Bio Factsheet

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Answering Examination Questions: Genetics

Introduction

1. Punnet Squares: Students commonly fail to show genetic diagrams/ punnet squares correctly. The following deficiencies may lose marks:

- failure to indicate which are parents(P), gametes(G), first filial generation(F_1) or second filial generation(F_2).
- failure to label the gametes or failure to ring or bracket the alleles within a gamete, for instance, (Ab) or (Ab).
- incorrectly labelling the offspring of a testcross (backcross) as the F_1. The symbols F_1 and F_2 must only be used for monohybrid and dihybrid type crosses

2. When answering questions on Mendelian genetics candidates frequently infringe Mendel's laws. Remember that each gene within a diploid organism's genotype must contain two alleles (with the exception of male X-linked characters).

- **Mendel's first law** states that only one of the alleles of a gene may be present in a single gamete. Thus if the parental gene has the two alleles Aa then the gametes cannot be (Aa) but will be (A) and (a)
- **Mendel's second law** states that either of the alleles of one gene may be combined with either of the alleles of a second gene within a gamete. Thus if the parental genotype is ABab, (so the two genes are Aa and Bb), the possible gametes are (AB) , (Ab) , (aB) , and (ab) . They cannot be (Aa) or (Bb) since this infringes Mendel's second law.

***Remember*:-**

- *It is the process of meiosis during gamete formation that is the basis of Mendel's laws. Thus by ensuring that your answers to genetics problems obey Mendel's laws you are simply stating the possible outcomes of the process of meiosis.*
- *Mendel's Laws do not apply in cases of autosomal-linkage or X-linkage. Mendel's laws only apply if the two or more genes under consideration are on different homologous chromosome pairs. If two genes are on the same homologous chromosome pair then they will be autosomaly linked and not obey Mendel's Second Law. X-linkage occurs because the male Y-chromosome only carries a few alleles. Thus the alleles present on the X-chromosome (which have no corresponding allele on the Y-chromosome) will all be expressed in a male (XY), irrespective of whether they are dominant or recessive. Recessive alleles on an X-chromosome in a female (XX) may be masked by dominant alleles on the other X-chromosome.*

(Autosomes are chromosomes that carry alleles not concerned with inheritance of sexual characters. The alleles relating to sex are all carried on the sex chromosomes. A diploid chromosome number will contain one pair of sex chromosomes (XY). All the other pairs will be autosomes).

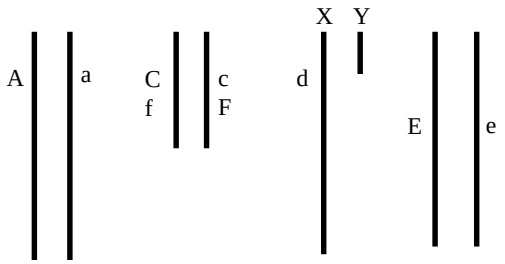
When analysing data presented in genetics questions it may be necessary for you to decide whether the data relates to Mendelian inheritance or to linkage inheritance. Certain clues will help your decision:

- If an F_2 generation shows a 3:1 ratio of phenotypes then the data relates to monohybrid (single gene) Mendelian inheritance.
- If an F_2 generation shows a 9:3:3:1 ratio of phenotypes then the data relates to dihybrid (two genes) Mendelian inheritance.
- If an F_2 generation shows a 3:1 ratio of phenotypes or approaches a 3:1 ratio of phenotypes then the data relates to autosomal linkage. For example, if you were expecting a Mendelian dihybrid 9:3:3:1 ratio, but found a 8.7: 0.3: 0.3: 0.7 ratio, then the genes would be autosomaly linked.
- If a phenotype appears much more frequently in males than in females it is probably an example of X-linked inheritance (sex-linkage).

Test Question

Fig 1 represents four pairs of homologous chromosomes from an animal and some of the genes they carry. State which of the genes/alleles will behave as Mendelian monohybrids, which as Mendelian dihybrids, which as autosomal linkage groups and which will be sex-linked.

