Hints For Biology 101 Exam #4

Mendelian Genetics & Immunology

For answers to many of the questions, please refer to the Reading List for Exam #4. Also try the Wayne's Word Index & Search. Answers to most of the questions can be found in Meiosis vs. Mitosis, The Genetics of Corn, Polygenic Inheritance, Polyploidy & Hybridization, Population Genetics, Antibodies, Vaccines & Serums, Blood Types, Color Blindness, & Poison Oak: Cell-Mediated Immune Response.

Part I. Multiple Choice Questions 1 - 10:

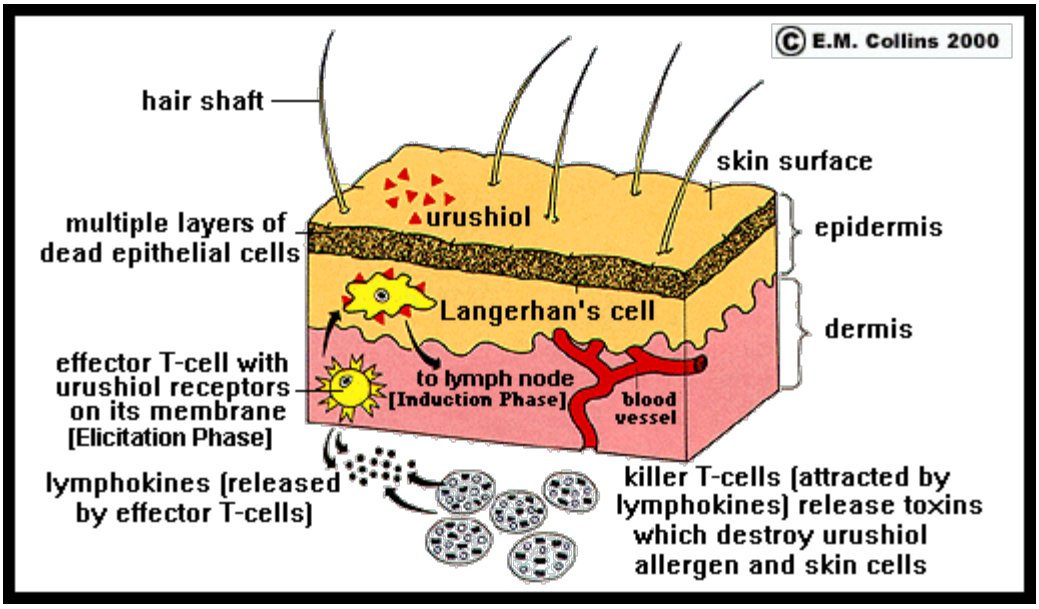


Illustration showing a hypothetical mechanism for the poison oak scenario: a delayed action, cell-mediated immune response. The urushiol allergen is carried on the membrane of Langerhan's cells and presented to effector T-cells (helper T-cells) during the induction phase.

Some immunology textbooks state that the urushiol allergen is engulfed by Langerhan's cells. The allergen and a small protein fragment called "major histocompatibility complex" (MHC) is then displayed on its membrane and presented to the effector T-cells.

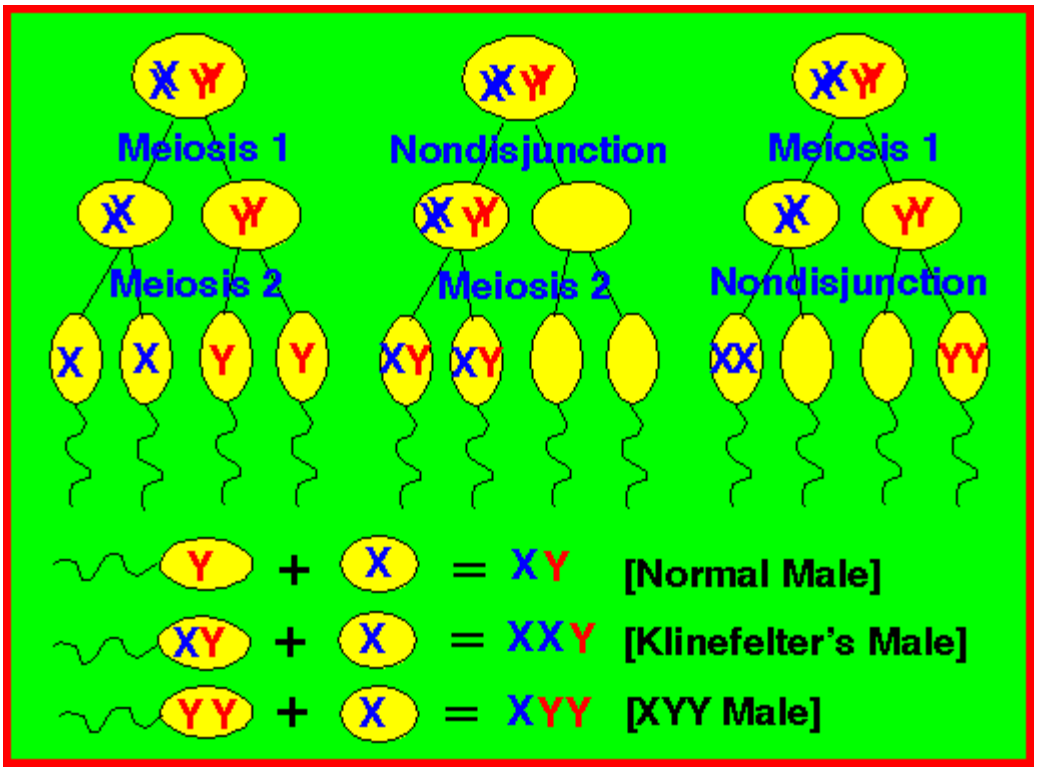
Poison Oak: A Cell-Mediated Immune Response

Part II. Multiple Choice Questions 11 - 34:

Question 11. The somatic (body) cells of a haploid organism typically contain only one set of chromosomes. In other words, the individual chromosomes do not occur in homologous pairs. A male honey bee or drone is haploid because its somatic cells only contain maternal chromosomes from the queen bee.

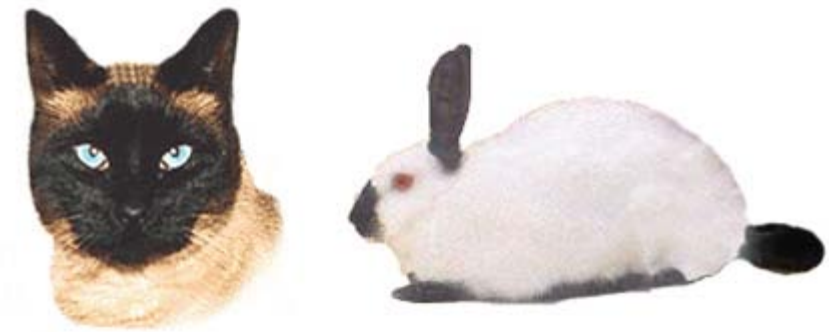
Question 12. The illustrations for Question #12 apply to nondisjunction of sex chromosomes (X and Y chromosomes) during meiosis (spermatogenesis). Nondisjunction can also occur with autosomes. These are all chromosomes excluding the X and Y. In other words, chromosome pairs #1 through #22 in human cells. The X and Y chromosomes are generally considered to be pair #23. In Down's syndrome, one sex cell gets an extra autosome #21. For example, lets say the egg carries two #21 autosomes (a total of 24 chromosomes) and the sperm carries one autosome #21 (a total of 23 chromosomes). During fertilization, the zygote gets three #21 autosomes (a total of 47 chromosomes). See the following diagram and hyperlink for an explanation of human chromosomal anomalies:

In the following diagram, normal spermatogenesis is compared with spermatogenesis with nondisjunction at meiosis I (anaphase I) and nondisjunction at meiosis II (anaphase II). If the doubled X and Y chromosomes move to the same cell at meiosis I, the resulting gametes will each contain single X and Y chromosomes. If meiosis I proceeds normally and nondisjunction occurs at meiosis II when the chromatids separate, it is possible to get gametes containing two single X chromosomes and gametes containing two single Y chromosomes:



