16. Inheritance

16.2 The Roles of Genes in Determining the Phenotype

Paper 4

Marking Scheme

Q1.

(a)	(gene ***L*** has) four alleles / L^V, L^T, L^R and L^r ; **A** a gene which has more than two alleles	**1**
(b)	parental genotypes: $L^T L^R$ x $L^T L^R$ gametes: (L^T) (L^R) (L^T) (L^R) ; offspring genotypes: $L^T L^T$ $L^T L^R$ ($L^T L^R$) $L^R L^R$; offspring phenotypes: dfm-a dfm-b (dfm-b) rufipennis ; linked to genotypes ratio of offspring phenotypes: 1 : 2 : 1 ; *accept correct phenotype descriptions*	**4**
(c)	L^T and L^R ; L^T and $L^R > L^V > L^r$;	**2**
(d)(i)	(female) $L^V L^r$ and (male) $L^r L^r$; $L^V L^r$ (and $L^V L^r$) ;	**2**
(d)(ii)	there are similar numbers of male and female offspring produced (for each phenotype) **or** female metallic offspring are produced **or** if linked to X chromosome no female metallic offspring are produced ;	**1**
(d)(iii)	chi-squared test ; **A** χ^2	**1**

Q2.

(a)	*any **five** from:* 1 a gene codes for a protein which determines the phenotype ; 2 *F8* gene ; 3 located on X chromosome / sex-linked ; 4 *ref. to* recessive allele ; 5 non-functioning factor VIII (protein) **or** less factor VIII (protein) **or** no factor VIII (protein) ; 6 (so) blood does not clot quickly enough / excessive bleeding occurs (after an injury) ; 7 link the phenotype to the genotype ; e.g. $X^F X^F$ = normal female $X^F X^f$ = normal female $X^f X^f$ = affected female $X^F Y$ = normal male $X^f Y$ = affected male 8 AVP ; e.g. prevents activation of thrombin / fibrinogen not converted to fibrin / *ref. to* mostly males affected / different mutations cause a range of severity of haemophilia	**5**

(b)	*any **three** from:* 1 *lele* is, homozygous recessive / two recessive alleles ; 2 *le* (allele) / *lele*, codes for a non-functional enzyme ; 3 no, active gibberellin / GA_1 **or** *ref. to* gibberellin inactive ; 4 no / less, cell elongation **or** no / less, stem elongation / increase in internodal length ; 5 AVP ; e.g. *ref. to* GA 3β-hydroxylase / GA3-oxidase / last enzyme in the pathway that produces, active gibberellin / GA_1 *le* allele codes for alanine instead of threonine (in the enzyme)	**3**

Q3.

(a)(ii)	*any **three** from*: **1** recessive / mutation = faulty / inactive / no, tyrosinase ; **2** (melanocytes) do not produce, melanin / pigment ; **3** *ref. to* skin / hair / iris ; **4** AVP ;	**3**

(b)	*gametes (on Punnett square)* **1** BF Bf bF bf ; *Punnett square* **2** correct offspring genotypes on Punnett square ; **3** phenotypes matching genotypes ; *offspring phenotype ratio* **4** 9 black : 3 brown : 4 white ;	**4**

	BF	Bf	bF	bf
BF	BBFF black	BBFf black	BbFF black	BbFf black
Bf	BBFf black	BBff white	BbFf black	Bbff white
bF	BbFF black	BbFf black	bbFF brown	bbFf brown
bf	BbFf black	Bbff white	bbFf brown	bbff white

Q4.

(a)	*parental genotype* **Rr** x **Rr** ***AND*** *gametes* (R) (r) (R) (r) ; *offspring genotype* RR Rr (Rr) rr ; red red red yellow ;	**3**

(b)	1 *ratio*=9:3:3:1 ; *any **two** from:* 2 independent / random, assortment ; 3 of, homologous chromosomes / bivalents / sister chromatids ; 4 stage of meiosis ; e.g. metaphase 1 or metaphase 11 **Ignore** *ref. to* crossing over / recombinants	**3**

Q5.