Fig.1. Four pairs of homologous chromosomes from an animal.



Answers

Mendelian monohybrids: A and a, E and e.

Autosomaly linked: C and f, c and F. Thus the four alleles, Cf and cF, may 'behave' as a single gene.

Mendelian dihybrids: A and a with E and e, A and a with Cf and cF. E and e with Cf and cF.

X-linked: d is sex-linked to the male.

Specimen exam questions:

(Examiner's answers/corrections/comments in italics)

1. In pigs, erect ears are controlled by the dominant allele E and flop ears by the recessive allele e. Black coat is controlled by the dominant allele B but red coat is controlled by the recessive allele b. The pairs of alleles are not linked.

(a) With the aid of a genetic diagram show the genotypes and phenotypes of a cross between two black erect-eared heterozygous pigs and state the ratio of the phenotypes obtained. ***5 marks***

(b) With the aid of a genetic diagram show the genotypes, phenotypes and ratio of offspring produced by crossing a black erect-eared heterozygous pig with a red flop-eared pig. Assume the genes are linked in adjacent loci on the same bivalent. Comment on the result obtained. ***6 marks***

Student's Answer

(a) P BbEe x BbEe ✓

BE Be bE be BE Be bE be ✗

(No G for gametes / gametes not ringed)

F_1	BE	Be	bE	be
BE	BBEE	BBEe	BbEE	BbEe
Be	BBEe	BBee	BbEe	Bbee
bE	BbEE	BbEe	bbEE	bbEe ✓
be	BbEe	Bbee	bbEe	bbee ✗

(Mark awarded for correct genotypes in table but not awarded for phenotypes because they must be associated with their genotypes in the table and not just written underneath).

9 black red : 3 black flop : 3 red erect : 1 red flop ✓
(Mark for correct ratio)
3 marks scored

(b) P BbEe x bbee ✓
G (BE) (be) (be) (be) (be) (be) (be) (be) ✗
((be) gametes duplicated)

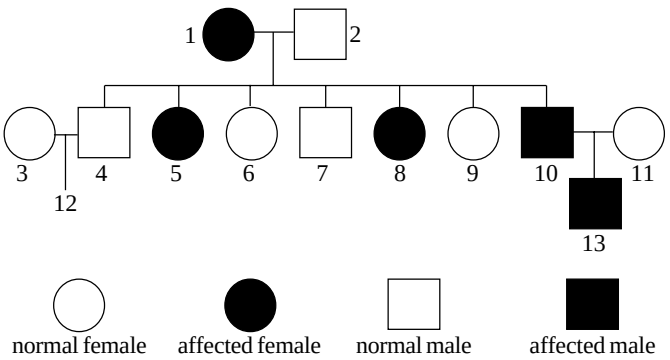
F_1 BbEe BbEe BbEe BbEe bbee bbee bbee bbee ✗
(too many genotypes)
black erect 50% red flop ✓ 50% ✓

Gametes (Be) and (bE) are unlikely to form since B is next to E and b is next to e on the same chromosome pair. Thus they are unlikely to be separated by a chiasma. *(Mark for correct comment)*
4 marks scored

The completed correct punnet square for part (a) is:

F_1	BE	Be	bE	be
BE	BBEE black erect	BBEe black erect	BbEE black erect	BbEe black erect
Be	BBEe black erect	BBee black flop	BbEe black erect	Bbee black flop
bE	BbEE black erect	BbEe black erect	bbEE red erect	bbEe red erect
be	BbEe black erect	Bbee black flop	bbEe red erect	bbee red flop

2. Inherited night blindness is a condition in which sufferers have an inability to see in dim light. The allele N for night blindness is dominant to n, the allele for normal vision. The gene is carried on an autosome. The family tree below shows the inheritance of night blindness.



