AP Chapter 14-15 Study Guide: Chromosomes and Mendelian Genetics

Teacher's Note: *Biology textbooks and biology teachers generally do a stupid thing……they start with a rather abstract concept of the gene, introduce chromosomes next and then proceed to a discussion of the DNA molecule. A superior pedagogical approach would be to introduce genetics with the concrete idea of the chromosome and then proceed to more abstract concepts. This is what I intend to do. Therefore, we will be jumping around a bit in the text. But before we progress to the text, answer the following questions. (You should know these off the top of your head.)*

1. All living things are made of _____, the basic unit of structure and function.
2. The organelle that contains the genetic materials is called the _____. The cell spend the majority of time in which stage of the cell cycle? _____During this time the DNA is loosely associated with its protein and is called _____. However, as the cell enters mitosis the DNA condenses down into rod shaped structures called _____.

Reread page 240 and pay particular attention to figure 13.3

3. What is the name of an ordered arrangement of chromosomes? _____
4. In what three ways are the chromosomes arranged? _____

_____

5. When examining an arrangement of chromosomes, you cannot determine physical characteristics but you can determine two things: _____ and _____

Jump to pages 285-288 and read about some chromosome abnormalities

6. How can a person wind up with an extra chromosome? _____

_____

7. One of the most common aneuploidys occurs when a person has three copies of chromosome 21. This disorder is commonly called _____ _____
8. Another, less common, aneuploidy occurs when a person inherits three copies of chromosome 18. This disorder is called Edwards syndrome and it is much more severe than trisomy 21. Individuals with Edwards rarely live to the age of 2. Suggest a reason why Edward's syndrome would be so much more devastating than Down's sysdrome _____

_____

Now on to Mendel and the gene. Mendel was greatly influenced by two of his professors. A man named Unger got Mendel interested in inheritance and a man named Doppler impressed Mendel with the idea that large sample sizes were important for statistical validity. Initially, Mendel began his experimentation with rats, but the bishop in charge of his abbey felt that mating rats was "unnatural" and force Mendel to quit. The ever resourceful Mendel fortuitously chose pea plants to study. (Some would say that he was divinely inspired because pea plants were ideal for his study). Read pages 251-256

9. Explain at least three reasons why peas were excellent subjects for Mendel's genetic experiments. _____

_____

_____

Mendel reasoned that if he crossed a tall pea plant with a short pea plant, he would get medium sized plant; however, Mendel got all tall plants. Mendel then hypothesized that the "heritable factor" (the word gene had not yet been invented) for short plants was not passed on. To test this hypothesis, he conducted an F_1 cross (a cross of the offspring from his first cross.) Much to his surprise, the F_2 generation had plants in a ratio of 3 tall to 1 short. From this experiment and others using different traits, Mendel developed several conclusions

10. Mendel realized that the gene for short plants did get passed on, but it was hidden. What do we call alleles that can be hidden? _____ What do we call alleles that always show up? _____

_____

11. Mendel also realized that just as there is a pair of parents, the individual plant must have a pair of alleles. What term do we used to describe an individual with two of the same alleles? _____

What term do we used to describe an individual with two different alleles? _____

13. Next, Mendel understood that while an individual has two genes for each trait, only one gets passed to the offspring. Mendel called this _____ . What actually segregates during meiosis? _____ In what part of the cell cycle do chromosomes segregate? _____

14. Mendel finally generated his law of independent assortment. State the law of independent assortment. _____

_____

_____

15. In what part of the cell cycle do chromosomes independently assort? _____

16. What meiotic event causes independent assortment? _____

_____

Do the language of genetics worksheet on the next two pages to reinforce important vocabulary

A man named Reginald Punnett devised a method where a box divided into squares could be used to predict the results of various genetic crosses. Usually, four or five steps are involved:

1. Assign the symbols (Indicate which letter of the alphabet stands for which gene)
2. Show the genotypes of the parents with an "X" in between
3. Make the Punnett square. Place the parents gamete on the top and sides and then match of the gamete to indicate the genotype(s) of the offspring
4. Write out the genetype(s) of the offspring (This is usually not done with dihybrid crosses)
5. Write out the phenotypes of the offspring

Examine the following example:

In rats, black fur color is dominant to white fur color. Cross a heterozygous, black-furred rat with a white rat:

1) **B** = gene for black fur
b = gene for white fur

2) Bb X bb

	B	b
b	**Bb**	**bb**
b	**Bb**	**bb**

3

4) ½ Bb, ½ bb
5) ½ Black fur, ½ White fur

Try this one on your own in the space below

17. In humans, free earlobes are dominant to attached earlobe. See diagram below. Cross two heterozygous, people with free earlobes.

