S3: Systems for Success in Science

(or, "How do you do 40 years of work in 1 hour?")

Systems vs Goals

The most valuable distinction you can learn is between goal thinking and systems thinking. A goal is a fixed point you try to reach, and then are done. A system is a series of interconnected, interacting parts. Put another way, a goal is something you work towards once, while a system is something you do repeatedly. For example, publishing a paper is a goal, revising your experimental protocols every week is a system.

Systems work, and goals don't.

Goals	Systems
Everyday Failure	Everyday Success
Limited	Open-Ended
Stressful	Energizing
Fragile	Anti-Fragile
Everyday Failure	Every

First, goals put you in a state of pre-success failure. You haven't reached your goal, and so, technically, you have failed, until you reach it. And when you do reach it, you can enjoy a brief moment of triumph before sliding back into pre-success failure. Conversely, systems put you in permanent success. You succeed every time you successfully implement your system, and succeed doubly when you make an improvement to it.

Second, goals give you tunnel vision. You focus purely on the goal, and ignore and side line any other opportunities that may arise, even if these are better than what you are currently working towards. Systems give you an outward vision, allowing to you to take advantage of new chances.

Third, goals are fragile, systems are anti-fragile. This is most important. Working towards a goal will provide you feedback only when you reach it, or fail, and in either case it will be too late to do anything about it. Worse, your entire effort may be invalidated by any unexpected change (someone else publishing first, for example). Treating your work as a system of moving parts provides you with rich feedback on a daily basis, allowing you to continually improve and not only endure, but thrive in response to the unexpected.

The superiority of systems thinking over goal thinking is generally true, but it is especially true in science. By its very nature, research seeks out the unknown. If your method of work is unable to accommodate this, you will have a hard time of it.

Have you ever noticed that in science there are no one hit wonders? There are regular careerists who produce set amounts of papers a year, and there are a minority of superstars with high numbers of high impact publications. These are the systems-thinkers.

Improved Gassman-and-Meyers: a starter system

Professors P.G. Gassman and A.I. Meyers wrote a series of letters to their research staff, outlining what they expected and what was necessary to succeed in science. Here is the refined and updated system, based on their work:

1. Work 60 hours a week.
2. Spend 10 of those hours reading the research literature. Take detailed notes, and review these regularly.
3. Never enter the laboratory without a detailed list of what you are going to accomplish
4. Keep a running list of work that needs to be done to keep your research going.
5. Keep a first rate lab book

This is demanding, there is no question. However, it is by no means impossible, and it should be clear how this relates to your scientific success. Carefully planned and recorded experiments, selected on the basis of a comprehensive knowledge of the subject literature, and carried out with high efficiency, leads to overall success in science. It really is that simple.

How to keep a lab-book that actually works for you

Here's a typical description of why you need to keep a lab notebook, courtesy of the US National Institute of Health:

To record your procedures, reagents, data etc. to pass on to other researchers

To explain why experiments were done, how they are performed and the results

To make a legal document to prove that your data and patents are yours

To leave a scientific legacy in the lab.

Who do these people think they are kidding?

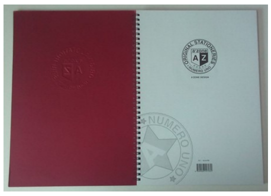
Right, the next person in the lab will read through your handwritten notes rather than, say, the nicely edited and formatted dissertation or paper you'll write. Yeah, you will totally produce not only really important results, but results so important they will be at the centre of a legal battle.

And even if any of these things were true, you really don't have time to care about them now. You have other things on your mind.

So forget about all this stuff. Here is the one you need to keep a lab notebook: to help you. Not the you in six months who is trying to repeat an experiment, or the you in eighteen months who is writing: to help the **you right now.**

Here's how you build a lab book that works for you.

1. Begin with your basic notebook. I prefer to write mine in blank notebooks but most universities provide their own lab-books with pre-printed title pages and content lists. Feel free to use those, or ignore them, or modify them, or rip them out completely if you so desire. This is your book, and it is there solely to serve you.



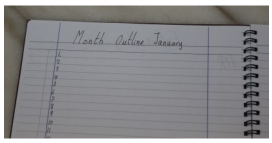
2. Add ruler thick margins to the first page. These margins are important throughout your book—they allow you to cross-reference and effectively hyperlink your book, integrating procedures, notes and plans into a seamless whole. They also help to break the psychological fear of a 'blank page'

3. Make your title page. Minimum you should add to this is your name, date, title of your lab book, lab book number, and contact number. I like to add a few quotations that I have found helpful throughout the years.

