SENIOR THESIS (BIOLOGY 495)
Guidelines for Proposing and Carrying Out a Year-Long Senior Research Thesis

Course Description

Biology 495 is a two semester-long independent research project. You are responsible for selecting a suitable project, in close consultation with two faculty advisers, and for designing and carrying out the necessary experimental and/or observational work. You will present the results of the research at the end of your senior year as a seminar for interested students and faculty and as a written thesis that becomes part of the department's archives. In a session with departmental faculty you will answer their questions about your work. To be eligible to carry out a senior thesis, a student must have at least a 3.5 GPA overall, and write a research proposal that is approved by departmental faculty.

Biology senior research is designed to serve as a capstone for your educational experience at Lewis & Clark College. It requires you to integrate the skills and knowledge you have gained in many of your courses. It will require an understanding of scientific methods, creativity, organizational ability, and skills in critical thinking, library research, time management, written expression, and oral presentation. We hope it will be the most challenging project you undertake at Lewis & Clark.

Applying for Permission to Enroll

Junior biology majors must submit a brief proposal to the Biology Department for permission to do a senior thesis (see "Topic Selection" for more details). Consultation with advising faculty is required during proposal development. Students must have a minimum 3.5 grade point average both within the major and in the College as a whole. **Your application must be approved by the Biology department before the pre-registration period for fall semester of your senior year (or correspondingly earlier if you plan to graduate in December).**

Evaluation of the Project by your Advisers

Senior research is unlike any other course in that there are few milestones along the way, like quizzes or exams. To help you evaluate your progress, here is a description of our expectations of honors students. To graduate with honors requires you to demonstrate:

1. A thorough understanding of the scientific issues involved in your project as well as a solid understanding of the methods you used in your work. You will need to understand and be able to explain the general scientific issues that your work addresses, and how your work is related to previous work. This understanding should be more complete and sophisticated than that of a student who had merely taken a course in the area. This will require that you diligently research your project, reading reviews and original research articles to develop your knowledge of the field.

2. That you can design sound experiments with proper controls, adequate sample sizes, etc.

3. An ability to analyze data critically. 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 well-designed graphs and tables with appropriate titles and figure legends.

4. That you can organize your time effectively and meet deadlines.

5. That you can express yourself articulately in written form and orally.

The specific stages we will use to judge your mastery of these skills, along with the weight we will assign to each, are listed below. Each stage is described in detail in the sections that follow.

Stage of project	*Weight*	*For Spring Graduates*	*For Fall Graduates*
Topic Selection		prior to Fall pre-registration	prior to Spring pre-registration
Research Proposal		end of 1st week of Fall sem	end of 1st week of Spring sem
Annotated Bibliog.	5%	middle of Fall semester	middle of Spring semester
Progress Report	10%	last week of Fall semester	last week of Spring semester
Thesis Draft	20%	negotiated with readers (sugg: 11th wk of spr sem)	negotiated with readers (sugg: 11th wk of fall sem)
Final Written Thesis	50%	negotiated with readers (sugg: last Fri of spr sem)	negotiated with readers (sugg: last Fri of fall sem)
Oral Presentation & Defense of Thesis to Faculty	15%	reading days	reading days

All deadlines are at 5:00 PM on the designated day.

Topic Selection

If you are interested in senior research, begin by talking to faculty members in your areas of interest about whether they would serve as your advisers. You need to do this in the spring of your junior year. Together you can identify some topics that you might find interesting and feasible. Be sure you are adequately prepared to take on this topic, through your previous coursework or other background. Because one of these people may need to provide you with laboratory space and equipment, and both will be responsible for supervising your work, you must be prepared for them to say no if the topic you want to study is too far afield from their area of expertise, or if they judge your ideas are insufficiently developed. Plan to have several meetings with them before you reach an agreement.

If you are interested in pursuing research in ecology, animal behavior, or another field-oriented area, you should strongly consider using the summer between your junior and senior years for your data collection phase. Field-oriented projects performed in the fall and winter months are restricted to a quite narrow range of possible topics, given that most animals and plants are inactive during these times. In this case your formal research proposal will be due before the summer begins.

Once two faculty members have agreed to serve as your advisers, and all of you have agreed on a suitable topic, you should submit to the Biology Department Chair a 1-2 sentence statement of the topic you have selected, accompanied by a 1-2 paragraph description of your ideas so far. Both of your advisers must sign this paper. Attach a copy of your transcript as evidence that you have the required GPA. Upon submitting this paper, you will receive conditional permission to pre-register for Biology 495. This registration is conditional on departmental approval of a more detailed proposal that you submit at the beginning of the subsequent term (see table above) or before the summer begins, if you propose to do field work in the summer.

The Research Proposal

Once you have identified a topic, you should do some reading so as to focus your specific goals. Plan to do this in the summer, since your proposal is due at the beginning of the fall term.