Free Attached

While you can train a chimpanzee, or a freshman for that matter, to correctly do a Punnett square problem, neither will develop a deep understanding of what it really represents. Complete the diagram below and add in the letters that represent the gene that the pea plants possess on the sheet labeled Mendel's Work.

Now let's see if you have learned anything.

18. When you place the letters on the top and side of the Punnett square, what process are you really illustrating?

    _____. What did Mendel call this? _____

    In what stage of meiosis does segregation of alleles actually occur? _____

19. When you match the letters in the Punnett square, what process are you really illustrating? _____

Read about test crosses on pg. 256

20. _____ -mating an unknown with a recessive individual.

Example: In chickens, the gene for rose comb is dominant to the gene for single comb. Conduct a test cross with an unknown dominant.

R=gene for rose comb
r =gene for single comb

R? X rr

	r	r
R	**Rr**	**Rr**
?	**?r**	**?r**

21. If all of the offspring express the dominant phenotype the unknown must be a _____.

22. If any of the offspring express the recessive phenotype, the unknown must be _____.

Read pages 256-257 concerning crosses involving more than one trait. Because more than two types of gametes can be formed, a two by two Punnett square will not do. If both parents are heterozygous for both traits, four types of gametes can be formed and the Punnett square will have to be four by four. Other permutations are possible also so the savvy student will determine how many different gametes can form and then make the Punnett square accordingly. Ie. It might be 4X2 or 4X1,2X2 or 4X4.

23. In pea plants yellow seeds are dominant to green seeds and round seeds are dominant to wrinkled seeds. Cross two plants that are heterozygous yellow, heterozygous round seeded plants in the space below.

24. Cross a plant that is heterozygous yellow, heterozygous round seeded with a green, wrinkled plant in the space below.

Read pgs 258-260 on Probability and Genetics

The chance of a random event occurring is one divided by the number of possible outcomes.

25. **Product Rule** or **Addition Rule** - the probability that independent event will occur simultaneously is a product of their individual probabilities

26. **Product Rule** or **Addition Rule** -the probability of an event that can occur two or more independent ways is a sum of the separate probabilities of the different ways

Expected results do not always match observed results. Statistical analysis is required. Ie. Chi Square (X^2)
Keep in mind that chance has no memory. Do the probability problems below and show your work

27. What are the chances of flipping a coin and having it come up heads?

28. What are the chances of a heterozygote placing a dominant gene in its gamete?

29. What are the chances of flipping two coins and having them both come up heads?

30. What are the chances of two heterozygote having a child the expresses the recessive phenotype?

31. What is the probability of rolling a 7 with 2 dice?

32. If a couple have three children who are female, what is the probability of their next child being female?

Chi Square (X^2) *is a statistical analysis based on the probability of probability causing any given variations from mathematically predicted results. Do the Chi Square worksheet on the next three pages*

Read about an exception to independent assortment on pages 274-279

33. Genes located on the same chromosome that tend to be inherited together are called _____.

34. Linked genes do not _____ _____, because they are on the same chromosome and move together through meiosis and fertilization.

35. Since independent assortment does not occur, a dihybrid cross will not produce a F2 phenotype of _____.

36. Thomas Hunt Morgan and his students performed a cross between flies with autosomal recessive mutant alleles for black body (b) and vestigial wings (vg). In Fruit flies, grey body is dominant to black body and long wings are dominant to vestigial wings (a small, crinkled-up wing.) Cross a heterozygous fly with a fly with a black body and vestigial wings. NOTE: THESE GENES APPEAR ON THE SAME CHROMOSOME!

