Chapters 1 & 2 Homework

Ordered by topic: DNA structure & function; mitosis & meiosis; inheritance patterns; monohybrid crosses; pedigrees

5. Consider Figure 1-8a.
   a. What do the small blue spheres represent?
   b. What do the brown slabs represent?
   c. Do you agree with the analogy that DNA is structured like a ladder?

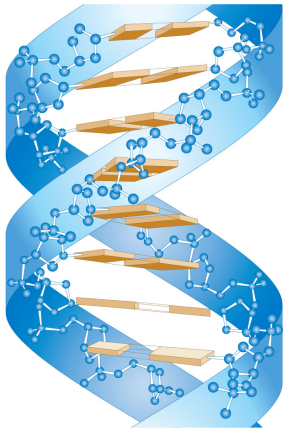

Figure 1-8a
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Answer:
   a. The blue ribbon represents sugar phosphate backbone (deoxyribose and a phosphate group), while the blue spheres signify atoms
   b. Brown slabs show complementary bases (A, T, G, and C)
   c. Yes, it is a helical structure

6. In Figure 1-8b, can you tell if the number of hydrogen bonds between adenine and thymine is the same as that between cytosine and guanine? Do you think that a DNA molecule with a high content of A + T would be more stable than one with a high content of G + C?

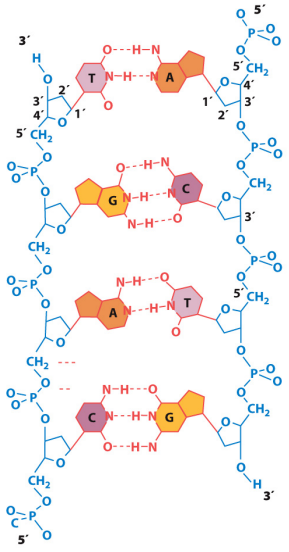

Figure 1-8b
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Answer: There are two hydrogen bonds between adenine and thymine and three between guanine and cytosine. Because A-T has only two hydrogen bonds it will be less stable than a molecule with a high content of G-C (three hydrogen bonds).

10. Below is the sequence of a single strand of a short DNA molecule. On a piece of paper, rewrite this sequence and then write the sequence of the complementary strand below it.

GTTCGCGGCCGCGAAC

Comparing the top and bottom strands, what do you notice about the relationship between them?

Answer:

GTTCGCGGCCGCGAAC
CAAGCGCCGGCGCTTG

They are palindromes — the same forwards and backwards.

12. If a DNA double helix that is 100 base pairs in length has 32 adenines, how many cytosines, guanines, and thymines must it have?

Answer:
A = T and G = C. Therefore, 32 adenines means there are also 32 thymines, for a total of 64 bases. This means the remainder (100 - 64 = 36) are guanines and cytosines. Split 36 in two because the number of Gs and Cs are equal, and you get 18 guanine and 18 cytosine.

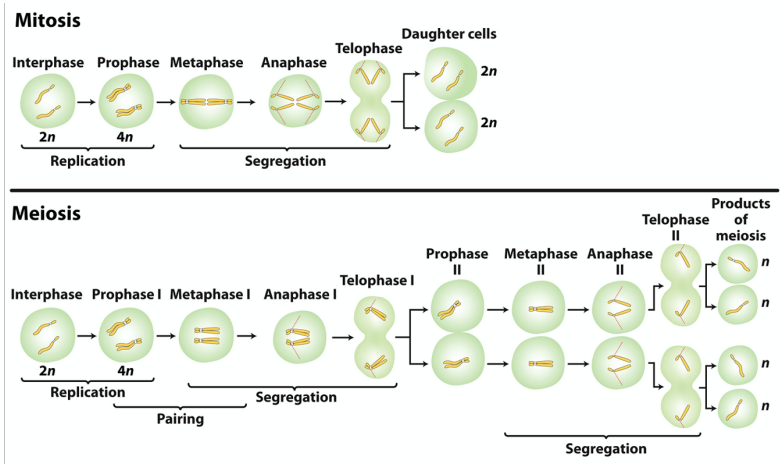

Figure 2-8
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BOTH:

- Chromosomes made up of chromatids; one from mom and one from dad
- Interphase: chromosomes duplicate and become two identical chromatids joined at centromere (now 92 chromosomes)
- Prophase: spindle fibers form in the corners
- Metaphase: spindle fibers catch chromsomes and they line up in the "middle" (equator of cell)
- Anaphase: spindle fibers shorten and centromere divides, so each chromosome becomes separate chromatids
- Telophase: nucleus forms around each – now back to 46 chromosomes each
- Cytokinesis: cell membane pinches and we now have two identical daughter cells with 46 chromosomes (same as parent)

