Laroche:

Mouse Colouration

During module 4 on evolution, we will spend several classes examining the evolutionary significance of fur colour in a certain group of mice from the Sonoran desert in the South-Western United States. To prepare for this module, in the review activities for the first 3 modules we will be examining the molecular, cellular, and genetic basis for mouse coat colour.

In the review activities for modules 1 and 2, we learned about a protein called MC1R that is found in the cell membranes of specific mouse cells called melanocytes, whose job it is to produce the pigment melanin, which gives mice the colouration of their fur. In this activity we will further examine the genetic and molecular basis for the production of fur colour.

The Rock Pocket Mouse:

The rock pocket mouse, *Chaetodipus intermedius*, is a small, nocturnal animal found in the deserts of the south-western United States. Most rock pocket mice have a sandy, light-coloured coat that enables them to blend in with the light color of the desert rocks and sand on which they live. However, populations of primarily dark-coloured rock pocket mice have been found living in areas where the ground is covered in a dark rock called basalt caused by geologic lava flows thousands of years ago. Scientists have collected data from a population of primarily dark-coloured mice living in an area of basalt called the Pinacate lava flow in Arizona, as well as from a nearby light-coloured population. Researchers analyzed the data from these two populations in search of the genetic mutation responsible for the dark color. Their analysis led to the discovery of a mutation in the *Mc1r* gene which is involved in coat-colour determination.

The *Mc1r* Gene:

The coat colour of rock pocket mice is determined by two pigments: *eumelanin*, which is dark-coloured; and *pheomelanin*, which is light-coloured. The synthesis of these pigments is controlled by the products of several genes, including the *Mc1r* gene. The mouse *Mc1r* gene is located on mouse chromosome 16 (rock pocket mice have $n=23$ just like humans), and encodes a protein called the Melanocortin-1-Receptor (MC1R), which you have seen in each of the last two review activities. This receptor is found embedded in the membrane of specialized cells called melanocytes, which you have also examined. The melanocytes of wild-type (non-mutant) mice produce much more pheomelanin than eumelanin (or almost no eumelanin); the result is a sandy-coloured mouse. The mutated allele of the *Mc1r* gene, however, triggers melanocytes to increase the production of eumelanin, resulting in the dark coat-colour phenotype.
Wild-type *Mc1r* allele (light phenotype)

Below are five 15 base DNA nucleotide sequences from the wild-type (light coat colour) *Mc1r* allele template DNA strand. Use the sequences provided to determine the complementary mRNA sequence and the translated amino acid strand. Note: the actual gene contains 951 base pairs (317 amino acids). The amino acid position in the protein sequence is provided for each segment.

**Extracellular Domain I**  
**Amino Acids 015 → 019**

Template Strand: 3′–TTGAGGTGGGCGTGT–5′

mRNA Strand (identify 5′,3′): 5′–AAC UCC ACC CGC ACA–3′

Amino Acid Strand (identify N,C): N-Asn-Ser-Thr-Arg-Thr-C

**Extracellular Domain III**  
**Amino Acids 105 → 109**

Template Strand: 3′–CGGGACCGGTGGGCC–5′

mRNA Strand (identify 5′,3′): 5′–GCC CUG GCC ACC CGG–3′

Amino Acid Strand (identify N,C): N-Ala-Leu-Ala-Thr-Arg-C

**Intracellular Domain I**  
**Amino Acids 160 → 164**

Template Strand: 3′–GCCCGAGCCACCGCC–5′

mRNA Strand (identify 5′,3′): 5′–CGG GCU CGG UGG CGG–3′

Amino Acid Strand (identify N,C): N-Arg-Ala-Arg-Trp-Arg-C

**Transmembrane V**  
**Amino Acids 210 → 214**

Template Strand: 3′–TACGAACGTGGGGAG–5′

mRNA Strand (identify 5′,3′): 5′–AUG CUU GCA CCC CUC–3′

Amino Acid Strand (identify N,C): N-Met-Leu-Ala-Pro-Leu-C

**Intracellular Domain III**  
**Amino Acids 230 → 234**

Template Strand: 3′–GAACAGGTGGTTCCA–5′

mRNA Strand (identify 5′,3′): 5′–CUU GUC CAC CAA GGU–3′

Amino Acid Strand (identify N,C): N-Leu-Val-His-Gln-Gly-C
**Mutant Mc1r allele (dark phenotype)**

The sequences below are for the mutant (dark coloured) Mc1r allele. There are 5 mutations in this allele (one per sequence). Compare the DNA sequences of the wild-type and mutant Mc1r alleles to identify the locations of these mutations. **You only need to transcribe/translate the 3-base codons with the mutations and the corresponding amino acids!**

### Extracellular Domain I
#### Amino Acids 015 → 019

Template Strand: 3’–TTGAGGTGGzCGTGT–5’

mRNA mutated codon: 5’–AAC UCC ACC UGC ACA–3’

Altered Amino Acid: **N-Asn-Ser-Thr-Cys-Thr-C**

### Extracellular Domain III
#### Amino Acids 105 → 109

Template Strand: 3’–CGGGACCGGTGGACC–5’

mRNA mutated codon: 5’–GCC CUG GCC ACC UGG–3’

Altered Amino Acid: **N-Ala-Leu-Ala-Thr-Trp-C**

### Intracellular Domain I
#### Amino Acids 160 → 164

Template Strand: 3’–ACCCGAGCCACCGCC–5’

mRNA mutated codon: 5’–UGG GCU CGG UGG CGG–3’

Altered Amino Acid: **N-Trp-Ala-Arg-Trp-Arg-C**

### Transmembrane V
#### Amino Acids 210 → 214

Template Strand: 3’–TACGAGCGTGGGGAG–5’

mRNA mutated codon: 5’–AUG CUC GCA CCC CUC–3’

Altered Amino Acid: **N-Met-Leu-Ala-Pro-Leu-C**

### Intracellular Domain III
#### Amino Acids 230 → 234

Template Strand: 3’–GAACAGGTGGTGCCA–5’

mRNA mutated codon: 5’–CUU GUC CAC CAC GGU–3’

Altered Amino Acid: **N-Leu-Val-His-His-Gly-C**
1. The five codons with mutations correspond to amino acids 18, 109, 160, 211, and 233. Explain why the mutation at codon 211 is not as significant as the other mutations.

Mutation 211 is a silent point mutation. This means that the altered nucleic acid base doesn’t actually result in a change in amino acid, and so there is ultimately no effect on the protein or on phenotype. An organism can sustain any number of silent mutations, because they ultimately have no effect one way or another.

2. Complete the table below comparing the chemistry of amino acids in the wild-type MC1R protein and the mutant MC1R protein.

<table>
<thead>
<tr>
<th>Amino Acid Mutation Position Number</th>
<th>Wild-type MC1R Amino Acid Chemistry</th>
<th>Mutant MC1R Amino Acid Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>211</td>
<td>Non-Polar</td>
<td>Non-Polar</td>
</tr>
<tr>
<td>18</td>
<td>+ Charged</td>
<td>Non-Polar</td>
</tr>
<tr>
<td>109</td>
<td>+ Charged</td>
<td>Non-Polar</td>
</tr>
<tr>
<td>160</td>
<td>+ Charged</td>
<td>Non-Polar</td>
</tr>
<tr>
<td>233</td>
<td>Polar</td>
<td>+ Charged</td>
</tr>
</tbody>
</table>
As you should have determined from one of the previous review activities, the Melanocortin-1-Receptor (MC1R) protein is a trans-membrane receptor protein involved in a typical cell communication pathway (diagram A above). In other words, this protein receives signals from outside the cell, and activates molecular pathways in the cell when it is triggered. This type of receptor contains an extracellular binding site for a signal molecule, and an intracellular binding site for internal pathway molecules.

For MC1R, the signal molecule is a hormone called melanocyte stimulating hormone (α-MSH; see it bound to MC1R in diagram A). When α-MSH binds to MC1R, this protein changes its shape, and its intracellular portion is then in the proper shape to bind to and activate an internal pathway protein (the three ‘G’ molecule complex also shown bound to MC1R in diagram A), which, through a complex set of reactions, ultimately results in the cell producing a protein enzyme called tyrosinase.

This enzyme then enters into the metabolic pathway outlined in diagram B. When tyrosinase is present, it interacts with and alters a molecule called dopaquinone, ultimately sending this molecule along a metabolic pathway that results in the molecule becoming the dark coloured pigment eumelanin. When tyrosinase is not present, dopaquinone proceeds along a different metabolic path and eventually becomes the light pigment pheomelanin.

3. Using your knowledge of mutations, amino acids, and proteins, develop hypotheses to explain the following:

1. How the extracellular mutations result in a dark phenotype (hint: think about the chemistry of amino acids, particularly their charge).

   The extracellular mutations result in the MC1R protein being able to bind more effectively with the α-MSH signal molecule. When these molecules are bound together, more internal signal is sent to produce eumelanin instead of pheomelanin.

2. How the intracellular mutations result in a dark phenotype (hint: think about the chemistry of amino acids, particularly their charge).

   The intracellular mutations result in the MC1R protein being able to bind more effectively with the G-protein complex. When these molecules are bound together, more internal signal is sent to produce eumelanin instead of pheomelanin.

3. How the wild-type MC1R proteins leads to the light phenotype (hint: it might be helpful to think of the wild-type protein NOT leading to the dark phenotype).

   The wild type MC1R does not bind effectively with either the α-MSH signal molecule or the G-protein complex. The result is that very little internal signal is sent to produce tyrosinase, and so the cell produces pheomelanin instead of eumelanin.
4. The creation of only a modest amount of tyrosinase in a mouse’s melanocyte cells is sufficient to produce enough eumelanin for export into the hair follicles that the mouse will have dark fur. Based on this information, as well as the information presented to this point and your answers to the questions above, what do you believe is the pattern of inheritance for the mutant \textit{Mc1r} allele at the molecular, cellular, and organismal levels?

