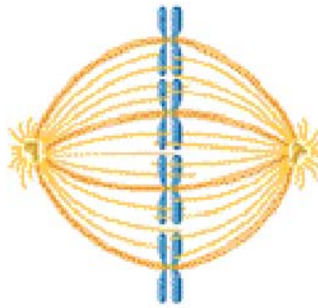
S1.A diploid cell has eight chromosomes, four per set. In the following diagram, what phase of mitosis, meiosis I or meiosis II, is this
cell in?



Answer: The cell is in metaphase of meiosis II. You can tell because the chromosomes are lined up along the metaphase plate, and it has only four pairs of sister chromatids. If it were mitosis, the cell would have eight pairs of sister chromatids.

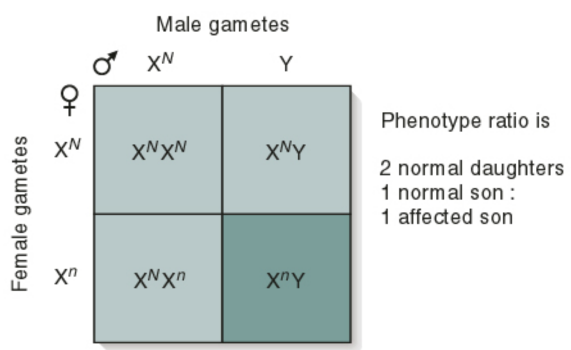
S2. An unaffected woman (i.e., without disease symptoms) who is heterozygous for the X-linked allele causing Duchenne muscular dystrophy has children with a normal man. What are the probabilities of the following combinations of offspring?

A. An unaffected son

B. An unaffected son or daughter

C. A family of three children, all of whom are affected

Answer: The first thing we must do is construct a Punnett square to determine the outcome of the cross. *N* represents the normal allele, *n* the recessive allele causing Duchenne muscular dystrophy. The mother is heterozygous and the father is hemizygous for the normal allele.



A. There are four possible children, one of whom is an unaffected son. Therefore, the probability of an unaffected son is 1/4.

B. Use the sum rule: 1/4 + 1/2 = 3/4.

C. You could use the product rule, since there would be three offspring, in a row, with the disorder: (1/4)(1/4)(1/4) = 1/64 = 0.016 = 1.6%.

S3. What are the major differences between prophase, metaphase, and anaphase when comparing mitosis, meiosis I, and meiosis II?

Answer: The table summarizes key differences.

A Comparison of Mitosis, Meiosis I, and Meiosis II

Phase	**Event**	**Mitosis**	**Meiosis I**	**Meiosis II**
Prophase	Synapsis:	No	Yes	No
Prophase	Crossing over:	Rarely	Commonly	Rarely
Metaphase	Alignment along the metaphase plate:	Sister chro-matids	Bivalents	Sister chro-matids
Anaphase	Separation of:	Sister chro-matids	Bivalents	Sister chro-matids

S4. Among different plant species, gametophytes can be produced by single individuals or by separate sexes. In some species, such as the garden pea, a single individual can produce both male and female gametophytes. Such a species is called monoecious (or monecious).

In monoecious species, fertilization takes place via self-fertilization or cross-fertilization. A monoecious plant species that has a single type of flower producing both pollen and eggs is a monoclinous plant. In other plant species, two different types of flowers produce pollen and eggs. When this occurs, it is most common for the "male flowers" to be produced near the top of the plant and the "female flowers" toward the bottom. There are also a few species of plants that are dioecious. For dioecious species, one individual makes either male flowers or female flowers, but not both.

Give examples of monoecious plants that are monoclinous and some that are not. Give examples of dioecious plants. What would be the advantages and disadvantages of being monoecious compared to dioecious?

Answer:

Monoecious, monoclinous plants—pea plant, tulip, and roses. The same flower produces pollen on the anthers and egg cells within the ovary.

