- E)** II and III only.

► **Problem 8**

The following pedigree shows the ABO-system blood types of a family. What is the probability of individual 11 having blood type O?



- A) Zero
- B) 1/4
- C) 1/2
- D) 3/4

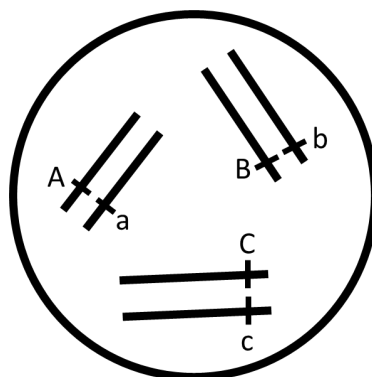
► **Problem 9**

Suppose a diploid organism,  $2n = 4$ , has a gene *A* in one homologous chromosome pair and a gene *B* in another homologous chromosome pair. An individual heterozygous for both genes will generate:

- A) 2 types of gamete in the proportion 1 : 1.
- B) 2 types of gamete in the proportion 3 : 1.
- C) 4 types of gamete in the proportions 9 : 3 : 3 : 1.
- D) 4 types of gamete in the proportions 1 : 1 : 1 : 1.
- E) 4 types of gamete in the proportions 1 : 2 : 1.

► **Problem 10**

Sixty cells of an animal, with the constitution illustrated below, undergo meiosis. The number of sperm cells with genetic constitution *ABC* is:



- A) 30 sperm cells.
- B) 60 sperm cells.
- C) 90 sperm cells.
- D) 120 sperm cells.

► **Problem 11**

Suppose that, among dogs, barking or not barking while running are traits governed by a pair of allelic genes. Likewise, suppose the same applies to prick ears. Barking while running and prick ears are dominant traits, while not barking while running and having drop ears are recessive. Consider a crossing between two individuals; one has genotype *BbEe* (barks while running and has prick ears), while other has genotype *Bbee* (barks while running and has drop ears). The probability that one of their offspring will bark while running and have drop ears is:

- A) 25%
- B) 37.5%
- C) 50%
- D) 62.5%

► **Problem 12**

The color of wheat seeds is established by two pairs of additive effect (polygenic) genes. The following table lists the number of dominant genes and the ensuing seed colors. From the crossing of an  $AaBb$  individual with a  $Aabb$  individual, the expected proportion of individuals with red seeds is:

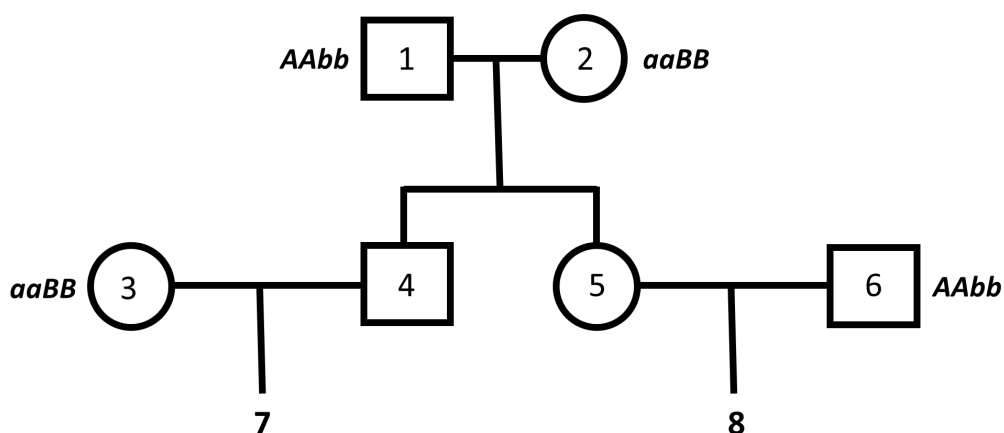
Number of dominant genes	Seed color
4	Dark red
3	Medium red
2	Red
1	Clear red
None	White

- A) 1/8
- B) 1/4
- C) 3/8
- D) 1/2
- E) 3/4

► **Problem 13**

Suppose that, in a certain animal, bodily retention of water is controlled by the quantitative interaction of two pairs of genes, so that there are five types of phenotypes from “minimum water retention” to “maximum water retention.” Animals with genotype  $AABB$  display maximum water retention, while animals with genotype  $aabb$  display minimum water retention. Animals with two “upper case” alleles and two “lower case” alleles in their genotype exhibit intermediate water retention.

In the following genealogy, the genotypes of individuals 1, 2, 3 and 6 are given. Considering that the genes in question segregate independently, what is the probability that individuals 7 and 8 will *simultaneously* exhibit intermediate water retention?



- A) 1/8
- B) 1/4
- C) 1/3
- D) 1/2

► **Problem 14**

The height of a plant species is determined by two pairs of genes  $P$  and  $Q$  and their respective alleles  $p$  and  $q$ . Alleles  $P$  and  $Q$  exhibit an additive effect and, when present, each allele confers the plant an additional 0.5 m height. The plants have height ranging from 2 m to 4 m. Crossing individuals  $PpQQ$  with  $ppqq$ , we can predict that, among their descendants:

- A) 100% will have 3 m height.
- B) 75% will have 3 m height and 25% will have 3.5 m height.
- C) 25% will have 2 m height and 75% will have 4 m height.
- D) 50% will have 2.5 m height and 50% will have 3 m height.
- E) 25% will have 2.5 m height, 25% will have 3 m height, 25% will have 3.5 m height, and 25% will have 4 m height.

### → Problem 15.1

In a type of fruit fly, curly wings dominates vestigial wings and red eyes dominates white eyes. Pure females with curly wings and red eyes were crossed with males endowed with vestigial wings and white eyes. Then, females from the  $F_1$  generation were with crossed with recessive males, yielding the offspring described below.

