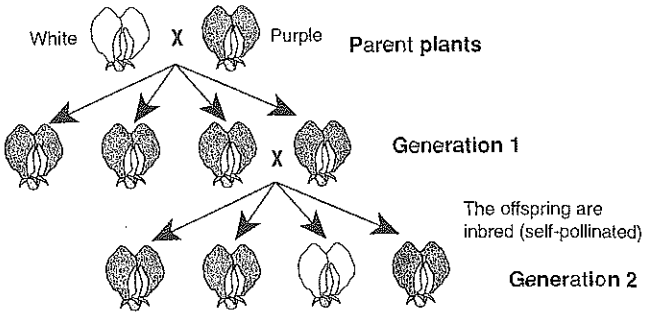
Mendel's Laws of Inheritance

From his work on the inheritance of phenotypic traits in peas, Mendel formulated a number of ideas about the inheritance of characters. These were later given formal recognition as Mendel's laws of inheritance. These are outlined below.

The Theory of Particulate Inheritance

Characteristics of both parents are passed on to the next generation as discrete entities (genes).

This model explained many observations that could not be explained by the idea of blending inheritance, which was universally accepted prior to this theory. The trait for flower color (right) appears to take on the appearance of only one parent plant in the first generation, but reappears in later generations.

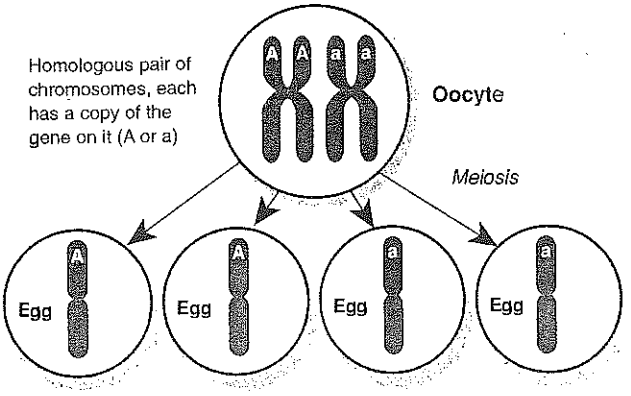


Law of Segregation

During gametic meiosis, the two members of any pair of alleles ***segregate*** *unchanged and are passed into different gametes, so that each gamete receives only one allele of a pair.*

These gametes are eggs (ova) and sperm cells. The allele in the gamete will be passed on to the offspring.

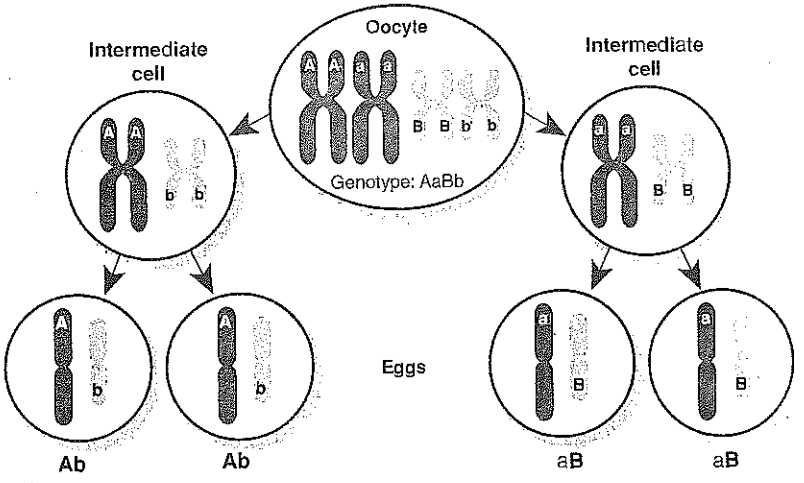
NOTE: This diagram has been simplified, omitting the stage where the second chromatid is produced for each chromosome.



Law of Independent Assortment

Allele pairs separate independently during gamete formation, and traits are passed on to offspring independently of one another (this is only true for unlinked genes).

This diagram shows two genes (A and B) that code for different traits. Each of these genes is represented twice, one copy (allele) on each of two homologous chromosomes. The genes A and B are located on different chromosomes and, because of this, they will be inherited independently of each other i.e. the gametes may contain any combination of the parental alleles.



