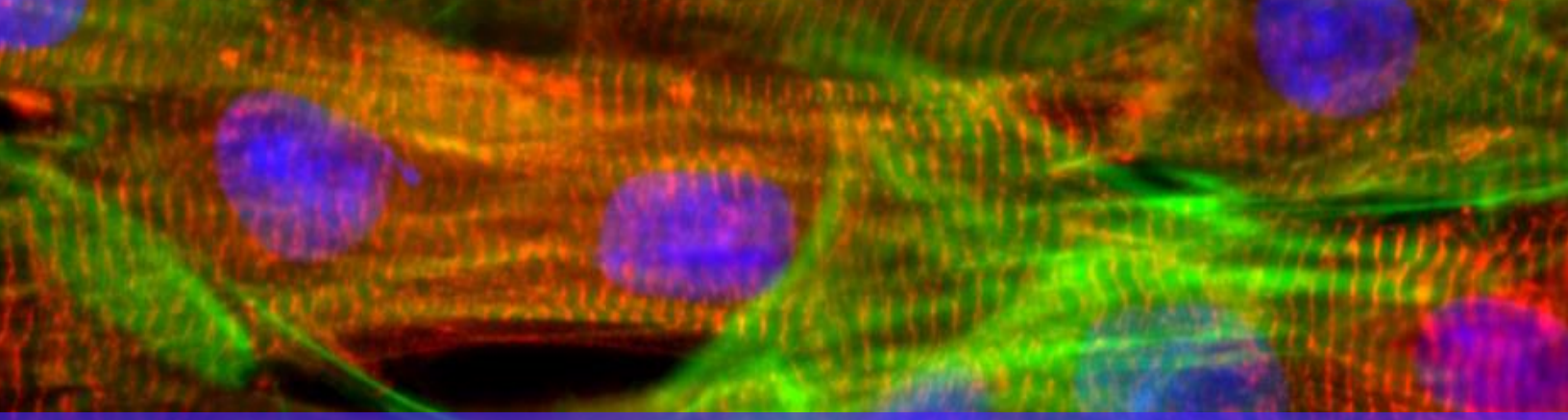
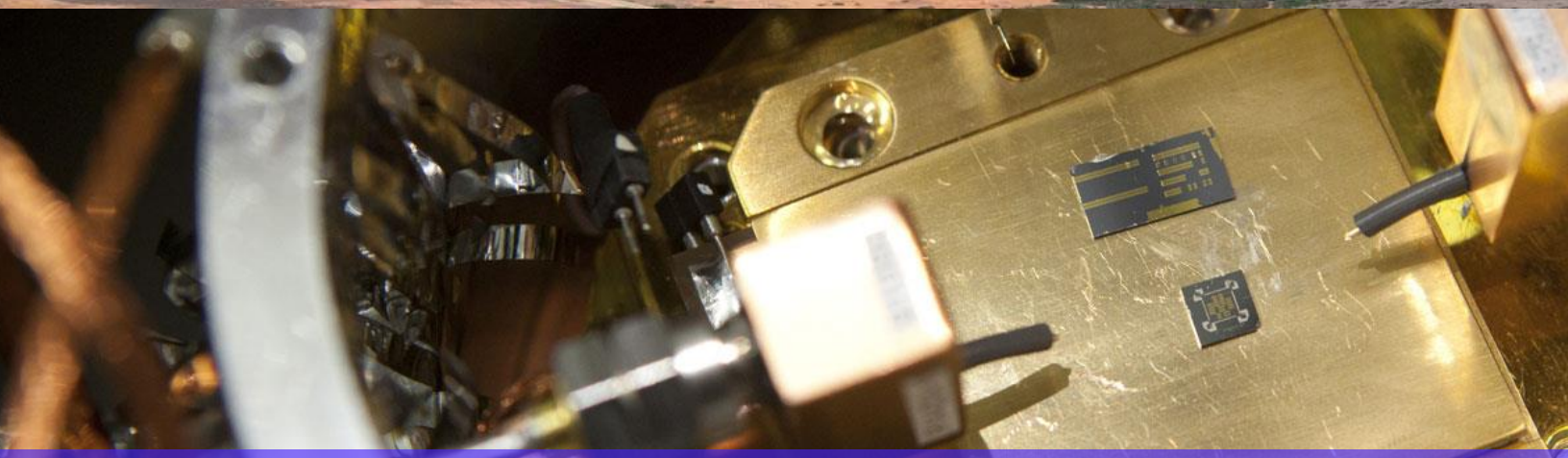


A Guide to Writing a Senior Thesis in Engineering



2019-20

John A Paulson School of Engineering and Applied Sciences

This thesis guide has been put together to help guide students who are writing or interested in writing a thesis in engineering.