Curly wings and red eyes	<b>43%</b> of descendants
Vestigial wings and white eyes	<b>43%</b> of descendants
Curly wings and white eyes	<b>7%</b> of descendants
Vestigial wings and red eyes	<b>7%</b> of descendants

What is the arrangement of the genes in the double-heterozygous females of the  $F_1$  generation?

- $\alpha$ ) *Cis*
- $\beta$ ) *Trans*
- $\gamma$ ) There is not enough information.

### → Problem 15.2

What is the relative distance between the genetic loci in question?

- A) 3.5 cM
- B) 7 cM
- C) 14 cM
- D) 28 cM

### ► Problem 16

In a type of mice, the dominant allele  $E$  determines black fur and recessive allele  $e$  determines white fur. Likewise, dominant allele  $A$  yields normal fur and recessive allele  $a$  yields curly fur.  $F_1$  individuals, obtained from a cross between  $EEAA$  and  $eeaa$  mice, were crossed with double-recessive individuals and gave rise to an offspring with the following distribution:

- **160** with black and normal fur;
- **160** with white and curly fur;
- **40** with black and curly fur;
- **40** with white and normal fur;

Which of the following alternatives contains the correct percentages of each type of gamete produced by individuals  $F_1$ ?

- A)  $EA = 10\%$ ,  $Ea = 40\%$ ,  $eA = 40\%$ ,  $ea = 10\%$
- B)  $EA = 20\%$ ,  $Ea = 30\%$ ,  $eA = 30\%$ ,  $ea = 20\%$
- C)  $EA = 25\%$ ,  $Ea = 25\%$ ,  $eA = 25\%$ ,  $ea = 25\%$
- D)  $EA = 30\%$ ,  $Ea = 20\%$ ,  $eA = 20\%$ ,  $ea = 30\%$
- E)  $EA = 40\%$ ,  $Ea = 10\%$ ,  $eA = 10\%$ ,  $ea = 40\%$

### ► Problem 17

In a certain corn species, a colored grain is conditioned by a dominant gene  $B$  and a smooth grain is conditioned by a dominant gene  $R$ . The recessive alleles  $b$  and  $r$  determine, respectively, white grains and rough grains. Upon crossing of a colored smooth individual with a white rough individual, the following offspring was obtained:

- **150** individuals that produced colored and smooth seeds;
- **150** individuals that produced white and rough seeds;
- **250** individuals that produced colored and rough seeds;
- **250** individuals that produced white and smooth seeds;

With reference to these results, we can conclude that the genotype of the parental colored smooth individual and the distance between genes  $B$  and  $R$  are, respectively:

- A)  $BR/br$ , 62.5 cM
- B)  $BR/br$ , 37.5 cM
- C)  $Br/Br$ , 62.5 cM
- D)  $Br/bR$ , 37.5 cM
- E)  $BR/br$ , 18.75 cM

► **Problem 18**

The percentage of recombination between the genes of a pair of chromosomes provides an indication of the distance between them. Considering hypothetical genes *F*, *G*, and *H*, the following frequencies of recombination were verified: *F* and *G* = 25%, *G* and *H* = 12%, *F* and *H* = 15%. Choose the alternative that correctly designates the organization of these genes in the chromosome.

- A) *F*, *H*, *G*
- B) *F*, *G*, *H*
- C) *H*, *F*, *G*
- D) *G*, *F*, *H*

► **Problem 19**

Four genes, *A*, *B*, *C*, and *D*, are located in the same chromosome and exhibit the following recombination frequencies:

<b>A-B</b>	32%
<b>A-C</b>	45%
<b>A-D</b>	12%
<b>B-C</b>	13%
<b>B-D</b>	20%
<b>C-D</b>	33%

The most likely sequence of these genes in the chromosome is:

- A) *ABCD*
- B) *ABDC*
- C) *ACDB*
- D) *ADBC*
- E) *ADCB*

► **Problem 20**

Consider two species, one with a sex determination system of type XY and another with sex determination system of type ZW. The sex of the offspring is determined by:

- A) The female in both cases.
- B) The female in the former species and the male in the latter.
- C) The male in the former species and the female in the latter.
- D) The male in both cases.

► **Problem 21**

Choose the alternative that associates the sex determination system with the types of gamete produced.

<b>P.</b> XY System	<b>I.</b> One type of ovule and one type of sperm cell;
<b>Q.</b> X0 System	<b>II.</b> Two types of ovule and one type of sperm cell;
<b>R.</b> ZW System	<b>III.</b> One type of ovule and Two types of sperm cell;
	<b>IV.</b> Two types of ovule and two types of sperm cell;

- A) P.III, Q.IV, R.II
- B) P.III, Q.III, R.II
- C) P.II, Q.III, R.IV
- D) P.I, Q.IV, R.III.
- E) P.I, Q.I, R.III

► **Problem 22**

A non-hemophilic woman, daughter of a hemophilic father, marries a hemophilic father. With respect to this situation, choose the correct alternative.

- A) All of the couple's children will be hemophilic.
- B) This couple has a 25% probability of having non-hemophilic children.
- C) The father-in-law of the woman is certainly hemophilic.
- D) The woman carries the gene that determines hemophilia.
- E) The woman's mother is homozygous for the gene that determines hemophilia.

