# What is a PhD?

A properly trained PhD should be able to go into an empty lab with nothing but a pencil and paper and create a viable, externally funded research program. This requires that the PhD be able to do the following:

1) Read and evaluate the literature.

2) Identify a research problem based on a critical evaluation of the literature.

3) Devise an experimental approach to studying the problem, using techniques which are documented in the literature or are based on the literature.

4) Write a grant describing the problem, justifying the problem, and describing the experimental approach to solving the problem, all based on a critical evaluation of the literature.

5) Order equipment and supplies. Set up and operate the equipment. Maintain the supplies. Maintain the equipment in good repair. Be mindful of laboratory safety.

6) Plan a controlled experiment.

7) Do the experiment.

8) Interpret the results of the experiment.

9) Consider the impact of your interpretation on the "Big Picture" and modify the "Big Picture" accordingly, if appropriate.

10) Repeat steps 6-9. Before initiating step 6 on any occasion, justify the experiment for yourself in terms of the current "Big Picture". Be sure to consider the experiment you did a long time ago that you didn't understand. It may make sense now.

11) Write and publish a paper describing the work. This includes the artwork. The paper must not only describe your work, but also integrate it into the "Bigger Picture" presented by the literature.

Hints and comments:

1) The only truth is data. This goes for the literature, your colleague's work, and your work. Assume everybody is a jerk, including yourself. (Everyone knows the Boss is a jerk.) Don't believe what anyone tells you -- ask to see the data. This is not an insult -- it's the way good science is done.

2) Each new procedure you set up is like a miniature version of the main theme outlined above. For example, you may want to analyze your gene product by western blot analysis, when

you may never have done a western blot. Although there may be protocols for the procedure in use in the lab, you should assemble all the protocols from procedure books, your colleagues (ask to see the data!), and from the literature. Compare all the protocols in an organized fashion. Be sure you understand the purpose of all of the reagents and steps in the procedure. Try in particular to understand the critical parameters. These are places where preliminary controls and titrations will help you get a grasp of the procedure. It is not sufficient just to follow a protocol without understanding in detail the design of the protocol.

3) Learn how all the equipment works. It is not sufficient just to follow a procedure for operating a piece of equipment. Furthermore, you will find that if you understand how a piece of equipment works, it will be much easier to remember how to run it, and you will be able to use it much more effectively. The notion of a mechanically disinclined scientist is a non-sequitur.

4) Learn to recognize when you should be able to interpret an experiment and when you should not. For example, a restriction digest of a sequenced clone should be completely interpretable. If it is not, something is wrong. Don't proceed with it until you understand it completely or you'll be sorry. On the other hand, if the molecular weight of the band you see on your (well controlled) western blot does not fit with the predicted molecular weight of your gene product based on the open reading frame analysis, that could be interesting.

5) Keep the facts separate from the superstition, rumor, hearsay, and (most dangerous of all) models. If you're stuck on a problem, ask yourself, "What are the facts?" (This really is just another way of saying that the only truth is data.)

6) Seek criticism from your colleagues on a daily basis. Have them check your protocols. Have them help you interpret your data. Talk theory with them. Don't accept or deal out wimpy advice or criticism. Remember, the only truth is data, you are a jerk, your friends are jerks, none of us know what is going on, and ego has no place in a good laboratory.

6a) You are solely responsible for your work. If a senior colleague helps you interpret your results and says it's OK to move on to the next step, they might be wrong. The mistake becomes your responsibility for following bad advice.

6b) Senior lab members have a responsibility to instruct junior lab members. The instruction must be correct. Learn to say "I don't know". Most important learn to distinguish what you DO know and what you DON'T know.

7) Technical staff should be able to do steps 5 and 7 at a minimum. If they can do 6 and 8, they'll get paid more, and they'll probably be around longer (assuming they can stand it).

8) You can often save a whole day by spending an extra 10 minutes today to start an overnight or something, or by coming in for ten minutes on Sunday.

9) Although it may be necessary to run a lot of gels to obtain your goal, you will not necessarily obtain your goal just by running a lot of gels. A poorly planned experiment is a complete waste of time and money.

9b) You definitely won't obtain your goal if you do not run a lot of gels. Probably at least half and more like ¾ of your time should be spend actually at the bench doing experiments. If you're spending over half your time at your desk something is wrong.

10) Time is money. In fact it is our most expensive reagent.

11) Take time off on a regular basis. Take a vacation.

12) Be considerate of your colleagues (even if they are jerks), and mindful of the general laboratory environment. For example, order something before you run out, get the broken machine fixed, clean up after yourself. We are all housemates in a complicated house.

13) Take the Boss to lunch once a year.

14) Profanity and ethnic slurs are strictly forbidden.

15) Be prepared to repeat steps 1 through 4 several times before proceeding to step 5.

16) Don't hesitate to call an expert for reagents or advice even if you don't know them. The phone can save a lot of time.

17) Learn to keep a detailed, neat, and well organized notebook. Title and date (including the year) all your experiments for easy reference. Include a purpose, materials, procedure, results, interpretation, and conclusions with each experiment. Review your notes periodically and even make a table of contents as you review. Your experiments are worthless if they are not recorded properly. The experiments that don't work can be just as important as the experiments that do work, so don't wimp out and give up on taking notes on an experiment that is going wrong.

18) A good carpenter never blames his tools.

19) Remember Freddybird.

R. Condit, June 14, 1988, updated and revised periodically