A

Introduction

We really mean the "No Lecture" part of the title. This book is not intended to teach you all you need to know about basic biology. It's focused on providing an affordable, intense, reasonably comprehensive introductory biology lab experience. The background material we do provide is intended solely as a reminder of some important points that you've studied previously. For example, in one of the early lab sessions on biologically-important molecules, we spend a couple pages covering carbohydrates and lipids and then jump into the actual lab work. If you start that lab work knowing only what we've told you about carbohydrates and lipids you'll learn less than you should from doing the labs.

To get the most benefit from this book, use it in conjunction with a standard biology text, such as CK-12 *Biology* (*www.ck12.org/flexbook/book/2537*), which is freely downloadable, or Miller & Levine *Biology* (*www.millerandlevine.com*), both of which we highly recommend. Otherwise, you'll miss a lot of *really* important stuff. And you'll never know what you missed.

We sometimes refer in passing to things that you may be completely unfamiliar with. For example, in one early lab session we talk about aldehyde and ketone functional groups. If you've not yet taken first-year chemistry, let alone organic chemistry, you probably don't know much about aldehydes and ketones other than what little information we provide in the text. That's fine. For our purposes, all you really need to know is that aldehydes and ketones are different types of organic chemical compounds.

If you want to learn more about such topics, check Wikipedia (*www.wikepedia.org*). Although Wikipedia often presents a biased viewpoint in articles on controversial subjects, most science articles are well-written and reasonably comprehensive.

Using this Book with Your Curriculum

There are many ways to organize a first-year biology book. Some books take a generally top-down approach, starting with organisms and working their way down through organs and tissues to cells and cell structures and eventually to molecular biology. Other books take a generally bottom-up approach, starting with the molecular basis of life and working their way up to larger structures.

This book takes the latter approach, because we believe that to understand the whole it's best to first understand the parts that make up that whole. But regardless which approach your textbook takes, you should have no difficulty in correlating the lab sessions in this book with topics in your text. With few exceptions, which are noted in the lab sessions themselves, you can do the lab sessions in this book in any order.

> We do strongly recommend doing the first and second group of lab sessions before anything else. The first group of lab sessions covers basic microscope skills, which you'll need in many later lab sessions. We assume those skills in later lab sessions. For example, in a later lab session we may tell you to make a smear mount and stain it without providing details about how to do so, because we assume you've already learned those skills in the first group of lab sessions. The second group of lab sessions involves building microcosms, which are self-contained soda bottle worlds of pond life. You should do those sessions early, both because you'll observe these microcosms over a period of weeks to months and because you'll use some of the organisms growing in these microcosms in later lab sessions.

Feel free to pick and choose among the lab sessions and procedures to fit your curriculum, interests, and available time. For example, the third group of lab sessions covers the chemistry of life. This group has seven lab sessions, which incorporate 17 individual procedures. Ideally, you should do all of the sessions and procedures, but if time is limited you can eliminate procedures or even entire lab sessions as necessary.

We designed this book with the intention of covering as much useful material as possible in an intense year-long laboratory course. That's not to say that you need to complete this material in two semesters or any other arbitrary period. One of the huge advantages of homeschooling is that you can take things at your own speed, fitting the course material to the student rather than shoehorning students into predefined standard-length courses as public schools must do. If it takes you 18 months or two years to cover all of the material, so be it.

Conversely, do not be afraid to incorporate other laboratory sessions from your biology text or elsewhere, either as a supplement to the lab sessions in this book or as replacements for some of them. In our experience, students who learn—really learn—laboratory sciences do so by spending lots of time doing actual lab work rather than just reading about it. The more lab work, the better.

Planning and Scheduling

Nature runs on its own schedule and, other than building greenhouses and other artificial environments, there's not much we can do about it. For example, if you plan to study leaf structures in January, unless you live in a warm area there probably won't be many leaves on the trees. Of course, you can work around this problem, at least to some extent, by using leaves from house plants, the florist, a garden center, and so on, but that's less than an ideal solution. If you plan ahead, you can gather many different leaf specimens during the spring and summer and preserve them by pressing them between sheets of absorbent paper.

Similarly, biology lab work doesn't lend itself to nice, self-contained lab sessions that you can begin and finish in one lab period. Living things take time to grow, mature, and senesce. If you you want to observe the life cycle of a particular organism, you may find yourself making observations over a period of weeks to months, or longer. If you decide to complete all of the lab sessions in this book, expect that at times you may have several sessions in progress. Some of those may require observation or other attention daily, others perhaps only weekly or monthly, but it's important to keep track of what needs to be done when. (We use the calendar/to-do list on our computer to track action items and prompt us when it's time to do something.)

