GENERAL BIOLOGY LABORATORIES

General Biology Laboratorie

…STIGATING THE UNITY AN… DIVERSITY OF LIFE

SHERRY S. HERRON • RAYMOND W. SCHEETZ

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INVESTIGATING THE UNITY AND DIVERSITY OF LIFE

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UNIVERSITY OF SOUTHERN MISSISSIPPI

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Preface

The exercises and investigations contained in this manual represent an effort to address the ways by which students learn most effectively. Research in the fields of cognitive psychology, biology, and education, among others, has demonstrated that learning is facilitated when students can help each other; when prior knowledge is revealed and misconceptions identified and challenged; when conceptual understanding is given a higher priority than rote memory; and when learning is embedded in authentic, appealing exercises. We have also tried to stress that science is a *process*, first through guided investigations and culminating in an open-ended one in which the students are responsible for designing and performing a group experiment.

As with many human endeavors, this manual is an evolving effort. Even as this manuscript goes to press, there are questions to add, statements to revise, and illustrations to draw. Suggestions for improvement are appreciated.

Acknowledgments

I sincerely wish to thank Dr. Bobby Middlebrooks and Dr. Frank Moore for the administrative support that made this manual possible. I sincerely thank the graduate students who contributed to the development of these exercises with earnest and enthusiasm. They worked with me during extended prep sessions to establish our goals and then to determine how best to accomplish those goals. I wish to give Stefan Woltmann and Bobbie Meyer particular recognition, who, as you will see, did much of the actual writing. Stef has a wonderful writing style that makes you *want* to read the exercises. He has a talent for making difficult concepts easy to understand. Bobbie has the exceptional ability to organize, prepare, and foresee problems that may occur. Bobbie also had the challenging task of establishing new setups and protocols. Others who made significant contributions in developing and piloting the exercises include Sarah Mabey, Tom Woodward, Jeff Clark, and Ryan Heise. Travis Harrington and Alan Niven provided editorial and emotional support during the critical final days of work. To them all, I am most grateful.

Finally, Dr. Scheetz has been the ballast, rudder, and wind (Did I mention artist?) for this project, and, yet, he would deny that he had contributed very much. How can a ship (or boat, in this case) sail without the wind? I could never thank him enough.

Dr. Scheetz and I have our families, most of all, to thank for putting up with us.

Sherry S. Herron

To the Student

We are committed to provide you with opportunities to engage in independent thinking, do science in an atmosphere of cooperation and collaboration, and to establish a solid foundation on which to build a scientific career.

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Topic 1

What is Science?

Stefan Woltmann

☞ Biology is *science* as a way of *understanding life.* It's all about:

☞ Observing life

☞ Detecting and describing patterns in life

☞ Explaining patterns in life

☞ Answering "how" and "why" questions....about life!

Science isn't really as scary as it seems. A recent survey I just made up reveals that lots of people think of scientists as totally deranged geeks with heavy glasses, lab coats and pocket protectors who create rabbits with six heads. The other half of the people think of scientists as totally deranged folks with crazy hair who blow things up in their labs late at night. Well, I'm not going to say that there *aren't* scientists like that, but honestly, being totally deranged doesn't (necessarily) make you a good scientist. Most scientists are actually a reasonably normal bunch, and to be fair, there are psychos *everywhere,* not just in the sciences. But that's not the point of this Topic. My point is that YOU are already a scientist; just about everyone is: you may just not *realize* it yet.

Science is often described as a "way of knowing," and biology is simply **science as a way of understanding life.**

The way we humans see and understand the world around us is through **patterns**. We like patterns because they allow us to predict certain things about life. Predicting things is nice because it often means we have a clue about what's going on. That the sun will rise tomorrow is a prediction based on the pattern that, well, it's come up every other day, why not tomorrow? Knowing that the sun will rise can be very comforting or very distressing, depending on whether or not you finished that paper that's due at 8:00, but at least it won't surprise you.

