AP Biology

Basic Genetics Practice Problems

North Salem University

MISSION: *Engage students to continuously learn, question, define and solve problems through critical and creative thinking.*

WINTER 2024

If you have any problems – please sign up for extra help after school.

Ch.14 – Mendelian Genetics

Chapter 14: Mendelian Genetics

OBJECTIVES:

Gregor Mendel's Discoveries

__1. Explain how observations by Mendel and others and Mendel's hypothesis of inheritance differed from the blending theory of inheritance.

__2. List several features of Mendel's methods that contributed to his success.

__3. Define true breeding, hybridization, monohybrid cross, P generation, F_1 generation, and F_2 generation.

__4. List and explain the four components of Mendel's hypothesis that led him to deduce the law of segregation.

__5. Explain how Mendel's law of segregation got its name.

__6. Use a Punnett square to predict the results of a monohybrid cross and state the phenotypic and genotypic ratios of the F_2 generation.

__7. Distinguish between the following pairs of terms:
dominant and recessive; heterozygous and homozygous; genotype and phenotype.

__8. Explain how a testcross can be used to determine if a dominant phenotype is homozygous or heterozygous.

__9. Use a Punnett square to predict the results of a dihybrid cross and state the phenotypic and genotypic ratios of the F_2 generation.

__10. Define Mendel's law of independent assortment.

__11. Use the rule of multiplication to calculate the probability that a particular F_2 individual will be homozygous recessive or dominant.

__12. Given a Mendelian cross, use the rule of addition to calculate the probability that a particular F_2 individual will be heterozygous.

__13. Use the laws of probability to predict from a trihybrid cross between two individuals that are heterozygous for all three traits, what expected proportion of the offspring would be:
a. homozygous for the three dominant traits
b. heterozygous for all three traits
c. homozygous recessive for two specific traits and heterozygous for the third

__14. Explain why Mendel was wise to use large sample sizes in his studies.

Extending Mendelian Genetics

__15. Give an example of incomplete dominance and explain why it is not evidence for the blending theory of inheritance.

__16. Explain how the phenotypic expression of the heterozygote is affected by complete dominance, incomplete dominance, and co-dominance.

__17. Explain why Tay-Sachs is considered recessive at the organismic level but co-dominant at the molecular level.

__18. Explain why genetic dominance does not mean that the dominant allele subdues a recessive allele. Illustrate your explanation with the use of the round versus wrinkled pea seed shape.

__19. Explain why dominant alleles do not necessarily mean that the allele is more common in a population. Illustrate your explanation with the character polydactyly.

__20. Describe the inheritance of the ABO blood system and explain why the I^A and I^B alleles are said to be co-dominant.

__21. Define and give examples of pleiotropy and epistasis.

__22. Describe a simple model for polygenic inheritance and explain why most polygenic characters are described in quantitative terms.

__23. Describe how environmental conditions can influence the phenotypic expression of a character.

__24. Explain why studies of human inheritance are not as easily conducted as Mendel's work with his peas.

__25. Given a simple family pedigree, deduce the genotypes for some of the family members.

__26. Explain how a lethal recessive gene can be maintained in a population.

__27. Describe the inheritance and expression of cystic fibrosis, Tay-Sachs disease, and sickle-cell disease.

__28. Explain why lethal dominant genes are much rarer than lethal recessive genes.

__29. Give an example of a late-acting lethal dominant in humans and explain how it can escape elimination.

__30. Explain how carrier recognition, fetal testing, and newborn screening can be used in genetic screening and counseling.

KEY TERMS:

alleles	amniocentesis	carrier	chorionic villus sampling
codominance	complete dominance	cystic fibrosis	dihybrid
dominant allele	epistasis	F_1 generation	F_2 generation
genotype	Heterozygous	homozygous	huntington's disease
hybridization	Incomplete dominance	law of independent assortment	law of segregation
monohybrid	P generation	pedigree	phenotype
pleiotropy	polygenic inheritance	Punnett squar	recessive allele
sickle–cell disease	Tay–Sachs disease	trait	

- -

WORD ROOTS:

co- = together (*codominance*: phenotype in which both dominant alleles are expressed in the heterozygote)