► **Problem 23**

Color blindness is a hereditary disease linked to sex. A color-blind man marries a normal-sighted woman who does not carry the recessive allele inherent to color blindness. The probability that this couple may have a male child with color blindness is:

- A) zero.
- B) 25%
- C) 50%
- D) 75%

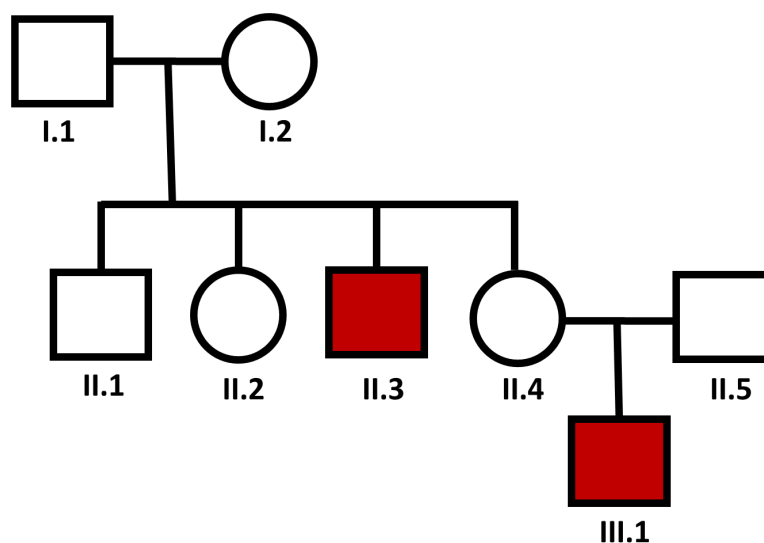
► **Problem 24**

A couple has the following genetic constitution: the husband is albino and normal for color blindness, while the wife is heterozygous for both loci. The probability that this couple can have a male child with normal phenotype for both conditions is:

- A) zero
- B) 12.5%
- C) 25%
- D) 37.5%

→ **Problem 25.1**

In the following pedigree, there are two hemophilic boys.



What is the probability that a second child of II.4 and II.5 will be affected?

- A) Zero
- B) 1/4
- C) 1/2
- D) 3/4

→ **Problem 25.2**

What is the probability that II.2 carries the allele that causes hemophilia?

- A) Zero
- B) 1/4
- C) 1/2
- D) 3/4

→ **Problem 25.3**

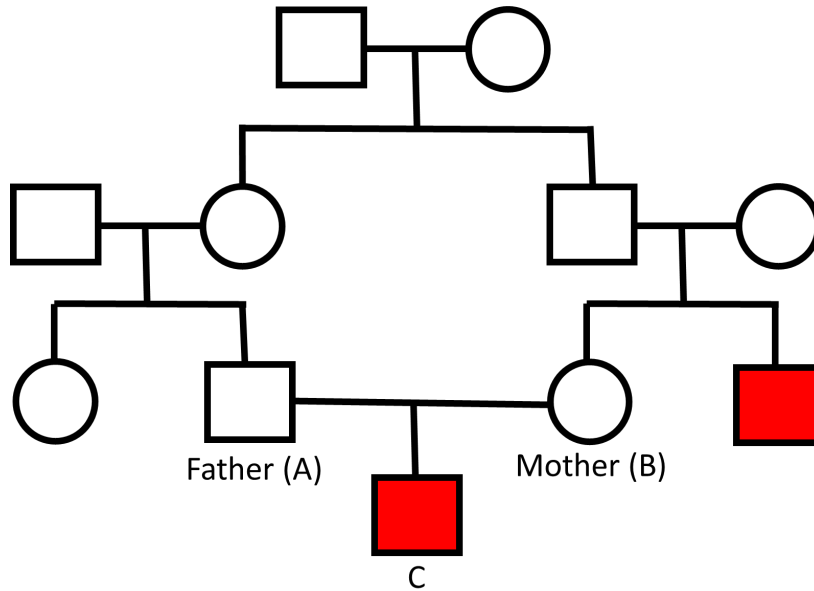
Knowing that the maternal grandparent of II.4 was affected, what was the phenotype of the maternal grandmother?

- $\alpha$ ) The maternal grandmother had hemophilia.
- $\beta$ ) The maternal grandmother did not have hemophilia.
- $\gamma$ ) There is not enough information to determine the phenotype of the grandmother.

► **Problem 26**

In the following pedigree, the red squares indicate boys affected by a hereditary disease. If the disease is conditioned by recessive alleles located in autosomes, the probabilities that the father (A) and the mother (B) of one of the affected boys (C) carry this recessive allele are (I) and (II), respectively.

If the anomaly is determined by a recessive allele linked to the X chromosome, in a segment with no homology to chromosome Y, the probabilities that the father and mother carry this allele are (III) and (IV), respectively.

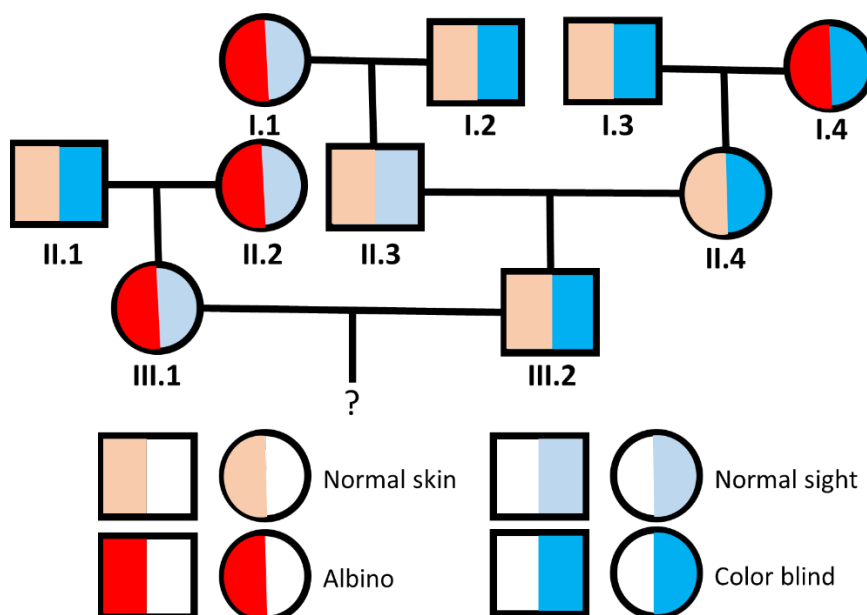


Choose the alternative that correctly indicates the values of (I) to (IV).