[Nondisjunction & Human Chromosomal Anomalies]

Question 13. See the following hyperlink for an explanation of the dark extremities of Himalayan rabbits and Siamese cats:



[Recessive Albino & Himalayan Genes]

Question 14 - 15. A study conducted at a men's prison many years ago revealed that a higher than normal percentage of the inmates carried an extra Y chromosome. It was concluded (incorrectly) that these men developed a criminal tendency because of the extra Y chromosome, perhaps by causing them to be more aggressive during their childhood and adolescent years. Subsequent studies have proven this conclusion to be false. Men with noncriminal behavior can also carry an extra Y chromosome. See the following table and hyperlink for an explanation of human chromosomal anomalies:

1. A phenotypic male with one Barr body.	**XXY**
2. A phenotypic female with zero Barr bodies.	**X_**
3. A phenotypic female with one Barr body.	**XX**
4. A phenotypic male with no Barr bodies.	**XY**
5. A phenotypic female with two Barr bodies.	**XXX**

Nondisjunction & Human Chromosomal Anomalies

Question 16. Simply place a 2 above each heterozygous gene pair and a one above each homozygous gene pair. Then multiply the numbers together to obtain the total number of different possible gametes.

2	1	2	2	1	2	1	1	2
Bb	**rr**	**Ss**	**Pp**	**AA**	**Tt**	**yy**	**nn**	**Vv**

Question 18. Matching genes occurring at the same loci on homologous chromosomes are called alleles. If a pair of alleles are identical they are called homozgous. If the pair contains two different alleles (one dominant and one recessive) they are termed heterozygous. [homo meaning "same" and hetero meaning "different"]

Question 19. In simple Mendelian genetics, alleles typically occur in two forms (one dominant and one recessive). For example, there are two alleles (one pair of alleles) for seed coat in garden peas: The dominant allele for round (R) and the recessive allele for wrinkled (r). In real life, there may be more than two alleles to choose from, and they are not always dominant and recessive. In human blood types there are 3 alleles, A, B and O. They all occur at the same loci on homologous chromosome pair #9 (autosome #9). Since you must inherit a pair of these alleles, there are six different possible genotypes: AA, AO, BB, BO, AB and OO. Since there are more than two alleles to choose from, this type of inheritance is called "multiple allele inheritance." Multiple allele inheritance always involves alleles that occur at the same loci on homologous chromosomes. This is illustrated at the A-B-O Blood typing page at:

Genetics Of The A-B-O Human Blood Types

Question 20. Sometimes a number of genes are involved in the inheritance of a trait. This may involve several pairs of alleles from several different loci on homologous chromosomes. Since different loci are involved, you can't use the term multiple allele inheritance. So geneticists have devised the term "multiple gene" or "polygenic inheritance." Many human traits are attributed to polygenic inheritance, including height, weight, skin color and eye color. Because there are different genes on different loci involved, numerous genotypes and phenotypes (appearances) are possible. The Rh factor is a good example of polygenic inheritance. It is illustrated at the following link:

Rh Blood Types: An Example of Polygenic Inheritance

Question 21. The disease sickle-cell anemia is a good example of a genetic mutation in which the gene for the vital protein hemoglobin has mutated. The sickle-cell gene has an altered DNA base pattern so that it codes for the amino acid valine instead of glutamic acid at a precise location in the hemoglobin molecule. This results in a change in the structure of the molecule resulting in sickle-shaped rather than normal disk-shaped red blood cells. These abnormal cells do not flow as well through minute capillaries, forming painful "log jams" that impede blood circulation. In order to appreciate the answer to this question, please refer to the following hyperlink about proteins:

See Summary Of Protein Structure & Function

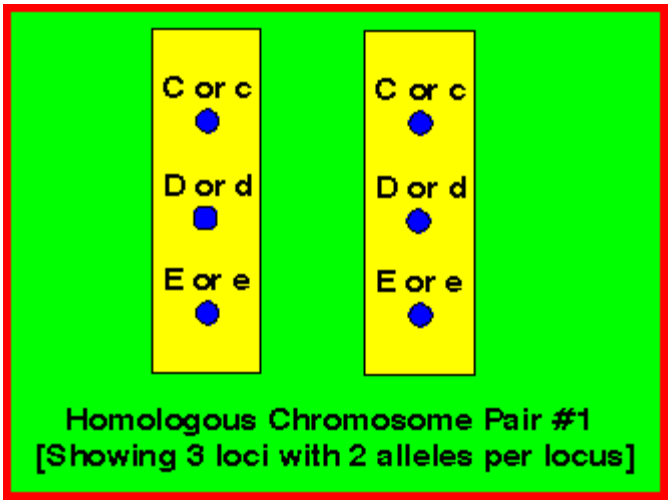
Questions 24 - 26. See the following table showing chromosomal sex determination in four different types of animals:

Animal	Male	Female
Human	**44 autosomes + X & Y chromosomes**	**44 autosomes + two X chromosomes**
Domestic Fowl	**16 autosomes + two X chromosomes**	**16 autosomes + X & Y chromosomes**
Grasshopper	**22 autosomes + one X chromosome**	**22 autosomes + two X chromosomes**
Honey Bee	**Drone (n=16)**	**Worker (2n=32)**

Question 27. A human male and female each have 23 pairs of homologous chromosomes per

cell, a total of 46 chromosomes. A male or female with Down's syndrome has the 21st chromosome (autosome) in triplicate. Instead of the normal homologous pair, there are three #21 chromosomes. In Klinefelter's syndrome, there are three #23 chromosomes (X-Y chromosomes) rather than the normal pair. In this case the individual has two X chromosomes and one Y chromosome. Because the Y chromosome carries the male-determining factor, the individual is a phenotypic male with a penis, although there may be some breast enlargement. In both of these syndromes, the total number of chromosomes per cell is raised by one compared with normal somatic cells.

Question 28. See the following table: The Rh factor is an interesting example of polygenic inheritance. Unlike the A-B-O blood types where all the alleles occur on one pair of loci on chromosome pair #9, the Rh factor involves three different pairs of alleles located on three different loci on chromosome pair #1. In the following diagram, 3 pairs of Rh alleles (C & c, D & d, E & e) occur at 3 different loci on homologous chromosome pair #1. Possible genotypes will have one C or c, one D or d, and one E or e from each chromosome. For example: CDE/cde; CdE/cDe; cde/cde; CDe/CdE; etc.



In order to determine how many different genotypes are possible, you must first determine how many different gametes are possible for each parent, then match all the gametes in a genetic checkerboard. Although the three pairs of genes are linked to one homologous pair of chromosomes, there are a total of eight different possible gametes for each parent: CDE, CDe, CdE, Cde, cDE, cDe, cdE, and cde. This number of gametes is based on all the total possible ways these genes can be inherited on each chromosome of homologous pair #1. [It is not based on the independent assortment of these genes during meiosis in the parents because all three genes are closely linked together on the same chromosome; therefore, all three genes tend to appear together in the same two gametes: CDE and cde.] The possible different genotypes are shown in the following table:

Gametes	CDE	CDe	CdE	Cde	cDE	cDe	cdE	cde
CDE	CDE/ CDE	CDE/ CDe	CDE/ CdE	CDE/ Cde	CDE/ cDE	CDE/ cDe	CDE/ cdE	CDE/ cde