1. State the **property of genetic inheritance** that allows parent pea plants of different flower color to give rise to flowers of a single color in the first generation, with both parental flower colors reappearing in the following generation:

   _____

2. The oocyte is the egg producing cell in the ovary of an animal. In the diagram illustrating the **law of segregation** above:

   (a) State the genotype for the oocyte (adult organism): _____

   (b) State the genotype of each of the **four** gametes: _____

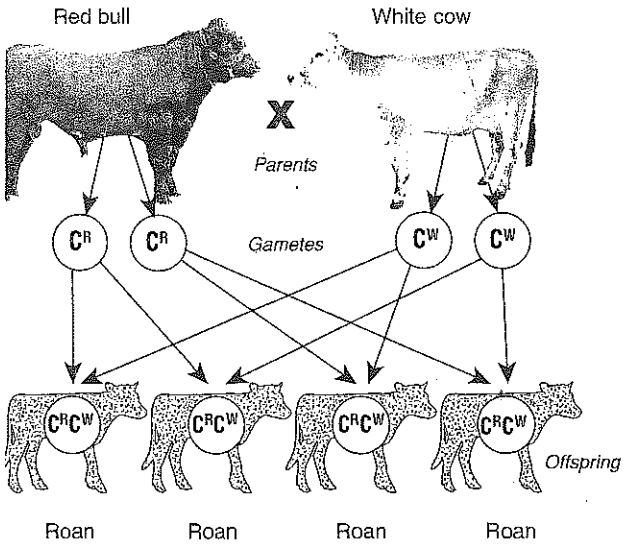
   (c) State how many different kinds of gamete can be produced by this oocyte: _____

3. The diagram illustrating the **law of independent assortment** (above) shows only one possible result of the random sorting of the chromosomes to produce: Ab and aB in the gametes.
   (a) List another possible combination of genes (on the chromosomes) ending up in gametes from the same oocyte:

   _____

   (b) How many different gene combinations are possible for the oocyte? _____

Codominance refers to an inheritance pattern in which both alleles in a heterozygote contribute to the phenotype. Both alleles are **independently** and **equally expressed**. One example includes the human blood group AB which is the result of two alleles: A and B, both being equally expressed. Other examples include certain coat colors in horses and cattle. Reddish coat color is equally dominant with white. Animals that have both alleles have coats that are roan-colored (coats with a mix of red and white hairs). The red hairs and white hairs are expressed equally and independently (not blended to produce pink).




A roan shorthorn heifer

In the shorthorn cattle breed, coat color is inherited. White shorthorn parents always produce calves with white coats. Red parents always produce red calves. However, when a red parent mates with a white one, the calves have a coat color that is different from either parent; a mixture of red and white hairs, called roan. Use the example (left) to help you to solve the problems below.

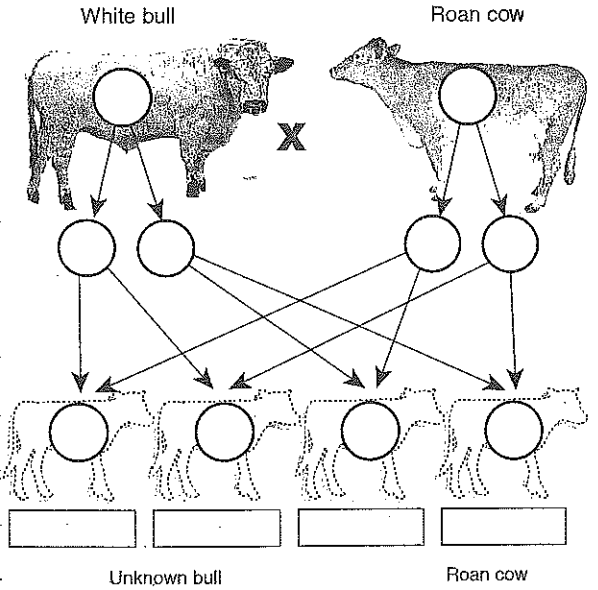
Explain how codominance of alleles can result in offspring with a phenotype that is different from either parent:

A white bull is mated with a roan cow (right):

(a) Fill in the spaces to show the genotypes and phenotypes for parents and calves:

(b) What is the phenotype ratio for this cross?

(c) How could a cattle farmer control the breeding so that the herd ultimately consisted of only red cattle?