We recommend that before you begin any lab work you first skim through this book to decide which lab sessions you intend to do over the course of the year, in what order, and (if possible), approximately when you intend to do them. That way, you can be sure that you'll have everything you need, when you need it. Also decide what you intend to buy from science supply vendors versus making yourself or obtaining locally. For example, rather than collecting live protozoa from a pond, you might decide to order a mixed live protozoa culture from Carolina Biological Supply. That involves some delay for order processing and shipping, which you'll need to take into account when scheduling the lab session(s) that require that culture. Furthermore, that culture may have a lifetime measured in days, so you want to make sure to order it to arrive just before you start the lab session.

Also, if you intend to make rather than buy, allow time to collect specimens, prepare and stain slides, and so on. Of course, these activities can themselves be a part of the lab experience, but it's important to factor in the time needed and have the specimens available on lab day.

Work Areas

Give careful consideration to your work areas. You will, at various times, be working with chemicals that are toxic, corrosive, flammable, or otherwise hazardous. Biological stains do exactly what their name suggests—staining anything they come into contact with, sometimes indelibly. You may even decide to risk working with potentially pathogenic microorganisms.

Although the risks to your person are small and manageable, the same cannot always be said for the risks to your furniture, countertops, and floors. If you get Sudan III stain on your hands, for example, it will eventually wear off. But if you spill Sudan III on your antique dining room table or hardwood floor or composite countertop, the stain may never come out, short of sanding down the surface and refinishing it.

If you have a well-lit, well-ventilated basement workshop or similar utility area, great. That's an ideal location for doing the messier work involved in a biology lab course. For many people, though, it's the kitchen table or nothing. That's workable if it's the only realistic option, but you'll probably want to take some precautions:

- It's a bad idea to keep science equipment, chemicals, cultures, and other related materials in an area where food is prepared and consumed, so have these items in the kitchen only while you're actually doing the lab sessions. Store them elsewhere, secure from children and pets. (As a young teenager, Robert learned this lesson the hard way when his mother screamed after spotting a 10 cm centipede crawling across the kitchen table.)
- When you finish a lab session, immediately wash and dry the equipment separately and put it away. Do not, for example, put a used beaker in the dishwasher with ordinary dishes, even if the beaker contained nothing hazardous and you rinsed it thoroughly. Doing so is a bad habit to get into. In fact, don't run science equipment through the dishwasher at all, even separately. Wash it by hand and keep it segregated.
- Protect the kitchen table or other work surfaces against spills. A cheap plastic tablecloth is good insurance. Cover the tablecloth with newspaper, old towels, or something else that will absorb spills, and always have a roll of paper towels handy.
- Photography darkrooms are always organized with a wet bench and a dry bench. Use the same principle in your lab work. For example, you might do all wet work in the kitchen, but keep your microscope in another room, safe from spills.

Maintaining a Laboratory Notebook

A *laboratory notebook* is a contemporaneous, permanent *primary record* of the owner's laboratory work. In university and corporate labs, the lab notebook is often a critically important document, for both scientific and legal reasons. The outcome of zillion-dollar patent lawsuits often hinges on the quality, completeness, and credibility of a lab notebook. Many organizations have detailed procedures that must be followed in maintaining and archiving lab notebooks, and some go so far as to have the individual pages of researchers' lab notebooks notarized and imaged on a daily or weekly basis.

If you're just starting to learn about lab work, keeping a detailed lab notebook may seem to be overkill, but it's not. Developing the habit of keeping comprehensive records of all lab work is a critical skill for any STEM student and certainly for any working scientist, and such habits are best developed early. If you're using this book to prepare for college biology, and particularly if you plan to take the Advanced Placement (AP) Biology exam, you should keep a lab notebook. Even if you score a 5 on the AP Biology exam, many college and university biology departments will not offer you advanced placement unless you can show them a lab notebook that meets their standards.

Laboratory Notebook Guidelines

Use the following guidelines to maintain your laboratory notebook:

- The notebook must be permanently bound. Looseleaf pages are unacceptable. Never tear a page out of the notebook. We use inexpensive Mead hardbound 100-sheet composition books, available at drugstores, WalMart, Costco, and so on.

  > Always keep at least one spare lab notebook on hand. If you complete all of the procedures in this book and document all of your work properly, you can expect to fill several such notebooks. We order the Mead composition books by the case from Costco.

- Use permanent ink. Pencil or erasable ink is unacceptable. Erasures are anathema.

  > The one departure from this rule that we consider acceptable is using colored pencils for making sketches of your observations. Colored marking pens are simply too crude a tool for recording fine details and subtle gradations of color.

- Before you use it, print your name and other contact information on the front of the notebook, as well as the volume number (if applicable) and the date you started using the notebook.
- Number every page, odd and even, at the top outer corner, *before* you begin using the notebook.
- Reserve the first few pages for a table of contents.
- Begin a new page for each experiment or observing session.
- Use only the right-hand pages for recording information. The left-hand pages can be used for scratch paper. (If you are left-handed, you may use the left-hand pages for recording information, but maintain consistency throughout.)
- Record all observations as you make them. Do not trust to memory, even for a minute.
- Do not record information that you don't actually have. For example, if you observe a protist that you are certain is an *Amoeba* and believe to be *Amoeba proteus*, do not record your observation with more specificity than justified. Rather than recording the protist as "*Amoeba proteus*", record it as *Amoeba sp.* to indicate that the phylum is known but the species is uncertain. You can record uncertain information in the form "*Amoeba sp.* (poss. *proteus*)" or

"*Amoeba sp.* (prob. *proteus*)" to indicate your belief as to species and the level of your uncertainty.

