Best Practices for Keeping a Lab Notebook

HARVARD LONGWOOD CAMPUS

November 22

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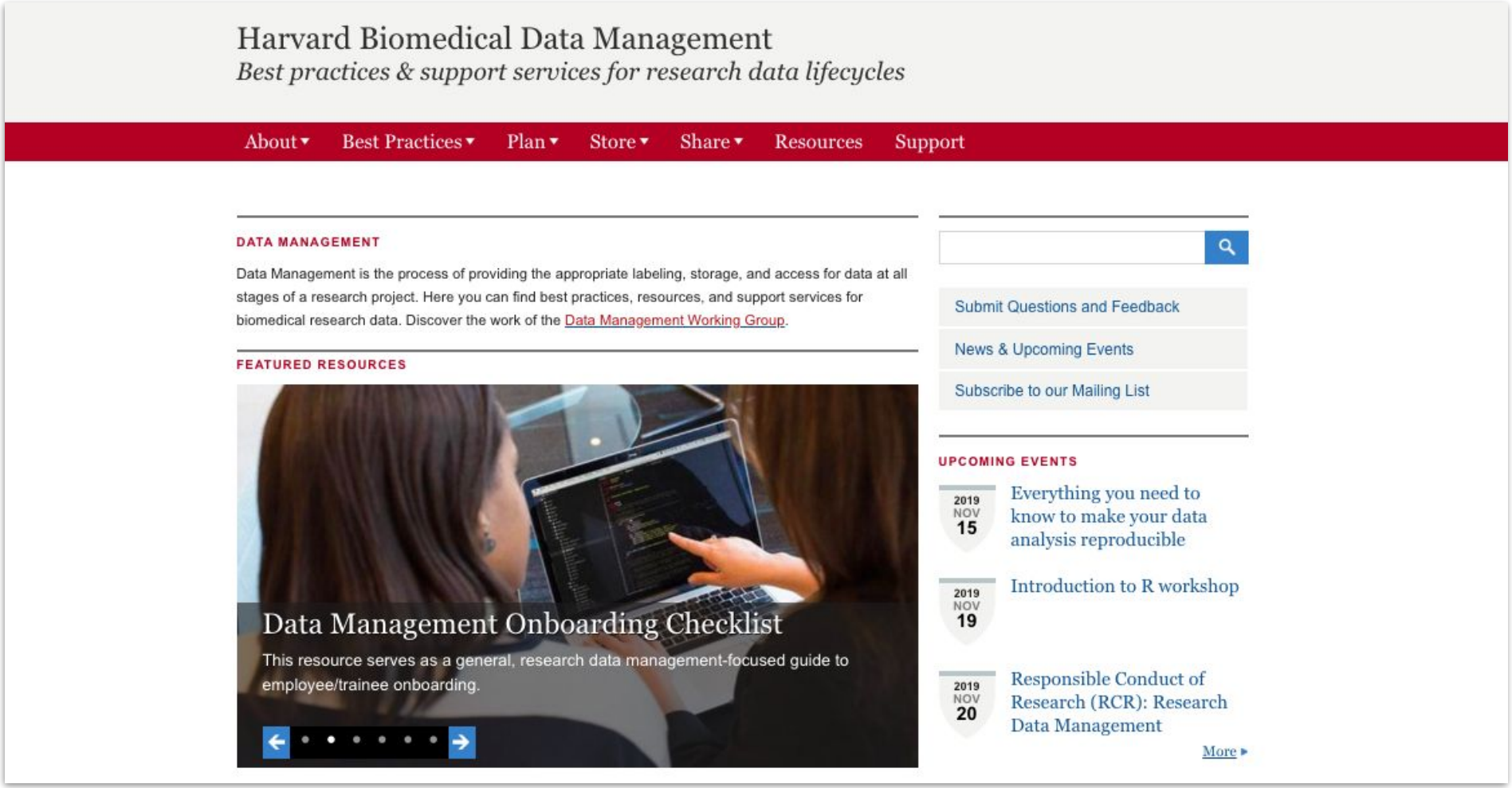
https://datamanagement.hms.harvard.edu



Learning Objectives

- Discuss the different types of notebooks
- Cover basics do’s and don’ts in keeping a lab notebook
- Review ethical considerations around lab notebooks
- Provide examples of what a good lab notebook looks like
- Offer help to better manage your data and support good practices

"Research data management concerns the organization of data, from its entry to the research cycle through the dissemination and archiving of valuable results. It aims to ensure reliable verification of results, and permits new and innovative research built on existing information."

Whyte, A., Tedds, J. (2011). 'Making the Case for Research Data Management'. DCC Briefing Papers. Edinburgh: Digital Curation Centre

Why should you care?

Benefits for yourself, researchers, and science:

- Your future self will thank you!
- Facilitate and ensure seamless team transitions
- Conduct analysis effectively when collaborating with others
- Check and verify research results
- Support FAIR principles: Findable, Accessible, Interoperable, & Reusable

Compliance:

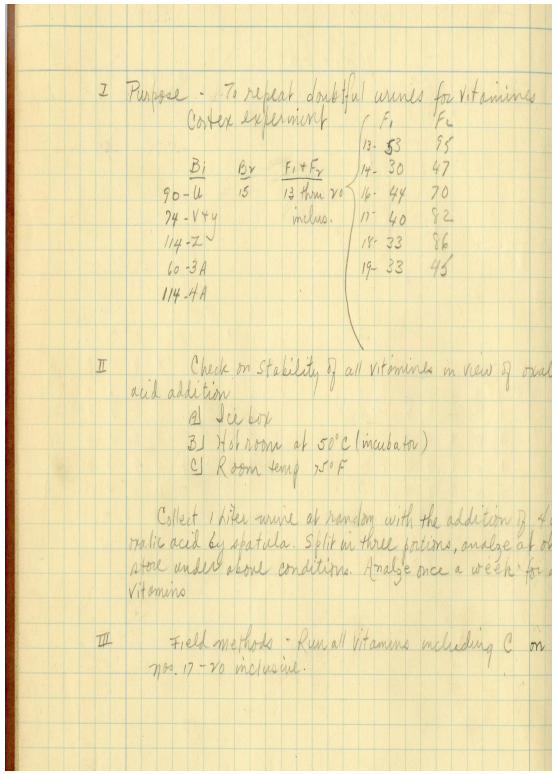
- Be **compliant with University and School policies**
- Be **compliant with funding organizations** that require a data management plan and data sharing
- Be **compliant with journals** that require to submit your data accompanying the article

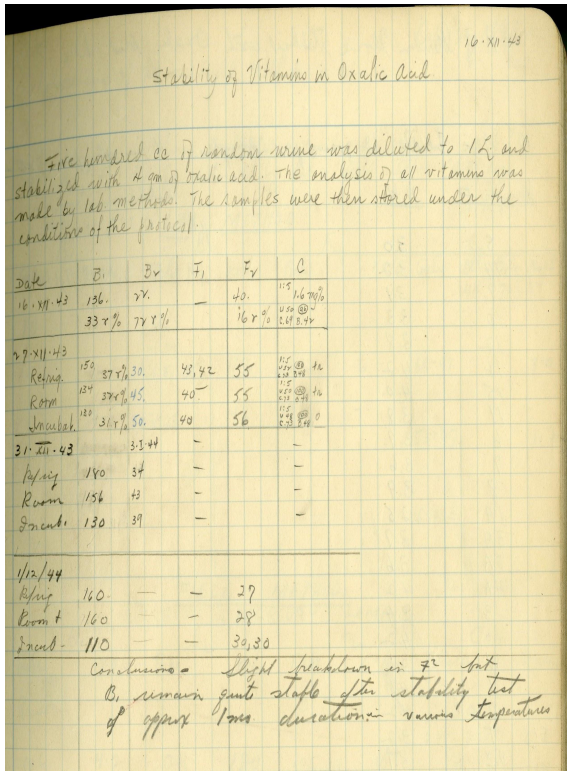
Why Notebooks are Important!

