

Making the Right Moves

A Practical Guide to Scientific Management for Postdocs and New Faculty

Chapter 8

DATA MANAGEMENT AND LABORATORY NOTEBOOKS

Burroughs Wellcome Fund
Howard Hughes Medical Institute



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Chapter 8

DATA MANAGEMENT AND LABORATORY NOTEBOOKS

This chapter is based on the session “Data Management and Laboratory Notebooks” that was held at the BWF-HHMI Course in Scientific Management. The session was organized by Maryrose E. Franko, Ph.D., Howard Hughes Medical Institute, with presentations by David J. Adams, Ph.D., Duke University Medical Center; Howard Kanare, Construction Technology Laboratories; and Joseph M. Vinetz, M.D., University of Texas Medical Branch–Galveston. Additional information was obtained from some of the resources noted in this chapter.

As science explodes with new information and competition increases, and as academic scientists engage in more collaborations with industry scientists, proper recording of laboratory activities and managing the volumes of data produced by a laboratory are becoming increasingly important.

This chapter covers some of the basics: the importance of day-to-day record keeping and good practice for laboratory notebooks; what to consider when developing a system to track and store information; and finding the right data management system for you.

DAY-TO-DAY RECORD KEEPING: THE LAB NOTEBOOK

Why Keep Daily Records?

Every person working in a lab should keep detailed records of the experiments conducted each day. Here are some reasons why.

Establishing good work practices. Lab records allow your work to be reproduced by others. The records you keep should allow you and others to re-create the work and achieve the same results, thereby validating or extending your work. The records also allow you to prepare formal reports, papers, and presentations. They also serve as a source for assigning credit to lab members.

Teaching the people in your lab. Scientific training involves gathering information, forming hypotheses, designing experiments, and observing results. Lab notebooks, in which these activities are carefully recorded, can be a valuable aid in teaching your grad students, postdocs, and technicians how to analyze results, construct new theories and tests, and retrace their steps to identify an error.

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Enter all your work in a notebook—even procedures that did not work.

—David Adams, Duke University Medical Center

Reading notebooks is a nonconfrontational way to keep current with your students' and postdocs' work, and notebooks are critical when these lab members leave.

—Joseph Vinetz, University of Texas Medical Branch—Galveston

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Meeting contractual requirements. From grants to contracts to patent applications, researchers have explicit terms and implicit expectations to meet, for which detailed records and data are essential. For example, the National Institutes of Health has the legal right to audit and examine records that are relevant to any research grant award. Accordingly, the recipients of research grants have an obligation to keep appropriate records.

Question: For patent purposes, what's an “original” record?

Answer: An original is the first human-readable form—for example, a printout of a measurement but not a photocopy of it. It should be dated, signed, and filed.

Question: Genomics produces massive amounts of data. If the data are burned on a CD, are they considered “original”?

Answer: In this era of computer-assisted research, many pieces of data are collected, stored, and analyzed by computer. The problem with electronic records is that it is hard to prove that the data are not added to, deleted from, or in some way tampered with. The Food and Drug Administration (FDA) has published clear guidelines for maintaining electronic records in a way that will meet legal scrutiny (http://www.fda.gov/oral/compliance_ref/part11/). If you have really important results, it is probably safer to print them out, sign and date the documents, and indicate why they are significant.

Avoiding fraud. Lab directors are responsible for the integrity of their lab and everything it produces. Periodic checks of raw data in notebooks and project files can uncover and correct carelessness or outright fraud before it becomes a huge problem.

Defending patents. U.S. patent law follows a first-to-conceive rather than a first-to-file system. That is why documentation to support the date of discovery or invention is critical and why pages of lab notebooks and other records should be consecutively numbered, dated, and signed. Careful records can save a patent.

Good Practice for Laboratory Notebooks

Although individual scientists are responsible for maintaining their own notebooks, heads of labs are responsible for making sure that the notebooks of those under their direction are in order. The precise way in which to document scientific research varies from field to field and from institution to institution, but some general rules apply, such as the following:

- ◆ Use a permanently bound book, with consecutive signed and dated entries. When appropriate, witness entries as well.

Question: Why should I learn to write in the notebook?