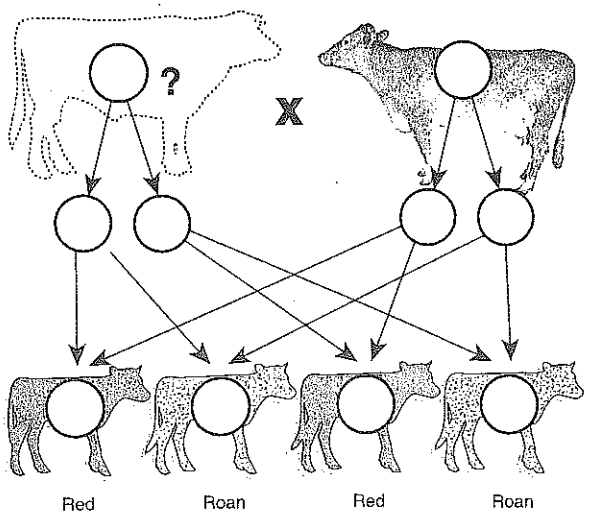


A farmer has only roan cattle on his farm. He suspects that one of the neighbors' bulls may have jumped the fence to mate with his cows earlier in the year because half the calves born were red and half were roan. One neighbor has a red bull, the other has a roan.

(a) Fill in the spaces (right) to show the genotype and phenotype for parents and calves.

(b) Which bull serviced the cows? **red** or **roan** (*delete one*)

Describe the classical phenotypic ratio for a codominant gene resulting from the cross of two heterozygous parents (e.g. a cross between two roan cattle):



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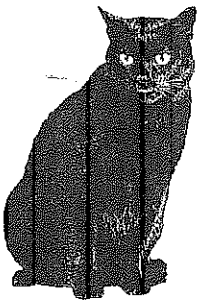
Related activities: *Codominance in Multiple Allele Systems*
Weblinks: *Drag and Drop Genetics*

Problems Involving Dihybrid Inheritance

Dihybrid inheritance can involve genes in which there is no interaction between them (such as genes for the wrinkliness and color of pea seeds). Other dihybrid crosses can involve genes that do interact with each other and the combination of dominant and recessive alleles can have an outcome on a single phenotype.

1. In cats, the following alleles are present for coat characteristics: black (B), brown (b), short (L), long (l), tabby (T), blotched tabby (tb). Use the information to complete the dihybrid crosses below:



(a) A black short haired (BBLl) male is crossed with a black long haired (Bbll) female. Determine the genotypic and phenotypic ratios of the offspring:

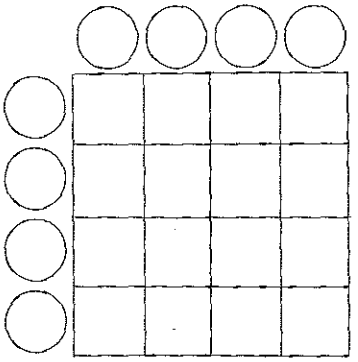
Genotype ratio: _____

_____

Phenotype ratio: _____

_____

_____



(b) A tabby, short haired male (TtbLl) is crossed with a blotched tabby, short haired (tbtbLl) female. Determine ratios of the offspring:

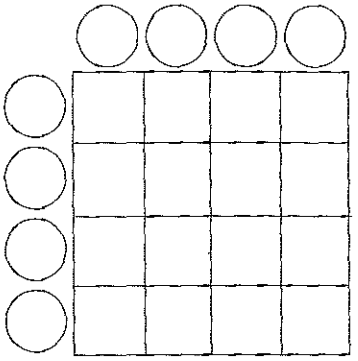
Genotype ratio: _____

_____

Phenotype ratio: _____

_____

_____



2. A plant with orange-striped flowers was cultivated from seeds. The plant was self-pollinated and the F_1 progeny appeared in the following ratios: 89 orange with stripes, 29 yellow with stripes, 32 orange without stripes, 9 yellow without stripes.

(a) Describe the dominance relationships of the alleles responsible for the phenotypes observed: _____

_____

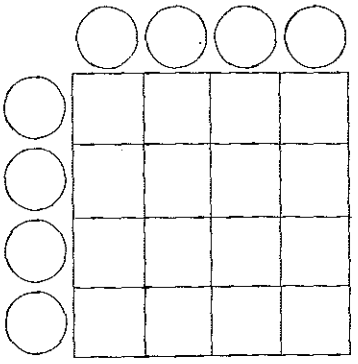
_____

(b) Determine the genotype of the original plant with orange striped flowers: _____

_____

_____

3. In rabbits, spotted coat **S** is dominant to solid color **s**, while for coat color, black **B** is dominant to brown **b**. A brown spotted rabbit is mated with a solid black one and all the offspring are black spotted (the genes are not linked).