	I	II	III	IV
<b>A)</b>	50%	50%	100%	0%
<b>B)</b>	100%	100%	100%	0%
<b>C)</b>	50%	50%	0%	100%
<b>D)</b>	100%	100%	0%	100%
<b>E)</b>	100%	100%	50%	50%

→ **Problem 27.1**

Type I albinism in humans is an autosomic inheritance determined by a recessive allele. Color blindness, in turn, is determined by a recessive allele in the X chromosome. In the following pedigree, individuals of a family are represented by shapes divided in two halves: the left half indicates the phenotype for skin color (normal or albino) and the right half indicates the phenotype for color sight (normal or color blind).



Find the probability that a child of III.1 and III.2 will have albinism but not be color blind.

- A)** 1/36
- B)** 1/24
- C)** 1/12
- D)** 1/6



→ Problem 27.2

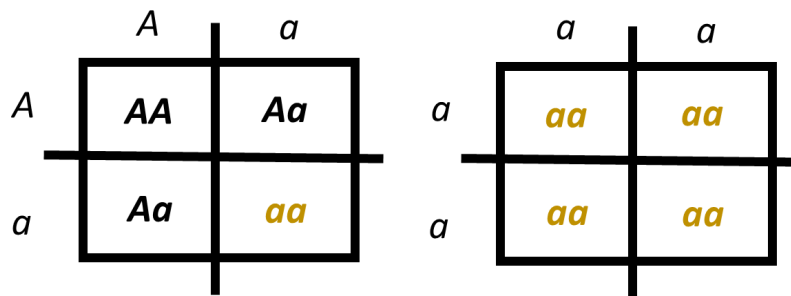
Knowing that couple III.1 × III.2 has already had a male albino son who is not color blind, what is the probability that the next male son of the couple will be albino and color blind?

- A) 1/12
- B) 1/8
- C) 1/6
- D) 1/4

▶▶ SOLUTIONS

P.CS → Solution

Let  $A$  be the dominant allele, which determines black color, and  $a$  be the recessive allele, which determines brown color. As shown in the first Punnett square below, crossing between black heterozygous  $Aa$  individuals will produce black descendants and brown descendants, which is compatible with one of the results mentioned in the problem statement. In the second Punnett square, we find that a crossing between brown  $aa$  individuals can only produce  $aa$  descendants, i.e. brown descendants, which corroborates another observation mentioned in the problem statement. We conclude that the phenotype in question – moth color – is determined by a pair of alleles, with the allele for black color being dominant over the allele for brown color.



♦ The correct answer is **B**.

P.2 → Solution

The male plant produces sperm cells with a single  $a$  allele each, while the female plant produces ovules with a single  $A$  allele each, with the result that an embryo will have a  $Aa$  genotype. The two polar cells formed during gamete production will have a single  $A$  allele each, and will combine with a sperm cell to become the original endosperm cell; as a result, the endosperm cells should have a  $A + A + a = AAa$  genotype.

♦ The correct answer is **B**.

P.3 → Solution

Let  $A$  represent the *alpha* allele,  $B$  the *beta* allele, and  $g$  the *gamma* allele. The possible genotypes and phenotypes are listed below.

$AA$ or $Ag$	Phenotype 1
$BB$ or $Bg$	Phenotype 2
$AB$	Phenotype 3
$gg$	Phenotype 4

Accordingly, the gene determines four phenotypes and six genotypes.

♦ The correct answer is **D**.

P.4 → Solution

**1. False.** Individuals of type O blood can only receive blood from other individuals of type O; accordingly, there are 20 liters available for individuals with this type of blood.

**2. True.** Individuals of type A blood can receive blood from individuals of types A or O; thus, there are  $12 + 20 = 32$  liters available for individuals with this type of blood.

**3. True.** Individuals of type B blood can receive blood from individuals of types B or O; therefore, there are  $10 + 20 = 30$  liters available for individuals with this type of blood.

**4. False.** Individuals of type AB blood can receive blood from any of the four ABO blood types; hence, there are  $20 + 12 + 10 + 4 = 46$  liters of blood available for individuals with this type of blood.

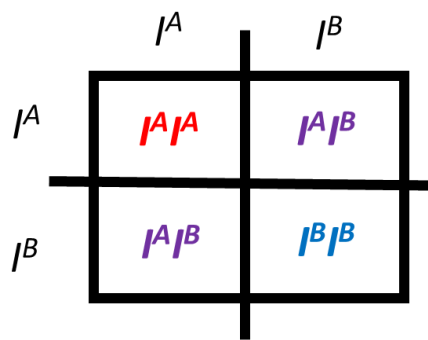
**P.5** → **Solution**

**1. True.** The dominance relationship is  $I^A = I^B > i$ .

**2. False.** In actuality, individuals of blood type B have anti-A agglutinins and B agglutinogens.

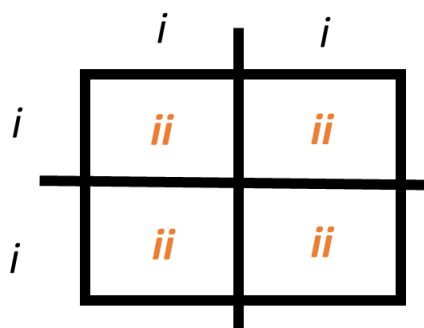
**3. False.** Individuals with the blood type in question may have one type of phenotype (the A blood type itself) and two genotypes (either  $I^A I^A$  or  $I^A i$ ).

**4. False.** Refer to the following Punnett square. Individuals with AB blood have  $I^A I^B$  genotype, so that, when crossed with one another, they yield 25% descendants with  $I^A I^A$  genotype (blood type A), 25% descendants with  $I^B I^B$  genotype (blood type B), and 50% descendants with  $I^A I^B$  genotype (blood type AB).