- **Molecular:**
  Melanocyte cells in heterozygous mice (mice with both the wild and mutated \textit{Mc1r} alleles) produce both the normal and mutated versions of the MC1R proteins, and both of these protein types get embedded in the plasma membrane. Thus, if you examine the melanocytes of heterozygous mice you will find both types of proteins equally expressed, separate, and distinct from each other. Thus, on a molecular level, the \textit{Mc1r} allele is co-dominant.

- **Cellular:**
  The paragraph above states that the creation of only a modest amount of tyrosinase is enough to produce enough eumelanin to make a mouse look dark. As described for the previous answers, heterozygous mice will have both the wild and mutated MC1R proteins in their membranes. The wild protein will not bind to either the $\alpha$MSH molecule or the G-protein complex, and thus will essentially not result in the production of any tyrosinase. However, the mutated version of the MC1R protein that the mice have in their membranes will bind to both molecules, and will produce tyrosinase. While the ultimate amount of tyrosinase produced in a heterozygous mouse will only be about half of what is produced in a mouse homozygous for the dark allele, this amount of tyrosinase will result in enough eumelanin for the cell to look dark. Thus, if you examine the melanocyte cells of heterozygous mice they will look equally as dark as the melanocyte cells of homozygous dark mice, meaning that, on a cellular level, the mutated \textit{Mc1r} allele inherits as an autosomal dominant (remember that the gene is found on chromosome 16, not on an autosome).

- **Organismal:**
  The answer provided above for the cellular phenotype is essentially the same answer here. If the cells of heterozygotes are the same colour as the cells of homozygous dark mice, then, on an organismal level, heterozygous mice will be dark, and the mutated \textit{Mc1r} allele inherits as an autosomal dominant.

5. If a mouse that is heterozygous at the \textit{Mc1r} gene locus mates with a light mouse, approximately what proportion of their offspring would you expect to be dark coloured?

   From the previous question you should have figured out that the dark allele is dominant. Thus, the heterozygote has both alleles ($Dd$), while the light mouse must be homozygous recessive ($dd$), because having two copies of the recessive allele is the only way that these mice will not be dark. So, the cross is $Dd \times dd$, and a simple Punnet square will identify that 50\% of the babies will inherit the $D$ dark allele, and will thus be dark coloured.
Hemophilia

Two prospective parents are meeting with a genetic counsellor because of the presence of factor VIII deficiency hemophilia in both of their families. Factor VIII is a protein that helps the blood to clot, and when a person’s factor VIII level is very low, even the smallest cuts can be troublesome, and internal bleeding is common. Complications include swelling, joint damage, and an increased likelihood of neurological complications due to intracerebral bleeding.

Neither of the two prospective parents suffer from this disorder, but both have close family members who do. Since they are now thinking about starting a family of their own, they are therefore concerned about the risks of passing on genetic diseases to their children. For example, they know that hemophilia A is an inherited disease; the prospective mother’s father is also red-green colour-blind, and they know that this condition runs in families as well.

As a first step, the genetic counselor asks them to fill out a narrative history listing their relatives, relationships, and if they were affected by any genetic diseases that they know of:

NAME: Greg

I have one brother and one sister, neither of whom are married. My brother suffers from factor VIII deficiency, but no one else in my immediate family does. My mother has two sisters and one brother, all of whom are normal, but one of my aunts has a son (my cousin Tim) who also has this disorder; all of my other cousins are normal. Both of my maternal grandparents are normal, but my grandmother had a brother who presumably had this deficiency (he wasn’t able to clot properly and died very young). My great grandmother on my mom’s side also had a brother who died very young because he was sick, but none of my relatives have actually been able to confirm that he suffered from this disorder. My father is completely normal. He was adopted from an orphanage and nothing is known about his family.

NAME: Olga

I have two brothers, one of whom has factor VIII deficiency. The brother with the disease is married to a woman who does not have the disease. They have two young boys, both normal. My father is an only child who does not suffer factor VIII deficiency. His father is also an only child, but his mother has a brother, none of whom suffer from any hemophilia. They are all still living. My maternal grandmother is healthy and had a sister who died from this just after birth. She married my grandfather who was one of four children, all boys, none of whom were affected by any disease that anyone is aware of. My grandparents had two children, my mother and my uncle. My uncle has hemophilia but my mom doesn’t. My uncle married my (normal) aunt and they had two children, neither of whom showed any sign of any disease. Their boy is still single but their girl got married, to a normal man, and had a son, who has hemophilia A.

My dad is red-green colour blind, but neither of my brothers are. My dad’s parents don’t have this problem either, but his uncle does. Nobody on my mom’s side has this.
The pedigrees for both of these narratives are provided below, where individual ‘A’ is Greg and individual ‘B’ is Olga. However, you can (and should) try to construct these yourself at home based on the narratives... it’s good practice.
The genetic counsellor is familiar with hemophilia and factor VIII deficiency, but decides to do her due diligence regardless and do some background research. What she finds is that the gene encoding the factor VIII protein is called \( F8 \), and that this gene is expressed primarily in the liver. Once exported from liver cells, the factor VIII protein circulates in the bloodstream in an inactive form, until an injury that damages blood vessels occurs. In response to injury, coagulation factor VIII is activated, and the active protein sets off a chain of additional chemical reactions that form a blood clot. The hemophilia condition arises due to a mutation in the \( F8 \) gene which results in the production of a non-functional factor VIII protein. However, the quality control mechanisms of the cell don’t identify this protein as being faulty, and so cells in the liver produce and excrete it in exactly the same manner as they do the normal factor VIII protein. The faulty protein simply circulates in the bloodstream until it is degraded, but has no discernible action during this time.

4. Based on all of the information provided to this point, including the pedigree of the two families and a description of the function of factor VIII, what conclusion do you think the genetic counsellor would come to with regard to the pattern of inheritance for hemophilia A on an organismal level? What does this imply with regard to the location of the \( F8 \) gene within the human genome?

   The \( F8 \) gene is located on the X chromosome, and the hemophilia allele is recessive. Thus, the pattern of inheritance is X-Linked recessive. This can be identified from the pedigree because many more males are affected than females and because parents are normal but have affected children, and also from the information provided in that the factor VIII protein doesn’t do anything, and its effect will be masked by the function of a normal factor VIII protein in a heterozygous (female) individual.

5. How would you describe the pattern of inheritance for the normal and hemophilia \( F8 \) alleles on a molecular level?

   The alleles are co-dominant on a molecular level because they both get produced and secreted into the bloodstream. Thus, in the blood of a heterozygous (female) individual, there are equal amounts of both the normal and mutated factor VIII proteins, expressed separately, distinctly, and equally.

6. The paragraph above states that the mutated factor VIII protein has no discernible action, although, of course, by not doing what it’s supposed to do it results in the hemophilia phenotype. Imagine, instead, that the mutated protein still cannot form blood clots, but that its new shape results in it interacting with the proteins in myocyte muscle cells, ultimately leading to increased muscle mass in people with this \( F8 \) mutation (this likely wouldn’t be possible, but just run with this as a hypothetical). In this situation, what biological term would you use to describe the action of the mutated \( F8 \) allele?

   This would be an example of a pleiotropic effect, as the mutated \( F8 \) allele would have effects on multiple and seemingly unrelated phenotypes.
7. If you’re reading this question without having answered number 4, note that the answer for question 4 can actually be found in the description below. Do not keep reading if you want to legitimately challenge yourself to answer question 4 correctly without assistance.

The F8 gene is located on the X chromosome, and hemophilia inherits in an X-linked recessive manner (on an organismal level). The gene whose mutated version results in colour blindness (CB) also happens to be on the X chromosome. There is a 25% recombinant frequency between F8 and CB. Based on the pedigree created by the genetic counsellor (above), calculate the probability of Greg and Olga having a son who is both colour blind and has hemophilia.

Both genes are X-linked, and the question asks about the probability of Greg and Olga having a son. In this scenario, the son receives the Y chromosome from the father, not the X, and so we don’t care at all about Greg’s side, because it contributes 0 probability to this answer.

However, because the son only gets one X and this is from mom, any alleles on this chromosome will be expressed. So, for the son to be colour blind and have hemophilia, what needs to happen is Olga needs to pass on a chromosome that has the colour blind allele and the hemophilia allele. However, it is guaranteed that she does not possess such a chromosome, as the X chromosome with the colour blind allele came from her father (colour blindness only on the father’s side), while the X chromosome with hemophilia would have come from her mother (hemophilia only on the mother’s side). Thus, even if she does indeed possess both alleles, they will be on homologous chromosomes.

Of course, the possibility exists that crossing over could recombine the alleles and get them both on the same X chromosome. So, we need to figure out the probability of Olga having both alleles, AND the probability that crossing over would occur, AND the probability that Olga would pass on the chromosome with both alleles of interest.

First, Olga’s father is colour blind, which means his only X chromosome, which he gave to his daughter, includes the colour blind allele. So, she has this allele with 100% certainty. Next, we see that Olga’s brother has hemophilia, which means he must have inherited the allele on the X chromosome he got from his mother. Since Olga’s mother does not display the disorder, this means she is a carrier (heterozygous). Thus, she would have a 50% chance of having passed on this allele to Olga, meaning Olga has a 50% probability of having the hemophilia allele. If she does have both alleles, these would be on opposite chromosomes, but there is a 25% probability that crossing over will occur and put them on the same chromosome. Finally, if all of this happens, there is a 50% probability of passing on the recombinant chromosome with both alleles of interest.