- Print all information legibly, preferably in block letters. Do not write longhand.
- If you make a mistake, draw one line through the erroneous information, leaving it readable. If it is not otherwise obvious, include a short note explaining the reason for the strikethrough. Date and initial the strikethrough.
- Do not leave gaps or whitespace in the notebook. Cross out whitespace if leaving an open place in the notebook is unavoidable. That way, no one can go back in an fill in something that didn't happen. When you complete an experiment, cross out the white space that remains at the bottom of the final page.
- Incorporate computer-generated graphs, charts, printouts, images, and similar items by taping or pasting them into the notebook. Date and initial all add-ins on the add-in itself.
- Include only procedures that you personally perform and data that you personally observe. If you are working with a lab partner and taking shared responsibility for performing procedures and observing data, note that fact as well as describing who did what and when.
- Remember that the ultimate goal of a laboratory notebook is to provide a permanent record of all the information necessary for someone else to reproduce your experiment and replicate your results. Leave nothing out. Even the smallest, apparently trivial, detail may make the difference.

Laboratory Notebook Format

Use the following general format for recording an experiment in your lab notebook:

Introduction

The following information should be entered before you begin the laboratory session:

Date

Enter the date at the top of the page. Use an unambiguous date format, for example 10 June 2012 or June 10, 2012 rather than 10/6/12 or 6/10/12. If the experiment runs more than one day, enter the starting date here and the new date in the procedure/data section at the time you actually begin work on that date.

Experiment title

If the experiment is from this or another laboratory manual, use the name from that manual and credit the manual appropriately. For example, "Investigating Bacterial Antibiotic Sensitivity (Illustrated Guide to Home Biology Experiments, Lab VII-4)". If the experiment is your own, give it a descriptive title.

Purpose

One or two sentences that describe the goal of the experiment. For example, "To investigate the sensitivity of the bacteria *Bacillus subtilis*, *Micrococcus luteus*, and *Rhodospirillum rubrum* to amoxicillin, chlortetracycline, sulfadimethoxine, and neomycin ."

Introduction (optional)

Any preliminary notes, comments, or other information may be entered in a paragraph or two here. For example, if you decided to do this experiment to learn more about something you discovered in another experiment, note that fact here.

Chemical notes

For investigations in which chemical reactions play a prominent role, include balanced equations for all of the reactions involved in the experiment, including, if applicable, changes in oxidation state. Record important information about all chemicals used in the experiment, including, if appropriate, physical properties (melting/boiling points, density, etc.), a list of relevant hazards and safety measures (from the MSDS), and any special disposal methods required. Include approximate quantities, both in grams and in moles, to give an idea of the scale of the experiment.

Organism notes

For investigations that focus on a particular organism or organisms, record the particulars about the organism(s), including type, binomial name, the reason (if any) that particular organism was chosen, and so on.

Planned procedure

A paragraph or two to describe the procedures you expect to follow.

Main body

The following information should be entered as you actually do the experiment:

Procedure

Record the procedure you use, step by step, as you actually perform the procedures. Note any departures from your planned procedure and the reasons for them.

Data

Record all data and observations as you gather them, in-line with your running procedural narrative. Do not attempt to organize or tabulate the data here; simply record them in-line with your running narrative.

Sketches and/or images

Make sketches or, if you have the necessary equipment, shoot images of what you observe. Label significant features. For microscopic observations, indicate the magnification used, any special staining protocols, and so on. Always include a dimensional scale to indicate the approximate size of individual features in the image.

Calculations

Include any calculations you make. If you run the same calculation repeatedly on different data sets, one example calculation suffices.

Table(s)

If appropriate, construct a table or tables to organize your data. Copy data from your original in-line record to the table or tables.

Graph(s)

If appropriate, construct a graph or graphs to present your data and show relationships between variables. Label the axes appropriately, include error bars if you know the error limits, and make sure that all of the data plotted in the graph are also available to the reader in tabular form. Hand-drawn graphs are preferable. If you use computer-generated graphs, make sure they are labeled properly and tape or paste them into this section.

Conclusion

The following information should be entered after you complete the experiment:

Results

Write a one or two paragraph summary of the results of the experiment.

Discussion

Discuss, if possible quantitatively, the results you observed. Do your results confirm or refute the hypothesis? Record any thoughts you have that bear upon this experiment or possible related experiments you might perform to learn more. Suggest possible improvement to the experimental procedures or design.

Answer questions

If you've just completed a lab exercise from this or another book, answer all of the post-lab questions posed in the exercise. You can incorporate the questions by reference rather than writing them out again yourself.