    Write out the expected results in the space below:

    Observed results:
    Gray body, normal wings: 965
    Black body, vestigial wings: 944
    Black body, Normal wings: 206
    Gray body, vestigial wings: 185

37. How the heck did the last two phenotypes appear? _____

    _____

Morgan's understood that the results from this cross showed that the genes were neither unlinked nor totally linked!

38. If the genes were unlinked, a _____ ratio would be expected.

39. If the genes were completely linked, a _____ ratio would be expected.

40 Since 17% of the offspring were recombinants (391 unexpected phenotypes/2300 # offspring x 100 = 17%). Morgan proposed that chromosomes could _____ and exchange parts of homologous chromosomes.

Morgan's Drosophila studies showed that some genes are linked more tightly than others. The frequency of recombination for cn, cinnabar eye color and body color is 9% A.H. Sturtevant (a student of Morgan's) determined that the probability of crossover is proportional. That is, the closer two genes on a chromosome are located from each other the less likely crossover is. Therefore, Sturtevant could use recombination frequencies to assign genes to a linear sequence on a chromosome map. Read pgs 279-281 on genetic maps based on crossover data.

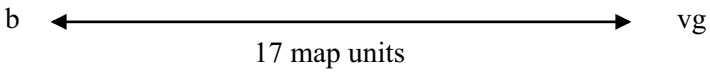
41. Sturtevant expressed the distances between gene in _____ _____ defining it as 1% recombination frequency

Using crossover data to construct a chromosome map.

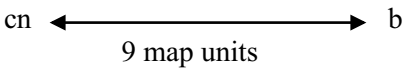
Data

Loci	Recombination Frequency	Approx. Map Units
b vg	17%	18.5*
cn b	9 %	9.0
cn vg	9.5%	9.5

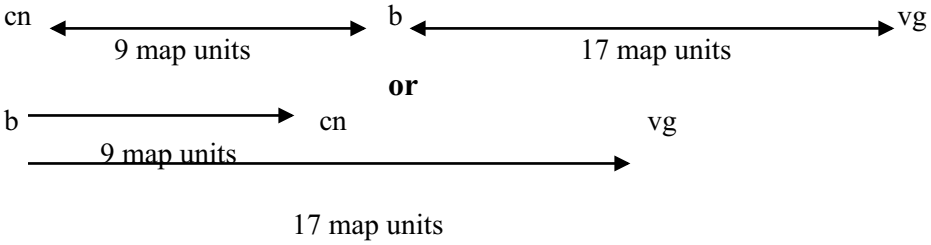
Procedure: Establish the relative distance of the genes that are the furthest apart. Genes with the highest recombination frequencies.



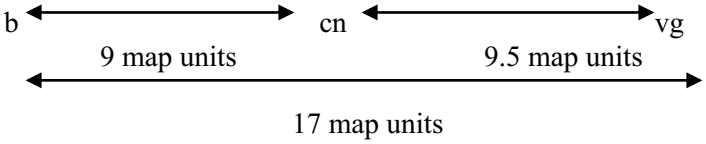
Determine the recombination frequency between the third gene and the first.



Consider the possible placements.



Determine the recombination frequency between the third gene and the second.



***NOTE**: Because vg and b are relatively far apart, double crossover will occur and go unnoticed. Therefore, the actual distance between vg and b is 18.5 map units, not the predicted 17.

42. Construct a linkage map based on the data in the table in the space provided below:

Genes located on chromosome #1:

M+ = normal wings	m = miniature wings
F+ = normal bristles	f = forked bristles
V+ = red eyes	v = vermillion eyes

Data from test crosses:

CROSS #1	F1 generation
P generation	397 normal wings, normal bristles
M+F+mf (x) mfmf	397 miniature wings, forked bristles
	103 miniature wings, normal bristles
	103 normal wings, forked bristles
CROSS #2	F1 generation
P generation	480 normal bristles, red eyes
F+V+fv (x) fvfv	493 forked bristles, vermillion eyes
	13 normal bristles, vermillion eyes
	14 forked bristles, red eyes
CROSS #3	F1 generation
P generation	375 normal wings, red eyes
M+V+mv (x) mvmv	388 miniature wings, vermillion eyes
	117 normal wings, vermillion eyes
	120 miniature wings, red eyes