Final tally: 1 X 1/2 X 1/4 X 1/2 = 1/16

There is a 1/16 probability of having a child with both disorders.
8. The Mc1r gene described in the first section of this review for mice can also be found in a similar version in humans. In our species, Mc1r is also a gene that affects pigmentation, and a particular mutant variant of this gene results in red hair. This particular mutant inherits as an autosomal recessive. Imagine that Greg from the story above has red hair, and that Olga has brown hair, but carries a copy of the recessive Mc1r red hair allele. What would be the probability of them having a red haired daughter?

To have red hair, the daughter needs to receive a mutant Mc1r from both her mom and dad. Greg is homozygous recessive, with two copies of this allele, so she will get the allele from him with 100% certainty. Olga, on the other hand, is heterozygous. Thus, there is a 50% probability of her passing on the mutant allele to her daughter. That’s all you need to know in terms of the Mc1r allele.

However, the question is also phrased such that it is asking you the probability of the two parents having a daughter in the first place. Thus, you must incorporate the probability of this, which is 50%.

Final tally: 1 X 1/2 X 1/2 = 1/4
Roffey:

Follow the steps outlined in the monohybrid crosses homework. Use a separate sheet of paper. Questions below are for 2 unlinked traits.

1. In pea plants, the allele for axial (A) flowers (located on the side of the stem) is dominant over the allele for terminal (a) flowers (located on the top of the stem). The allele for inflated pods (I) is dominant over the allele for constricted pods (i). A cross between 2 pea plants with axial flowers and inflated pods gives the following offspring: 20 with axial flowers and inflated pods, 7 with axial flowers and constricted pods, and 5 with terminal flowers and inflated pods. What are the genotypes of the 2 parents? Explain your answer and show the Punnett square.

This is a dihybrid cross, where the parents are both AaIi. The expected phenotypic ratio for such a cross would be 9:3:3:1. Out of 32 organisms, that would make 18 axial inflated, 6 axial constricted, 6 terminal inflated, and 2 terminal constricted. These expected proportions match the observed proportions fairly closely; note that the absence of terminal constricted plants could simply have happened by chance, as only 2/32 would have been expected to have this phenotype.

2. Cross two pea plants. One is heterozygous for tall stems and round seeds (both are the dominant phenotypes). The other is also heterozygous for stem height, but homozygous recessive for seed shape.

TtRr X Ttrr = Draw 4 X 2 Punnet square, gametes of TR, Tr, tR, and tr on top, gametes of Tr and tr on the side.

3. In Japanese four o'clocks, the alleles for red flower color (R) is incompletely dominant over the allele for white flower color (R'). Cross the four o'clocks with the genotypes: RRTt x RR'Tt. Assume that tall stems (T) are dominant over short stems (t). (Yes, you are supposed to do this cross with one square. Organisms possess both dominant-recessive traits and incomplete traits - think about it...).

Draw 4 X 2 Punnet square, gametes of RT, Rt, R'T, and R't on top, gametes of RT and Rt on the side. Progeny will include 3 different flower colours (red: RR, white: R’R’, pink: RR’) and two different stem lengths (tall: TT and Tt, short, tt).

4. In rabbits, the allele for black coat color (B) is dominant over the allele for brown coat color (b). The allele for straight fur (S) is dominant over the allele for curly fur (s). Someone gives you a male rabbit with black straight fur and a female rabbit with brown curly fur. If you bred these two, would you expect to get any offspring with brown curly hair in the first generation (F1)? Explain your answer with 4 Punnett squares.

The brown curly female has the genotype bbss. The black straight male has one of four possible genotypes: BBSS, BBSSs, BbSS, or BbSs. The only way you could get brown curly offspring in F1 would be if the father is BbSs.
More Crosses (fun, fun, fun 😊)

5. In 1908, British biologists William Bateson and Reginald Punnett discovered an inheritance pattern that was different than Mendel’s discoveries. They crossed pea plants heterozygous for the traits of flower color and pollen shape (PpLl x PpLl). (In pea plants, purple flowers are dominant over white flowers and long pollen grains are dominant over short pollen grains.) The crosses produced offspring with a phenotypic ratio of 3:1 instead of the expected 9:3:3:1. (1) Show with a Punnett square what they predicted their offspring would be. (2) Explain why their ratio was different. (3) Show with a Punnett square how they got their results.

Predicted offspring were a straight dihybrid cross. See example from a textbook. Their ratio was different because the two genes they looked at are linked on the same chromosome, and do not assort independently during meiosis 1. In other words, the gametes produced by PpLl would only be PL and pl (assuming the dominant alleles are on the same homolog), as opposed to PL, Pl, pL, and pl you would expect if the alleles assorted independently.

6. In reindeer, black noses are dominant over red, and walking is dominant over flying. (1) What is Rudolph’s genotype and phenotype? (2) If Rudolph’s mom is a black-nosed walker and dad is a red-nosed flyer, what are their respective genotypes? (3) What are the predicted genotypes and phenotypes of Rudolph’s siblings?

Rudolph: bbww (homozygous recessive for both genes); Mom: BbWw; Dad: bbww; siblings: BbWw, bbWw, Bbww, bbww

7. A “roan” stallion is mated with a mare of the same phenotype. Among their many offspring over the next several years, 4 are also roan, one is red (chestnut) and 2 are white. What is the simplest explanation for the inheritance of these colors in horses? What would be the most probable phenotype and genotype of the foal produced from a cross of a roan mare and red stallion?

Epistasis, with two genes. The roan gene dominates the other, so if you have a dominant roan allele you have a roan horse. With a horse homozygous recessive for roan the chestnut allele is expressed, if a dominant allele is present. If not, the horse ends up white.

8. In tigers, a recessive allele causes an absence of fur pigmentation (a "white tiger") and also a cross-eyed condition. (1) What is the explanation for this? (2) If two phenotypically normal tigers that are heterozygous for both traits are mated, what percentage of their offspring will be cross-eyed? What percentage will be white?

Pleiotropy. This question is misleading, because we’re only dealing with one gene. Straight monohybrid cross: ¼ will be cross-eyed white.
9. In corn plants, a dominant allele (I) inhibits kernel color, while the recessive allele (i) permits color when homozygous (ii). At a different gene, the dominant allele P causes a purple kernel color, while the homozygous recessive genotype (pp) causes red kernels. If plants that are heterozygous for both traits are crossed, what are the predicted genotypes and phenotypes of the offspring? (This is a special condition called “epistasis” which was unknown to Mendel)

12:3:1 ratio, yellow (inhibited) : purple : red

1. You were born with 6 toes on your feet. The extra digits were surgically removed when you were 2 years old. Your dad also has this disorder, as does your paternal Uncle Bob and their father Martin. Your sister does not have extra toes.
   • What is the name of this disorder? polydactyly_________________________
   • What is its inheritance (i.e., autosomal or x-linked, recessive or dominant)? Autosomal dominant___________
   • Draw a pedigree for your family. Fill in the genotypes.
   • Your mom is going to have another child soon. What is the percent chance this child will have extra digits? 1/2__________

2. Your brother is color-blind but marries someone with normal vision. Her father is also color-blind. You have normal vision, as do your parents.
   • What is the inheritance of this disorder? X-linked recessive_________________________
   • Draw a pedigree for your family. Fill in the genotypes.
   • If you are female, what is the percent chance you are a carrier? 50%__________
   • If you are male, what is the percent chance you are a carrier? 0%__________
   • What is the percent chance that your future nieces will be color-blind? 50%__________
   • What is the percent chance that your future nephews will be color-blind? 50%__________
1. Grace operated a nursery business and crossed true-breeding red flowers with true-breeding white flowers and obtained all red flowers. How would you classify the appearance of these flowers?

Red plants express the dominant trait (but they are all genotypically heterozygous).

2. In budgies (a type of bird), the allele for green color (B) is dominant over the allele for blue color (b). If a true-breeding green budgie and a true-breeding blue budgie mated, what are the possible genotypes of their young?

BB parent crossed with bb parent gives 100% probability of Bb (heterozygotes) in the offspring.

3. In cats, the white fur allele (C) is dominant over color (c). If a heterozygote was bred to a colored cat, what would be the genotypes of the gametes of the two parents?

Parents’ gametes are C, c in the heterozygous parent; c, c in the coloured parent.

4. Sheila was a horticulturalist who developed a variety of rose that was a recurrent bloomer, a trait controlled by a recessive allele (r). The allele for annual blooming (R) was dominant. If she crossed a true-breeding annual bloomer with a recurrent bloomer, what would be the genotypes of the gametes of the parents?

Parents’ gametes are R,R in the annual bloomer parent; r,r in the recurrent bloomer parent.

5. Hal crossed true-breeding tall barley with true-breeding dwarf barley plants and obtained all tall plants. If he crossed two tall plants from the progeny, about what percentage of dwarf plants might he expect?

25% probability of dwarf in the offspring (in the F2 generation; all F1 progeny will be heterozygous).

6. Jane crossed a lavender flower with a white flower and obtained progeny that were all lavender. To investigate further the pattern of inheritance, she decided to use the progeny in a test cross. What is a test cross for this situation?

A test cross is when the heterozygous progeny (Ll) are crossed with individuals with the homozygous recessive trait (ll; i.e., white flowers).

7. George was a pheasant breeder and he wanted to produce some pheasants with ornamental ear tufts. He had observed that the ear tuft allele (t) was recessive to the tuftless allele (T). If he bred a heterozygote to a tufted pheasant, what is the probability that he would obtain a tufted young?

Tt parent crossed with tt parent gives 50% probability of tufted offspring.

8. In sheep, the allele for fleece spotting (s) is recessive to the allele for no-spotting (S). If a spotted sheep was bred to a true-breeding unspotted sheep, what would be the phenotype and genotype of the lamb?

ss parent crossed with SS parent gives Ss lamb genotype; phenotype = not spotted.

