

BCMB 496: BIOCHEMISTRY/MOLECULAR BIOLOGY SENIOR RESEARCH

Course Description

Biochemistry/Molecular Biology senior research is a two-semester commitment to an independent undergraduate research project that culminates in the submission of a written thesis and an oral defense. The student is responsible for developing, in close consultation with his/her faculty advisor, a suitable project, and for designing and carrying out the necessary experimental work. Students doing a senior thesis must also enroll in BCMB 410 (Biochemistry/Molecular Biology Seminar), and present the results of their senior thesis as a seminar in the spring of their senior year.

BCMB senior research is designed to serve as a capstone for the educational experience at Lewis & Clark College. It will require that students integrate all the skills and knowledge they have gained in four years here, in courses in Biology, Chemistry, Math, and Physics, as well as in other courses. A senior thesis helps students develop their creativity, their critical thinking skills, their library research skills, their time management skills, their organizational ability, their writing skills, and their oral presentation skills.

Invitation

If you are interested in doing a senior thesis, you should start planning for this some time in your sophomore year so that you can obtain some research experience. Your thesis will need to be focused on a problem in biochemistry/molecular biology, and you will need a BCMB faculty mentor. Consult with the Director of the BCMB program to find out who might be able to mentor your thesis if you are unsure. You need to do this sometime in the spring (or fall if you are going overseas) of your junior year. As this person will need to provide you with laboratory space, supplies and equipment, and will be responsible for supervising your work, you must be prepared for them to say no if there is inadequate space, time or money. Once you have identified a mentor, you will develop with them a suitable topic for your thesis. You will need to do some reading and begin to focus your direction. You should plan to do this in the summer before your senior year, so that you are able to turn in a well-written proposal by the Monday of the second week of the fall term. Your advisor's agreement to supervise your thesis and permission to do a thesis will be contingent on the submission of a satisfactory thesis proposal before the add/drop date of the fall semester of your senior year.

Student Evaluation

Senior research is unlike your other courses in that there are very few milestones along the way by which you can judge your progress. To help you evaluate your progress, we include here an explicit description of our expectations of thesis students. To earn a high grade for your thesis project, you will need to demonstrate mastery of the following skills:

1. You will need to demonstrate a solid understanding of the scientific issues involved in your project as well as a solid understanding of the techniques you used in your work. You will need to understand why your project is important and where your work fits in the context of previous work. This will require that you diligently research your project,

reading the scholarly reviews and primary research articles to develop your knowledge of the field throughout the year-long project.

2. You will need to demonstrate that you can design experiments with the proper controls, adequate sample size, etc.
3. You will need to demonstrate an ability to critically analyze data. This may require knowledge of statistical analysis in some cases. In addition, you will need to demonstrate that you know how to present your data in graphs and tables with appropriate titles and figure legends.
4. You will need to demonstrate that you can express yourself articulately both orally and in written form.

The specific work we will use to judge your mastery of these skills are listed below along with the dates on which the work is due. Each assignment is described in detail below. Your project proposal, progress report, and thesis will be evaluated for a grade by your thesis research advisor and a thesis reader assigned by the Director of BCMB. The thesis defense will be evaluated by the BCMB steering committee.

Assignment	Due Date
Research Proposal	Monday of second week of fall semester
Progress Report	Last day of class fall semester
Thesis	<ul style="list-style-type: none">• To your advisor, three weeks before last day of class spring semester• Revised thesis due Friday of last full week of classes spring semester (i.e., one week before reading days)
Oral Defense	Last week of class spring semester

The Research Proposal

The research proposal should be 1500 to 2000 words in length and include the following sections.

- **Introduction.** This section should contain a clear statement of the question your study proposes to answer. This section should provide the background information necessary to understand your proposed experiments. Be certain to both critically evaluate existing knowledge and specifically identify the gaps that your research project is intended to address. State concisely the importance of your research by relating the specific aims of your research project to long-term objectives of research in this field. This will be your first attempt to understand the field and will naturally not be as substantial as it will be in your progress report, but we expect you to have made a good effort to prepare yourself for your project. This section should be roughly two-thirds of the proposal.
- **Proposed Experiments.** This section is usually written as one or two **specific aims**. In each aim, you should explain the following:

1. Describe the hypothesis and how you are going to test it. Here is where you describe the *design* of the experiment
2. How are you going to do the work? What procedures will be used to accomplish the objectives of this aim. Include how the data will be collected, analyzed and interpreted. This is not a methods section. But it needs to be clear whether this approach will be able to address the hypothesis.