Unfortunately many inheritance patterns are much more complex than simple Mendelian genetics can predict. There are situations where neither gene is dominant, or both genes are dominant or multiple alleles. Read pages 260-262 about these modes of inheritance and answer the questions below:

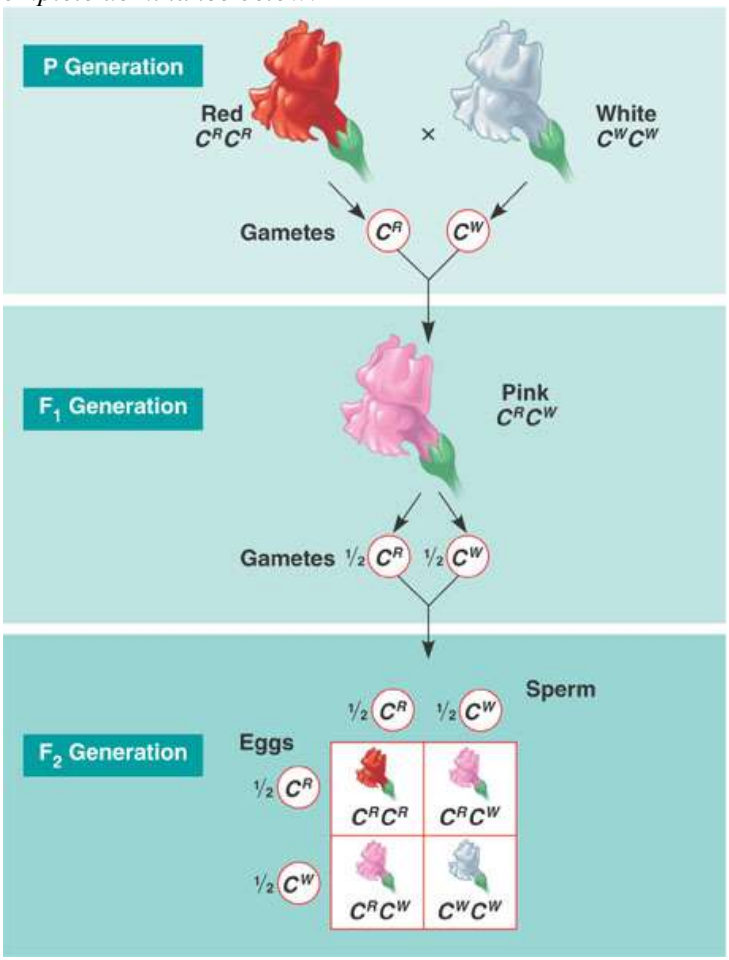
43. What is the name of the inheritance pattern in which one gene is dominant over another as in Mendel's pea plants? _____ _____

44. What is the name of the inheritance pattern in which two alleles are dominant and both affect the phenotype in separate distinguishable ways? _____

45. What is the name of the inheritance pattern in which neither allele is dominant and heterozygotes display a phenotype that is intermediate between the phenotypes of either homozygote? _____

_____

Look at the example of incomplete dominance below:



46. Cross a red snap dragon and a pink snap dragon in the space below:

47. In guinea pigs, the gene for a long tail is incompletely dominant with the gene for a stub tail producing a guinea pig with a medium sized tail. Cross a stub-tailed pig with a medium tailed pig in the space below

48. Read about ABO blood group determination and fill out the rest of the table below:

Phenotype	Genotype(s)	Proteins	Antibodies	Trans-fusions
Type A	I^AI^A, I^Ai	Isoagglutinin A	Anti B	A or O

