5

Laboratory Notebooks

THE LABORATORY NOTEBOOK is the record you keep of the methods and results of your experiments. *If there is a fire in the lab, grab your lab notebook.* Leave the computer, the plasmids in the freezer, the special apparatus the glass shop rigged up for you—*nothing is as valuable as your raw data.* With it, you can write papers, plan experiments, and build on your results: Without it, you might as well have not been in the lab.

Your lab notebook should be clear and thorough. If something goes wrong, you must be able to go back and figure out what happened: Did you use older cells in the previous experiment? Was the incubation buffer made correctly? Did the enzyme suddenly stop working from one day to the next? Your lab book should be packed with clues that will help you solve the problem. Furthermore, *another scientist* should also be able to interpret your notes. A scribbled record, interpretable only by the writer, is not only obscure but is actually suspicious. Your lab book should be a defense against, not a proof of, fraud. It is proof of who you are, as a scientist.

TYPE AND FORMAT

Sheets versus book? There are many ways to record data. Before you invest your time in a particular method, be sure to *find out if the organization or P.I. requires a certain format.* Some companies and organizations have extremely stringent rules: This is not only because of issues of fraud, but also for protection, in the case of drug development and/or lawsuits.

For example, in one international pharmaceutical company, numbered notebooks must be signed out of the office. The lab book, with numbered pages, must be

kept every day, and countersigned every day by someone not connected with the project. The lab books are locked every night. They are kept indefinitely, and are microfiched once a year: They are never considered to be personal property. When a compound is being considered for human trials, the data and calculations in the notebooks are checked for errors by a group of people.

Needless to say, not all of these rules are followed in every laboratory. But if you are required to stay on top of your data this way, just do it. You'll never regret having organized data, and you will just have to cope with the sometimes tedious attention to detail.

Academic laboratories tend to be much more liberal in their lab book requirements, and many have no rules or guidelines whatsoever. Here you may find everything from data kept on paper towels to bound notebooks with carbon paper. Check with the P.I., and follow his recommendations. Most will recommend a book.

There are advantages and disadvantages to all styles of lab notebooks.

Type	Advantages	Drawbacks
Bound book	No lost sheets Proof against fraud	Experiments entered as done, no logical order
Loose leaf sheets/ folders	Can group by experiment, maintain order Easy to record data during experiments	Can lose sheets, harder to prove authenticity
Computer/ spread sheet	Easy to read Easy to do calculations	Can lose data, harder to prove authenticity

Looseleaf sheets are good for organizing multiple projects. They are also good for manipulations during experiments, since you can use a clipboard and not worry about the bulk of a notebook. Entering data directly into a computer makes further manipulations, such as graphing and statistics, quite simple. But accountability is an issue that only a bound notebook can address. If you have a choice of notebook type, *go with the bound book.*

What to look for in a bound lab notebook

- Large, 8 1/2 by 11 inches. You can attach photographs and some printouts, and have room for notes.

- Bound pages. It should be impossible to rip pages out without destroying the integrity of the book.
- Numbered pages.
- White, gridded pages. Lined pages are too confining, blank pages become messy quickly.
- Duplicate pages. The second page is usually yellow, with perforations that allow it to be torn out easily.

Effective use of a bound lab notebook

Use pen only, never pencil. Write on the white page, with carbon paper to record a copy on the yellow page. The white page remains in your notebook.

The yellow pages will be your second copy. Set up a file system for these pages, in folders. Put all data that don't fit into the notebook into the corresponding folder with the yellow pages.

Write the date and the experiment on *all* pieces of data, including printouts and photographs.

Keep your notebook and folders in different places.

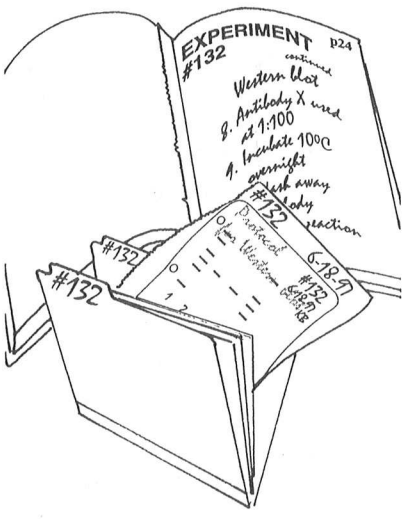


FIGURE 1.