Meiosis:

- Sexual reproduction requires gametes – sperms and eggs!
- Includes all the same phases, but happens twice in meiosis to produce FOUR haploid (half) "granddaughter" cells, all genetically different!
- Interphase, then Prophase I: homologous chromosomes line up and crossing over occurrs (recombination) – new genetic combinations! Then Metaphase I and Anaphase I same as mitosis.
- When we begin prophase II, we have two cells each with 46 chromosomes and 92 chromatids
- Second round now, except no DNA replication so that we will get 23 chromosomes in each

18. Name the key function of mitosis.

Answer:
The key function of mitosis is to generate two daughter cells that are genetically identical to the original parent cell. This process is involved in growth, cell repair, and asexual reproduction.

19. Name two key functions of meiosis.

Answer:
Two key functions of meiosis are to halve the DNA content and to reshuffle the genetic content of the organism to generate genetic diversity among the progeny.

22. In what ways does the second division of meiosis differ from mitosis?

Answer:
As cells divide mitotically, each chromosome consists of identical sister chromatids that are separated to form genetically identical daughter cells. Although the second division of meiosis appears to be a similar process, the "sister" chromatids are likely to be different. Recombination during earlier meiotic stages has swapped regions of DNA between sister and nonsister chromosomes such that the two daughter cells of this division typically are not genetically identical.

30. Four of the following events are part of both meiosis and mitosis, but only one is meiotic. Which one? (1) chromatid formation, (2) spindle formation, (3) chromosome condensation, (4) chromo- some movement to poles, (5) synapsis

Answer:
(5) synapsis (chromosome pairing)
Synapsis is the pairing of two homologous chromosomes that occurs during meiosis. It allows matching-up of homologous pairs prior to their segregation, and possible chromosomal crossover between them. Synapsis takes place during prophase I of meiosis.
Chromosome condensation is the dramatic reorganisation of the long thin chromatin strands into compact short chromosomes that occurs in mitosis and meiosis.
A sister chromatid refers to the identical copies (chromatids) formed by the DNA replication of a chromosome, with both copies joined together by a common centromere

Figure 2-5
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11. Mendel studied a tall variety of pea plants with stems that are 20 cm long and a dwarf variety with stems that are only 12 cm long.
    a. Under blending theory, how long would you expect the stems of first and second hybrids to be?
    b. Under Mendelian rules, what would you expect to observe in the second-generation hybrids if all the first-generation hybrids were tall?

Answer:
    a. Blending theory suggests that offspring would exhibit traits in between both parents, i.e., the average. In this case, offspring would be 16cm tall.
    b. If all F1 hybrids were tall, this suggests that tall is dominant to short and all offspring are heterozygous. Thus, upon mating F1 hybrids, you would expect a 3:1 ratio of tall to short.

46. Suppose that a husband and wife are both heterozygous for a recessive allele for albinism. If they have dizygotic (two-egg) twins, what is the probability that both the twins will have the same phenotype for pigmentation?

Answer:
Both parents are A/a. Both twins could be albino or both twins could be normal (for probability calculations: and = multiply, or = add). The probability of being normal is the probability of having one dominant allele (A/–) – $\frac{3}{4}$. The probability of being albino is the probability of having two recessive alleles (a/a) – $\frac{1}{4}$.
p(both normal) + p(both albino) =
p(first normal) × p(second normal) + p(first albino) × p(second albino) =
$\frac{3}{4} \times \frac{3}{4} + \frac{1}{4} \times \frac{1}{4} = \frac{9}{16} + \frac{1}{16} = \frac{5}{8}$

27. If children obtain half their genes from one parent and half from the other parent, why aren't siblings identical?

Answer:
Because the "half" inherited is very random, the chances of receiving exactly the same half is vanishingly small. Ignoring recombination and focusing just on which chromosomes are inherited from one parent, there are $22^3 = 8,388,608$ possible combinations!

4. Figure 1-7 shows a simplified pathway for arginine synthesis in Neurospora. Suppose you have a special strain of Neurospora that makes citrulline but not arginine. Which gene(s) are likely mutant or missing in your special strain? You have a second strain of Neurospora that makes neither citrulline nor arginine but does make ornithine. Which gene(s) are mutant or missing in this strain?