9. Lila crossed tall green corn plants and found that about one in four seedlings were white and one in four were dwarf. What is the probability that a seedling would be both white and dwarf?

Cross two TtGg parents; gives 1/16 (0.0625 = 6.25%) probability for a white and dwarf plant (must cross both alleles, which gives a 9:3:3:1 pattern in offspring).

10. Lila crossed tall green corn plants with dwarf green corn plants and found that about half the seedlings were dwarf and one quarter were white. What is the probability that a seedling would be a white dwarf?

Cross TtGg parent with ttGg parent; gives 1/8 (0.125 = 12.5%) probability for a white and dwarf plant (must cross both alleles, which gives a 9:3:3:1 pattern in offspring).
11. Marty the mouse breeder obtained a mouse variety in which the allele for black (C) was dominant over the allele for cream fur (c), and the allele for short tail (s) was recessive to long tail (S). If Marty obtained a mouse that was homozygous for black fur and short tail, what would be the genotype of the mouse?

Mouse genotype = CCss for black fur with a short tail

12. Marty the mouse breeder obtained a mouse variety in which the allele for black (C) was dominant over the allele for cream fur (c), and the allele for short tail (s) was recessive to long tail (S). If Marty obtained a mouse that was heterozygous for both alleles, what would be its genotype?

Mouse genotype = CcSs for mouse heterozygous for both alleles

13. Shane bred guinea pigs and found that the allele for short hair was dominant over the allele for long hair, and the allele for black hair was dominant over the allele for brown hair. If Shane bred a heterozygous black long-haired guinea pig to a guinea pig heterozygous for fur color and length, what is the probability that he would obtain a long-haired brown guinea pig?

Cross Bbss parent with BbSs parent; gives 1/8 (0.125 = 12.5%) probability for a long-haired brown guinea pig (must cross both alleles, which gives a 9:3:3:1 pattern in offspring)

14. In fruit flies, the red eye color allele (R) is X-linked and dominant to the X-linked white eye color allele (r). What would be the genotype of a white-eyed male and its sperm?

White-eyed male genotype = XrY; sperm would be either Xr or Y

15. In fruit flies, the red eye color allele (R) is X-linked and dominant to the X-linked white eye color allele (r). If a red-eyed male was crossed with a white-eyed female and the progeny included 100 male flies, about how many males would you expect to have red eyes?

Red-eyed male (XRY) crossed with white-eyed female (XrXr) gives 0 males with white eyes (would be XrY)

16. What chance will a daughter have of being colorblind if she has a normal mother and a colorblind father?

Normal mother (XcXc) and colorblind father (XcY) gives 0 colorblind daughters (would be XcXc)

17. What chance will a daughter have of being colorblind if she has a colorblind mother and a colorblind father?

Colorblind mother (XcXc) and colorblind father (XcY) gives 100% probability of colorblind daughters (XcXc)

18. Joshua has curly hair and Madison has straight hair, and their child has wavy hair. What pattern of inheritance is likely operative in this family?

One parent with curly hair, one parent with straight hair, child with wavy hair indicates incomplete dominance as the inheritance pattern (i.e., an intermediate phenotype is possible in a heterozygote).

19. Olivia, blood type B, had an immune reaction when transfused with blood type A red cells. Her son, blood type AB, had no such reaction when transfused with blood type A red cells. Why?

Type B individuals produce anti-A antibodies, which will result in a transfusion reaction when type A cells are received. Type AB individuals possess no anti-A or anti-B antibodies.

20. Emily has an autosomal dominant disorder for deafness, as did her parents, although her sister has normal hearing. What are possible genotypes of Emily, her mother, father, and sister?

Emily can be DD or Dd. Her sister is dd. Her mother and father must be heterozygous (Dd) (and this type of deafness is autosomal dominant).
1. In squash, a gene for white colour (W) is dominant over its allele for yellow colour (w). Give the genotypic and phenotypic ratios for the results of each of the following crosses:
   a. WW x ww
   b. Ww x ww
   c. Ww x Ww

2. The pollen from the anthers of a heterozygous white-fruited squash plant is placed on the pistil of a yellow-fruited plant. Show, using ratios, the genotypes and phenotypes you would expect from this cross.

3. In humans, brown eyes are usually dominant over blue eyes. Suppose a blue-eyed man marries a brown-eyed woman whose father has blue eyes, what proportion of their children would you predict will have blue eyes?

4. A brown-eyed man marries a blue-eyed woman and they have ten children, all brown-eyed, can you be certain that the man is homozygous? If the eleventh child has blue eyes, what will that show about the father’s genotype?

5. A brown-eyed man whose father was brown-eyed and whose mother was blue-eyed married a blue-eyed woman whose father and mother were both brown-eyed. The couple has a blue-eyed son. For which of the individuals mentioned can you be sure of the genotypes? What are their genotypes? What genotypes are possible for the others?

6. In peas, a gene for tall plants (T) is dominant over its allele for short plants (t). The gene for smooth peas (S) is dominant over its allele for wrinkled peas (s). Calculate both phenotypic ratios and genotypic ratios for the results of each of the following crosses:
   a. Tt Ss x Tt Ss
   b. Tt ss x tt ss
   c. Tt Ss x Tt ss
   d. TT ss x tt SS

7. In watermelons the genes for green colour and for short shape are dominant over their alleles for striped colour and for long shape. Suppose a plant with a long striped fruit is crossed with a plant heterozygous for both these characters. What phenotypes would this cross produce and in what ratios?
8. If two gene pairs A and a, and B and b are assorting independently, with A dominant to a, and B dominant to b, what is the probability of obtaining:
   a. An AB gamete from an AaBb individual?
   b. An AB gamete from an AABb individual?
   c. An AABB zygote from a cross of AaBb x AaBb?
   d. An AABB zygote from a cross of aabb x AABB?
   e. An AB phenotype from a cross of AaBb x AaBb?
   f. An AB phenotype from a cross of aabb x AABB?

9. Assume that curly hair (C) in humans is dominant to straight hair (c).
   a. If 2 curly-haired parents have a straight-haired child, what are the parental genotypes?
   b. List all the possible genotypic and phenotypic combinations of parents that can produce a curly-haired child.

10. Dentinogenesis imperfecta (D) is dominant to the normal condition, as is brachydactyly (B) dominant to its normal allele. These two traits are found on different chromosomes. Both are found very rarely in the population. A man with brachydactyly and normal teeth marries a woman with normal fingers and dentinogenesis imperfecta.
    a. State the genotypes of these two individuals.
    b. State all the possible genotypes and phenotypes of the offspring of this couple, and their expected frequencies.

11. Pheynylketonuria (PKU) is inherited as an autosomal recessive disorder. Two normal parents have a child with PKU.
    a. What are the genotypes of the parents?
    b. What is the chance that their next child will also have PKU?
    c. What is the chance that a normal child of these parents is a carrier of PKU?

12. Colour-blindness is inherited as a sex-linked recessive disorder.
    a. If a colour-blind man marries a normal woman whose brother is colour-blind, what is the probability that their first son will be colour-blind?
    b. If a normal man marries a normal woman whose brother is colour-blind, what is the probability that their first child will be a colour-blind son?

13. Albinism is inherited as an autosomal recessive, while colour-blindness is inherited as a sex-linked recessive disorder. A colour-blind albino man and a woman with normal colour vision and pigmentation produce a colour-blind albino daughter. Give the genotypes of the parents and the child.
14. Can two colour-blind parents produce:
   a. a normal son?
   b. a normal daughter?
15. Can two normal parents produce:
   a. a colour-blind son?
   b. a colour-blind daughter?
16. A woman of A blood type and normal colour vision had five children as described (in no particular order):
   a. male, A blood type, colour-blind
   b. male, O blood type, colour-blind
   c. female, A blood type, normal colour vision
   d. female, B blood type, normal colour vision
   e. female, A blood type, colour-blind
   Of the two men that may have had children with this woman, the first has AB blood type and is colour-blind, while the second has A blood type and normal colour vision. Which of these men is the most probable biological father in each case?
17. As Mendel discovered, smooth seeds in peas is dominant to wrinkled ones. In the following experiments, parents with known phenotypes (but unknown genotypes) produce the listed progeny:

<table>
<thead>
<tr>
<th>Parents</th>
<th>Progeny</th>
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<tbody>
<tr>
<td></td>
<td>Smooth</td>
</tr>
<tr>
<td>a) smooth x wrinkled</td>
<td>82</td>
</tr>
<tr>
<td>b) wrinkled x wrinkled</td>
<td>0</td>
</tr>
<tr>
<td>c) smooth x smooth</td>
<td>118</td>
</tr>
<tr>
<td>d) smooth x wrinkled</td>
<td>74</td>
</tr>
<tr>
<td>e) smooth x smooth</td>
<td>90</td>
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</tbody>
</table>

Use W for the smooth allele and w for the wrinkled allele to report the most probably genotype of each parent.
18. In crosses (c), (d), and (e) above, indicate how many of the smooth progeny produced by each cross would be expected to produce wrinkled progeny when self-fertilized.
19. Assume that eye colour in humans is controlled by a single pair of genes of which the effect of that from brown (B) is dominant over the effect of that for blue (b).

a. What is the genotype of a brown-eyed individual who marries a blue-eyed individual and produces an offspring that is blue-eyed?

b. For the mating (in “a” above), what proportions of the two eye colours are expected among future offspring?

c. What are the expected proportions of eye colour among the offspring of a mating between two brown-eyed individuals who each had one parent who was blue-eyed?

