Exercise 8.1
Inheritance of One Pair of Characteristics

INTRODUCTION:

From the work of *Gregor Mendel* and the research workers who followed him we know that the various hereditary characteristics are controlled by genes and that these *genes occur in pairs* e.g. you have 2 genes for type of ear lobe, 1 gene inherited from your father and 1 gene from your mother. However, reproductive cells or gametes contain the haploid chromosome number and, therefore, only have 1 gene member of each gene pair.

Also 1 gene in a pair may mask the other gene. The gene that does the masking is called the *dominant* gene and the masked gene is the *recessive* gene. Dominant genes are represented by a capital letter and recessive genes by the corresponding lower case letter e.g. in pea plants the gene for tallness is dominant to the gene for dwarfness, therefore, "T" represents the gene for tallness and "t" the gene for dwarfness.

Learn the following terms before continuing with this exercise.

Homozygous: the paired genes for a particular characteristic are identical e.g. TT or tt.

Heterozygous: the paired genes for a particular characteristic are different e.g. Tt.

Pure breeding organism: the paired genes are identical e.g. a pea plant with the genotype tt is pure breeding for dwarfness.

Hybrid organism: the offspring of a cross between two parents that differ in one or more characteristics e.g. if we cross a pure breeding tall pea plant (TT) with a pure breeding dwarf pea plant (tt) then the offspring (Tt) is a hybrid.

Genotype: the genes carried by an organism and indicated by paired symbols e.g. the genotype of a pure breeding tall pea plant is TT, the genotype of a hybrid tall pea plant is Tt.

Phenotype: the effect of an organism's genotype e.g. a hybrid tall pea plant has the genotype Tt and its phenotype is tall.

Punnett square: this is a grid system used for working out all the possible combinations of gametes in various crosses.

Alleles: these are the alternate forms of a gene. e.g. the alleles for height of pea plants are "T" and "t".

Procedure:

In this exercise you will use the punnett square method to show diagramatically the inheritance of one pair of characteristics.

Study the type example very carefully, paying particular attention to the setting out.

Type Example No. 1. A pure breeding tall pea plant is crossed with a pure breeding dwarf pea plant. Given that the gene for tallness is dominant to the gene for dwarfness, determine the genotypes and phenotypes of the first (F_1) and second (F_2) generation offspring.

Let the symbol "T" represent the gene for the tallness character in pea plants.

Let the symbol "t" represent the gene for the dwarf character in pea plants.

Parents:	phenotypes	Tall	×	Dwarf
	genotypes	TT		tt
Possible gametes:		T and T		t and t

1st Generation Offspring (F)

	t	t
T	Tt	Tt
T	Tt	Tt

genotypes all Tt

phenotypes all tall hybrids

To obtain the second generation offspring (F_2) you cross two of the first generation offspring i.e. the tall hybrids:

Parents: phenotypes Tall × Tall

genotypes Tt Tt

Possible gametes: T and t T and t

2 nd Generation Offspring (F_2)

	T	t
T	TT	Tt
t	Tt	tt

genotypes: $\frac{1}{4}$ TT + $\frac{1}{2}$ Tt + $\frac{1}{4}$ tt or as a ratio- 1 TT : 2 Tt : 1 tt

phenotypes: $\frac{3}{4}$ tall + $\frac{1}{4}$ dwarf. or as a ratio- 3 tall : 1 dwarf

You should now try the following question yourself. Remember to set out your work neatly so that your teacher can easily follow your working.

TRIAL QUESTION 1. Cross a pure breeding, black coated guinea pig with a pure breeding, white coated guinea pig. Given that, in guinea pigs, black coat colour is dominant to white coat colour, determine the genotypes and phenotypes of the first and second generation offspring.

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Type Example No. 2: A pure breeding, dwarf pea plant is crossed with a hybrid, tall pea plant. Given that the gene for tallness is dominant to the gene for dwarfness, determine the genotypes and phenotypes of the offspring resulting from such a cross.