This should be used as a guide.

It is expected that each student work most closely with their thesis advisors. See additional requirements for students working with advisors outside of SEAS.

Latest version: 3/11/2020

Created by Linsey Moyer

Many thanks to Laura Magnotti and Ryan Draft for sharing their senior thesis guide and tips. Much of their wisdom is also contained herein.

Contents

Why write an A.B. thesis in engineering?

Writing a thesis is an opportunity to showcase the skills and knowledge you've acquired during your undergraduate career. It allows you to demonstrate depth of knowledge as well as ownership of a research project. It is a culminating document that reveals your mastery of part of the field of engineering in which you are concentrating. Students who complete a thesis have the opportunity to explore cutting edge research in some of the best research labs in the country.

In more practical terms, writing a thesis can be extremely beneficial when applying to graduate school, including medical school. Students going into industry often demonstrate some of their knowledge and skills through their thesis project and it is often discussed in interviews. A thesis is required in engineering to be considered for high or highest honors.

Writing a thesis is something that must be self driven and paced throughout at least a year. It is best to start early and meet with advisors regularly. Included in this guide are some practical tips and timelines to keep in mind.

How do I find a research mentor and a thesis project?

Most students find thesis advisors by reaching out to faculty from SEAS, but others find advisors at the Medical School or other FAS departments. Some common places to find research labs include (see appendix 5): the engineering faculty pages within SEAS, the Wyss Institute, the Broad Institute, the Roland Institute, or the Harvard University Center for the Environment. Students might start contacting faculty because they've taken a course with them or because they are interested in their research. It's also possible to search for faculty based on a topic. The Harvard Catalyst database is searchable by topic area or keyword. It will return a list of faculty and clinicians involved in research related to that topic area. Students in Biomedical Engineering should also feel free to reach out the Life Sciences Research Advisor, Anna Babakhanyan (ababakhanyan@fas.harvard.edu), for help with constructing emails to faculty and for connections to faculty outside of SEAS.

The thesis project should represent the student's own work but it is expected that the scope of the project is defined with help from one or more advisors within the research lab. These may be graduate students or postdoctoral fellows who are familiar with the specific research area.

Less commonly a student comes up with a project on their own. In this case the student still needs at least one faculty advisor. The faculty advisor should be found as early as possible, generally no later than the end of the 6th semester.

What are the deadlines? And timelines?

Suggested Timeline for A.B. Engineering Thesis Writers

Junior Fall

- ❑ Search for thesis advisor/lab
- ❑ Discuss thesis topic with concentration advisors, DUS, and thesis advisor

Junior Spring

- ❑ Finalize lab/mentor by end of term
- ❑ Start literature review
  - Attend thesis prep info session
  - Attend session on example theses

Senior Fall

- ❑ Meet weekly with advisor
- ❑ Finalize thesis readers (see additional information in the Thesis Guide)
  - Attend bi-weekly section with other thesis writers in engineering
    - ➢ Workshop on literature review and citations
    - ➢ Workshop on technical writing
    - ➢ Updates and presentations monthly
  - Optional: Enroll in ES 91r
- ❑ Write the introduction or background chapter from the literature review by mid-October.

Senior Spring

- ❑ Meet weekly with advisor
- ❑ Finish writing thesis chapters including results and analysis
  - Attend bi-weekly section with other thesis writers in engineering
    - ➢ Workshop on poster design
    - ➢ Updates and presentations with peer evaluation
    - ➢ Workshop on presentation tips
  - Final presentation mid March
- ❑ Submit final thesis by **April 3rd, 2020 by 4 pm (updated)**

- ❑ The checkboxes are items that are required for all thesis writers and the due dates are strongly encouraged.
- The gray bulleted list is optional even for joint thesis writers. Any A.B. engineering student who is writing a thesis may opt in.

What are the goals of the senior thesis?