<table>
<tr><td>(a)</td><td>(melanic x melanic)
Aa x Aa
(Gametes) A a and A a ;

(Offspring) AA Aa Aa aa ;
(melanic, melanic, melanic, typical)

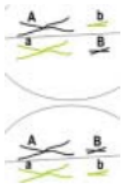
(Ratio) 3 melanic : 1 typical ;</td><td>3</td></tr>
<tr><td>(b)</td><td>it / (melanic) allele, is dominant ;</td><td>1</td></tr>
<tr><td>(c)(i)</td><td>melanic / dominant phenotype, is crossed with homozygous recessive ;</td><td>1</td></tr>
<tr><td>(c)(ii)</td><td>
<table>
<tr><td></td><td>same locus
(A / a)</td><td>different loci
(A / a and B / b)</td></tr>
<tr><td>genotypes of melanic
moths from cross 1</td><td>AA
Aa
(aA) ;</td><td>AaBb
Aabb
aaBb ;</td></tr>
<tr><td>proportion of test crosses
(cross 2) giving 100%
melanic offspring</td><td>1 in 3</td><td>none / 0 ;</td></tr>
</table>
</td><td>3</td></tr>
</table>

Q6.

(a)(i)	**AAb^hb^h** **Aab^hb^h** **AAb^hb** **Aab^hb** ; ;	**2**

(a)(ii)	long, white / albino ;	**1**
(b)	**1** *F1 parent genotypes:* AaBb x AaBb ; **2** *gametes:* (A B) (A b) (a B) (a b) (A B) (A b) (a B) (a b) ; **3** *F2 offspring genotypes:* **4** evidence of deduction of phenotypes from (min 9 different) genotypes ; **5** *F2 offspring phenotype ratio:* **9** black short : **3** white short : **3** black long : **1** white long ;	**5**

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

(c)(i)	*any **three** from:* **1** because they are, on separate chromosomes / not linked ; **2** each, bivalent / pair of homologous chromosomes, orients itself separately ; **3** (at equator) in metaphase I of meiosis ; **4** gives, four / different / new, combinations of alleles / gametes ; **5** parental allele combinations are not, preserved / fixed ; **6** AVP ; 	**3**
(c)(ii)		**1**
(c)(iii)	1.036 ;	**1**

phenotype	observed number (*O*)	expected number (*E*)	$(O - E)^2$	$\frac{(O-E)^2}{E}$
short, black fur	25	**27**	4	0.148
long, black fur	11	**9**	4	0.444
short, white fur	8	**9**	1	0.111
long, white long	4	**3** ;	1	0.333

Q7.

(c)	*any **three** from:* *haploid* 1 only cell with harmful mutation will, be affected / die ; 2 rest of population unaffected / AW ; *diploid* 3 recessive allele for harmful mutation, will be masked by dominant (normal) allele / not expressed in heterozygote ; 4 AVP ; e.g. (haploid) removes mutated allele from population	**3**

Q8.

(a)	all correct (1827) ; **phenotype** / **observed number** / **expected number** brown body colour, straight wings / 2843 / 1827 brown body colour, curved wings / 855 / 1827 black body colour, straight wings / 842 / 1827 black body colour, curved wins / 2768 / 1827	**1**
(b)	*any **four** from:* 1 *ref. to* 3 degrees of freedom ; 2 the, χ^2 value / 2098, is greater than 7.815 (at p=0.05) ; 3 there is a significant difference ; 4 reject the null hypothesis ; 5 any difference is not due to chance / less than 5% (probability) that difference is due to chance ; 6 the, χ^2 value / 2098, is greater than, 11.345 at p=0.01 / 16.266 at p=0.001 **or** less than, 1% / 0.1% (probability), that difference is due to chance ;	**4**

(c)	*any **four** from:* 1 greater numbers of parental phenotypes / fewer numbers of recombinants ; 2 genes are linked / autosomal linkage / genes are on same chromosome ; 3 alleles inherited together ; 4 **B** inherited with **D** and **b** inherited with **d** **or** **B** and **D** in the same gamete and **b** and **d** in the same gamete ; 5 no independent assortment ; 6 crossing over (produces recombinants) ; 7 during, meiosis / prophase I / gamete formation ; 8 AVP ; e.g. idea that genes are far enough apart on chromosome for recombination to occur	**4**

Q9.