-centesis = a puncture (*amniocentesis*: a technique for determining genetic abnormalities in a fetus by the presence of certain chemicals or defective fetal cells in the amniotic fluid, obtained by aspiration from a needle inserted into the uterus)

di- = two (*dihybrid cross*: a breeding experiment in which parental varieties differing in two traits are mated)

epi- = beside; **-stasis =** standing (*epistasis*: a phenomenon in which one gene alters the expression of another gene that is independently inherited)

geno- = offspring (*genotype*: the genetic makeup of an organism)

hetero- = different (*heterozygous*: having two different alleles for a trait)

homo- = alike (*homozygous*: having two identical alleles for a trait)

mono- = one (*monohybrid cross*: a breeding experiment that uses parental varieties differing in a single character)

pedi- = a child (*pedigree*: a family tree describing the occurrence of heritable characters in parents and offspring across as many generations as possible)

pheno- = appear (*phenotype*: the physical and physiological traits of an organism)

pleio- = more (*pleiotropy*: when a single gene impacts more than one characteristic)

poly- = many; **gen-** = produce (*polygenic*: an additive effect of two or more gene loci on a single phenotypic character)

Gregor Mendel
(July 20, 1822 – January 6, 1884)

Guided Reading: Chapter 14

Gregor Mendel's Discoveries

1. In the 1800s the most widely favored explanation of genetics was blending. Explain the concept of blending, and then describe how Mendel's particulate (gene) theory was different.

2. One of the keys to success for Mendel was using pea plants. Explain how using pea plants allowed Mendel to control mating; that is, how did this approach let Mendel be positive about the exact characteristics of each parent?

3. Define the following terms. Then, consider your own family. Which generation would your Mom's grandparents be? Your Mom? You?

    P generation -

    F$_1$ generation -

    F$_2$ generation -

4. Explain how Mendel's simple cross of purple and white flowers did the following:

    refuted blending -

    determined dominant and recessive characteristics -

5. Alternate versions of the same gene, like purple and white flower color, are termed _____.

6. On the figure at below, label the *allele* for both purple and white flower color, a *homologous pair*, and the *locus* of the flower color gene.
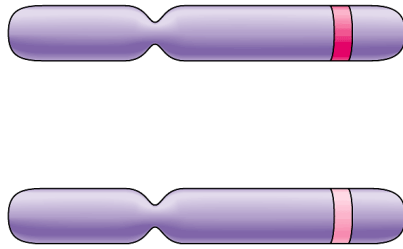
7. In sexually reproducing organisms, why are there exactly two chromosomes in each homologue or homologous pair?

8. Mendel's model consists of four related ideas. Describe each idea and indicate which of the ideas can be observed during meiosis by placing an asterisk by the concept.
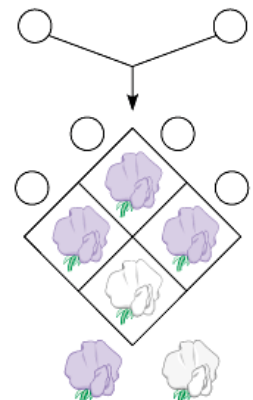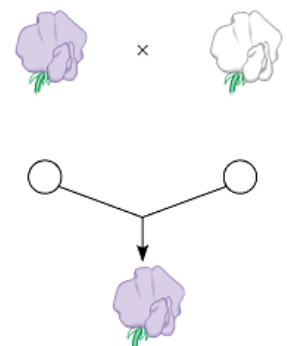
   (1)

   (2)

   (3)

   (4)

9. Using Figure 14.4 as your guide, provide the missing notations for the figure to the right. (P, F$_1$, F$_2$).

   a. What is the F$_2$ phenotypic and genotypic ratio?

   b. Which generation is completely heterozygous?

   c. Which generation has both heterozygous and homozygous offspring?

10. In pea plants, *T* is the allele for tall plants, while *t* is the allele for dwarf plants. If you have a tall plant, demonstrate with a *test cross* how it could be determined if the plant is homozygous tall or heterozygous tall.

11. Explain the difference between a *monohybrid* cross and a *dihybrid cross*.

12. As you start to work word problems in genetics, two things are critical: the parent's genotype must be correct, and the gametes must be formed correctly. Using Figure 14.7 as your guide, explain how the gametes are derived for the following cross. You should have four different gametes. (*Hint: FOIL it*)

$YyRr \times YyRr$

13. Complete the cross given in questions 12 by placing the gametes in a *Punnett square*. Then provide the phenotypic ratio of the offspring.

Pheotypic Ratio:

_____

_____

_____

_____

14. An event that is certain to occur has a probability of _____, while an event that is certain not to occur has probability of _____.