Your senior thesis is a formal research report that summarizes the work you have conducted in the laboratory. Important goals of your thesis are: 1) to review the relevant background in your specific subfield field; 2) to describe how your work fits into the larger scientific context; 3) to clearly describe your experimental measurements and data 4) to demonstrate your independence and mastery of technical engineering depth; and 5) to fully quantify, analyze and criticize your results. It is also important to 6) discuss how future experiments should address particular issues or build upon your work.

As you write your thesis, you should keep in mind that *clarity is of the utmost importance*. In order to write very clearly, it is crucial that you always keep in mind the basic scientific question(s) or design goals that your work attempts to address. These questions should be introduced and explained well in your Introduction. You should return to these driving questions in subsequent sections throughout the thesis, regularly reminding the reader how each result fits into your overall scientific/engineering goal.

If you are unsure if your research project will fulfill a thesis in your area of engineering please reach out early (sophomore or junior year) to your DUS or ADUS in engineering.

Biomedical Engineering ADUS: Linsey Moyer, PhD lmoyer@seas.harvard.edu

Electrical Engineering and Mechanical Engineering ADUS: Chris Lombardo lombardo@seas.harvard.edu

Environmental Science and Engineering ADUS: Patrick Ulrich pulrich@seas.harvard.edu

What constitutes an engineering thesis? (or joint thesis?)

It is highly recommended that students review past theses to better understand the expectations for technical depth and project scope expected in a thesis.

A thesis in engineering <u>should</u>

- Contain a level of technical depth beyond upper level engineering courses
- Be research, design, or a combination of the two
- Extend from skills acquired in one or more engineering courses
- Be quantitative and based on scientific and engineering principles
- Contain statistical or other analytical evaluation
- Show independence of thought and experimentation

[Note: It is ultimately up to your thesis committee (advisors and readers) to determine if your project and written thesis are sufficient for a senior thesis in engineering to fulfill the requirements honors for a Bachelor of Arts in Biomedical Engineering, Environmental Science and Engineering, or Engineering Sciences.]

An engineering thesis <u>is not</u>

- a literature review of a topic (although this can form an introductory chapter to a thesis)
- a project whose scope can ordinarily be completed in a single semester
- a lab report or a final project in a course
- required to be an engineering design project, although it may be design or hypothesis driven

- **Formal approval of single engineering thesis topics is done by the SEAS thesis advisor. If the advisor is not a SEAS ladder faculty, the project will be approved by both the Director of Undergraduate Studies and the primary project advisor.**

- **Formal approval of joint thesis topics is done by the Director of Undergraduate Studies in consultation with the thesis advisor(s).**

How do I find thesis readers, what are the requirements?

For engineering, thesis readers are chosen by the student. It is the responsibility of the student to select their thesis readers and to ensure that the readers are committed. No readers are ever assigned. For Engineering only (non-joint) the thesis committee typically consists of the advisor and two more faculty from FAS/SEAS. At least two of these must be from SEAS. For joint concentrators the student must still have at least three readers, two of whom must be from SEAS. Note: At least three readers are required for Engineering single and joint theses.

Thesis course (Why is there no thesis course?)

Engineering does not offer a 99-level writing focused thesis workshop. Projects vary greatly so the majority of the guidance should come from the advisor as opposed to centralized course.

Students are welcome to enroll in Engineering Sciences 91r to allow time in their schedule for research, but this is not a formal course, and there is no assistance with writing in ES 91r. No thesis course is required for BME, ESE, or ES thesis writers regardless of if they are joint or single concentrator. (There may be an optional thesis section group. Check with your ADUS/DUS to see if one is being offered that term.)

Appendices

Appendix 1: Writing resources

A student guide to writing in the Life Sciences

https://writingproject.fas.harvard.edu/files/hwp/files/life_sciences.pdf

Harvard College Writing Center

Strategies for Essay Writing: These concise explanations provide advice on some fundamental elements of academic writing.

Bok Writing Fellows (BWFs): Bok Writing Fellows provide discipline-specific writing tutorial services to concentrators.

Harvard Guide to Using Sources: This resource helps students think carefully about the challenges and methods of developing their own ideas from material they read in print or on the Internet. The guide is divided into sections focusing on locating sources, evaluating sources, integrating sources into your paper, citing sources, and avoiding plagiarism.

Brief Guides to Writing in the Disciplines: These guides introduce students to the specific challenges of writing in different fields.