(a) Individual 12 is a girl. What is her genotype and phenotype relating to vision? **2**
(b) What is the genotype of individual 1? Why? **2**
(c) What is the genotype of individual 13? Why? **2**
(d) What is the probability that the next child born to individuals 10 and 11 will be a boy with night blindness. Show how you reach your answer. **4**

Student's answer:
(a) nn, normal vision. ✓✓
(b) NN, because she has night blindness. ✗ ✗
(Nn, because although she has night blindness she must carry the recessive allele, because some of her children are double recessive with normal vision).
(c) Nn. He is night blind and so has the dominant allele but must have received a recessive allele from his mother who was double recessive. ✓✓
(d) Genotype of individual 10 is Nn since he is night blind but had a double recessive father. ✓
Genotype of individual 11 must be nn since she has normal vision.

P Nn x nn ✓
G (N) (n) (n) *(correct genetic diagram)*
F_1 Nn nn ✓
night blind normal

Thus there is a 50% probability of producing a child with night blindness. (Incomplete answer -the student did not read the question carefully - they were asked for the probability of a boy being born with night blindness: Probability of 50% of offspring being male. Thus the probability of having a boy with night blindness is 50% of 50% = 25% (or 0.25 or ¼)
7 marks scored

3. The Manx cat is a variety that has no tail. The trait is caused by a dominant allele M. In the homozygous condition the allele is lethal and the kittens die in the uterus. The recessive allele, m, results in the tailed condition.
(a) What would be the probability of producing a tailed kitten when two Manx cats are interbred? Explain your answer with a genetic diagram. **4**
(b) How can breeders of Manx cats avoid getting stillborn kittens? Explain your answer with genetic diagrams. 6

Student's answer:
(a) P Mm x Mm ✓ *(Correct parental genotypes)*
M m M m ✗ *(No G/gametes not ringed)*
F_1 MM Mm Mm mm
stillborn Manx Manx tailed ✓ *(Correct F_1)*

Probability of producing a tailed kitten is 1 in 4. ✗
(The correct answer is 1 in 3. We cannot include the MM kittens because theyare born dead)

(b) Never breed two Manx cats together because this may produce stillborn kittens:
P Manx Manx
Mm x Mm ✓
G M m M m
F_1 MM Mm Mm mm ✓
stillborn
(correct gametes indicated by G so mark given)
(correct genotypes and stillborn indicated)

(Also need reference to: only crossing Manx cats with tailed cats so that Manx cats may be produced but no stillborns.(1 mark)

P Manx x tailed
Mm mm
G (M) (m) (m) (1 mark)
F_1 Mm mm
Manx tailed (No stillborns) (1 mark)
5 marks scored

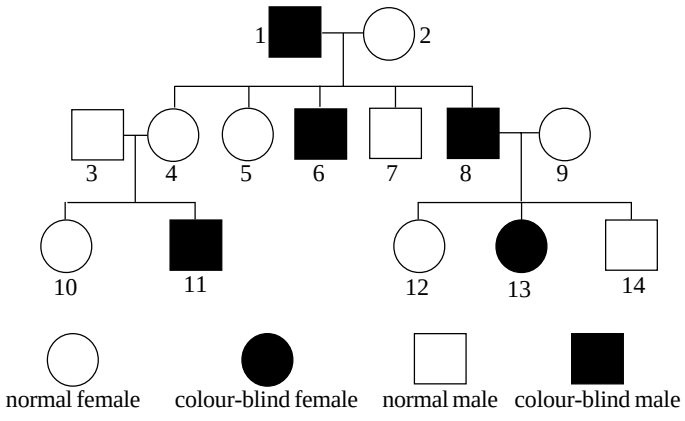
4. Read through the following passage about inheritance of seed colour in maize and then fill in the missing spaces with the correct information.