- Tufts University immunologist Thereza Imanishi-Kari admitted that her poor-record keeping led to misconduct allegations regarding falsification and fabrication of data in her 1986 paper in Cell with co-author Nobel Laureate David Baltimore
    - Kaiser, J.; Marshal, E., 1996, Imanishi-Kari Ruling Slams ORI. Science, 272, 1864-1866 https://www.ncbi.nlm.nih.gov/pubmed/8658151
- December 2011, a paper about Sleep Apnea was retracted from the *New England Journal of Medicine* due to the authors' inability to locate original data
    - Retraction Watch http://retractionwatch.com/2013/10/30/nejm-paper-on-sleep-apnea-retracted-when-original-data-cant-be-found
- A survey of 90 major research institutions' Research Integrity Officers showed that 38% of 553 misconduct cases involves some degree of poor record keeping
    - Wilson, K.; et. al. 2007, Research Records and the Resolution of Misconduct Allegations at Research Universities. *Accountability in Research* 14, 57-71 https://dx.doi.org/10.1080%2F08989620601126017
- In a 2007 NIH survey of 1,479 researchers, 27.5% admitted to inadequate record keeping
    - Shamoo, A.E.; Resnik, D.B., 2009, Responsible Conduct of Research (2nd Ed.). Oxford University Press https://global.oup.com/academic/product/responsible-conduct-of-research-9780199376025

Harvard Scientists and their Notebooks

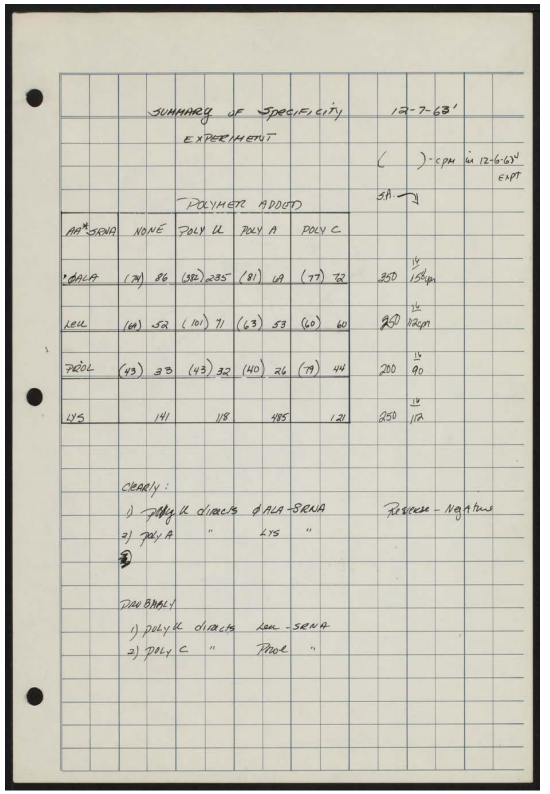
Harvard Fatigue Lab

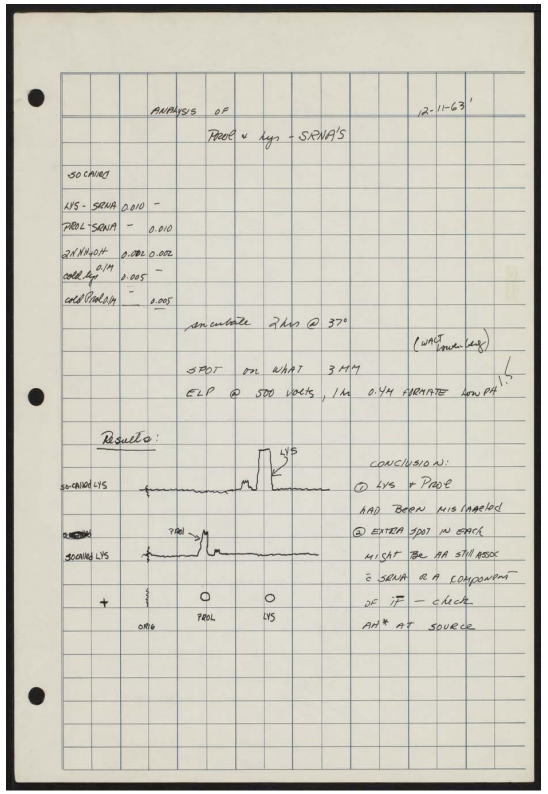




Harvard Fatigue Laboratory Records, 1916-1952 (inclusive), 1941-1947 (bulk). Harvard Medical Library, Francis A. Countway Library of Medicine, Boston, Mass.

Philip Leder

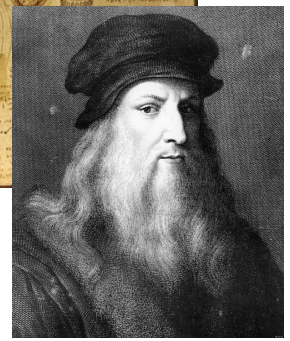


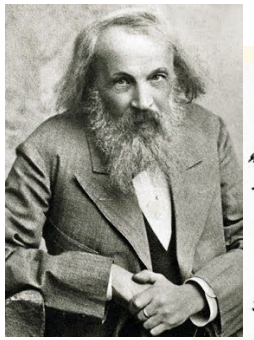


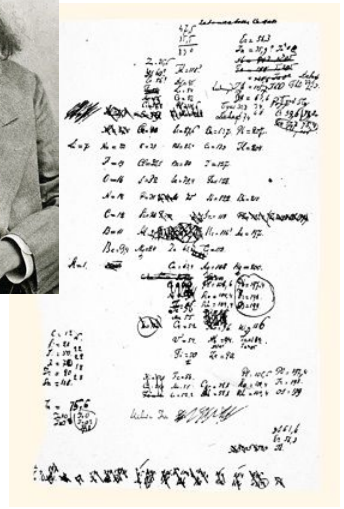
Philip Leder laboratory notebook. H MS c296. Harvard Medical Library, Francis A. Countway Library of Medicine, Boston, Mass.

