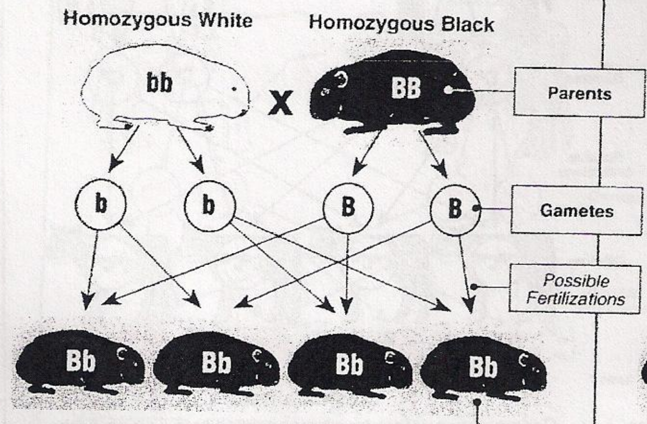
Patterns of Inheritance booklet - answers

A 1

Monohybrid Cross

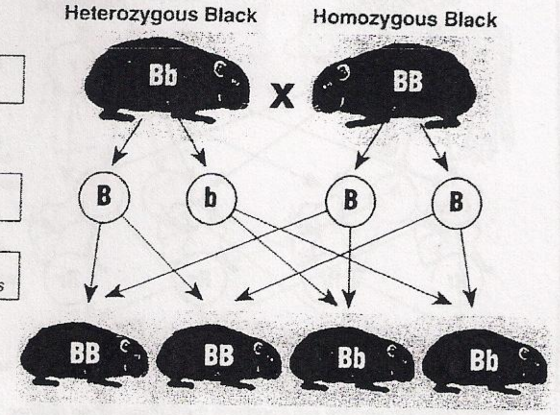
The study of ***single-gene inheritance*** is achieved by performing ***monohybrid crosses***. The six basic types of matings possible among the three genotypes can be observed by studying a pair of alleles that govern coat colour in the guinea pig. A dominant allele: given the symbol ***B*** produces **black** hair, and its recessive allele: ***b***, produces white. Each of the parents can produce two types of gamete by the process of ***meiosis*** (in reality there are four, but you get identical pairs - see the page on meiosis). To follow how each of the gametes come together to form combinations in the offspring, take an offspring and follow the arrows backwards to the gametes that formed them. Determine the genotype and phenotype ratios for crosses 2 and 3 (the first one has been done for you). For the crosses 4 to 6, you must also determine: **1.** gametes produced by each parent (write these in the circles); **2.** offspring genotypes and phenotypes (write in the genotype inside the offspring and state if black or white); **3.** genotype and phenotype frequencies (enter the frequencies in the spaces provided).



Cross 1:

(a) Genotype frequency: 100% Bb

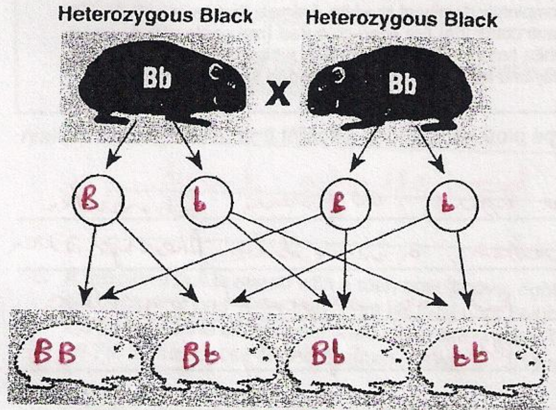
(b) Phenotype frequency: 100% black



Cross 2:

(a) Genotype frequency: 50% BB, 50% Bb

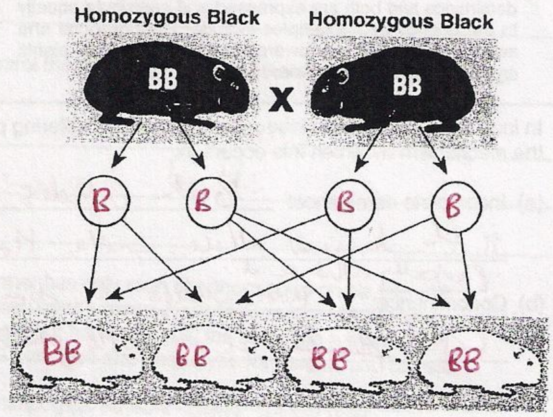
(b) Phenotype frequency: 100% Black



Cross 3:

(a) Genotype frequency: 25% BB, 50% Bb, 25% bb

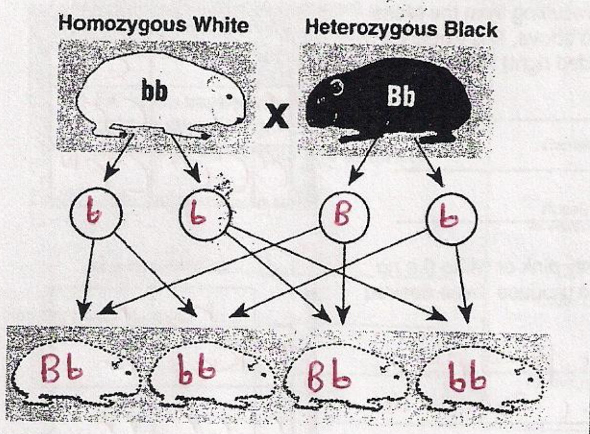
(b) Phenotype frequency: 75% Black, 25% white



Cross 4:

(a) Genotype frequency: 100% BB

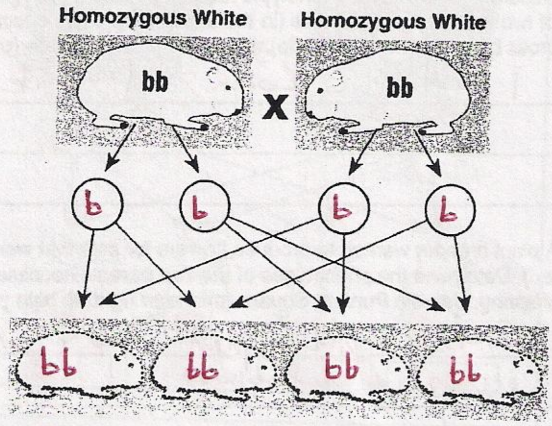
(b) Phenotype frequency: 100% Black



Cross 5:

(a) Genotype frequency: 50% Bb, 50% bb

(b) Phenotype frequency: 50% Black, 50% White



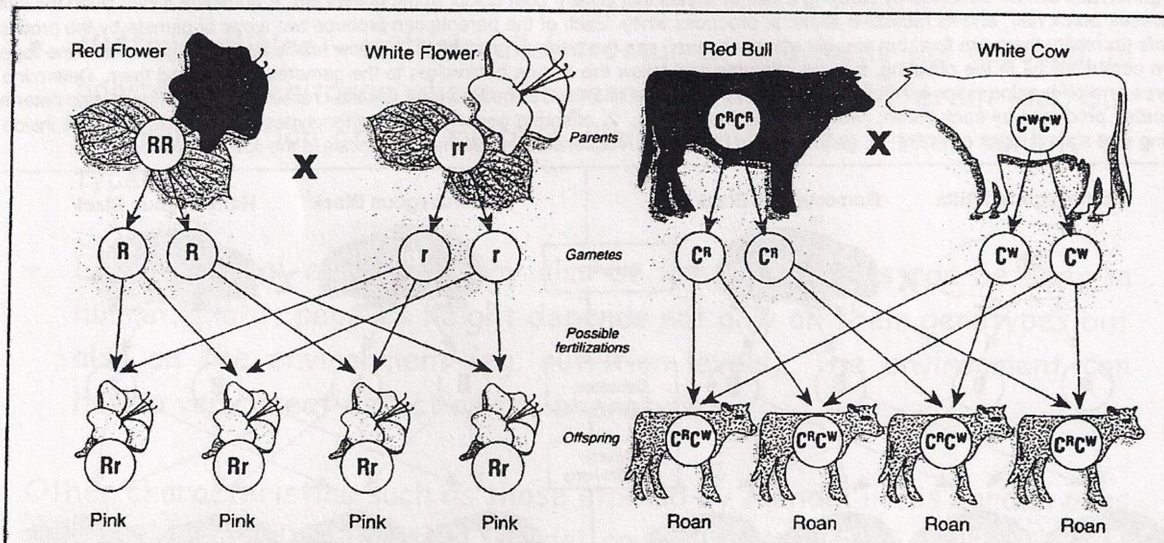
Cross 6:

(a) Genotype frequency: 100% bb

(b) Phenotype frequency: 100% White

A 2

Dominance of Alleles



I.C.D. alleles:

Both have equal dominance and form an intermediate if both present

Incomplete Dominance

Incomplete dominance is a condition that arises when neither allele in a heterozygous organism is dominant. When two parents produce a heterozygous offspring the phenotype is **intermediate** between them, resulting from the partial influence of both of them. In these types of crosses the *phenotype and genotype ratios* are *identical*. In this type of inheritance the alleles for the same gene have equal dominance and both are expressed and contribute equally to the phenotype. Examples include: Snapdragons and sweet peas, where red-flowered and white-flowered plants cross to produce pink-flowered plants.

Codominance

Codominance refers to inheritance patterns when both alleles in a heterozygous organism are **dominant.** Both alleles are **independently** and **fully expressed.** One example includes the human blood group AB which is the result of two alleles: A and B, both being equally expressed, neither being dominant. Other examples include certain coat colours in horses and cattle. Reddish coat colour is not completely dominant to white. Animals that have both alleles have coats that are **roan**-coloured (red coats with spots of white hairs). The red hairs and white hairs are expressed fully and independently (not blended to produce pink).

Both dominant & are expressed equally

1. In incomplete and codominance, two parents of differing phenotype produce offspring different from either parent. Explain the mechanism by which this occurs in:

(a) Incomplete dominance: Both alleles have equal dominance so neither is the dominant allele. In the the condition, an intermediate phenotype is seen as both partially influence it.

(b) Codominance: Both alleles are dominant and are expressed equally so both ~~pheno~~ are seen in the phenotype fully and separately.

2. For each situation below, explain how the heterozygous individuals differ in their phenotype from homozygous ones:

(a) Incomplete dominance: An intermediate form between the phenotypes of the homozygous individuals.

(b) Codominance: A phenotype were both the two phenotypes are seen

3. Describe the classical phenotypic ratio for a codominant gene resulting from the cross of two heterozygous parents (in the case of the cattle described above, this would be a cross between two roan cattle). Use the Punnett Square (provided right) to help you:

1 Red : 2 Roan : 1 White

Gametes from male / Gametes from female

	C^R	C^W
C^R	C^RC^R	C^RC^W
C^W	C^RC^W	C^WC^W

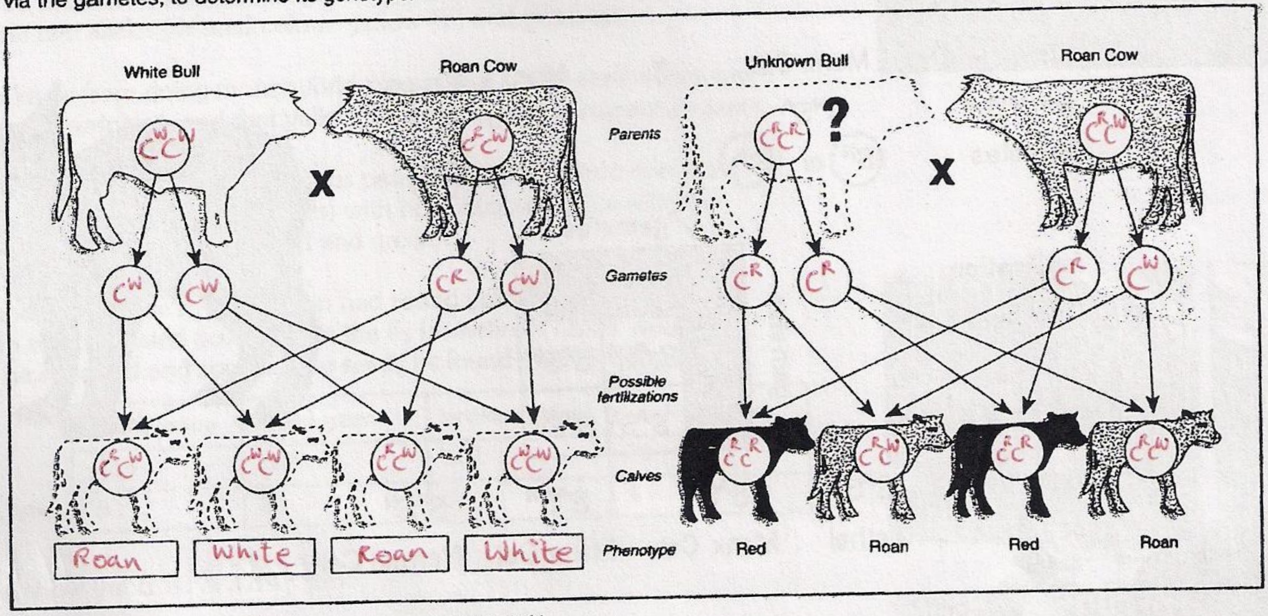
4. A plant breeder wanted to produce flowers for sale that were only pink or white (i.e no red). Determine the phenotypes of the two parents necessary to produce these desired offspring. Use the Punnett Square (provided right) to help you:

- Cross a pink a plant and a white flowering plant.
- 2 Pink : 2 White flowering = 1:1 Pink : White
- No chance of homozygous RR condition appearing (red)

Gametes from male / Gametes from female

	r	r
R	Rr	Rr
r	rr	rr

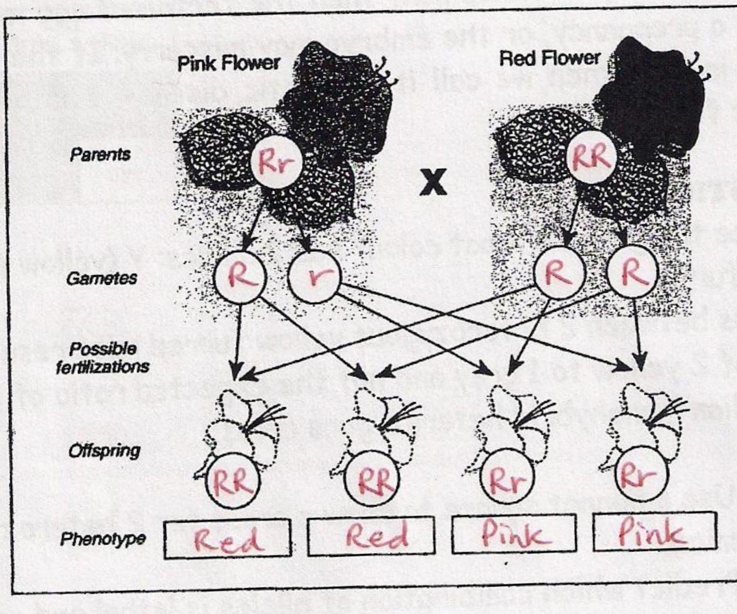
In the Shorthorn cattle breed coat colour is inherited. White Shorthorn parents always produce calves with white coats. Red parents always produce red calves. But when a red parent mates with a white one the calves have a coat colour that is different from either parent – called roan (a mixture of red hairs and white hairs). Look at the example on the previous page for guidance and determine the offspring for the following two crosses. In the cross on the left, you are given the phenotype of the parents. From this information, their genotypes can be determined, and therefore the gametes and genotypes and phenotypes of the calves. In the cross on the right, only one parent's phenotype is known. Work out the genotype of the cow and calves first, then trace back to the unknown bull via the gametes, to determine its genotype.



5. A white bull is mated with a roan cow (above, left).
   (a) Fill in the spaces on the diagram (above, left) to show the genotype and phenotype for parents and calves.
   (b) State the phenotype ratio for this cross: 1 Roan : 1 White
   (c) Suggest how the farmer who owns these cattle could control the breeding so that the herd ultimately consisted of red coloured cattle only:
   Breed only the roan cows with roan bulls ; then breed only the red cows and bulls.

6. A unknown bull is mated with a roan cow (above, right). A farmer has only roan shorthorn cows on his farm. He suspects that one of the bulls from his next door neighbours may have jumped the fence to mate with his cows earlier in the year. All the calves born were either red or roan. One neighbour has a red bull, the other has a roan bull.
   (a) Fill in the spaces on the diagram (above, right) to show the genotype and phenotype for parents and calves.
   (b) State which of the neighbour's bulls must have mated with the cows: **Red or ~~White~~** *(delete one)*