(a) State the genotypes:

Parent 1: _____

Parent 2: _____

Offspring: _____

(b) Use the Punnett square to show the outcome of a cross between the F_1 (the F_2):

(c) Using ratios, state the phenotypes of the F_2 generation: _____

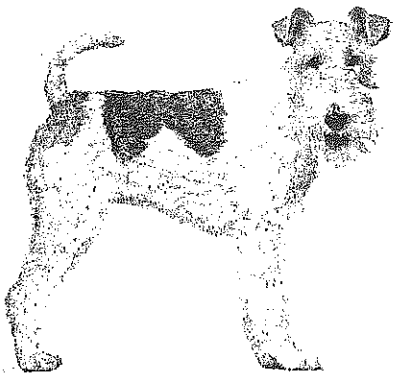
_____

_____

_____

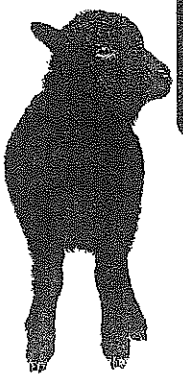
roblems Involving Monohybrid Inheritance

ıe following problems involve Mendelian crosses. The alleles volved are associated with various phenotypic traits controlled by a single gene. The problems are to give you practice in problem solving using Mendelian genetics.



1. A dominant gene (W) produces wire-haired texture in dogs; its recessive allele (w) produces smooth hair. A group of heterozygous wire-haired individuals are crossed and their F_1 progeny are then test-crossed. Determine the expected genotypic and phenotypic ratios among the **test cross** progeny:

2. In sheep, black wool is due to a recessive allele (**b**) and white wool to its dominant allele (**B**). A white ram is crossed to a white ewe. Both animals carry the black allele (b). They produce a white ram lamb, which is then back crossed to the female parent. Determine the probability of the **back cross** offspring being black:



3. A recessive allele, a, is responsible for albinism, an inability to produce or deposit melanin in tissues. Humans and a variety of other animals can exhibit this phenotype. In each of the following cases, determine the possible genotypes of the mother and father, and of their children:

(a) Both parents have normal phenotypes; some of their children are albino and others are unaffected:

(b) Both parents are albino and have only albino children:

(c) The woman is unaffected, the man is albino, and they have one albino child and three unaffected children:

4. Chickens with shortened wings and legs are called creepers. When creepers are mated to normal birds, they produce creepers and normals with equal frequency. When creepers are mated to creepers they produce two creepers to one normal. Crosses between normal birds produce only normal progeny. Explain these results:

5. In a dispute over parentage, the mother of a child with blood group O identifies a male with blood group A as the father. The mother is blood group B. Draw Punnett squares to show possible genotype/phenotype outcomes to determine if the male is the father and the reasons (if any) for further dispute:

2. **Autosomal recessive traits**
Albinos lack pigment in the hair, skin and eyes. This trait is inherited as an autosomal recessive allele (i.e. it is not carried on the sex chromosome).

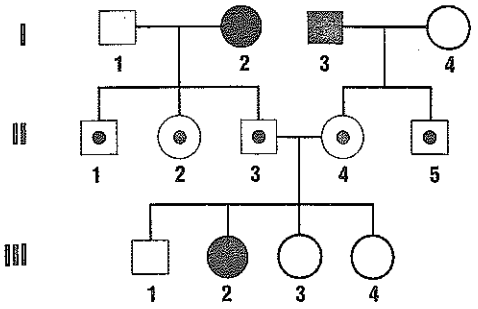
(a) Write the genotype for each of the individuals on the chart using the following letter codes: **PP** normal skin color; **P-** normal, but unknown if homozygous; **Pp** carrier; **pp** albino.

(b) Why must the parents (II-3) and (II-4) be **carriers** of a **recessive** allele:

_____

_____

Albinism in humans



3. **Sex linked recessive traits**
Hemophilia is a disease where blood clotting is affected. A person can die from a simple bruise (which is internal bleeding). The clotting factor gene is carried on the X chromosome.

(a) Write the genotype for each of the individuals on the chart using the codes: **XY** normal male; X_hY affected male; **XX** normal female; X_hX female carrier; X_hX_h affected female:

(b) Why can males never be carriers?