Answer: You want to create an accurate, original, permanent record. There is a tendency to record information on the handiest piece of paper available, even on a paper towel lying on a bench, and then later transferring the information to a notebook. Therefore, you should get into the habit of immediately recording data as they are being collected into your lab notebook.

Question: What's the responsible way to document errors?

Answer: Make the required changes as soon as possible without obliterating the original entry. Electronic documents may require a new entry, not an override. If the error is logged by hand, do not erase or alter the initial entry. Correct the data at the point in the log where the error was discovered, refer to the original page, and go on (e.g., "Reagent was 50 percent of the strength we originally thought.").

Question: How do I get people in my lab to keep good records?

Answer: All students, technicians, and post-docs should be issued their own laboratory notebooks, with instructions on how to record in them. Establish expectations early and reinforce them periodically. The job interview is not too early to describe expected lab record-keeping methods and media. Many lab heads have a system for regularly reviewing all lab notebooks.

- ◆ For computer-kept logs, you can use a loose-leaf notebook, but pages must be consecutively numbered (using a sequential page-number stamp), dated, and signed.
- ◆ Record entries chronologically.
- ◆ Each entry should stand on its own to permit others to replicate the work.
- ◆ Organize material with sections and headings.
- ◆ Identify and describe reagents and specimens used.
- ◆ Identify sources of those materials (e.g., reagent manufacturer, lot number, purity, expiration date).
- ◆ Enter instrument serial numbers and calibration dates.
- ◆ Use proper nouns for items.
- ◆ Write all entries in the first person, and be specific about who did the work.
- ◆ Explain nonstandard abbreviations.
- ◆ Use ink and never obliterate original writing; never remove pages or portions of a page.
- ◆ If a page is left blank or a space within a page is left blank, draw a line through it.
- ◆ Permanently affix with glue any attachments (such as graphs or computer printouts) to the pages of the notebook; date and sign both the notebook page and the attachment.
- ◆ Outline new experiments, including their objectives and rationale.
- ◆ Include periodic factual, not speculative, summaries of status and findings.
- ◆ Enter ideas and observations into your notebook immediately. Summarize discussions from lab meetings and ideas or suggestions made by others, citing the persons by name.

Electronic Laboratory Notebooks

Electronic laboratory notebooks (ELNs) do everything their handwritten forebears do but with the attractive bonus of search and organization functions. Through links to analytical software, ELNs can usually download and store data directly, and many ELNs also support secure access for multiple users and remote users.

Choosing the right ELN for your lab requires homework. One important consideration is whether the ELN complies with the FDA's rules for acceptance of electronic documents, which were published in March 1997 in title 21 of the *Code of Federal Regulations*, part 11, available online at http://www.fda.gov/ora/compliance_ref/part11/.

So far, few ELNs have been subjected to legal scrutiny, and it is doubtful that many would pass the test. For this reason, most researchers in academic and industry settings are sticking to paper records.

When Is a Witness Warranted?

Some companies require that all notebook pages be witnessed. In academia, few labs follow this practice, but under some circumstances, having a certain record signed by a witness is desirable.

Learn to recognize an entry that merits a witness. When you think you have conceived an invention or an idea that may have intellectual property value, the date you did so is when you want a witness. For example, if lunch with a colleague leads you to an idea so tantalizing that you simply must go write it down, that's a notebook page you want witnessed. Another important date from a patent law standpoint is when the idea is put into actual practice, called "reduction to practice" (see chapter 11, "Understanding Technology Transfer").

Learn who constitutes an appropriate witness. Although a witness serves a certifying function much like a notary public, unlike a notary, a witness needs a sound grasp of the science. However, the witness should *not* be a co-inventor, who, from a legal perspective, has

a vested interest in verifying the claim. Find someone who is not directly involved in your work but who understands and can explain your idea. You may also need different people to witness pages containing different ideas. Do not designate one person as the "official" witness in your lab. Rote signatures unsupported by suitable scientific credentials will not meet the standard for credibility in court.

Where and How Long to Keep the Notebook

Lab notebooks that are "in progress" should be kept in the lab and reviewed periodically. Usually, notebooks are kept on a lab bench, but if you are concerned about the risk of damage or contamination, make it a rule that at the end of each day, all lab notebooks are placed in a fireproof cabinet or other designated space.