**5. True.** Since people with O type blood have neither agglutinin A nor agglutinin B, they can donate blood to people of any blood type in the ABO system; for that reason, they are said to be universal donors.

**6. True.** Refer to the following Punnett square. Individuals with O-type blood necessarily have a  $ii$  genotype; accordingly, their descendants will necessarily inherit an  $i$  allele from each parent and themselves end up with a  $ii$  genotype. Accordingly, a cross of individuals with O-type blood can only produce individuals with O-type blood.



**P.6** → **Solution**

When a Rh-negative mother gives birth to a child with Rh-positive blood, contact between their blood causes the mother to produce anti-Rh antibodies. If the mother bears another child with Rh-positive blood, fetal blood stimulates immunological memory and causes the mother to produce anti-Rh antibodies. These antibodies cross the placenta and enter the bloodstream of the fetus, destroying its RBCs and leading to severe anemia. Further, hemoglobins released when the RBCs are destroyed enter the liver and are converted to bilirubin, which accumulate and cause the newborn to develop jaundice. To compensate the destruction of RBCs, the newborn releases erythroblasts, immature red blood cells, whence comes another term for the disease, erythroblastosis foetalis, commonly used in the Romance languages.

♦ The correct answer is **A**.

**P.7** → **Solution**

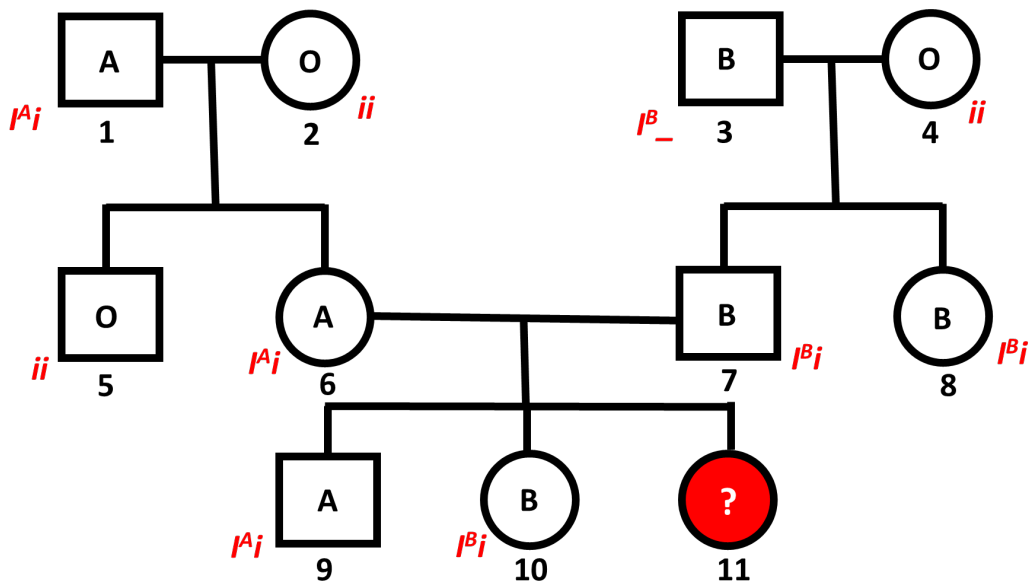
Statement I is true, because the mother has Rh-negative blood and has had a Rh-positive child; consequently, she has immunological memory for anti-Rh antibodies and her second child, if endowed with Rh-positive blood, may develop HDN. Statement II is false, because the son has type O blood and hence can only receive blood from another type O individual; this excludes his father

(A type) and his mother (B type). Statement III is also false, as the father must be A-type heterozygous, i.e., its genotype can only be  $I^A i$ , otherwise it would be impossible for his child to have O-type blood.

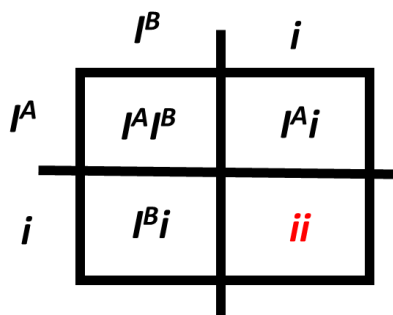
♦ The correct answer is **A**.

**P.8** → **Solution**

The complete pedigree with genotypes is shown in continuation.



A Punnett square for a crossing between individuals 6 and 7 is shown in continuation. Clearly, there is a 25% chance that the crossing will yield an individual with  $ii$  genotype, i.e., with type O blood.



♦ The correct answer is **B**.

**P.9** → **Solution**

The number of types of gamete is given by  $2^n$ , where  $n$  is the number of heterozygous genes; the individual in question has  $n = 2$  heterozygous genes for the characters in question, therefore it can produce  $2^2 = 4$  types of gamete. Meiosis ensures that non-recombinant genes are distributed equally and independently to the gametes; accordingly, we surmise that the individual will generate 4 types of gamete in the proportion 1 : 1 : 1 : 1.

♦ The correct answer is **D**.

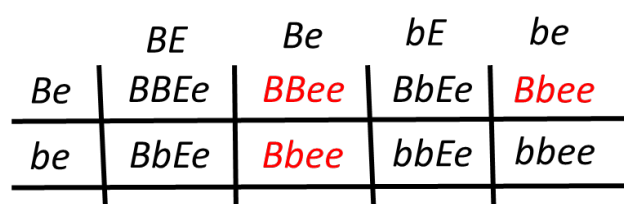
**P.10** → **Solution**

Upon undergoing meiosis, 60 diploid cells should yield  $60 \times 4 = 240$  haploid cells. From the illustration, we surmise that the animal cell has  $AaBbCc$  genotype. The number of different types of gamete produced from the cell is  $2^n$ , where  $n$  is the number of heterozygous genes; in the present case, the cell has  $n = 3$  heterozygous genes and the number of possible types of gamete is  $2^3 = 8$ . The number of gametes with  $ABC$  genotype is then  $240/8 = 30$ .