(a)(i)	*any **two** from:* 1 transparent phenotype (reappears) in F2 (but not F1) ; 2 so it is, inherited / passed down / genetic / not environmental ; 3 new / recessive, allele ;	**2**
(a)(ii)	9 : 3 : 3 : 1 ;	**1**

(a)(iii)	*any **four** from:* 1 two genes ; 2 on separate chromosomes / not linked ; 3 not sex-linked / autosomal ; 4 each gene has / both genes have, two alleles ; 5 albino / white stripes, is recessive (allele) ; 6 transparent / non-gold, is recessive (allele) ; 7 wild type is dominant for both genes ;	**4**

Q10.

(a)	1 *symbols* **B** / $\mathbf{X^B}$ = (allele for) black (fur) **G** / $\mathbf{X^G}$ = (allele for) ginger (fur) ; *parents phenotypes* *tortoiseshell female* *ginger male* 2 *parents genotypes* $\mathbf{X^BX^G}$ $\mathbf{X^GY}$; 3 *gametes* $\mathbf{X^B}$ $\mathbf{X^G}$ $\mathbf{X^G}$ $\mathbf{Y}$; 4 offspring *genotypes* $\mathbf{X^BX^G}$ $\mathbf{X^BY}$ $\mathbf{X^GX^G}$ $\mathbf{X^GY}$; 5 *offspring phenotypes* tortoiseshell female / black male / ginger female / ginger male ;	**5**
(b)	*any **three** from:* 1 *TYR* codes for tyrosinase ; 2 converts tyrosine into DOPA ; 3 converts DOPA into dopaquinone ; 4 dopaquinone converted to melanin ;	**3**

Q11.

(d)	*any **three** from:* **1** obtain, blood / tissue / DNA ; **2** (test) both (sub)species / migratory and non-migratory ; **3** use PCR to amplify DNA ; **4** use, (gel) electrophoresis / DNA profiling / DNA fingerprinting, **and EITHER** compare results **OR** to see genetic, differences / changes ; **5** sequence DNA and, count / identify, differences / changes ; **6** check / test, for correlation between, DNA / genetic profiles / alleles / markers, and migratory behaviour ; **7** use, databases / bioinformatics, to find, name / role of, genes / sequences (that, differ / are associated with migration) ; **8** AVP ;	**3**

Q12.

(a)	*gene* length of DNA coding for a polypeptide ; *allele* alternative / different, form / version, of a gene ;	**2**
(b)	*parents phenotypes* red eyes apricot eyes *parents genotypes* C^RC^H C^AC^W *gametes* (C^R C^H C^A C^W) *offspring genotypes* C^RC^A C^RC^W C^HC^A C^HC^W ; *offspring phenotypes* red eyes (red eyes) apricot eyes honey eyes ; *ratio* 2 : 1 : 1 ;	**3**
(c)	**1** cross with, white-eyed fly / C^WC^W ; *any **two** from:* **2** if all red-eyed then C^RC^R ; **3** if (some red-eyed and) some apricot-eyed then C^RC^A ; **4** if (some red-eyed and) some honey-eyed then C^RC^H ; **5** if (some red-eyed and) some white-eyed then C^RC^W ;	**3**

Q13.

(a)(i)	DOPA / dopaquinone / melanin ;	**1**
(a)(ii)	cyclic AMP / cAMP ; **A** calcium ions	**1**
(a)(iii)	*any **two** from:* 1 albino / albinism ; 2 no pigment or melanin in skin / pale skin **or** white hair ; **Ignore** fair, skin / hair 3 red / pink, eyes / irises ; **A** blue 4 poor vision / described **or** eyes sensitive to light **or** jerky eye movements ; **Ignore** blindness	**2**
(b)	symbols ; e.g. **B** allele for black fur **b** allele for (light) brown fur parental genotypes **Bb x Bb** gametes **B b B b**] ; offspring genotypes **BB Bb (Bb) bb** ; offspring phenotypes black black (black) (light) brown ; *accept gametes mark from a Punnett square*	**4**

Q14.