Seed colour in maize is controlled by ……. inheritance. The two alleles of the gene are dominant P for purple seed colour and recessive p for yellow seed colour. When two heterozygous purple-seeded maize plants were crossed, producing an offspring maize plant, 484 seeds were harvested from the offsprings ear(cob). Of these seeds, 345 were purple in colour and 139 were yellow. The heterozygous maize plants used for the cross had a genotype ……. and produced offspring with genotypes …… . The expected ratio of purple to yellow seeds was …… and there should have been ……. purple seeds formed and ……. yellow seeds formed. A ……. statistical test was performed to assess the null hypothesis that 'seed colour in maize is inherited by ……. inheritance. **8**

Student's answers (in bold)

Seed colour in maize is controlled by **Mendelian** ✗ *(Monohybrid - Mendelian too general)* inheritance. The two alleles of the gene are dominant P for purple seed colour and recessive p for yellow seed colour. When two heterozygous purple-seeded maize plants were crossed, producing an offspring maize plant, 484 seeds were harvested from the offsprings ear(cob). Of these seeds, 345 were purple in colour and 139 were yellow. The heterozygous maize plants used for the cross had a genotype Pp ✓ and produced offspring with genotypes **PP, Pp, and pp**. ✓ The expected ratio of purple to yellow seeds was **3:1** ✓ and there should have been 365 ✗ *(Maths error, 363)* purple seeds formed and **121** ✓ yellow seeds formed. A statistical **T-test** ✗ *(Chi squared test)* was performed to assess the null hypothesis that 'seed colour in maize is inherited by **monohybrid** ✓ inheritance'. **5 marks scored**

5. Red-green colour blindness in humans is a sex-linked trait. The dominant allele, C, controls normal vision and the recessive allele c, controls red-green colour blindness. These alleles are situated on the X-chromosome. The family tree below shows the occurence of red-green colour blindness over three generations of a family.



(a) Complete the table by writing in the most probable genotypes of each of the numbered individuals. **5**

Individuals	Genotype	
2, 10,	$X^C X^C$	✓
4, 5, 9, 12.	$X^C X^c$	✓
13.	$X^c X^c$	✓
3, 14.	$X^C Y$	✓
1, 6, 8, 11.	$X^c Y^c$	✗

(XcYc is wrong because there is an allele for colour blindness shown on the Y-chromosome. The Y-chromosome does not carry any alleles relating to vision)

***Remember:**- when writing sex-linked genotypes always show the X and/or Y-chromosomes and the relevant alleles carried as a suffix on, usually, the X-chromosome.*

(b) Explain your answers for individuals 2, 3, 5 and 9. 4

Individual 2 has normal vision and so has at least one dominant allele C. Because none of her daughters are colour-blind, although her husband is, it is probable that her second X-chromosome also carries a dominant C. ✓

(the incidence of the colour-blindness allele is quite low in the population, only 1 in 40 males are colour blind.Thus it is most likely that her second allele is dominant C.)

Individual 3 is a normal male and so his only X-chromosome must carry a dominant C. ✓

Individual 5 has normal vision and so has at least one dominant allele C.She must also have received an X-chromosome from her colour-blind father and so must also have a recessive allele c. She is a carrier. ✓

Individual 9 has normal vision and so has at least one dominant allele C. She must have donated an X-chromosome carrying a recessive allele to the colour-blind daughter and so must be a carrier. ✓

8 marks scored

6. The ABO blood-group system is controlled by multiple alleles. The alleles are designated IA, IB, and IO. The alleles are co-dominant. The alleles control the development of two agglutinins situated on the red cell membranes.

(a) Complete the following table by inserting the possible genotypes of the four blood groups. **4**

Blood group	Genotypes (student's answers)	
A	$I^A I^A$	✗
B	$I^B I^B$	✗
AB	$I^A I^B$	✓
O	$I^O I^O$	✓

(Group A could also be IA IO. Group B could also be be IB IO).

(b) With reference to group AB explain the meaning of 'co-dominance'. **3**

Both alleles exert an effect in the phenotype. ✓ ✗ ✗

(This answer is incomplete - there is no reference to group AB. The examiners would require a reference to group AB blood containing both agglutinin A and agglutinin B, also a reference to the fact that the influence of the two alleles is equal). **3 marks scored**

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