20. In dogs, dark coat colour is dominant over albino, and short hair is dominant over long hair. If these effects are caused by two independently segregating gene pairs, write the most probable genotypes for the parents of each of the following crosses: (Use the symbols D and d for dark and albino coat colour alleles, and S and s for the short- and long-hair alleles, respectively.)

<table>
<thead>
<tr>
<th>Parental Phenotypes</th>
<th>Phenotypes of the Offspring</th>
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<tbody>
<tr>
<td></td>
<td>Dark, Short</td>
</tr>
<tr>
<td>a) dark short x dark short</td>
<td>89</td>
</tr>
<tr>
<td>b) dark short x dark long</td>
<td>18</td>
</tr>
<tr>
<td>c) albino short x albino short</td>
<td>0</td>
</tr>
<tr>
<td>d) dark long x dark long</td>
<td>0</td>
</tr>
<tr>
<td>e) dark short x dark short</td>
<td>46</td>
</tr>
<tr>
<td>f) dark short x dark long</td>
<td>29</td>
</tr>
</tbody>
</table>

21. Red-green colour blindness is inherited as a sex-linked recessive disorder. If a colour-blind woman marries a man who has normal colour vision, what would be the expected phenotypes of their children with reference to this character?

22. A man and his wife both have normal colour vision, but a daughter has red-green colour blindness, a sex-linked recessive trait. The man sues his wife for divorce on grounds of infidelity. Can genetics provide evidence supporting his case?

23. If a man with blood type B, one of whose parents had blood type O, marries a woman with blood type AB, what will be the theoretical percentage of their children with blood type B?

24. Both Mrs. Smith and Mrs. Jones had babies the same day in the same hospital. Mrs. Smith took home a baby girl, whom she named Shirley. Mrs. Jones took home a baby girl, whom she named Jane. Mrs. Jones began to suspect, however, that her child had been accidentally switched with the Smith baby in the nursery. Blood tests were done:
Mr. Smith was type A, Mrs. Smith type B, Mr. Jones type A, Mrs. Jones type A, Shirley type O, and Jane type B. Had a mix-up occurred?

25. In Labrador Retrievers (a breed of dogs), the dominant gene B determines black coat colour and bb produces brown. A separate gene, E, however, shows dominant epistasis over the B and b alleles, resulting in a “golden” coat colour. The recessive e allows expression of B and b. A breeder wants to know the genotypes of her dogs, so she breeds them and makes note of the offspring of several litters. Determine the genotypes of the parent dogs.

a. Golden female x Golden male
   Offspring: 7 Golden, 1 black, 1 brown

b. Black female x Golden male
   Offspring: 8 Golden, 5 black, 2 brown
Answers to Biology NYA Genetic Problems - Set #2

1. a) All heterozygous white

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<tr>
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b) Genotype ratio = 1 Ww : 1 ww  
Phenotype ratio = 1 white : 1 yellow

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c) Genotype ratio = 1 WW : 2 Ww : 1 ww  
Phenotype ratio = 3 white : 1 yellow

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2. Let \( W \) be the allele for white colour and \( w \) be the allele for yellow colour. Therefore, the genotype of the pollen, the male gamete, is \( Ww \) and the female gamete is \( ww \). The cross is \( Ww \times ww \), and the offspring, determined by the Punnett square are as follows:

   - Genotype ratio = 1 Ww : 1 ww  
   - Phenotype ratio = 1 white : 1 yellow

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<thead>
<tr>
<th>Male Gametes</th>
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3. Let \( B \) be the allele for brown eyes and \( b \) the allele for blue eyes. The man must be \( bb \), but the woman is \( B- \). However, since her father is \( bb \), she must have a \( b \) allele. Hence, her genotype is \( Bb \). The cross is \( bb \times Bb \), and the Punnett square shows that 50 percent blue-eyed offspring is predicted.

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<thead>
<tr>
<th>Male Gametes</th>
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<tbody>
<tr>
<td>b</td>
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<td>b</td>
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</table>
4. This time the man is B-, and the woman is bb. The cross is Bb x bb, or BB x bb. The first cross would yield 50 percent blue-eyed children as in question above, and the second cross would yield all brown-eyed children as shown in the Punnett square below. In this case, every child would receive a dominant B allele from Dad. His ten brown-eyed children indicate that he is BB. However, if his eleventh child were blue-eyed, then the man’s genotype is Bb.

<table>
<thead>
<tr>
<th>Male Gametes</th>
<th>B</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female gametes</td>
<td>b</td>
<td>Bb</td>
</tr>
<tr>
<td>b</td>
<td>Bb</td>
<td>Bb</td>
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</table>

5. In this problem, the brown-eyed man’s genotype is Bb since his blue-eyed mother is bb. The man’s father is either BB or Bb. The wife’s genotype is bb, and both of her parents are Bb heterozygotes. The blue-eyed son is bb.

6. a) This is a dihybrid cross.
Genotype ratio = 1 TTSS : 2 TTSs : 1 TTss : 2 TtSS : 4 TtSs : 2 Ttss : 1 ttSS : 2 ttSs : 1 ttss
Phenotype ratio = 9 tall & smooth : 3 tall & wrinkled : 3 short & smooth : 1 short & wrinkled

b) This is a test cross. The phenotypes will reflect the alleles present in the tall and wrinkled parent in equal numbers. Phenotype ratio = 1 tall & wrinkled : 1 short & wrinkled. Genotype ratio = 1 TTss : 1 ttss. Take note that none of the offspring from a testcross can have a homozygous dominant genotype.

c) Parent 1’s gametes = TS, Ts, tS and ts, Parent 2’s gametes = Ts and ts.
Genotype ratio = 1 TtSs : 1 Ttss : 1 ttSs : 1 ttss
Phenotype ratio = 1 tall & smooth : 1 tall & wrinkled : 1 short & smooth : 1 short & wrinkled

d) Both parents can only produce one type of gamete, so there is only one type of offspring possible. Parent 1 produces Ts and Parent 2 produces tS. The genotype of all the offspring is TtSs. The phenotype of all the offspring is tall and smooth.

7. Let S be the allele for green, s for stripped, L for short, and l for long.
The cross is ssll x SsLl. Since this is a test cross, the phenotypes will reflect the alleles present in the green and short parent plan in equal numbers. (Assume there is no linkage—that is, that the genes for fruit pattern and length are on different chromosomes.)
Phenotype ratio = 1 green & short : 1 green & long : 1 stripped & short : 1 stripped & long

8. a) AaBb individual produces four types of gametes: ¼ AB, ¼ ab, ¼ Ab, ¼ aB.
Answer = ¼ AB gametes.
b) AABb individual produces two types of gametes: ½ AB, ½ Ab
Answer = ½ AB gametes.
c) AaBb x AaBb
d) aabb x AABB

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<tr>
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<th>¼ AB</th>
<th>¼ Ab</th>
<th>¼ aB</th>
<th>¼ ab</th>
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<tr>
<td>♀</td>
<td>¼ AB</td>
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<td>¼ Ab</td>
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<td>¼ aB</td>
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<tr>
<td>♀</td>
<td>¼ ab</td>
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Answer = ½ AABB

f) aabb x AABB

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<th>AB</th>
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<tr>
<td>♀</td>
<td>ab</td>
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<td>AaBb</td>
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Answer = no AABB zygotes

e) AaBb x AaBb

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<th></th>
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<th>¼ Ab</th>
<th>¼ aB</th>
<th>¼ ab</th>
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<td>¼ aB</td>
<td>X</td>
<td>X</td>
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<tr>
<td>♂</td>
<td>¼ ab</td>
<td>X</td>
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Answer = 9/16 A-B- (AB phenotype)

9. a) Parental genotypes = Cc x Cc. Both parents must be Cc so that each could give c to their cc child.
   b) Parents that can have a curly-haired child:
   CC x CC (curly x curly), CC x Cc (curly x curly), CC x cc (curly x straight), Cc x Cc (curly x curly), Cc x cc (curly x straight). All of these matings will produce curly-haired children.
10. a) The man’s genotype is Bbdd (heterozygous for brachydactyly and normal teeth). The woman’s genotype is bbDd (normal fingers and heterozygous for dentinogenesis imperfecta).
   
   b) Bbdd x bbDd

<table>
<thead>
<tr>
<th>♂</th>
<th>½ bD</th>
<th>½ bd</th>
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<table>
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<tr>
<th>½ Bd</th>
<th>¼ BbDd</th>
<th>¼ Bbdd</th>
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<tbody>
<tr>
<td>½ bd</td>
<td>¼ bbDd</td>
<td>¼ bbdd</td>
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</table>

Genotypic and phenotypic frequencies
- ¼ BbDd; brachydactyly and dentinogenesis imperfecta
- ¼ bbDd; normal fingers and dentinogenesis imperfecta
- ¼ Bbdd; brachydactyly and normal teeth
- ¼ bbdd; normal fingers and normal teeth

11. a) Pp x Pp; both parents must be heterozygous (Pp) to have an affected child (pp).
   
   b) Pp x Pp

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<tr>
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<th>½ P</th>
<th>½ p</th>
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<tr>
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<tr>
<th>½ P</th>
<th>¼ PP</th>
<th>¼ Pp</th>
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<tbody>
<tr>
<td>½ p</td>
<td>¼ Pp</td>
<td>¼ pp</td>
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</table>

Answer = ¼ pp

   c) The normal children are ¼ PP + ½ Pp. Of these normal children 2/3 are carriers of PKU.

