The ABI Major

Student Survival Manual

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The Animal Biology Major Program

The Animal Biology (ABI) major specifically caters to those students ultimately seeking a professional career in research focused on the biology of animals. ABI intensively educates students in the natural sciences, with heavy emphasis on methods for deriving new information about animals. Thus, the process and principles of science, and concepts in research methodology receive the highest priority. ABI encourages students look beyond particular groups of animals in which they are interested and to apply the process of science as a way of establishing new and reliable information about them. The major places priority on seeking solutions to conflicts between the needs of animals, and evermore pervasive human enterprise, such as agriculture or advancing urban areas. However, animal behavior, animal nutrition/diet, conservation, ecology/ecosystem function, genetics, immunology, parasite-host interactions, reproduction, wild animals in captive settings and wildlife management exemplify the diversity of research areas encouraged in ABI. Animal production, care and husbandry largely remain the prevue of other programs.

Student Learning Outcomes for the Animal Biology Major

1. Ask and answer novel questions in biology, and derive new information and ideas using the process and principles of science.

2. Simply and effectively communicate complex ideas in biology in writing and speech to groups of people.

3. Mediate conflicts between the biosphere and human enterprise incorporating the most reliable biological fact and thought.

4. Distinguish between real scientific fact and progress in biology from bias-driven public-relations pseudoscience.

5. Using a team approach and the most contemporary thinking in biology, solve problems of a biological nature.

The Curriculum
The curriculum consists of core biological sciences courses that build on animal biology from molecular foundations to the ecological and evolutionary levels of organization. After completing the core courses, and usually at the beginning of the junior year, ABI students design their own academic program. The program includes a research project of the student’s choice called the Senior Practicum, (essentially an undergraduate thesis project), completed under the guidance of a faculty mentor. The student and mentor select twenty-five units of supportive coursework or Restricted Electives; these provide the foundation for the Practicum. Essential corollary skills of science, including scientific writing, critical thinking; public speaking and research teamwork naturally develop from this process. The ABI research experience thus remains almost unique among undergraduate science majors at UC Davis. By graduation, in addition to completing coursework on the principles of biology, every ABI student engages in one complete cycle of the scientific process by conceiving an idea, formulating a question, deriving hypotheses, making predictions, testing those predictions with observations and completing a manuscript (frequently publishable) detailing their efforts and results. The student directs this entire effort in a manor to catalyze their post graduate aspirations.

**Appropriate Practicum Projects**

Identifying post-graduate professional aspirations constitutes the key to selecting a Practicum Project, a Mentor, and the Restricted Electives. That ultimate professional interest obviously identifies the kinds of scientific inquires, list of potential mentors and the coursework from which the student selects. Realize that the “practicum” qualifies as an undergraduate thesis, and actually becomes a permanent part of your academic record here at UC Davis.

Many students have a well-established longstanding interest in some profession, and for this group the selection process becomes comparatively easy. But for those that remain unsure, the process remains rather more difficult. Universities certainly top the list of great places to make that decision; in no other venue are nearly all the choices so well advertised as in a Course Catalogue, and available direct access to any
potential choice via coursework! However, it comes about, it behooves the student to give this decision top priority.

The practicum may be experimental biological research, or a problem-solving issues paper. These take on the same basic scientific inquiry and report structure. Practicum projects may be off campus, and the primary mentor need not be a UCD faculty member, however, in this case students must additionally have an on-campus faculty member with “gradebook access” as a co-mentor. Groups of students may collaborate on a project, provided that the project requires effort commensurate to the number of students. An “Internship” does not constitute a practicum in and of itself, but may be an entrée to a laboratory, a practicum project or to a relationship with a prospective mentor.

**Experimental biological research**

Essentially this constitutes a standard scientific inquiry with hypotheses that make predictions about future observations derived from experiment, using the process and principles of science. In general, a student or team of students conducts such an inquiry in the laboratory or field. The research project may be independent of, or be within the mentor’s program of research, most often the later. Collaborating in a research team on an ongoing project with other researchers in the laboratory constitutes a highly desirable option. The student receives mandatory safety and other training to complete the work. With faculty mentor guidance and administrative oversight, the student may collaborate with a graduate student or post doc. In general, students develop a protocol, set up the experiment, collect, analyze and interpret the data, and write a research paper in the format of a publishable scientific manuscript. This becomes the Practicum Report. The discussion section of the paper should argue the significance of the research in the greater context of science and societal interests.

**Animal Issues Research**

A student or team of students selects some animal-related issue and conducts a scientific inquiry in the standard way with hypotheses and predictions, but where the
observations derive from library, interview-based survey and similar sources. Thus, “Issues Research” differs from an experimental biological research project only in that observations come from the literature, interview, opinion surveys and the like. The proposal and manuscript exhibit the same logical construction, format and structure as for experimental biological research. The discussion of the manuscript evaluates the findings in relation to economics, society, stakeholder interests, animal welfare or environment, and makes relevant conclusions. The faculty mentor again guides all aspects of the work.

Ongoing research

Alternatively, having identified a potential mentor in a field of study commensurate with your personal interests and goals, and possessing a few general project ideas in mind, ask him or her if there is an ongoing research effort in their lab with which they could use assistance. In this case the student becomes part of the lab team, a far better experience as virtually all modern science is done by teams of collaborators. Importantly, in the eyes of the mentor the student becomes a valuable asset to the laboratory rather than an additional responsibility. The student can easily organize their portion of the ongoing project into a practicum proposal and report as described in the sections of this document devoted to those requirements. In situations of this kind the student comes to qualify as a co-author on the publication that derives from the research.