So you may be sitting there thinking, "yeah, well....so?", which, by the way, is exactly what scientists do most of the time (congratulations! you're a scientist!) The yeah-well-so? point of the example about predicting sunrise is that it's a simple pattern. But most of life isn't so simple, is it? The real challenge of science is to recognize patterns in a world that often has so many patterns going on all at once that it's hard to pick out any one pattern in particular. And, to be honest, we often need to decide whether or not there actually *is* a pattern in something we are looking at.

> *"1,500 years ago everybody 'knew' the Earth was the center of the universe. 500 years ago everybody 'knew' the Earth was flat. And 15 minutes ago you 'knew' that people were alone on this planet. Imagine what you'll 'know' tomorrow."*
>
> ~Tommy Lee Jones to Will Smith regarding the fact that New York City was full of space aliens in "Men in Black," 1997.

Here's something important to remember: almost nothing in science is written in stone. (That's why we use pencils with erasers.) What I mean by this is that it is fair to assume that all scientific statements start with "To the best of our knowledge..." We just don't say that every time we talk about something because it gets tedious really fast, and we all know it's in there, anyway. Remember that in life, anything is possible; it's just that some things are *more likely* than others. Some things are so likely to happen that we think we are 100% certain that we can predict them. Some things are so *unlikely* to happen that, for all intents and purposes, they are. The phrase "when pigs fly" comes to mind.

Ideally, when we use science, we are looking for the "truth" about some phenomenon. What we are looking for are the simplest and most logical patterns, and we are looking for the simplest and most logical explanations (or "truths") for those patterns. (Let me insert here, my opinion that religion and science are far too often thought of as opposing each other. Really, they are usually just two completely different ways of looking at the same thing, and the nice thing about this country is that you are free to form your own conclusions about what it all means.) The goal of science is to describe and explain phenomenon *objectively*.

The Process

Because you are more than likely taking the lecture along with this lab course, I am only briefly going to touch on a few basic principles regarding the scientific process. Most of this is just terminology, because I maintain that people are inherently scientific in their actions. Terminology is good to know because it allows us to realize that we are talking about the same thing.

To borrow an example from another lab manual I recently read, imagine that you throw your white socks in the washing machine with your new jeans, and your white socks turn into bluish socks. If you were totally illogical, you might wonder where your white socks went. A more reasonable explanation would be that something happened to your white socks while they were in the machine. If you care about the difference between white socks and bluish socks, you might try washing your other white socks all by themselves, and then maybe washing them with other things of various colors. Eventually, though, you'd realize that every time you washed white socks with new jeans you ended up with one less pair of white socks and one more pair of bluish ones.

The scientific process starts with an **observation**! The job of every scientist is to come up with **hypotheses** (that's plural) that relate to observations. A **hypothesis** (that's singular) is simply an educated guess, or at least a good one is, anyway. For example, "Washing white socks with new jeans causes white socks to turn blue" would be a good hypothesis for the previous example. Essentially, a good hypothesis is a statement that we can then go and gather conclusive evidence for or against. Sounds easy, but coming up with good hypotheses is often one of the most difficult things about science. The next step would be to make a **prediction** about what you think would happen if you were to conduct an experiment regarding this. The obvious prediction that follows from the "white sock-new jean" hypothesis would be: "The next time I wash white socks with new jeans, the socks will turn bluish."

So you do this: you do ten loads of laundry, five with white socks and new jeans and five with just white socks. Never mind that this isn't going to happen on your college budget--it's just an example. As it would probably turn out, all the socks washed with jeans would become bluish, and all the ones washed alone would still be white. What do you conclude? OK, so maybe it's not a GREAT or FASCINATING example, but you get the point...

This whole process has a fancy name. It's called the **Hypothetico-deductive process**. It can be summed up like this:

1. You make an observation.
2. You form a hypothesis.
3. You make a prediction about what might happen if your hypothesis is correct.
4. You collect data that relate to the prediction.
5. You analyze your data and make a decision about how likely it is that your hypothesis is true.

