**C H A P T E R**

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A Preview of Cell Biology

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| 1-1. | (a)(b)(c) | C (d) B (g) G (j) GB (e) G (h) B, C (k) CG (f) C (i) B (l) B |

1-2. (a) Bacterial cell: *V* = *πr*2*h* = (3.14)(0.5)2(2.0) = **1.57 *µ*m3.**

 Liver cell: *V* = 4*πr*3/3 = 4(3.14)(10)3/3 = **4200 *µ*m3.**

 Palisade cell: *V* = *πr*2*h* = (3.14)(10)2(35) = **11,000 *µ*m3.**

(b) Number of bacterial cells in a liver cell: 4200/1.57 = **2700.**

(c) Number of liver cells in a palisade cell: 11,000/4200 = **2.62.**

1-3. (a) Light microscope: limit of resolution = 200 nm. Because one membrane has a thickness
of about 8 nm, the number of membranes that must be aligned laterally is 200/8 =
**25 membranes.**

 Electron microscope: limit of resolution = 0.1–0.2 nm. With a thickness of about 8 nm, a single membrane can be seen using an electron microscope.

(b) Liver cell: *V* = 4200 *µ*m3 (from Problem 1-2a).

 Ribosome: *V* = 4*πr*3/3 = 4(3.14)(0.015)3/3 = 1.4  10−5 *µ*m3.

 Number of ribosomes in a liver cell: 4200/(1.4  10−5) = **3** **10**8**.**

(c) Bacterial cell: *V* = 1.57 *µ*m3 (from Problem 1-2a).

 DNA molecule: *V* = *πr*2*h* = (3.14)(1 nm)2(1.36 mm)

 = (3.14)(0.001 *µ*m)2(1.36 103 *µ*m)

 = (3.14)(1 10–6 *µ*m2)(1.36 103 *µ*m)

 = (3.14)(1.36)(10–3) *µ*m3 = 4.3 10–3 *µ*m3.

 DNA = (4.3 10–3) /1.57 = 0.0027 = **0.27% of cell volume.**

1-4. (a) The *limit of resolution* of a microscope is a measure of how close together two points can be and yet still be distinguished from one another when viewed under the microscope. (Note that the limit of resolution is inversely related to magnification; the greater the magnification of a microscope, the smaller its limit of resolution.) Hooke’s microscope can only magnify objects 30-fold, so its limit of resolution is one-thirtieth that of the human eye: 0.25 mm/
30 = 0.0083 mm, or 8.3 *µ*m. Van Leeuwenhoek’s microscope can magnify objects 300-fold, which is a 10-fold greater magnification than that of Hooke's microscope, so the limit of resolution of van Leeuwenhoek’s microscope is one-tenth that of Hooke’s microscope:
8.3 *µ*m/10 = 0.83 *µ*m.

(b) The smallest structures that Hooke could see were about 8.3 *µ*m in one dimension, which would have allowed him to see the plant and animal cells shown in Figure 1-4a of the textbook, but not a typical bacterial cell.

(c) The smallest structures that van Leeuwenhoek could see were about 0.83 *µ*m in one dimension, which would have allowed him to see all three of the structures shown in Figure 1-4a.

(d) The limit of resolution of a modern light microscope is about 200–350 nm (0.2–0.35 *µ*m) in one dimension, so structures must be at least this large in two dimensions to be visualized.

(e) Both Hooke and van Leeuwenhoek would have been able to see the plant and animal cells. At 30x, the image of a 20 mm cell would be 600 mm (= 0.6 mm) and be visible to the eye. At 30x, the image of the 1 *μ*m bacterium would only be 30 mm, so only van Leeuwenhoek would have seen the bacterium. Using his 300x microscope, the image would be 300 mm and therefore visible. None of the other five structures would have been visible to either of them or to us using today’s light microscopes. These five subcellular structures require an electron microscope to visualize.

Those structures with a diameter greater than 8.3 *µ*m can be seen using all three microscopes, whereas those with a diameter between 0.35 and 0.83 *µ*m can only be seen using van Leeuwenhoek’s microscope and a contemporary light microscope. Smaller structures (as small as 0.2–0.35 *µ*m in diameter) can only be seen with a contemporary light microscope.

1-5. (a) Cytological strand; electron microscopy is capable of a much higher magnification and hence much greater resolution compared with light microscopy, thereby allowing visualization of much smaller subcellular and even molecular structures.

(b) Biochemical strand; ultracentrifugation is capable of much higher speeds and hence much greater centrifugal force compared with centrifugation, thereby allowing resolution of small subcellular structures and large molecules that cannot be separated by lower-speed centrifugation techniques.

(c) These techniques involve aspects of all three strands. Model organisms have an advantage over cell cultures in that they more closely resemble actual conditions in nature.