The ABI Practicum During Suspended or Limited University Operations

Under the current conditions of Limited University Operations, the student must still develop a relationship with a mentor, and the mentor’s guidance has the first priority in how the student proceeds with the practicum proposal, the research effort and the project write up. However, the practicum and the conduct of the student must fall within the guidelines set out in this manual, and remain within the original intent of the major: to prepare students for professional post graduate research efforts in the biology of animals either in industry or academia. Within these guidelines, the latitude of acceptable practicum research efforts remains considerable.
Clearly, when campus operations are suspended or otherwise curtailed for foreseeable future, direct participation in laboratory or field research efforts becomes severely although not completely curtailed. But the intent of the major is to have students employ the process and principles of science as part of a team effort to seek an answer to a biological question. There are at least two ways students can satisfy this intent under the current restrictions.

The first would be to develop the most parsimonious and likely solution to a research problem from preexisting information derived from the refereed literature, together with cogent lines of reasoning predicated on intensive study of that literature. This is not a “literature review.” Essentially, this effort replicates the process in which all excellent researchers begin a line of inquiry so that they do not waste time and resources on side issues and blind alleys. The write up would have the same structure as the introduction to a refereed journal review paper, and contain arguments based on a logical analysis of the literature that resolve an explicit statement of alternate hypotheses. From these derive a set of real research objectives, a summary of the necessary research methods and predictions of the most likely outcomes. In some sense this research effort parallels a generic scientific grant proposal.

The second would be to derive alternate hypotheses based on preliminary observations that can be tested by careful study of the literature. Again, this is not a “literature review.” In essence this is similar to a “meta-analysis” except that the study is hypothesis driven and does not necessarily involve a statistical analysis of data sets from different studies. An analysis of verbal data, of trends in the biological literature and similar non numerical information or comparative studies of technical procedures in biology constitute a short list of the possibilities.

The subject of these research efforts would fall within the expertise of the mentor, if not directly in the line of his or her research. Thus, when conditions ameliorate and labs become more open, these kinds of studies could easily convert to lab or field projects under the original practicum proposal by writing a short memorandum of explanation to the Master Advisor which will be appended to the original proposal.
There can be no doubt that numerous other acceptable practicum project alternatives exist that be accomplished under the current limitations to life at universities. Mentors and students should feel free to design their own projects appropriate to these limitations. Please contact us with any ideas you may have; as long as they fulfill the objectives of the ABI Major, we shall be delighted to entertain them, and to assist in any way we can.

**Launching the Practicum effort: ABI187 Seminar**

The ABI 187 Seminar course offered every Fall and Winter quarter leads students through the process of deciding on a practicum project, writing the practicum proposal, finding a mentor, and together with the mentor, selecting the classes to fulfill the restricted electives requirement. ABI187 Seminar should be taken as soon as possible after ABI50A, (Animal Biology Laboratory). But to delay the decision process of searching out a mentor and beginning the practicum proposal until the ABI 187 Seminar risks may complicate the Junior and Senior years most students experience. Transfer students should take ABI 187 during the first fall or winter quarter at UCD.

The ABI major almost uniquely offers a great deal of freedom in choice of academic pathways, but the anxiety caused by the responsibility of this freedom troubles many students. Delay frequently occurs, most often attributable to indecision about postgraduate professional aspirations; no one wants to make a decision that prevents or delays graduation or proves misguided in the future! Deciding on future goals and preparing early and prior to ABI187 remains the best way to avoid such problems.

Thus, with defined interests, start thinking about projects and look for faculty with related research programs. Politely make an appointment and ask about working on one of their projects as an assistant. When you interview faculty, take copies of the ABI Practicum Mentor handout or this manual, and explain your interests to that person. If the situation seems auspicious, politely ask if he or she would be willing to be your mentor. Internships are a great way to gain experience and learn if you really like a
particular field of animal biology, and also to meet and develop relationships with potential mentors. Begin this process now.

**ABI Mentor Instructions and Responsibilities (What a Mentor Does)**

Prospective mentors interview ABI187 students when they make appointments and potentially choose one or more to work in their labs. They are strongly encouraged to contact the ABI Master Advisor or the ABI Staff Advisor with any questions about the student(s), the nature and intent of the practicum, or the ABI major.

The mentor helps students select research questions, hypotheses and research objectives that provoke thought and provide a rich undergraduate research experience. The ABI Practicum section of this handbook details the various categories of acceptable practicum projects. Ideally, the project should be in an area of research directly relevant to the student’s ultimate professional goals. Students establish a tentative, two-quarter timetable for completion of the practicum including writing for the mentor to approve.

Students may work with anyone in a lab under the supervision of the mentor, and may work in groups. Thus, with mentor oversight, a graduate student or post doc may day-to-day guide students on the project. Mentors meet regularly with students to help keep them on track.

Mentors assist students in selecting the restricted electives and for their academic plan. These provide the concepts, background ideas or skills that amplify the practicum project. They must total 25 units. This document lists the selection criteria for restricted electives that may be used by the student in his or her practicum proposal, together with the restricted electives form for the student to fill out and the mentor to sign. Mentors see that students have necessary technical and safety training, together with the environment, resources, and guidance for the work to be completed.

We recommend students log their activities and thoughts during the project in notebooks in the standard way, whether the project is experimental research, or issues research or ongoing research in the mentor's laboratory. Notebook entries should be made in a timely manner, and the mentor should read and comment on the notebook
periodically. The mentor should encourage high quality work, analysis, writing, timely completion, and enforce the universal processes and principles of science. Make corrections on drafts of the report and the final report prior to submission. Hopefully the mentor will interact with students in the standard way a principal investigator guides anyone working in their lab.

