S1.Coat color in rodents is determined by a gene interaction between two genes. If a true-breeding black rat is crossed to a true-breeding albino rat, the result is a rat with agouti (brownish/dark gray) coat color. If two agouti animals of the F_1 generation are crossed to each other, they produce agouti, black, and albino animals in a 9:3:4 ratio. Explain the pattern of inheritance for this trait.

Answer: Since the parental generation is true-breeding, we know that the F_1 offspring are heterozygous for two genes. One strategy for solving this problem is to consider how a 9:3:4 ratio deviates from the 9:3:3:1 ratio we have already encountered in (two-gene) independent assortment problems. A 9:3:3:1 ratio has four categories of phenotypes. If we consider that the last two categories are combined via a gene interaction, this would yield a 9:3:4 ratio. With this idea in mind, we can then proceed to fill in a Punnett square to deduce the pattern of inheritance.

The F_1 offspring are heterozygous for two genes. Let's call them *A* (for albino) and *C* (for colored).

CcAa x *CcAa*

♀ \ ♂	*CA*	*Ca*	*cA*	*ca*
CA	*CCAA* Agouti	*CCAa* Agouti	*CcAA* Agouti	*CcAa* Agouti
Ca	*CCAa* Agouti	*CCaa* Albino	*CcAa* Agouti	*Ccaa* Albino
cA	*CcAA* Agouti	*CcAa* Agouti	*ccAA* Black	*ccAa* Black
ca	*CcAa* Agouti	*Ccaa* Albino	*ccAa* Black	*ccaa* Albino

In this case, *C* is dominant to *c*, and *A* is dominant to *a.* If an animal has at least one copy of both dominant alleles, it will have the agouti coat color. If an animal has a dominant *A* allele but is *cc* homozygous, it will develop a black coat. The four cases of albino animals all are *aa* homozygous. This occurs even when an animal carries the dominant *C* allele. Therefore, *a* is epistatic to *C.* The converse, however, does not yield the same result. Animals with *ccAA* or *ccAa* genotypes are black.

S2. In Ayrshire cattle, the spotting pattern of the animals can be either red and white or mahogany and white. The mahogany and white pattern is caused by the allele *M.* The red and white phenotype is controlled by the allele *m.* When mahogany and white animals are mated to red and white animals, the following results are obtained:

Genotype	Phenotype	
	Females	Males
MM	mahogany and white	mahogany and white
Mm	red and white	mahogany and white
mm	red and white	red and white

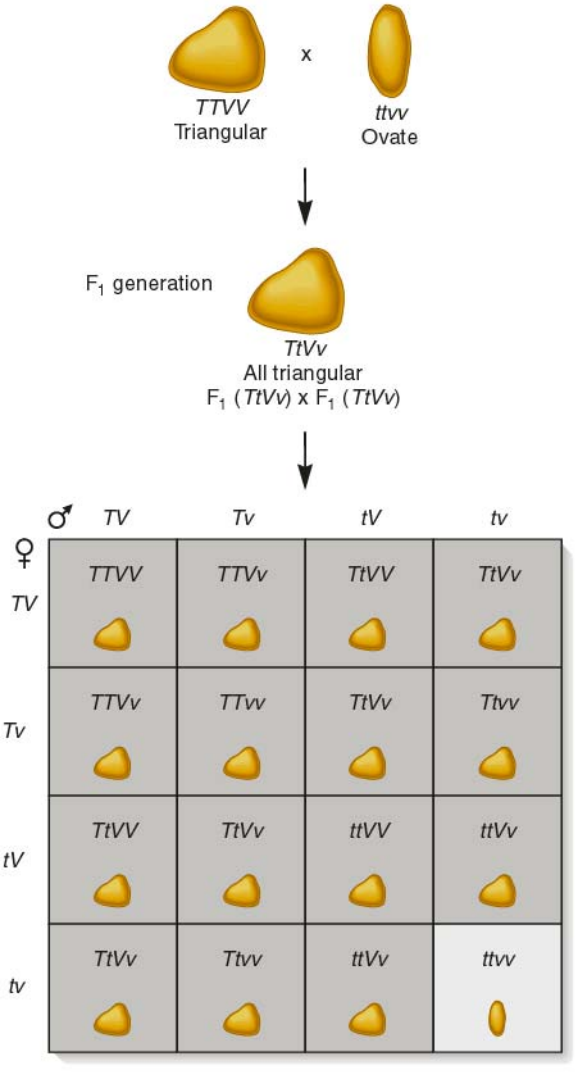
Explain the pattern of inheritance.

Answer: The inheritance pattern for this trait is sex-influenced inheritance. The *M* allele is dominant in males but recessive in females, while the *m* allele is dominant in females but recessive in males.