♦ The correct answer is **A**.

**P.11** → **Solution**

Refer to the following Punnett square.



As highlighted in red,  $3/8 = 37.5\%$  of the offspring will bark while running and have drop ears.

♦ The correct answer is **B**.

**P.12** → **Solution**

Refer to the following Punnett square.

	<i>AB</i>	<i>Ab</i>	<i>aB</i>	<i>ab</i>
<i>Ab</i>	<i>AABb</i>	<i>AAbb</i>	<i>AaBb</i>	<i>Aabb</i>
<i>ab</i>	<i>AaBb</i>	<i>Aabb</i>	<i>aaBb</i>	<i>aabb</i>

Of the eight genotypes that the crossing *AaBb* × *Aabb* can produce, three contain 2 dominant alleles, that is, three correspond to red seed color. Accordingly, the expected proportion of individuals with red seeds is  $3/8$ .

♦ The correct answer is **C**.

**P.13** → **Solution**

From the crossing of individuals 1 and 2, it is easy to see that 4 and 5 both have genotype *AaBb*. Consider the crossing between 3 and 4. Individual 3 can produce only one type of gamete, *aB*, while individual 4 can produce four types. Crossing of 3 and 4 is outlined in the following Punnett square.

	<i>AB</i>	<i>Ab</i>	<i>aB</i>	<i>ab</i>
<i>aB</i>	<i>AaBB</i>	<i>AaBb</i>	<i>aaBB</i>	<i>aaBb</i>

As highlighted in red, two of the four possible genotypes for this crossing have two dominant alleles, which, as mentioned in the problem statement, translates to intermediate water retention. Thus, the probability that individual 7 will exhibit intermediate water retention is  $1/2$ .

Consider now the crossing of individuals 5 and 6. Individual 6 can produce only one type of gamete, *Ab*, while individual 5 can produce four types. We proceed to draw up the following Punnett square.

	<i>AB</i>	<i>Ab</i>	<i>aB</i>	<i>ab</i>
<i>Ab</i>	<i>AABb</i>	<i>AAbb</i>	<i>AaBb</i>	<i>Aabb</i>

As before, two of the four possible genotypes for the descendants of 5 and 6 have two dominant alleles, which as before means that the probability that individual 8 will display intermediate water retention is  $1/2$ . Finally, the probability that individuals 7 and 8 will both manifest intermediate water retention is  $1/2 \times 1/2 = 1/4$ .

♦ The correct answer is **B**.

**P.14** → **Solution**

One of the individuals produces gametes with genotype *PQ* or *pQ*, while the other can only produce *pq* gametes. Crossing the two individuals, we obtain the following Punnett square.

	<i>PQ</i>	<i>pQ</i>
<i>pq</i>	<i>PpQq</i>	<i>ppQq</i>

Clearly, 50% of the offspring will have two dominant alleles, which corresponds to a height of 3 m, while the other 50% will have only one dominant allele, which corresponds to a height of 2.5 m.

♦ The correct answer is **D**.

**P.15** → **Solution**

**Part 1:** As it consists of a test cross (cross with a recessive individual), the phenotype of the offspring is determined by the genotype of the gametes

produced by the individual with dominant traits. Thus, the types of ovules that generated each class of descendants are as follows.

Phenotypes of the descendants	Genotypes of the ovules	Percentage
Curly wings and red eyes	<i>MV</i>	43%
Vestigial wings and white eyes	<i>mv</i>	43%
Curly wings and white eyes	<i>Mv</i>	7%
Vestigial wings and red eyes	<i>mV</i>	7%

Clearly, the arrangement of the alleles in the double-heterozygous females was *cis* (*MV/mv*); this can be inferred from the fact that gametes *MV* and *mv* were produced in greater frequency, 43% each.

◆ The correct answer is **α**.

**Part 2:** To answer this part of the problem, we estimate the relative distance between two genetic loci with reference to their recombination frequency. The recombination frequency equals the sum of the frequency of the recombinant classes, which, in this case, equals  $7 + 7 = 14\%$ . Accordingly, the distance between these genetic loci is 14 recombination units or 14 centimorgans.

◆ The correct answer is **C**.

**P.16** → **Solution**

As evidenced by the proportion of individuals obtained in the  $F_1$ -double-recessive cross, this is a case of genetic linkage. The offspring consists of 400 individuals. Of these,  $160/400 = 40\%$  have the same phenotype as the  $F_1$  individuals, indicating that 40% of the gametes carry the dominant alleles for both traits, that is, 40% of the gametes should have genotype *EA*. Another  $160/400 = 40\%$  exhibit the same phenotype as the double-recessive progenitors, attesting that 40% of the gametes should harbor genotype *ea*. The same rationale applies to the recombinant descendants, from which we infer that 10% of gametes should have genotype *Ea* and 10% of gametes should have genotype *eA*.

◆ The correct answer is **E**.

**P.17** → **Solution**

The genotype of the parental colored smooth individual is *BbRr*. To see whether the arrangement of the genes is *cis* (*BR/br*) or *trans* (*Br/bR*), we need only look at the phenotypes of the offspring from the colored smooth-white rough cross; the fact that the offspring is mainly constituted of colored/rough and white/smooth descendants, that is, individuals that share one trait from one parent and one from another, indicates that the parent in question surely had a *trans* genotype. Lastly, in order to determine the distance between the genes in question, we observe that, out of the 800 descendants obtained in the cross,  $150 + 150 = 300$  individuals are recombinant and the recombination frequency is determined to be  $300/800 = 37.5\%$ ; it follows that the distance between the genes is 37.5 cM.

