Lessons From The Lab: A Guide For Young Scientists

Written by Ishmam A Ahmed, June 2011

Have a seat. Let's talk about your future.

Chances are you're reading this because you're either very, incredibly, or extremely awesome. Or as many might put it, you have an interest in science. Seeing as you've made it through the title and a few sentences, I'd say you're pretty motivated, disciplined, and maybe even willing to experiment or *experience* the scientific method. So congrats, give yourself a pat on the back; you're worthy of reading on.

Once you get involved in it, scientific research becomes a way of life, especially for students like us. A project of *any* sort requires time, commitment, and an unwavering drive for knowledge. But in most cases, ironically, getting started may be the hardest part.

Whether you enjoy mixing chemicals or cutting up mice, your garage is *not* the place to do it. For lab-oriented sciences like chemistry and biology, it's critical to find a suitable facility for your research interest. In other words, you need to find yourself a professional lab. In nearly all cases, joining a lab means convincing a busy, highly successful individual that you're worth their time, that is, finding a mentor with research interests similar to your own. But once you've got that squared away, either through informational interviews, phones calls, emails, or formal visits, it's what happens in the lab that really matters.

This is a guide written by a student, for a student. If lab-centered scientific research is within your near future, then the advice, experience, counsel, and anecdotes you find here may prove useful. This is your road map to the laboratory. You'll find insight on the scientists that work tirelessly therein, tips on how to take advantage of the tools at your disposal, and the ins and outs of an investigative experiment. Once you've mastered the setting, there's no telling how far your research will go.

Are you the next Carver? Edison? Curie? Einstein?
The laboratory may be your gateway to that answer.

Trust me, I'm a scientist.

Walking into my mentor's lab for the first time was a bit like walking into a foreign country. Even with a solid background as a former AP Biology student and being relatively well-read on the topic of my mentor's research focus, I only qualified as an unaccustomed immigrant. A better-than-average novice. A fluent tourist.

That's me, momentarily pretending to do science.

Having been part of the lab scene for over a year now, I've had the opportunity to work through my very own experiment and have continued onto more. I've devoted a considerable amount of time to the lab and still spend about ten hours there each week.

Progress is always being made; knowing that *sonic hedgehog* is neither blue nor a hedgehog, having made friends among my mentors, and having memorized most of the protocols, I can proudly say that I'm a denizen of the laboratory. Things will only continue to evolve from here.

For me, the enterprise of stem cell research has changed my character. As science fair deadlines approached and time became a commodity, I learned to budget it strictly and efficiently. Even though some sleep and free time were sacrificed, it wasn't in vain. I achieved an equilibrium between my time spent at school, my time spent commuting, my time spent researching, and my time spent doing homework. It was a hassle at first, but my work ethic and mentality adapted. I was doing exactly what my stem cells were doing: transforming into something better, something more efficient.

This marks the end of the beginning. It's time to turn our focus to *you* and *your* lab experience.

