Bio Factsheet

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Dominant and Recessive Alleles

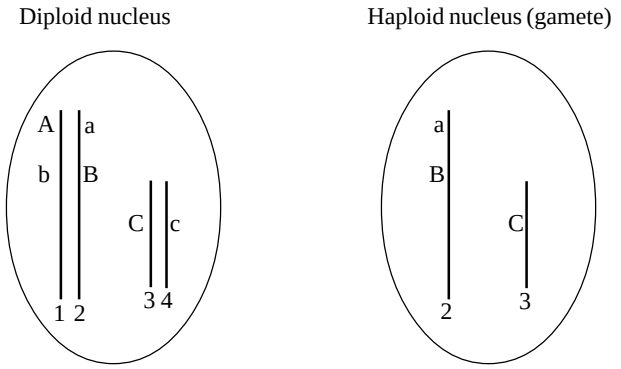
Remember the following facts about genes.

- A gene is a unit of inheritance which codes for the development of a particular characteristic in an organism.
- A specific gene is always on a specific place (locus) on a specific chromosome.
- A gene will contain at least two different alleles. Some genes contain many alleles. An allele is a particular form of a gene occupying the same locus on a chromosome as any alternative allele of the same gene.
- Different alleles of a gene code for the development of particular variations in the characteristic coded for by the gene.
- A diploid organism will always contain two alleles for a specific gene because they contain two of every chromosome.
- A haploid gamete (or haploid organism) will only contain one allele for a specific gene because only one of each chromosome will be present.
- A **dominant allele**, if present, masks the expression of another allele of the same gene. The **dominant character** is the characteristic which develops because of the presence and expression of the dominant allele.
- A **recessive allele**, if present, has its expression masked or blocked by the presence of a dominant allele of the same gene. The **recessive character** is the characteristic which develops because of the presence and expression of the recessive allele. This can only happen in the absence of a dominant allele for the gene.

An allele is actually a segment of DNA double helix that codes for the synthesis of a messenger RNA molecule, this then codes for the synthesis of a specific polypeptide which causes the development of the particular characteristic coded for by the allele.

By convention, a dominant allele of a gene is shown by a capital letter, for example **A**. The recessive allele is shown by a small, (but the same) letter, in this example, **a**. If the gene had many alleles they can be shown as A_1, A_2, A_3 ….. A_n, a_1, a_2, a_3 ….. a_n.

Fig. 1. Arrangement of alleles in nuclei.



This diploid nucleus has two pairs of homologous chromosomes, one pair carrying alleles of genes A and B, the other pair carrying alleles of gene C. When the chromosomes segregate independently (in meiosis) to form haploid gametes either of chromosomes 1 or 2 may segregate with either of chromosomes 3 or 4. Thus four possible combinations occur in the gamete nucleus - chromosome combinations 1-3, 1-4, 2-3, or 2-4. The specific alleles are carried on their chromosomes into the gamete.

You should now be able to understand the genetic basis of two types of inheritance.

- Alleles on chromosome pair 1-2 will be inherited independently of alleles on chromosome pair 3-4. This is the basis of **Mendelian inheritance**.
- Alleles on chromosome 1 or chromosome 2 will be inherited together. This is the basis of **linkage inheritance**.

Sometimes a process called chiasma formation occurs during meiosis. This may interchange specific alleles between 1 and 2 – but it does not alter the actual alleles. Thus, within the 'linkage group' shown on the diagram, allele **A** could be carried with **B** or with **b,** allele **a** could be carried with **B** or **b**.

By a combination of Mendelian and linkage genetics, the diploid nucleus shown above could have given eight types of gamete: ABC, ABc, AbC, Abc, aBC, aBc, abC and abc.

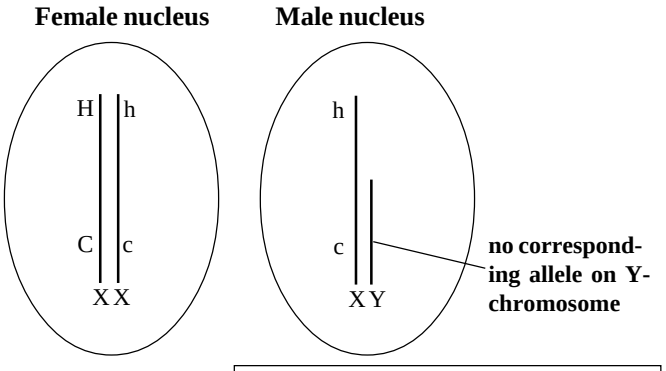
Exam questions may only involve Mendelian genetics, or only involve linkage genetics. They sometimes involve a combination of Mendelian and linkage genetics and you should be able to recognise and explain this.