15. In probability, what is an *independent event*?

16. State the *multiplication rule* and give an original example.

17. State the *addition rule* and give an original example.

18. What is the probability that a couple will have a girl, a boy, a girl, and a boy in this specific order?

19. Explain how *incomplete dominance* is different from *complete dominance*, and give an example of incomplete dominance.

20. Compare and contrast *codominance* with *incomplete dominance*.

21. Dominant alleles are not necessarily more common than recessive alleles in the gene pool. Explain why this is true.

22. Explain what is meant when a gene is said to have *multiple alleles*.

23. Blood groups are so important medically that you should be able to solve genetics problems based on blood types. The first step in accomplishing that is to understand the genotypes of each blood type. Before working any problems, complete the ABO blood type chart to the right.

24. Question 6 on p.267 is a blood type problem. Complete it here, and show your work.

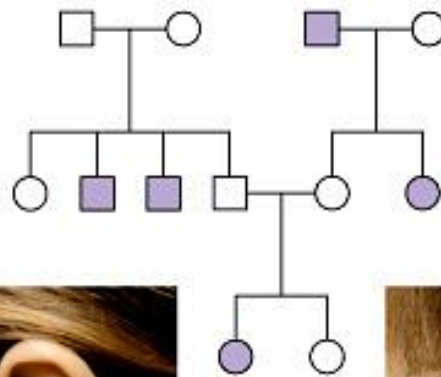| Phenotype	Genotype(s)
A	
B	
AB	
O	

25. Explain *epistasis*.

26. Explain why the dihybrid cross detailed in Figure 14.11 has 4 white mice instead of the 3 that would have been predicted by Mendel's work.

27. Why is height a good example of *polygenic inheritance*?

28. What is a pedigree?

29. Pedigree analysis is often used to determine the mode of inheritance (dominant or recessive, for example). Be sure to read the "Tips for pedigree analysis" in Figure 14.14; then complete the unlabeled pedigree by indicating the genotypes for all involved. What is the mode of inheritance for this pedigree?

30. Explain why you know the genotype of one female in the third generation, but are unsure of the other.

31. Describe what you think is important to know medically about the behavior of recessive alleles.

32. Students are expected to have a general knowledge of the pattern of inheritance and the common symptoms of a number of genetic disorders. Provide this information for the disorders listed below.

Cystic Fibrosis		
Cause	**Pattern of Inheritence**	**Pathology**
Protein:		

Tay-Sachs Disease		
Cause	**Pattern of Inheritence**	**Pathology**
Protein:		

Sickle-Cell Disease		
Cause	**Pattern of Inheritence**	**Pathology**
Protein:		

Phenylketonuria (PKU)		
Cause	**Pattern of Inheritence**	**Pathology**
Protein:		

Adrenoleukodystrophy (ALD)		
Cause	**Pattern of Inheritence**	**Pathology**
Protein:		

Hemophilia		
Cause	**Pattern of Inheritence**	**Pathology**
Protein:		