Harvard Writing Project writing guides: These guides provide advice on writing in the specific concentrations and courses, plus guidance for senior thesis writers.

Senior Thesis Tutoring

Please Note: This service is available only to Harvard College undergraduate students working on the senior thesis.

Are you looking for help with your senior thesis? The Writing Center offers thesis writers the opportunity to work with tutors who can read drafts in advance and meet with you to talk about structure, argument, and clear writing. Thesis tutors can also help you plan your writing process. We can provide help most effectively if you contact us early or midway through your writing - it is difficult to provide meaningful feedback in the days before a thesis is due. (Nonetheless, if you are pressed for time, please do not hesitate to contact us and we will do our best to provide whatever guidance we can.)

Departmental Writing Fellows

https://writingcenter.fas.harvard.edu/pages/departmental-writing-fellows-0?admin_panel=1

Appendix 2: Titles of representative past theses

2015

Engineering a Functionalized Biofilm-Based Material for Modulating Escherichia Coli's Effects in the Mammalian Gastrointestinal Tract; Nash, Trevor R (Full thesis available) https://dash.harvard.edu/handle/1/17417585

The MiR-130/301 Family Controls Cellular Survival in Pulmonary Hypertension; Park, Joseph (Abstract only available)

The Role of Cell Compaction in Radiation Therapy for Breast Cancer; Welbeck, Arakua Naa Korkoi (Abstract only available)

Stable Isotope Systematics of Abiotic Nitrate and Nitrite Reduction Coupled With Anaerobic Iron Oxidation: the Role of Reduced Clays and Fe-Bearing Minerals; Grabb, Kalina (Full thesis available) https://dash.harvard.edu/handle/1/17417576

2016

Solar Photovoltaic Power: Short Term Volatility and Its Future Under Climate Change; Barringer, Tyler (Full thesis available) https://dash.harvard.edu/handle/1/38811441

2017

Towards 3D Bioprinting of a Vascularized Convolutated Proximal Tubule; Herrmann, Jessica (Full thesis available) https://dash.harvard.edu/handle/1/38811514

Biomechanical Therapy: A Soft Robotic Drug Delivery Device; Mendez, Keegan (Full thesis available) https://dash.harvard.edu/handle/1/38811484

Comparison and Calibration of Climate Proxy Data in Medieval Europe; Luongo, Matthew (Full thesis available) https://dash.harvard.edu/handle/1/38811487

Metasurface diffraction gratings for arbitrary polarization state generation and measurement; Zaidi, Aun

Shape memory in crumpled thin sheets; Li, Franklin

Practical navigation: Autonomous behavior on inexpensive robots; Ernst, Annaleah

2018

The Clean Cut: Design, Synthesis, Assay Optimization, and Biological Evaluation of Compounds That Can Produce Double Strand Breaks in Deoxyribonucleic Acid; Brouard, Maria (Full thesis available) https://dash.harvard.edu/handle/1/38811523

2019

Dilating Health, Healthcare, and Well-Being: Experiences of LGBTQ+ Thai People; Sowapark, Montita (Not yet available) Joint with Women and Gender Studies

Appendix 3: Contents and formatting of the thesis

As an engineering concentrator, your thesis must integrate your knowledge of physics, math, and engineering (and biology for BME) with your research topic. You should consider how your previous coursework relates to your thesis. A good rule of thumb is that at least two of your upper-level concentration courses are related to your thesis project. While your lab mentor(s) will be able to help you, the onus is on you to find the appropriate literature/background materials and think about how they relate to your work.

THESIS STRUCTURE

In terms of how it is written and its structure (but not necessarily in terms of the quality of data), the thesis should read like a typical journal article from your subfield of engineering (e.g. cardiovascular tissue engineering), but with more detailed (longer) introduction, analysis and discussion sections.

Your thesis should have a clear point and there should be no doubt to the reader (or to you) what that point is. You should be able to complete the following sentence: "The goal of this thesis is to _____." To develop your goal(s), you must first clearly identify the overall and specific scientific questions or engineering design goals that your experiments attempt to address. *Explicitly* explain these to the reader (in your Introduction or in one of your introductory chapters). You should also explain clearly things that may seem obvious to you (e.g., Poiseuielle flow or connexins that form gap junctions). Your readers may not know as much about your specific topic as you do. Even if they do, what you don't explain in your writing may seem like a lack of understanding on your part. Take the time to explain things in concrete sentences. In addition, try to frame your thesis like a good story, arranging the material so that the reader will follow enthusiastically from beginning to end.

