

7.013 Recitation 4 -2012

Summary of Lectures 5 - 7:

Introduction to Genetics: Each double-stranded piece of DNA in a cell is a chromosome. A eukaryotic cell usually contains 5-50 linear chromosomes. A chromosome is comprised of DNA and histone proteins and usually has a few thousand genes on it, all in a row. A gene is a short region of DNA (a few 1000 nucleotides) that encodes the RNA or a protein that has some specific cellular function. Two alleles (or versions) of the same gene may differ at only a single nucleotide and often affect the identity of only a single amino acid in the protein product of the gene. This single amino acid change may alter a gene product such that it works differently or not at all. The changed function of that protein may affect the phenotype of the organism possessing that allele; for instance, a single nucleotide change in the DNA of a plant can result in wrinkled seeds instead of round seeds. The genotype of an organism is the alleles possessed by that organism. The phenotype of an organism is how that organism looks on the outside (round or wrinkled).

Mendel's laws and monohybrid cross: A monohybrid cross is when you cross two true-breeding (i.e. homozygous) organisms that differ by a single characteristic, such as plants that produce rounded versus wrinkled seeds. The two organisms you cross are called the P (parental) generation. For example, a cross between two individuals, which are both homozygous and differ from each other in one gene can be represented as AA X aa. The offspring will all receive one allele from each parent and will have the genotype Aa. They will display whichever of the two phenotypes is dominant. If you cross two F1 organisms together (Aa x Aa), you create the F2 generation. The ratios of different genotypes and phenotypes within the F2 generation can be derived either by using the laws of basic probability (the sum rule and the product rule) or by using a Punnett Square.

Dihybrid cross: A dihybrid cross is when you cross two true-breeding organisms that differ by two characteristics, such as plants that produce rounded green (AABB) versus wrinkled yellow (aabb) seeds. The F1 will be genotypically AaBb and will display the dominant shape and dominant color phenotype. If you cross two F1 organisms together, you create the F2 generation. Each parent passes on one of their two alleles at each gene to the new progeny, and thus the F2 will consist of a phenotypic ratio of 9:3:3:1 (if the genes are independent from one another).

Cell division: Mitosis consists of four phases. In prophase, the chromosomes become condensed and visible. In metaphase, the chromosomes all align along the central axis of the cell. In anaphase, the sister chromatids separate from each other such that one copy of the genome goes to each daughter cell. In telophase, the separated nuclei decondense their chromosomes so that you can no longer see individual DNA molecules. Right after mitosis, cytokinesis occurs, which is the division of everything else besides the nucleus (i.e. the cytoplasm and all of the organelles contained in the cytoplasm). Meiosis has two divisions; meiosis I looks different from mitosis, but meiosis II looks similar to mitosis. The result of meiosis is the production of haploid gamete cells such as eggs or sperm, each of which has half the number of chromosomes as a diploid somatic cell.

Recombination and crossing over: Homologous recombination is the reciprocal exchange of DNA between two homologous chromosomes that occurs only during metaphase of meiosis I. During homologous recombination, two homologs (e.g. the chromosome #7 inherited from dad and the chromosome #7 inherited from mom) break at the same place and switch ends with each other. Homologous recombination results in a change in which alleles are on the same chromosomes together (e.g. a cell with "AB" on the maternal homolog and "ab" on the paternal homolog can give rise to gametes containing "Ab" or "aB" chromosomes). The two recombinants ("Ab" and "aB") will always be created in equal frequencies because one of each kind is created by a single recombination event.

Two genes can either be unlinked, completely linked or somewhat linked. Genes that are unlinked are usually located on different chromosomes from each other or are located far apart from each other on the same chromosome. Genes that are completely linked are very close to each other on the same chromosome. Genes that are somewhat linked are located on the same chromosome with a map distance of <50cM. Unlinked genes assort independently from each other; this means that an AaBb parent would create their four possible gametes (AB, ab, Ab, and aB) each 25% of the time. Genes that