Set up a file system for printouts, photographs, X-rays, duplicate (yellow) lab notebook pages, and for all data that cannot be neatly taped onto a notebook page. Each experiment should have its own folder.

CONTENT

The record of every experiment should contain:

- **Date of the start of the experiment.** Put a complete date (including the year) on every page, even on continuation pages.
- **Title of the experiment.** *Brief* is best. Examples are "Mini-preps of library clones" or "PMA effect on chemokine release from fibroblasts."
- **Brief statement of purpose.** This is an extension of the title, with a bit more detail. For the titles above, one might add "To check the insert sizes of the chicken cDNA library" and "Compare sparse vs dense cultures for IL-8 release." The title and purpose may be combined.
- **Description of the experiment.** *The protocol for the experiment* could be written out in the book before you begin, and amended as you do the experiment. A copy of a protocol could be pasted in, and also amended as you go. Always give a reference for the protocol you are using. This may be a journal article or a protocol from a book, or a reference to a protocol you developed ("as done on 9/5/97; see page 13").

Record *calculations* on an empty, adjoining page. Include calculations for concentrations, dilutions, molecular weights, and molarities.

Everything that happens—and doesn't happen—is *data.* Include all controls as data, including standard curves and 0 time point numbers.

As you go, tape what *print-outs and pictures* will fit into the notebook. Keep everything else together, well-labeled, so that the origin can be determined if they are separated from the rest of the write-up. File in folders with the yellow copies.

If it makes it easier for you to keep track of the data points, draw a scheme of the layout of the samples. For example, if you often use a 96-well plate, photocopy a plate or a template, tape it into your book, and record the sample descriptions onto it.

At the end of the accumulation of all data, write a *one-sentence summation of the results* of the experiment. Note any oddity or aberration, and add any comments about why the experiment may or may not have worked.

Table of contents. At the beginning of the lab notebook, or on a separate blank sheet, keep a table of contents, with experiments listed by title, date, and page number. It seems like a pain, but it will always save you time when you are searching for a particular set of data.

YOU WILL NOT BE ABLE TO REMEMBER EVERYTHING. YOU MIGHT NOT BE ABLE TO REMEMBER ANYTHING.

Record everything. There is nothing too minor to record. Write so anyone (including yourself) can pick up your notebook and duplicate the experiment (and the results) perfectly.

Information commonly omitted that you might need later:

Serum lot number
Antibody titer
Other people involved
Centrifuge model, speed, and temperature
Incubation time
Number of washes
Tube type and sizes
Unanticipated delays in incubations, washes, and treatments
Growth medium used
Buffer pH
Calculations
Initial number of cells
Age and passage number of culture
Agarose or acrylamide percentage of gel
Growth stage of bacteria
Condition of the cells used: sparse vs overgrown culture, granular cells, floating cells in an adherent culture

MAINTENANCE

It is not enough to record data as you go along. Unless you update and review the notebook, you will not have a good grasp of the contents.

Record everything as soon as you can. Try to record the experiment as you proceed through the experiment. If this is not possible (for example, when you are working with radioactivity), do it at the end of the experiment. And if you can't do this, do it the next day, at the latest. DO NOT save one day a week to record your data. The 20+ experiments that you might do in a week can become a mental muddle by the end of the week.

Do weekly check-ups. Set a regular block of an hour to go through your notebook. Even if you are working all weekend, Friday is often a convenient time. Use this time to do the following (see p. 96):

Lab notebook styles can be very individualized, but must still contain the essential elements. (See sample notebook pages on pages 94 and 95; courtesy of Jian Guo, University of Washington, Hongxia Fan, Rockefeller University, and Clare Carroll, Rockefeller University.)