Here's something else that is *extremely important to remember*: Learning that your hypothesis was wrong is JUST AS IMPORTANT as learning that it was right!!! In that respect, scientists are wrong far more often than they are right, because they are always coming up with hypotheses that end up not working. So don't get too personally attached to your hypotheses. A **theory**, by the way, is a hypothesis that no one has been able to disprove. It's basically a hypothesis or a bunch of them that work very, very well, like the hypothesis (or theory) that gravity keeps us from floating out into space all the time, which would be rather inconvenient, don't you think?

The Science of Cards and Peanuts

In this lab we are going to use a few exercises to illustrate some things you probably already know, and hopefully point out a few things that you didn't know you knew.

We know now that science is about patterns and the ability to predict things by recognizing patterns when we see them.

Look at this line of cards:

A♤ 2♡ 5♧ 6♢ 9♤ 10♡

Is there a pattern? In this line there are a bunch of possible patterns going on: Alternating Black-Red, Alternating Odd-Even, From low value to higher value. There might be the pattern of ♤-♡-♧-♢, but there aren't enough cards to know whether this pattern repeats itself. Accept for now that there is one "true" pattern. A very common problem in science is not having enough information to detect a pattern. Imagine that we manage to get a peek at the next card, a 9♧. Now we have this:

A♤ 2♡ 5♧ 6♢ 9♤ 10♡ 9♧

Which patterns are still patterns? Red-Black still works, so does Odd-Even. All of the previous patterns are still there except the one about the value getting progressively higher. So what we learned from seeing a little more of the pattern is that that *isn't* the pattern. That is, we have logically eliminated one of the possible patterns. We still need more information to decide what the "real" pattern is; Odd-Even, Red-Black, or the suit pattern. What if we get to see one more card?

A♤ 2♡ 5♧ 6♢ 9♤ 10♡ 9♧ 3♡

The "real" pattern in this case, Alternating Red-Black, was only revealed to us by seeing enough of the pattern to eliminate similar patterns.

✏EXERCISE 1-1

The instructor is going to give you a piece of cardboard with some cards stuck on it. The two cards at the end of the sequence have little covers over them so you can't see what they are right away. You will flip the covers over to add 1 card at a time to the pattern. You are also going to get a sheet of paper with six questions on it.

Important!: These things both have a two-letter code on them, something like "AB" or "DD." *You need to make sure the cardboard thing and the question sheet have the same code!!!*

On a separate sheet of paper answer the questions. Make sure you write that two-letter code on your answer sheet! It also helps to write your name on your answer sheet....

Found a Peanut...

Good science depends very heavily on good observations. This next exercise is about careful observations and accurate descriptions.

We are also going to start thinking about the fact that scientists work together more often than they work alone. Because life is so very complex, it is impossible for any one person to figure out everything about anything. As a scientist you need to be able to communicate with scientists as well as everyone else.

In front of you is a bowl of peanuts. Please don't eat them because then we won't be able to collect the data we need. A scientist without data is a sad thing to see. Take a peanut and look at it. Write down a description of it that would allow you to find your peanut if it were put back in the bowl.

DO NOT MARK YOUR PEANUT!!!

Describing a peanut is hard. A *qualitative* description might include things like "it's tan" or "it's big" or "it smells bad." Qualitative is nice, but qualitative words mean different things to different people. *How* big is a "big" peanut?

Qualitative information is better. "The peanut is 35mm long" or "it has two nodes (the part that holds the thing you eat)" are statements that can be verified by anyone.

✏EXERCISE 1-2

DO THIS:

1. Find a peanut.
2. Don't eat it.
3. Write down all the things that can help identify that peanut. Be as clear as you can: measure things about it (for example, how long is it?), note if it has any unusual markings, count the number of nodes, etc.
4. Put your peanut back in the bowl and mix them all up.
5. Try to find your peanut again.

Was your description good enough to help you find the same peanut?