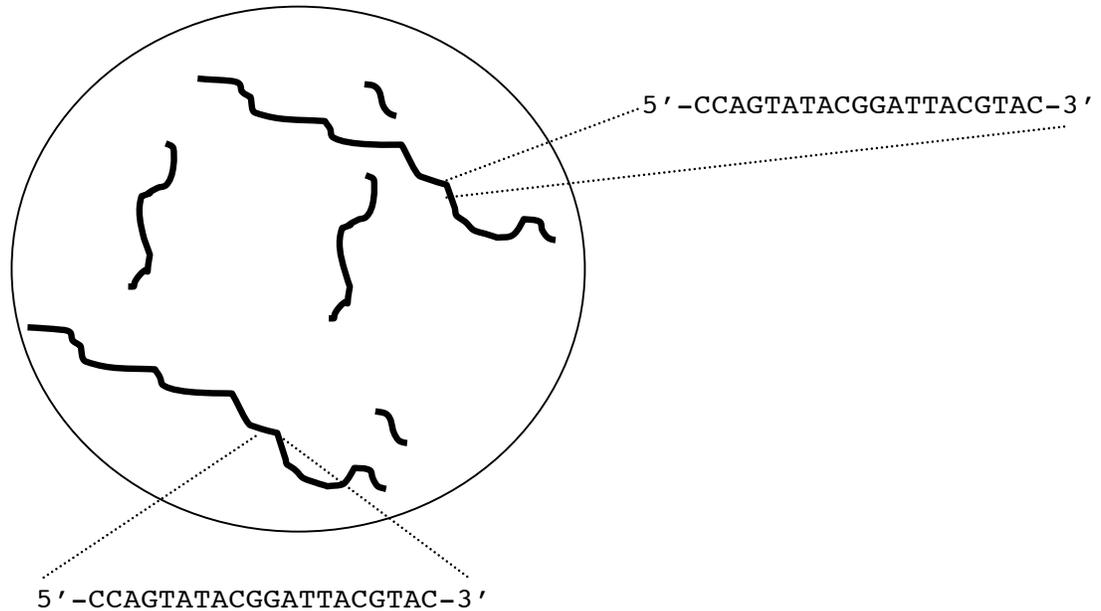
are completely linked always segregate with each other. This means that an AaBb parent would create only two of the four possible gametes. Genes that are somewhat linked to each other show a pattern that is in between what is seen for unlinked genes and completely linked genes.

Questions:

1. Below is pictured the nucleus from a skin cell taken from a mouse (named Mouse #1), with the chromosomes shown in bold.

a) Is the cell haploid or diploid?

b) Let's say we blew up a region of the longest chromosome to look at its sequence at one small gene.



- i. Is Mouse #1 homozygous or heterozygous for this gene?
- ii. Now we zoom in on the same exact gene on the long chromosome in a cell from a mouse named Mouse #2 and find that its two homologous chromosomes have the sequences:

5'-CCAGTATACGGAGTACGTAC-3'
Sequence 1

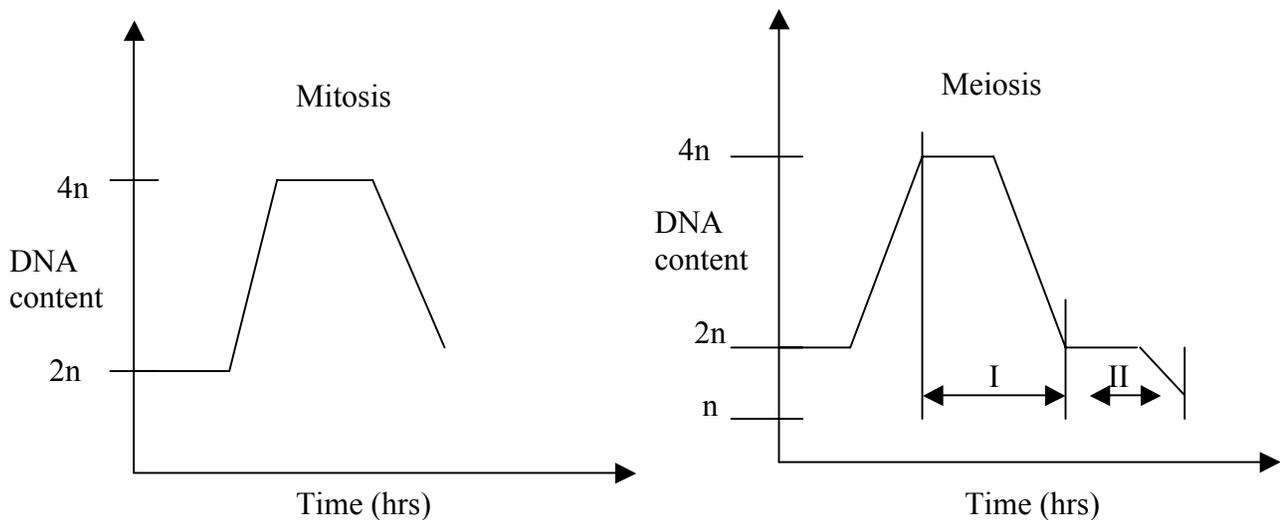
5'-CCAGTATACGGATTACGTAC-3'
Sequence 2

How might we write the genotypes of Mouse #1 and Mouse #2 if Sequence #1 encodes a functional protein but Sequence #2 encodes a protein that no longer works? (*Note: Use the upper case or lowercase A while writing the genotypes*).

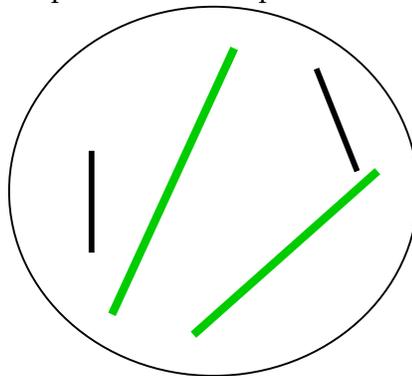
2. Consider a humming bird whose body color is controlled by the B gene. These humming birds are either green or yellow, where green color is dominant to yellow. Give the expected ratio (both phenotypes and genotypes) of the offspring for the following crosses.

	Genotypic ratio	Phenotypic ratio
Cross 1: BB x BB	Offspring:	
Cross 2: bb x bb	Offspring:	
Cross 3: Bb X Bb	Offspring:	
Cross 4: Bb X bb	Offspring:	

3. In a diploid cell (2n), that is undergoing cell division, draw a graph showing the variation in the DNA content (n = haploid) against time for the mitosis and meiosis.



4. A schematic of a diploid nucleus prior to DNA replication is drawn below. It contains two pairs of chromosomes (2n = 4).



The genotype of the cell above is DdEeFf, where the D and E loci are on the large chromosome and the F locus is on the small chromosome. This cell was taken from an F1 organism that resulted from the cross of two true-breeding parents such that Parent 1 is DDeeFF and Parent 2 is ddEEff. Draw and align the chromosomes as they could be when in **metaphase of meiosis I**. Include the D, d, E, e, F, and f alleles on the drawing and assume no recombination. Given your drawing, draw the chromosomes in each of the two products resulting from meiosis I. Include the D, d, E, e, F, and f alleles on the drawing.

5. Tomato plants can be **tall** or **short** and have **notched** or **smooth** leaves. You cross a tall, smooth leafed plant with a short, notched leafed plant. All of the progeny are **tall**, and **notched** leafed.

a) Which traits are dominant and which are recessive?

b) What are the genotypes of the two **true-breeding** parents? Use the letters *H* or *h* to represent the alleles of the height gene and the letters *S* or *s* to represent the alleles of the leaf gene. In each case, use the uppercase letter for the allele associated with the dominant phenotype and the lower case letter for the allele associated with the recessive phenotype.

c) Two tall, notched F1 plants were crossed.

i. Diagram this cross.

ii. If these two traits are **unlinked**, what ratio of phenotype do you expect in the F2 generation?

6. In fruit flies, the “B/b” gene and the “G/g” gene are linked. In one specific fly whose genotype is GgBb, “B” is linked to “g” on the maternal chromosome #2, and “b” is linked to “G” on the paternal chromosome #2. Note: *This is a practice question related to lecture 8.*

i. List all parental type (non-recombinant) gametes by genotype that could be produced by this GgBb fly.

ii. List all recombinant gametes by genotype that could be produced by this GgBb fly.

iii. Say that 40% of all gametes produced by the GgBb fly are “Bg.” What percentage of all gametes produced by this fly are recombinants?

iv. As the recombination frequency between two genes on the same chromosome rises, does the physical distance between those two genes lower or rise?

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