33. *Amniocentesis* and *chorionic villus sampling* are the two most widely used methods for testing a fetus for genetic disorders. Use the unlabeled diagram below to explain the three main steps in amniocentesis and the two main steps of CVS.
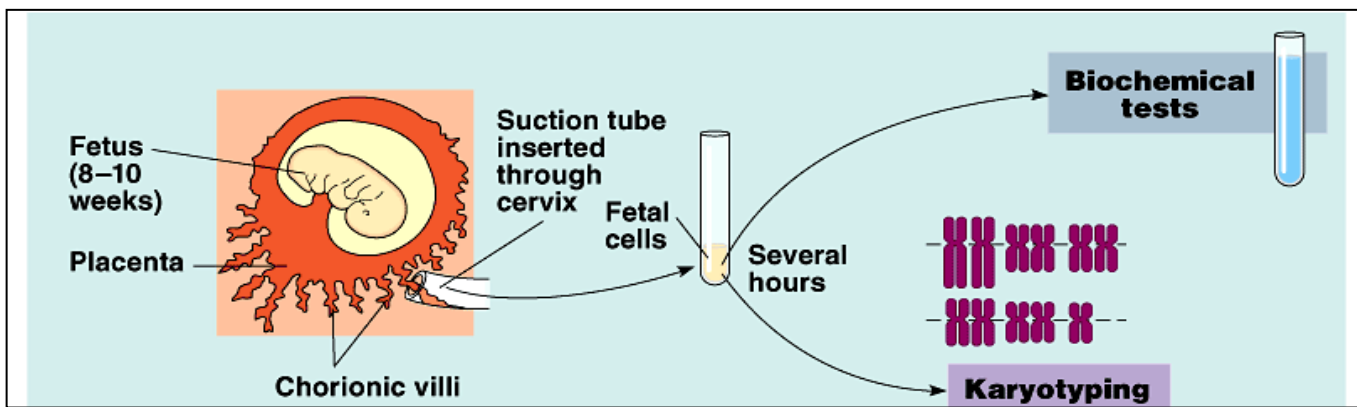
Amniocentesis
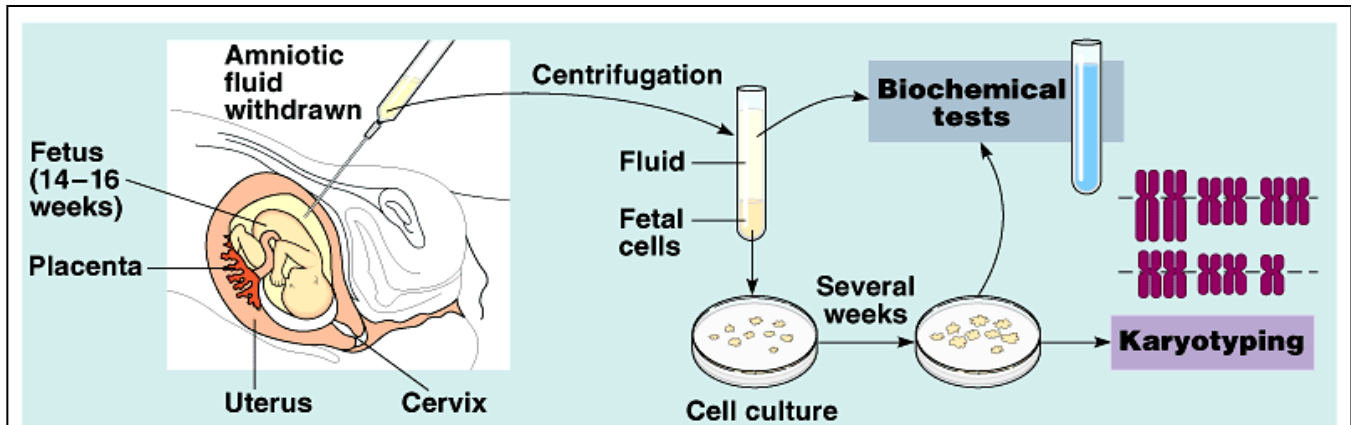
(1)   **(2)**   **(3)**

Chorionic villus sampling

(1)   **(2)**

34. What are the strengths and weaknesses of each fetal test?

Chapter 14: Summary of Key Concepts

GREGOR MENDEL's DISCOVERIES

- Mendel brought an experimental and quantitative approach to genetics (pp. 247-249, FIGURE 14.1) Gregor Mendel formulated a particulate theory of inheritance based on experiments with garden peas, carried out in the 1860s. He showed that parents pass on to their offspring discrete genes that retain their identity through the generations.
- By the law of segregation, the two alleles for a character are packaged into separate gametes (pp. 249-252, FIGURE 14.4) Mendel arrived at this law by making hybrid offspring and letting them self-pollinate. The hybrids (F_1) exhibited the dominant trait. In the next generation (F_2), 75% of offspring had the dominant trait and 25% had the recessive trait, for a 3:1 ratio. Mendel's explanation was that genes have alternative forms (now called alleles) and that each organism inherits one allele for each gene from each parent. These separate (segregate) during gamete formation, so that a sperm or an egg carries only one allele. After fertilization, if the two alleles of a gene are different, one (the dominant allele) is expressed in the offspring and the other (the recessive allele) is masked. Homozygous individuals have identical alleles for a given character and are true-breeding. Heterozygous individuals have two different alleles for a given character.
  By the law of independent assortment, each pair of alleles segregates into gametes independently (pp. 252-254, FIGURE 14.7) Mendel proposed this law based on dihybrid crosses between plants heterozygous for two characters (for example, flower color and seed shape). Alleles for each character segregate into gametes independently of alleles for other characters. The offspring of a dihybrid cross (the F_2 generation) have four phenotypes in a 9:3:3:1 ratio.
- Mendelian inheritance reflects rules of probability (pp. 254-255, FIGURE 14.8) The rule of multiplication states that the probability of a compound event is equal to the product of the separate probabilities of the independent single events. The rule of addition states that the probability of an event that can occur in two or more independent ways is the sum of the separate probabilities.