Monoecious, nonmonoclinous plant—corn. In corn, the tassels are the male flowers and the ears result from fertilization within the female flowers.

Dioecious plants—ginkgo and fig trees. Certain individuals produce only pollen while others produce only eggs.

An advantage of being monoecious is that fertilization is relatively easy because the pollen and egg cells are produced on the same individual. This is particularly true for monoclinous plants. The proximity of the pollen to the egg cells makes it more likely for self-fertilization to occur. This is advantageous if the plant population is relatively sparse. On the other hand, a dioecious species can reproduce only via cross-fertilization. The advantage of cross-fertilization is that it enhances genetic variation. Over the long run, this can be an advantage because cross-fertilization is more likely to produce a varied population of individuals, some of which may possess combinations of traits that promote survival.

S5. In humans, why are X-linked recessive traits more likely to occur in males compared to females?

Answer: Because a male is hemizygous for X-linked traits, the phenotypic expression of X-linked traits depends on only a single copy of the gene. When a male inherits a recessive X-linked allele, he will automatically exhibit the trait because he does not have another copy of the gene on the corresponding Y chromosome. This phenomenon is particularly relevant to the inheritance of recessive X-linked alleles that cause human disease. Some examples are described in chapter 22.

S6. To test the chromosome theory of inheritance, Calvin Bridges made crosses involving the inheritance of X-linked traits. One of his experiments involved two different X-linked genes affecting eye color and wing shape. For the eye color gene, the red-eye allele is dominant to the white-eye allele. A second X-linked trait is wing size; the allele called miniature is recessive to the normal allele. In this case, *m* represents the miniature allele and m^+ the normal allele. A hemizygous male fly containing a miniature allele has small (miniature) wings. A female must be homozygous, *mm,* in order to have miniature wings.

Bridges made a cross between $X^{w,m+}$ $X^{w,m+}$ female flies (white eyes and normal wings) to $X^{w+,m}$ Y male flies (red eyes and miniature wings). He then examined the eyes, wings, and sexes of thousands of offspring. Most of the offspring were males with white eyes and normal wings, and females with red eyes and normal wings. On rare occasions (i.e., approximately 1 out of 1,700 flies), however, he also obtained female offspring with white eyes or males with red eyes. He also noted the wing shape in these flies and then cytologically examined their chromosome composition using a microscope. The following results were obtained:

Offspring	Eye color	Wing Size	Sex Chromosomes
Expected females	Red	Normal	XX
Expected males	White	Normal	XY
Unexpected females (rare)	White	Normal	XXY
Unexpected males (rare)	Red	Miniature	X0

Data from: Bridges, C. B. "Non-Disjunction as Proof of the Chromosome Theory of Heredity," *Genetics 1*, 1–52, 107–63.

Explain these data.

Answer: Remember that in fruit flies, it is the number of X chromosomes (not the presence of the Y chromosome) that determines sex. As seen in the data, the flies with unexpected phenotypes were abnormal in their sex chromosome composition. The white-eyed female flies were due to the union between an abnormal XX female gamete and a normal Y male gamete. Likewise, the unexpected male offspring contained only one X chromosome and no Y. These male offspring were due to the union between an abnormal egg without any X chromosome and a normal sperm containing one X chromosome. The wing size of the unexpected males was a particularly significant result. The red-eyed males showed a miniature wing size. As noted by Bridges, this means that they inherited their X chromosome from their father rather than their mother. This observation provided compelling evidence that the inheritance of the X chromosome correlates with the inheritance of particular traits.

At the time of his work, Bridges's results were particularly striking since chromosomal abnormalities had been rarely observed in *Drosophila.* Nevertheless, Bridges first predicted how chromosomal abnormalities would cause certain unexpected phenotypes and then he actually observed the abnormal number of chromosomes using a microscope. Together, his work provided evidence confirming the idea that traits that follow an X-linked pattern of inheritance are governed by genes that are physically located on the X chromosome.