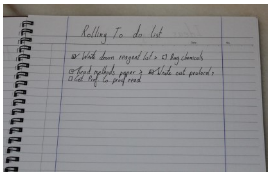
4. Take the next two pages and create your index. This is usually neglected, but I cannot emphasize how important this is. A good index does more than let you know where things are—it shows you your progress. When you read back over your entries, you will see how far you have come, and how each step leads to the next

5. Divide the next two pages into six sections for your 'future log'. This is your projected work for the next six months. Work out where you want to be six months from now, and divide it into six monthly milestones.

6. Take the next page and set up your monthly log. This one is often misunderstood. Don't try to plan in every day. Instead, at the end of each workday, write down for the next day two things you want to accomplish—and make sure that they get done. If you do two important things a day, even with weekends off, you will accomplish forty milestones a month. That is not nothing. Be sure to enter your goals for the next day directly at the end of your work day; you will be best able to judge what matters when work is fresh in your mind.



7. Take the next page and begin your 'Rolling To Do' list, the last to-do list you will ever need.



The Rolling 'To Do' List

You've had this experience: you decide to get organized, make a detailed to-do list, and diligently sort out each item on it. Three weeks later, nothing has changed and you are just as productive, or otherwise, as you were before.

Why? No follow-up. Practically nothing worthwhile - certainly nothing in a PhD - can be done in one sitting. So normal to-do lists leave you with two bad options.

The first bad option is to enter major, multi-step items that need doing. This doesn't work because it leaves you wide open to unexpected problems that will show up at each stage (not 'might', will) that will then side-track you from the stuff on your list. Worse, this list will seem to never grow shorter, which is psychologically debilitating.

The second bad option is just to enter items you can get done in one sitting. This collapses quickly, because when you cross those items off, you are left with a 'now what feeling', and nothing left to do but draw up a new list. That's even more mentally straining as you need to recall the next step in each project and activity you are involved in. Don't count on keeping it up more than a week.

The Rolling To Do List avoids both of these pitfalls. It has all the simplicity of the 'single sitting' list while making sure you don't lose sight of the follow up.

Start with writing out items you need to get done. Only one item per line, or one per two lines, if it is going to need a lot of follow-up. Make sure that all these items are ones that you can and will get done in a single sitting. For example:

☐ Read new methods paper

Be sure not to fool yourself! If you know you aren't going to make it beyond the introduction of the paper on the first sitting, be sure to only write that on your rolling to do list.

Then when that item is complete, immediately - immediately, that very moment, right then - put a ">" next to it and add the next logical step in the process. For example:

☐ Read new method's paper > ☐ write experimental protocol

The beauty of this is that the next step will automatically occur to you with no strain when you have just finished working through the previous step. It will cost you nothing in willpower or energy, or time for that matter. Progressing through your tasks with the necessary follow up will become almost automatic.

What happens when one such sequence uses up the available space? Just transfer it to the next free page, listing only the last items in each sequence. So the following on the previous page:

☐ Read new method's paper > ☐ write experimental protocol > ☐ find the failure points > ☐ get Prof. to proof-read it.

becomes:

☐ get Prof. to proof-read it.

On the new page.

And if you ever find you've written something that no longer is necessary or doesn't make sense? Just strike it out and forget it.

Simple and straightforward.