Completed lab notebooks should be indexed and kept in a safe central repository, along with corresponding patent applications or patents. Notebooks should be catalogued. Every time someone takes a notebook, it should be checked out and then returned. A person who is leaving the lab for a position elsewhere should not take any original lab notebooks but could be allowed to take copies of the lab notebooks he or she has maintained.

In general, the principal investigator should keep notebooks for at least five years after funding for the study ends. At that point, the notebooks can continue to be stored on site or moved to a storage facility. For anything that has been patented, the general rule is that the corresponding lab notebooks should be kept for the life of the patent

plus six years. Your institution may have specific policies for you to follow. If you move to a new institution, you should also check your old institution's policies; some institutions require departing faculty to leave their original lab notebooks.

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Every gel should be dried down and put in the lab notebook—even negative results.

—Joseph Vinetz, University of Texas Medical Branch—Galveston

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TRACKING AND STORING INFORMATION

Developing a Data Management System

Take the time to think about and produce a plan to track and store data generated by the people in your lab. Some requirements of your system will include the following:

- ◆ **Ability to sort and search.** If you want to be able to sort data in your system by a particular criterion, the information has to be entered as a sortable field. Try to identify at the beginning all the ways you might want to retrieve your data later. This is a challenging but productive exercise in thinking ahead.
- ◆ **Consistency.** For comparability, you need standards that are followed consistently. If everyone in your lab uses a different document-naming protocol, the departure of one person can create chaos. Decide on a consistent system for the file names of electronic and paper documents as well as the identification of samples and specimens—everything that your lab catalogues and stores. Figures 8.1 and 8.2 (page 126) present examples of alphanumeric coding systems for electronic documents and specimens.
- ◆ **Ability to update records.** It is important that you set up a system for logging in reagents and that everyone in the lab uses the system.

Assign Responsibility

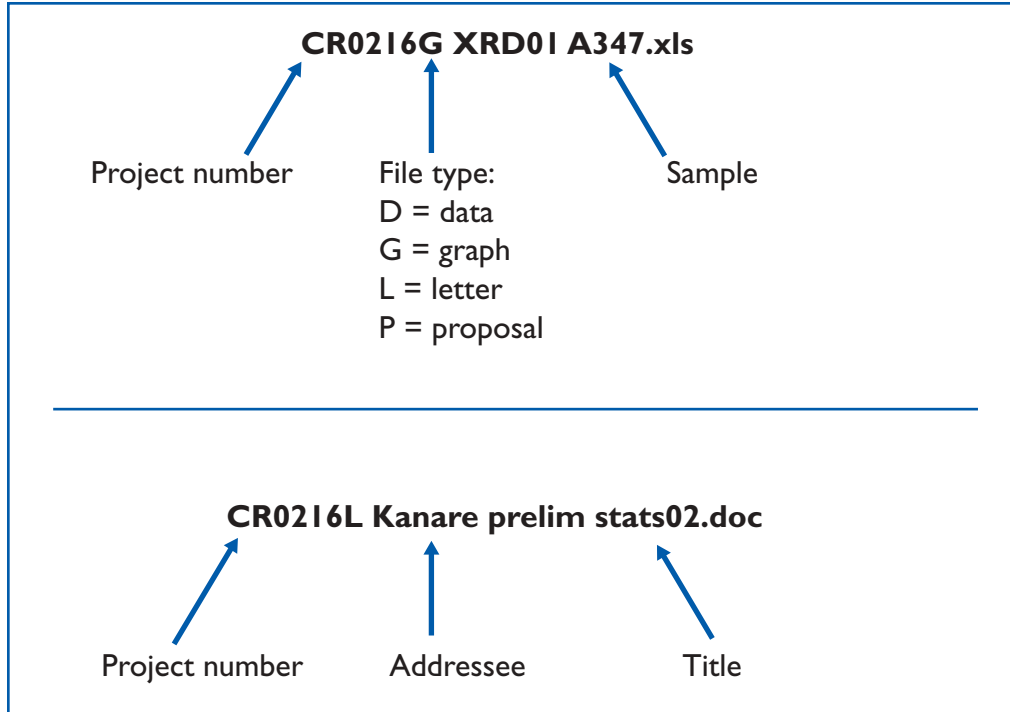
It's not enough to have a data management plan; someone needs to make sure the plan is executed. Because this is your lab, it's your responsibility—to handle personally or to delegate. Once you have made that choice, put quality assurance procedures in place, including scheduled spot checks of your established procedures. Make sure that everyone in your lab knows what to store where, how to do it, and who needs to log in that information.