12. a) Colour-blind man’s genotype = XbY
   
   Genotype of normal woman with colour-blind brother = XBXB or XBXb

   XbY x XBXB or XbY x XBXb

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<thead>
<tr>
<th>♂</th>
<th>Xb</th>
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<table>
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<tr>
<th>½ Xb</th>
<th>XbXb</th>
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<tbody>
<tr>
<td>½ Y</td>
<td>XbY</td>
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or

<table>
<thead>
<tr>
<th>♂</th>
<th>½ Xb</th>
<th>½ Xb</th>
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<table>
<thead>
<tr>
<th>½ Xb</th>
<th>¼ XbXb</th>
<th>¼ XbXb</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ Y</td>
<td>¼ XbY</td>
<td>¼ XbY</td>
</tr>
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</table>

Answer = chance that the first son is colour-blind = ¼
= 0% in first mating (consider only the second mating), ½ in second (depends on mother being carrier—1/2 chance that she inherited the allele from her mother)

b) chance that first child is a colour-blind son = 1/8
again there is ½ chance that the mother is a carrier and ¼ chance of first child being male and being colour blind (note wording of the question)

<table>
<thead>
<tr>
<th></th>
<th>½ X^B</th>
<th>½ X^b</th>
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<tbody>
<tr>
<td>♀</td>
<td>¼ X^B X^B</td>
<td>¼ X^B X^b</td>
</tr>
<tr>
<td>♂</td>
<td>¼ X^B Y</td>
<td>¼ X^b Y</td>
</tr>
</tbody>
</table>

13. man is colour-blind and albino (X^b Y aa)
woman has normal vision and normal pigmentation (X^B X^b Aa) heterozygous for both colour-blind and albinism since her daughter has both traits
daughter is colour-blind and albino (X^b X^b aa)

14. Parents: X^b X^b x X^b Y

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<th>X^b</th>
<th>Y</th>
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<td>X^b X^b</td>
<td>X^b Y</td>
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a) answer: cannot produce a normal son
b) answer: cannot produce a normal daughter

15. Parents: X^B X^- x X^B y

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<th>X^B X^-</th>
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a) answer: can produce a color-blind son if mother is X^B X^b; cannot if mother is X^B X^B
b) answer: cannot produce a color-blind daughter (as above) since she must get X^B from dad

16. woman I^A i X^B x X^b  (I^A: because of child b; X^B X^b because of child e)

Man #1 I^A^B X^b Y
Man #2 I^A i X^B Y  (I^A: because of child b)

a) answer: male, I^A X^B Y  man #1 or #2 (A blood type & Y chromosome from #1 or #2)
b) answer: male, i i X^B Y  man #2 (O blood type only from man #2)
c) answer: female, I^A X^B X^-  man #1 or #2 (A blood type & X^B or X^b from either #1 or #2)
d) answer: female, I^A i X^B X^-  man #1 (B blood type & I^B from #1; I from mom)
e) answer: female, I^A i X^B X^-  man #1 (A or O blood type & X^B from #1, A or O & X^b from mom)

17.

a) answer: Ww x ww  (because ½ of progeny is ww)
b) answer: ww x ww  (because “w” is recessive)
c) answer: Ww x Ww  (because ¼ of progeny is ww)
d) answer: WW x ww  (because all progeny is Ww)
e) answer: WW x W_  (because one parent must be WW as all progeny is W_)
18. c) Ww x Ww \[\rightarrow \frac{1}{4} WW; \frac{1}{2} Ww; \frac{1}{4} ww\]
   answer: 2/3 smooth progeny (W_) can produce ww progeny when self-fertilized.

d) WW x ww \[\rightarrow \text{all Ww}\]
   answer: all smooth progeny (Ww) can produce ww progeny when self-fertilized.

e) WW x W_
   answer: no wrinkled progeny if both parents are WW
   \[\frac{1}{2} \text{of progeny if one parent WW & other is Ww}\]

19. a) B_ x bb \[\rightarrow \text{bb child}\]
   answer: B_ parent must be Bb to produce a bb child

b) Bb x bb

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<td>½ b</td>
<td>½ bb</td>
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c) Bb x Bb (both are heterozygous since each had a blue-eyed (bb) parent

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20. a) D_S_ x D_S_
   answer: DdSs x DdSs because some offspring (1/4) are dd (albino) & some (1/4) are ss (long)

b) D_S_ x D_ss
   answer: DDSs x Ddss or DDSs x Ddss or DdSs x DDss (all are possible)
   - at least one parent must be homozygous DD since there are no dd offspring
   - first parent must be Ss since 1/2 of the offspring are ss (long)

c) ddS_ x ddS_
   answer: ddSs x ddSs - both parents must be Ss since some offspring (1/4) are long (ss)

d) D_ss x D_ss
   answer: Ddss x Ddss – both parents must be Dd since some offspring (1/4) are albino (dd)

e) D_S_ x D_S_
   answer: DDDS x D_Ss - at least one parent must be DD since all offspring are dark (D)
   - both must be heterozygous Ss since some offspring (1/40 are long (ss)

f) D_S_ x D_ss
   answer: DdSs x Ddss - both parents must be Dd since some offspring (1/4) are albino (dd)
   - first parent must be Ss since some offspring (1/2) are long (ss)

21. Let C be normal and c be color-blind. The cross is X^C/Y x X^c/X^c. Thus all males receive an X^c from their mother & will be color-blind. All the females will receive the dominant X^C from their father & have normal vision.
22. Yes, genetics can, and the man does have grounds. Since he is normal \(X^C/Y\), he will give all his daughters the dominant allele and they will have normal vision. (Perhaps there was a mix up at the hospital.)

23. The man is \(I^B/i\) since one parent is \(ii\), which is actually irrelevant. The cross is \(I^B/i \times I^A/I^B\), so that half of the offspring will have an \(I^A\) allele from the mother. They cannot be pure \(B\) type. The other half will get the \(I^B\) allele.

24. Every parent has one unknown allele and thus Shirley, who is \(i/i\), may belong to either family. Jane, who is \(I^B/i\), cannot be the daughter of the Joneses, where no \(I^B\) allele is present. Thus, a mix up did occur in her case, and she could belong to the Smiths. However, since Shirley may also be their daughter, a third family may be involved.

25. a) First figure out possible genotypes \(\_\_E\_\) = golden (any \(B\) combination with at least 1 \(E\)). \(B_ee = \) black, \(bbee = \) brown. All you know of parents at start is \(\_\_E\_ \times \_\_E\_\). Since you see black and brown offspring, you know that both had to be heterozygous for \(Ee\). And at least one was heterozygous for \(Bb\) (to get a black dog). Since black and brown are in a 1:1 ratio (like a testcross ratio), then one dog was \(Bb\) and the other was \(bb\).

\[\text{answer: } BbEe \times bbEe\]

b) For the second cross, you know that one dog is \(\_bEe\) and the other must be \(B_ee\). A ratio of approximately 3:1 black to brown looks like a cross of heterozygotes, so both parents must be \(Bb\).

\[\text{answer: } BbEe \times Bbee.\]
**Mendelian Genetics**

1. A locus is
   a. a recessive gene.
   b. an unmatched allele.
   c. a sex chromosome.
   d. the location of an allele on a chromosome.
   e. a dominant gene.

2. Various forms of a gene at a given locus are called
   a. chiasmata.
   b. alleles.
   c. autosomes.
   d. loci.
   e. chromatids.

3. Diploid organisms
   a. have corresponding alleles on homologous chromosomes.
   b. are usually the result of the fusion of two haploid gametes.
   c. have two sets of chromosomes.
   d. have pairs of homologous chromosomes.
   e. all of these

4. Which of the following genotypes is homozygous?
   a. $AaBB$
   b. $aABB$
   c. $aaBB$
   d. $aaBb$
   e. $AaBb$

5. The most accurate description of an organism with genotype $AaBb$ is
   a. homozygous dominant.
   b. heterozygous.
   c. heterozygous dominant.
   d. homozygous recessive.
   e. heterozygous recessive.

6. Gene $A$ occurs on chromosome 5, gene $B$ is on chromosome 21. Therefore, these two parts of the chromosomes can NOT be
   a. genes.
   b. dominant.
   c. loci.
   d. alleles.
   e. recessive.
7. If short hair \((L)\) is dominant to long hair \((l)\), animals \(LL\) and \(Ll\) have the same
   a. parents.
   b. genotypes.
   c. phenotypes.
   d. alleles.
   e. genes.

8. If tall \((D)\) is dominant to dwarf \((d)\), and two homozygous varieties \(DD\) and \(dd\) are
crossed, then what kind of offspring will be produced?
   a. all intermediate forms
   b. all tall
   c. all dwarf
   d. 1/2 tall, 1/2 dwarf
   e. 3/4 tall, 1/4 dwarf

9. If all offspring of a cross have the genotype \(Aa\), the parents of the cross are most likely.
   a. \(AA\times aa\).
   b. \(Aa\times Aa\).
   c. \(Aa\times aa\).
   d. \(AA\times Aa\).
   e. none of these

10. The theory of segregation
    a. deals with the alleles governing two different traits.
    b. applies only to linked genes.
    c. applies only to sex-linked genes.
    d. explains the behavior of a pair of alleles during meiosis.
    e. none of these

11. The phenotypic ratio of offspring of a monohybrid cross is
    a. 1:1.
    b. 2:1.
    c. 9:3:3:1.
    d. 1:2:1.
    e. 3:1.

12. In a Punnett square, the letters within the little boxes represent
    a. offspring genotypes.
    b. parental genotypes.
    c. gametes.
    d. offspring phenotypes.
    e. parental phenotypes.