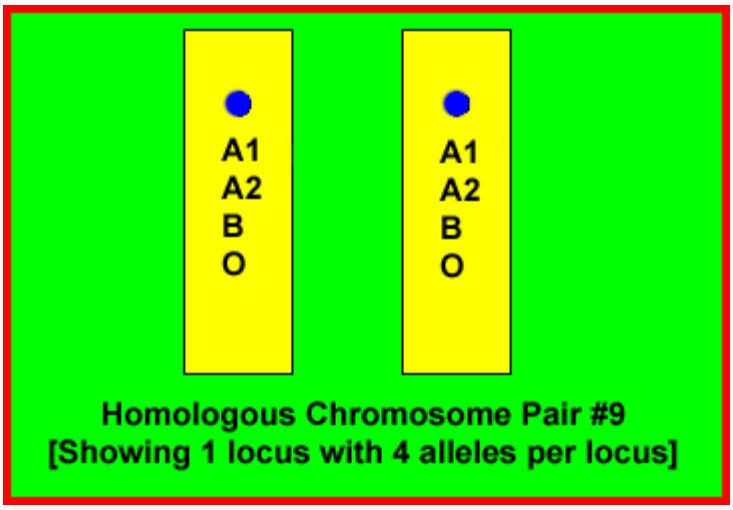
CDe	**CDe/ CDE**	**CDe/ CDe**	**CDe/ CdE**	**CDe/ Cde**	**CDe/ cDE**	**CDe/ cDe**	**CDe/ cdE**	**CDe/ cde**
CdE	**CdE/ CDE**	**CdE/ CDe**	**CdE/ CdE**	**CdE/ Cde**	**CdE/ cDE**	**CdE/ cDe**	**CdE/ cdE**	**CdE/ cde**
Cde	**Cde/ CDE**	**Cde/ CDe**	**Cde/ CdE**	**Cde/ Cde**	**Cde/ cDE**	**Cde/ cDe**	**Cde/ cdE**	**Cde/ cde**
cDE	**cDE/ CDE**	**cDE/ CDe**	**cDE/ CdE**	**cDE/ Cde**	**cDE/ cDE**	**cDE/ cDe**	**cDE/ cdE**	**cDE/ cde**
cDe	**cDe/ CDE**	**cDe/ CDe**	**cDe/ CdE**	**cDe/ Cde**	**cDe/ cDE**	**cDe/ cDe**	**cDe/ cdE**	**cDe/ cde**
cdE	**cdE/ CDE**	**cdE/ CDe**	**cdE/ CdE**	**cdE/ Cde**	**cdE/ cDE**	**cdE/ cDe**	**cdE/ cdE**	**cdE/ cde**
cde	**cde/ CDE**	**cde/ CDe**	**cde/ CdE**	**cde/ Cde**	**cde/ cDE**	**cde/ cDe**	**cde/ cdE**	**cde/ cde**

You can also plug into this neat little formula for calculating the number of different genotypes based on the number of alleles per locus and the number of loci per chromosome. The formula was actually devised by several of my general biology students. It may occur somewhere in a textbook, but the students came up with it independently.

$$\frac{X^{2n} + X^{n}}{2}$$

X = # of alleles per locus per chromosome
n = # of loci per chromosome

Question 29. See the following diagram showing one pair of homologous chromosomes, each with a single locus. Only one allele can occur at each locus, but there are 4 possible alleles per locus.

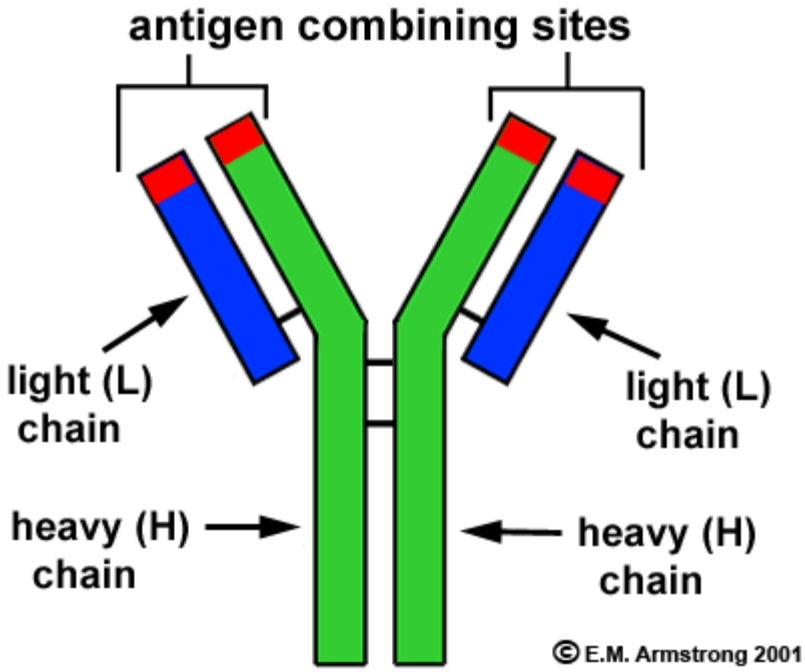


Since the A1, A2, B and O alleles are located on one pair of loci on homologous chromosome pair number nine, the following genotypes are possible: A1A1, A1A2, A2A2, A1O, A2O, BB, BO, A1B, A2B and OO.

Questions 32 - 33. See the following table showing the number of different gametes due to independent assortment of chromosomes during meiosis and random combination of gametes.

No. of homologous chromosome pairs (heterozygous genes)	No. of different gametes from each parent	Total number of zygotic combinations or squares in genetic checkerboard
1 (Aa X Aa)	2 (2^1)	4 $(2^1)^2$
2 (AaBb X AaBb)	4 (2^2)	16 $(2^2)^2$
3 (AaBbCc X AaBbCc)	8 (2^3)	64 $(2^3)^2$
4 (AaBbCcDd X AaBbCcDd)	16 (2^4)	256 $(2^4)^2$
20 pairs of chromosomes	1,048,576 (2^{20})	1,099,511,627,776 $(2^{20})^2$
23 pairs of chromosomes	8,388,608 (2^{23})	70,368,744,000,000 $(2^{23})^2$
(n) pairs of chromosomes	(2^n) n = haploid number	$(2^n)^2$
Including Crossover Factor (2^3) During Meiosis**		
23 pairs of chromosomes	67,108,864 (2^{26})	4,503,599,600,000,000 $(2^{26})^2$

Question 34. Go to the following hyperlink for an explanation:

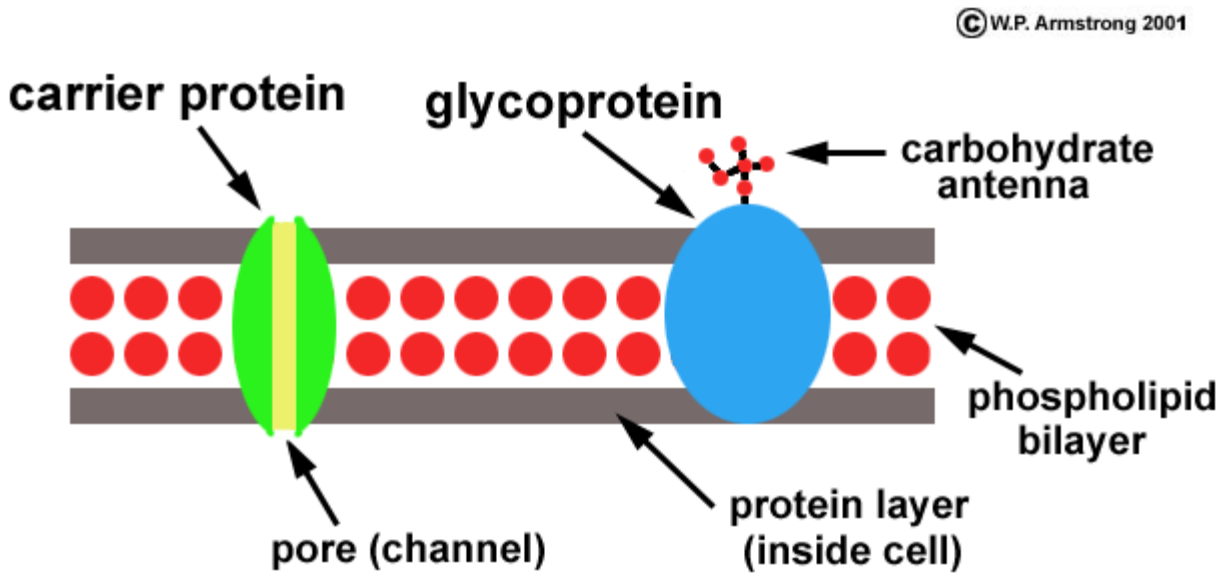


Model For The Structure Of Immune-Type (IgG) Antibodies

Part III. Matching Questions 35 - 60:

1. Mitosis Compared With Meiosis
2. Cell Division & Chromosomes
3. Genetics Of Corn & Parakeets
4. Molecular Models & Antibodies
5. Transposons: Jumping Genes
6. Red-Green Color Blindness
7. Determining A-B-O Blood Types
8. Polygenic Inheritance
9. Rh Factor: Polygenic Inheritance
10. Selection & Genetic Drift
11. Genetics Extra Credit Problems

Question 35. The following illustration shows a highly magnified cell membrane containing two kinds of embedded proteins, a carrier protein and a cell recognition protein. The cell recognition protein contains a carbohydrate "antenna" composed of polysaccharide subunits. Go to the following hyperlink for more explanation:



[Fluid Mosaic Model Of Cell Membrane Proteins]

1. [Vaccines Resulting In Active Immunity]
2. [Serums Resulting In Passive Immunity]
3. [Antivenins For Bites Of Venomous Snakes]

Part IV, Multiple Choice Questions 61 - 134:

1. [Mitosis Compared With Meiosis]
2. [Cell Division & Chromosomes]
3. [Genetics Of Corn & Parakeets]
4. [Molecular Models & Antibodies]
5. [Transposons: Jumping Genes]
6. [Red-Green Color Blindness]
7. [Determining A-B-O Blood Types]
8. [Polygenic Inheritance]
9. [Rh Factor: Polygenic Inheritance]
10. [Selection & Genetic Drift]
11. [Genetics Extra Credit Problems]

Questions 61 - 62. Remember that the gene (allele) for taster (T) is dominant over the gene (allele) for nontaster (t):

Gparents: tt x tt

Mother: tt Father: T _

John: T ?

Gfather: tt

Mother: ? t Father: tt

Mary: T ?

Questions 63 - 66. Remember that the X-linked gene (allele) for normal vision (+) is dominant over the recessive gene (allele) for color blindness (o):

Gparents: X^+Y x X^+X^o

Bob: X^oY Jane: X^+X^o

Gparents: X^+Y x X^+X^o

Father: X^oY

Mary: X^+X^o

Genetics Of Red-Green Color Blindness

Questions 67 - 68. Human skin color is a good example of polygenic inheritance in people. The following table shows a cross between two mulatto parents (AaBbCc x AaBbCc). The offspring contain seven different shades of skin color based on the number of capital letters in each genotype.

Gametes	ABC	ABc	AbC	Abc	aBC	aBc	abC	abc
ABC	6	5	5	4	5	4	4	3
ABc	5	4	4	3	4	3	3	2
AbC	5	4	4	3	4	3	3	2
Abc	4	3	3	2	3	2	2	1
aBC	5	4	4	3	4	3	3	2
aBc	4	3	3	2	3	2	2	1
abC	4	3	3	2	3	2	2	1
abc	3	2	2	1	2	1	1	0

Assume that three "dominant" capital letter genes (A, B and C) control dark pigmentation because more melanin is produced. The "recessive"alleles of these three genes (a, b & c) control light pigmentation because lower amounts of melanin are produced. The words dominant and recessive are placed in quotation marks because these pairs of alleles are not

truly dominant and recessive as in some of the garden pea traits that Gregor Mendel studied. A genotype with all "dominant" capital genes (AABBCC) has the maximum amount of melanin and very dark skin. A genotype with all "recessive" small case genes (aabbcc) has the lowest amount of melanin and very light skin. Each "dominant" capital gene produces one unit of color, so that a wide range of intermediate skin colors are produced, depending on the number of "dominant" capital genes in the genotype. For example, a genotype with three "dominant" capital genes and three small case "recessive" genes (AaBbCc) has a medium amount of melanin and an intermediate skin color. This latter genotype would be characteristic of a mulatto.

In the above cross between two mulatto genotypes (AaBbCc x AaBbCc), each parent produces eight different types of gametes and these gametes combine with each other in 64 different ways resulting in a total of seven skin colors. The skin colors can be represented by the number of capital letters, ranging from zero (no capital letters) to six (all capital letters). The approximate shades of skin color corresponding to each genotype are shown in the above table. Note: Skin color may involve at least four pairs of alleles with nine (or more) shades of skin color.

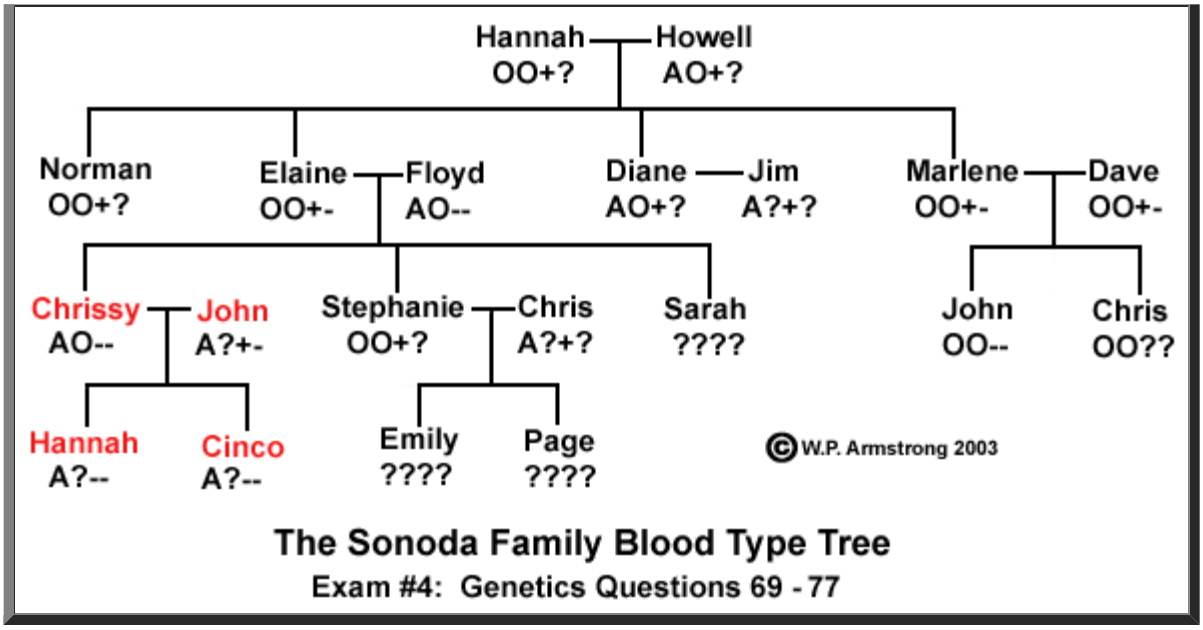
The above cross between two mulattos can also be shown with the binomial expansion $(a + b)^{6}$ where the letter a = number of capital letters and the letter b = number of small case letters. Each term in the expression represents the number of offspring with a specific skin color phenotype based on the number of capital letters in the genotype. For example, 20 offspring have three capital letters in their genotype and have a skin color that is intermediate between very dark with all caps (AABBCC) and very light with no caps (aabbcc).

$$(a + b)^{6} = a^{6} + 6a^{5}b + 15a^{4}b^{2} + 20a^{3}b^{3} + 15a^{2}b^{4} + 6ab^{5} + b^{6}$$

6 Caps **5 Caps** **4 Caps** **3 Caps** **2 Caps** **1 Cap** **0 Caps**

See Multiple Gene (Polygenic Inheritance)

Questions 69 - 77. These questions refer to the Rh and A-B-O blood types of Chrissy and John, and their baby boy named Cinco.



Questions 69 - 72. These questions refer to the Rh types of Chrissy and John, and their baby boy named Cinco.

Questions 63 - 77. These questions refer to the A-B-O blood types of Chrissy and John, and their baby boy named Cinco.

Questions 78 - 82. Remember that the A and B alleles are dominant over the O allele. The type O blood phenotype must be homozygous for the O allele. Type AB blood phenotype must be heterozygous for the A and B alleles.

Bob: O ? John: B ? | Miss X: A ?

