CHAPTER 10 MEIOSIS AND SEXUAL LIFE CYCLES

Scientific Skills Exercise

Teaching objective: Students will identify the independent and dependent variables in a table of data and graph the data to identify phases of meiosis in a yeast culture. They will also get practice doing calculations with exponents, such as calculating the haploid genome size for this species of yeast (*Saccharomyces cerevisiae*, commonly known as budding yeast).

Teaching tips: A version of this Scientific Skills Exercise can be assigned in MasteringBiology.

This is a basic graphing exercise with time-related data. Students may have difficulty with the extremely small units—femtograms (fg)—used for the DNA. A review of metric units will be helpful to them. If you want your students to have more practice with calculations, you could extend question 4 by asking questions such as how many base pairs are in a nanogram (ng) or how many kilobases (kb) are in a femtogram, etc.

The points at which samples were taken are not all 1 hour apart. This means that the students will have to decide what interval to use on the *x*-axis for the tick marks. It doesn't matter whether they use 0.5 or 1 hour intervals so long as they are consistent and put the dots in the correct locations. You can explain that the researchers collected samples more frequently during the stages when the DNA content was changing, to better resolve when the events occurred.

Students may question why the line on the graph is not flat for each stage of meiosis. This is because the data come from a population of cells, and there is some variation among the yeast cells in their timing of progression through the process. This also explains why the amount of DNA does not drop instantly at the end of MI and/or MII phase: Not all of the cells divide at exactly the same time and so the average includes some pre-division cells, some dividing cells, and some post-division cells for the relevant time points. This subtlety is addressed in question 3(d). The more advanced students will be able to think this through and realize that because the *y*-axis is the amount of DNA per cell, the cell will have the duplicated amount of DNA (48 fg) in one cell until two cells form at the end of meiosis I. At this point, the DNA content drops in half. If you were graphing the DNA content of a single cell, this line would drop vertically to about 24 fg. Because this is a population of cells and they are completing MI at slightly different times, given that the line represents the *average* of the population, it gradually decreases as a diagonal rather than a vertical drop.

Students will not be able to precisely delineate each stage on the graph due to the population variability. Instruct them to approximate based on what they expect for DNA content at each stage.

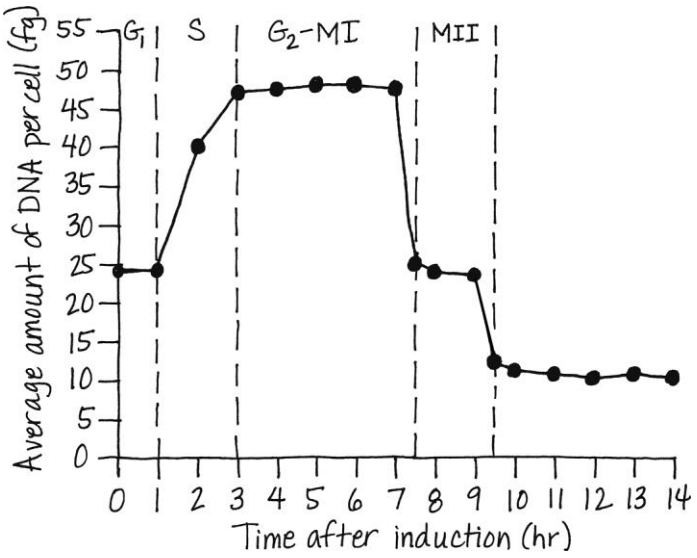
Answers:

1. (a) The independent variable is time, which goes on the *x*-axis, measured in hours (hr). The dependent variable is average amount of DNA per cell, which goes on the *y*-axis and is measured in femtograms (fg). (b) The *x*-axis has data points over 14 hours, so it makes sense to label a tick for each hour. (It would also be fine to label a tick for each half-hour, as long as all were labeled,

but this could look cluttered.) The *y*-axis has data points as high as 48.0 fg, so a logical decision would be to label tick marks every 5 fg up through 50 or 55 fg. See the graph in the answer to question 3.

2. See the graph in the answer to question 3.

3. (a) There are 24 fg of DNA in G_1 (at 0.0 hr). (b) There should be 48 fg in G_2; 24 fg at the end of MI; and 12 fg at the end of MII. (c)



(d) Because the *y*-axis is the amount of DNA per cell, the cell will have the duplicated amount of DNA (48 fg) in one cell until two cells form at the end of meiosis I. Therefore, the "corner" in the data line represents the stage at which the cell divides at the end of meiosis I (cytokinesis). At this point, the DNA content in each cell drops in half. If you were graphing the DNA content of a single cell, this line would drop vertically to about 24 fg. Because this is a population of cells—and they are completing MI at slightly different times—given that the line represents the *average* of the population, it gradually decreases as a diagonal rather than a vertical drop.