Notable Scientists and their Notebooks

Leonardo Da Vinci

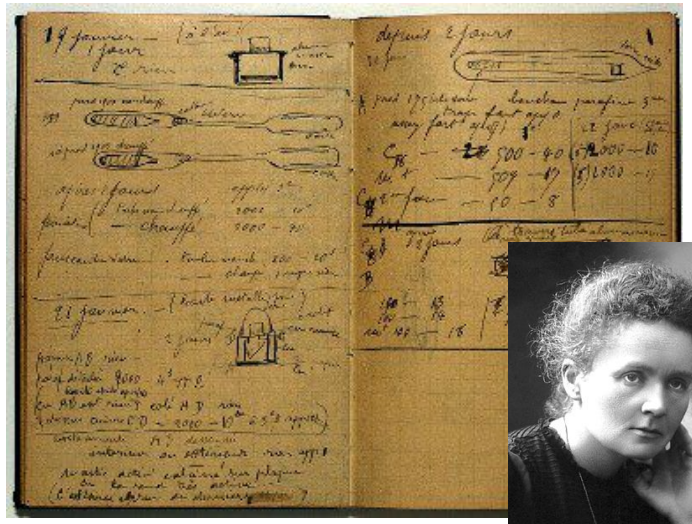


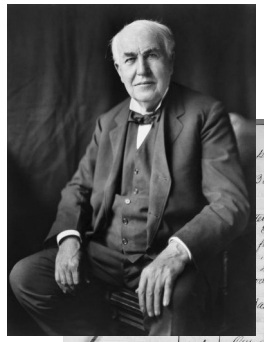


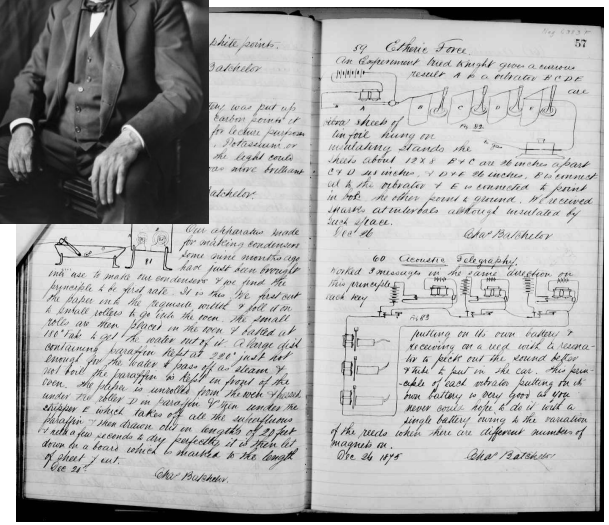


Dmitri Mendeleev

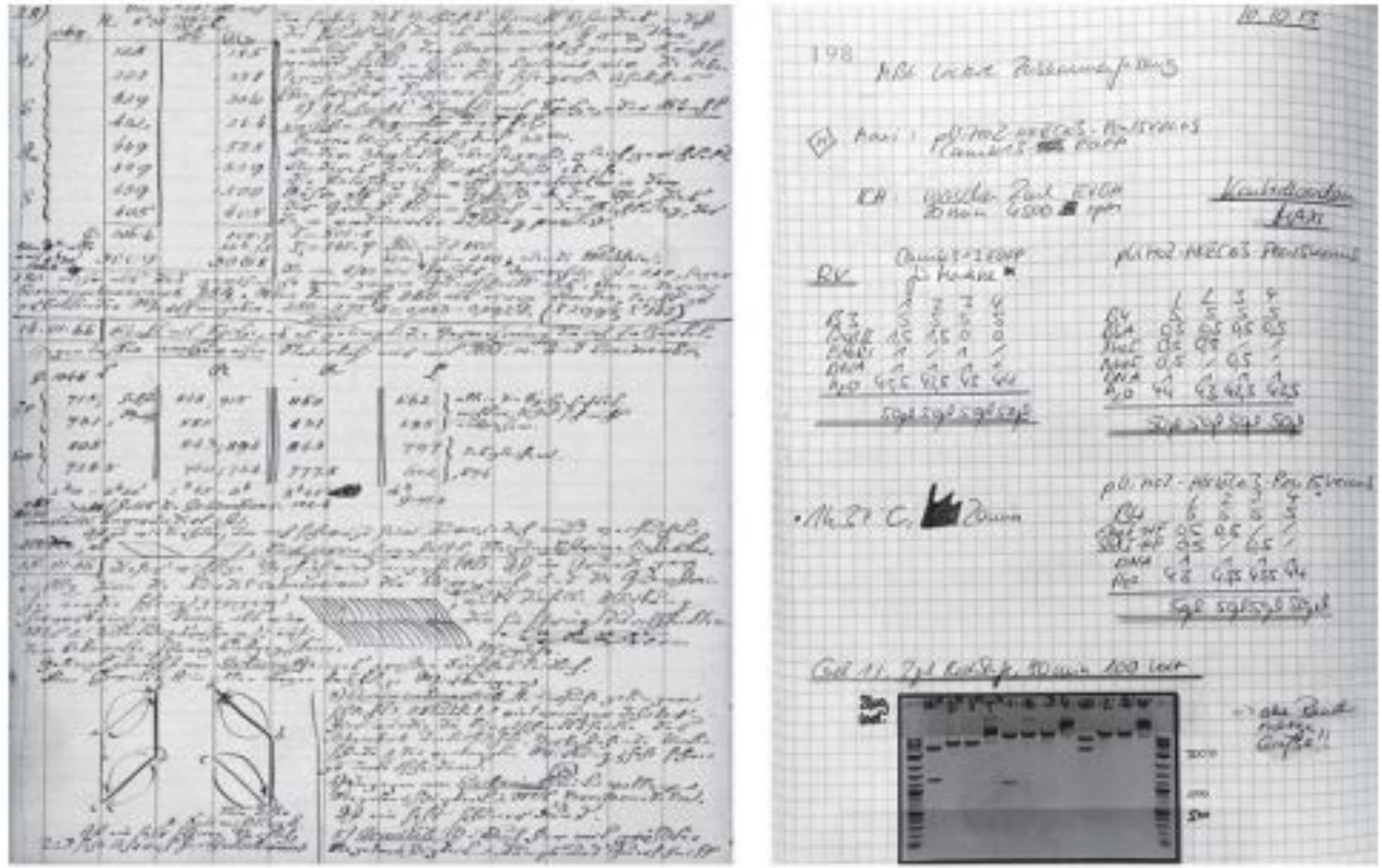
Marie Curie







Thomas Edison



A B

Figure 1. Laboratory notebooks have remained essentially unchanged throughout the last centuries. A: Page from the laboratory notebook of the father of experimental electrophysiology, Emil Dubois-Raymond (7 November 1818 – 26 December 1896). [Staatsbibliothek Berlin, 1865–1868, XIII, 22. VII. 65–9. VI. 68, reproduced with permission]. **B**: Pages from a contemporary laboratory notebook from the laboratory of the authors.

A Lab Notebook Is...

- Complete record of procedures, reagents, data, and thoughts to pass on to other researchers
  - Relevant thought processes that would enable another scientist to reproduce your observations
- Explanation of why experiments were initiated, how they were performed, and the results
- Legal document to prove patents and defend your data against accusations of fraud
- Scientific legacy in the lab
  - Long after you have moved on from the lab, your notebook will remain and be referenced
  - Others will be building on the research that you are doing now and it is imperative that they can replicate what you have done

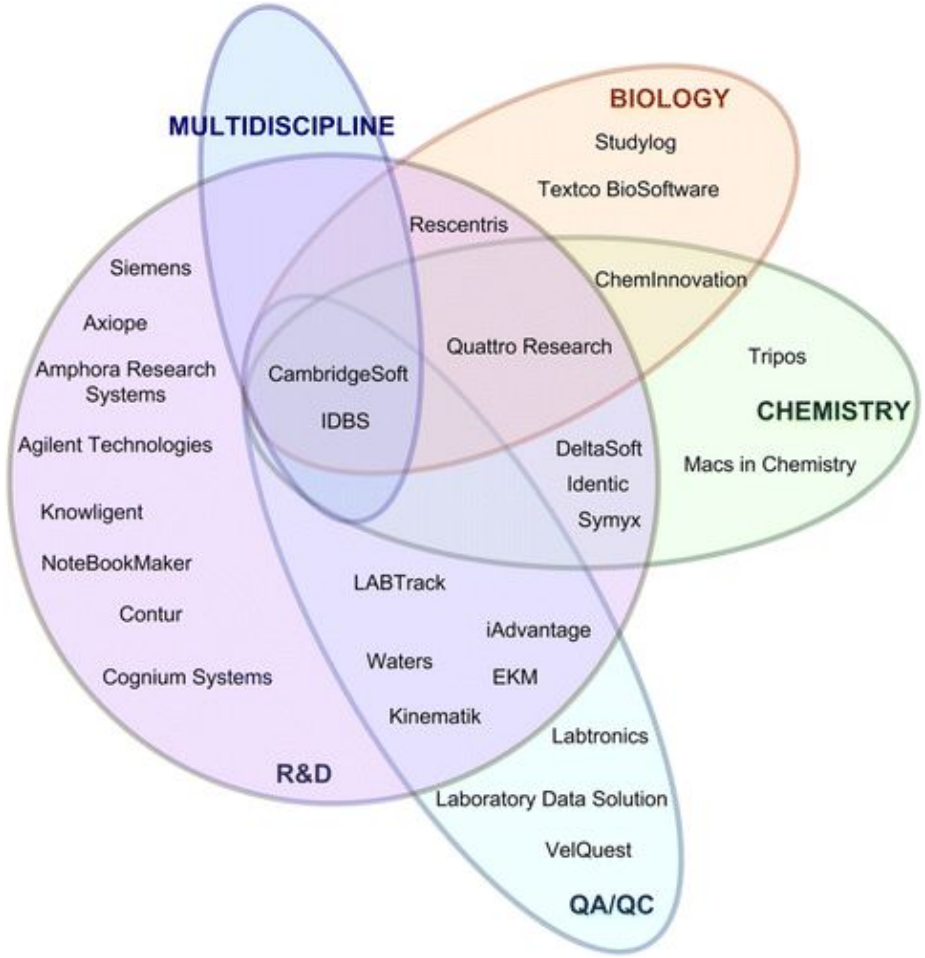
A Lab Notebook Is Not...