✏EXERCISE 1-3

Easy? OK, now DO THIS:

1. Pass your bowl to the table next to you.
2. Pass along your written descriptions to the table next to you.
3. Take *someone else's* written description and their bowl of peanuts and try to find that peanut.
4. Make sure, by talking to the person who wrote the description, that you have found the right peanut.

Was your colleague's description clear enough for you to find their peanut?

DESCRIBING THINGS WITH GRAPHS

"A picture is worth a thousand words."

Scientists are just like most other people in that they like to look at pretty pictures. Right now, you might not think a graph is a pretty picture. But you'd have to admit that it's more interesting to look at a graph and know what someone is trying to say than to read a whole bunch of paragraphs describing the same thing. Graphing is one of the most effective tools for communication that scientists have, and its definitely something you need to know how to do.

The things people graph are called **variables**. They are called that because, well, they are things that *vary*. A graph that showed the number of different types of nuts in the bowl in front of you wouldn't tell you much because they're all peanuts. "Type of nut" is just not a variable in this case.

Look at the graphs I made about peanuts. Figure 1 shows how many nodes the peanuts I looked at had. Notice that most of them had 2, a few had 1 or 3, and one crazy mutant peanut had 4. The variable in this graph is the number of nodes each peanut has.

Figure 2 shows the length of the peanut compared to the number of nodes it had. As you could expect, generally, the more nodes a peanut has, the longer it is. This graph plots the two variables "number of nodes" and "length."

Most graphs have two **axes** (plural): an **x axis** (singular) and a **y axis**. The x axis is the horizontal axis, and the y axis is vertical.

Remember this: A GOOD GRAPH SHOULD NOT BE HARD TO FIGURE OUT.

1. A good graph needs to have a TITLE. Nothing fancy, just a concise statement that explains what your graph shows.

2. The axes need to be LABELED, and you must SPECIFY UNITS. (Did you measure time in inches? Height in pounds?)

3. The points all fit on the graph. They also aren't all scrunched up at the bottom of the graph.

✏**EXERCISE 1-4 : Homework**

This is a group exercise, and will mostly be done out side of class. Discuss with the people (your scientific colleagues, your pals) in your lab two things on campus that might be interesting to graph. One of your graphs should describe a one-variable question, and might be something like the number of cars of different colors in the parking lot, or the number of times different people hit the "snooze" button on their alarm clocks before they actually get up.

Your other graph will describe a two-variable thing. This could be something like the height of a person compared to their weight, or maybe the difference between how many times men hit "snooze" as compared to how many times women hit "snooze."

Each graph is going to contain 40 pieces of information (also called data points), which isn't really a lot if everyone in the group does some of the work.

Divide up the work of collecting the data amongst you. Then figure out a time and place where you can all meet and exchange your data and discuss your graphs.

Although this is a group exercise and you are absolutely encouraged to work together, remember that everyone will be handing in their *own* work. Sorry, but Xeroxes of someone else's work won't cut it here, or anywhere else, for that matter. And remember about labeling your axes and writing titles for your graphs!