- In Mendelian inheritance, if a single gene is involved (monohybrid inheritance) the ratio of different phenotypes in the F_1 (first filial generation) will always be 3:1.
- In Mendelian inheritance, if two genes are involved (on different chromosome pairs) the ratio of different phenotypes in the F_2 (second filial generation) will always be 9:3:3;1.
- In linkage inheritance, where two genes on the same chromosome are involved, certain combinations of alleles will occur more frequently than in Mendelian inheritance. In the F_2 generation an expected 9:3:3:1 ratio could become a 3:1 ratio. This is when alleles are at adjacent loci on the chromosome so that they are unlikely to be separated into new combinations (recombinants) by chiasmata. The two alleles thus tend to behave as if they were a single gene controlling two characters.

Genetics questions often include **sex linkage**. Sex linked characters are those which occur much more frequently in one sex than in the other. In most organisms, the X-chromosome carries alleles regulating development of female characteristics and the Y-chromosome carries alleles regulating development of male characteristics. The X-chromosome also carries many alleles that regulate characteristics other than sex. In many species, including humans, the Y-chromosome is very short and carries few or no alleles apart from those relating to inheritance of sex. The female carries two X chromosomes (XX) and the male carries one X-chromosome and one Y-chromosome (XY).

Fig. 2. Basis of sex-linkage

In humans, red-green colour blindness and haemophilia are two examples of sex-linkage to the male.



A recessive character can only be expressed if the recessive allele is present on both X-chromosomes, (dominant allele missing).

This individual has inherited the X-chromosome carrying the recessive alleles. 'h' must be expressed because that region of the X-chromosome is not covered by an X or Y-chromosome carrying the dominant allele. 'c' must be expressed because the Y-chromosome is 'genetically empty' and has no corresponding dominant allele. 'h' and 'c' will therefore always be expressed when they occur in the male and are said to be 'male sex-linked'.

In **codominance**, if both alleles of a gene are present, both are expressed. The alleles are not dominant or recessive. For example, the ABO blood group gene contains three alleles, $\mathbf{I^A}$, $\mathbf{I^B}$ and $\mathbf{I^O}$. $\mathbf{I^A}$ produces antigen A on the red cells, $\mathbf{I^B}$ produces antigen B on the red cells but $\mathbf{I^O}$ does not produce any antigen. Codominance is shown in people with genotype $\mathbf{I^AI^B}$ because both alleles are expressed so the red cells carry antigen A and antigen B. In horses coat colour is governed by a pair of alleles, $\mathbf{C^C}$ that governs the development of a cream coat and $\mathbf{C^B}$ that governs the development of a brown coat. Codominance is shown in heterozygotes which are $\mathbf{C^CC^B}$**.** The alleles are both expressed and result in a palomino horse with a golden coat and white mane. The homozygotes $\mathbf{C^BC^B}$ and $\mathbf{C^CC^C}$ would develop a brown coat and a cream coat respectively.

In **epistasis** one gene may hide or inhibit the expression of another gene. In other words, 'the genes interact to modify the effects in the phenotype'. For example, rats have a dominant allele **B** that gives a black coat colour and a recessive allele **b** that gives a cream coat colour. This colour gene acts in association with an epistatic gene on another chromosome (so randomly assorting) which has a dominant allele **E** which allows the development of colour and a recessive allele **e** which inhibits colour development, resulting in albino rats with white fur and pink eyes. The albino rats could have genotypes BBee, Bbee, or bbee. Black rats could have genotypes BBEE, BBEe, BbEE or BbEe. Cream rats could have genotypes bbEE or bbEe.

Practice questions

Try to answer these questions based on the information given above and then refer to the mark schemes for answers and comments.

1. Cockatiels (a species of small parrot) have colouration controlled by several genes.
   (a) One gene determines the presence or absence of red cheek patches. When birds with red cheek patches are interbred the offspring may or may not have red cheek patches.
   Interbreeding birds without red cheek patches always produces birds without red cheek pouches.
   (i) Explain this information, using the symbols R and r for the alleles involved. 3
   (ii) By means of a genetic cross show how interbreeding birds with red cheek patches could produce birds without red cheek patches.
   Parental genotypes:
   Gametes:
   Offspring genotypes:
   Offspring phenotypes:
   Expected ratio of offspring phenotypes: 5

   (b) Another gene controls the main colour of the body feathers of cockatiels. One allele (S) produces silver colouration. The other allele (G) produces grey colouration.
   Heterozygous birds are silvery grey.
   (i) Identify and comment on this type of inheritance. 2
   (ii) Show, using a genetic diagram, the results of crossing a heterozygous bird with a silver bird.
   Parental genotypes:
   Gametes:
   Offspring genotypes:
   Offspring phenotypes:
   Expected ratio of offspring phenotypes: 5

(c) A sex-linked gene governs the appearance of feathers with a dark edge. The dark edge is caused by a recessive allele (d).
In birds the male has two X-chromosomes which are the same length and carry the allele. Female birds carry an X-chromosome and a shorter Y-chromosome which does not carry the allele.
State the possible genoypes of the following birds:
(i) female with dark edged feathers:
(ii) male with dark edged feathers:
(iii) male with plain feathers:
(iv) female with plain feathers. 4

(d) Write down the genotype of a female bird with silvery grey dark edged feathers and no red cheek patches. 1