This section should be roughly one-third of the proposal.

- **References:** Include a complete list of references that you used to develop your proposal. You should cite original research papers when you refer to specific data, and review articles when you are discussing current models. In the text, use first author, year for citations as in (Balinski et al, 1990). You are strongly encouraged to use Zotero (a free citation management solution) for managing your citations. As your proposal will evolve into a progress report and then the final thesis, using Zotero will help you manage your ever-increasing number of citations and easily insert them into your document.

In writing the proposal you might want to read a grant proposal written by your advisor to get an idea of how such proposals are written. Your proposal will, of course, be much shorter and we do not expect the kind of detail necessary to obtain a research grant, but it will inform you as to style and to the kind of information that should be included. The Director of the BCMB Program will have copies of past proposals available. You should consult one of these before you write your proposal. Be sure you plan ahead so that you can obtain critical input from your advisor before you have to turn your proposal in to the BCMB program.

You should submit your proposal to the BCMB Program Director, who will then distribute it to the faculty in the BCMB program. The BCMB faculty will read all proposals and will grant (or deny) permission to proceed by the add/drop date fall semester.

The Progress Report

At the end of the fall semester, you will need to submit a progress report to your advisor and your reader. This report is essentially a first draft of your thesis. It should be written in the style of a scientific paper with discrete sections: Introduction, Materials and Methods, Results and Discussion, Future Plans, and References. For the Progress Report, you can combine the Results and Discussion sections into one, but for the final thesis you will need a fully developed and separate Discussion section – see below.

The length of the progress report will depend significantly on the nature of the thesis project and how far the project has advanced in the fall semester. You should check with your faculty advisor about specific expectations. That said, as a very rough guide the Introduction should be 1500-2000 words (about 10-12 double-spaced pages, not including figures), the Materials and Methods should be 5-10 pages (including tables and figures), the Results and Discussion should be 5-10 pages (including tables and figures), and the Future Plans should be at least 250 words. In all, progress reports tend to anywhere from 25 to 40 pages (reports on the longer side are usually due to an abundance of tables/figures).

The Introduction section should be essentially complete at this point. You should have completed the library research on your project by this time and be able to write a thorough, fully referenced background section for your project. You should expect that the introduction section of your finished thesis will look very similar to the Introduction you write for the Progress Report. The Materials/Methods section can also be quite detailed at this point. All procedures that you have used so far in your research must either be described in detail (if not published) or referenced if a published protocol was used (see below). Your report should include whatever results you have by this time with analysis and interpretation of those results. Finally, you should describe your plans for completing the project in the spring semester.

PLEASE use the self-evaluation form at the end of this document as your guide in writing your progress report. Your advisor and your thesis reader will use a version of this form to grade your progress report. While the progress report will receive a grade, you will receive only a CR/NC on your transcript. It will be returned to you with suggestions for improvement. You will need to make an appointment with both your thesis advisor and your reader to discuss their comments on your progress report. You should plan on revising your progress report to incorporate their suggestions in early January when their ideas are still fresh in your mind.

The Thesis

The thesis is the culmination of your senior research project. A thesis is written in the form of a scientific research paper with separate introduction, methods, results, and discussion sections. It must be well organized; both in terms of the overall construction of the paper and in terms of individual paragraph construction. We cannot appreciate your work unless your ideas are developed in a clear and logical manner. It must be free of errors of grammar, spelling, and punctuation. You should avoid the use of scientific slang or jargon; a thesis is a formal piece of writing. Abbreviations must be defined. It should be written at the appropriate level, neither too elementary nor assuming too much; a good strategy is to aim to make it understandable to a fellow BCMB senior student. A thesis does differ from a scientific paper in one important way; in a thesis, both positive and negative results can be reported. Experiments that are not publishable in a scientific paper can be detailed in a thesis. You can record not only the experiments that yielded publishable results, but also the trouble-shooting you did to get a method working.