Although the practicum report should be written with the standard sections, logic and format of any common scientific report prepared for publication as stipulated in this manual under the section “Structure of the Practicum Report”, the mentor may suggest other manuscript writing methods. Otherwise sections in this document detail preferable criteria for the process or writing a generic scientific publication. “Issue Research” projects follow the same basic structure. In this case data used to test predictions from the student’s hypotheses derive from the literature or other sources. The guide to authors of a good journal in the mentor’s field would provide appropriate details of format. Where the nature of a practicum deviates from normal scientific reporting, students should be guided by an agreement between the master advisor and mentor.

The mentor determines that the final project paper meets his or her critical standards and signs the signature page.

**The first meeting with a potential mentor: The Approach**

Realize that meeting with a prospective mentor for the first time is just like having a job interview. For all practical purposes you will be interviewing that person to determine if he or she constitutes a good fit for you and your research aspirations. Interestingly, this interview will be reciprocal, each of you will be “interviewing” the other! You will interview a potential mentor, and be interviewed as a potential researcher. Conduct yourself as you would in a professional setting. Dress appropriately, prepare by reading the mentors publications, understand the mentor’s work, and have whatever questions you may have ready. The key words are Preparation and Questions, it is vital that you are fully prepared for your mentor meeting.

*Always be professional* when working with a mentor; it is of the utmost
importance to be so during the first contact with him or her. The **goal** is to convince your prospective mentor that you would make a valuable team player to his/her lab. Do not pursue mentors, labs or projects in which you are not truly interested, nor settle for a research effort simply because the lab is willing to accept you as labor or to merely satisfies your ABI requirements. Focus on people and situations that match your career goals.

If a potential mentor does not respond to an initial email, contact them again after about a week or so. Researchers at universities are exceedingly busy, obtaining a response often requires several attempts; most delightedly talk to students about their research and professional development, particularly during office hours. Once you establish contact, restate your real interest in the kind of work they do and your fascination with becoming involved in a research project in that area. Ask if they need help on a research project in which they are currently engaged. Even if they seem to respond ambivalently, meet with that person anyway. Their personal impression of you may change their attitude. At the least they will likely know of other persons involved in the same area of research you can contact.

Be certain to study the faculty member’s research interests, areas of specialization and publications before you go to office hours. Be able to state why you are seeking out this particular person's advice. Take along a list in your mind of specific questions or requests for guidance. Do not walk in and say "So, I want to do research in your lab and you to be my mentor so I can graduate," with no clue what the researcher is doing or what part of his or her work you could be involved in; **you need to prepared!**

Bring background information about yourself, including your name, address, phone number, email address, your area of research interest, your educational background, any previous research experience, should the prospective mentor want to see such documents. Include a paragraph or two summarizing your research interests. In effect, go prepared with the Curriculum Vita (CV) (aka Resumé) that you develop in ABI187. Many mentors also like to see a copy of your academic transcripts. Take along all these items so that if asked for they can be immediately provided.
Bring along some potential senior practicum project ideas you have thought through. This will demonstrate to the mentor that you have critically thought about key questions, and developed corresponding hypotheses to test your ideas. Realize that your mentor will likely find flaws in your potential research effort and suggest modifications or alternatives. Be open to these approaches; this is what a mentor is for-putting you on a viable track. Under no circumstances give the impression that you will be just another drain on your potential mentor’s time, ideas and resources. Rather, make it clear that you will be exactly the opposite, a contributing facilitator in the mentor’s research team.

**Some tips for interviewing:**

1. Write down the office number and time you are supposed to meet. Laboratories can be confusing.
2. Arrive at the building early. You may want to do a quick walk-by to make sure you know where the office is.
3. Knock on the door (even if it is open). Do not just barge in because it’s 4 p.m. and that’s when you were supposed to meet.
4. Always bring a notebook and a pen
5. Bring a copy of background research
6. Maintain good posture
7. Dress appropriately
8. Be polite and respectful

Before leaving, think about the follow-up you should have with the potential mentor. If you have established a good rapport and can develop an ongoing relationship, make arrangements for the next meeting to continue the process. Ask what you can accomplish in the interim period.

If there isn’t a good match between your interests and those of the potential mentor, remember to ask that person to suggest other colleagues you might approach. Even if this particular individual has been very helpful, it will likely be useful to speak with those people as well, the more input you get in finding a mentor, the better.
Questions a Student might ask a Mentor

Try to begin the conversation by talking about the potential mentor’s current research. Communicate your fascination with it.

- What are the various projects in the mentor’s research program?
- What journals are important to read?
- How did you get into this particular area of research?
- What has been your career path and former positions? (Actually you should have a general idea about these from the background research you have done on your potential mentor)
- Who helped you in that process and how did you progress in this field?
- Looking back, is there anything you would change or do differently based on what you have learned over the course of your career?
- What is the best piece of professional advice you’ve ever received and used or implemented?
- What are the things you find personally rewarding in your career?
- What characteristics do you look for in a student?

Questions a Mentor might ask a Student

- What do you want to be when you grow up (What profession do you want to be in when you’re older?) and why?
- Why did you choose to attend UC Davis?
- Why did you choose Animal Biology as a Major?
- What classes have you taken? Which one did you enjoy and why?
- What is your motivation for pursuing this (the mentor’s) area of interest?
- What have you learned in your course work that fascinates and interests you enough to engage in a more in depth investigation?
- Tell me the 5 best things about you?
- What skills do you have?
- What skills would you like to develop here at UC Davis?
What have you done, in school or sports or anywhere that you are most proud of?