7. A plant breeder crossed two plants of the plant variety known as Japanese Four O'clock. This plant is known to have its flower colour controlled by a gene which possesses incomplete dominant alleles. Pollen from a pink flowered plant was placed on the stigma of a red flowered plant.
   (a) Fill in the spaces on the diagram on the right to show the genotype and phenotype for parents and offspring.
   (b) State the phenotype ratio:
   1 Red : 1 Pink



Lethal Allelic Combinations

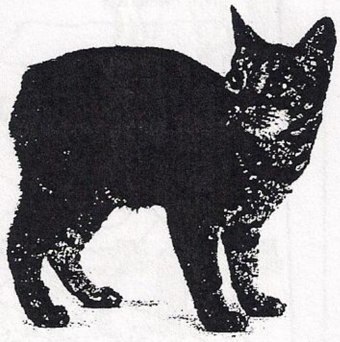
An unusual effect of codominance is found in Manx cats, which have no tails. If two Manx cats are crossed the litter has ratio of 2 Manx kittens to 1 normal (long-tailed) kitten. The explanation for this unexpected ratio is explained in this genetic diagram:

phenotype	Manx Cat	X	Manx Cat	
genotype	$S^N S^A$		$S^N S^A$	
gametes	S^N or S^A		S^N or S^A	

fertilisation

♀ gametes \ ♂ gametes	S^A	S^N
S^A	$S^A S^A$	$S^A S^N$
S^N	$S^A S^N$	$S^N S^N$

genotype	$S^A S^A$	$S^A S^N$	$S^A S^N$	$S^N S^N$
phenotype	Lethal	Manx Cat	Manx Cat	Normal Cat



The gene S actually controls the development of the embryo cat's spine. It has two codominant alleles: S^N (normal spine) and S^A (abnormal, short spine). The three phenotypes are:

$S^N S^N$ **Normal.** Normal spine, long tail

$S^N S^A$ **Manx Cat.** Last few vertebrae absent, so no tail.

$S^A S^A$ **Lethal.** Spine doesn't develop, so this genotype is fatal early in development. The embryo doesn't develop and is absorbed by the mother, so there is no evidence for its existence.

Many human genes also have lethal alleles, because many genes are so essential for life that a mutation in these genes is fatal. If the lethal allele is expressed early in embryo development then the fertilised egg may not develop enough to start a pregnancy, or the embryo may miscarry. If the lethal allele is expressed later in life, then we call it a genetic disease, such as muscular dystrophy or cystic fibrosis.

QUESTION

In mice the gene for coat colour has 2 alleles: Y (yellow fur) being dominant to y (grey fur).
A cross between 2 heterozygous yellow furred mice results in off spring in the ratio of 2 yellow to 1 grey and not the expected ratio of 3 yellow to 1 grey for a mendelian monohybrid heterozygous cross.

Parents: Yy x Yy

Gametes: Y y Y y

1. Use a punnet square to show a cross for 2 heterozygous yellow furred mice.
2. Predict which combination of alleles is lethal and causes death of the embryo in the uterus.

F1:

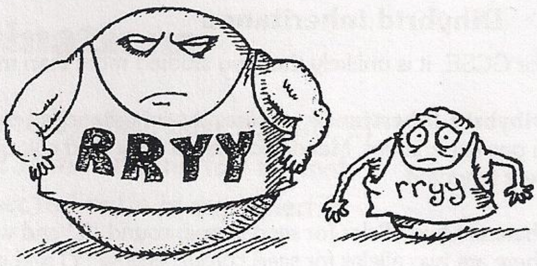
	Y	y
Y	YY	Yy
y	Yy	yy

YY = lethal alleliz combination

Yy = Yellow

yy = Grey

Questions on dihybrid inheritance



Dihybrid crosses often appear in advanced examinations. If you are not careful, especially with the layout of the cross, you can make mistakes.
Here are some useful tips.