EXTENDING MENDELIAN GENETICS

- The relationship between genotype and phenotype is rarely simple (pp. 255-260, FIGURES 14.9, 14.13 In incomplete dominance, a heterozygous individual has a phenotype intermediate between those of the two types of homozygotes. In codominance, a heterozygote exhibits phenotypes for both its alleles. Many genes exist in multiple (more than two) alleles in a population. Pleiotropy is the ability of a single gene to affect multiple phenotypic traits. In epistasis, one gene affects the expression of another gene. Certain characters are quantitative; they vary continuously, indicating polygenic inheritance, an additive effect of two or more genes on a single phenotypic character. Quantitative characters also influenced by environment are said to be multifactorial.

MENDELIAN INHERITANCE IN HUMANS

- Pedigree analysis reveals Mendelian patterns in human inheritance (p. 260, FIGURE 14.14 Family pedigrees can be used to deduce the possible genotypes of individuals and make predictions about future offspring. Any predictions are usually statistical probabilities rather than certainties.
- Many human disorders follow Mendelian patterns of inheritance (pp. 261-264). Certain genetic disorders are inherited as simple recessive traits from phenotypically normal, heterozygous carriers. Some human disorders are due to dominant alleles. Medical researchers are beginning to sort out the genetic and environmental components of multifactorial disorders, such as heart disease and cancer.
- Technology is providing new tools for genetic testing and counseling (pp. 264-266, FIGURE 14.17) Using family histories, genetic counselors help couples determine the odds that their children will have genetic disorders. For certain diseases, tests that identify carriers define the odds more accurately. Once a child is conceived, amniocentesis and chorionic villus sampling can help determine whether a suspected genetic disorder is present.

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Chapter 14 - Review Questions

Now you should be ready to test your knowledge. This chapter, like all the other chapters in your textbook, has questions at the end of it (*along with the answers*) for you to check your understanding.
One of the ways to determine your understanding of Mendelian genetics is to do as many genetic problems as possible. With that said, complete each of the following questions located on **pp.267-268** in your textbook as neatly as possible. Be sure to show all your work and to check your answers.

As always, make an appointment to see me if you have any questions.

Questions 1, 2, 3, 4, 5, 8, 9, 10, 11, and 12

__1)   Mendel conducted his most memorable experiments on -
A) peas.   C) guinea pigs.
B) roses.   D) fruit flies.

__2)   Varieties of plants in which self-fertilization produces offspring that are identical to the parents are referred to as -
A) hybrids.   C) monohybrid crosses.
B) the F_2 generation.   D) true-breeding.

__3)   A monohybrid cross is -
A) the second generation of a self-fertilized plant.
B) a breeding experiment in which the parental varieties have only one trait in common.
C) a breeding experiment in which the parental varieties differ in only one character.
D) a breeding experiment in which the parental varieties have only one prominent trait.

__4)   Which of the following statements regarding genotypes and phenotypes is *false*?
A) The genetic makeup of an organism constitutes its genotype.
B) An organism with two different alleles for a single trait is said to be homozygous for that trait.
C) Alleles are alternate forms of a gene.
D) The expressed physical traits of an organism are called its phenotype.

__5)   Research since Mendel's time has established that the law of the segregation of genes during gamete formation -
A) applies to all forms of life.   C) applies to all asexually reproducing organisms.
B) applies to all sexually reproducing organisms.   D) is invalid.

__6)   All the offspring of a cross between a black-eyed mendelien and an orange-eyed mendelien have black eyes. This means that the allele for black eyes is _____ the allele for orange eyes.
A) codominant to   C) more aggressive than
B) recessive to   D) dominant to

__7)   All the offspring of a cross between a black-eyed mendelien and an orange-eyed mendelien have black eyes. What is the expected phenotypic ratio of a cross between two orange-eyed mendeliens?
A) 3 black-eyed:1 orange-eyed   C) 1 black-eyed:3 orange-eyed
B) 0 black-eyed:1 orange-eyed   D) 1 black-eyed:0 orange-eyed

__8) The alleles of a gene are found at _____ chromosomes.
A) the same locus on non-homologous
B) different loci on homologous
C) different loci on non-homologous
D) the same locus on homologous

__9) The phenotypic ratio resulting from a dihybrid cross showing independent assortment is expected to be -
A) 1:2:1.
B) 3:1.
C) 9:1:1:3.
D) 9:3:3:1.