Let the symbol "T" represent the gene for the tall character in pea plants
Let the symbol "t" represent the gene for the dwarf character in pea plants

Parents: phenotypes Dwarf × Tall

genotypes tt Tt

Possible gametes t and t T and t

Possible offspring

	T	t
t	Tt	tt
t	Tt	tt

genotypes $\frac{1}{2}$ Tt + $\frac{1}{2}$ tt or 1 Tt: 1 tt

phenotypes $\frac{1}{2}$ tall + $\frac{1}{2}$ dwarf or 1 tall: 1 dwarf

TRIAL QUESTION NO. 2. A hybrid black guinea pig is crossed with a pure breeding white guinea pig. Determine the genotypes and phenotypes of the offspring, given that, in guinea pigs, black coat dominant to white coat.

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HOMEWORK:

(1) A pure-bred wire haired terrier is crossed with a pure-bred smooth-coated dog. Given that, in dogs, wire hair is dominant to smooth hair, determine the genotypes and phenotypes of the F_1 and F_2 generations.

(2) In guinea pigs, rough coat is dominant to smooth coat. Determine the possible genotypes and phenotypes of the offspring if two rough coated hybrid guinea pigs are mated.

(3) In fruit flies, red eyes are dominant to white eyes. Determine the possible genotypes and phenotypes of the offspring if a pure breeding red eyed fruit fly is crossed with a hybrid red eyed fruit fly.

FOR THE RESEARCH STUDENT:

Given that, in guinea pigs, black coat is dominant to white coat, you can have three possible genotypes for coat colour in guinea pigs e.g. BB; Bb and bb. However, guinea pigs with the genotypes BB and Bb have the same phenotype, black coat colour. Find out what is meant by a "test cross" and show how it can be used to determine if a black coated guinea pig is homozygous (BB) or heterozygous (Bb).

BIOLOGICAL TERMS TO LEARN: Gregor Mendel, dominant, recessive, homozygous, heterozygous, pure breeding, hybrid, genotype, phenotype, punnett square.

RESEARCH REPORT:

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Exercise 8.2
Inheritance of One Pair of Characteristics (Incomplete Dominance)

INTRODUCTION:

When a pure breeding, red coated shorthorn bull is crossed with a pure breeding, white coated cow, the offspring always has a roan coat. Neither coat colour is completely dominant so that both colours are expressed in the hybrid offspring. This is an example of *incomplete dominance*.

Procedure:

In this exercise you will use the punnett square method to show diagrammatically the inheritance of one pair of characteristics where one allele is incompletely dominant to the other.

Study the type example carefully then work through some examples yourself.

Type example: In shorthorn cattle, red coat colour is incompletely dominant to white coat colour. Determine the genotypes and phenotypes of the F_1 and F_2 generations if a pure breeding, red coated shorthorn bull is crossed with a pure breeding, white coated shorthorn cow.

Let the symbol "R" represent the gene for the red coated character.

Let the symbol "W" represent the gene for the white coated character.

*As there is incomplete dominance, both alleles can be represented by capital letters.

Parents: phenotypes red coated bull × white coated cow

genotypes RR WW

Possible gametes R and R W and W

1st Generation Offspring (F_1)

	W	W
R	RW	RW
R	RW	RW

genotypes all RW

phenotypes all roan hybrids

Parents: phenotypes Roan bull × roan cow

genotypes RW RW

Possible gametes R and W R and W

2nd Generation Offspring (F_2)

	R	W
R	RR	RW
W	RW	WW

genotypes $\frac{1}{4}$ RR + $\frac{1}{2}$ RW + $\frac{1}{4}$ WW or 1 RR : 2 RW : 1 WW:

phenotypes $\frac{1}{4}$ red coat + $\frac{1}{2}$ roan coat + $\frac{1}{4}$ white coat
or 1 redcoat : 2 roan coat : 1 white coat

TRIAL QUESTION: In Andalusian chickens, the black Andalusian character is incompletely dominant to the white-splashed Andalusian character. The heterozygous condition produces blue Andalusian chickens. Determine the genotypes and phenotypes of the F_1 and F_2 generations if a pure breeding, black Andalusian is crossed with a pure breeding, white-splashed Andalusian.