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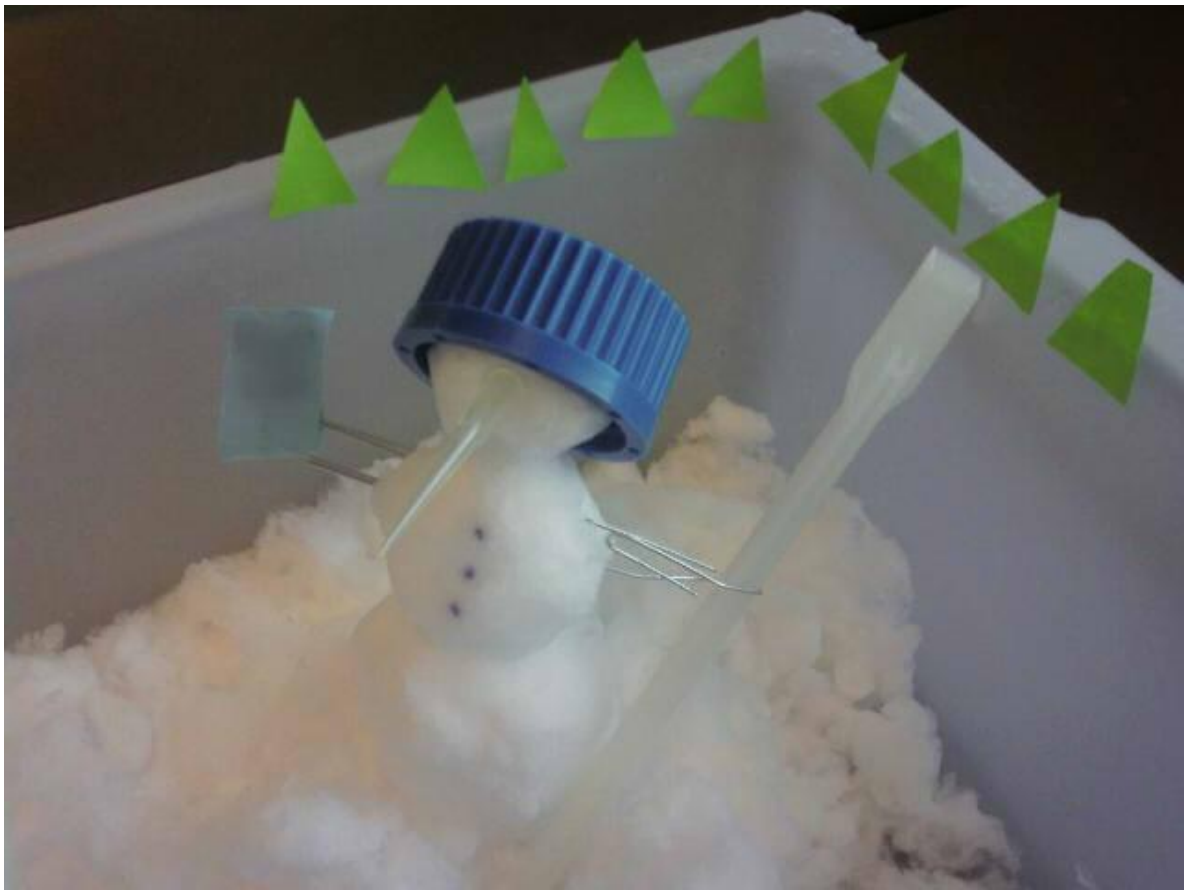
Here's a thing or two on lab attitude.

The laboratory has a distinctive culture, and I'm not talking about cell culture. There's a certain dynamic, a method of interaction between inhabitants that can't be found anywhere else. Normally, you'd visualize uptight people in stark lab coats, fiddling with test tubes, and frowning at any semblance of fun.

During my first week at the lab, I realized that this was far from reality. First of all, there was nothing exceedingly formal about the way people dressed. In fact, I was informed that the only enforced dress-code called for closed-toe shoes and long pants. But don't worry, gloves, goggles, masks, and coats are worn when required (safety first). Secondly, the technicians, postdocs, grad students, and lab aides proved to be surprisingly normal people. For starters, they had lives. And although they didn't laugh maniacally (with or without accompanying lightning flashes), they had, and continue to have, good senses of humor.

Case in point, this past holiday season resulted in the following Frankensteinian creation at our lab, made from the residual ice beneath the liquid nitrogen tank's lid:



Even though the people in my lab did not, fortunately, embody my expectation of introverted, quirky lab rats, there remains a distinct charm in the way they interact. Namely, it seems that everyone is implicitly

critical of each other. For example, even though there's no definite, correct way to attach a tip to a pipette aid, as the trainee, I was prone to biased instruction from pros, who insisted that their way was the right way. The same goes for numerous other nuances.

From my time in lab so far, I have identified a friendly, understood distrust between lab members. Since everyone is doing different things at different times with the same equipment, needless interference is harshly looked down upon, but usually manifests in nothing more than a false smile or fleeting expression of annoyance. That said, be sure not to get on anyone's bad side.

Although the lab has a unique vibe, it's your job to embrace it. At first, it will be difficult to assimilate. But include yourself in conversation whenever you can and be sure to ask plenty of questions. In no time, you'll be part of the machine too.

Lab rats or lab personnel, call 'em what you want.