June 3, 1992 COUNTS of ^{3}H uracil uptake Mouse 5-26 D.1, D2. D5

	TCA D.1	TCA D.2	TCA D.5	D.1	D.2	D.5
–	3701.5	1529.4	187.7	4688.2	1496.8	322.6
–	1608.5	1633.6	309.9	4288.6	1496.0	2692.3
1:1 155	274.9	689.9	49447.0	382.5	4672.1	40883.3
1:1 155	275.7	3828.4	55954.2	271.5	3616.8	35166.9
5:1 155	17460.4	10108.0	96939.7	15998.3	11483.8	92498.5
5:1 155	16787.9	10901.8	101587.1	7843.9	11055.0	81693.5
10:1 155	665.8	16159.4	100727.0	6587.9	28667.0	98439.9
10:1 155	521.5	22503.8	101739.4	604.7	24266.9	76547.8
20:1 155	873.6	67394.5	146437.4	1164.8	69448.2	140389.3
20:1 155	778.4	78718.4	146041.4	800.2	64456.4	121926.8
5:1 coli	1988.0	1470.3	36800.3	20336.4	4990.8	5646.4
5:1 coli	903.3	27143.3	45760.6	23151.1	6158.7	3717.0
10:1 coli	15204.2	20207.2	46095.1	12424.0	6033.3	4796.7
10:1 coli	14104.2	26519.3	48387.4	16603.1	6569.3	4540.5
5:1 BCL 10s.	1346.5	25314.0	2934.5	681.8	21839.3	1083.9
5:1 BCL 10s	1318.6	34581.4	1439.2	4192.8	21968.9	1113.4
10:1 BCL 10s	5222.3	2789.8	87981.0	4027.9	30749	7026.4
10:1 BCL 10s	3197.3	2170.7	81634.3	21299.8	26757	8199.4
5:1 BCL 20s	9905.0	1677.1	5110.7	19151.3	2154.8	1575.8
5:1 BCL 20s.	8490.8	1520.2	1801.7	7213.7	1779.5	1170.2
10:1 BCL 20s	4721.8	4390.7	5128.9	5813	6743.0	1943.2
10:1 BCL 20s.	4281.1	2554.8	2716.4	4197	6450.2	1932.5

Added 125 ul TCA

TCA samples washed w/ETOH only. (Kept at 4°c)
Plain samples washed w/H_2O + ETOH. (Kept frozen at -20c)

036

March 15, 1993. [155 RNA]

Using LEES DNA, innoculate the rest of DNA #3.* (4°walk-in) into 500 ml LB/AMP. → SHAKE 37°C. MAXI-Prep tomorrow.

RNA ISOLATION

KB grew up 6 500-600 mls 155. Isolated RNA in Guitch, 2M NaAcetate etc.

Reprecipitated 2x in GuHCl. Pellets look big but KB added glycogen. (we'll see after OD reading.)

Wash 2x in 70% ETOH. Spin 10', 13K. 4°c.
Pellets are a nice size. (Could be DNA!)
Reprecipitated in 1/10 vol NAcet 3M, 100% ETOH 2 vol.

3-16-93.
Spin down RNA 30', 15K 4°c.
SMALL PELLETS

PHOTOMETRIC SET SAMPLE, PRESS START KEY
λ 260.0 5ul → 600ul add H_2O.
No. A1
1 0.130 → LEE DNA 500ul TE.
2 0.068 → RNA 1st
3 0.029 → RNA 2nd 155. 5oul DEPC

DNA = 121df × .130 × 50. = 786.5ug/ml in 500ul → 393.25 ug

RNA 121 × .068 × 40 = 329.12 in 50ul → 16.5 ug.

RNA 121 × .029 × 40 = 140.36 ug/ml in 50ul → 7.0 ug.

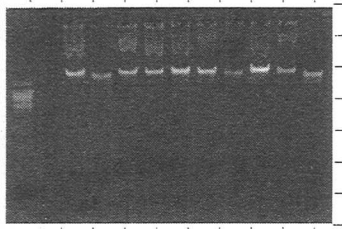
RNA at -20 in salt/alcohol.