(d) Genetic strand; genome sequencing simply provides a large amount of data about the DNA present in the genome, whereas bioinformatics involves the use of computer analyses to interpret and understand those data in terms of gene numbers and expression.

(e) Cytological strand; scanning electron microscopy allows visualization of subcellular structures and macromolecules with a sense of depth (i.e., in three dimensions).

(f) Biochemical strand; electrophoresis separates molecules based on charge differences to allow separation of molecules that are so similar in size, shape, and density that they may not be readily resolved by most chromatographic techniques.

1.6. (a) Initially thought to be true because animal cells do not have cell walls, which made it difficult to distinguish individual cells using the crude microscopes available to early investigators. This notion was shown by Schwann (1839) to be incorrect for cartilage cells, which have well-defined boundaries of collagen fibers, and later for all animal cells.

(b) Initially thought to be true because living organisms seem to increase in complexity spontaneously, unlike other systems known to early chemists or physicists. This misconception was laid to rest by Wöhler (1828), who demonstrated that urea, a compound made by living organisms, can be synthesized in the laboratory from an inorganic starting compound.

(c) Originally thought to be true because the order of nucleotide monomers in DNA was erroneously considered to be an invariant tetranucleotide repeat sequence. This was disproved by Avery, et al. (1944) in bacteria and by Hershey and Chase (1952) in bacterial viruses.

(d) Initially thought to be true because of the demonstration by Pasteur that yeast cells were needed for alcoholic fermentation; Buchner and Buchner (1897) showed later that extracts from yeast cells can substitute for intact cells, which we now know is because of the presence of enzymes that catalyze the various reactions in the fermentation process in the extracts.

1-7. (a) By using super-resolution microscopy, structures as small as 50 nm can be clearly seen under a light microscope.

(b) Fluorescence microscopy can identify cells by using a fluorescently labeled antibody that recognizes a particular antigen unique to the target cell.

(c) Although similar in chemical composition, different DNA molecules can be separated from each other by electrophoresis, which separates molecules based on size and charge.

(d) It is better to try to disprove the null hypothesis by designing an experiment in which only one condition is varied at a time.

(e) RNA viruses can synthesize mRNA directly without requiring a DNA template. Other RNA viruses can use the information in RNA to synthesize DNA in the process of reverse transcription.

1-8. When choosing a model organism to benefit your research, it is important to consider how closely related the model organism is to your organism of interest, the particular processes you want to study, whether these process occur in a particular model organism, and the “hands-on” advantages of working with a certain model organism in the lab. Note that these questions do not have one correct answer because there are many unpredictable variables in research, and often an open mind and creativity are the keys to success. You will likely use a variety of techniques involving recombinant DNA technology, bioinformatics, genetic analysis, and biochemical purifications.

(a) Since the oil is being produced in your algal cells, you might try to use *Chlamydomonas,* an algal model organism that is easy to grow in the lab. You could test whether *Chlamydomonas* produces a similar compound and try to isolate the genes and enzymes necessary to produce it. Alternatively, you could mutagenize (“knock out”) genes in your algal cell and see which ones are needed to produce the biofuel.

(b) You can introduce genes encoding one of your enzymes of interest into *Chlamydomonas* and induce it to produce the biofuel. Because these algae are easy to grow in large amounts in the lab, they could be a good source of a particular enzyme. You could try using *E. coli* because it is also easy to grow, but because it is a bacterium and less closely related to algae, its use may be more difficult.

(c) If you can get *E. coli* or *Chlamydomonas* to produce the biofuel, you may be able to isolate multienzyme complexes from these cells, since they are easy to grow and manipulate in the lab. Alternatively, if you can isolate the algal genes producing your enzymes of interest, you can introduce them into *Saccharomyces,* a yeast commonly used to study protein–protein interactions. Then, you might be able to test pairs of enzymes to see if they interact with each other.

(d) To study organelles, you should use a eukaryotic organism, because bacteria such as
*E. coli* do not have organelles. Yeast may be a good choice because it has eukaryotic secretion processes that could be helpful in isolating the oil. You could also try *Arabidopsis,* which is a plant and therefore more closely related to your algae than either *E. coli* or yeast.

1-9. The images are taken using a fluorescent light microscope. The average length of a *C. elegans* embryo is 50 *µ*m. This is well within the limit of resolution of a light microscope. The high resolving power of an electron microscope is not necessary to examine the fluorescent signals in these samples. In addition, the fluorescent microscope, a specialized light microscope, allows one to distinguish different wavelengths of fluorescent light. This is useful for localizing tagged proteins in a sample. In this case, protein A has a red tag, and protein B has a green tag. If the two proteins are interacting with each other, the overlay of their two separate colored images would reveal areas of yellow color. Since this is clearly observed in the merged image, we can conclude that proteins A and B are likely interacting with each other in the developing *C. elegans* embryo.