Lab rats come in a variety of flavors. Each member of a lab has a unique role, with differing levels of experience, differing levels of commitment, and differing areas of expertise. Although you might be at the bottom of the food chain during your first visits to the lab, it's critical to know who's responsible for what. On a typical safari through your lab, you'll meet the:

- **Principal investigator**, or P.I. for short. These are the head-honchos, the bosses of your lab, and, most likely, your mentor. Although their academic credentials and research experiences may go on and on, most of their time is devoted to administrative aspects of research. The P.I. is the intellectual force behind most projects in the lab, whether they actually do the dirty work or not.
- **Postdoctoral associates, assistants, or fellows**, who you can call postdocs. These are people who have received their Ph.D. or, in some cases, their M.D. Usually, they'll be chipping away at a 2 to 5 year training period before sliding into a position as P.I. For the most part, you'll find them working independently.
- **Technicians or research assistants,** who are cooler than their title makes them sound. These folks are usually college students who want to get a feel for the lab before diving into graduate or medical school. Technicians are usually responsible for a variety of tasks such as ordering tools, preparing chemicals, or assisting with experiments. As you begin your own research journey, it will most likely be techs that train and assist you with your own project. That said, make sure you get, and stay, on their good side! After all, these guys are the backbone of the lab.
- **Graduate students,** who are busy doing the lab work required for their M.S. or Ph.D. In most cases, you'll find them deeply involved with their own projects. Like postdocs, they are particularly independent. But don't be shy; ask them about their research. You can learn a lot with just a couple friendly questions.
- **Rotation students,** who exist only because some graduate schools require their students to work in several different labs before they decide on the lab for their thesis work. A rotation student is in the lab anywhere between 6 weeks to 6 months and usually work on a short-term project.

- **Summer students,** who are usually college students but may include high schoolers. A new student usually tags along with a tech and is kept busy with simple lab chores. A more experienced student may be able to tackle their own small project.
- **Secretary or administrative assistant,** who is in charge of ordering supplies for the entire lab and may, in addition, organize lab meetings and seminars. These people usually work very closely with the P.I.
- **Laboratory safety officer,** who's someone that---you guessed it---is responsible for maintaining the safety of lab procedures. If you have any questions about health, safety, or anything else that may cause you concern, take it up with the safety officer.

During the first week, pretending to be a scientist is just fine.

During those first few days, you'll feel useless among the dozens of qualified, professional scientists around you. Although you might not be able to get started with an experiment right off the bat, take advantage of your naïveté by asking questions. Take a look at the tools and devices around you, the bottled reagents, the charts, diagrams, and storage boxes. Simple curiosity can lead to a great deal of learning.

Most importantly, introduce yourself to others. Tell them why you joined the lab and what type of sciences interest you. Asking each person about his or her own project is usually a good icebreaker. As you warm up to your lab mates, ask if you can help out with any work they might be doing. However, keep in mind that lab members are devoted to their research, so don't get discouraged if you don't get red carpet treatment.

Usually, you'll begin actual lab work after a series of training sessions. One or two lab assistants might be assigned to show you the ropes. They might start by walking you through basic laboratory procedures. Even if the first few simple tasks feel mundane and unnecessary, maintain a good attitude and ask questions. Laboratory training always includes a safety component, which will be specific to your discipline. Take notes whenever possible, not only to keep yourself informed, but to show others that you are indeed motivated.

Take the first week or so to familiarize yourself with how the lab is run, where things are kept, and who does what and when. Doing so is important both for your own safety and for the sake of your own research.

Think of lab meetings as board meetings, minus the bored.

Science is meant to be shared, and lab meetings are *the place* for sharing. These meetings are usually held on a regular basis by your P.I. or administrative assistant. Current research in the field, recent study results,

and organizational issues are all topics that are typically discussed during lab meetings.

Many labs have a weekly journal club meeting, which is a casual discussion on a particular, recently published paper. The paper is often posted a few days prior to the meeting so that lab members have a chance to read and interpret it. Also note that journal club meetings are known to involve free food.

As a beginner in the lab, it is a gesture of respect and interest to attend all lab meetings. Journal club meetings are always a valuable use of time; a lot can be learned from other published papers. The papers themselves usually expand beyond the scope of a lab's particular research and can thus provide insight into other, but related, fields of study. That said, don't be afraid to ask for a copy of the journal club article to be covered. Do your best to read and understand the data and, as always, ask questions.

In sum, lab meetings are an efficient way to share information and discuss issues that need addressing. Not to mention, your P.I. may call a lab meeting to introduce you to the rest of the members.

Common sense and courtesy are key.