13. If short hair \((L)\) is dominant to long hair \((l)\), then what fraction of the offspring produced
    by a cross of \(Ll\times ll\) will be homozygous dominant?
    a. 1/2
    b. 1/4
    c. 1/3
    d. none (no chance of this offspring)
    e. none of these
14. If short hair (L) is dominant to long hair (l), then to determine the genotype of a short-haired animal it should be crossed with
   a. LL
   b. Ll
   c. ll
   d. all of these
   e. none of these

15. What fraction of the time will the cross of Aa Bb Cc with Aa Bb Cc produce an offspring of genotype aa bb cc?
   a. 1/64
   b. 1/32
   c. 3/64
   d. 1/16
   e. 9/64

16. What fraction of the time will the cross of Aa Bb Cc with Aa Bb Cc produce an offspring of genotype Aa bb CC?
   a. 1/64
   b. 1/32
   c. 3/64
   d. 1/16
   e. 9/64

17. Short hair (L) is dominant to long hair (l). If a short-haired animal of unknown origin is crossed with a long-haired animal, and they produce one long-haired and one short-haired offspring, this would indicate that
   a. the short-haired animal was pure-breeding.
   b. the short-haired animal was not pure-breeding.
   c. the long-haired animal was not pure-breeding.
   d. the long-haired animal was pure-breeding.
   e. none of these can be determined with two offspring

18. Assume short hair (L) is dominant to long hair (l) and black hair (B) is dominant to brown (b). If you found a black, short-haired animal, you could determine its genotype by crossing it to an animal with a genotype of
   a. LL BB
   b. ll BB
   c. ll Bb
   d. ll bb
   e. LL bb

19. If all the offspring of a cross had the genotype Aa Bb, the parents of the cross would most likely be
   a. AA BB x aa bb
   b. AA bb x aa BB
   c. Aa Bb x Aa Bb
   d. Aa bb x aa Bb
   e. both AA BB x aa bb, and AA bb x aa BB
20. In cocker spaniels, black coat color ($B$) is dominant over red ($b$), and solid color ($S$) is dominant over spotted ($s$). If a red male was crossed with a black female to produce a red, spotted puppy, the genotypes of the parents (with male genotype first) would be
   a. $Bb$ $Ss$ x $Bb$ $Ss$.
   b. $bb$ $Ss$ x $Bb$ $Ss$.
   c. $bb$ $ss$ x $Bb$ $Ss$.
   d. $bb$ $Ss$ x $Bb$ $ss$.
   e. $Bb$ $ss$ x $Bb$ $ss$.

21. In cocker spaniels, black coat color ($B$) is dominant over red ($b$), and solid color ($S$) is dominant over spotted ($s$). If a red, spotted male was crossed with a black, solid female and all the offspring from several crosses expressed only the dominant traits, the genotype of the female would be
   a. $BB$ $SS$.
   b. $Bb$ $SS$.
   c. $Bb$ $Ss$.
   d. $BB$ $Ss$.
   e. none of these

22. In cocker spaniels, black coat color ($B$) is dominant over red ($b$), and solid color ($S$) is dominant over spotted ($s$). If two dihybrids ($Bb$ $Ss$) were crossed, the most common phenotype would be
   a. black and solid.
   b. black and spotted.
   c. red and solid.
   d. red and spotted.
   e. none of these

23. The usual offspring phenotypic ratio of a dihybrid cross is
   a. 1:1.
   b. 2:1.
   c. 9:3:3:1.
   d. 1:2:1.
   e. 3:1.

24. An individual with a genotype of $Aa$ $Bb$ $CC$ is able to produce how many different kinds of gametes?
   a. 2
   b. 3
   c. 4
   d. 7
   e. 8
Chromosomal Inheritance

1. Choose the one most appropriate answer for each.
   1. ______ colchicines (drug which stops cells at metaphase)
   2. ______ deletion
   3. ______ duplication
   4. ______ polyploidy
   5. ______ monosomy
   6. ______ trisomy

A. \((2n - 1)\); an individual deprived of a chromosome
B. a repeat of a particular DNA sequence in the same chromosome or in nonhomologous ones
C. \((2n + 1)\); three chromosomes of the same kind are present in a set of chromosomes
D. a piece of the chromosome is inadvertently left out during the repair process
E. inhibits microtubule assembly; prevents chromosome movement
F. describes an embryo with multiple sets of chromosomes

Multiple Choice

1. Genes are
   a. located on chromosomes.
   b. inherited in the same way as chromosomes.
   c. arranged in linear sequence on chromosomes.
   d. assorted independently during meiosis.
   e. all of these

2. Which of the following is NOT true concerning homologous chromosomes?
   a. There are two of each kind.
   b. Each parent contributes one of each homologous pair.
   c. Most homologous chromosomes carry the same genes for the same traits.
   d. The number of homologous chromosomes is doubled in each generation.
   e. Homologous chromosomes pair up during early meiosis.

3. Chromosomes other than those involved in sex determination are known as
   a. nucleosomes.
   b. heterosomes.
   c. alleles.
   d. autosomes.
   e. liposomes.
4. DNA coding regions that affect the same trait are called
   a. homologues.
   b. alleles.
   c. autosomes.
   d. loci.
   e. gametes.

5. The location of a gene on a chromosome is its
   a. centromere.
   b. locus.
   c. autosome.
   d. allele.
   e. centriole.

6. Sex chromosomes
   a. determine gender.
   b. vary from one sex to another.
   c. carry some genes that have nothing to do with sex.
   d. all of these

7. Which of the following is an accurate characterization of a mutation?
   a. an exchange of chromosomes between two chromosomes
   b. the linkage of two unrelated chromosomes
   c. a change in the nucleotides of DNA
   d. the reassortment of chromosomes at meiosis
   e. the shuffling of genes during gamete preparation

8. Which of the following statements is false?
   a. The SRY gene is absent in females.
   b. The SRY gene apparently is the gene that controls the development of
      male sexuality.
   c. The development of maleness is by default because males lack two X
      chromosomes.
   d. Femaleness develops in the embryo before maleness.
   e. There is no difference in external genitalia of males or females until four
      weeks after conception when the genes determining sex begin to be
      expressed.

9. In human females, one of the sex chromosomes is switched off during early
   development in a phenomenon called
   a. karyotyping.
   b. X inactivation.
   c. X linkage.
   d. crossing over.
   e. SRY activation.

10. A condensed, female X chromosome is called a
   a. Barr body.
    b. Morgan sphere.
    c. SRY gene.
    d. karyotype.
    e. linkage map.
13. If alleles L, M, and N are on the maternal chromosome and l, m, and n are on the paternal chromosome, the only way that a gamete from such a heterozygote will produce a gamete with alleles l, m, and N is through
   a. nondisjunction.
   b. the laws of segregation.
   c. the law of independent assortment.
   d. crossing over.
   e. chromosome aberration.

15. Genetic recombination as a result of crossing over occurs more readily in genes that
   a. are on the sex chromosomes.
   b. are on the autosomes.
   c. are located close together on the same chromosome.
   d. are located farther apart on the same chromosome.
   e. are located on different chromosomes.

16. In genetic analyses, researchers know that linkage of genes will introduce exceptions to the principle of
   a. dominance.
   b. segregation.
   c. recessiveness.
   d. independent assortment.
   e. chromosomal inheritance.

17. An autosomal recessive disorder
   a. requires that only one parent be a carrier.
   b. displays its symptoms only in heterozygotes.
   c. is more frequent in males than females.
   d. can appear only in children of parents who both carry the gene.
   e. is dominant in females.

18. The probability of producing a phenotypically normal child by two parents who are carriers for an autosomal recessive disorder is
   a. 50 percent.
   b. 0 percent.
   c. 100 percent.
   d. 25 percent.
   e. 75 percent.

19. The probability of producing a child who suffers from cystic fibrosis by two parents who are carriers for the autosomal recessive disorder is
   a. 50 percent.
   b. 0 percent.
   c. 100 percent.
   d. 25 percent.
   e. 75 percent.
20. A woman is diagnosed to have the genetic disease known as Huntington’s disorder. It is a rare defect caused by an autosomal dominant allele. The chance for any one of her children to inherit the disease is
   a. dependent on the sex of the child.
   b. 1 out of 3.
   c. 1 out of 2.
   d. 3 out of 4.
   e. 0.

21. In an autosomal dominant disorder such as Huntington’s, two carrier parents have the probability of passing the gene on to __________ percent of their children.
   a. 50
   b. 0
   c. 100
   d. 25
   e. 75

23. In which of the following does the onset of symptoms usually occur in individuals after childbearing age? a. Tay-Sachs
   b. hemophilia
   c. Huntington's
   d. muscular dystrophy
   e. achondroplasia

25. A color-blind man and a woman with normal vision whose father was color-blind have a son. Color blindness, in this case, is caused by an X-linked recessive gene. If only the male offspring are considered, the probability that their son is color-blind is
   a. 25 percent.
   b. 50 percent.
   c. 75 percent.
   d. 100 percent.
   e. none of these

26. Red-green color blindness is an X-linked recessive trait in humans. A color-blind woman and a man with normal vision have a son. What is the probability that the son is color-blind?
   a. 100 percent
   b. 75 percent
   c. 50 percent
   d. 25 percent
   e. 0 percent

27. Red-green color blindness is an X-linked recessive trait in humans. What is the probability that a color-blind woman and a man with normal vision will have a color-blind daughter?
   a. 100 percent
   b. 75 percent
   c. 50 percent
   d. 25 percent
   e. 0 percent

28. If a daughter expresses an X-linked recessive gene, she inherited the trait from
   a. her mother.
   b. her father.
   c. both parents.
   d. neither parent.
   e. her grandmother.
29. An X-linked carrier is a
   a. homozygous dominant female.
   b. heterozygous female.
   c. homozygous recessive female.
   d. homozygous male.
   e. heterozygous male.

30. A human X-linked gene is
   a. found only in males.
   b. more frequently expressed in females.
   c. found on the Y chromosome.
   d. transmitted from father to son.
   e. found on the X chromosome.