**The Practicum Proposal: What it looks like, how to format it, etc.**

The practicum proposal usually constitutes a description of standard scientific inquiry with hypotheses that make predictions about future observations derived from experiment. The Issues Research option differs from an experimental biological research project only in that the observations come from the literature, interview, opinion surveys and the like. Both kinds of practicum use the process and principles of science in the same way. Thus, experimental biological research and issues research proposals take the same form described herein. A brief outline of the Practicum Proposal follows here. Explanations of each section follow in subsequent sections. (See Appendix 1 for an example of a real ABI Practicum Proposal written by a former student)

**Outline of the proposal**

A. Title/Signature page: (See Appendix 2 for this signature page)

B. Cover page

C. Project Description
   1. Abstract
   2. Introduction
   3. Hypotheses
   4. Research objectives
   5. Methods
   6. Predicted outcomes
   7. Timetable

D. Importance to self and society

E. Academic Plan
   1. Academic Interest
2. Restricted electives (See appendix 3 for Restricted Electives page)
3. Academic Schedule

F. Curriculum Vitae (Résumé)

G. Opportunities Related to the Practicum (If any)

Explanation of Sections

A. Title/Signature Page (See Appendix 2 for the title/signature page)

Print out The Title Signature Page (Appendix 2) and obtain the required signatures after the mentor approves the proposal. Include this on top of the proposal packet as the first page. Student and mentor signatures on the proposal indicate that both accept responsibility for the project. The specifics of the proposal, however, are tentative, and aspects may change as the project develops. This proposal becomes part of the student’s academic file. If major changes occur to the proposal, a mentor-signed revised-proposal must be submitted. Minor changes require no resubmission. Seek guidance from the Master Advisor to determine if this is necessary; most often, it is not.

B. Cover page (Format in some attractive way)

1. Practicum Title (Descriptive title of proposed Practicum)

2. Name (Your name as on your UC documents)

3. Projected graduation date

4. Coursework Specialization Title (Descriptive title of proposed coursework specialization)

5. Academic Advisor (Name and departmental affiliation)

6. Mentor (Name, affiliation, and addresses of mentor for the Practicum)

7. Date
C. Project Description

The project description should approximately be four single spaced pages of text, but may be longer if necessary. Follow the section format below. Much of the structure and logic of a good proposal parallels the scientific report one would write detailing the results of the work, but written in the future tense (we shall do, rather than we did).

1. Abstract. Write the abstract last. The first sentence is essentially your hypothesis rewritten as a statement of what will be done, followed in sequence by the each of your research objectives, and your anticipated results. Copy and paste each of these sentences to the abstract and then edit them as necessary so they form a short cohesive paragraph.

2. Introduction. This section should only consist of two paragraphs. The first defines the broad context of the problem to be studied and begins with a very broad statement like: “Fishes are known to swim sometimes but drown occasionally”. Subsequent sentences set the stage and inform the reader about where, when and why, and what form of science this problem effects. It ends with a statement of the general problem as you understand it and intend to study.

   In the second paragraph the writer takes the general problem stated above and through logical arguments focuses on the question that seems most central to its solution. The usual method develops the question either as a paradox or lacuna: Problems stated as a paradox (two mutually exclusive truths) have very much greater power than those stated as a lacuna (region where knowledge is lacking). Bring in any citations that are germane to your arguments here, but do not attempt to provide a “literature review”. Subsequent sentences narrow down, define and rule out the possible solutions to this problem until you have only one or as few as possible. Develop an argument that ultimately specifies a particular question central to the solution of your problem and which can be answered by scientific research. This paragraph ends with a concise statement of this question you have developed from the research problem.
3. Hypotheses. This section organizes the research based on the question. The first sentence is a concise statement of the hypothesis(es) to be tested, which derives from the last sentence of the second paragraph of the introduction. In fact, it can be that sentence but inverted and stated as a hypothesis: “It may be that.............” is one way of beginning a hypothesis. This would be followed by a statement of the alternate hypotheses.

4. Research objectives. Here, write a series of sentences or numbered clauses that state in sequence exactly what you must do to test your hypothesis: “Accordingly we will (1)…..,(2)……., and etc”. These objectives or experiments must be logically arrayed so that the first provides a foundation for the second which then builds on the first and so on. The final sentence defines the one piece of critical information that would falsify your hypothesis: “In particular, we seek to determine if……. (Whatever it is) ”.

5. Methods. Write the “M&Ms” by copying and pasting each of the research objectives to that section. These are the “Accordingly we shall” sentences or clauses. Each becomes a topic sentence for a short paragraph about the techniques you anticipate using. They begin something like: “In order to determine such and such, we shall do such and such”. Be certain you include how you collect your data and how they shall be analyzed. Thus, the objectives and M&Ms are written in parallel.

6. Predicted outcomes. Copy and paste each of the research objectives to this section as you did for the M&Ms. Each of these now becomes a topic sentence for a short paragraph detailing what you reason the results will most likely be. They begin something like: “We first shall first determine if”. Then go on to write what you think the most likely result will be. Where alternate results seem not unlikely, include those as well. Again, these are arrayed in parallel with the objectives.

7. Timetable. Here, with the guidance of your mentor provide a schedule of work with estimates of how long each objective will take to complete and a calendar of
approximate completion dates. Consider doing this graphically. The actual work on a project should last about 2 quarters or completed over a summer.

D. Importance to self, society, and biology

This section constitutes a more personal exposé on the importance of the work you intend to do, not only to yourself and your career development but to societal interests. State what the project means to you as a student or as a person. Talk about why do you want to do this project and what will you learn.

E. Academic Plan

1. Academic Interests. This constitutes a statement of the student’s broad areas of academic interest and particular area of specialization.

2. Restricted Electives. Selected with and approved by the mentor, the academic plan includes a list of courses that the student takes to fulfill the Restricted Electives requirement for graduation in the ABI major (See Appendix 3). This consists of 25 quarter hours of upper division courses; lower division courses generally do not qualify. Independent Research (limited to two 199 units) must be approved by the mentor together with a brief written explanation about how they fit into the academic plan. The courses should fulfill one of the following criteria:

a. Teach skills needed to complete the practicum. For example, if collecting numerical data needing analysis, take an advanced course in statistics.

b. Teach procedures required in the laboratory. For example, take one or two 199 research units with the mentor before the practicum begins to learn highly technical processes in cases where training is unlikely to be available elsewhere.

c. Provide background adding depth and breadth to knowledge about the practicum project.
3. Academic Schedule. Organized with academic advisor guidance, this constitutes a schedule of classes the student will take during each remaining quarter.