While you're in the lab, you're in the professional world. There's no room for immaturity or horseplay. That's not to say the lab can't be fun; just remember to use proper judgment. If your fellow lab members are fooling around, don't think of it as permission for you to do the same. Stay polite, calm, and focused. Let your P.I. or administrative assistant know if there is anything that makes you feel uncomfortable.

The unspoken rules are usually the most important. Some courtesies you should keep in mind during your entire research experience:

- Ask, don’t command.
- Don't assume. Anything.
- Write down everything when someone is giving you instructions.
- Make appointments or request time with people.
- Don’t remove journals or lab notebooks from the document library or lab.
- Don’t discuss a fellow lab member’s results with people not in the lab.
- If you do something wrong, confess.
- Request the minimum of favors.
- Clean.
- Don't wear a lab coat outside of the lab area.
- Don't ask questions of someone who is manipulating materials. Make your presence known, and wait until they are ready to respond.
- Don't read novels, play games, or inappropriately use a computer in the lab.
- Don't use the phone or photocopy machine for personal reasons.
- Never use chemicals without permission.
- Let someone know when something is running low.
- Don't ignore broken equipment.

- Keep your personal items separate from the lab space.
- Sanitize, as necessary, after each part of an experiment.
- Know how to help yourself and other lab members in case of an emergency.
- Don't do anything you feel is unsafe.

So if there's one thing you ought to remember, it's to not be a bozo. If you work hard and display your interest, even your superiors will begin to respect you. The former is pretty self-explanatory. Working hard means showing up when you're supposed to, doing work that's assigned to you, and having a good attitude toward the opportunities you've been given. After all, being able to work in a lab is a special privilege. Similarly, be sure to make your interest apparent to others. The lab-savvies around you *love* to answer questions, so don't be shy. Even if you already know the answer to a particular question, ask it! Showing curiosity will only increase your standing among your lab peers. Don't be passive; the only way you're going to learn in a lab is by learning *actively*.

Your lab notebook is your best friend.

The laboratory notebook is the record you keep of the methods and results of your experiments. All your raw data goes in here, everything you've done since Day 1. In essence, it is the single most important tool at your disposal. With it, you can draft papers, plan experiments, build on your results, and brainstorm.

It is essential that your lab notebook be clear and thorough. It is important that one should be able to look back at pages in your notebook and understand exactly what you did at a particular time and why you did it. More importantly, if something goes wrong, you can retrace your steps and figure out exactly what happened. Another scientist should be able to interpret your notes without any help.

Your lab book should be a defense against fraud. It is proof of you who are, as a scientist.

What should you look for in a laboratory notebook? I recommend:

- Large 8.5 by 11" pages. You should be able to attach photographs or printouts when necessary.
- Bound pages. It should be impossible to rip pages out without destroying the integrity of the book.
- Numbered pages.
- Grid pages. Not blank and not lined.

What goes in your laboratory notebook?

- **Dates**. The date you started an experiment, the date you finished. Put a date on every entry you include. Whenever you're in the lab, record the date you were there, and what you accomplished during that time. Include all relevant details.
- **Titles.** Of your experiments, of useful journal articles, and of useful books or reference materials.
- **Statement of purpose.** Such a statement usually serves as an extension to a title and provides additional insight as to why something is being performed, studied, or noted.

- **Descriptions and conclusions.** Anything from detailed lab protocols to accounts of what you got done in the lab today should be included. The more details you have, the more useful the lab notebook will be in the future.
- **Calculations.** If applicable, show your work as to how you arrived at certain answers. Input like this is as useful to you as it may be to someone who leafs through your notebook in the future.

Make sure you fill out your lab notebook in pen. This makes sure your data is authentic, as typed or penciled information can be easily manipulated. If you make a mistake, it's okay to cross out, draw arrows, or redirect readers to another page. Be sure to remember that others may need to look through your notebook, so keep everything clear and understandable.

Put that lab notebook to the test; plan your own experiment.

Again, don't expect to do this right off the bat. Once you complete all of your formal training and feel comfortable in the lab, don't hesitate to ask your mentor if you can conduct your own experiment. In most cases, you'll get assigned to a basic project that your mentor feels you can handle. At other times, you may be asked to join a lab group and help with an experiment that's already under way. Whatever the case, take up the opportunity given to you without hesitation.