- A journal
  - There is a difference between recording a hypothesis to be tested by a specific experiment and writing down ideas about how things might work
- A record of communications
- A place to compile lab protocols/manuals
  - Document the company and product, you can reference the manual in your procedures
- Yours to take home
  - It belongs to the institution for which you are working.
  - If appropriate, you should have the right to make photocopies of all your work
- Just for ‘wet lab’ or ‘bench science’
  - It is an organizational tool and memory aid for even scientists pursuing exclusively “dry” research

Type of Notebook

Type of Notebook	Advantages	Disadvantages
Bound/Stitched Notebook	No lost pages, legally stronger	Difficult to copy, not logically organized, requires references to data stored elsewhere
Loose Leaf/Three Ring Binder Notebook	Organized by experiment, data stored together	Sheets fall out, difficult to authenticate
Electronic Notebook	Easy to search, easy to read, digital data easy to store	Requires electronic security, corrupted files, software compatibility issues

Many Electronic Notebook Types



- Blogs
- Wikis
- Note taking software
- Document management systems
- Project management platforms
- Computational notebooks

Rubacha, M., Rattan, A. K., & Hosselet, S. C. (2011). A Review of Electronic Laboratory Notebooks Available in the Market Today. *JALA: Journal of the Association for Laboratory Automation* 16(1): 90–98. https://doi.org/10.1016/j.jala.2009.01.002

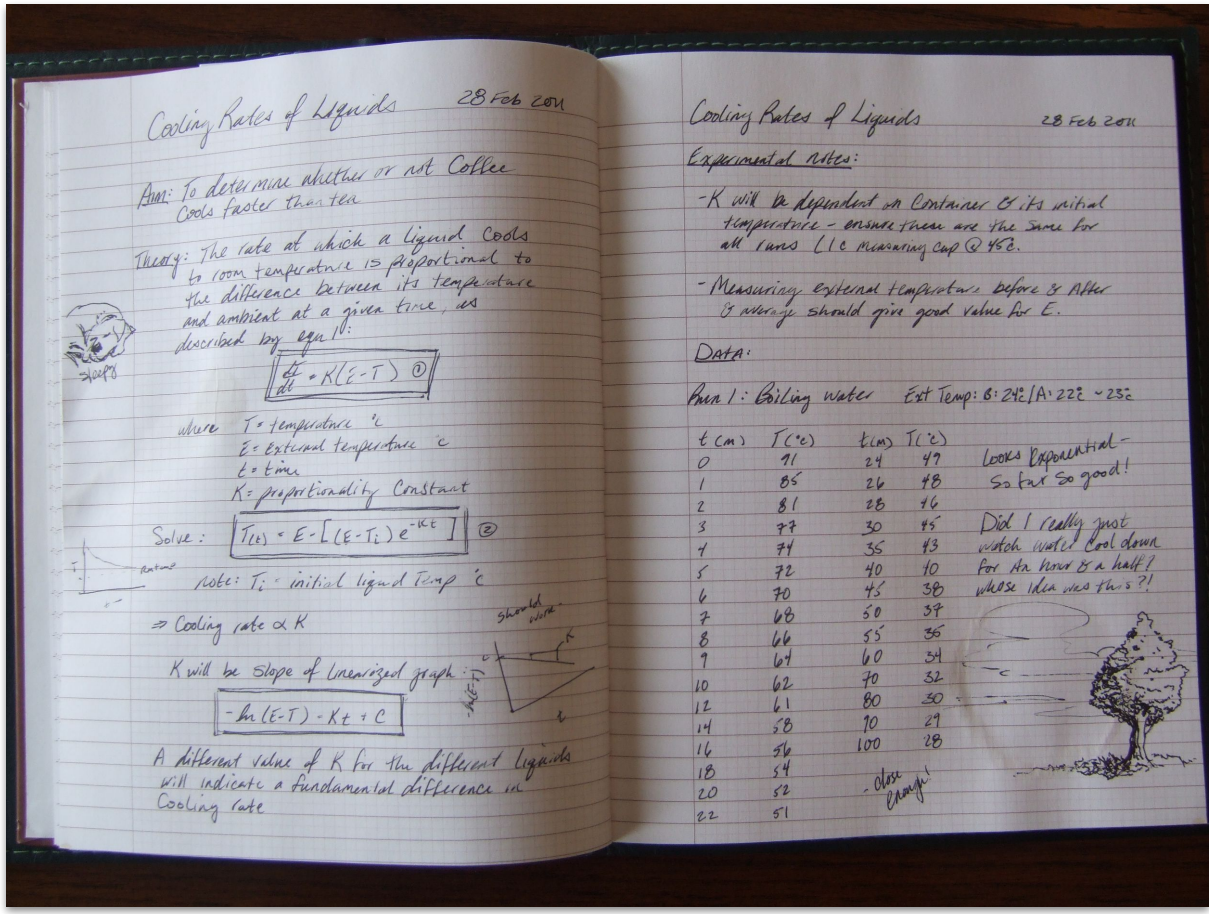
Good Research Notes

- Clear and concise
- Legible
- Well organized
- Easy to follow
- Reproducible by someone
- Transparent

Melissa Zahralban-Steele and Tapiwa Nkhisang, researchers on Harvard AIDS Initiative, review data from a recent experiment. Consider the Lab Notebook (https://aids.harvard.edu/consider-the-lab-notebook)