33. Which of the following would be considered a carrier of a sex-linked recessive defect?
   a. a man with the defect
   b. a woman with the defect
   c. a father of a son with the defect
   d. the normal daughter whose father had the defect
   e. a son of two unaffected parents

35. The condition occurring when an organism has a $2n + 1$ chromosome composition is known as
   a. monosomy.
   b. trisomy.
   c. diploid.
   d. haploid.
   e. both trisomy and haploid.

36. Choose any and all of the following that would describe a gamete that is missing one chromosome.
   a. The chromosome number would be expressed as $2n - 1$.
   b. One chromosome would occur without its homologue.
   c. The condition would be called monosomy.
   d. The chromosome number would be expressed as $2n - 1$ and the condition would be called monosomy.
   e. The chromosome number would be expressed as $2n - 1$, the condition would be called monosomy, and one chromosome would occur without its homologue.

37. The failure of chromosomes to separate during mitosis or meiosis is called
   a. genetic displacement.
   b. trisomy.
   c. crossing over.
   d. nondisjunction.
   e. disjunction.
### Answers to Genetics Problems - Set #3

**A. Mendelian Genetics**

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<td>23. c (see #22)</td>
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**B. Chromosomal inheritance**

1. 1) E (drug that stops cells at metaphase)
   2) D
   3) B
   4) F (not covered in class)
   5) A
   6) C

**Multiple choice**

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23. Basic Mendelian Pedigrees

a. Determine if the pedigrees show the inheritance of a dominant or recessive disorder.
b. Determine if the pedigree shows the inheritance of an autosomal or sex-linked disorder.
c. Determine the probability that the individual indicated will express the disorder.

(A)

(B)

(C)

(D)
23. (A) Autosomal dominant; 50% probability (mother is Bb; father is bb)
(B) Autosomal recessive; 25% probability (parents are heterozygous)
(C) X-linked recessive; 50% if a boy; 0% if a girl (mother is X^AX^a, father is X^AY)
(D) X-linked dominant; #9 would have 100% probability if a girl, 0% probability if a boy (as in Generation II); #15 would have 50% in either sex (as in Generation III)
1. Mendel’s Law of Independent Assortment has its physical basis in which phase of the cell cycle?
   a) the separation of homologous chromosome pairs in anaphase I of meiosis
   b) the orientation of homologous chromosome pairs in metaphase I of meiosis
   c) the orientation of homologous chromosome pairs in metaphase II of meiosis
   d) the separation of homologous chromosome pairs in anaphase II of meiosis
   e) the orientation of homologous chromosome pairs in metaphase of mitosis

2. Carrie’s sister has the recessive disorder phenylketonuria. Neither Carrie nor either of her parents displays symptoms of this disorder. Carrie ends up marrying a man who knows that he is a carrier for phenylketonuria. What is the chance that Carrie’s first child will have the disorder?
   a) 1/2
   b) 1/12
   c) 1/6
   d) 1/4
   e) There is not enough information to answer the question.

3. In pea plants, the allele for purple flower color is dominant to the allele for white flower color. If you were to perform a test cross to determine the genotype of a purple-flowered plant, what would you expect the phenotypic ratio of purple-flowered to white-flowered progeny to be if the plant is homozygous? And what would you expect if the plant is heterozygous?
   a) If the purple-flowered plant is homozygous, then the progeny would all have purple flowers; if the purple-flowered plant is heterozygous, then the progeny would have purple to white flowers in a 1:1 ratio.
   b) If the purple-flowered plant is homozygous, than the progeny would all have white flowers; if the purple-flowered plant is heterozygous, then the progeny would have purple: white flowers in a 1:1 ratio.
   c) If the purple-flowered plant is homozygous, than the progeny would have purple to white flowers in a 1:3 ratio; if the purple-flowered plant is heterozygous, then the progeny would have purple to white flowers in a 1:1 ratio.
   d) If the purple-flowered plant is homozygous, than the progeny would all have purple flowers; if the purple-flowered plant is heterozygous, then the progeny would have purple:white flowers in a 3:1 ratio.
   e) If the purple-flowered plant is homozygous, than the progeny would have purple to white flowers in a 1:3 ratio; if the purple-flowered plant is heterozygous, then the progeny would have purple to white flowers in a 1:3 ratio.

4. Pedram and Monica are both heterozygous for the widow’s peak trait. Individuals who have two copies of the widow’s peak allele exhibit a sharp, pointed hairline. What is the probability that the couple’s first three children will all have sharp, pointed hairline?
   a) 1/4
   b) 1/12
   c) 1/64
   d) 1/3
   e) 3/4
5. A man with the autosomal recessive disorder phenylketonuria (PKU) and a woman without PKU have a son named Peter, who does not have PKU. Peter is curious about whether his mother is a carrier for PKU. Which of the following facts would allow him to know?
   a) Peter’s own daughter has PKU.
   b) Peter submits his own blood sample to a local genotyping lab, which establishes that he is a carrier for PKU.
   c) Peter’s maternal grandmother does not have PKU.
   d) Peter’s maternal grandfather has PKU.
   e) Peter's paternal grandfather does not have PKU.

6. A plant had the genotype FfGgHh. If 2 such plants were crossed:
   a) What proportion would show the dominant phenotype F?  \( \frac{3}{4} \)
   b) What proportion would show the recessive phenotype for all 3 loci?  \( \frac{1}{64} \)

7. In human, polydactyly is due to a dominant allele and results in extra fingers and/or toes. Phenylketonuria (PKU) is recessive and is a condition due to a disorder in the metabolism of the amino acid phenylalanine. Unless given a special diet as infants, people with PKU may have varying levels of mental disorders. A man who has neither condition but whose father has PKU and a woman with polydactyly like her father but without the PKU allele wonder what the probability is of having a child with both conditions. What about with one of these conditions?

   None of the children will have both conditions. Half of the offspring are expected to have polydactyly.

8. A cross in chickens involved the diplopodia and “naked neck” loci. Diplopodia is a recessive mutation that results in extra bones in the wings and feet, a shortened beak, and an inability to hatch because they are unable to peck their way out of the shell. The “naked neck” trait is caused by a recessive mutation that results in loss of feathers on the neck. The offspring included 81 normal, 4 with naked neck and diplopodia, 22 with naked neck and 34 with diplopodia. What were the genotypes and phenotypes of the parents?

   The ratio is almost 9:3:3:1, therefore, it is a dihybrid cross (DdNn x DdNn)

9. Mrs. Idengaku was one of 2 mothers in a maternity ward. When she was given baby #1, she denied that it was hers, claiming baby #2 instead. Another mother also claimed baby #2. Mrs. Idengaku is blood type O. Baby #1 is A, and baby #2 is O. Unfortunately, Mr. Idengaku died just before the baby was born, so we can’t find out his phenotype or genotype, but the Idengaku family has 3 other children whose phenotypes are known. Keiko is A, Tohru is B, and Kenichi is B. Who is right, Mrs. Idengaku or the other mother? What is your reasoning?

   Keiko is IAi and Tohru is IBi. Therefore, Mr. Idengaku was IAIB (blood type AB). The Idengaku family cannot have a child with blood type O (ii), so Mrs. Idengaku is mistaken.
10. A heterozygous, but phenotypically wild-type fruit fly (gray body and normal wings) was mated to a black fly with vestigial wings. The offspring had the following phenotypic distribution: wild type 729; black-vestigial 780; black-normal 280; gray-vestigial 220. What conclusion is likely from these results?
   a) Black and vestigial loci assort independently.
   b) Black and vestigial loci are allelic
   c) Epistasis has modified a 9:3:3:1 ratio
   d) Black and vestigial loci are linked with a frequency of recombination of 25%.
   e) Black and vestigial loci are linked with a frequency of recombination of 75%.
1. A woman is a carrier for a sex-linked gene that causes an embryo to spontaneously abort. She has nine children. How many of these children do you think are boys? Indicate your alleles, use a punnett square and circle your final answer for full marks.

\[ L = \text{normal, } l = \text{lethal.} \]

Woman is \( X(L)X(l) \)--a carrier for the sex-linked allele that causes spontaneous abortion. Her husband must be \( X(L)Y \). Of all pregnancies, her children would have the genotypes:

- \( X(L)X(L) \): 25% girls all survive,
- \( X(L)Y \): 25% boys all survive,
- \( X(L)X(l) \): 25% girls all survive,
- \( X(l)Y \): 25% boys all die as embryos.

Of her surviving children, 1/3 are boys, so 3 of her 9 children are boys.

2. Individuals affected by a condition known as polydactyly have extra fingers or toes. The following pedigree shows the pattern of inheritance of this trait in two families (figures A and B).

(3 marks)

\[
\text{a. From the pedigrees, can you tell if polydactyly comes from a dominant or recessive allele? What criteria helped you to form you opinion?}
\]
a. Polydactyl is caused by a DOMINANT allele because every individual that has polydactyl has at least one parent with the condition.

b. Is the trait sex-linked? What criteria helped you to form your opinion?

b. No the trait is not sex-linked, it is autosomal. Affected boys inherit the disease from both affected fathers or affected mothers. And, affected fathers pass the disease on to both his sons and daughters, not just his daughters.

c. What is the probability that the individual marked as a diamond will be born with polydactyly

c. probability is 0%. Neither parent has the dominant allele.

3. Snapdragons are flowers that come in a variety of colors, including red, pink, and white. A series of crosses with snapdragons having flowers of different colors produced the following results:
   pink × pink: 27 pink, 13 red, 14 white
   red × red: all red
   white × white: all white
   pink × white: 29 pink, 26 white
   pink × red: 28 pink, 27 red
   white × red: all pink

   Based on the results, what is the most reasonable explanation for the inheritance of these flower colors?
   A) pleiotropic effects
   B) qualitative effects
   C) incomplete dominance
   D) codominance
   E) more than two alleles