Children: O ? & B ? (from same father)

[See The Genetics Of A-B-O Blood Types]

Questions 83 - 86. For these questions, use the process of elimination. Start with the type O parents (O & O) that can only have a type O baby. Then eliminate the only parents that could have an AB baby, and so forth.

Questions 87 - 90. Remember that the A and B alleles are dominant over the O allele. The type O blood phenotype must be homozygous for the O allele. Type AB blood phenotype must be heterozygous for the A and B alleles.

Mother Father	
Parents: T?AB x ttB?	Parents: T?OO x ttB?
John: T?A?	Mary: T?B?

To determine the fractional probability for a taster boy with type B blood, you must make a cross between John and Mary using a genetic checkerboard (Punnett square). When you determine the fractional probability of a taster type B child, multiply by 1/2 to include the sex of the child.

Questions 91 - 94. Use + for the dominant Rh positive gene and - for the recessive Rh negative gene. Place only decimal values in the squares of your checkerboard because you can't multiply percentages. The total decimal value for gametes must add up to 1.0. In other words, 0.3 + and 0.7 - add up to 1.0. The total genotype values must also add up to 1.0. In other words, + + , + - and - - add up to 1.0.

Gametes	+ 0.?	- 0.7
+ 0.?	+ + 0.?	+ - 0.?
- 0.7	+ - 0.?	- - 0.49

[See Wayne's Word Page On Population Genetics]

Questions 95 - 96. The following table using 5 coins illustrates these two questions. Simply change the five coins to three coins or children. Remember that sex determination is much more complicated than tossing coins because many other factors are involved.

Five coins have a total of 32 permutations: H = Head & T = Tail

		HHHTT	TTTHH		
		HHTTH	TTHHT		
		HHTHT	TTHTH		
		HTHTH	THTHT		
		HTHHT	THTTH		
	HHHHT	HTTHH	THHTT	TTTTH	
	HHHTH	TTHHH	HHTTT	TTTHT	
	HHTHH	THHHT	HTTTH	TTHTT	
	HTHHH	THTHH	HTHTT	THTTT	
HHHHH	THHHH	THHTH	HTTHT	HTTTT	TTTTT

5 H's 4 H's 1 T 3 H's 2 T's 2 H's 3 T's 1 H 4 T's 5 T's

The above table of coin permutations is an example of Pascal's Triangle. It can be expressed algebraically by the following binomial expansion:

$$(H + T)^5 = H^5 + 5H^4T + 10H^3T^2 + 10H^2T^3 + 5HT^4 + T^5$$

5 H's 4 H's 1 T 3 H's 2 T's 2 H's 3 T's 1 H 4 T's 5 T's

What is the chance of getting 3 Heads and 2 Tails in that exact order (i.e. HHHTT)? There is only one permutation out of 32 (refer to the top permutation, 3rd column from left).

HHHTT = 1/2 X 1/2 X 1/2 X 1/2 X 1/2 = 1/32

What is the chance of getting 3 Heads and 2 Tails in any order? In this example you must consider all possible permutations with 3 Heads and 2 Tails. The 3rd column from left in the above Pascal's Triangle shows 10 permutations out of 32 with 3 Heads and 2 Tails. This is also the probability of having 3 girls and 2 boys when all possible orders are considered. Another way to solve this problem is to multiply 1/32 by the number of permutations: 1/32 X 10 = 10/32 = 5/16.

# of permutations: 5! / 3! 2! = 5 X 4 X 3 X 2 X 1 / 3 X 2 X 1 X 2 X 1 = 120 / 12 = 10

See Wayne's Word Page On Elementary Probability

Questions 97 - 99. Remember that the A and B alleles are dominant over the O allele. The type O blood phenotype must be homozygous for the O allele. Type AB blood phenotype must be heterozygous for the A and B alleles.

Alleles	0.2 A	0.1 B	0.7 O
0.2 A	AA 4%	AB 2%	AO 14%
0.1 B	AB 2%	BB 1%	BO 7%
0.7 O	AO 14%	BO 7%	OO 49%

6 Genotypes In Above Table Appear In The Trinomial Expansion $(A + B + O)^2$ = A^2 (4%) + 2AB (4%) + B^2 (1%) + 2AO (28%) +2BO (14%) + O^2 (49%)

Note: Since the A, B and O alleles are located on one pair of loci on homologous

chromosome pair number one, there are a total of six genotypes: AA, AO, BB, BO, AB, and OO. If you include two variations of A (A_1 and A_2), there are a total of ten genotypes: A_1A_1, A_1A_2, A_2A_2, A_1O, A_2O, BB, BO, A_1B, A_2B and OO.

See The Determination Of A-B-O Blood Types

Questions 100 - 109. In garden peas, the gene for round (R) is dominant over the gene for wrinkled (r) and the gene for tall (T) is dominant over the gene for short (t). All of these questions refer to the following two crosses:

RrTt x rrtt

Gametes	RT	Rt	rT	rt
rt	RrTt	Rrtt	rrTt	rrtt

rrTt x rrTt

Gametes	rT	rt
rT	rrTT	rrTt
rt	rrTt	rrtt

Dihybrid Crosses With Genetic Corn

Questions 110 - 119. Serious complications may arise when the antibodies of the recipient clump the blood cells of the donor. [The reverse scenario is not as serious because the antibodies of the donor are diluted by the recipient's blood volume.] The following table shows the A-B-O blood donor-recipient compatibility. Clumping of the donor's blood is indicated by the word "Clump" in the red squares. No clumping of the donor's blood is indicated by the word "None" in the green squares. None also denotes the lack of anti-A or anti-B antibodies in the type O recipient. It is clear from this chart that the "universal donor" is type O, while the "universal recipient" is type AB. If you include the Rh factor, then the universal donor becomes O Negative while the universal recipient becomes AB Positive.

Chart Of A-B-O Blood Donor & Recipient Compatibility

RECIPIENT

DONOR	Alleles & Antibodies	O anti-A anti-B	A anti-B	B anti-A	AB None
	O	None	None	None	None
	A	Clump	None	Clump	None
	B	Clump	Clump	None	None
	AB	Clump	Clump	Clump	None

See The Genetics Of A-B-O Blood Types

Questions 120 - 123. Although it is much more complicated, the Rh blood factor can be explained by a pair of alleles on homologous chromosome pair #1. The dominant Rh positive gene (+) produces the Rh antigen, a glycoprotein constituent of the red blood cell (RBC) membrane. Like the type O gene, the recessive Rh negative gene (-) does not produce an antigen. The following table summarizes Rh inheritance in humans:

Blood Phenotype	Blood Genotype	Antigen on RBC Membrane	Immune (IgG) Antibodies
Rh Positive (85% of U.S.)	**+ + or + -**	**Rh antigen**	**None**
Rh Negative (15% of U.S.)	**- -**	**No antigen**	**May Produce anti-Rh**

If Rh positive blood is accidentally given to an Rh negative recipient, the recipient will begin producing anti-Rh antibodies. Because of the time factor involved in building up a concentration (titre) of antibodies, the first transfusion may not cause any major problems; however, a subsequent transfusion of Rh positive blood could be very serious because the recipient will clump all of the incoming blood cells. The donor-recipient scenario with Rh blood types is summarized in the following table:

		Anti-Rh Antibodies

Donor	Recipient	in Recipient's Blood
Rh Positive	Rh Negative	**Will** Produce anti-Rh Antibodies
Rh Negative	Rh Positive	Will **Not** Produce anti-Rh Antibodies

Since Rh negative people may produce anti-Rh antibodies, Rh positive blood should not be given to an Rh negative recipient. Based upon the above table, Rh positive recipients can theoretically receive positive or negative blood, and Rh negative donors can theoretically give to Rh positive and Rh negative recipients. Therefore, the "universal donor" is O Negative, while the "universal recipient" is AB Positive.

See The Genetics Of A-B-O Blood Types

Questions 124 - 125. Remember that the A and B alleles are dominant over the O allele. The type O blood phenotype must be homozygous for the O allele. Type AB blood phenotype must be heterozygous for the A and B alleles.