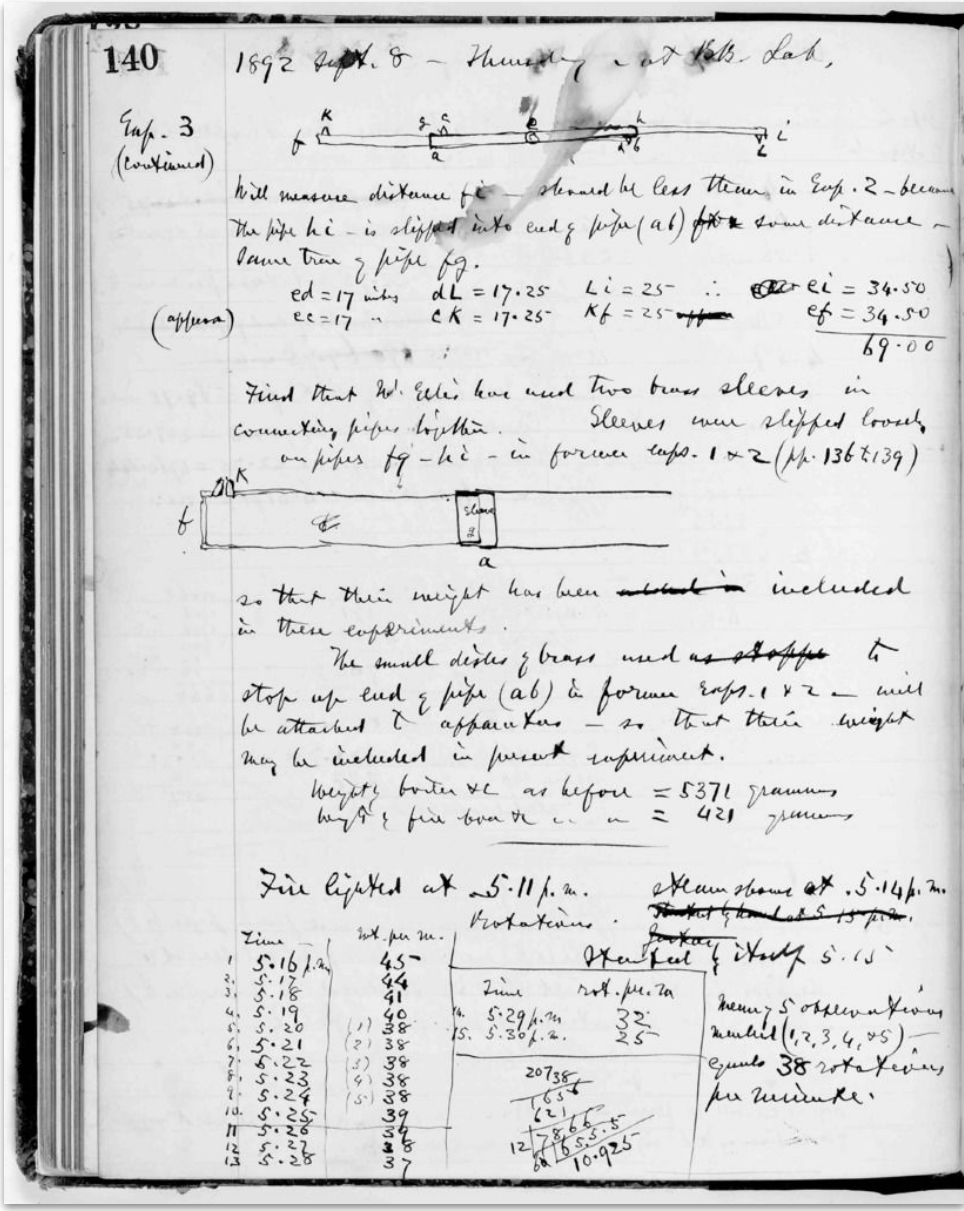
What Goes in the Lab Notebook

- Notebook name
- Inside cover or cover page
  - Your name and year
  - Position
  - General project name
  - Fund/grant number
  - Lab mailing address
- Table of Contents
- Body of notebook
  - Experimental entries



Naming Your Notebook

- Naming laboratory notebook allows for:
  - Easy identification to the owner of the notebook
  - Ability to easily reference collected data to a certain notebook entry
- There are many practices that are used in both industry and academia which include:
  - Use of name/initials of researcher
  - Assignment of a numeric or alphabetic code to each researcher, code may be unique for each notebook used by researcher



Naming Your Notebook

- Some research groups may have established notebook naming conventions, check with your PI
- Label your notebook clearly with your full name on the front
- If using a bound notebook label the spine
- During the course of research, multiple lab notebooks may be used, identify each one with either Roman Numerals or numbers
- Indicate the dates notebook is used
- If the notebook is specific to a particular project, include on the front cover

Table of Contents

- Table of contents help you (and present and future researchers) quickly find previous experiments
- If there is not a space provided for a table of contents, make your own within the first few pages of the notebook
- Write down the date and title of experiment
- If completing an experiment that is multi-page, record the entry on the first page used, then use arrows to show the number of pages devoted to that entry

Table of Contents

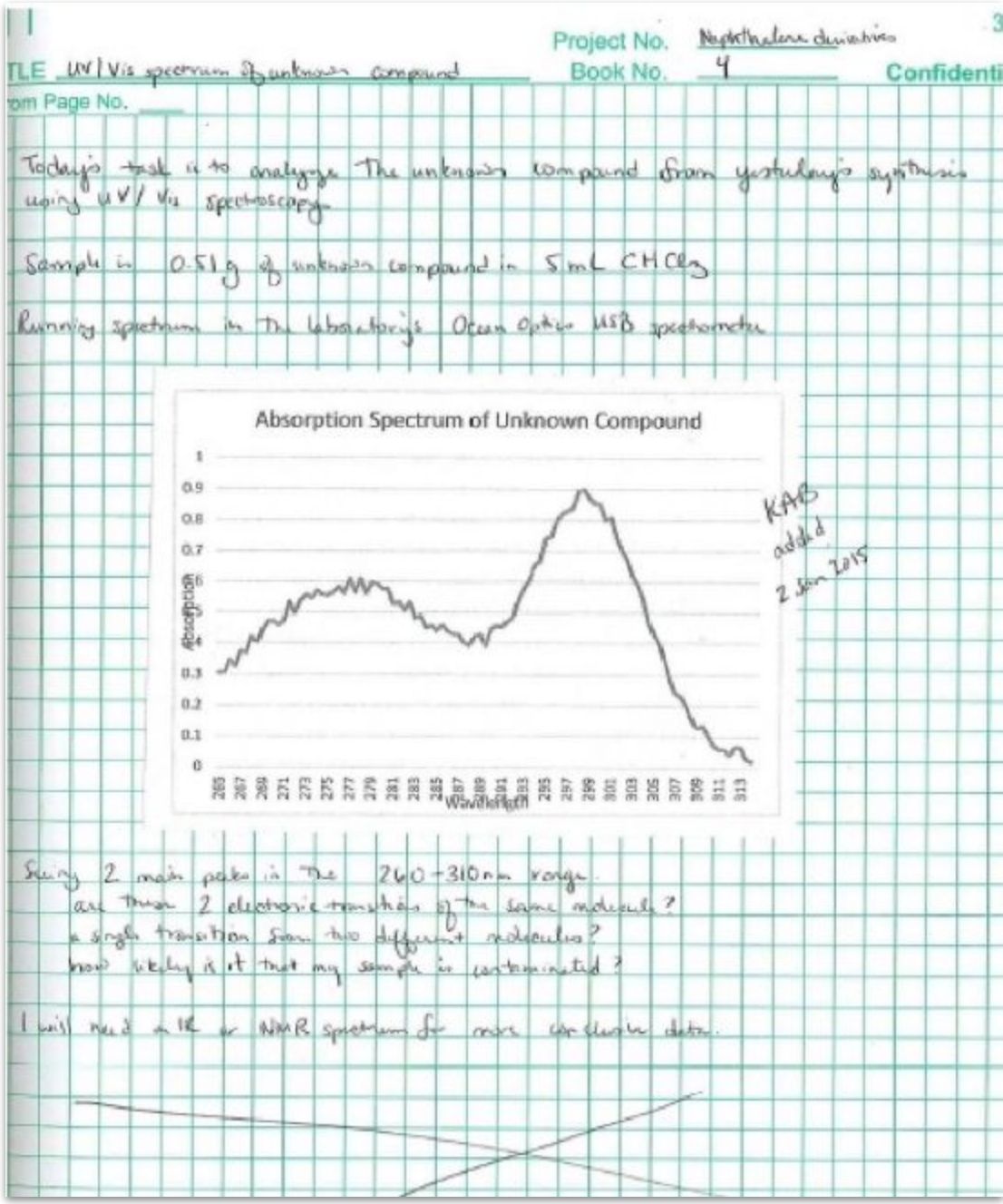
Date	Experiment/Subject	Page #
2019-10-04	Synthesis of Fe_2O_3 nanoparticles	1
2019-10-05	Raman of Fe_2O_3 nanoparticles	2
2019-10-07	Synthesis of $Ru(bpy)_3$	3
		4
		5
2019-10-09	Calculations for citric acid buffer pH=6	6
2019-10-09	NMR analysis of bypyridine ligand	7