What to Store and How

You will likely want to store the following:

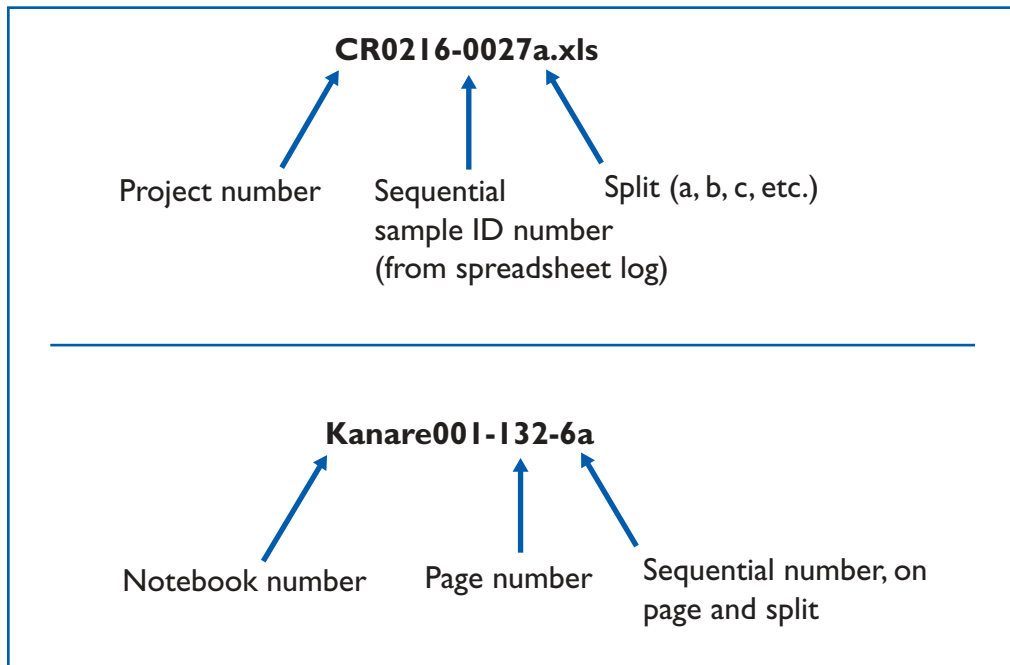
- ◆ Lab protocols
- ◆ Primary data, including images

Figure 8.1.
Electronic
document file
names



Source: Howard Kanare, Construction Technology Laboratories

Figure 8.2.
Sample and
specimen IDs



Source: Howard Kanare, Construction Technology Laboratories

- ◆ Lists of specimens and reagents
- ◆ Information about instruments

Where and how long you keep this information will likely be dictated by the type of information, but you also need to consider issues of lab space, fees and security issues for off-site storage, and the shelf life of the materials being stored. Here are some general guidelines.

Printed records. Records written in ink on acid-free paper and laser-printed records can be archived for a long time; ideal conditions are approximately 50 percent relative humidity and 21°C or cooler.

Electronic records. In theory, CD-ROMs and DVDs can last more than 200 years when stored in the dark at 25°C and 40 percent relative humidity. Floppy disks, however, have a shelf life of only about three years. Similarly, magnetic media are not designed for long-term storage. Another point to consider is whether the hardware and software needed to read the information will be available in the long term.

Lab protocols. Many labs keep a master collection of lab protocols, which is available either electronically or in print and is updated periodically by the revised versions kept in each lab member's own files. Lab protocols are rarely the type of records you need to store for the long term.