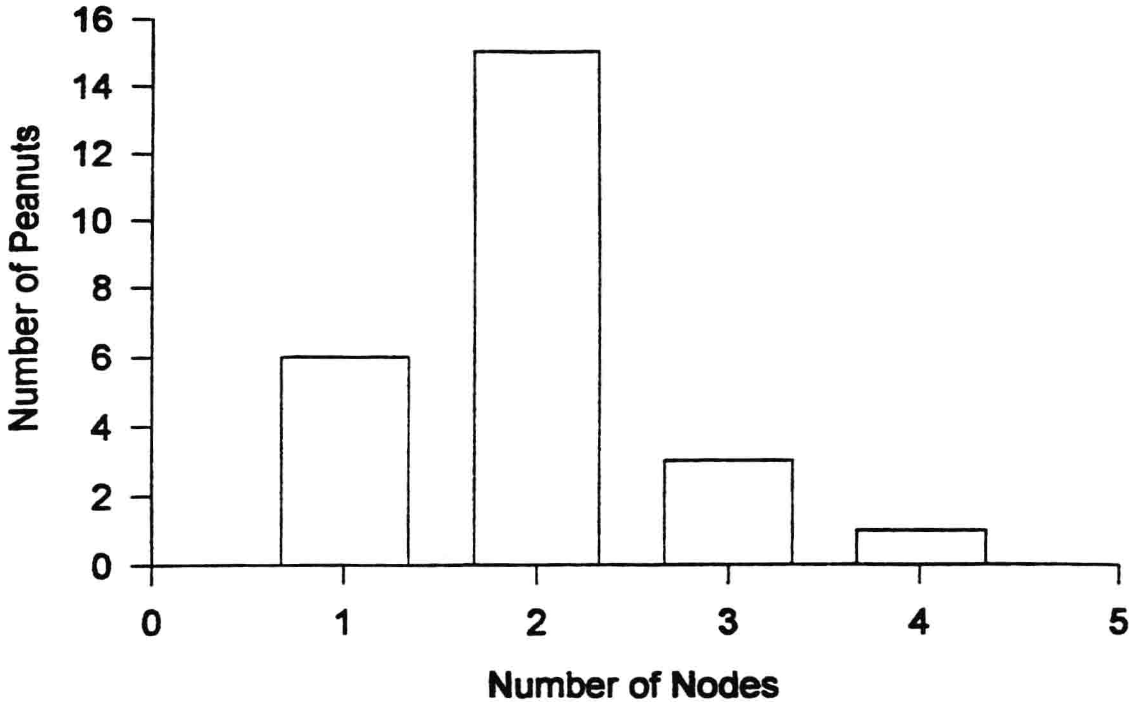

Figure 1. The number of nodes noted on 25 peanuts.

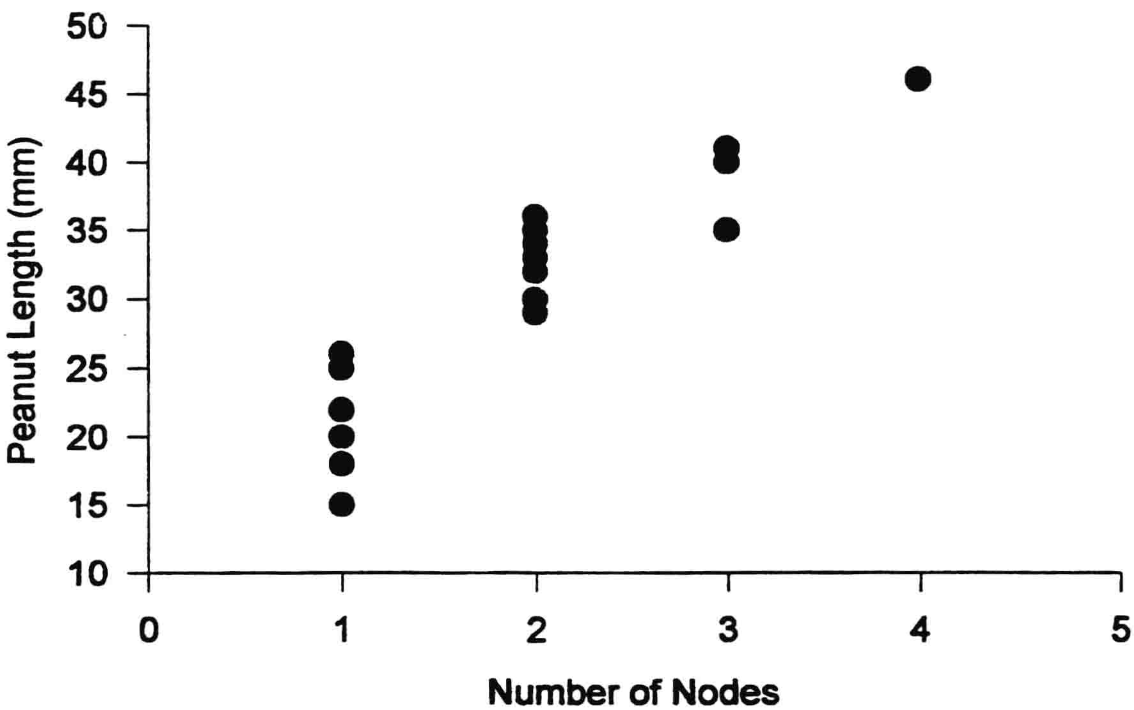

Figure 2. The number of nodes vs. length of 25 peanuts.

