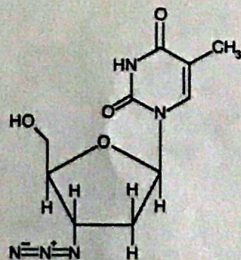


1. The bacterium *E. coli* has a single circular DNA molecule containing 4.7 million base pairs. The bacterial cell itself is roughly a cylinder with a diameter of 1  $\mu\text{m}$  and a length of 2  $\mu\text{m}$ . Each turn of the helix contains close to 10 base pairs, and a single turn of the helix is 3.4 nm in length. The diameter of the helix is 2 nm.
  - a. Consider the chromosome to be a piece of string. How long would it be?
  - b. Calculate the volume that a single DNA molecule occupies. Assume that it is a long cylinder.
  - c. What proportion of the total volume of the bacterial cell does the DNA occupy?
  - d. *E. coli* cells can divide every twenty minutes. Based on this, estimate how fast DNA replication must proceed (in nucleotides/sec). Does this strike you as pretty fast or pretty slow?
  - e. At what rate must the double helix unwind (in revolutions per minute) in order to sustain this rate of replication? Does this strike you as pretty fast or pretty slow? For context, compare this rate to some piece of machinery whose RPMs you know.
  
2. In the DNA of certain bacterial cells, 18% of the nucleotides are cytosine. What are the percentages of the other nucleotides?
  
3. The compound whose structure is shown below can be used to treat patients with AIDS. The disease is caused by the human immunodeficiency virus (HIV), which is a member of the class of viruses known as retroviruses. Retroviruses contain RNA as their genetic material; a DNA copy of the viral RNA is made during infection by a viral enzyme called reverse transcriptase.



Given the structure of this compound, how do you think it might work to reduce the amount of HIV present in some patients?

4. An adult human is composed of about  $10^{13}$  cells, all of which are derived by cell division from a single fertilized egg.
- Assuming that all cells continue to divide at the same rate after fertilization, how many generations of cell divisions would be required to produce an adult?
  - Human cells in culture typically divide about every 24 hours. Assuming that all cells divide at this rate during development, how long would it take to generate an adult?
  - Why is it, do you think, that adult humans take longer to develop than these calculations might suggest?
5. Cell growth depends on nutrient uptake and waste disposal. You might hypothesize that the rate of movement of nutrients and waste products in and out of the cell would be an important determinant of the rate of cell growth. You therefore wonder whether there might be a correlation between a cell's growth rate and its surface-to-volume ratio. Assuming cells are spheres, compare a bacterium (radius  $1\ \mu\text{m}$ ), which divides every 20 minutes, with a human cell (radius  $10\ \mu\text{m}$ ), which divides every 24 hours. Is there a match between the surface-to-volume ratios and the doubling times for these cells? Do you think that growth rate can be explained based on the hypothesis stated earlier in the problem?
6. DNA that is isolated from the bacterial M13 virus contains 25% A, 33% T, 22% C, and 20% G. Do these results surprise you at all? Why or why not? How can you explain these values?
7. As a born skeptic, you plan to confirm for yourself the results of the classic Meselson and Stahl experiment. You "synchronize" a culture of growing cells so that virtually all cells begin and complete DNA synthesis at the same time. You first grow the cells in a medium that contains nutrients highly enriched in heavy isotopes of nitrogen and carbon ( $^{15}\text{N}$  and  $^{13}\text{C}$  in place of the naturally abundant  $^{14}\text{N}$  and  $^{12}\text{C}$ ). Cells growing in the "heavy" medium use the heavy isotopes to build all their macromolecules, including nucleotides and nucleic acids. You then transfer the cells to a normal, "light" medium containing  $^{14}\text{N}$  and  $^{12}\text{C}$  nutrients. Finally, you isolate DNA from cells that have grown for different numbers of generations in the light medium and determine the density of their DNA by density-gradient centrifugation. Your data, plotting the amount of DNA isolated versus its density, are shown below:

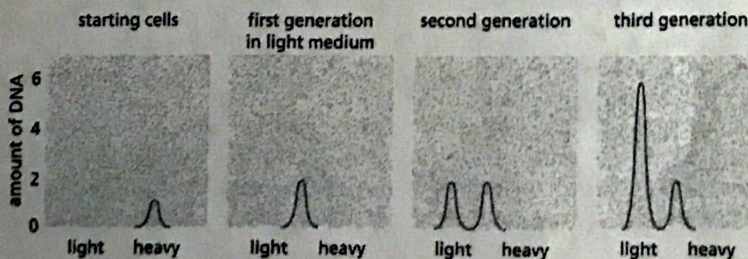


Figure 5-5 Density of DNAs isolated from cells that were grown for different times in "light" medium after initial growth in medium enriched for heavy isotopes of nitrogen and carbon (Problem 5-35). Equal culture volumes were analyzed for each time point. Amount of DNA is in arbitrary units, with the peak amount of DNA in the sample containing starting cells set equal to 1.

Explain these results. Are these data in agreement with your expectations?