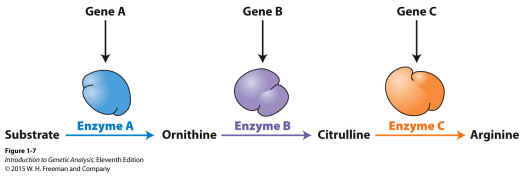

Figure 1-7
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Answer: If the mutant strain is able to produce citrulline, then genes A and B must work. Gene C, the gene responsible for the transition from citrulline to arginine, must be mutated. In the second strain, gene A must be functional since it is able to make ornithine. Gene B must be missing or mutant since it is unable to make citrulline. However, gene C may or may not be missing or mutantated. Enzyme C converts citrulline into arginine (they are in the same sequential pathway), and enzyme C is dependent on the availability of citrulline for its function.

1. If the white-flowered parental variety in Figure 1-3 were crossed to the first-generation hybrid plant in that figure, what types of progeny would you expect to see and in what proportions?

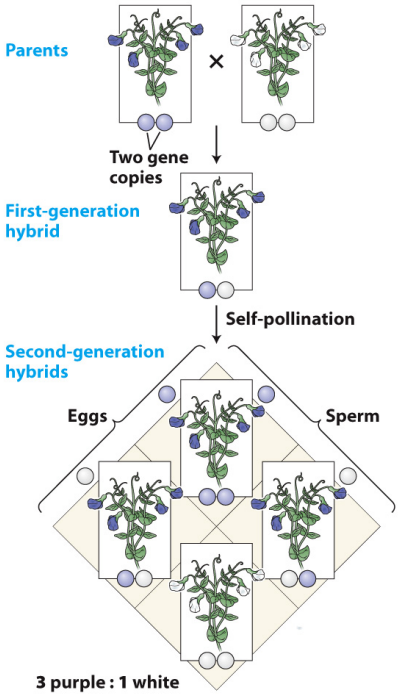

Figure 1-3
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Answer: Let's assign genotypes for each of these hypothetical parents. First, we assign a genotype of AA to the purple plant, and aa to the white plant. If a pure-breeding (homozygous) purple plant and a pure-breeding (homozygous) white plant mated, we would observe the following:

$$AA \times aa \rightarrow Aa$$

Thus, all hybrid plants have a genotype of Aa. If we cross this to a pure-breeding white-flowered plant (aa), we observe the following:

	a	a
A	Aa	Aa
a	aa	aa

Like all single-locus crosses between a homozygote and heterozygote (with complete dominance), we observe a 1:1 phenotypic and genotypic ratio.

3. In Table 2-1, state the recessive phenotype in each of the seven cases.

TABLE 2-1 Results of All Mendel's Crosses in Which Parents Differed in One Character

Parental phenotypes	F_1	F_2	F_2 ratio
1. round × wrinkled seeds	All round	5474 round; 1850 wrinkled	2.96 : 1
2. yellow × green seeds	All yellow	6022 yellow; 2001 green	3.01 : 1
3. purple × white petals	All purple	705 purple; 224 white	3.15 : 1
4. inflated × pinched pods	All inflated	882 inflated; 299 pinched	2.95 : 1
5. green × yellow pods	All green	428 green; 152 yellow	2.82 : 1
6. axial × terminal flowers	All axial	651 axial; 207 terminal	3.14 : 1
7. long × short stems	All long	787 long; 277 short	2.84 : 1

Table 2-1
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Answer:
wrinkled seeds; green seeds; white petals; pinched pods; yellow pods; terminal flowers; short stems

40. In the plant *Arabidopsis thaliana*, a geneticist is interested in the development of trichomes (small projections). A large screen turns up two mutant plants (A and B) that have no trichomes, and these mutants seem to be potentially useful in studying trichome development. (If they were determined by single-gene mutations, then finding the normal and abnormal functions of these genes would be instructive.) Each plant is crossed with wild type; in both cases, the next generation (F1) had normal trichomes. When F1 plants were selfed, the resulting F2's were as follows:

- F2 from mutant A: 602 normal; 198 no trichomes
- F2 from mutant B: 267 normal; 93 no trichomes

a. What do these results show? Include proposed genotypes of all plants in your answer.
b. Under your explanation to part a, is it possible to confidently predict the F1 from crossing the original mutant A with the original mutant B?