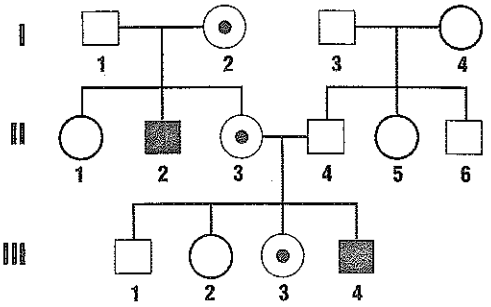
_____

_____

_____

_____

Hemophilia in humans



4. **Autosomal dominant traits**
An unusual trait found in some humans is woolly hair (not to be confused with curly hair). Each affected individual will have at least one affected parent.

(a) Write the genotype for each of the individuals on the chart using the following letter codes:
WW woolly hair; **Ww** woolly hair (heterozygous); **W-** woolly hair, but unknown if homozygous; **ww** normal hair

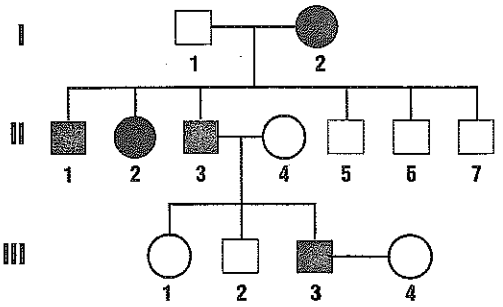
(b) Describe a feature of this inheritance pattern that suggests the trait is the result of a **dominant** allele:

_____

_____

_____

Woolly hair in humans



5. **Sex linked dominant traits**
A rare form of rickets is inherited on the X chromosome. All daughters of affected males will be affected. More females than males will show the trait.

(a) Write the genotype for each of the individuals on the chart using the following letter codes:
XY normal male; X_RY affected male; **XX** normal female; X_{R-} female (unknown if homozygous); X_RX_R affected female.

(b) Why will more females than males be affected?

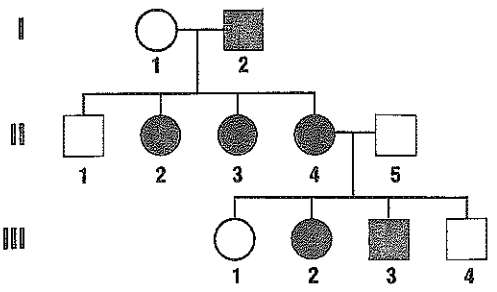
_____

_____

_____

_____

A rare form of rickets in humans

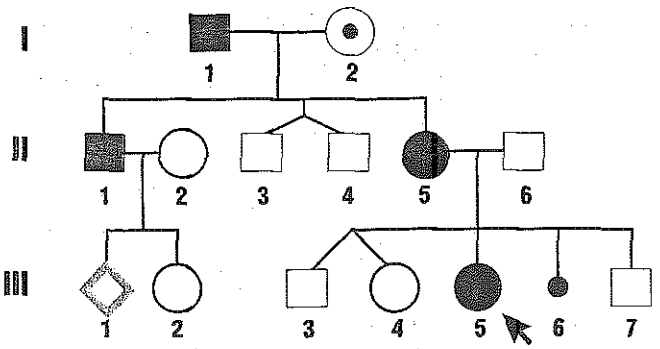


Sample Pedigree Chart

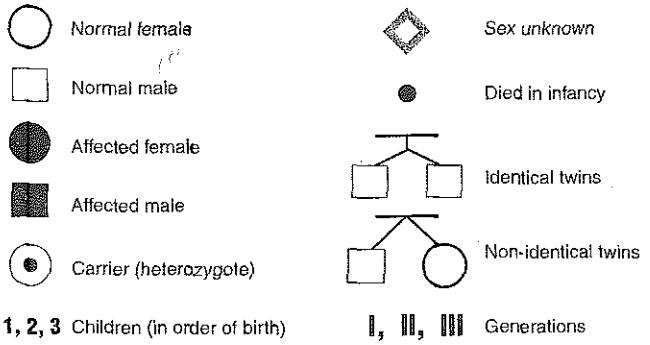
edigree charts are a way of graphically illustrating neritance patterns over a number of generations. They e used to study the inheritance of genetic disorders. ne key (below the chart) should be consulted to make ense of the various symbols. Particular individuals are entified by their generation number and their order umber in that generation. For example, **II-6** is the xth person in the second row. The arrow indicates the **ropositus**; the person through whom the pedigree was *scovered (i.e. who reported the condition).*

the chart on the right were illustrating a human family *se, it would represent three generations: grandparents* -1 and I-2) with three sons and one daughter. Two of ne sons (II-3 and II-4) are identical twins, but did not narry or have any children. The other son (II-1) married nd had a daughter and another child (sex unknown). he daughter (II-5) married and had two sons and two aughters (plus a child that died in infancy).

or the particular trait being studied, the grandfather was xpressing the phenotype (showing the trait) and the randmother was a carrier. One of their sons and one of neir daughters also show the trait, together with one of neir granddaughters.