2. In mice, black fur is due to a dominant allele, B, brown fur is due to the recessive allele, b. A second (epistatic) gene, on a different chromosome pair, regulates the expression of the coat colour gene and has two alleles – a recessive allele, a, gives a non-agouti coat where the black or brown pigment is evenly distributed along the hairs, also a dominant allele, A, which gives an agouti coat where the pigment is only present in uneven bands along the hair and the other parts of the hairs are yellow.
(a) In a cross between a brown agouti mouse and a black non-agouti mouse, some of the offspring were brown and some were non-agouti.
Explain how this could occur, illustrating your answer with a genetic diagram. 6

(b) What proportion of the offspring would you expect to have black non-agouti fur? Explain your answer. 2

(c) A third gene contains a dominant allele, M, which causes the production of the pigment melanin. Its recessive mutant allele, m. prevents melanin synthesis so that mice which are homozygous (mm) for this allele have white fur and pink eyes, (the albino form). Write down the colour phenotypes of mice with the following genotypes:
(i) BbAaMm:
(ii) BBAAMm:
(iii) bbaa mm. 3

3. In sweet peas a gene governing flower colour has a dominant allele, P, for purple flowers and a recessive allele, p, for red flowers. Another gene governing pollen shape has a dominant allele, L, for long pollen grains and a recessive allele, l, for short pollen grains.
(a) What possible gametes could be produced by the heterozygous purple flowered plants with long pollen grains with genotype PpLl, if:
(i) the two genes behave in a Mendelian fashion; 4
(ii) the two genes are very closely linked. 4
In each case explain your answer.

(b) By means of a genetic diagram show the results of crossing two purple flowered long pollen grain plants, heterozygous for both characters, together. Assume that the two genes are completely linked together. Explain your answer. 6

Answers

1. (a) (i) allele r must be the recessive allele for absence of cheek patches; because birds with no cheek patches must be homozygous/ double recessive/rr because when interbred they can't produce offspring with red cheek pouches;
allele R must be the dominant allele for red cheek pouches so crosses between heterozygous/Rr birds can produce offspring with red cheek pouches (RR or Rr) and offspring with no cheek pouches (rr);

(ii) Parental genotypes: Rr × Rr ;
Gametes: R and r R and r ;
Offspring genotypes: RR Rr rr ;
Offspring phenotypes: red red no pouches
Expected ratio of offspring phenotypes: 3 red pouches to 1 no pouches ;

(b) (i) it is codominance;
both alleles are expressed in the heterozygotes/SG individuals;

(ii) Parental genotypes: SG × SS ;
Gametes: S and G only S ;
Offspring genotypes: SS SG ;
Offspring phenotypes: silver silvery grey ;
Expected ratio of offspring phenotypes: 1 : 1 ;

(c) (i) female with dark edged feathers: X^dY ; (allow X^dO)
(ii) male with dark edged feathers: X^dX^d ;
(iii) male with plain feathers: X^DX^D or X^DX^d ; (both needed)
(iv) female with plain feathers. X^DY ; (allow X^DO)
(d) X^dYSGrr ;

2. (a) to give brown offspring the black parent must have a recessive allele for brown/be heterozygous for colour;
to give non-agouti offspring the brown agouti parent must contain a recessive allele for non-agouti/be heterozygous for agouti;

Parental phenotypes:	brown agouti	×	black non-agouti (no mark)	
Parental genotypes:	bbAa		Bbaa ;	
Possible gametes:	bA and ba		Ba and ba ;	
Offspring genotypes:	BbAa	bbAa	Bbaa	bbaa ;
Offspring phenotypes;	black agouti	brown agouti	black non-agouti	brown non-gouti;

(b) 25%;
the two genes are on different homologous pairs of chromosomes and so are inherited in a Mendelian fashion/are not linked (on the same chromosomes);
(c) (i) BbAaMm: black agouti;
(ii) BBAAMm: black agouti;
(iii) bbaa mm. albino;

3. (a) (i) PL, pL, Pl, pl ;
two pairs of homologous chromosomes are involved;
one pair carries alleles P and p, the other pair carries alleles L and l;
these chromosomes segregate independently in meiosis so P can be inherited with L or l and p can be inherited with L or l/ recombinants pL and Pl can form;
(ii) PL and pl/ nearly all PL and pl with a very low percentage of recombinants pL and Pl;
the two genes are on the same homologous pair of chromosomes;
thus must be inherited together;
'very closely linked' implies that they are on adjacent loci on the chromosome and so unlikely to be recombined by a chiasma;

(b) P and L being adjacent on one chromosome will behave as one allele producing two effects, ditto for alleles p and l;
Parental genotypes: PLpl × PLpl (no mark)
Possible gametes: PL and pl PL and pl ;
recombinants are unlikely to form because a chiasma is unlikely to separate adjacent alleles;

Offspring genotypes:	PLPL	PLpl	plpl ;
Offspring phenotypes:	purple flowers long pollen	purple flowers long pollen	red flowers short pollen ;

Expected ratio: 3 purple flower long pollen : 1 red flower short pollen;
(Give due credit to candidates who linked P with l and p with L on the original pair of homologous chromosomes).

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