Make sure you keep your notebook and a pen handy at all times. Experimentation requires that you write the following things:

- **The question and hypothesis.** An experiment should always address a hypothesis by answering one or two specific questions. If you're not quite sure how to word, or what the question even is, ask your colleagues immediately, even before starting any experimentation. You don't want to be chipping away at an experiment without knowing what question it's trying to answer.
- **The experimental design.** An outline of your experiment is crucial. You should be keenly aware of the components of your experiment and the methods through which data will be obtained. Some important things to include are:
- **The experimental variables.** What do you want to observe? For example, are you interested in the effect of something over time? What will you, the scientist, manipulate, and what do you expect to see as a result of those manipulations? An independent variable is one you control, and a dependent variable is one that changes in correspondence with changes in the independent variable; thus, the dependent variable is *dependent* on the independent variable.
    - **controls.** Every experimental variable needs a control to show that the results obtained are the results of the treatment.
    - **the number of samples or trials.** Should you run samples in duplicate? Triplicate? More? How many times will you test a certain component? This is important information

to include, as it may provide insight on trends in your data, or may even prove its consistency.
    - **protocols.** The protocol is a procedural guide, an instructions list. Be sure to record it in your lab notebook so that it can be accessed at any time during your experiment. If at any time you're not sure what to do, take a look at the protocol and then check with a supervisor.
    - **equipment and chemical used.** Include a concise list of the materials you used. Keep in mind that someone reading your lab notebook should be able to replicate your experiment from the information in your notebook alone.
    - **data.** Raw data is the most important part. List whatever data you can obtain in an appropriate form. This may include lists, charts, graphs, or simply observations and descriptions. Record all data, even if you think it's wrong. There's no such thing as bad data; every bit of information provides insight.
- **Background research.** Before beginning any experiment, you should be well-read on the topic of your experimentation. If you completed an annotated bibliography or read through relevant journal articles before or during experimentation, be sure to attach them to your notebook or at least include a brief synopsis of each item and its title. That said, don't stop reading after you finish an experiment! As a scientist, it is important to keep up in your field of study by reading current literature.

Here's the word on stats.

Will your data need to be analyzed statistically in order to be convincing? Sometimes, the numbers you record while experimenting may not be indicative of anything relevant and may require further statistical processing before becoming applicable. Generally, your lab either does or doesn't do statistical analysis on the data it generates. You will have to decide for yourself whether you will analyze your data. Examples of the uses of statistics in a biological laboratory:

- Estimating characteristics of a population based on numerical information
- Predicting characteristics of a sample and finding probabilities using a normal distribution curve.
- Observing whether differences between the means of two sets of observations, such as before and after treatment, can be explained by chance.
- To determine the probability of any given sample drawn from a population within a given population.
- To predict the effect of one related measure on another using linear regression. If two measures have a linear relationship, you can calculate a correlation coefficient.
- To consider data from several samples at the same time and distinguish systematic differences between groups from the chance variations found in each group.
- To look at the difference between two independent samples.
- Use standard deviation to show how reproducible a particular data point is, based on multiple samples.

Most labs are equipped with computer spreadsheet programs that will aid your statistical analysis. If this is applicable to your experiment, be sure to get your mentor's permission and instruction before using the algorithms.

On your marks, get set, go!

Well, what are you waiting for? Be assertive, ask for a volunteer position at a nearby laboratory, pursue your interest. Research facilities need all the hands they can get, so don't be afraid to take a ride on the cutting edge of your field. Getting involved is the stepping stone between interest and application.

The lab is a fascinating, exciting, and enjoyable place to work. The work is worthwhile and the dress code, if any, is casual. The work hours are often self-determined and based on the needs of the experiment. The lab is filled with bright and interesting people, with whom you can discuss the salt concentration needed for a kinase assay or the implications of the latest congressional bill. It can come to have all the psychological comforts of home.

“Like any complex social organizations, research laboratories have their own customs and rules. The difficulty is that the rules have been unspoken. You are expected to decipher the many obtuse clues and become a law-abiding member of a society in which individualism is highly prized. In a profession in which communication of data is the goal and the reward of research, not all people can communicate with you clearly and satisfactorily. Don't worry, you will manage! In a short time, the pleasure of working together with colleagues on interesting and similar projects will supplant any initial feelings of unease. But to get your work done well, you must first navigate among sometimes vague and mixed signals and learn how you lab beats and hums.”

-Kathy Barker, *At the Bench: A Laboratory Navigator*