15:31 3/17 '93 260.0NM 0.029A

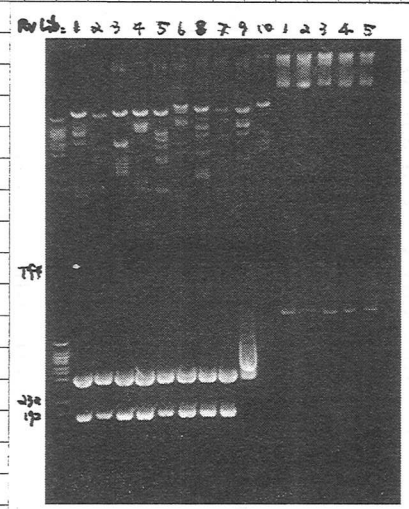
→ count colonies
→ grow up 10 colonies in 2ml of LB/Amp/2% Maltose/Kan, 37°C, o/n
→ miniprep DNA

CFU / Dilution	Bug (µl) 20	50
10^{-3}	600	3600

5.0 λ	DNA
1.5	#3 NEB
0.5	BamHI (20 u/λ)
5.0	RNase A
3.0	dd H_2O
15.0	37°C, 1 hr



∴ vector is not pYuB 078.



- Transformation of 155

200–400 µl 155 competent cells
0.5 µl each of 10 colonies / 10 µl pMY206 (0.14 µg/λ) for ①, ②, ③–⑦

		10' 4°C (on ice)	⑦	①	②	③	④	⑤	⑥
→ electroporate at	T=	2.5 kV	2.5	2.5 kV	2.5	2.5	2.5	2.5	2.5
	R=	129 Ω	129	480 Ω	480	189	129	72	720
	S=	1.45 kV	2.45	2.45 kV	1.45	1.25	1.25	1.25	1.25
	Gap=	0.2 cm	0.2	0.2 cm	0.2	0.2	0.2	0.2	0.2
	FS=	5.18 kV/cm	5.88	2.78 kV/cm	1.38	1.38	1.34	1.38	1.38
	t=	1.33 msec	2.44	16.8 msec	17.1	8.05	4.08	2.95	10.69

→ mic on ice, 10'
→ add 400 µl of comp 7H9, 37°C, 2 hrs

7 - 1 - 97

Immunoscreen — 16 day mouse embryo cDNA library in λEXlox® Vector

1 titer library
~ 1.3×10^6 pfu

2. make BL21
① grow BL 21 O/N
② spin 20' at 2000 rpm 4°C
③ resuspend the cells to c. $OD_{600} = 0.5$ in 10mM $MgSO_4$

3 plate (15cmm 2XYT plates)
① 2.5 ml original ϕ
747.5 ml SM
750 ml BL 21 ($OD_{600} = 0.5$)
② mix well, at 37°C for 15'–20'
③ add ~8ml 2XYT top agar
④ plate, and incubate at 37°C for 7 hrs just until small plaques become visible (0.5 – 1mm in size)
⑤ apply the numbered IPTG-treated membrane to the plates
⑥ keep at 4°C O/N

4. treat the membrane with 10mM IPTG before apply the membrane to plate
① dilute IPTG in sterile dH_2O to 10mM
② 30' prior to use, wet the membrane in IPTG sol place the membranes on Whatman 3mm paper to air dry

- *Attach all data, printouts, and X-rays to the appropriate experiments.* If the paper or picture is small, tape it into the book. If it is large, place it in the experiment file. Most films need to be held up to the light to be seen properly, so file even small films instead of putting them in the book.

- *Make tables and graphs.* Try to do this during the week, but certainly do it before the week is over. A graph or a table makes all data easier to interpret; it looks "real," and will validate your position in a discussion far better than a wordy explanation. You also want to avoid making dozens of graphs and tables only when you are writing the paper or giving a lab seminar. If the table or graph is small, tape it into the notebook; otherwise, file it in the folder.