49. Cross an individual who is heterozygous type A with a person who is heterozygous type B.

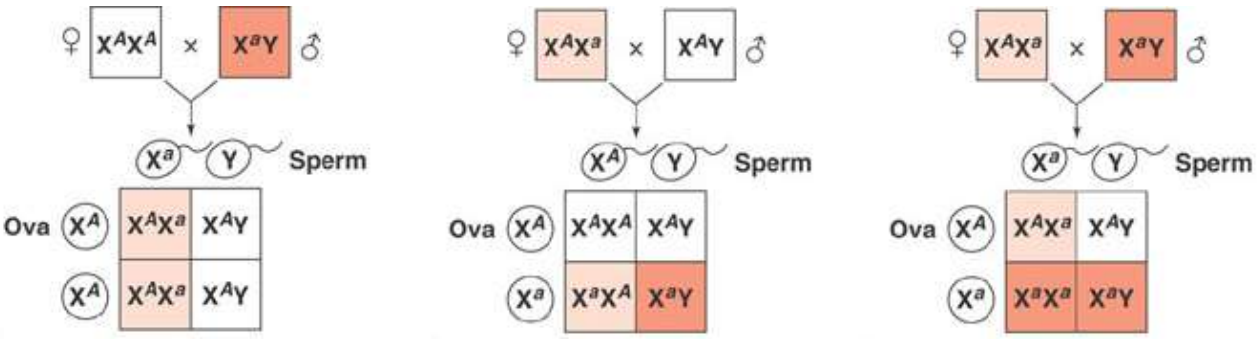
50. Cross an individual who is type AB with a person who is type O.

51. Three babies were recently mixed up in a hospital. Baby #1 has type B blood, baby #2 has type O blood, baby #3 has type AB blood. Mr. and Mrs. Smith both have blood type A. Mr. Jones has blood type A while Mrs. Jones has blood type B. Mr. Thomas has blood type B and Mrs. Thomas has blood type O. Which babies belong to which parents? Show how you know below.

Jump back to chapter 14 and read about sex determination and inheritance of sex linked genes on pgs 282-284.

52. Normal females have two _____ chromosomes whereas normal males contain a _____ chromosome and a _____ chromosome. Because of this the **mother** or **father** determines the sex of the offspring in humans.

Because men only have one X chromosome, men cannot be heterozygotes. Men express the phenotype of the allele that they receive. See the diagram below:



Therefore, deleterious recessive alleles like the ones for Duchenne muscular dystrophy, hemophilia and colorblindness occur much more frequently in men than women because they must receive two copies of the harmful allele while men only need one. Answer the X-linked gene problems below:

53. In humans the allele for colored vision is dominant to the allele for colorblindness. The locus for these alleles is on the X chromosome. Cross a woman who has normal vision but carries the colorblind allele with a man with normal colored vision.

54. In humans the allele for blood clotting protein is dominant to the allele for hemophilia. The locus for these alleles is on the X chromosome. Cross a woman who is homozygous normal blood clotting with a hemophiliac man.

55. Why don't women make twice as much X-linked gene product as men? _____

_____

Read the paragraph on pleiotropy on page 262 and the read about cystic fibrosis and sickle cell disease on pages 266-267

56. What is pleiotropy? _____

_____

57. Choose either cystic fibrosis or sickle cell disease and explain why it is an excellent example of pleiotropy.

_____

_____

_____

Read about epistasis and multifactorial inheritance on 262-264 and answer the problems below:

58. In mice and other rodents, the gene for black fur is dominant to the gene for brown fur and the gene for pigment deposition (C) is dominant to the lack of pigment deposition. The pigment deposition gene is epistatic to the gene for pigment production. In other words, whether the pigment can be deposited determines whether the gene for fur color can be expressed. Homozygous recessive pigment deposition (cc) will result in an albino mouse regardless of the genotype at the black/brown locus. (BB,Bb,bb). Cross two mice that are heterozygous for black fur and pigment deposition.

59. Multifactorial inheritance, as the name implies, involves multiple gene and environmental influences. Skin coloration is an excellent example of multifactorial inheritance. It is believe that at least three separately inherited genes are involved. Inheritance of the dominant allele at any of the loci increases the production of melanin and results in darker skin. Gene that have an additive effect on the phenotype like the melanin genes

are said to be _____ _____. Other genes for the thickness of the skin and the epistatic pigment deposition genes also play a role.

60. List some environmental factors that effect skin coloration. _____

_____