Answer:
The data indicates that each mutant is homozygous recessive for a mutation that inhibits trichome development (aa). When crossed with wild-type plants (AA), all F1 progeny were normal suggesting the following cross:

	a	a
A	Aa	Aa
A	Aa	Aa

Thus, the F1 progeny were all heterozygous and their offspring display the expected 3:1 ratio from the following cross:

	A	a
A	AA	Aa
a	Aa	aa

49. In nature, the plant *Plectritis congesta* is dimorphic for fruit shape; that is, individual plants bear either wingless or winged fruits. Plants were collected from nature before flowering and were crossed or selfed with the following results:

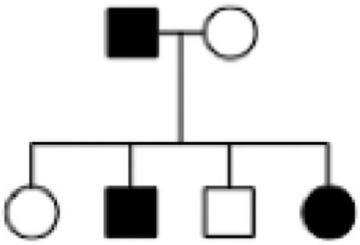
Pollination	Winged	Wingless
Winged (selfed)	91	1
Winged (selfed)	90	30
Wingless (selfed)	4	80
Winged x wingless	161	0
Winged x wingless	29	31
Winged x wingless	46	0
Winged x winged	44	0
Winged x winged	24	0

Answer:

Pollination	Genotypes	Winged	Wingless
Winged (selfed)	AA x A-	91	1
Winged (selfed)	Aa x Aa	90	30
Wingless (selfed)	aa x aa	4	80
Winged x wingless	AA x aa	161	0
Winged x wingless	Aa x aa	29	31
Winged x wingless	AA x aa	46	0
Winged x winged	AA x A-	44	0
Winged x winged	AA x A-	24	0

The five unusual plants are most likely due either to human error in classification or to contamination. Alternatively, they could result from environmental effects on development. For example, too little water may have prevented the seedpods from becoming winged, even though they are genetically winged.

43. In the pedigree below, the black symbols represent individuals with a very rare blood disease. If you had no other information to go on, would you think it more likely that the disease was dominant or recessive? Give your reasons.



Answer:
If the disease were recessive, it would mean that the father has two copies of the allele, and the mother has one. Otherwise, the children could not be affected – for them to have a recessive phenotype, they must each inherit one allele from each parent! And yet, you are told this disease is very rare. If it is dominant, it simply means the father has one copy of the allele and he passed it to each of the parents. Thus, the disease is likely dominant.

13. Could the pedigree in Figure 2-31 be explained as an autosomal dominant disorder? Explain.

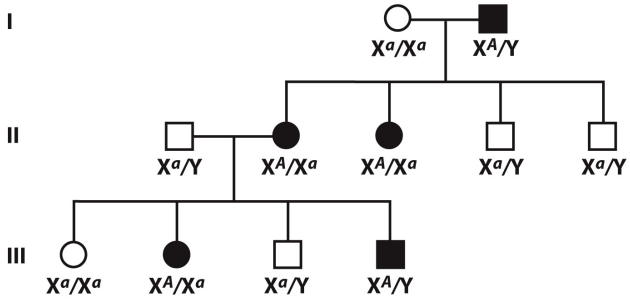


Figure 2-31
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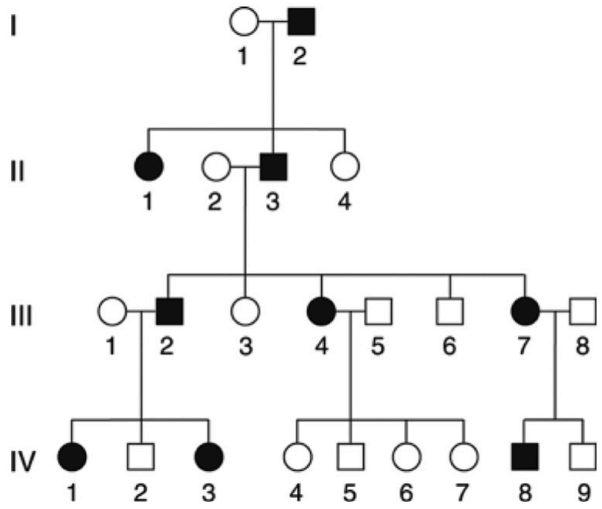
Answer: It could be explained this way in some cases. However, we have two clues that this may be sex-linked dominant.

1. If fathers have a gene, only daughters would receive it.
2. If mothers have a gene, both sons and daughters would receive it.

We see this pattern demonstrated here, so it is more likely to be sex-linked than autosomal.