F. Curriculum Vitae (CV, Résumé) Limit this to two pages. Format it in an attractive way. Go to one of the meetings at the Resume Clinic at the UCD Internship and Career Center, for guidance on how to write an effective Résumé). Include the following:

1. Personal information
   a. Name and citizenship; birth date is optional and by law cannot be required, but not a bad idea to include in this context
   b. Contact information (Address and phone number, either home, work, e-mail, or webpage address, whichever reliably reaches the student)

2. Statement of Interests (One objective paragraph statement of interests and most likely career goal and alternates, i.e., an expanded statement of purpose)

3. Education (Junior colleges attended; current university, college, major, minor, expected graduation date; list of “important” classes; current GPA)

4. Work and Volunteer Experience (Demonstrate good work ethic and technical and other skills. Include dates, position titles, employing organizations, supervisors, duties and skills demonstrated, reason for leaving if not obvious)

5. Special skills (Relevant skills, be explicit)

6. Awards and Accomplishments (Relevant special awards and accomplishments)

7. References (Names and addresses of 3 people who can write substantive letters of recommendation. Annotate the list to explain what each writer can contribute (e.g., how you demonstrate your intellect, communications skills, creativity, work ethic, humanity. Before listing a referee ask their permission.)

Opportunities Related to the ABI Practicum (Optional)
UCD has a number of opportunities for undergraduate student to present and fund their work. While no requirement for ABI students to participate in any of these opportunities exists, they can be rewarding in a number of ways. Not exhaustive, this list should make you think about how to make the most of your research experience.

1. Internships

Under the guidance of a faculty or staff member, a campus department or off-campus organization, students may frequently undertake specific tasks in order to learn a technical skill or a particular set of procedures relevant to animal biology. There are numerous state, federal and industry organizations that have such internships, and these can have the added advantage of positioning a student for employment upon graduation. In some fields, internships are essential for later employment- forensics for example.

2. Provost’s Undergraduate Fellowship (PUF)

https://urc.ucdavis.edu/PUF

The Provost’s Undergraduate Fellowship (PUF) supports undergraduate students doing research or creative projects under the guidance of UC Davis faculty members. Students from all discipline areas are eligible to apply. Applicants need to be enrolled during the time of the research project. Past projects have involved laboratory research, field studies, survey research, film production, design and creation of art elements, music composition, fine arts performances, travel to library or research collections, and many other endeavors. Group projects are not appropriate, however, separate (but linked) projects may be considered. The maximum award is $1,500 toward approved costs directly related to the project.

3. Annual Undergraduate Research, Scholarship and Creative Activities Conference at UC Davis. The conference is described below. This conference along with
many other types of opportunities for undergraduate research funding and 
organizations are listed at the following website: http://www.urc.ucdavis.edu/.

UC Davis undergraduates in all academic fields are invited to submit an 
abstract and registration information to participate in the annual Undergraduate 
Research, Scholarship and Creative Activities Conference. Research projects 
must have been conducted under the supervision of a faculty member or 
professional in the field. The conference is designed to acquaint undergraduates 
with the process and academic rigors of presenting research in a scholarly 
manner. Additionally, the conference will stimulate interaction between students 
and faculty, while encouraging undergraduates to pursue advanced degrees 
toward the goal of research and college teaching.

Students will present their research projects to faculty, staff and other 
conference participants in either an oral or poster format. The oral presentation 
will allow students to give a 15-minute presentation of their topic and includes 
time for questions. Each oral session will be moderated by a faculty member. In 
the poster session, students will have designed a visual poster representing their 
research and will be presenting their work to individual conference participants.

Look for the annual announcement in January of each year.

**General expectations of the Practicum**

1. It should be consistent with the above format.

2. It should take approximately two academic quarters to complete, from the start of 
the work to the submission of the project report. It is not an open-ended mini-
master’s thesis.

3. It must provide the student opportunities to demonstrate critical thinking, develop 
practical skills, communicate, and be creative in an animal biology and scientific 
environment.

4. Practicum quality must reflect the expected development of general admissions
undergraduates. We expect students to do their very best and extend themselves. Mentors assure quality of work.

**ABI 189 and 189d: Measures of research and writing progress**

ABI 189 units measure your practicum work. Students sign up for units over two quarters while actively engaged in completing the practicum project. Arrange a CRN with your mentor and the staff advisor at the beginning of the first of the two quarters work. Credit hours vary, but plan on three hours of practicum work for each credit hour.

ABI 189d gives each student working on their practicum an opportunity to discuss progress and problems with an advisor and other ABI students once a week during the first quarter of practicum work. This fosters discussion of your research topics and efficient problem solving. During Fall, Winter and Spring quarters every year, an advisor will be available for set office hours.

A student cannot register for these courses until a completed and Mentor signed Practicum Proposal is turned in to the Academic Advisor and Staff Advisor and approved.

**Potential Exceptions to the Rules Governing Restricted Electives**

Including “lower division” courses in the 25 units of Restricted Electives (RE) requires special approval. ABI students and mentors must provide evidence justifying a major requirement exception, and we review such evidence during the process of “Degree Certification”, for graduation of each student. Within the ABI Major all special exceptions to the major requirements are considered on a case by case basis. But the rules are as follows:

1. Use no more than one pre-approved lower division course for RE 25 unit requirement.

2. All requests for exception must be in writing signed by the mentor with an explanation why it should be considered. A copy of this document must be provided to us for the student’s file.
3. If a comparable upper division course does not exist to meet a heuristic need, we will consider approving the lower division course for RE unit credit only if becomes crucial to your practicum project and your mentor approves.