Figure 1: ____

Figure 2: ____

Topic 2

Microscopy and Cells

Stefan Woltmann

☞ How and why we use microscopes.

☞ A practical lab, mostly.

☞ Looking at various cells.

A scientist who doesn't know how to use a microscope is like a carpenter who doesn't know how to use a hammer, or a mathematician who doesn't know how to use a calculator. It doesn't really matter what field of biology you want to go into; at some point you will use a microscope for something, and hopefully it won't be to hammer in a nail.

As you have probably realized by now from the lectures, a lot of biology deals with very small things. One of the basic building blocks of living things is the cell, and it happens that most cells are what one would call small. Bacteria are among some of the smallest cells, and several hundred bacterial cells could easily fit on the period at the end of this sentence. Some cells, though, are as big as Ostrich eggs. As a matter of fact, Ostrich eggs, which can hold up to a gallon of stuff, are single cells. In this lab we will not be using microscopes to look at Ostrich eggs.

Look at Figure 2.1 on page 12. Then look at the microscope on your table. They should look pretty much the same. This is called a **compound microscope** because it uses several different lenses to magnify something. Really, there are only a few basic concepts you need to know before you start messing around with your scope. Probably the most important thing you need to know is that compound microscopes are **incredibly expensive** and **fairly delicate**. Be nice to them!

Here are a few more things you should know:

1. **Don't** touch the lenses! They are very easily scratched and smudged!

2. **Only** clean the lenses with **lens paper** and **lens cleaning fluid**. Mostly you will need to clean lenses because somebody ignored the previous point.

3. Don't move a microscope from table to table unless you *absolutely need* to.

Other than that, you should take a few minutes to play around with the various moving parts of the microscope to see what they do. If you've used microscopes before, this whole lab should be a piece of cake. If you haven't (OK, even if you have) used a microscope before, don't feel stupid if it takes you a little while to get the hang of it. A hammer is a much simpler tool and even experienced carpenters smash their thumbs once in a while, though they may not admit it. Here's some terminology that will make talking about microscopes easier:

→ **Oculars** are the things you actually look into.

→ **Objective Lenses** are the things pointing at the object you're trying to see.

→ The **stage** is the platform where the slide sits.

→ The **iris diaphragm adjuster** varies the amount of light that goes through the slide.

➔ **Focus knobs** are very handy features on a microscope. There are two: a **coarse** one and a **fine** one. The fine one is the smaller of the two. ** Be careful about using the coarse focus knob in a fast and furious manner. If you are not careful, it is possible to smash the slide against the objective lens, thereby breaking one or the other (or both!)*

Magnification

One of the most common things we talk about when using microscopes is **power**, or **magnification**. They mean the same thing, and refer to how much bigger something looks when seen in the scope.

You need to know how to calculate power. It's easy: just multiply the number on the ocular you are using by the number on the objective you are using. For example, if your ocular is 10x (the "x" means "times," as in ten *times* bigger) and your objective lens is 4x, then your total magnification is 40x. Simple.

How do I use this thing?

Everything you ever look at with a compound microscope will be on a slide. If it's not on a slide, you're doing it wrong.

ALWAYS start with your microscope on low power, usually around 40x. Turn the light on. Lower the stage (use your coarse focus knob) and put the slide on the stage in the little slide-holder-thingy. Use the knobs on the one corner of the stage to move the slide around and center the stuff ("subject") over the hole in the middle where the light shines through.