Father: A ? (no B allele) | Mother: B ?

Children: A ?, B ?, AB, and O ?

See The Genetics Of A-B-O Blood Types

Question 126. Remember that the A and B alleles are dominant over the O allele. The type O blood phenotype must be homozygous for the O allele. Type AB blood phenotype must be heterozygous for the A and B alleles.

Father: ? ? | Mother: O ?

Sister: A ?, Sister: B ?, Brother: B ?

See The Genetics Of A-B-O Blood Types

Questions 127 - 133. The following tables explain how to calculate the answers for questions 127 - 133. The data in the tables is slightly different from your exam, but the method of calculation is the same.

Genotype	RR	Rr	rr
Tabulation	|||||	||||| ||	||||| ||||| ||
Genotype Frequency	5/24 = 20.8%	7/24 = 29.2%	12/24 = 50.0%
Phenotype Frequency	Red: 12/24 = 50%		White: 12/24 = 50%

Genetic Drift After 24 Crosses With Red & White Beads.

The following calculations show that the ratio of red and white beads from the above 24 draws in above Table 4 are different from the original 24 red beads and 24 white beads:

- Number Of Red Beads: 5 x 2 (from RR) + 7 (from Rr) = 17
- Number Of White Beads: 12 x 2 (from rr) + 7 (from Rr) = 31
- Since the original number of 24 white beads has increased to 31 and the original number of 24 red beads has decreased to 17, genetic drift has occurred.

See The Wayne's Word Page About Genetic Drift

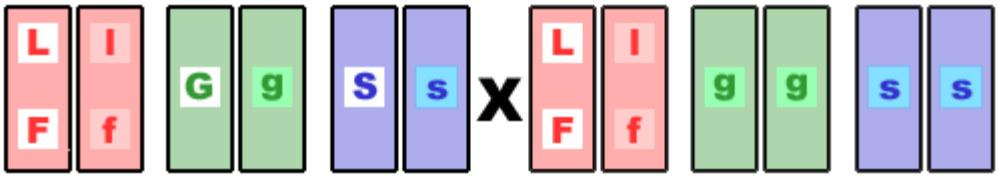
A Genetic Cross Between Watermelons

Questions 134 - 139. These questions refer to a cross between two hypothetical watermelons with four pairs of fruit characteristics.

In watermelons the gene for green rind (G) is dominant over the gene for striped rind (g), and the gene for short fruit (S) is dominant over the gene for long fruit (s). The alleles for rind color and fruit length occur on two different pairs of homologous chromosomes. For this

question, assume that a gene for large melons (L) and and gene for many seeds (F) occur at opposite ends of another chromosome (linkage). The alleles for size and seed number, i.e. the genes for small melons (l) and few seeds (f), occur on a third homologous chromosome. A watermelon plant bearing large, green, short fruits containing many seeds was crossed with a plant bearing large, striped, long fruits containing many seeds. Some of the offspring from this cross produced small, striped, long fruits with few seeds.

Assuming **no crossing over between homologous chromosomes**, what is the fractional chance of producing the following offspring? Remember that there are three pairs of homologous chromosomes in this problem, and one of the homologous pairs exhibits autosomal linkage. The chromosomes of each parent are shown in the following illustration:



There are several ways to solve this problem, but one way is to construct a 16 square checkerboard with eight rows and two columns. To the left of each row, put the eight gametes of the parental plant bearing large, green, short fruits containing many seeds. At the top of each column, put the two gametes of the parental plant bearing large, striped, long fruits containing many seeds. The most difficult part of this problem is to figure out the exact gene combinations of the gametes. Once this is known, you can simply fill in the squares of the checkerboard with the correct gene combinations (genotypes) for each offspring. Remember that each genotype must contain eight letters: An LF or lf, plus two G's (GG, Gg or gg) and two S's (SS, Ss or ss). For example, one of the 16 squares contains the genotype LLFFGgSs; one of the 16 squares contains the genotype LLFFGgss; two of the 16 squares contains the genotype LlFfGgss; and one of the 16 squares contains the genotype llffGgSs. There a total of 12 different genotypes in the checkerboard.

Gametes	LFgs	lfgs
LFGS	LLFFGgSs	LlFfGgSs
LFGs	LLFFGgss	LlFfGgss
LFgS	LLFFggSs	LlFfggSs
LFgs	LLFFggss	LlFfggss
lfGS	LlFfGgSs	llffGgSs
lfGs	LlFfGgss	llffGgss
lfgS	LlFfggSs	llffggSs

lfgs	LlFfggss	llffggss

Checkerboard Showing Cross Between Watermelons

The gene combinations of the gametes are shown in the above Table 1. The plant bearing large, striped, long fruits containing many seeds can produce only two different kinds of gametes (shown in red in Table 1) . The gametes must contain one of the LF or lf chromosomes, one of the g chromosomes, and one of the s chromosomes. Therefore, the two possible gametes are: LFgs and lfgs. The LF and lf genes always appear together because they occur on the same chromosomes. Without crossing over, you could never have Lf together or lF together.

The plant bearing large, green, short fruits containing many seeds can produce eight different kinds of gametes (shown in green in Table 1). The gametes must contain one of the LF or lf chromosomes, one of the G or g chromosomes, and one of the S or s chromosomes. Since there are two possibilities for each of the three kinds of chromosomes, there are eight different possible gametes (2 x 2 x 2 = 8). Four of the eight gametes will contain LF plus GS, Gs, gS or gs. Four of the eight gametes will contain lf plus GS, Gs, gS or gs.

When all the 16 squares of the checkerboard are filled in, simply find the genotypes in the squares that are described in questions 77-80. The correct answers are expressed as a fractional ratio, such as 1/16. Remember that L = large fruit and l = small fruit; F = many seeds and f = few seeds; G = green rind and g = striped rind; S = short fruit and s = long fruit. The capital letters represent dominant genes (alleles) while the small case letters represent recessive genes (alleles). Therefore, a plant with a genotype of LlFfGgss would produce large (L), green (G), long (s), fruits containing many (F) seeds. A genotype of LlFfggSs would produce large (L), striped (g), short (S) fruits containing many (F) seeds.

Part V. Multiple Choice Questions 140 - 176:

Question 142. The medical term for this maternal-fetal condition is "erythroblastosis fetalis" because of the presence of nucleated, immature RBCs called erythroblasts in the fetal circulatory system. The fetus bone marrow releases immature erythroblasts because of the destruction of mature RBCs (erythrocytes) by the mother's anti-Rh antibodies. RhoGam®, a serum containing anti-Rh antibodies, is now given to Rh negative woman within 72 hours after giving birth to their Rh positive baby. The RhoGam® enters the mother's circulatory system and destroys any residual fetal positive RBCs that may be present in her system. This prevents her from producing anti-Rh antibodies. RhoGam® must be given after each Rh positive baby. In this scenario of erythroblastosis fetalis, the fetus must be Rh positive, the mother Rh negative and the father Rh positive. You can easily determine the exact genotype of the mother and fetus, but the father's genotype could be homozygous or heterozygous Rh positive. Rh incompatibility is summarized in the following table:

Rh Pos Father
+ + or + -

X

Rh Neg Mother
- -

1st Rh Pos Child
+ -

Rh positive RBCs from the fetus enter the mother's circulatory system. After several days, the mother begins to produce anti-Rh antibodies.

2nd Rh Pos Child
+ -

Anti-Rh antibodies from mother pass through placenta and enter fetal circulatory system. The antibodies begin clumping fetal postive RBCs.

See The Genetics Of Rh Blood Type

Question 143. This question is explained in the following two tables:

Sex	Color-blind	Normal Vision
Male	X^oY	X^+Y
Female	X^oX^o	X^+X^+ X^+X^o

Cross Between A Color-blind Man (X^oY) and Heterozygous Normal Vision Woman (X^+X^o)

Gametes	X^o	Y
X^+	X^+X^o	X^+Y
X^o	X^oX^o	X^oY

See The Genetics Of Red-Green Color Blindness

Question 145. A dihybrid cross between two green parakeets (BbCc X BbCc) is shown in the following simplified table. This cross involves codominance and gene interaction resulting in a 9:3:3:1 phenotypic ratio of offspring. Codominant alleles B & C together = Green (neither gene is completely dominant over the other). Homozygous or heterozygous dominant B alleles with recessive c alleles = Blue. Homozygous or heterozygous dominant C alleles with recessive b alleles = yellow. All recessive alleles (bbcc) = white.