Apart from the College's requirement of the Honor Code, engineering has no requirements for what you put into your thesis. This is partly because different sub-fields within engineering have different traditions and styles of presentation. However, here are some general guidelines. Some flexibility is allowed for your thesis format so please consult with your thesis advisor before writing and formatting your thesis. Suggested page lengths are very rough. (See below for details on each section.)

Title page
Honor Code page
Acknowledgements
List of Contributions
Abstract
Table of Contents
Table of Figures
Introduction
Materials and Methods
Results
Figures (each placed where appropriate within Results)
Analysis and Discussion
References

Title Page. Please follow this format in centering and spacing the appropriate text.

[Title] (centered about ¼ down the page)

A thesis presented by

[Name]

to

the Faculty of the

Harvard John A. Paulson School of Engineering and Applied Sciences

in partial fulfillment of the requirements for

the Bachelor of Arts degree with honors in

[Biomedical Engineering / Engineering Sciences / Environmental Science and Engineering]

Faculty Adviser: Prof. [Advisor's Name]

Harvard University

Cambridge, MA

[Month Day, Year]

Honor Code Page. Honor Code Page. A signed statement of the Honor Code page is required. Suggested text: ***

In submitting this thesis to the Harvard John A. Paulson School of Engineering and Applied Sciences in partial fulfillment of the requirements for the degree with honors of Bachelor of Arts, I affirm my awareness of the standards of the Harvard College Honor Code.

Name: _____

Signature: _____

The Harvard College Honor Code Members of the Harvard College community commit themselves to producing academic work of integrity – that is, work that adheres to the scholarly and intellectual standards of accurate attribution of sources, appropriate collection and use of data, and transparent acknowledgement of the contribution of others to their ideas, discoveries, interpretations, and conclusions. Cheating on exams or problem sets, plagiarizing or misrepresenting the ideas or language of someone else as one's own, falsifying data, or any other instance of academic dishonesty violates the standards of our community, as well as the standards of the wider world of learning and affairs.

Acknowledgments. Acknowledgements should appear after the honor code page. This section is reserved for you to thank and acknowledge individuals who may have been helpful to you during the thesis process.

List of Contributions. (Optional) In this section, you should clearly and simply state who did what portions of the project. You should explain which portions were done independently by you, which were done in collaboration with others, and what data others may have contributed. For example, if your name were "A. Student":

"Following the initial discovery of spontaneous calcium waves by other members of the laboratory, the current research project was conceived by Dr. M. Labdirector but jointly designed by A. Student, Dr. M. Labdirector, and Dr. C. Postdoc. Behavioral assays, brain dissections, and histological analysis were done independently by A. Student. Sciatic nerve dissections were done by C. Technician. Electrophysiological recordings were done jointly by A. Student and C. Postdoc. The immunohistochemistry presented in Figure 9b was performed by P. Gradstudent. Cell counts and all statistical analyses were done independently by A. Student. Computer modeling was done jointly by A. Student with C. Postdoc. Data and results were interpreted by A. Student with assistance and guidance from both C. Postdoc and M. Labdirector."

(Please note that although this example is written in the passive voice, some advisors suggest that a thesis should be written in the active voice – see "Style" section below.) In addition, any figures

that include someone else's data should *also* be fully explained in the accompanying figure caption. See Figures for more information.

Abstract. The Abstract should be placed after the List of Contributions. The Abstract should be a single paragraph and should not exceed 250 words. It should be designed to define clearly what is dealt with in the thesis and should (1) state the principal objectives and scope of the investigation, (2) describe the methods employed, (3) summarize the results, and (4) state the principal conclusions. Most of the abstract should be written in the past tense, because it refers to completed work. The abstract should never give any information or conclusion that is not stated in the thesis. References to the literature should not be cited in the abstract.

Table of Contents. (Optional) The table of contents should list every subsequent section of the thesis, as well as the abstract and other pages that precede it.