4. If the lower division course is a “required" prerequisite to more than one of your upper division RE courses, we will consider including this course for your RE units. However, many upper division courses require prerequisite lower division courses, just because a prerequisite course is required for some RE does not mean it also qualifies as an RE.

Students should additionally select alternate courses that qualify for RE status and can be substituted into their RE list should one or more of their “first choice" courses become unavailable. Check with the offering department about the scheduling of their RE courses to be certain that they actually still exist and will be offered when the UCD course catalogue indicates.

**Alternatives for Required Upper Division Morphology and Structure and Function Courses**

An upper division morphology or structure and function course is required in the ABI major. Under the current conditions of limited university operations, the situation boils down to finding alternatives to the now comparatively rare upper division courses in structure and morphology of biological organisms. For the time being this means finding alternatives that are as close to those forms of science as is possible.

Clearly this excludes general courses in ecology, behavior, molecular biology, genomics, genetics, population biology, biodiversity, biological chemistry, evolution, systematics, phylogenetics, general biology, biogeography, paleontology and animal plant interactions. Upper division courses on evolution, paleontology, systematics or phylogenetics that focus on morphological phenomena likely are acceptable however.

The acceptable list includes upper division courses on anatomy, organs, organology, organ systems, systems physiology such as cardiovascular, respiratory, renal, reproductive or gastrointestinal physiology, cellular physiology, neurobiology,
reproduction, endocrinology, neuroanatomy, sensory systems, developmental biology or general immunology to name a few. Courses of these kinds but focused on particular groups of animals like birds or ruminants are acceptable as well. Likely there are other upper division courses that essentially fall within the same guidelines that may also be acceptable, and these can be evaluated on a case by case basis by the master advisor.

Structure of the Practicum Report

What follows here is a brief description of how to write a scientific report. Realize that there are many different kinds of scientific articles with different objectives and audiences. The one we provide you here is very good for the general case. You should use this structure and logic for your final individual report whether it is bench, field or literature based.

Abstract:

Write the abstract last. The first sentence is essentially your hypothesis rewritten as a statement of what was done, followed in sequence by the final sentences of each paragraph of the results section, and the final sentence of the paper. Copy and paste each of these sentences to the abstract and then edit them as necessary so they form a cohesive paragraph.

Introduction

The introduction to your report should only consist of three paragraphs. The first paragraph defines the broad context of the problem to be studied and begins with a very broad statement like: “Birds are known to fly upside down sometimes but tend to crash and burn when they do so”. Effectively the subsequent writing narrows the topic sentence down to a specific problem. It also sets the stage and informs the reader the about where, when and why of the problem, and what form of science this problem effects. It ends with a statement of the specific problem as you understand it and intend to study.

In the second paragraph the writer takes the problem stated above and through
logical arguments focuses on the likely solutions that seem most central to its resolution. Bring in any citations that are germane to your arguments here, but do not attempt to provide a “literature review”. Subsequent sentences narrow down, define and rule out the possible solutions to this problem until you have as few as possible, generally two. Develop an argument that ultimately specifies a particular question central to the resolution of your problem and which can be answered by scientific research. The usual method develops possible solutions either as a paradox or lacuna: Probable solutions stated as a paradox (two mutually exclusive truths) have very much greater power than those stated as a lacuna (region where knowledge is lacking). This paragraph ends with a concise statement of this question you have developed from the research problem.

The third paragraph organizes the research based on the question. The first sentence is a concise statement of the hypotheses to be tested, which derives from the last sentence of the second paragraph. In fact, it can be that sentence but inverted and stated as a hypothesis: “It may be that...........” is one way of beginning a hypothesis. The second sentence begins a series of sentences or numbered clauses that state in sequence exactly what you must do to test your hypothesis: “Accordingly we did (1)......,(2)....... , and etc”. These objectives or experiments must be logically arrayed so that the first provides a foundation for the second which builds on the first and so on. The final sentence of the third paragraph defines the one piece of critical information that would falsify your hypothesis: “In particular, we sought to determine if....... (what ever it is) “.

Materials and Methods

The “M&Ms” may be written anytime, potentially during the conduct of the research when applying them. Copy and paste all but the first and final sentences of the third paragraph of the introduction to an empty page. Rewrite each sentence to become the “Accordingly we did” sentences or clauses. Each becomes a topic sentence for a short telegraphically written paragraph about the techniques you used. They can begin something like: “In order to determine such and such, we did such and
such”. Be certain you include how you collected your data and how they were analyzed. Particularly short or related paragraphs can be combined as is expedient. Thus, the third paragraph of the introduction and the M&Ms are written in parallel.

**Results**

This is the first section to write, in part because once you have written it, you know exactly what you have (or do not have)! Focus particularly on generating the graphs, charts and tables you must show your readers. This section and the introduction could be written as the work progresses, in part to keep the research on track.

Simply copy and paste all but the first and final sentences of the third paragraph of the introduction to an empty page as you did for the M&Ms. Rewrite each of these to become a topic sentence for a paragraph about the results you achieved for that objective. They begin something like: “We first determined…….”, or “We compared such and such and discovered…….”. Again these are arrayed in parallel with the sequence in the third paragraph of the introduction. As with the Materials and Methods, particularly short or related paragraphs can be combined as is expedient. Each ends with an explicit statement of the particular result obtained. The final sentence of the results section states whether you falsified your hypothesis- the final result of your research effort.

There is no discussion in this section, factual results only.

**Discussion**

The first sentence of the discussion states the most important fact you have discovered with your research, preferably the one which determined whether your original hypothesis was correct. The rest of the paragraph discusses its impact on our understanding of the research problem as a whole.