Key to Symbols



1. **Pedigree chart of your family**
   Using the symbols in the key above and the example illustrated as a guide, construct a pedigree chart of your own family *(or one that you know of) starting with the parents of your mother and/or father on the first line. Your parents will appear* on the second line (II) and you will appear on the third line (III). There may be a fourth generation line (IV) if one of your brothers or sisters has had a child. Use a ruler to draw up the chart carefully.

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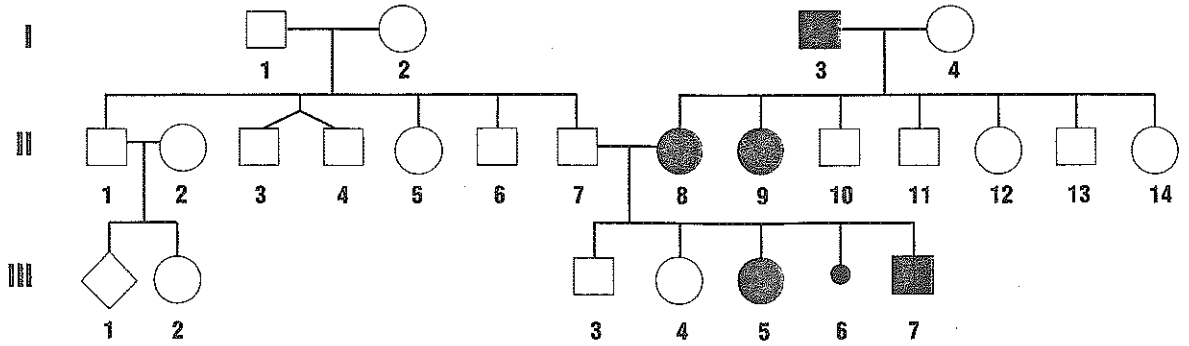
Periodicals: *Secrets of the gene*

Related activities: *Sex Linkage, Inheritance Patterns*
Web links: *Patterns of Inheritance*



(a) State whether the trait is **dominant** or **recessive**, and explain your reasoning: _____

_____

_____

_____

(b) State whether the trait is **sex linked** or not, and explain your reasoning: _____

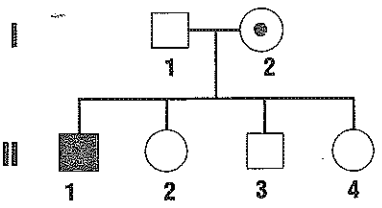
_____

_____

_____

The recessive sex linked gene (h) prolongs the blood-clotting time, resulting in the genetically inherited disease called hemophilia. From the information in the pedigree chart (right), answer the following questions:

Hemophilia in humans



(a) If **II2** marries a normal man, determine the probability of her first child being a hemophiliac:

_____

(b) Suppose her first child is actually a hemophiliac. Determine the chance that her second child will be a hemophiliac boy:

_____

(c) If **II4** has children with a hemophilic man, determine the probability of her first child being phenotypically normal:

_____

(d) If the mother of **I2** was phenotypically normal, state the phenotype of her father: _____

The phenotypic expression of a dominant gene in Ayrshire cattle is a notch in the tips of the ears. In the pedigree chart on the right, notched animals are represented by the solid symbols.

Determine the probability of notched offspring being produced from the following matings:

(a) III1 x III3 _____

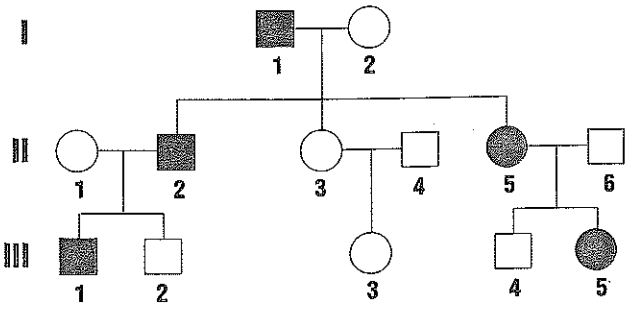
(b) III3 x III2 _____

(c) III3 x III4 _____

(d) III1 x III5 _____

(e) III2 x III5 _____

Ear notches in Ayrshire cattle



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