Introduction. The Introduction should present an overall framework for your research by reviewing the literature, discussing what is currently known about the particular subject (as well as perhaps how this knowledge may have evolved historically), identifying relevant questions or debates that exist in the field, and detailing the specific questions that you investigate in the thesis. The Introduction often reads like a mini review article on your topic. It should be very obvious to the reader what specific scientific questions you aim to address with your work. If you introduce the background well, the reader should also understand why your specific experiments are an important and obvious next step for your particular field or laboratory.

You should end your introduction by clearly stating (or perhaps restating) your objectives and rationale for the thesis. This provides a starting point for the thesis and tells the reader what to expect in the forthcoming sections. For example, your Introduction may end with something like the following: "This thesis investigates the role of calcium waves in the development of the embryonic mammalian cortex. Specifically, we will 1) use calcium imaging techniques to characterize the morphology and frequency of calcium waves that occur spontaneously in embryonic cortical slice preparations; 2) demonstrate electrophysiologically that calcium waves can be recapitulated with extracellular stimulation; 3) demonstrate pharmacologically that calcium waves are dependent upon ATP receptors; and 4) use a cell proliferation assay in embryonic brain slices to demonstrate that calcium waves are crucial to embryonic neurogenesis." Try your best to list these items in a logical order that walks the reader through your 'story'. Also include here any significant components of your work that it might be important to highlight, for example if your research involves a detailed statistical analysis.

Throughout the introduction you should supply sufficient information to allow the reader to understand the forthcoming results without their needing to read previous publications. Assume that your audience has the background of a general undergraduate engineer but not necessarily one that knows your field well. (I.e., this means that you don't have to describe what MATLAB is, but you should explain things like "IHC", "iPS cells", or "MEMs".) When in doubt, explain briefly. Include schematic figures or diagrams in your Introduction that illustrate the details you are introducing, e.g., important cell types/electrical system/prior art you are discussing or a complex biochemical pathway/system diagram. If it is something crucial for the reader to understand, a figure is always a good idea. It improves your overall presentation and also helps the reader to focus on the important points they must understand for the remainder of the thesis. Many authors feel that one figure should be included for every main point in a scientific paper.

Throughout the Introduction and all subsequent sections, you should include in-text citations of all relevant published work. References serve multiple purposes. Beyond their most important role in giving credit to previous work, references also serve as resources for the reader to learn where they might find further reading on a particular subject. Be sure to include relevant reviews or even textbook chapters that you found helpful as you learned about your topic. (See "References" section below for citation format.)

Materials and Methods. This section details how you conducted the experiments. Give enough detail so that the reader would be able to conduct a similar experiment to reproduce similar results (e.g., include all concentrations, final dilution amounts, incubation times, etc.), but don't include the excruciating details of full step-by-step protocols (if desired and relevant, these can be placed in an Appendix). Use subheadings to help guide the reader through the Material and Methods section (e.g., "Tissue preparation"; "Imaging & Analysis"; etc.).

Results. This section comprises the body of the thesis. The Results section should be presented in an explicit, logical order, so that the reader will understand the purpose of each experiment. This section summarizes the data obtained from the experiments and should describe the results in a matter-of-fact manner but not overly interpret them (which will be done in the Discussion). Rather than simply listing one experiment monotonously after another, walk us through your logic using key transition sentences that remind us of your underlying scientific questions. For example, instead of saying "Next, we used antibodies against Protein X at three different time points", you might say "Next, in order to determine whether autism-associated proteins are indeed localized in the striatum throughout development, we used antibodies against Protein X at various postnatal ages." If you completed two unrelated projects, you may consider separate sections or chapters within the Results section. You may also include relevant experiments with negative or no results.

Figures. The visual elements in your thesis should be a mirror of the written elements such that either the figures or the text may stand alone to tell your story. In other words, you should ideally have a figure to visually represent each main result described in your text. Your figures, diagrams, and tables should be properly labeled, with descriptive figure legends and any sources acknowledged. (See below.) Clear, well-labeled figures help significantly to impress readers with the overall professional presentation of your thesis. Figures and tables should be numbered in the order that they are cited in the text (for example, Figures 1-2 in the Introduction, Figure 3 in the Methods, Figures 4-11 in the Results, etc). Ordinarily, figures should be presented in portrait orientation with the figure legends accompanying the appropriate figures. You can place the figure and caption immediately following the paragraph in which it was introduced or, for very large figures, you can dedicate an entire page, placed just after the page where the figure is first mentioned in the text. The figures should be numbered in sequence with the text.