4. (a) Each haploid cell has 12 fg of DNA. (12 fg of DNA) x (9.78×10^5 base pairs per fg) = 1.2×10^7 or 12×10^6 base pairs, therefore there are 12 megabase pairs (Mb) of DNA in each haploid cell. (b) The answer for this will depend on the length of the S phase in the student's graph. The answer is 1.2×10^7 base pairs (haploid value) x 2 (for diploid value) divided by the number of minutes of the S phase. For the example shown, (1.2×10^7 base pairs)(2)/120 minutes = 200,000 (or 2.0×10^5) base pairs per minute.

Suggested Answers for End-of-Chapter Essay Questions

See the general information on grading short-answer essays and a suggested rubric at the beginning of this document.

7. Scientific Inquiry
The alleles for freckles or no freckles are on all four chromatids at the F locus, and those for

black or blond hair are at the H locus. Let's assume that the alleles on the red chromatids are for freckles and black hair and the alleles on the blue chromatids are for no freckles and blond hair. By drawing the chromatids, you can follow the alleles through meiosis. The chromatids that did not participate in crossovers will donate either freckles and black hair alleles or no freckles and blond hair alleles (which you can determine by the color of the chromatid). The chromatids that were involved in crossovers have the other possible combinations, so all four possibilities will exist in the gametes from this meiotic division:

- freckles, black hair (If you drew the chromosomes in the gametes after meiosis II, the chromosome in this gamete will be red at both F and H.)
- no freckles, blond hair (blue at both F and H)
- freckles, blond hair (red at F and blue at H)
- no freckles, black hair (blue at F and red at H)

No other possible combinations exist, so no additional combinations will be seen in gametes from other meioses in this individual. (If we tried the other assumption, that the alleles on the blue chromatids were for freckles and black hair and those on the red chromatids were for the other traits, the results would be the same with the colors reversed.)

8. Focus on Evolution

When the environment becomes unfavorable, this means it is unfavorable for a particular genotype or genome that had been successfully adapted to the previous environment. At such times, it becomes advantageous to switch from asexual reproduction, which results in genetically identical daughter cells (all of which would be at a disadvantage), to sexual reproduction, which introduces genetic variation into the daughter cells. Doing so increases the likelihood that at least some of the individuals in the next generation will have genetic combinations that allow them to survive and reproduce under the new conditions.

9. Focus on Information

Sample key points:

- Genes are stretches of DNA in chromosomes that encode traits and are passed on from parent to offspring.
- Chromosome behavior during sexual reproduction accounts for both similarity and variation among offspring.
- Inheritance of genes accounts for offspring exhibiting traits similar to those of each parent.
- In sexual reproduction, meiosis alternates with fertilization.
- Crossing over and independent assortment of chromosomes during meiosis lead to genetic variation among gametes.
- Random fertilization increases the genetic variation among diploid offspring.

Sample top-scoring answer:

Genes encoding traits exist as stretches of the DNA molecule in a chromosome. Chromosome behavior during meiosis and fertilization—processes that alternate in sexual reproduction—accounts for both the inheritance of traits and the generation of genetic variation. Meiosis in each parent generates haploid gametes with a single set of chromosomes. During this process, crossing over and independent assortment of chromosomes result in many gametes with novel combinations of alleles. Any pair of gametes, each containing chromosomes from one parent, can fuse during fertilization to make a diploid cell. This random fertilization further augments the number of different possible combinations of traits that can be obtained. The zygote develops

through mitosis into a multicellular diploid offspring. Because the offspring inherits genes from both parents, it exhibits traits of each, in new combinations. Thus, both meiosis and fertilization ensure inheritance of parental traits as well as genetic variation among offspring.

10. Synthesize Your Knowledge

With three sets of chromosomes, there is no way for the sets to be separated equally to gametes during meiosis, and so seeds (which are embryos formed after meiosis and fertilization) cannot form. Thus, taking cuttings from the plants and rooting them is the only way new plants can be grown. Sexual reproduction generates genetic diversity, whereas asexual reproduction generally does not. Genetic diversity would allow more genetic variants to be present. Some of the genetic variants might have a particular combination of genes that would allow them to resist infection by the fungus. These genetic variants would not be possible in a population of plants that reproduces (or is reproduced by growers) asexually. (In fact, this is one argument against agricultural "monocultures" that are propagated by cloning—they are often less resistant to bacterial, fungal, and other pests.)