Subsequent discussion paragraphs may address a variety of lateral issues impacted by your results, or provide you the opportunity to further discuss why you did
things the way you did, or to make further predictions along this line of research, or improve your arguments, and the like. Describe briefly where you think the research should go from here. Be sure to discuss and hopefully dismiss with evidence from the results section or argument any alternate explanations that compete with your findings. Include where necessary, what might be wrong and how could future workers deal with the problem. You might speculate what the next experiment should be and why. End the paper with an explicit statement of final result of your hypothesis test.

There are no new results written into this section not previously set out in the results section.

References Cited

Pay close attention to references format in the guide to authors provided by the journal in which you and your mentor intend to publish. Be careful to check each citation for correctness. Cite only those publications necessary to your arguments, techniques or counter arguments. DO NOT TRY TO PROVIDE A COMPLETE BIBLIOGRAPHY. These are a waste of time (and money- you pay out of pocket for each page published in a journal!!)

Figures

Figures are last, each on their own page with a Figure number at the top left corner of the page. They occur in the same sequence as they are called in the text: Fig 1., Fig 2. Table 1., and etc. Each figure should have a title and an explanation.

Format of the Practicum Report

The format of your report can follow the guidelines preferred by your mentor, or the Guide to author of the best scientific journal you could publish your study in or the very generic and standard criteria set out by the ICMJE (See Appendix 4.).

Whatever format you chose, the top page must be a signature page set out in the same way as for the practicum proposal (see Appendix 2), with signatures of the Faculty Advisor, the Academic Advisor, your Mentor and you.
Appendix 1. Example of an ABI project proposal written by a former ABI student. (The names have been changed to protect the innocent).

Valley Oak Overwinter Leaf Retention Affects Cynipid Diversity and Density
Valley Oak Overwinter Leaf Retention Affects Cynipid Diversity and Density

Student
Arnold Schwarzenegger
Projected Graduation Date: Fall 1531
Insect Ecology

Academic Advisor
Elizabeth of England
Department of Entomology
152 Hutchison Hall
University of California, Davis

Practicum Mentor
Peter Ilyich Tchaikovsky
Department of Entomology
380 Briggs Hall
University of California, Davis

December 2, 1492
Valley Oak Overwinter Leaf Retention Affects Cynipid Diversity and Density

Abstract

I seek to determine if both green and brown leaf retention affect a large portion of cynipid species on all sizes of trees in both spring and summer. With a series of herbivore and leaf phenology survey, I will examine how valley oak (Quercus lobata) overwinter leaf retention affects the diversity and density of 15 cynipid species across different tree size in spring and summer. I will assess whether the effect of leaf retention on cynipid diversity and density is dependent on tree size and time of the year. I will also emphasize the distinction between green and brown leaf retention, which are often conflated, by comparing the effect and explanatory power of physiologically active green leaves and inactive brown leaves. I expect leaf retention to be positively associated with some cynipids, but the overall community level effect to be dampened out. Green leaves and brown leaves will have opposite effects on herbivores and green leaves will perform better as a predictor.

Introduction

Many trees in temperate habitats abscise their leaves annually, but considerable intraspecific and interspecific variation exists in regard to the precise timing. Whereas the consequences of the variation in leaf flush phenology on herbivores have been studied intensely (Crawley and Akhteruzzaman 1988, Aide 1992, 1993, Murali and Sukumar 1993, Fenner 1998), less is known about the impact of winter leaf retention phenology. Tchaikovsky (2007, 2008) provided the first experimental evidence that overwinter retention incurs a cost of higher herbivory in the following spring. Concordantly, Pearse and Tchaikovsky (2013) reported that herbivory pressure from leaf miners may have selected for the variation in leaf lifespan in the genus Quercus. Yet, despite these convincing evidence linking leaf retention to herbivory, much remains unclear about its mechanism, consistency, and generality in the herbivore community.

In the semi-evergreen Q. lobata system, the vast majority of the herbivore community are composed of galling wasps from the family Cynipidae. Two species of this family in the genus Neuroterus were reported to occur in association with leaf retention possibly because they use retained leaves as an oviposition cue (Tchaikovsky 2007). Indeed, as overwintering leaves may reveal information about host identity, location, and vigor, dropping leaves may render a tree less apparent, if not force herbivores to recolonize by physically removing them. However, whether these factors are also applicable to other members of the herbivore community or whether their influence stay robust under different conditions remains unclear. Cynipids that attack the stems or reproductive structures may rely more on cues from their target organ, whereas those that emerge after leaf flush have no retained leaves to be cued by. Similarly, some bud galls and stem galls stay attached to the plant (Russo 2006), thus, physical removal of galls through abscission cannot not reduce their density.

While it is possible that trees with higher leaf retention are more vigorous (Tchaikovsky 2008) and the herbivores distribute accordingly (Price 1991), for more deciduous trees that retain primarily brown leaves, it is questionable that the physiologically inactive brown leaves would improve host suitability for herbivores. Unlike green leaves, dead leaves cannot sustain herbivores nor photosynthesize. Volatile chemical cues are also likely less reliable for herbivores.
because no physiological differences exist between retained and dropped leaves. In contrast, as green leaves rapidly senesce after abscission, green leaf volatile chemical cues more reliably inform the location of trees. Hence, whether leaf retention is associated with more herbivory may depend on the qualitative nature of the leaves retained.

Further, *Q. lobata* are abundant and often attain a large size. These traits are uncharacteristic of plants that can effectively use the lack of apparenty to escape herbivores. While the saplings that Tchaikovsky (2007) manipulated may have been small enough for leaf abscission to be effective, older trees cannot ‘hide’ and may instead have suffered from the inability to produce defenses in the spring as their vigor is reduced (Tchaikovsky 2008).