- **Introduction.** You need to place your work in the broader context of other work related to your research. You will need to understand the work leading up to your project in detail and this requires a thorough search of the current relevant literature. In this section, you should describe previous work critically, but no original data from other papers is included. You should discuss the strengths and weaknesses of previous work if appropriate and address the issue of how your work addresses gaps in our knowledge.
- **Methods.** The methods section should be detailed enough that other students/scientists could repeat the experiment. This section is usually more elaborate than the methods section in a published manuscript. You will need to include such things as the *final* concentration of the components of the reaction, the sequences of the primers you designed, the details of how images were captured, etc. Basically, all procedures that you

have used in your research must either be described in detail (if not published) or referenced if a published protocol was used. Any modifications from the published procedure must be noted. One way of thinking about the level of detail needed is to think about what a future BCMB thesis student need to know to be able to replicate and extend your research.

- **Results.** This section should be organized into subsections, each describing one experiment. Within each section, you should briefly state the purpose of the experiment (what hypothesis are you testing). It can often increase the clarity of your results section if you then explain what result you expect if your hypothesis is supported. The actual results should then be summarized and the reader referred to the appropriate table or graph. The meaning of the result can then be stated, but extensive interpretation of the results must be reserved for the discussion section.

Sometimes (even often!) a project is recalcitrant despite your best efforts and even a year is not sufficient time to complete a project. If you are unlucky in this regard, the faculty will not penalize you if they are persuaded that you made the best possible effort to obtain results. In this case, we expect you to write in detail about what went wrong, why it might have gone wrong, how you could test your speculations, and what you might do differently another time. This will show us that you learned something important from the experience.

- **Discussion.** In this section you must interpret your results. This will require a knowledge of the field and some creativity and risk. You do not have to be right in your interpretation, but you have to make your best effort to place your results into the context of your field. Here is where you practice learning the difference between over-interpreting your data, and under-interpreting it. Here you can discuss what limitations there might be to your interpretation, what other possible interpretations there are and whether these alternatives can be excluded or are less likely.

The length of a BCMB thesis varies considerably; you should consult with your faculty advisor about specific expectations for your thesis. As a rough guide, BCMB theses are typically 7,500-10,000 words for the main text (30-40 double-spaced pages). The overall length is usually 60-80 pages once figures, tables, appendices, references, table of contents, title page, etc. are included. That said, *quality is prized over quantity*. We have had excellent theses (with work that has ended up published by students that went on to win the College's highest academic honor) that were less than 60 pages in length.

The Seminar

You will present a seminar about your research as part of the BCMB Seminar (BCMB 410). How to present a seminar is detailed in the syllabus for this course. BCMB thesis students will be scheduled to present seminars on their work in the second half of the semester. This seminar is your chance to celebrate with your friends (hopefully this includes all of your BCMB faculty!) the culmination of your work.

The Oral Defense

Your thesis defense will normally occur during reading days. In the defense, we will try to clear up any unanswered questions we had after reading your thesis and listening to your seminar. The better your thesis, the shorter your defense! The defense usually takes 30-40 minutes. We try to ask you questions that we know you can answer as well as some that we expect you do not know. No one fails a defense, and often, students understand their own work better than their thesis implies and the defense allows them to explain themselves in a different format. The defense is always nerve-wracking, but many of our past graduates have told us how important the experience was for them, and how glad they were that their first experience of an oral defense was in college. We offer a thesis defense in this spirit – to ensure you are ready to excel in your future careers.

Some Advice

Reading. To write a good thesis requires a very solid foundation in the intellectual background for your project. You will need to understand the work leading up to your project in detail. Your bibliography should include at the minimum five reviews and 15 or more original research papers. The introduction section of your advisor's grant proposal is a good starting place for relevant research papers, but you will also need to know how to use PubMed and other online searches. We strongly suggest that you plan on reading several papers during the summer preceding your thesis and at least a paper a week during fall term of your senior year. You should take notes on these papers just as if you were in a course. In addition to content, note carefully how scientific papers are written. Note the construction of the sections and how ideas are organized.

Research. All researchers encounter some technical difficulties. As you approach problem solving these technical problems, be sure you know the variables in your technique and which ones are important and why. We will expect to see evidence of this in your thesis. There are a number of publications that contain information about the theory behind lab procedures; ask your advisor for some suggestions.