The research proposal is 4-6 pages long and includes the following sections:

Introduction – This section should contain a clear statement of the question(s) your study proposes to answer. Include a critical summary of what is already known/published that is relevant to your question. Write this section in such a way that it can be clearly understood by any biologist, no matter what their field.

Proposed experiments/data collection – Explain what you intend to do, why, and how. This section should be detailed enough for your advisers to be able to assess whether or not the proposed experiments/observations are likely to answer the question(s) you are posing.

Literature cited – Provide the complete citations of any references you used in the Introduction. Ask your readers for some appropriate journals to consult if you need advice on the correct format.

Budget – In this section you should provide an itemized list of the supplies that you will need to carry out your thesis, and the estimated cost of each. Indicate which of these costs, if any, will be covered by one of your readers. Remaining costs may be covered by the Biology Department, but students whose needs are great may need to seek support through SAAB or other sources. Indicate any plans to seek other support in this section.

Submit your proposal to the Biology chair. The Biology faculty will read all proposals,

and if we judge your proposal to be insufficiently developed or unfeasible, you will have to withdraw from the course. **It is therefore important to work closely with your advisers as you prepare your proposal; communication during the summer is crucial. Expect to revise several drafts before developing a finished proposal.**

Students who spent the spring semester of their junior years off campus may submit a proposal to do senior research without going through the topic selection stage. In that event, their proposal should include the signatures of the two faculty who agree to be their advisers, and a copy of their transcript.

Students who expect to graduate in December, or to spend the spring semester of their senior year on an overseas program, or who wish to take advantage of the summer for field work, may petition the department to do senior research during the summer and fall preceding graduation, or during the spring of their junior year and the fall of their senior year. See the table for the deadlines that would apply in these cases.

Supplies and Equipment

You will be informed by your advisers of the size of the budget allocated to your thesis. Order supplies through Wendy McLennan or the department's administrative assistant. All orders must be done using an official order form (available outside Wendy's office); one of your advisers must approve your request. Be sure to plan in advance, because paying for overnight shipping will use up your funding very quickly!

For constructing equipment, take advantage of the Natural Science Shop in Olin. See Steve Attinasi for assistance. He can show you how to use various tools to build the apparatus you need.

Annotated Bibliography

As you carry out your work, it is very important that you be well-informed about how it fits into the larger body of knowledge about the subject area you have chosen. It is also critical that you discover what studies have already been performed that relate to the topic you have chosen. So one of your first priorities should be to become familiar with the literature of your field. The literature that you read at this stage will help you write a good general introduction and will help you to interpret the importance of your findings once you finish your work.

This bibliography should be annotated; that is, each citation should be accompanied by a sentence or two summarizing the work and/or explaining its relevance or value to your own research. (The Writing Center has a good handout available on annotated bibliographies.) We expect that it will be much more extensive than the bibliography you submitted with your research proposal, and that it will include citations that are as current as possible. Be sure to be familiar with standard citation format, and to include only those publications that you have actually read. See the Biology Department website for advice

on citation format. Turn in one copy to each of your advisers.

The Progress Report

At the end of the first semester, you must submit a progress report to each of your advisers. This report is essentially a first draft of your thesis. It should be written in the style of a scientific paper with these sections: Introduction, Methods, Results/Discussion, Plans for the Second Semester, and Literature Cited. Students are expected to follow the Department's guidelines for effective scientific writing at all stages of their writing. For advice on scientific writing, please consult the Biology Department website.

The *Introduction* section should be essentially complete at this point. You should have completed the library research on your project and be able to write a more thorough, fully referenced background section than that which you prepared for your proposal. We expect that the Introduction section of your finished thesis will look very similar to the Introduction you write for the Progress report. Place your work in the broader context of other, related work. 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, be sure to discuss the strengths and weaknesses of previous work and describe how what you have done addresses gaps in our knowledge. Imagine that your audience is a senior biology major who is unfamiliar with your work; write with enough background information that any biologist can understand the significance of your question and approach. This will probably require 8-12 pages of text.

As always, be careful when reporting what you have read not to accidentally plagiarize an author's words. Take notes cautiously, so that you can be sure that you are describing what you have learned from your reading in your own words. Any violations of academic honesty will automatically be denied departmental honors at graduation. If you have any questions about what is appropriate, ask your advisers.

The *Methods* section should also be nearly complete at this point. Provide your reader with the technical information needed to repeat the study. All methods and procedures that you have used so far must either be described in detail or referenced if you used a published protocol.

The *Results/Discussion* section of your report should include whatever results you have by this time, with as much analysis and interpretation of those results as you have completed.

The *Plans for the Second Semester* section should describe what remains to be done, and include a projected timetable for completing the project.

The *Literature Cited* should provide the complete citations to all the references you use in the Progress Report.

This progress report will be graded, to give you some feedback about how you are doing.