◆ The correct answer is **D**.

**P.18** → **Solution**

The relative disposition of genes in the chromosome can be inferred from their recombination frequencies. Noting that the recombination rate of genes *F* and *G* is relatively high (25%), we surmise that these genes must be significantly far apart in the chromosome; in contrast, the recombination rate of *G* and *H* (12%) is substantially lower, attesting that these genes must be close together in the chromosome; the same applies to *F* and *H*. Clearly, the genes should be organized as *F, H, G*.

◆ The correct answer is **A**.

**P.19** → **Solution**

The same rationale of Problem 18 applies here. The recombination frequency of *A* and *C* is the highest, suggesting that these genes must be farther apart than any of the other genes in question; we surmise that the genes must be organized as *A\_ \_C*, where the two underscores denote spaces for the other two genes. Turning to other available data, we verify that the recombination frequency of genes *C* and *D* is also quite high; thus, it makes sense to place gene *D* away from *C*, so we can write *A D \_ C*. Lastly, the

recombination frequencies between the remaining gene, *B*, and either *C* (13%) or *D* (20%) are both low, suggesting that *B* can be placed adjacently to these two genes. The sequence of the four genes in the chromosome is ultimately found to be *ADBC*.

♦ The correct answer is **D**.

**P.20** → **Solution**

In the XY system, the male gamete may carry either the X sexual chromosome or the Y sexual chromosome, and hence determines the sex of the offspring. In the ZW system, the female gamete may carry either the Z sexual chromosome or the W sexual chromosome, and therefore determines the sex of the offspring.

♦ The correct answer is **C**.

**P.21** → **Solution**

In the XY system, the female produces one type of gamete, carrying the sexual chromosome X, and the male produces two types of gamete, carrying either the sexual chromosome X or the sexual chromosome Y. In the XO system, the female produces one type of gamete, carrying the sexual chromosome X, and the male produces two types of gamete, carrying either the sexual chromosome X or no sexual chromosome at all. In the ZW system, the female produces two types of gamete, carrying either the sexual chromosome Z or the sexual chromosome W, and the male produces one type of gamete, carrying the sexual chromosome Z.

♦ The correct answer is **B**.

**P.22** → **Solution**

The keen student will certainly realize, without using Punnett squares, that the woman in question necessarily carries the gene that determines hemophilia. Her father has a genotype  $X^hY$ , where  $X^h$  is the X chromosome with the recessive allele that gives rise to hemophilia; any of the father's female children will inherit a copy of this X chromosome from him, including the disease-causing allele in question. Thus, statement D is correct.

♦ The correct answer is **D**.

**P.23** → **Solution**

The man has genotype  $X^dY$ , while the woman has genotype  $X^DX^D$ , as mentioned in the problem statement. Their crossing is outlined in the following Punnett square.

	$X^d$	$Y$
$X^D$	$X^DX^d$	$X^DY$
$X^D$	$X^DX^d$	$X^DY$

Note that, if the couple comes to have a male child, its genotype will necessarily be  $X^DY$ . That is, the child will carry X chromosomes with a dominant allele  $X^D$ , and hence will not develop color blindness. The odds that the couple can have a son with the disease in question are zero.

♦ The correct answer is **A**.

**P.24** → **Solution**

We draw up separate Punnett squares for albinism and color blindness.

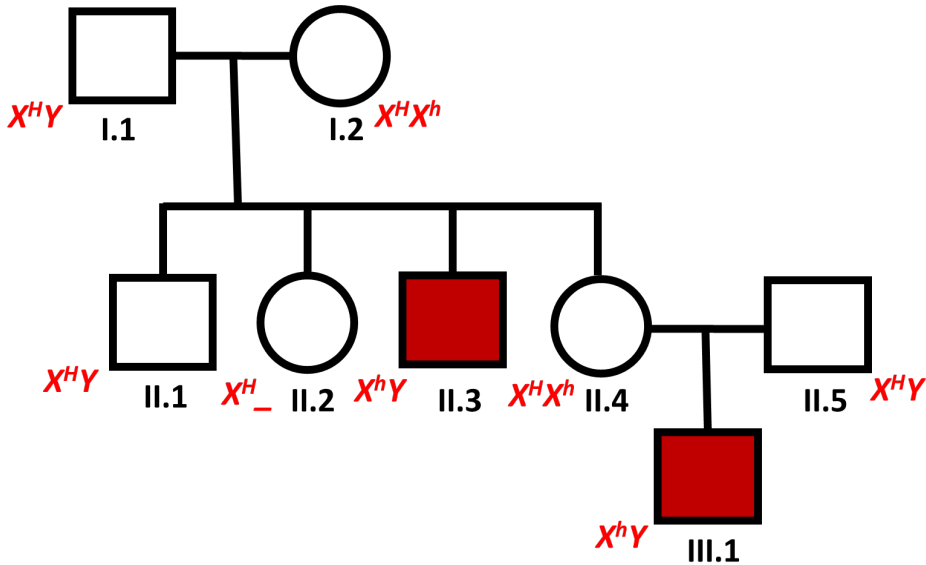
	<i>a</i>	<i>a</i>		$X^D$	$Y$
<i>A</i>	<i>Aa</i>	<i>Aa</i>	$X^D$	$X^DX^D$	$X^DY$
<i>a</i>	<i>aa</i>	<i>aa</i>	$X^d$	$X^DX^d$	$X^dY$

As highlighted in red, there is a 1/2 probability that this couple will have a normal child with respect to albinism. In turn, the odds that the couple can have a normal son with respect to color blindness are 1/4. Appealing to the multiplication rule, the probability that the couple can have a son with neither condition is  $1/2 \times 1/4 = 1/8 = 12.5\%$ .