Reagents. It is important to have a system in place for keeping track of reagents that are used in your lab. While work is in progress, maintain records about the reagents used and keep the reagents themselves easily accessible in storage. Database programs such as FileMaker are easy to use and useful for keeping track of items such as oligos, antisera, plasmids, and cell lines. Many labs also use Excel spreadsheets or even paper records. When people leave the lab, have them place their unique reagents in storage boxes and document their location. Make sure everyone in the lab updates the database regularly.

You will also need a reliable tracking system for the sharing of reagents—requesting them from other sources and transferring yours to other labs. This involves Request for Materials forms and Material Transfer Agreement forms (see chapter 11, “Understanding Technology Transfer”).

Instrument histories. The care and maintenance of equipment are important responsibilities that affect the entire lab. Make sure someone accepts them and follows through. Lab records should include instrument logs that contain purchase, upgrade, and repair information; a calibration schedule and results; a control chart for performance trends; and blind quality control/quality assurance checks.

FINDING THE RIGHT DATA MANAGEMENT SYSTEM FOR YOU

Many academic labs, especially small ones, track samples, reagents, and experiments through paper records and simple electronic spreadsheets. But as the amount and complexity of data grow, some investigators may turn to specialized software products, such as laboratory information management systems (LIMS), data repositories, archival software, and tools to integrate the different applications.

Selecting a suitable program—one that fits your lab’s needs and budget—involves something at which you excel: research. Consult colleagues who have been through this process themselves, and don’t be shy about involving your institution’s information technology office. Once you have narrowed the list of candidate software, arrange vendor demonstrations and visits to labs that use these systems, and, of course, conduct reference checks. Your institution’s purchasing office may also be helpful.

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Redundancy is good. Cross-reference data sources—files, documents, samples—according to whatever consistent alphanumeric or other system your lab uses.

—Howard Kanare, Construction Technology Laboratories

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Some of the questions that you should consider are

- ◆ Is the system compatible with your existing software and hardware? Will it interface with your instruments?
- ◆ Are other users satisfied? (Talk to people in your field who have purchased a system.)
- ◆ What kind of support is available from the vendor?
- ◆ How much flexibility does the system offer? Can it be configured to satisfy your particular needs?
- ◆ How much training will be required?
- ◆ Is the company that sells the system well established or is it likely to be out of business in a few years?
- ◆ Is it worth it, or can you get by with the system you already have? Do you really need more software?

Laboratory Information Management Systems

Traditionally, LIMS have been used by chemistry labs that conduct batteries of tests on thousands of samples. In recent years, however, the LIMS marketplace has unveiled new products adaptable to the specialized needs of life sciences research (e.g., microbiology and genomics). LIMS can be used to

- ◆ Receive, log in, and label samples
- ◆ Assign work (e.g., tests and analyses for each sample)
- ◆ Schedule work
- ◆ Check status of work

- ◆ Integrate data collection by interfacing with instruments
- ◆ Track records and specimens

Be aware that a flexible system may not be ready for use straight out of the box. You may have to configure it to your specifications first.

Archival Software

The multitude of data generated by a single lab can be overwhelming. A growing number of software systems allow the user to collect, store, and visualize disparate kinds of information—ranging from mass spectrometry readings to microarray data. The systems provide a central repository for all data generated in a lab. One of the critical features that sets different types of software apart is the degree to which stored data can be retrieved and manipulated in the absence of the original instrument software. Another important consideration is the degree to which the stored data meet the FDA criteria set forth in title 21 of the *Code of Federal Regulations*, part 11 (see box “Electronic Laboratory Notebooks,” page 124).

Resource: Buyer's Guide

BioIT World produces an annual buyer's guide of products, including LIMS, which is available at <http://www.bio-itworld.com/buyersguide>.

As principal investigator, you know that maintaining accurate and consistent laboratory records and managing the flow of data your lab generates are critical to the success of your research program. So, be proactive. As you're setting up your lab, determine the standards and procedures for record keeping and communicate these to the members of your lab. Develop a plan to efficiently track and store

data and find an electronic data management system to help you implement this plan. Once you've done this, you're well on your way to keeping the avalanche of data organized and retrievable.

RESOURCES

American Association for the Advancement of Science. Scientific integrity videos, <http://www.aaas.org/spp/video/orderform.htm>.

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