- As you see in our example, there are ***two*** genes involved, each with ***two*** alleles.
  So this time we write ***four*** letters, one for each of the four alleles.
  For example, **RRYY** and **rryy**.
- Always put the alleles for the same characteristic together.
  For example, **RrYy** never **RYry**.
  This looks clearer and will help you to show segregation better.
- At segregation, remember Mendel's first law still applies, so only show ***one*** allele of each gene in the gamete.
  For example, **RY**, **Ry**, **rY** or **ry**.
  It is always a good idea to ***circle*** the gametes so you don't get them mixed up with the F_1 or the F_2 generations, and remember – an individual that is heterozygous for both characteristics can produce four different types of gametes.
- To keep things neat, use a **Punnett square**.
  If you are crossing two individuals that are heterozygous for both characteristics, you'll need to show $4 \times 4 = 16$ individuals in the F_2.
- Always write the gametes down in the same sequence on each axis of the Punnett square, starting with the two dominant alleles and ending with the two recessive alleles.
  If you do this, you can almost anticipate the position of each of the genotypes within the square.
- Try drawing out a Punnett square for a cross between **RrYY** and **RRYy**.

same sequence of gametes →

same sequence of gametes ↓

gametes	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

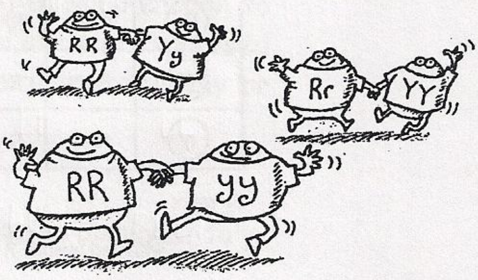
The results of the dihybrid cross led Mendel to formulate his second law of inheritance: the **law of independent assortment**.

> **Either of a pair of alleles may combine randomly with either of another pair.**

So in our example, we don't just get **RR** and **YY** together, or **rr** and **yy** together.
We can get ***either*** of each pair of alleles combining to give any of the following:

RRYY, RRYy, RRyy, RrYY, RrYy, Rryy, rrYY, rrYy and rryy.

Another important hint is to make sure that you convert the correct number of genotypes into the correct ratio of phenotypes if asked. Remember that there are 16 individuals in the Punnett square. In some examination questions, they give you the ratios or even the raw numbers of the phenotypes of the F_2 and expect you to work backwards to the correct genotypes of the F_1 and parents. Remember that practice makes perfect and that you can gain full marks for genetic crosses. They are ***always*** examined.



Either of a pair of alleles can combine with either of another pair

Cross No. 1

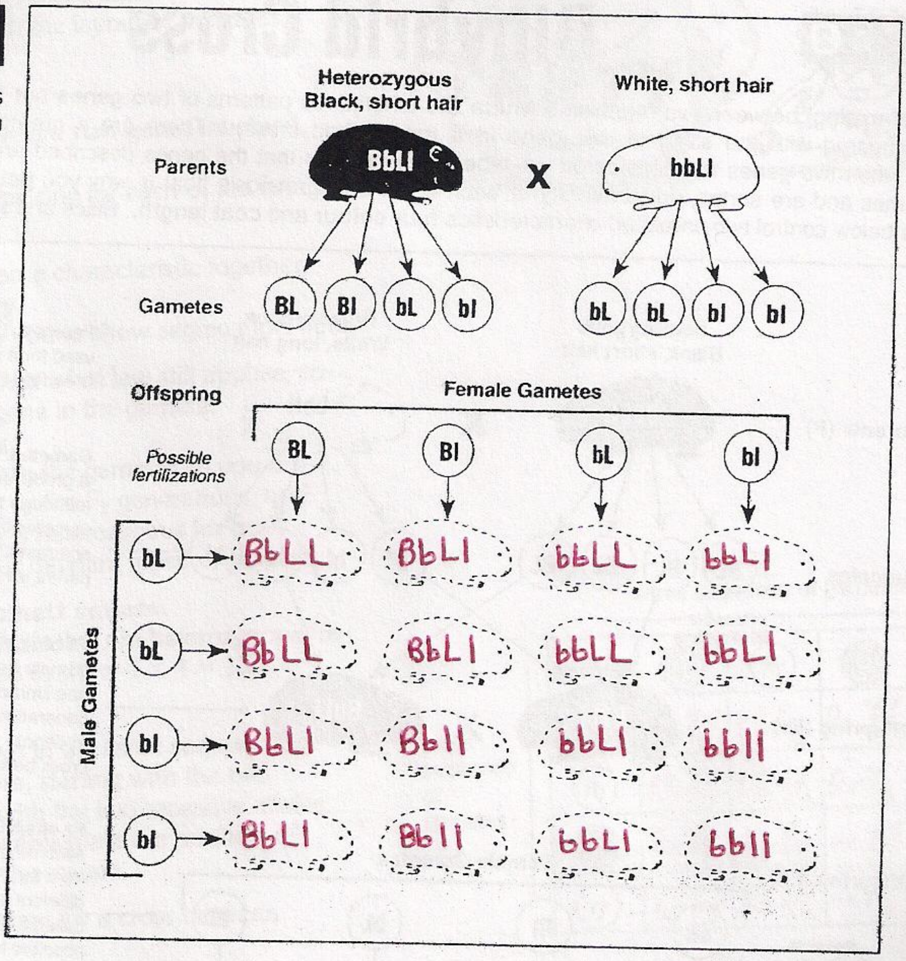
The dihybrid cross on the right has been partly worked out for you. You must determine:

1. The genotype and phenotype for each animal (write your answers in its dotted outline).
2. Genotype **ratio** of the offspring:

2 BbLL, 4 BbLl,
2 Bbll, 2 bbLL,
4 bbLl, 2 bbll
(1:2:1:1:2:1)

3. Phenotype **ratio** of the offspring:

6 Black, short hair
2 Black, long hair
6 White, short hair
2 white, long hair
(3:1:3:1)



Cross No. 2

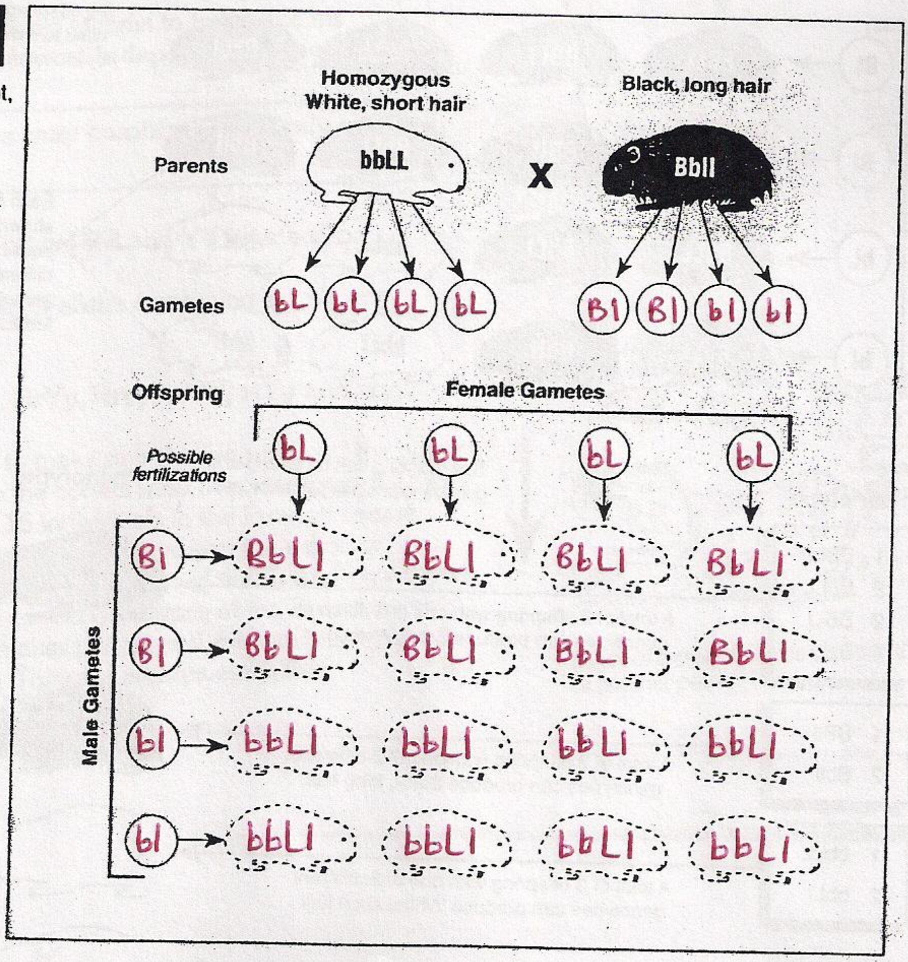
For the dihybrid cross on the right, determine:

1. Gametes produced by each parent (write these in the circles).
2. The genotype and phenotype for each animal (write your answers in its dotted outline).
3. Genotype **ratio** of the offspring:

8 BbLl
8 bbLl
(1:1)

4. Phenotype **ratio** of the offspring:

8 Black, short hair
8 White, short hair
(1:1)



Froggy questions on Patterns of inheritance – answers

1. a)

	TR	**Tr**	tR	tr
tR	TtRR	**TtRr**	**ttRR**	ttRr
tr	TtRr	**Ttrr**	ttRr	**ttrr**

b)
3 Tall, red flowered
1 Tall, white flowered
3 Short, red flowered
1 Short, white flowered

2. a)
i) Gene
ii) Genotype

b) One has been inherited from the mother (in the ovum originally) and one from the father (in the sperm originally)

c) This is due to the segregation of chromosomes during anaphase 1 of meiosis (Mendel's first law)

3.
Parents: Bbrr X bbRr

Gametes: Br br bR br

F1:

	bR	br
Br	BbRr	Bbrr
br	bbRr	bbrr

1 Black, rough coat
1 Black, smooth coat
1 Albino, rough coat
1 Albino, smooth coat

4. a)
i) A section of DNA that codes for a protein (which then controls a characteristic)
ii) A form of the same gene

b) Mendel's second law dictates that either of a pair of alleles can **randomly** combine with either of another pair. The ratio is just the **probable** outcome (according to probability)

5. a)
i) AABB = Grey
ii) AaBb = Grey
iii) AAbb = Grey
iv) aaBB = Black

b)

i) AaBb

ii)

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

1	AABB	Grey	
2	AABb	Grey	
1	AAbb	Grey	
2	AaBB	Grey	12
4	AaBb	Grey	
2	Aabb	Grey	
1	aaBB	Black	
2	aaBb	Black	3
1	aabb	Chocolate	1

c)

	AB	Ab	aB	ab
ab	AaBb	Aabb	aaBb	aabb

2 Grey : 1 Black : 1 Chocolate

6. a)

Parents: PpBW X PpBW

Gametes: PB PW pB pW X PB PW pB pW

	PB	PW	pB	pW
PB	PPBB	PPBW	PpBB	PpBW
PW	PPBW	PPWW	PpBW	PpWW
pB	PpBB	PpBW	ppBB	ppBW
pW	PpBW	PpWW	ppBW	ppWW

b)

i) Pea combed = 12

ii) Black feathered = 4

iii) Blue feathered = 8

iv) Blue feathered and pea combed = 6

v) Single combed and white feathered = 1

8. a) They would need to be given a recessive allele from both the father and mother and there is less chance of this happening than for a male to receive a recessive X allele

b)

Carrier female = $X^H X^h$

Haemophiliac male = $X^h Y$

	X^H	X^h
X^h	X^HX^h	X^hX^h
Y	X^HY	X^hY

9. a) 8 and 10, the daughters of 4 and 5 inherited recessive X alleles from their father and normal X alleles from their mother and did not suffer the condition. This shows that the normal allele masks the effect of/is dominant over the recessive allele

b)

i) The X that 12 inherited from his father (11) was normal, as his father was normal. However, he is a sufferer of the condition, therefore he inherited the recessive allele from his mother, who must be a carrier as she did not suffer the condition herself

ii) MISTAKE IN THE QUESTION: It should read: “individual 11 must be $X^D Y$”

ANSWER: This male (11) does not suffer the condition, therefore must have the normal X allele. The son, 12, receives his recessive X allele from his carrier mother, 10

10. a)

Queen Victoria

Prince Albert

	X^H	X^h
X^H	X^HX^H	X^HX^h
Y	X^HY	X^hY

Duke Leopold

Princess Helen

	X^h	Y
X^H	X^HX^h	X^HY
X^H	X^HX^h	X^HY

OR

Princess Alice of Athlone

Alexander of Teck

	X^H	X^h
X^H	X^HX^H	X^HX^h
XY	X^HY	X^hY

Viscount Rupert

b) A female who does not suffer the disease but does have the recessive allele as well as the normal one. She can pass this allele on to her offspring, potentially creating a suffering male

c) (Did not suffer the condition but produced offspring that did):
- Queen Victoria
- Princess Alice
- Princess Alice of Athlone
- Princess Alexandria

d) (Could have inherited a recessive allele but did not suffer from the condition, or produce any offspring/any offspring that suffered):
- Princess Victoria
- Princess Alice of Greece
- Lady Mary
- Olga
- Tatyana
- Maria
- Anastasia