

THE REAL FINAL EXAM

(SOME THOUGHTS TO PONDER ALONG YOUR WAY)

I have no more insight into science than many others; I was just naive enough to list the obvious to which most of us are blinded because of measurements by false yardsticks and examples which are always in vogue. I know that with time you can expand and improve your own list. In my weakness, I give students so many sheets or handouts of useless data to memorize that I thought a few important concepts might be worth sharing with you.

1.) IF THIS IS TRUE, WHAT DOES IT IMPLY?

Calculate the time it takes to do an experiment, then put down the per cent of time you actually thought about the results; you will be lucky if it is 10%. We usually don't need more experiments, we need more clear thinking. If you can practice this to an art, you will always have new ideas and insight. (Inhibitions to generate ideas and present trends and concepts, tend to paralyze this important process.)

2.) GENERATE MORE THAN ONE CONCEPT TO EXPLAIN YOUR DATA, THEN GIVE ALL POSSIBILITIES EQUAL ATTENTION AND EFFORT

(Your pet theory . . . will usually turn out to be just that.)

3.) YOU DON'T HAVE TO ASSUME ANYTHING THAT YOU CAN PROVE.

"When you assume, you are going to make an ASS-of U and ME" - Coach, in Bad News Bears.

4.) THE EXPERIMENT THAT DIDN'T COME OUT THE WAY YOU THOUGHT IT WOULD, IS THE ONLY EXPERIMENT THAT IS REALLY GOING TO TEACH YOU SOMETHING NEW.

(The key observations are usually "swept under the rug" or rationalized away. The one fact that doesn't fit the theory is always the most important fact.)

5.) EVERY DATUM IS SCREAMING TO TELL YOU SOMETHING, BUT YOU MUST DO THE LISTENING AND THINKING.

(If it isn't worth thinking about, it wasn't worth doing. A burning curiosity is the "ATP" of the laboratory.)

6.) WHAT YOU ARE THINKING ABOUT WHILE YOU ARE COMING TO WORK DETERMINES YOUR REAL INTEREST . . . AND WILL DIRECT YOUR ACCOMPLISHMENTS FOR THE DAY.

7.) A COMPLEX EXPERIMENT IS USUALLY THE LEAST PRODUCTIVE

A 500 tube experiment is very susceptible to Murphy's first law. Don't try to answer it all at once. Do a few things right. Too much phenomenology provides more complexity and little insight.

8.) IT IS TIME TO DO SOME EXPERIMENTS, OTHERS MUST WAIT.

There are many experiments worth doing but only a few great ones. Don't do the next experiment to come to mind. Try to think up a critical experiment that will go to the heart of the question.

9.) YOU ARE GOING TO BE SURPRISED AT THE SIMPLICITY AND BEAUTY OF THE REAL ANSWER.

(Almost a billion years went into selecting the system that you are studying. Remember, Crick and Watson didn't make the double helix, they only discovered an ancient system still operating today. It had plenty of time to be perfected.)

- 10.) ALL NEW IDEAS ARE RESISTED BY YOU - AUTHORITIES - THE EDITORS - STUDY SECTIONS - DEPARTMENT CHAIRMEN - PEERS - AND FRIENDS. IF THIS DISCOURAGES YOU, YOU SHOULD RETIRE EARLY. HOWEVER, MOST CRITICISM CAN BE CONSTRUCTIVE IF YOU LISTEN WITH AN OPEN MIND.
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(There is a fine line between being persistent and being bullheaded. Remember, no one can make you feel inferior without your consent. Don't give it. If your ideas are easily accepted, they are probably wrong. Most of the real great discoveries were first rejected and turned down for publication. There is a direct relationship between the unusual nature of a new discovery and the resistance to acceptance.

- 11.) A GOOD PAPER IS SIMPLE, CLEAR AND TO THE POINT.

(If the average reviewer can't understand your point, the average reader probably won't either; the reviewer usually spends more time with your paper. You know what you did, but you won't be there to explain it to the reader. You don't have to tell them every experiment you did and bore them to tears, just be sure they understand the most critical ones. A paper can be correct but not informative to the average reader. An example - read your insurance policy. Someone is going to try to confirm your observation; make it easy for them to repeat your work.)

- 12.) IF TWO GOOD INVESTIGATORS DISAGREE AND A PARADOX SEEMS TO EXIST, BOTH OF THEIR DATA ARE PROBABLY CORRECT, AND WE JUST NEED A NEW EXPLANATION TO ENCOMPASS BOTH OBSERVATIONS.
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Never assume that those who oppose your ideas are stupid. The more you disagree with the data of others, the less chance you have of finding the truth. Try to devise a model that also integrates as many observations of others as possible. All good experiments must be accounted for in the end. You are not the only one who can do a good experiment.

- 13.) GIVE EVERYONE CREDIT.

(You are not the first one to study this problem, nor will you be the last. Remember, the ones reviewing and judging your paper have already worked in the same field and they also know who did what. Give the true credit where it is due. Your reputation will be made by all of your studies and by how professional you are.

- 14.) DO NOT BE FOOLED BY THE AUTHORITY OF THE PRINTED PAGE.

(The observation of the "proof" might be correct, but how was the experiment conducted? Most of what you and I think today will appear silly in 20 years. At least, we can do our best. Keep in mind the limitations and state them.

- 15.) MANY BRIGHT PEOPLE ARE PARALYZED BY NEGATIVE THINKING.

They are often busy trying to prove someone wrong instead of trying to find out what is right or new. Every experiment, yours and others, is limited and is only an approximation. Look for clues because few things are ever proven. Test all theories.

- 16.) THE MOST IMPORTANT INGREDIENTS ARE HONESTY, DESIRE, CLEAR THINKING, CONFIDENCE AND HARD WORK.
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If you aren't willing to work long, hard hours and sacrifice in pursuit of this goal, then you are not willing to pay the price and maybe you should move over and give someone else a chance.

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IN CONCLUSION: If you are lucky, the world will be paying you a modest salary for what you consider your hobby, and you, in turn, will be contributing to some important answers for our present and future society. As you teach and lead, you will amplify your efforts and those of others, and if appropriate, the influence will continue after you cease. What you learn from courses, lectures and books that are reflected in your course grades will be a very small fraction of your FINAL EXAM. Good luck in your careers.