If a figure is a multi-panel plate, individual panels within the figure should be consecutively lettered, and for all images, a scale bar should be included in the figure and defined within the figure legend. Figures should be presented in a plain and unadorned style as much as possible. All text within the figure should be large enough to be read easily. Panels should not be set off by boxes or other edging, and lettering and images should not have gratuitous effects such as highlighting, three-dimensional edging, shading, etc. Where possible, figures should consist of black lines and lettering against a white background. Color should be used to differentiate or emphasize specific features of a drawing, but only if scientifically necessary (i.e., needed to differentiate the different parts of the image, such as different lines in a graph or different labels mapped against a brain section). Any data that was collected from replicate measurements (i.e., an average value on a plot) should be shown with an appropriate error bar (e.g., standard error or standard deviation). The figure caption should state what value the error bar represents and the number of replicates (e.g., n = 3).

In order to present a complete story, it is sometimes appropriate to include some minimal data conducted by another individual in the lab. Work done in collaboration with others or even by someone else may be included in your thesis, but *this must be acknowledged <u>in the figure legend</u> even if the appropriate researcher is also given credit elsewhere*. The reader assumes that all figure data presented are yours unless it is explicitly stated in the figure legend. Be sure that you do not make this ambiguous to the reader; their frustration/confusion may be reflected in your thesis recommendation.

Discussion. The discussion section should first of all summarize and analyze the results that you have presented. For example: “We demonstrated in Figure 8 that cell proliferation was decreased in the presence of ATP receptor antagonists. This result could be interpreted in a number of ways…” then go on to explain that one likely interpretation would support your overall hypothesis,

but a caveat might be that the pharmacological agents could have caused cell damage. (Ideally you have done a control experiment to rule that out – explain how that control supports your hypothesis here.) In addition to this type of discussion, recapitulate your overall argument(s) presented in the Introduction as well as strengths and weaknesses and address the theoretical issues that were used in approaching and analyzing the problem. You should also explain how you may have modified your view of the issues in the course of conducting the analysis. If your experiments did not produce significant or meaningful results, explain here your thoughts on why this might have occurred, and suggest how things could be done differently. Convince the reader that you have fully thought through and understand the implications of your work, no matter how individual experiments may have turned out. The discussion is an important aspect of your thesis and should place your findings into the larger perspective. It is the best section to demonstrate to the reader how carefully you have thought about your work and how sophisticated your thinking might be regarding its nuances and implications. Be sure to compare your findings to previously published results – are your data consistent with findings from other studies? Why or why not? Importantly, end with a section detailing further questions to be asked and directions for future study. Faculty readers will look specifically for a discussion of how future experiments may build upon or improve your work. If this is missing, they may feel that you have not adequately thought things through.

References. Factual statements and claims that you make throughout your Introduction, Methods, Results, and Discussion sections should be backed up by providing citations to relevant published work. For example, even a basic statement such as the following should include a citation using only bracketed numbers in IEEE format (to a review article or textbook chapter, for example):

The feasibility of imaging structures less a millimeter wide with dual-frequency ultrasound has been previously shown [1].

For references, you should use the **bibliographic notation style of the IEEE** journals. For example:

[1] R. Gessner, M. Lukacs, M. Lee, E. Cherin, F. S. Foster, and P. A. Dayton, "High-Resolution, High-Contrast Ultrasound Imaging Using a Prototype Dual-Frequency Transducer: In Vitro and In Vivo Studies," *Ieee Transactions on Ultrasonics Ferroelectrics and Frequency Control,* vol. 57, no. 8, pp. 1772-1781, Aug 2010, doi: 10.1109/tuffc.2010.1615.

Regarding in-text citation, please use only bracketed numbers as shown in the first sample above unless your lab explicitly uses another format. Do not use footnotes or “author, year” format.

To simplify the citation process, you are urged to use an in-text citation program such as Endnote or Refworks, Zotero, or Mendeley (licensed software can be downloaded online via Harvard). To read more about using these programs, visit http://guides.library.harvard.edu/cite.