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Given that, in Snapdragons, red flower colour is incompletely dominant to white flower colour (heterozygotes are pink) and that in shorthorn cattle, red coat is incompletely dominant to white coat (heterozygotes are roan) answer the following questions:—

(1) A pure breeding, red flowered snapdragon is crossed with a pink flowered snapdragon. Determine the possible genotypes and phenotypes of the offspring.

(2) A roan shorthorn bull is crossed with a roan shorthorn cow. Determine the possible genotypes and phenotypes of their offspring.

(3) A pure breeding, red coated shorthorn bull is crossed with a roan coated, shorthorn cow.
   (a) What is the chance (probability) that they will produce a roan calf? Explain.
   (b) What is the chance that they will produce a white calf? Explain.

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HOMEWORK:

(1) Define the term incomplete dominance .....

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(2) Try to explain why it would be easier for a geneticist to work with characters exhibiting incomplete dominance than characters exhibiting dominance and recessiveness.

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(3) In four-o'clock plants, if a pure breeding red flowered plant is crossed with a pure breeding white flowered, the offspring have pink flowers.

(a) Explain the type of inheritance? Illustrate your answer diagramatically.

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(b) Determine the genotypes and phenotypes of the offspring if two pink flowered four-o'clock plants are crossed.

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BIOLOGICAL TERMS TO LEARN: incomplete dominance.

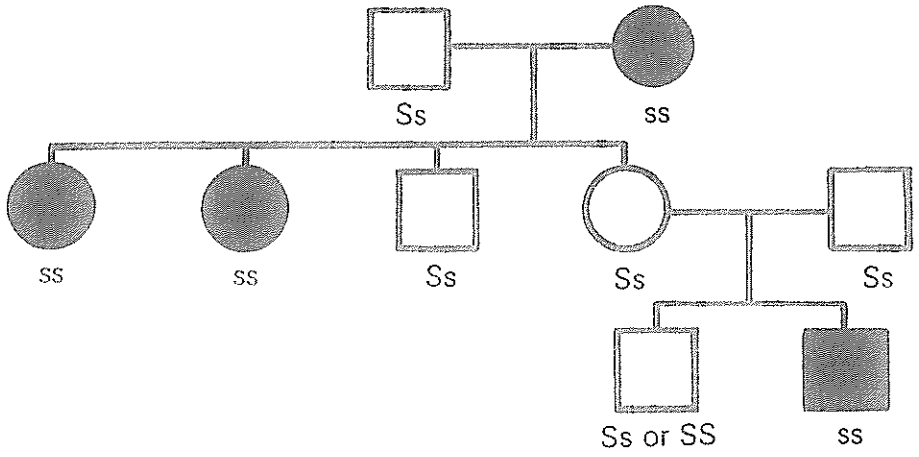
Exercise 11.1
Family Trees

INTRODUCTION:

When we draw family trees the squares represent males and the circles females. Individuals that show the character under investigation are shaded in.

Carefully study the following family tree that shows the incidence of short eyelashes.

Family Tree—Short Eyelashes



(i) How many members of this family have short eyelashes? .....
How do you know? .....

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(ii) How many members have long eyelashes? .....

In the family tree the genotypes are indicated below the squares and circles.

(iii) Do the shaded individuals have homozygous or heterozygous genotypes? .....

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(iv) Is short eyelashes a recessive or dominant character? .....

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(v) One male member of the family tree has two possible genotypes. Explain .....