If you don't know your data, the experiments are useless. Only by knowing your results can you plan your course, discuss your conclusions, and be in control.

- *Write summaries for all the week's experiments.* Go through every experiment, and be sure there is a sentence or two summarizing the results at the end of every one. Feel free to write more—interpretations, recommendations for other experiments—but always write your summary where you can flip through the notebook and find it.

- *Record the experiment in the table of contents.* By simply recording the titles and dates of the experiments you will greatly boost your organization, since you can much more quickly find any experiment you want. If appropriate, record the page number.

- *Make a plan for the following week.* While the data are fresh in your mind, think a bit about what they mean and what you need to do next. A written summary is probably unrealistic, but would be amazingly helpful.

Solicit feedback on your data and your plans. Once you know your data, discuss them with coworkers or your P.I. You don't need to completely understand what all the results mean to initiate a discussion, but you certainly must know what the data are.

ETHICS

Ownership. *The lab notebook belongs to the laboratory, not to the labworker.* If you are terribly attached to your book and want to keep it when you leave, discuss it with the

P.I. He or she may be happy with a copy, but that would be unusual. Ask whether you may take the yellow copies.

It is considered to be an invasion of privacy for one lab worker to read another person's lab notebook without asking.

Don't be afraid to make your lab notebook personal, with remarks, lamentations, and peeves noted, as long as the data are reported clearly and thoroughly. But too much deviation from the data is unprofessional and could be embarrassing, so minimize the emotional information.

Public versus private. The lab notebook is a curious document, a mixture of a public and private record. In most places, it is left on desks or lab benches, but is never looked at by anyone but the "owner." Don't sneak a peek at another lab member's book, even (or especially) if you want to check on suspected fraudulent data. If you suspect fraud, speak to the P.I. And if you suspect someone is examining your book, lock it up or give it to the P.I. to lock up at night.

P.I. access. Generally, the P.I. will read technicians' and summer students' notebooks freely, but will not read graduate students' or post-docs', as this is viewed as intellectual infringement by many. But don't be offended if your book is examined, especially if the P.I. is helping you troubleshoot an experiment. It is technically a public document and should be able to stand up to scrutiny.

Archives. How long should a lab notebook and raw data be kept? Because of space limitations, most labs cannot keep all lab notebooks indefinitely. They should be kept for *5 years,* and disposed of only at the discretion of the head of the laboratory.

Don't dispose of

- Old notebooks you find when you start in a lab
- Your own notebooks, even after 5 years
- Any notebooks for an ongoing project
- Data found in drawers and on the computer

Omitting a result is falsifying data.

Recording data. A "mistake" made in your notebook will be amplified by the time it makes it into the literature, so be absolutely rigorous about recording everything as accurately and honestly as you can.

Never omit a data point from your notebook! There are statistical criteria for eliminating data points, and these should be followed. Some kinds of data do not lend themselves to this kind of analysis, and the decision to jettison a data point is harder to justify.

You may be pushed to obtain certain results. In many cases of fraud, the perpetrator has blamed the P.I., saying that the P.I. expected a particular result, and the researcher felt compelled to produce it. It is true that a P.I. may want a result. **But your data are your responsibility,** and it is up to you to be sure the data are recorded honestly and accurately.

If you drop a data point, note in your lab book the reason you have eliminated it from calculations and graphing. Write "since I think I had jiggled that plate," or "because such a result was not seen in 6 other experiments," or "the cells didn't look healthy." No matter how weak your reasoning seems to you (and if it does seem weak, perhaps you shouldn't be doing it), you must make clear what data you discounted and why.

RESOURCES

Broad W. and Wade N. 1992. *Betrayers of the truth. Fraud and deceit in the halls of science.* Simon and Schuster, New York.

Carr J.J. 1992. *The art of science. A practical guide to experiments, observations, and handling data.* HighText Publications, San Diego.

Schrader-Frechette K. 1994. *Ethics of scientific research. Issues in academic ethics.* Rowman & Littlefield, Lanham, Maryland.