__10) If *A* is dominant to *a* and *B* is dominant to *b*, what is the expected phenotypic ratio of the cross:
AaBb × *AaBb*?

A) 16:0:0:0
B) 8:4:2:2
C) 1:1:1:1
D) 9:3:3:1

__11) Mendel's law of independent assortment states that -
A) chromosomes sort independently of each other during mitosis and meiosis.
B) independent sorting of genes produces polyploid plants under some circumstances.
C) each pair of alleles segregates independently of the other pairs of alleles during gamete formation.
D) genes are sorted concurrently during gamete formation.

__12) A testcross is -
A) a mating between an individual of unknown genotype and an individual homozygous recessive for the trait of interest.
B) a mating between an individual of unknown genotype and an individual heterozygous for the trait of interest.
C) a mating between two individuals heterozygous for the trait of interest.
D) a mating between two individuals of unknown genotype.

__13) Using a six-sided die, what is the probability of rolling either a 5 or a 6?
A) 1/6 × 1/6 = 1/36
B) 1/6 + 1/6 = 1/3
C) 1/6 + 1/6 = 2/3
D) 1/6

__14) Assuming that the probability of having a female child is 50% and the probability of having a male child is also 50%, what is the probability that a couple's first-born child will be female and that their second-born child will be male?
A) 20%
B) 25%
C) 50%
D) 75%

__15) Dr. Smith's parents have normal hearing. However, Dr. Smith has an inherited form of deafness. Deafness is a recessive trait that is associated with the abnormal allele *d*. The normal allele at this locus, associated with normal hearing, is *D*. Dr. Smith's parents could have which of the following genotypes?
A) *DD* and *dd*
B) *dd* and *dd*
C) *Dd* and *Dd*
D) *Dd* and *DD*

__16) A carrier of a genetic disorder who does not show symptoms is most likely to be _____ to transmit it to offspring.
A) heterozygous for the trait and able
B) heterozygous for the trait and unable
C) homozygous for the trait and able
D) homozygous for the trait and unable

__17) Most genetic disorders of humans are caused by -
A) multiple alleles.
B) recessive alleles.
C) a mutation that occurs in the egg.
D) dominant alleles.

__18) Most people afflicted with recessive disorders are born to parents who were -
A) both affected by the disease.
B) not affected at all by the disease.
C) slightly affected by the disease, showing some but not all of the symptoms.
D) subjected to some environmental toxin that caused the disease in their children.

__19) Which of the following statements best explains why dominant alleles that cause lethal disorders are less common than recessive alleles that cause lethal disorders?
A) Lethal disorders caused by dominant alleles are usually more severe than lethal disorders caused by recessive alleles.
B) Unlike lethal disorders caused by recessive alleles, lethal disorders caused by dominant alleles usually cause the death of the embryo.
C) Most individuals carrying a lethal dominant allele have the disorder and die before they reproduce, whereas individuals carrying a lethal recessive allele are more likely to be healthy and reproduce.
D) The presence of a lethal dominant allele causes sterility.

__20) Amniocentesis and chorionic villus sampling allow for _____ and _____ of the fetus so that it can be tested for abnormalities.
A) imaging . . . karyotyping   C) karyotyping . . . biochemical testing
B) sexing . . . imaging   D) direct observation . . . biochemical testing

__21) All the offspring of a cross between a red-flowered plant and a white-flowered plant have pink flowers. This means that the allele for red flowers is _____ to the allele for white flowers.
A) dominant   C) incompletely dominant
B) codominant   D) recessive

__22) The expression of both alleles for a trait in a heterozygous individual illustrates -
A) incomplete dominance.   C) pleiotropy.
B) codominance.   D) polygenic inheritance.

__23) A person with AB blood illustrates the principle of -
A) incomplete dominance.   C) pleiotropy.
B) codominance.   D) polygenic inheritance.

__24) Which of the following terms refers to a situation where a single phenotypic character is determined by the additive effects of two or more genes?
A) incomplete dominance   C) pleiotropy
B) codominance   D) polygenic inheritance

__25) The individual features of all organisms are the result of -
A) genetics.   C) the environment and individual needs.
B) the environment.   D) genetics and the environment.