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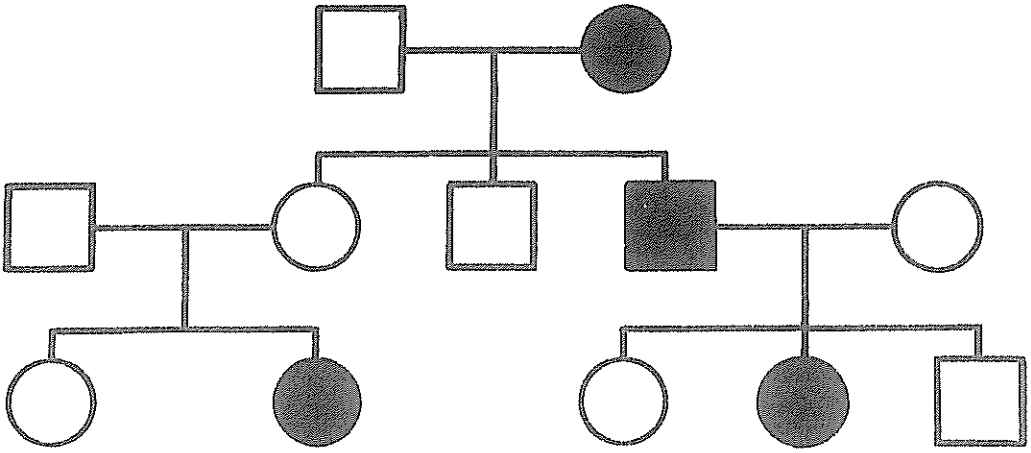
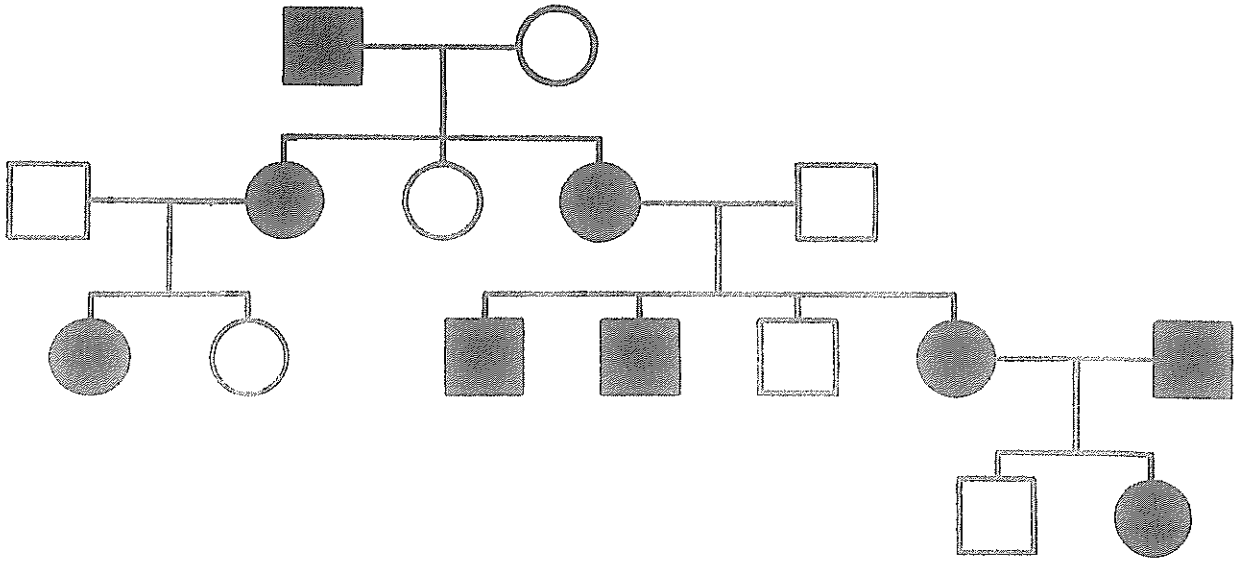
Procedure:

Carefully study each of the family trees, For each one you are to work out if the character is dominant or recessive and indicate the genotype of each number.