(a)	*allele* – variety / form, of a gene ; *dominant* –(allele) always expressed / always has effect on the phenotype / expressed in heterozygote / has effect on the phenotype of heterozygote ;	**2**

(b)(i) **5**

	wild type parent		double homozygous recessive parent		
parental phenotype	red eye, long wing		purple eye, vestigial wing		;
parental genotype	**RrNn**		**rrnn**		;
offspring					
offspring phenotype	red eye, long wing	purple eye, vestigial wing	red eye, vestigial wing	purple eye, long wing	;
offspring genotype	**RrNn**	**rrnn**	**Rrnn**	**rrNn**	;;
numbers of offspring	1339	1195	151	154	

offspring genotypes – 4 correct = 2 marks, 3 correct = 1 mark
allow short wing for vestigial wing
allow alleles in any order in genotypes
ignore brackets and circles around alleles

(b)(ii)	*any **three** from:* **1** (two) genes are linked / autosomal linkage **or** alleles inherited together ; **2** no, independent / random, assortment ; **3** large numbers of parental type offspring / small numbers of recombinant offspring ; **4** recombinants due to crossing over ; **5** during, meiosis / prophase 1 / gamete formation ;	**3**

Q15.

(a) — **3**

codominant
1 both (alleles), affect / seen in / expressed in / contribute to (phenotype) ;
2 in heterozygote ;

recessive
3 affects / seen in / expressed / contributes to, (phenotype) (only) when dominant (allele) absent / in homozygote ;

(b) — **3**

parental phenotype	A		B	
parental genotype	$I^A I^o$		$I^B I^o$	
gametes	I^A	I^o	I^B	I^o ;
offspring genotype	$I^A I^B$	$I^A I^o$	$I^B I^O$	$I^o I^o$;
offspring phenotype	AB	A	B	O ;

(c) — **3**

*any **three** from:*
1 males / men / boys, are, XY / have (only) one X chromosome ;
2 man / father, passes Y to, male offspring / son ;
3 man / father, does not pass X to, ♂ offspring / son ;
4 man / father, passes, X / mutation, to, female offspring / daughter ;
5 woman / mother, passes X / mutation, to, male offspring / son ;

Q16.

(a) — **2**

*any **two** from:*

1 tyrosine converted to, DOPA / dopaquinone ;

2 dopaquinone converted to melanin ;

3 *ref. to* melanocytes ;

Q17.

(a)(i) — **1**

AAbb, **Aabb**, **aaBB**, **aaBb** ;

(a)(ii) — **4**

	Alfresco	*Di Nizza*	*or*	*Di Nizza*	
parent genotypes	**aabb**	**Aabb**		**aaBb**	;
gametes	**ab**	**Ab ab**		**aB ab**	;
offspring genotypes	**aabb**	**Aabb**		**aaBb**	;
offspring phenotypes	long	spherical		spherical	;

(a)(iii) — **2**

random / independent, assortment ;

metaphase 1 ;

Q18.

(d)(i)	less, energy / resources, to make stem so, more to / larger, flowers **or** less likely to be damaged by, wind / storm / heavy rain **or** takes less, water / fertiliser / time to flower ;	**1**

(d)(ii)	*any **three** from:* *short / dwarf, plants:* 1 are, homozygous recessive / *le* ; 2 *le* / recessive allele, codes for, non-functional / no, enzyme ; 3 *le* / recessive allele / non-functional enzyme, gives inactive gibberellin ; 4 DELLA proteins, not broken down / stay bound to PIF ; 5 PIF cannot, bind to promoter / start transcription ; 6 of gene(s) that promote, growth / cell division / cell elongation ;	**3**

Q19.

(b)	1 key e.g. **H** = normal (allele) **h** = Hunter (syndrome allele) ; parental phenotype: normal male, normal female 2 parental genotype: X^HY, X^HX^h ; gametes: (X^H Y X^H X^h) 3 offspring genotypes: X^HX^H X^HX^h X^HY X^hY ; 4 offspring phenotypes: normal female, normal / carrier female, normal male, Hunter S male ; 5 probability: 0.25 / 25% / 1 in 4 ;	**5**

Q20.

(a)(i)	gametes correctly entered ; genotypes correct ; **A** ecf phenotypes match genotypes ; **A** ecf *ratio of fruit colours:* 12 white : 3 yellow : 1 green ; **A** ecf	**4**

	AB	**Ab**	**aB**	**ab**
AB	**AABB** white	**AABb** white	**AaBB** white	**AaBb** white
Ab	**AABb** white	**AAbb** white	**AaBb** white	**Aabb** white
aB	**AaBB** white	**AaBb** white	**aaBB** yellow	**aaBb** yellow
ab	**AaBb** white	**Aabb** white	**aaBb** yellow	**aabb** green

(a)(ii)	plant **P**: **AaBB** ; plant **Q**: **Aabb** ;	**2**

Q21.