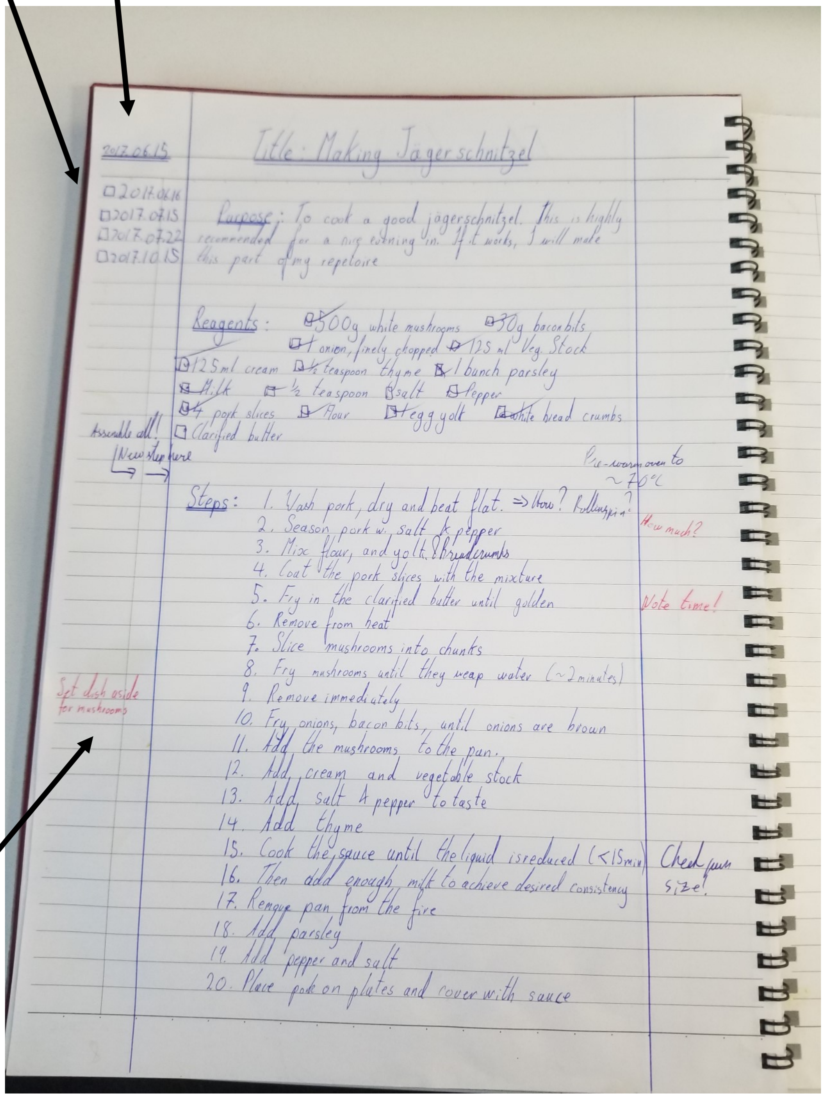
Experimental Entry Template

A note on literature notes. Keep all your literature notes in the same book that you plan your experiments in. The idea that they should be kept separate is bizarre and worse than useless. Keep them together with your experimental records and foster integration.

Review Dates. You should review any experimental record or literature notes one day, one week, one month, and four months from the date of creation.

Date

Title: Right at the top, something somewhat descriptive.



Purpose: One to three sentences. For example, *"I am testing the flammability of oil with certain additives. I am doing this because of the paper described on p 31. If this shows X, I will proceed with further experiment Y."*

Regents: Your shopping list of what to assemble before beginning.

Steps: A list of number steps detailing everything you will undertake. This means you will be free to simply write down your observations (step 4—saw this; step 7—saw this) and not lose precious time describing what you have done.

Proof-reading. You wouldn't submit an essay without proof-reading it, so why would you use a protocol before proofing it? When you have finished writing your protocol, go back over it and identify points of stress where error can creep in, and make a note of ways to expect and counter it.

All of the above should be written out in full **each time** before **every** experiment. Even if you have performed this procedure a dozen times before.

Writing the same protocol over and over will minimize mistakes, since it will make the procedure second-nature to you. Next, the act of writing it down will make you pay attention to the protocol, forcing you to see how it can be improved. Could the experiment fail at step five? Does step three perhaps introduce contamination? Couldn't I run more samples in one go at step nine?

Lastly, when it comes time for you to write your papers, you will be able to write significant chunks of your work automatically. This process will embed the fundamentals so thoroughly into your consciousness that you will be able to write it as easily as writing a letter.

Observations & Speculations Write down your observations as you perform your experiments. When you have completed your work, take a few moments to jot down some speculations as to the meaning of it all. These are not formal statistical conclusions, but anything that comes to mind.

The difference between effective and efficient

On the first page of this handout, you may have noticed a peculiar subtitle asking how you can do forty years of work in one hour. This may have struck you as hyperbolic. It's completely serious. The answer rests on the difference between effectiveness and efficiency.

Efficiency is doing things quickly, effectiveness is doing the right thing. No amount of efficiency or performance can compensate for misdirected action.

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ENZYME MECHANISMS: FAST REACTION AND COMPUTATIONAL APPROACHES

An end to 40 years of mistakes in DNA–protein association kinetics?

Stephen E. Halford

Biochemical Society Transactions
Apr 01, 2009,
37
(2)
343-348;
DOI: 10.1042/BST0370343

This is a completely real paper title, and it indeed demolished forty years of work by the most distinguished leaders in the field. To summarize, transcription factors were thought to find their targets on DNA two orders of magnitude faster than could be explained by classical diffusion mechanics. This paradox was investigated with the most outlandish models for four decades—until Halford reread the foundation papers of this field, and saw that the paradox only occurred in unusually low salt conditions.

Four decades of wasted effort because no one could be bothered to properly read the foundation literature. There is a lesson here: any mistake that it would take you an hour to find and prevent, will take you a month to correct after making it, and a year if your boss finds it, and decades if the scientific community needs to find it.

This should put the demands of the S3 system into perspective.