The grade will reflect your advisers' evaluation of the quality of the scientific work, of the writing, and of the effort you have expended on the project. This grade will be for your information and will be incorporated into your final grade (see table on previous page); however, you will receive a DFD (for "deferred") on your transcript for the first semester. This DFD grade will be replaced with your final letter grade once the thesis is completed and graded in the second semester. The report will be returned to you with suggestions. Before the end of finals week of the first semester, make an appointment with both your advisers to discuss their comments and your progress towards completion of your thesis.

The Thesis

A senior research project culminates with a written thesis. The research proposal and the progress report help prepare for this demanding writing assignment. The thesis is written in the form of a scientific research paper and must be well organized, both in terms of the overall construction of the paper and in terms of individual paragraph construction. Ideas need to be developed in a clear and logical manner. See the "Effective Science Writing" guide on the department's website for tips on organizing and structuring effective scientific writing.

We require you to submit both a draft and a finished version of your thesis. The draft should be as polished and complete as you can make it. It will receive a provisional grade, so that you can judge how close it comes to the faculty's expectations. This provisional grade will be incorporated into your final grade. You will receive extensive comments on the draft, and then you will be able to revise it to produce your final written thesis. Submit one copy of your draft to each of your advisers; do the same with the final thesis. Your final thesis does not have to be professionally bound. If you are willing to make it accessible to students and others in electronic form, please give us your permission to do so and send a PDF version to the Biology department's administrative assistant.

Professional conduct

To earn honors, in addition to writing an honors-worthy thesis and maintaining a 3.5 GPA throughout your senior year, you must demonstrate professional behavior. In addition to the Biology Department's general policies on such conduct (see http://www.lclark.edu/dept/biology/policies.html), this also includes: using laboratory equipment and facilities safely and responsibly; keeping your workspace clean as a courtesy to others; and returning borrowed items when finished with them.

Respecting deadlines is another important aspect of professional behavior. Once you and your advisers have established deadlines for your thesis draft and final version, we expect you to abide by these deadlines. Your readers will have planned their schedules around receiving your work at a particular day and time, and late submissions cause them considerable inconvenience. Failing to meet a deadline, or engaging in other unprofessional conduct, may result in one of the following sanctions: a lowered thesis

grade; failure to earn honors; or a letter of recommendation that describes your behavior as unprofessional. Unless specifically negotiated otherwise, all thesis deadlines are at 5 PM on the stated day.

The Oral Presentation

You must present your research to faculty, students and friends in a well-organized and well-rehearsed 20-minute research seminar, followed by an open question period. Work closely with your faculty advisors to prepare and rehearse your talk. Later the same day, you will meet with the Biology faculty for 30 minutes of further questions in which you will demonstrate your understanding of the conceptual background for your work and explain your design and data interpretation.

Some Advice

Reading. To write a good thesis requires that you be well-read. You will need to understand the work leading up to your proposal in detail. As background for your thesis, you should read several review papers and at least a dozen original research papers. Your advisers can recommend some places to start, but you will also need to have the library staff show you how to use various scientific databases (e.g. Web of Science, Biosis, Agricola, Medline) if you do not already know how. We strongly suggest that you begin doing this reading well before you begin work on your thesis. Take notes on these papers. In addition to content, note carefully how scientific papers are written. Note the construction of the sections and how ideas are organized. But also realize that not all scientific papers are good models of clear writing!

Research. If you are following experimental protocols designed by others, rather than designing your own experiments, there is a danger of incompletely understanding why you are doing each step. Ask lots of questions about how and why as you do your work. We will expect you to understand all of the methods or techniques you used, and at a deeper level than you are used to doing. Present your work to outsiders (other students, other faculty) if you have a chance. Outsiders will approach your work with a different set of assumptions and can often point out flaws in your analysis that both you and your advisers may miss.

Time management. Because this "class" does not meet on a regular basis, and there are few formal assignments, it will be your responsibility to make sure you are making steady progress toward successful completion of your project and of the written thesis. We expect that you will give your thesis at least as high 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. Expect to devote at least 8-10 hours per week to this project. One helpful motivator is to schedule regular meetings with one or both of your advisers, perhaps weekly or every other week. A previous thesis student suggested the following advice that you might find helpful. Require of yourself that you hand in a 1-2 page report every other week of what you have done, what you think about it and what you plan to do next. As he pointed out, writing it will require you to think through what you are doing.

And, when it comes time to write your thesis, there it will be on your computer disc, already analyzed and organized. You can even edit your reports on an ongoing basis. Writing the thesis is a big job and you need to work on it on a continuing basis. Don't delay thinking about your work until the week before the draft is due. Remember, due dates are firm and late submissions will result in lowered grades. This is your opportunity to demonstrate your ability to work independently and organize your time effectively.

And remember: whenever you have questions, faculty are here to help you. Feel free to seek advice from anyone in the department who might be able to help.

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