(a)	less / no, oxygen for (aerobic) respiration ; cells / tissues / organs, fail to function / die ;	**2**

Q22.

(a)(i)	*any **two** from:* **1** (codon) 976 where, T is replaced by C / TCT becomes TCC **or** (codon) 977 where, A is replaced by T / TCA becomes TCT ; **2** ser(ine) in, both / cats and humans ; **3** degenerate code ;	**2**
(a)(ii)	*any **two** from:* **1** base / C, deleted at, second codon / (codon) 975 ; **2** causes frameshift ; **3** next 9 codons changed / all codons afterwards are changed ;	**2**
(a)(iii)	*any **two** from:* **1** *ref. to* shortened polypeptide ; **2** no tyrosinase made ; **3** change in, 3D / tertiary, shape / structure **or** change in active site ; **4** (so) tyrosinase, non-functional / cannot bind to substrate / inactive ; **5** tyrosine not converted to, DOPA / dopaquinone ;	**2**

(a)(iv)	*any **one** from:* *why* **1** large amount of, data / DNA sequences ; **2** fast / accurate / efficient ; **A** description of fast / accurate / efficient / detects each small difference = accurate *any **one** from:* *conclusions* **3** more similarity the more **recent** a common ancestor / AW ; **4** molecular clock ;	**2**
(b)	*parent phenotypes:* (albino x fully pigmented) *parent genotypes:* $\mathbf{t^at^a}$ x $\mathbf{Tt^s}$; *gametes:* ($\mathbf{t^a}$ **T** $\mathbf{t^s}$) *F1 genotypes:* $\mathbf{Tt^a}$ $\mathbf{t^st^a}$; *F1 phenotypes:* fully pigmented Siamese **and** *ratio:* **1 : 1** ; *F1 phenotypes must match genotypes* *ecf for mp2 and mp3 if parent genotype incorrect*	**3**

Q23.

(a)	*any **two** from:* **1** changed amino acid / changed 1° structure / polar → non-polar amino acid ; **2** valine / non-polar R group, forms different bonds (than glutamine) ; **3** bonds form between HbS molecules / HbS molecules stick together ;	**2**

Q24.

(a)	*parent phenotypes:* long hair pointed x short hair full colour ; *parent genotypes:* **hhrr** x **HhRr** ; *gametes:* **hr** **HR Hr hR hr** ; *F1 genotypes:* **HhRr** **Hhrr** **hhRr** **hhrr** ; *F1 phenotypes:* short hair full colour / short hair pointed / long hair full colour / long hair pointed ;	**5**
(b)(i)	*any **one** from:* **1** two pointed parents (always) give (all) pointed offspring ; **2** two full colour cats can give a pointed offspring ; **3** pointed phenotype has, **– – /** homozygous **– /** no restriction site(s) ;	**1**
(b)(ii)	*any **two** from:* *autosomal because* **1** males have two alleles ; **2** (marker inheritance shows) sons get one number from father ; **3** colour of sons not determined only by mother ; **4** gene is not on X chromosome (linked to mps 1, 2 or 3) ;	**2**
(b)(iii)	*any **two** from:* plus or minus and marker number inherited, together / as a block / as a pair ; <u>no</u>, recombination / (results of) crossing over, seen ; no, +3 / +4 / –7, in bottom right hand cat ;	**2**

Q25.

(b)(i)	**RR dd PP** pale pink petals, red eye ; **Rr Dd Pp** dark pink petals, red eye ; **rr Dd Pp** white petals, no red eye / white centre ; **RR dd pp** white petals, red eye ;	**4**
(b)(ii)	*any **four** from:* 1 base, substitution / insertion / deletion ; 2 frameshift / described ; 3 changes, primary structure / amino acid sequence / primary sequence ; 4 changes, tertiary structure / 3D shape ; 5 STOP codon ; 6 shortened, protein / polypeptide ; 7 (protein / enzyme) unable to bind to, substrate / receptor / DNA ; 8 (so biosynthetic) pathway does not function / AW ;	**4**

Q26.