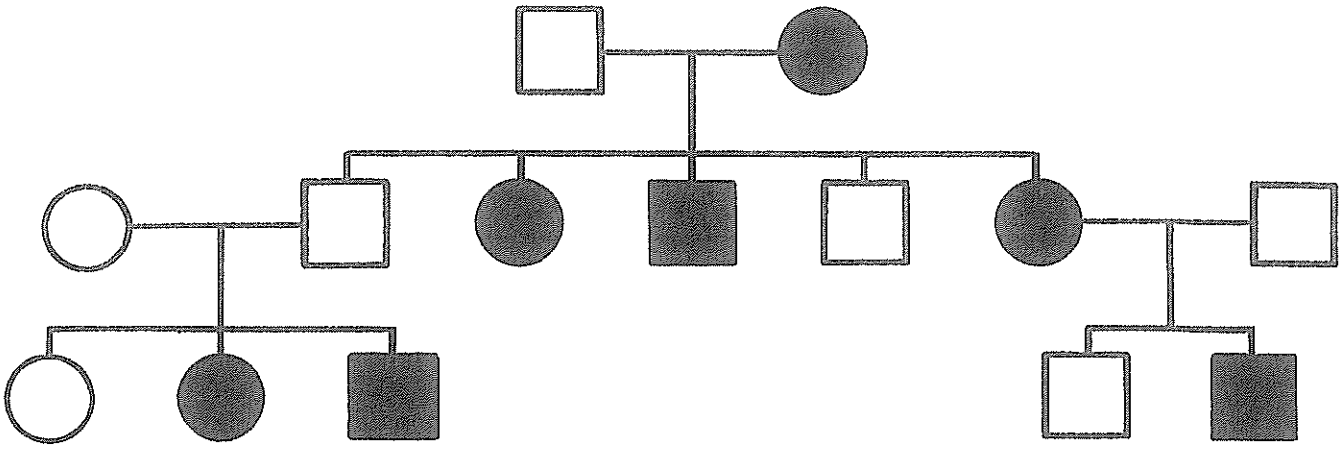
Family Tree: Albinism:



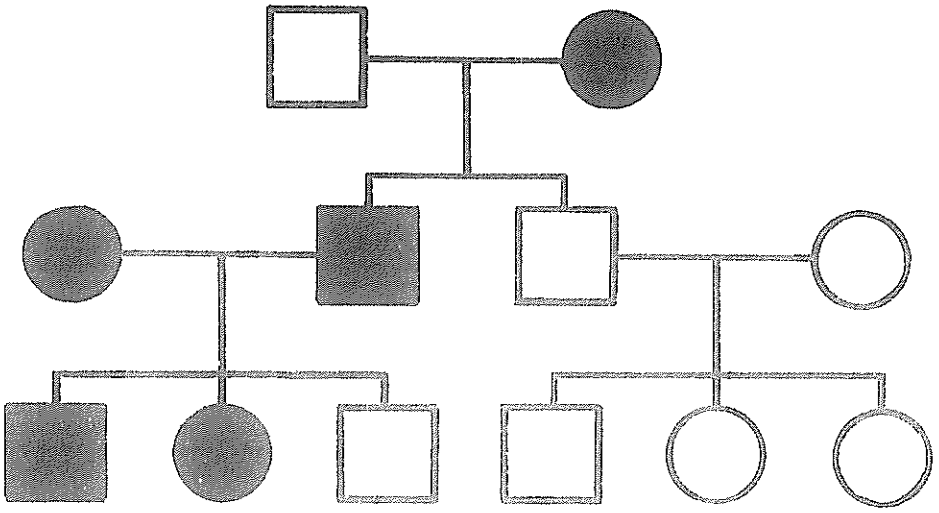
Family Tree: Prominent Nose:



Family Tree: Small Ears:



Family Tree: Markedly Shortened Fingers:



FOR THE RESEARCH STUDENT:

A boy has red hair (homozygous recessive) and neither of his parents has red hair but his father's father had red hair. Draw up a possible family tree to show how the boy inherited his red hair.

BIOLOGICAL TERMS TO LEARN: family tree

RESEARCH REPORT:

Exercise 16.1
Sex Linkage

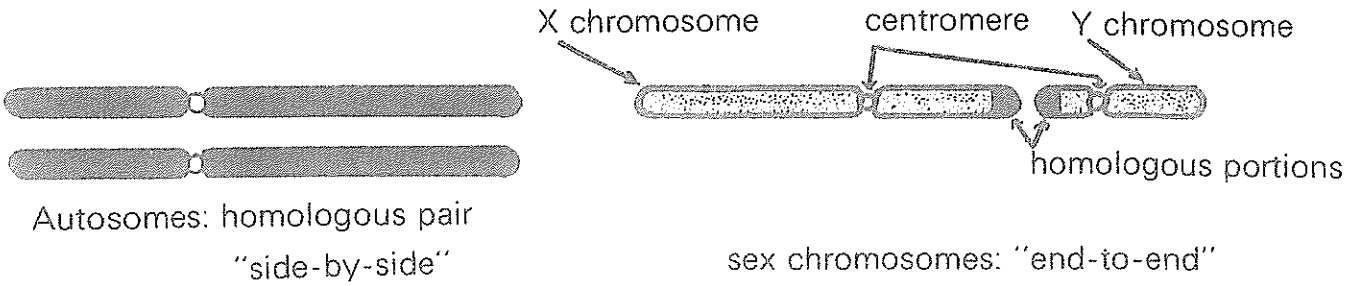
INTRODUCTION:

You have already learned (Exercise 7.1) that normal humans have 22 pairs of autosomes and 1 pair of sex chromosomes (either XX or XY), a total of 23 pairs of chromosomes.

(i) A male has 44 autosomes + ... chromosomes

(ii) A female has 44 autosomes + ... chromosomes

When the X and Y chromosomes pair up during meiosis they do so "end-to-end" rather than "side-by-side". This indicates that only a very small part of the X and Y chromosomes carry similar genes (are homologous). By far the greater portion of the X chromosome is not homologous with the Y chromosome. The genes in the non-homologous section of the X chromosome have no alleles in the Y chromosome and are called X-linked genes. It is these genes that we are concerned with when we study sex linkage in humans.



(iii) When two X chromosomes pair up would it be "side-by-side" or "end-to-end"? Explain.

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Procedure:

We can best study sex linkage by looking at a family tree in which a sex-linked character is evident. The sex-linked character we will study is *partial red-green colour blindness*. The gene for colour blindness is carried on the X chromosome and is a recessive gene. We can represent the gene for colour blindness by "c" and the gene for normal vision by "C".

(1) A colour blind female has the genotype X^cX^c. What will be the genotype of a:—

(a) normal visioned male? .....

(b) normal visioned female? .....

(c) colour blind male? .....

(2) A female who has the genotype X^CX^c is called a carrier. Would she be colour blind or have normal vision? Explain. .....

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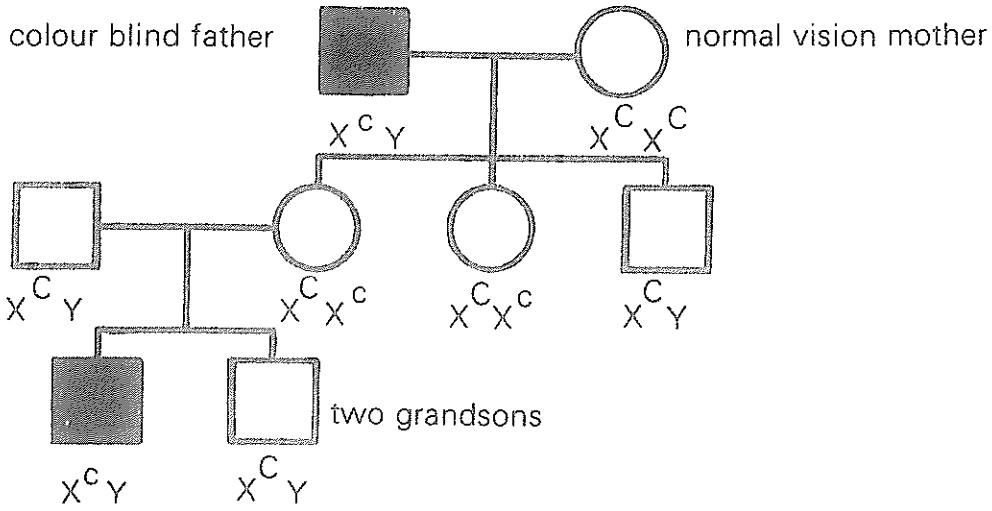
Study the following family tree very carefully (Any shaded in individuals are colour blind).



(3) In the family tree the son is shown as having normal vision and a genotype of X^CY. Would it be possible for the parents to have a colour blind son? Explain .....