Experimental Record

- Objective/purpose of experiment
- Plan, outline, or flow diagram
- Step-by-step procedure, including conditions such as temperature, equipment, reagents, it is important to remember to be specific
  - This could also be documented in a separate ‘protocols’ documentation and referenced or linked
- All important test conditions/parameters
- Supplementary information including citations
- Observations: everything that occurs either planned or unplanned
- Raw data, calculated data, and any transcribed data
- Results including graphs, tables, figures, and data analysis (affixed if a print-out)
- Units
- Conclusions: if objective was met and/or suggestions for future experiments

General Tips

- Use an ink pen to write in notebook
- Write as you go: the likelihood of remembering a procedural step decreases as time elapses
- Cross out any blank space not used (> 3 lines)
- Complete notebook entries in consecutive page order, avoid blank pages or X-out unused pages, do not remove pages
- Begin new experimental entries on a new page
- Draw a single line through errors, and write the correct information adjacent
- Never use white-out to fix error
- Sign/date entries



Notebook Ownership

- As a researcher, it is your responsibility to maintain your laboratory notebook in a format that is intelligible to yourself, your PI, and future researchers
  - Your notebooks and supplemental resources should remain in the possession of your PI after leaving the University
- As a federally funded research institution, the University must assert ownership over research data for project conducted at the University or under its auspices
- The PI is accountable to the University for the stewardship of research data.
- Collected data in the form of laboratory notebooks and supplemental resources are owned by the University as outlined by regulations and/or sponsors as well as intellectual property rights

OMB Circular A-110, Sec. 53, Retention and Access Requirements for Records. https://georgewbush-whitehouse.archives.gov/omb/circulars/a110/a110.html
Research Data Ownership Policy, Harvard University, 2019. https://vpr.harvard.edu/files/ovpr-test/files/data_ownership_policy_08.06.19.pdf

Notebook Ethics

- All data needs to go into notebook, even if the results are bad or the experiment failed
- Do not remove pages or mistakes. Simply draw a line through error and give correction. Consider writing initial and date of correction
- Record facts, not opinions (ex: no reaction occurred under these experimental conditions vs. this reaction will never work!)
- Be honest!

Leonardo Da Vinci

Best Practices for Managing Notebooks

Organization

Define how the data will be organized, including what is your folder hierarchy and how did you get from raw data to the final product? Consider versioning control for changes for both software and data products.

- Any system is better than none
- One project, one folder
- Separate folders for data or project stages
- Date-based folders (pairs well with lab notebook)

Data Analysis

When designing an analysis workflow:

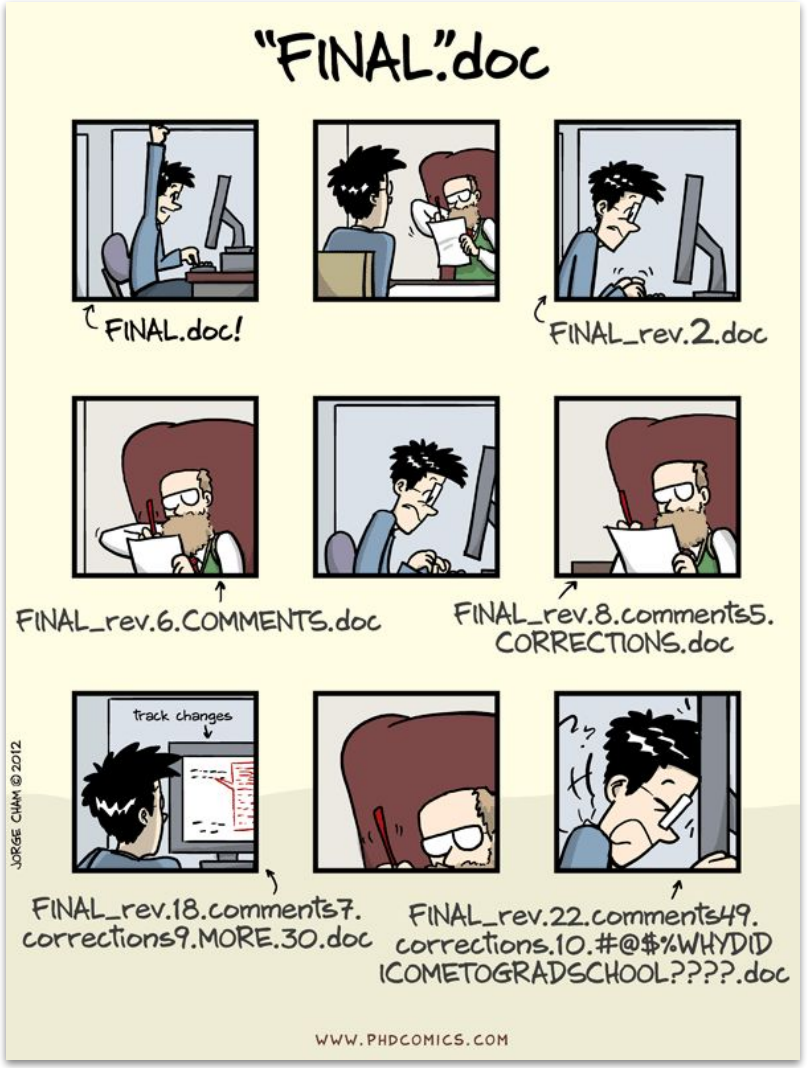
- Follow guidelines for data use as mandated in any associated DUAs
- Use appropriate tools and compute environments
- Keep track of tool versions and parameters used, document everything!
  - Keep raw data separate
  - Document any changes to the raw data
  - Create a master version for analysis
- Don’t reinvent the wheel
  - Use appropriate analysis tools to counter the differences
- Stay organized from the start
- Analysis should consider any differences in dataset metadata
  - e.g. microarray expression data ≠ RNA-seq data

File Naming

- Should be descriptive and provide contextual information
- Should be documented so that others in your lab or department can follow
- Establish a naming convention and use it consistently

Files with naming conventions:

20161104_ProjectA_Ex1Test1_SmithE_v1.xlsx
20180204-ProjectA-Report-SmithE-v5-FINAL.docx