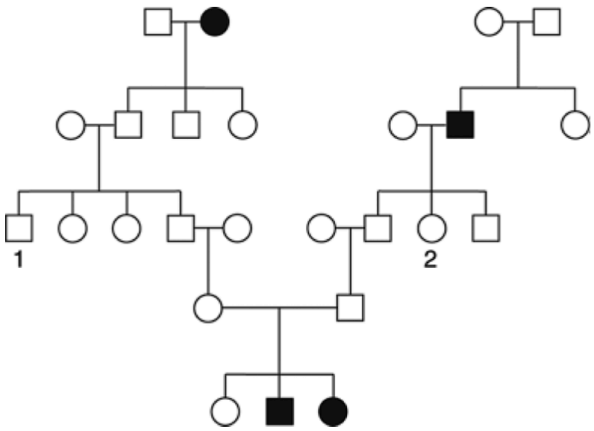
50. The accompanying pedigree is for a rare but relatively mild hereditary disorder of the skin.
    a. How is the disorder inherited? State reasons for your answer.
    b. Give genotypes for as many individuals in the pedigree as possible. (Invent your own defined allele symbols.)
    c. Consider the four unaffected children of parents III-4 and III-5. In all four-child progenies from parents of these genotypes, what proportion is expected to contain all unaffected children?



Answer:

a. Likely dominant – all individuals affected also have at least one affected parent.
b. I: d/d, D/d; II: D/d, d/d, D/d, d/d; III: d/d, D/d, d/d, D/d, d/d, d/d, D/d, d/d; IV: D/d, d/d, D/d, d/d, d/d, d/d, d/d, D/d, d/d
c. The mating is D/d x d/d. The probability of an affected child (D/d) equals 1/2, and the probability of an unaffected child (d/d) equals 1/2. Therefore, the chance of having four unaffected children (since each is an independent event) is 1/2 x 1/2 x 1/2 x 1/2 = 1/16.

53. The following pedigree was obtained for a rare kidney disease.
    a. Deduce the inheritance of this condition, stating your reasons.
    b. If persons 1 and 2 marry, what is the probability that their first child will have the kidney disease?



Answer:

a. (1) Affected individuals have unaffected parents, and (2) a daughter inherited the trait from an unaffected father. This suggests autosomal recessive.
b. Both parents must be heterozygous to have a 1/4 chance of having an affected child. Parent 2 is heterozygous, since her father is homozygous for the recessive allele and parent 1 has a 1/2 chance of being heterozygous, since his father is heterozygous because 1's paternal grandmother was affected. Overall, 1 x 1/2 x 1/4 = 1/8.

61. Duchenne muscular dystrophy is sex-linked and usually affects only males. Victims of the disease become progressively weaker, starting early in life.
    a. What is the probability that a woman whose brother has Duchenne's disease will have an affected child?
    b. If your mother's brother (your uncle) had Duchenne's disease, what is the probability that you have received the allele?
    c. If your father's brother had the disease, what is the probability that you have received the allele?

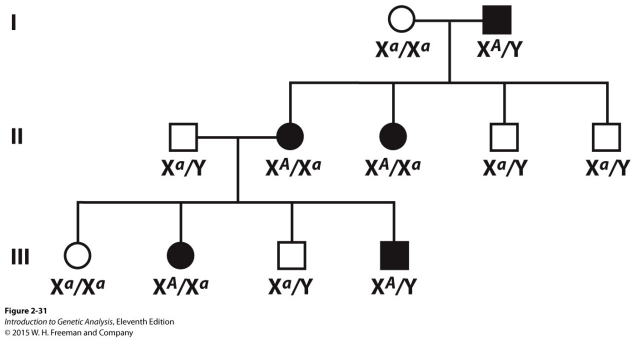


Figure 2-31
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Answer:

a. The 'maternal grandmother' had to be a carrier, D/d. The probability that the woman inherited the d allele from her is 1/2. The probability that she passes it to her child is 1/2. The probability that the child is male is 1/2. The total probability of the woman having an affected child is 1/2 x 1/2 x 1/2 = 1/8.

b. The pedigree in part (a) applies. The 'maternal grandmother' had to be a carrier, D/d. The probability that your mother received the allele is 1/2. The probability that your mother passed it to you is 1/2. The total probability is 1/2 x 1/2 = 1/4.

c. Because your father does not have the disease, you cannot inherit the allele from him. Therefore, the probability of inheriting an allele will be based on the chance that your mother is heterozygous. Since she is 'unrelated' to the pedigree, assume that this is zero.