Only after you have done this are you ready to actually look into the microscope. Sometimes people can't find their slide because they are so busy looking into the microscope that they don't realize that they have positioned the slide way off in Siberia. Did I mention that you should start at low power? The lower the power, the easier it is to find your subject.

When you are trying to look at something, always **start** by using the coarse focus knob to *find* your subject, and **then** use the fine focus to see your subject clearly. Remember the point about **not** smashing slides with the objective lens.

On TV and in movies, when ever someone looks at something in a microscope or through binoculars, they show it as if you are seeing the image through two round holes that are connected at the edges. This is wrong. Your image should be contained in a single circle. You can adjust the oculars on most microscopes if they are spaced too wide or too narrow for your eyes.

The only other fairly confusing thing about moving the slide around on the stage is that if you do it while looking into the microscope (which you need to do), the slide looks like it's moving in the *opposite* direction than it actually is.

Before we go any further...

I need to mention something about high power. On these microscopes, the highest magnification is about 1,000x, and involves using the 100x objective (the really long one.) I've noticed that some people get really excited about this microscope business (a good thing) and want to jump straight to 1,000x on everything they look at (NOT a good thing.)

Don't do this.

The 100x lens is a special kind of lens (an especially expensive one, too) and requires that you use a technique called **oil immersion**. We'll get to that later when we talk about looking at bacteria.

Making a Wet Mount

As a biologist, you will almost always be preparing your own slides. A **wet mount** is one of the most common ways to look at something. The instructor will demonstrate how to make a wet mount; it's pretty easy. Basically, you start by putting a drop of water on the slide. This helps make your subject stick to slide, and also keeps your subject from drying up. (Most living cells have a lot of water in them to begin with, but the light source from the microscope tends to heat the slide up and dry things out.)

Then you take a *thin* (I mean *thin*) slice of whatever you are looking at and put it (flat) in the drop of water. Very often you will put a cover slip on top of it. A **cover slip** is a very thin square of glass that helps flatten out your subject, which makes it much easier to focus. To put a cover slip on without having lots of bubbles under it, put one edge of the cover slip on the slide at the edge of the drop of water. Then slowly lower the cover slip so that it covers your subject.

Looking at things (finally...)

OK, maybe not *just* yet (sorry...). Everyone is going to make and look at a bunch of slides. The first one is a prepared slide of a letter "e." It's a good one to start with because if you can't find a letter e, you'll never find some of the other things we're going to look at. Next, you will prepare some wet mounts: an onion skin, a plant leaf and human cheek cells. Last, you will look at some bacteria cells using very high power and oil immersion.

As long as we're looking at different cells, we might as well learn something about a few different basic cell types. Probably you will have already talked about these things in lecture. If you haven't, don't worry about it, it's really not terribly complicated (yet!)

You-carry-*what*ick?

Basically, cells can be broken down into two different types. The first few slides you will look at will all be **eukaryotic** cells. Eukaryotic cells are more complex than the other kind. Eukaryotic cells have a **nucleus** (plural: nuclei) which contains all the information about that particular organism in the form of DNA. Eukaryotic cells also have **organelles**, which act like the organs in your body in that they all perform specific functions. All things we think of as animals, and all plants are made of eukaryotic cells. Eukaryotic organisms may be made up of lots of cells, though lots of them consist only of one cell. As long as it has a nucleus, it's a eukaryote. The word eukaryote has a Greek origin and means "good" (eu) "nucleus" (karyo.) Remember that **you** are made of *eu*karyotic cells.

The other kind of cell is called **prokaryotic**, and these are all bacteria (that's plural; a single prokaryotic cell is a bacterium.) Prokaryotic cells are very simple compared to eukaryotic ones; they don't have a nucleus and they don't have organelles. Although some prokaryotes are colonial, none are truly multicellular. Prokaryotic cells *tend* to be smaller than eukaryotic cells, and they have been around *much longer* (at least two *billion* years longer!) The prefix "pro" in this case is Greek for "before," as in "before cells had nuclei."

You, by the way, are covered with prokaryotic cells right now. Just about everyone and everything is. Yuck. But don't go running off to take a shower just yet, I promise we're going to actually look at stuff very soon.