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(4) Both daughters are carriers. Would it be possible for those parents to have a colour blind daughter? Explain. .....

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(5) Did the colour blindness character skip a generation? Explain .....

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Work through the following example with your teacher:—

EXAMPLE: A normal-visioned man marries a colour blind woman.

(a) What is the chance of a son being colour blind?

(b) What is the chance of a daughter being colour blind?

Parents	father	mother
phenotype:	normal vision	colour blind
genotype:	X^CY	X^cX^c
Possible gametes	X^C and Y	X^c and X^c

Possible children

	X^c	X^c
X^C	X^CX^c	X^CX^c
Y	X^cY	X^cY

genotypes $\frac{1}{2}X^CX^c + \frac{1}{2}X^cY$

phenotypes $\frac{1}{2}$ carrier daughters (normal vision) + $\frac{1}{2}$ colour blind sons.

(a) the chance of a son being colour blind is 100%
(b) the chance of a daughter being colour blind is 0%

Work the next example yourself. Check the answer with your teacher.

EXAMPLE 2: A colour blind man marries a carrier woman. What are the chances that any of their children will be colour blind?

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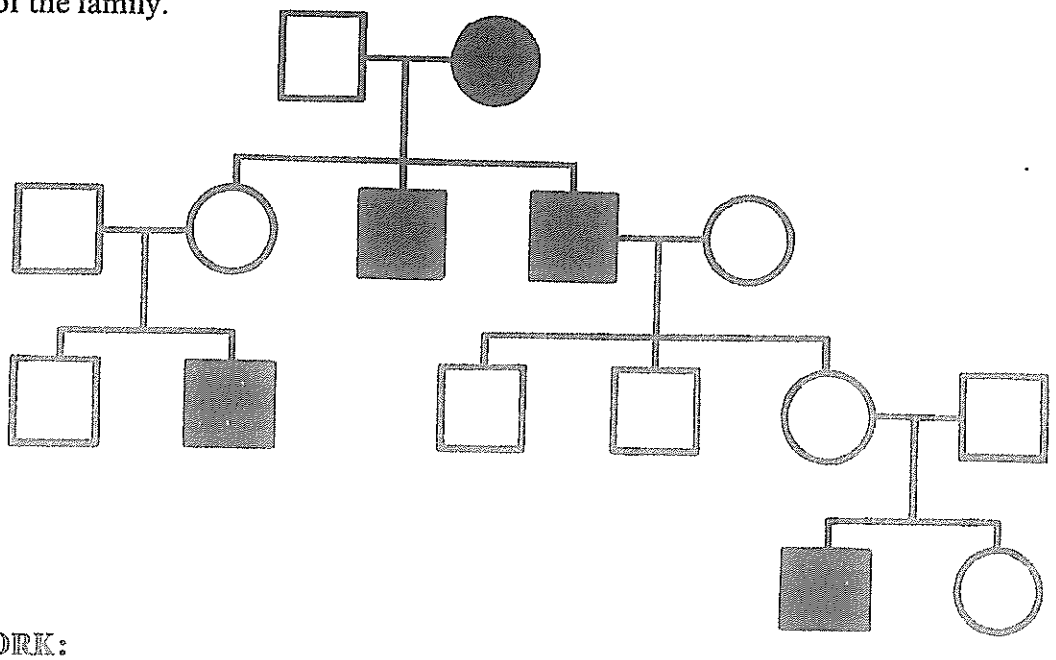
Study the following family tree for colour blindness. Work out the genotypes for the individual members of the family.



HOMEWORK:

(1) Haemophilia is a X-linked recessive gene. If a haemophiliac man marries a normal woman what is the probability that any of their children will be haemophiliacs? .....

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(2) Can a man be a carrier for haemophilia? Explain. .....

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(3) There are three children in a family and one is a colour blind son, another a colour-blind daughter and the third a non-colour-blind daughter. What are the phenotypes and genotypes of the parents? Show how you arrived at your answer:

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BIOLOGICAL TERMS TO LEARN: sex linkage, X-linked, colour blindness, haemophilia, carrier.