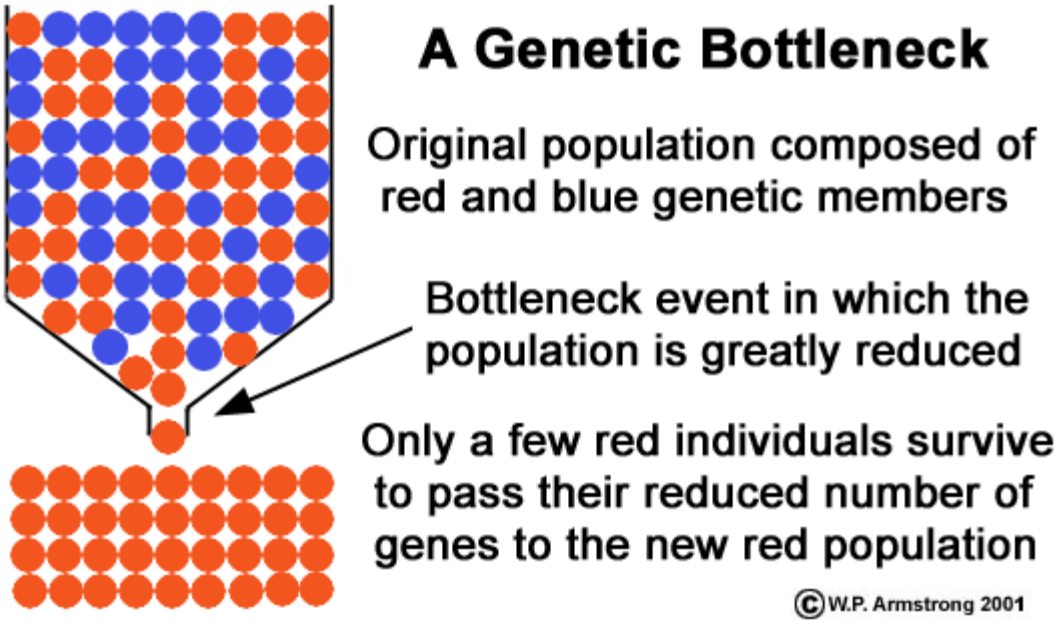
Gametes	BC	Bc	bC	bc
BC	BBCC	BBCc	BbCC	BbCc
Bc	BBCc	BBcc	BbCc	Bbcc
bC	BbCC	BbCc	bbCC	bbCc
bc	BbCc	Bbcc	bbCc	bbcc

Simplified Explanation For Inheritance Of Color In Parakeets

Question 146. This question is explained at the following link:

See Explanation For Genetic Drift In Small Populations

Question 147. This question is explained at the following link:



[Population Bottleneck Causing Loss Of Genetic Variability]

Question 148. Hint: Lethal recessive genes can be carried and passed on in diploid populations without ever being expressed; however, in a haploid population, there is no dominant gene to mask the lethal recessive trait.

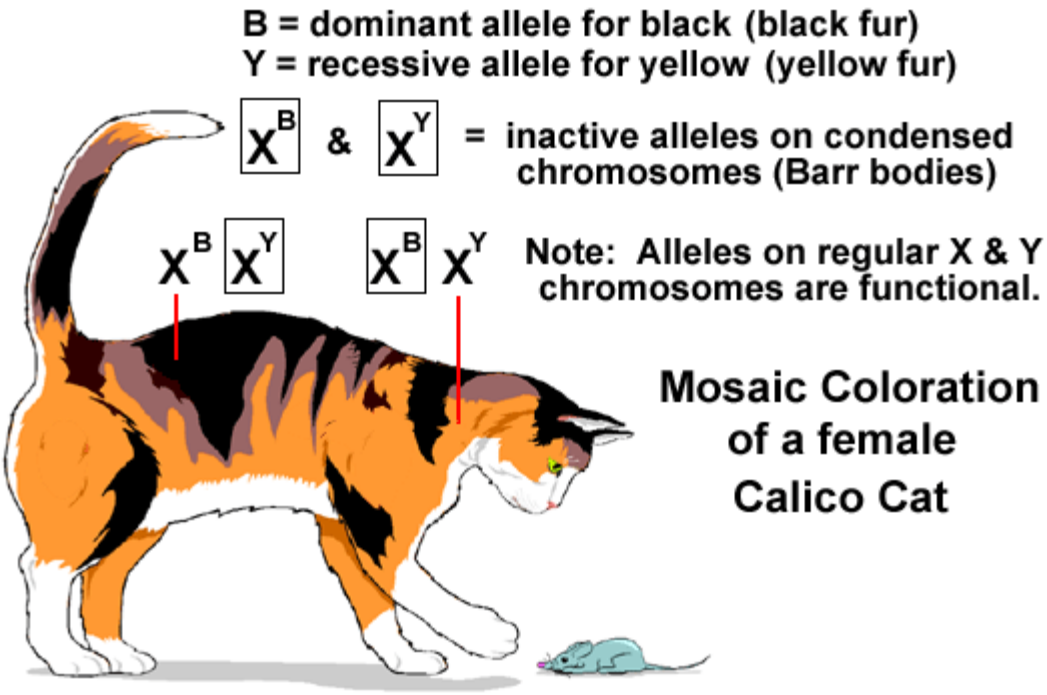
[See Chromosomal Sex Determination In Animals]

Question 149. Solid color dogs are more valuable to cocker spaniel breeders. To test your solid color dog, you would want to breed her with a known homozygous male. Barr bodies would be of little help in this case because the alleles for solid color (S) and spotted (s) do not occur on X chromosomes.

Image Obtained Through Google Image Search

Question 150. The fur coloration of calico cats is governed by two alleles (black and yellow),

both attached to the same loci on a homologous pair of X chromosomes. This question is explained in more detail at the following link:



[See Barr Bodies and Gender Verification]

Questions 151 - 153. When different species are crossed together, the result is a hybrid. Hybrid animals are typically sterile, although they can be male or female. For information about interesting examples of hybridization, please refer to the following hyperlink:

Information About Plant Hybrids:

1. Apples: Polyploid Varieties
2. Bananas: Seedless Triploids
3. Cereals: Some Polyploid Hybrids
4. Grapes: Some Seedless Cultivars
5. Sterile Hybrids (Including The Mule)
6. Mustard Family Vegetable Hybrids
7. Tomatoes: Genetically Engineered
8. Watermelons: Seedless Melons

[See Wayne's Word Article About Plant & Animal Hybrids]

Questions 154. The answers to this questions about Barr bodies can be found at the following hyperlink:

See Barr Bodies and Gender Verification

Questions 155 - 165. The answers to these questions about blood types and the immune system can be found at the following hyperlinks:

Immune Antibodies & The Immune System
A-B-O and Rh Blood Antigens & Antibodies

Question 166. The answer to this question can be found at the following hyperlink:

Hybridization Between a Horse and a Donkey

Question 168. The answer to this question can be found at the following hyperlink:

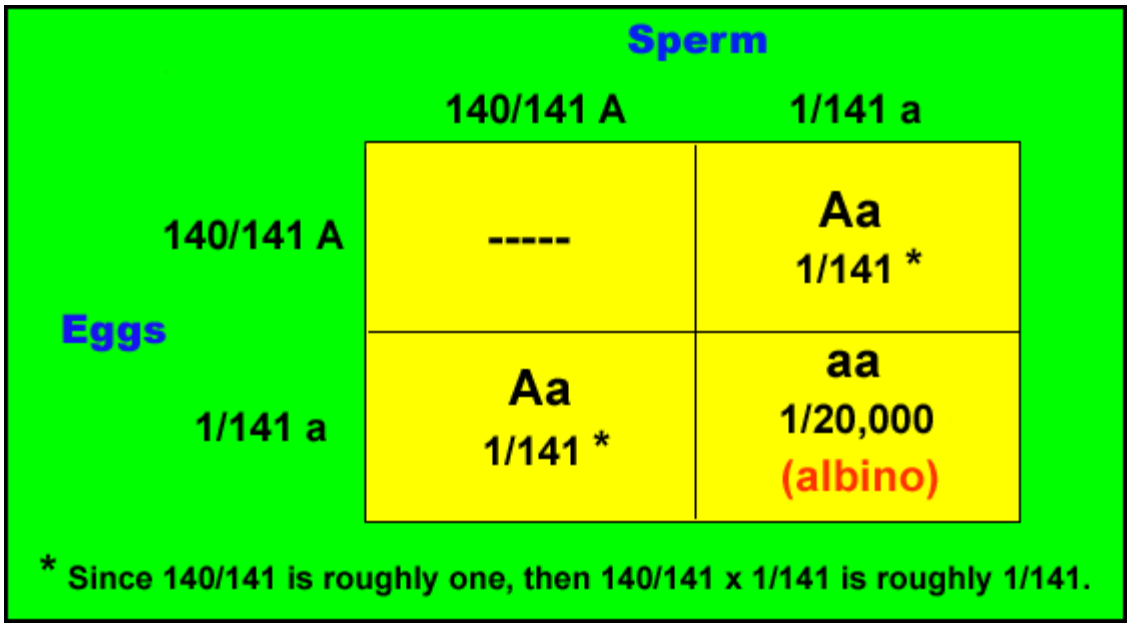
Generation Number (n) Interval of 24 years.	Decimal value of T & t alleles in gametes of the parents. t = 1/n + 1) T = 1 - (1/n + 1)	Fractional ratio of the t allele in parental gametes. 1/n + 1	Homozygous recessive (tt) nontasters. $(1/n + 1)^2$	Year
1	**0.5 T 0.5 t**	**1/2 or 0.5**	**0.25 or 25%**	**1983**
2	**0.67 T 0.33 t**	**1/3 or 0.33**	**0.11 or 11%**	**2007**
3	**0.75 T 0.25 t**	**1/4 or 0.25**	**0.06 or 6%**	**2031**
4	**0.8 T 0.2 t**	**1/5 or 0.2**	**0.04 or 4%**	**2055**
49	**0.98 T 0.02 t**	**1/50 or 0.02**	**0.0004 or 0.04%**	**3135**
99	**0.99 T 0.01 t**	**1/100 or 0.01**	**0.0001 or 0.01%**	**4335**

Selection Against Recessive Genes In Diploid Populations

Question 169. In a cross between two normally pigmented people who are heterozygous for albinism, the odds are that one out of four of their children will be an albino. Make a simple monohybrid cross where A = dominant allele for normal pigmentation, and a = recessive allele for albinism: Aa x Aa = 1/4 AA, 2/4 Aa and 1/4 aa. The aa genotype is an albino.

Question 170. The square root of 20,000 is approximately 141. With this information you can

set up the following genetic checkerboard (Punnett square) and find the total fractional probability for heterozygous carriers of albinism.



Calculating Fractional Genotype Ratios In A Population

Question 171. This question is explained at the following link:

See Explanation Of The Hardy-Weinberg Law

Questions 172 - 173. A cross involving 20 pairs of heterozygous genes from each parent could be represented as:

Father' Genotype:
AaBbCcDdEeFfGgHhIiJjKkLlMmNnOoPpQqRrSsTt

Mother's Genotype:
AaBbCcDdEeFfGgHhIiJjKkLlMmNnOoPpQqRrSsTt

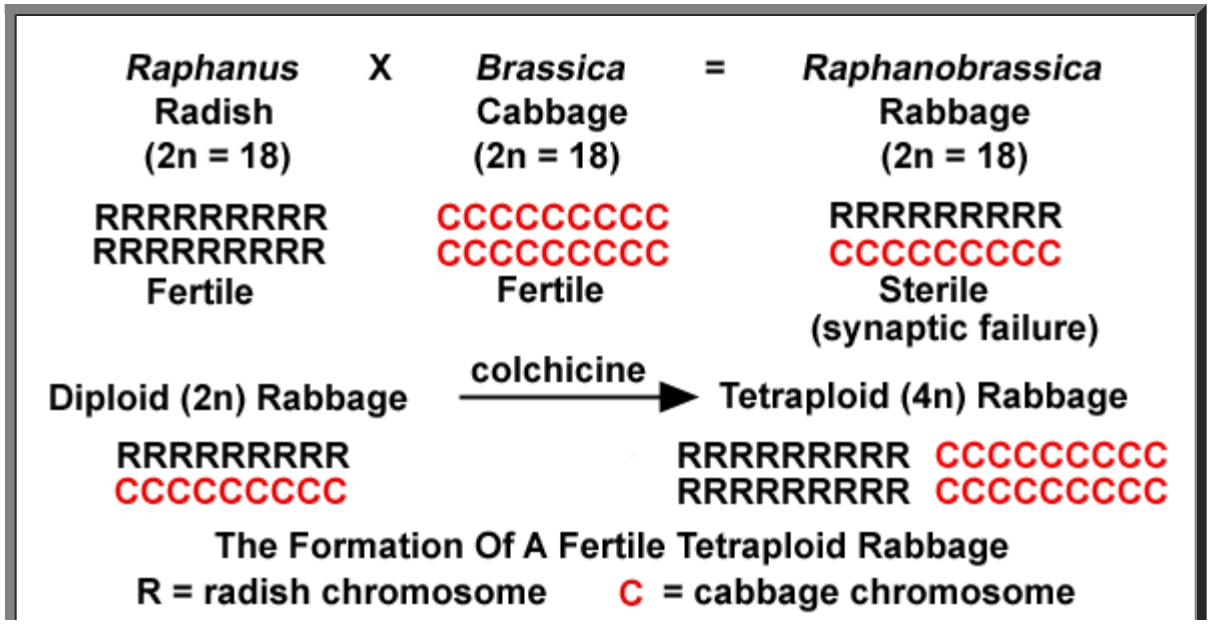
AaBbCcDdEeFfGgHhIiJjKkLlMmNnOoPpQqRrSsTt X AaBbCcDdEeFfGgHhIiJjKkLlMmNnOoPpQqRrSsTt

The enormous number of different possible chromosome combinations is due to independent assortment of chromosomes during meiosis, and random combination of gametes during sexual reproduction. The following table illustrates these exponential numbers of zygotic combinations based upon independent assortment of genes on separate chromosomes. If several genes (alleles) are linked to one pair of homologous chromosomes, then they are assorted as one pair of genes on one pair of chromosomes. We are not including crossing over in these two questions.

No. of homologous chromosome pairs (heterozygous genes)	No. of different gametes from each parent	Total number of zygotic combinations or squares in genetic checkerboard
1 (Aa X Aa)	2 (2^1)	4 $(2^1)^2$
2 (AaBb X AaBb)	4 (2^2)	16 $(2^2)^2$
3 (AaBbCc X AaBbCc)	8 (2^3)	64 $(2^3)^2$
4 (AaBbCcDd X AaBbCcDd)	16 (2^4)	256 $(2^4)^2$
20 pairs of chromosomes	1,048,576 (2^{20})	1,099,511,627,776 $(2^{20})^2$
23 pairs of chromosomes	8,388,608 (2^{23})	70,368,744,000,000 $(2^{23})^2$
(n) pairs of chromosomes	(2^n) n = haploid number	$(2^n)^2$
Including Crossover Factor (2^3) During Meiosis**		
23 pairs of chromosomes	67,108,864 (2^{26})	4,503,599,600,000,000 $(2^{26})^2$

[Chromosome Combinations Due To Independent Assortment]

Questions 174 - 176. The following table shows a cross between a diploid (2n = 18) radish and a diploid (2n = 18) cabbage. The hybrid mustard resulting from this cross is called a "rabbage."



Hybrid Vegetables In The Mustard Family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