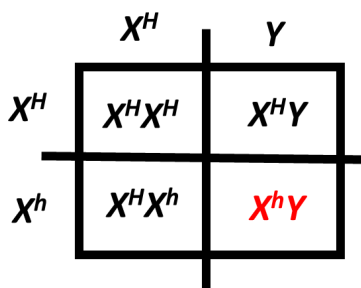
◆ The correct answer is **B**.

**P.25** → **Solution**

**Part 1:** A quick analysis of the pedigree reveals the following genotypes.



We can draw up a Punnett square for the crossing of II.4 and II.5. Of the four possible descendant genotypes, one will be hemophilic. Accordingly, the probability that a second child of II.4 and II.5 will be hemophilic is 1/4.



◆ The correct answer is **B**.

**Part 2:** Individual II.2 is the one individual in the pedigree whose genotype cannot be readily determined from the genealogy. This woman certainly inherited a dominant  $X^H$  allele from her father, but the X chromosome inherited from the mother can be either  $X^H$ , a chromosome that does not contain the recessive hemophilia-causing allele, or  $X^h$ , a chromosome that carries this allele. The genotype of the woman can be either  $X^H X^h$  or  $X^H X^H$ , and the probability of each is 1/2.

◆ The correct answer is **C**.

**Part 3:** Since the father of I.2 was affected, we surmise that his genotype was  $X^h Y$ . I.2 inherited chromosome  $X^h$  from her father, so her genotype is  $X^h _$ . Since I.2 is not affected, her other X chromosome certainly carries the dominant allele for hemophilia and her genotype is  $X^H X^h$ . The dominant X chromosome was inherited from her mother, who accordingly had a  $X^H _$  genotype and can only exhibit a non-hemophilic phenotype.

◆ The correct answer is **β**.

**P.26** → **Solution**

The first scenario is quite straightforward to analyze. If the disease is conditioned by an autosomic allele and father A and mother B had an affected child, their genotype can only be  $Aa$ , where A is a dominant allele and a is a recessive allele. Thus, the probabilities (I) and (II) that the father and mother harbor the recessive allele are both 100%. Suppose now the disease is determined by a recessive allele  $X^a$  in the X chromosome. We immediately infer that the father has genotype  $X^A Y$ , otherwise he would be affected; probability (III) is 0%. The mother, in turn, can only have a genotype  $X^A X^a$ , otherwise the

affected child would not have a parent from which to inherit the recessive allele; probability (IV) is 100%.

◆ The correct answer is **D**.

**P.27** → **Solution**

**Part 1:** The genotypes of the individuals in question can be easily determined as in previous problems; refer to the following table.

I.1 = $aaX^DX^-$	II.2 = $A_X^dY$	III.1 = $AaX^DX^d$
I.2 = $A_X^dY$	II.2 = $aaX^DX^-$	III.2 = $A_X^dY$
I.3 = $A_X^dY$	II.3 = $AaX^DY$	
I.4 = $aaX^dX^d$	II.4 = $AaX^dX^d$	

The genotype of III.1 was established as  $AaX^DX^d$ . Man III.2 is  $X^dY$ , but may be either homozygous  $AA$  or heterozygous  $Aa$ . Thus, a child of this couple will only be albino if III.2 is heterozygous  $Aa$ ; this probability is estimated as  $2/3$ , in view of the fact that his parents (II.3 and II.4) are both heterozygous. If III.2 is indeed heterozygous, the probability that his descendant with III.1 comes to be albino is  $1/4$ , as shown in the following Punnett square.

	A	a
A	AA	Aa
a	Aa	aa

Likewise, the probability that a child of III.1 and III.2 will have normal sight is  $1/2$ , as shown below.

	$X^d$	Y
$X^D$	$X^DX^d$	$X^DY$
$X^d$	$X^dX^d$	$X^dY$

The probability that the child will be albino but have normal sight is  $1/4 \times 1/2 = 1/8$ , assuming III.2 is heterozygous for the color blindness gene, which in turn has odds of  $2/3$ ; the final probability we aim for is  $1/8 \times 2/3 = 1/12$ .

◆ The correct answer is **C**.

**Part 2:** We were told that the couple has already had an albino son that had no albinism; accordingly, we can surmise that the genotype of the father is  $AaX^dY$ . It remains to compute the probability that a male child obtained from the cross  $AaX^DX^d \times AaX^dY$  will be albino and color blind; since the problem refers to a male descendant, we exclude female genotypes from the calculation. As before, we appeal to Punnett squares.

	A	a		$X^d$	Y
A	AA	Aa		-	$X^DY$
a	Aa	aa		-	$X^dY$

The probability that the son will be albino is  $1/4$ , and the probability that he will be color blind is  $1/2$ ; the probability for both conditions is  $1/4 \times 1/2 = 1/8$ .

◆ The correct answer is **B**.



## ▶ ANSWER SUMMARY

Problem CS		<b>B</b>
Problem 2		<b>B</b>
Problem 3		<b>D</b>
Problem 4		<b>T/F</b>
Problem 5		<b>T/F</b>
Problem 6		<b>C</b>
Problem 7		<b>A</b>
Problem 8		<b>B</b>
Problem 9		<b>D</b>
Problem 10		<b>A</b>
Problem 11		<b>B</b>
Problem 12		<b>C</b>
Problem 13		<b>B</b>
Problem 14		<b>D</b>
Problem 15	15.1	$\alpha$
	15.2	<b>C</b>
Problem 16		<b>E</b>
Problem 17		<b>D</b>
Problem 18		<b>A</b>
Problem 19		<b>D</b>
Problem 20		<b>C</b>
Problem 21		<b>B</b>
Problem 22		<b>D</b>
Problem 23		<b>A</b>
Problem 24		<b>B</b>
Problem 25	25.1	<b>B</b>
	25.2	<b>C</b>
	25.3	$\beta$
Problem 26		<b>D</b>
Problem 27	27.1	<b>C</b>
	27.2	<b>B</b>



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