(a)	*parental genotypes* **Aa** × **Aa** **and** *gametes* **A** **a** and **A** **a** ; *offspring genotypes* **AA** **Aa** (**Aa**) **aa** ; *offspring phenotypes (correctly linked to genotypes)* normal normal / carrier (normal / carrier) OCA1A / albino / described ; *probability* 25% ; **A** 1 in 4 / 0.25 / ¼ **I** ratio	**4**

Q27.

(a)	1 *symbols:* normal (allele) = **E** and EOPD (allele) = **e** ; 2 *parent genotypes + gametes:* **Ee** x **Ee** **and** **E** **e** **E** **e** ; 3 *offspring genotypes:* **EE** **Ee** **(Ee)** **ee** ; 4 *ratio of offspring phenotypes:* **3** normal **: 1**, EOPD / with disease ;	**4**

(c)	*any **two** from:* 1 only need one allele to produce inhibitor ; 2 other proteins cannot be, phosphorylated / activated ; 3 no / less, aerobic respiration / ATP, in (mitochondria of) neurones ; 4 (less ATP so) problem with, dopamine recycling / sodium-potassium pump / establishing resting potential / repolarisation; 5 neurones die ;	**2**

Q28.

(a)	*(autosomal)* not a sex chromosome ; *(linkage)* genes on the same chromosome / alleles inherited together ;	**2**
(b)(i)	1 *F1 genotypes* **FG/fg** **or** **FGfg** **or** **(FG)** **(fg)** ; **A FfGg** 2 *gametes* **FG** **fg** **FG** **fg** ; 3 *F2 genotypes* **FGFG** **FGfg** **FGfg** **fgfg** ; **A** **FFGG** **FfGg** **FfGg** **ffgg** 4 *F2 phenotypes* purple long / purple long / purple long / red round **ecf** *for mp3 from incorrect gametes (mp2)* **R** *if sex linkage*	**4**
(b)(ii)	*any 1 of:* do not show 9:3:3:1 ratio ; large(r) numbers of parental phenotypes / low(er) numbers of recombinant phenotypes ;	**1**
(c)(i)	**fgfg** / homozygous recessive ; **A ffgg**	**1**
(c)(ii)	12.7 **or** 13 ;	**1**
(c)(iii)	low, COV / crossover value, indicates genes closer together **or** high, COV / crossover value, indicates genes further apart ;	**1**

Q29.

(a)	*grey badgerface* $\mathbf{A^bA^g}$; *white* **AA** $\mathbf{AA^b}$ $\mathbf{AA^g}$ **Aa** ;	**2**
(b)	(grandparent cross **A–** x **aa** (any white x black) to give **Aa** white parent may be shown, but no mark) *cross 1:* **Aa** x $\mathbf{A^gA^g}$ → $\mathbf{AA^g}$ $\mathbf{A^ga}$; white grey ; *cross 2:* **Aa** x $\mathbf{A^ga}$ → $\mathbf{AA^g}$ **Aa** $\mathbf{A^ga}$ **aa** ; white white grey black ;	**4**
(c)	**(aa / a),** protein product does not, block / bind, melanocortin 1 / receptor ; (so) MSH / hormone, binds to, melanocortin 1 / receptor, causing melanin synthesis ;	**2**

Q30.

(a)	chi-squared / χ^2 (test) ; 9 : 3 : 3 : 1 ;	**2**
(b)	*parents:* **GgRr** x **ggrr** *gametes:* **GR** **Gr** **gR** **gr** x **gr** ; *offspring:* **GgRr** **Ggrr** **ggRr** **ggrr** ; *phenotypes:* grey (body) red (eyes) / grey (body) brown (eyes) / black (body) red (eyes) / black (body) brown (eyes) ;	**4**
(c)	*any five from* **1** expect (ratio) / (ratio) not, 1 : 1 : 1 : 1 ; **2** get, many / more / most / majority / large numbers of, grey(body)-red(eye) and black(body)-brown(eye) (flies / offspring) ; **3** majority resemble (original) parents / have parental phenotypes ; **4** 1 : 1 ratio of two parental types and 1 : 1 ratio of recombinant types ; **5** genes / loci / eye colour and body colour, are, linked / on same chromosome ; **6** (alleles) **G+R** linked and **g+r** linked (in, F1 / heterozygotes) ; **7** no, random / independent, assortment ; **8** crossing over (produces recombinants / minority phenotypes) ; **9** low numbers of recombinants show, genes / loci, close together ;	**5**