✏ **EXERCISE 2-1**

Looking at stuff (for real!)

There are two parts to all of these exercises. One part is preparing and looking at slides. The other is drawing what you see. Don't say things like "I can't draw." Really, you don't need to be a Rembrandt to draw a cell. Just draw what you see in the microscope. At these magnifications it's not like you're going to have to draw individual atoms or anything...

Use the work sheets to draw each of the slides you look at.

1. Get a prepared slide with the letter "e" on it and focus it at low power. Take your time, but if you really can't find it ask the person next to you or the instructor for help. As I said, finding your subject is sometimes the hardest thing about using a microscope.

Next, turn the objective lens to the next higher power. Often you need to reposition and refocus a little when you change the magnification. If you like, go to the next higher power, though DON'T GO TO THE VERY HIGHEST POWER. Notice how the image gets a bit darker and harder to find every time you increase the magnification.

Don't bother drawing this one.

2. Make a wet mount of an onion skin. Since onion cells aren't very colorful, you will need to use a drop of **methylene blue** *instead of water* so that you can see them. Methylene blue is a **stain**, and a good one at that. It'll come off your hands eventually, but it won't come out of your clothes; BE CAREFUL WITH IT.

Without trying too hard, you can probably use tweezers to pull off a small piece of onion skin that is only one cell-layer thick.

Look at this slide at several different magnifications, and note that the two most obvious features about these cells are the cell wall and the nucleus.

Draw a few cells.

3. Make a wet mount (using water) of an *Elodea* leaf. *Elodea* is an aquatic plant that happens to have very thin leaves (the edge of the leaf is thinnest.) The cell walls are fairly obvious in these cells as well, and they are also full of lots of little green balls; you may be able to see them swimming around in the cell. Those little green balls are called **chloroplasts** and are the organelles that allow green plant cells to take light and use it to make energy (photosynthesize). Life, as we experience it, would not exist if plants didn't do this.

By the way, draw a few cells.

4. Make a wet mount of your cheek cells. Take a toothpick from the box at the front of the room. You could probably find one on the floor if you looked hard enough, but I don't recommend it.

Gently rub the inside of your cheek (no need to draw blood!) and put the little blob now on the end of the toothpick on to a clean slide. It's not gross! Using a toothpick that you found on the floor...*that's* gross!

Put a drop of methylene blue on the slide and use a coverslip. These cells might not be as easy to find in the microscope as the plant cells, so be patient: they really are there.

Draw a few.

How are your cheek cells different from the other cells you've looked at so far?

✏ <u>EXERCISE 2-2</u>

Oil immersion

The last few slides you need to look at are of some prokaryotic cells. They have been professionally prepared for you. Looking at bacteria requires an additional technique because prokaryotic cells tend to be very small.

As usual, try to center your subject under the objective before you look into the microscope. When you look at these slides with just your naked eye the bacteria usually just look like a purple, blue or pink smear. That's the bacteria.

Go through the usual process of starting at low power and gradually using higher and higher power. For these slides we want to eventually use 1,000x.

The instructor will demonstrate how to use the oil immersion technique. Here's a brief description of how it's done.

1. Focus the cells at the next-to-highest power (should be about 400x.)

2. WITHOUT MOVING THE SLIDE OR THE FOCUS KNOBS, rotate the objective lenses so that they are half-way between the 40x objective and the 100x (the longest one.)

3. Put a small drop of **lens oil** on top of the slide. The pink or purple stuff in the bottle on the table IS NOT lens oil!!! It's cleaning fluid. Lens oil is clear or yellowish.

4. Rotate the 100x lens into place. It should end up so that the lens is in the oil, but not touching the slide.

IMPORTANT!: When using very high power, **Use only the <u>FINE</u> focus knob!!!** Otherwise it's easy to push the objective lens down into the slide and cause damage!

5. Bacteria come in three shapes:
Round (or **coccus**), Rod, or Spiral