Ask lots of questions about how and why as you do your lab work. Be constantly thinking about your work. It will not be sufficient to just do the experiments; you will need to understand your own work at a deeper level than you may be used to doing.

Time Management. Because this "class" does not meet on a regular basis, and there are few assignments except the final product (welcome to the real world), it will be your responsibility to make sure you are making steady progress toward successful completion of your project and of your thesis. We expect that you will give your thesis as high or higher a priority as your other classes and that you will not let your research slide when assignments and tests in your other classes come due. Experience suggests that successful completion of thesis research requires that you do not let other commitments get in the way of making steady progress in the lab and on your writing. A good rule of thumb to keep in mind is that you should expect to spend at least four hours per credit hour of time in the lab each week. As the thesis is a four-credit course each semester, this translates to at least sixteen hours of work on your thesis per week.

Writing. Writing the thesis is a big job and you need to work on it on a continuing basis and not expect to begin writing your progress report in the last three weeks of the fall term, or the final thesis in the last three weeks of spring term. One suggestion from a previous student is that you hand into your advisor written summaries of your data and your analysis of it every two weeks. When it comes time to write your thesis, these summaries will contain results that are already analyzed and organized.

You should plan on visiting either the Chemistry Department or Biology Department office and asking the administrative coordinator to show you where we keep previous theses. Spend some time reading one or two. An example is worth a thousand words of description. You should expect to write multiple drafts of both your progress report and your thesis. You should plan on getting feedback on your writing from your research advisor before you turn in a final copy to your advisor and reader. You should also use the self-evaluation form at the end of this document to monitor your own writing and make improvements in it before you turn it in. We will be using a similar form to evaluate your thesis and progress report.

Good Luck! Our good will and experience are at your service. We hope you will find the thesis experience a truly demanding, rewarding, and enriching one.

**BCMB Progress Report/Senior Thesis
Manuscript Self-Evaluation**

Student Name: _____

Date: _____

Yes	No	
Introduction		
		Is the background <i>relevant</i> and <i>sufficient</i> to understand the thesis rationale? Is extraneous background left out, and all the information necessary to understand the thesis included?
		Is the introduction divided by subheadings that organize the background?
		Are the experimental questions addressed by the thesis clearly stated?
		Is material from other sources properly cited and referenced?
		Do the sections of the Introduction follow in logical order? Does the introduction become progressively narrowed and focused upon the questions asked? Is the point of each paragraph clear? Do paragraphs have appropriate topic sentences and does each paragraph stay on topic? Is the Introduction grammatically correct? Is the spelling correct? Is the Introduction written in the active voice?
Methods		
		With access to referenced material, could the experiments be repeated with essential details intact?
		Are solutions/chemicals described in terms of final concentrations? Is the relevant experimental detail included and irrelevant information excluded?
		Is experimental rationale excluded from the Methods section and instead included in the Results section?
		Is this section written in the past tense? Passive voice is acceptable here. Is the spelling correct? Is the grammar correct?
		Is this section organized by subheadings that describe particular procedures?

Results		
		Is it clear in the first paragraph of each section what the question is and how the experiment was <i>designed</i> to address the question?
		Does the text explain what the data show? What the controls show? Are the figures/tables referred to where appropriate?
		Is the design of each figure appropriate for the data presented? Are control data handled properly and included?
		Do the figure legend <i>titles</i> describe what the data show?
		Do the figure legends explain the necessary details of how each experiment was done? Do the figure legends refrain from interpreting the data? Could you interpret the data from just the figure itself, or do you have to refer to the text to understand how the experiment was done?
		Is this section written in the active voice? Are paragraphs constructed properly? Do the ideas flow logically? Are the spelling and grammar correct?
Discussion		
		Is there a clear summary of what was discovered or shown in the thesis?
		Are the experimental data interpreted carefully and thoughtfully, <i>taking the control data into account</i> ? Are the data over-interpreted? When appropriate, are the data analyzed quantitatively?
		Do you draw conclusions, and are these supported by the data?
		Does the discussion analyze the biological meaning of your data rather than just exploring sources of error?
		Do you propose a next logical experiment?
		Is material in this section properly cited and referenced?
		Is this section clearly organized, grammatically correct, and written in the active voice?