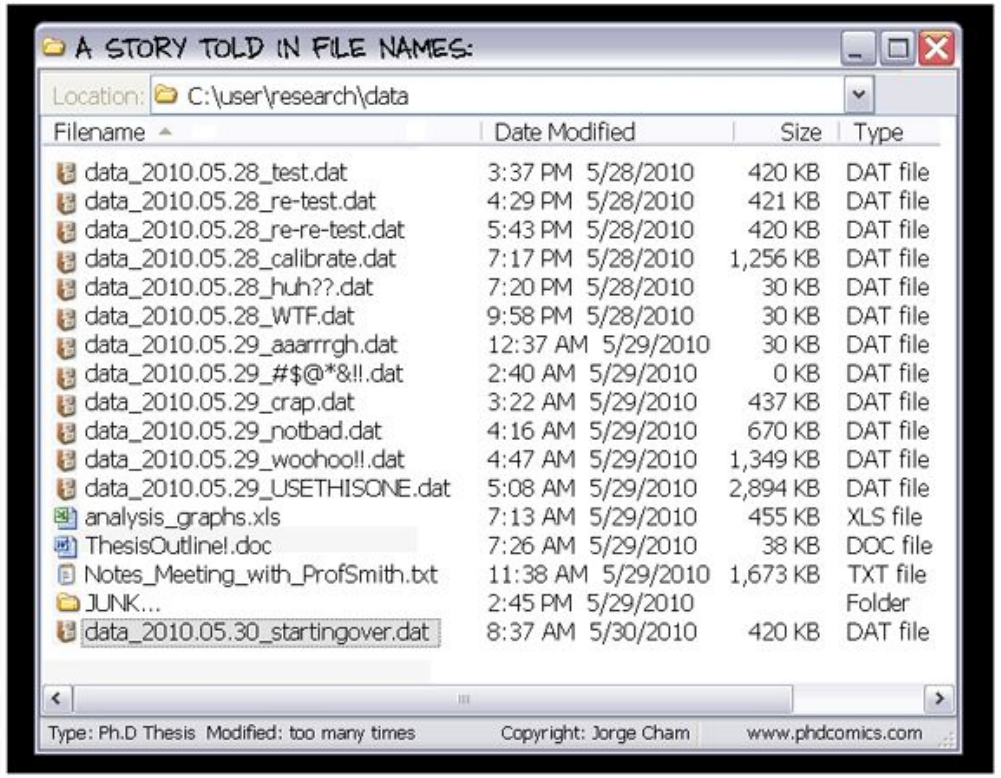


http://phdcomics.com/comics/archive.php?comicid=1531

https://datamanagement.hms.harvard.edu/file-naming-conventions

Naming Conventions

- Use naming conventions consistently
- Should be descriptive
  - Project or experiment name or acronym
  - Lab name/location
  - Researcher name/initials
  - Date or date range of experiment
  - Reference to lab notebook record
  - Type of data
  - Experiment conditions
  - Version number of file
- Should be consistent
  - Use ISO 8601 standard for dates (YYYYMMDD)
  - Sequential numbering: use leading zeros (e.g., 001, 002, … 010, 011, … 100, 101, etc.)

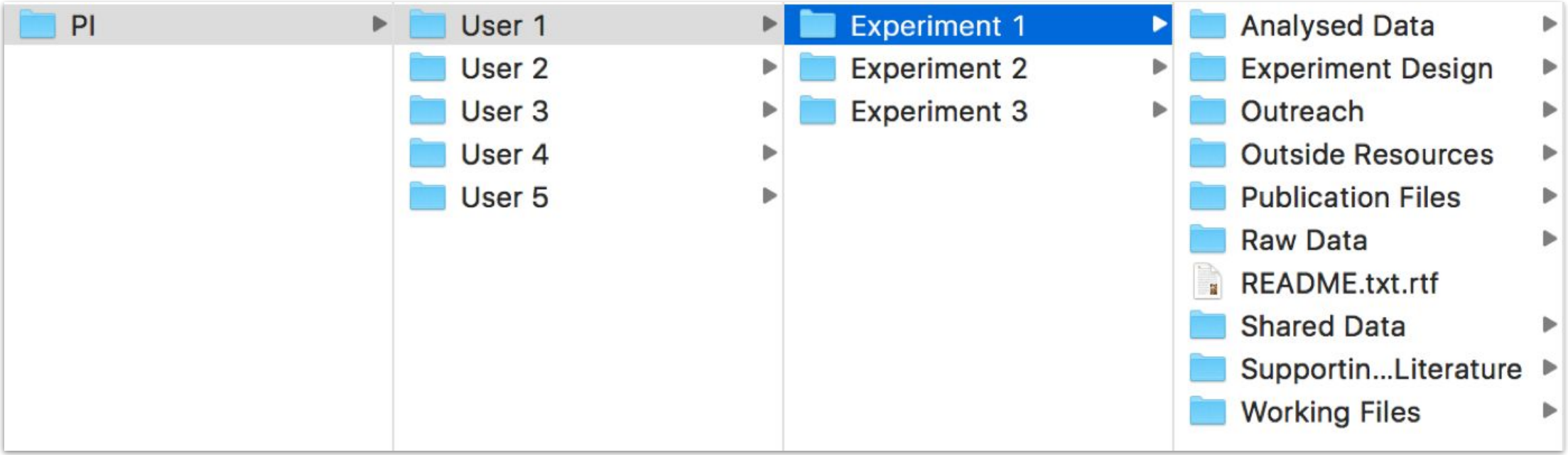


http://phdcomics.com/comics.php?f=1323

Directory

Create a directory structure for output files before running the analysis workflow

- Have README.txt files in higher level directories briefly describing their contents
- Have log files for each tool documenting the versions/parameters used



https://datamanagement.hms.harvard.edu/directory-structure

Electronic Lab Notebooks (ELN)

Lab notebooks are good for writing down procedures, observations, conclusions and for drawing flow charts and diagrams by hand. An ELN (electronic lab notebook) is a software tool that in its most basic form replicates an interface much like a page in a paper lab notebook. In this electronic notebook you can enter protocols, observations, notes, and other data using your computer or mobile device, offering several advantages over paper!

http://phdcomics.com/comics/archive.php?comicid=1994

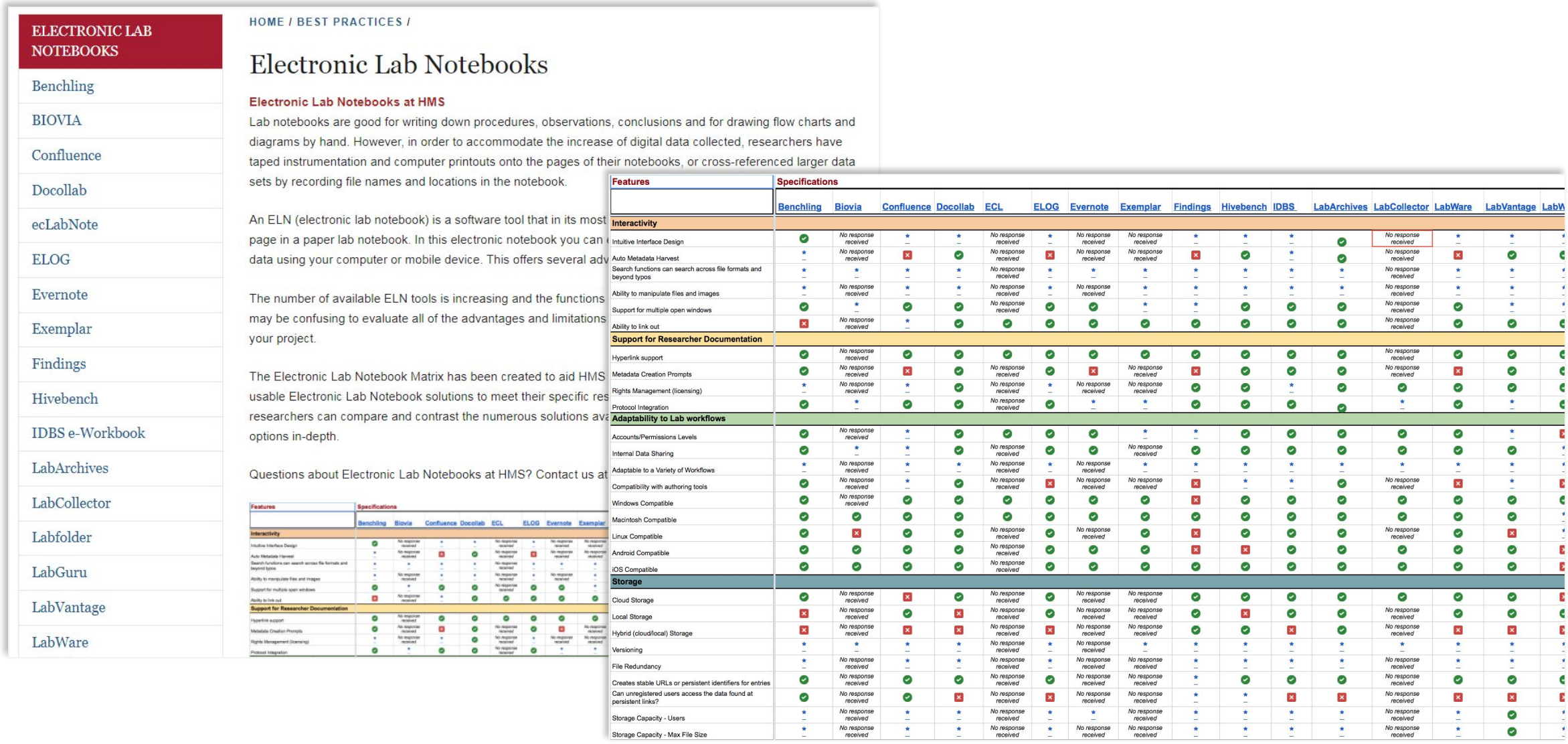
Electronic Lab Notebooks

Benefits:

- Searchable
- Export data
- Easily shareable
- Easily accessible
- Use the mobile App
- Embed images, protocols, etc

Considerations:

- Cost
- Software
- Storage
- Security
- Interactivity
- Migration (in & out)



ELECTRONIC LAB NOTEBOOKS

- Benchling
- BIOVIA
- Confluence
- Docollab
- ecLabNote
- ELOG
- Evernote
- Exemplar
- Findings
- Hivebench
- IDBS e-Workbook
- LabArchives
- LabCollector
- Labfolder
- LabGuru
- LabVantage
- LabWare

HOME / BEST PRACTICES /

Electronic Lab Notebooks

Electronic Lab Notebooks at HMS

Lab notebooks are good for writing down procedures, observations, conclusions and for drawing flow charts and diagrams by hand. However, in order to accommodate the increase of digital data collected, researchers have taped instrumentation and computer printouts onto the pages of their notebooks, or cross-referenced larger data sets by recording file names and locations in the notebook.

An ELN (electronic lab notebook) is a software tool that in its most
page in a paper lab notebook. In this electronic notebook you can
data using your computer or mobile device. This offers several adv

The number of available ELN tools is increasing and the functions
may be confusing to evaluate all of the advantages and limitations
your project.

The Electronic Lab Notebook Matrix has been created to aid HMS
usable Electronic Lab Notebook solutions to meet their specific res
researchers can compare and contrast the numerous solutions ava
options in-depth.

Questions about Electronic Lab Notebooks at HMS? Contact us at

Features	Specifications															
	Benchling	Biovia	Confluence	Docollab	ECL	ELOG	Evernote	Exemplar	Findings	Hivebench	IDBS	LabArchives	LabCollector	LabWare	LabVantage	LabW
Interactivity																
Intuitive Interface Design	✓	No response received	*	*	No response received	*	No response received	No response received	*	*	*	✓	No response received	*	*	
Auto Metadata Harvest	*	No response received	✗	✓	No response received	✗	No response received	No response received	✗	✓	*	✓	No response received	✗	✓	
Search functions can search across file formats and beyond typos	*	*	*	*	No response received	*	*	*	*	*	*	*	No response received	*	*	
Ability to manipulate files and images	*	No response received	*	*	No response received	*	No response received	*	*	*	*	*	No response received	*	*	
Support for multiple open windows	✓	*	✓	✓	No response received	✓	✓	*	*	✓	✓	✓	No response received	✓	*	
Ability to link out	✗	No response received	*	✓	✓	✓	✓	✓	✓	✓	✓	✓	No response received	✓	✓	
Support for Researcher Documentation																
Hyperlink support	✓	No response received	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	No response received	✓	✓	
Metadata Creation Prompts	✓	No response received	✗	✓	No response received	✓	✗	No response received	✗	✓	✓	✓	No response received	✗	✓	
Rights Management (licensing)	*	No response received	*	✓	No response received	*	No response received	No response received	✓	✓	*	✓	✓	✓	✓	
Protocol Integration	✓	*	✓	✓	No response received	✓	*	*	✓	✓	✓	✓	*	✓	*	
Adaptability to Lab workflows																
Accounts/Permissions Levels	✓	No response received	*	✓	✓	✓	✓	*	*	✓	✓	✓	✓	✓	*	
Internal Data Sharing	✓	*	*	✓	No response received	✓	✓	No response received	✓	✓	✓	✓	✓	✓	✓	
Adaptable to a Variety of Workflows	*	No response received	*	*	No response received	*	No response received	*	*	*	*	*	*	*	*	
Compatibility with authoring tools	✓	No response received	*	✓	No response received	✗	No response received	No response received	✗	*	*	✓	No response received	✗	*	
Windows Compatible	✓	No response received	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	
Macintosh Compatible	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Linux Compatible	✓	✗	✓	✓	No response received	✓	No response received	✓	✗	✓	✓	✓	No response received	✓	✗	
Android Compatible	✓	✓	✓	✓	No response received	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	
iOS Compatible	✓	✓	✓	✓	No response received	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Storage																
Cloud Storage	✓	No response received	✗	✓	No response received	✓	No response received	No response received	✓	✓	✓	✓	✓	✓	✓	
Local Storage	✗	No response received	✓	✗	No response received	✓	No response received	No response received	✓	✗	✓	✓	No response received	✓	✓	
Hybrid (cloud/local) Storage	✗	No response received	✗	✗	No response received	✗	No response received	No response received	✓	✓	✗	✓	No response received	✗	✗	
Versioning	*	*	*	*	No response received	*	No response received	*	*	*	*	*	*	*	*	
File Redundancy	*	No response received	*	*	No response received	*	No response received	No response received	*	*	*	*	No response received	*	*	
Creates stable URLs or persistent identifiers for entries	✓	No response received	✓	✓	No response received	✓	No response received	No response received	*	✓	✓	✓	No response received	✓	✓	
Can unregistered users access the data found at persistent links?	✓	No response received	✓	✗	No response received	✗	No response received	No response received	*	*	✗	✗	No response received	✗	✗	
Storage Capacity - Users	*	No response received	*	*	No response received	*	*	No response received	*	*	*	*	No response received	*	✓	
Storage Capacity - Max File Size	*	No response received	*	*	No response received	*	No response received	No response received	*	*	*	*	No response received	*	✓	

Electronic Lab Notebook Matrix

https://datamanagement.hms.harvard.edu/electronic-lab-notebooks

Remember: ‘dry’ scientists should keep a notebook!

1. Learn Your Institution’s or Laboratory’s Notebook Policy
2. Select the Right Medium for Your Lab Notebook
3. Make the Habit of Keeping the Lab Notebook in Your Desk
4. Record All Scientific Activities in Your Lab Notebook
5. Every Entry Should Be Recorded with a Date, Subject, and Protocol
6. Keep a Record of How Every Result Was Produced
7. Use Version Control for Models, Algorithms, and Computer Code
8. Keep a Lab Notebook That Can Serve As a Legal Record of Your Work
9. Create a Table of Contents for Your Lab Notebook
10. Protect Your Lab Notebook

Schnell S (2015) Ten Simple Rules for a Computational Biologist’s Laboratory Notebook. *PLoS Comput Biol* 11(9): e1004385. https://doi.org/10.1371/journal.pcbi.1004385

Notebook Checklist

As you record your activities in the laboratory, ask yourself, "Did I..."

- Keep up with the table of contents?
- Date each page?
- Number each page consecutively?
- Use continuation notes when necessary?
- Properly void **all** blank pages or portions of pages (front and back)?
- Enter all information **directly** into the notebook?
- Properly introduce **and** summarize each experiment?
- Include complete details of all first-time procedures?
- Include calculations?

Summary

- Always check with your PI regarding practices that are appropriate within the research group
- The laboratory notebook is a legal record of experiments as well as the foundation for thesis and publications
- Use a naming convention that uniquely identifies the notebook to the researcher
- Be as specific as possible when writing experimental records
- Include all data that is collected during the course of experiment, when necessary use supplemental sources to store hard-copies of data with cross-reference in notebook entry
- Honesty is the best policy