All thesis writers should read this brief guide regarding citations: '*Guide to Using and Citing Sources When Writing in the Life Sciences*': http://tinyurl.com/LSCitationGuide

THESIS FORMATTING AND STYLE

Length: Senior theses usually range from 40 to 80 pages in length with figures and diagrams. *Although this number is not a hard and fast rule*, you should be wary of exceeding these limits in either direction. Long, verbose theses are often too wordy or poorly written, edited, and argued. On the other hand, the reader may criticize a shorter work; s/he may not be able to discern whether you understand the material and see the larger picture.

Style: Your thesis should read like a professional scientific journal article. It is not appropriate to describe your personal experience (outside of the Acknowledgements section) or to demonstrate your creative writing style. Use this opportunity to develop your own scientific writing style – but write *clearly*. Committee members scrutinize the quality of the writing and editing. The thesis will be judged on the basis of content and writing effectiveness. Your final honors recommendation will be undercut by inattentiveness to style, form, grammar, punctuation, spelling, and citations.

Active or passive voice? In all sections except for the Methods, the active voice is preferable to the passive voice. *"I" versus "we"?* Since your List of Contributions page specifies what parts of the work you did independently, many students choose to use "we" throughout the thesis. If you are comfortable using "I", it is also appropriate in a senior thesis. Beware however that it can become confusing if you are constantly going back and forth between "I" and "we", depending upon the particular experiment or method.

Page Formatting: Leave at least 1-inch margins on all sides of 8 1/2 x 11" paper. All textual material should be double-spaced and printed on one side of the page only.

Font: Use a 12-point font, preferably Times or Arial.

Pagination: Page numbers (Arabic numerals) should appear centered at the bottom of the page, separated from the text by approximately 0.5 inch. Every sheet of paper in the document should be counted in the numbering sequence. The title page is the only page not physically numbered, but it is still counted as page one. (So your physical page numbering will begin with page "2" at the bottom of the Acknowledgements page.) Do not use letter suffixes (e.g., 10a) for page numbering. As specified earlier, pages with figures should be numbered in sequence with the rest of the document.

For examples of structure and format, previous theses are available through Harvard DASH (https://dash.harvard.edu). You may also wish to consult with counselors at the Writing Center (http://www.fas.harvard.edu/~wricntr). The counselors go over drafts of your writing. They also have a number of hand-outs on format, style, and other aspects of writing.

You should begin writing the thesis while experiments are still in progress (i.e., whenever you've started doing anything in conjunction with your senior thesis lab) while everything is fresh in your mind. You may identify inconsistencies in the data or interesting avenues that may be followed up while writing up the results section. At the latest, you should write a complete draft of your thesis by the middle of February to allow at least a month for revisions, printing, proofreading, copying, etc. Give a copy to your mentor(s) in lab as early as possible so that you can incorporate their feedback. Realize in advance that people will take longer to read and edit the thesis that you expect.

Appendix 4: Reference managers

All engineering students should use IEEE format for reference. Footnotes should not be used for references.

Endnote (or Endnote Online), Mendeley, and Zotero are all acceptable reference managers. More exist as well. It's most important that you are using a reference manager rather than which one you use.

To read more about using these programs, visit http://guides.library.harvard.edu/cite.

Appendix 5: Places to find research opportunities

Office of Undergraduate Research and Fellowships https://uraf.harvard.edu/finding-opportunities

Engineering faculty web pages: https://www.seas.harvard.edu/faculty-research/research#term220

*For BME students:

Wyss Institute, Roland Institute, Broad Institute

Biomedical engineering students are encouraged to reach out to Dr. Anna Babakhanyan (ababakhanyan@fas.harvard.edu), the Life Sciences Research Advisor, to find labs across the university (including the medical school and hospitals) that match their interests.

*For ESE students:

Harvard University Center for the Environment has a faculty search for professors across Harvard that are active in environmental research. The Summer Undergraduate Research Fund lists current research projects, and can provide funding to support thesis work in the summer before senior year.

Appendix 6: FAQ

Q: Is there separate funding for senior theses in engineering?

A: No, there is no separate funding source from SEAS for senior theses. If specific materials are required this should be discussed with your thesis advisor. Harvard College has some funds for students who are doing research and SEAS engineers are encouraged to apply for that. Additionally HCRP can fund research in a lab as long as the student isn't also enrolled in ES 91r.

Appendix 7: Forms

[TBD: see web link for forms on the SEAS website]

[Starting fall 2019 BME will use a proposal form that requires student, advisor, and DUS signatures.]