S3. George Shull, a botanist at Princeton University, conducted a genetic study of a weed known as shepherd's purse, a member of the mustard family. One trait he followed was the shape of the seed capsule, which can be triangular or a small ovate shape. When he crossed a true-breeding plant with triangular capsules to a plant having ovate capsules, the F_1 generation all had triangular capsules. When the F_1 plants were self-fertilized, the surprising result came in the F_2 generation. Shull observed a 15:1 ratio of plants having triangular capsules to ovate capsules. Explain this ratio based on a two-gene interaction.

Answer: This result can be explained by a two-gene interaction in which each gene is found as a dominant or recessive allele. The presence of one dominant allele in either gene results in a triangular capsule. If we let *T* and *t* represent the dominant and recessive alleles of one gene and let *V* and *v* represent the dominant and recessive alleles of a second gene, the results of Shull's crosses are outlined in the following Punnett square:

(a) Shepherd's purse capsule types



(b) The crosses of Shull

This experiment of George Shull demonstrates an important phenomenon, confirmed in subsequent genetic studies. Many eukaryotic genes appear to be redundant. In other words, there are two (or more) genes that can play analogous roles in the life of the organism. In this example, either of the dominant alleles, *T* or *V*, which are alleles of different genes, is sufficient to cause triangular capsules. If the expression of one of the two genes is abolished by a recessive mutation, a dominant allele of the other gene can still produce the triangular phenotype. At the molecular level, gene redundancy can sometimes be explained by the formation of extra copies of a gene during evolution.

S4. For the following pedigree involving a single gene causing an inherited disease, indicate which modes of inheritance are *not* possible. (Affected individuals are shown as filled symbols.)

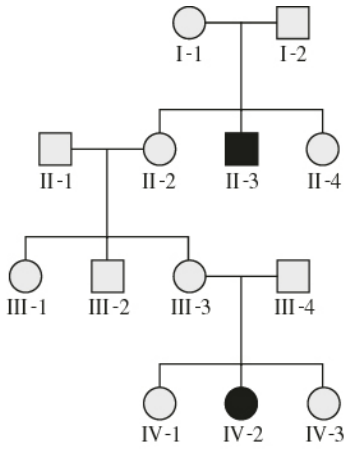
A. Recessive

B. Dominant

C. X linked, recessive

D. Sex influenced, dominant in females

E. Sex limited, recessive in females



Answer:

A. It could be recessive.

B. It is probably not dominant unless it is incompletely penetrant.

C. It could not be X-linked recessive because individual IV-2 does not have an affected father.

D. It could not be sex influenced, dominant in females because individual II-3 (who would have to be homozygous) has an unaffected mother (who would have to be heterozygous and affected).

E. It is not sex limited because individual II-3 is an affected male and IV-2 is an affected female.

S5. Pattern baldness is an example of a sex-influenced trait that is dominant in males and recessive in females. A nonbald couple produced a bald son. What are the genotypes of the parents?

Answer: Since the father is not bald, we know he must be homozygous, *bb*. Otherwise, he would be bald. A nonbald female can be either *Bb* or *bb*. Since she has produced a bald son, we know that she must be *Bb* in order to pass the *B* allele to her son.

S6. Two pink-flowered four-o'clocks were crossed to each other. What are the following probabilities?

A. A red-flowered plant.

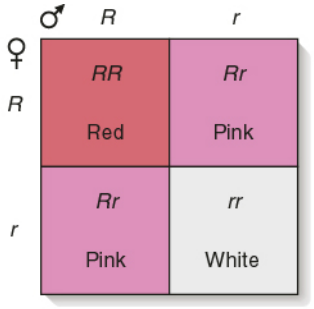
B. The first three plants examined will be white.

C. A plant will be either white or pink.

D. A group of six plants contain one pink, two whites, and three reds.

Answer: The first thing we need to do is construct a Punnett square to determine the individual probabilities for each type of offspring.

Since flower color is incompletely dominant, the cross is *Rr* x *Rr*.



Phenotypic ratio is 1 red : 2 pink : 1 white. In other words, 1/4 are expected to be red, 1/2 pink, and 1/4 white.

A. The probability of a red-flowered plant is 1/4, which equals 25%.

B. Use the product rule.

$$1/4 \times 1/4 \times 1/4 = 1/64 = 1.6\%$$

C. Use the sum rule because these are mutually exclusive events. A given plant cannot be both white and pink.

$$1/4 + 1/2 = 3/4 = 75\%$$

D. Use the multinomial expansion. See solved problem S7 in chapter 2 for an explanation of the multinomial expansion. In this case, there are three possible phenotypes.

$$P = \frac{n!}{a!b!c!} p^a q^b r^c$$

where n = total number of offspring = 6
a = number of reds = 3
p = probability of reds = (1/4)
b = number of pinks = 1
q = probability of pink = (1/2)
c = number of whites = 2
r = probability of whites = (1/4)

If we substitute these values into the equation:

$$P = \frac{6!}{3!1!2!}(1/4)^3(1/2)^1(1/4)^2$$

$$P = 0.029 = 2.9\%$$

This means that 2.9% of the time we would expect to obtain six plants, three with red flowers, one with pink flowers, and two with white flowers.