**Hypotheses**

It may be that green leaf retention affect a few cynipid species on small trees in the spring and not in the summer, whereas brown leaves retention affects no cynipids regardless of season. Alternatively, both green and brown leaf retention may affect most cynipid species on all sizes of trees in both spring and summer.

**Objectives**

Accordingly, I will select 75 *Q. lobata* and characterize their size and degree of green and brown leaf retention in the winter. During spring and summer, I will survey the density of different cynipid species on these trees. I will then examine the degree that members of the cynipid community associates with leaf retention by comparing the local species diversity and density of different cynipid species among the trees selected. I will assess whether the effect of leaf retention on cynipid diversity and density is dependent on tree size and time of the year. I will also assess whether green and brown leaf retention have different effects and explanatory power. In particular, I seek to determine if both green and brown leaf retention affect a large portion of cynipid species on all sizes of trees in both spring and summer.

**Methods**

The study will be conducted at two sites in the Putah Creek Riparian Reserve at Davis, California, USA. To survey size of 75 *Q. lobata*, I will estimate their diameter at breast height (DBH). To characterize their degree of leaf retention, in late January, I will also estimate the proportion of green and brown leaves retained by each tree. To ensure that the measure of leaf retention will be standardized across different tree sizes, I will select six branches on each *Q. lobata* and count the presence/absence of green or brown leaves over the length of ten nodes. I will then sum the number of present counts for each tree and derive the proportion leaf retention by dividing the sum by the total number of nodes surveyed.

To assess the density of different cynipids in spring and summer, I will survey the density of cynipid galls in early May and August respectively. For each tree, I will run 8 one meter transects on the lower branches from the tip towards the trunk. Every gall mass in the transects will be counted and summed by species for each tree. To ensure that the survey more accurately represent the density of active cynipids at a point in time, I will exclude species that have already emerged and whose gall appear no longer physiologically active.
To test whether leaf retention affects local cynipid diversity, I will compare the alpha diversity among the trees selected for spring and summer. Alpha diversity will be measured by the effective number of species. This index is derived from raising Euler’s number to the power equal to the shannon’s diversity index (Jost 2007). To examine if the effect of both green and brown leaf retention differs between season, in two generalized linear mixed models with a log-linked gamma distribution, I will fit alpha diversity for both seasons against season (spring or summer) interacting with proportion leaf retention (either brown or green), DBH, and site. DBH will be allowed to interact with proportion leaf retention to test if the effect is dependent on tree size. Individual trees will also be included as a random intercept term to keep track of each tree. When I find that the effect of leaf retention differs between season, I will subsequently examine spring and summer alone. For both green and brown leaf retention in spring and summer, I will regress species diversity on the predictor variables mentioned earlier, but without the fixed effect of season nor any random effect. Corrected Akaike information criterion (AICc) will then be calculated for the green leaf retention or brown leaf retention models to compare their explanatory power.

I will also test whether leaf retention affects the density of different cynipid species. Using two generalized linear models with a log-linked tweedie distribution, I will fit cynipid density against proportion leaf retention (either green or brown) and other covariates for each species. As different species will occur at different natural densities and patchiness, I will standardize the density of each species by ln(x+1) then divide the density by the species mean. Rare species that will appear on less than 15 trees will be excluded, as insufficient data exist for meaningful analysis. To examine cynipid responses more broadly, I will calculate the combined effect sizes and 95% confidence intervals (Hedges et al. 1999). Weights will be assigned as the inverse variance of the odds ratio coefficients. To compare the effect across spring and summer, the odds ratio coefficients will be fitted against season in a meta-regression. The residual $I^2$ heterogeneity index will be used to assess the degree to which species respond similarly (Higgins and Thompson 2002). AICc will be used to compare green and brown leaf retention.

**Expected Outcomes**

I seek to determine if leaf retention affects a large portion of cynipid species in the spring and summer. I expect leaf retention to affect a few cynipid species in the spring and not in the summer. The lack of association between leaf retention and cynipid distribution generally among different species can be attributed to the likely fact that retained leaves, being an unreliable source of information, rarely cue cynipid oviposition. Competitive interactions between herbivores within and between season may also dampen any weak effect leaf retention has. The effect of leaf retention will be stronger in the spring compared to the summer because new leaves would have taken the place of retained leaves from the previous year by summer. Alternatively, leaf retention may affect cynipids like that observed by Tchaikovsky (2007, 2008) and Pearse and Tchaikovsky (2013) previously.

I will also examine the role of tree size in determining the effect of leaf retention on cynipid diversity and density. Due to the hosts’ differential minimum apparency and defense investment, I expect leaf retention to reduce herbivory for large trees. Alternatively, large trees could be more susceptible to herbivory at high leaf retention because they provide more resources; thus, leaf abscission would reduce herbivory more than a small tree would.
Finally, I will examine how different types of leaf retained determine the effect of leaf retention on cynipid diversity and density. As green leaves and brown leaf retention are mutually exclusive, they must necessarily be negatively associated with each other and generally have opposite effects. I predict green leaves will perform better as a predictor than brown leaves because they are a more reliable cue. Alternatively, brown leaves may be a better predictor because they generally outnumber green leaves by magnitudes.

**Timetable**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Schedule</th>
</tr>
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<tbody>
<tr>
<td>Survey <em>Q. lobata</em> overwinter leaf retention</td>
<td>Dec 2018 ~ Jan 2019</td>
</tr>
<tr>
<td>Survey <em>Q. lobata</em> spring cynipids</td>
<td>May 2019</td>
</tr>
<tr>
<td>Survey <em>Q. lobata</em> summer cynipids</td>
<td>Aug 2019</td>
</tr>
<tr>
<td>Data analysis</td>
<td>June 2019 ~ Sep 2019</td>
</tr>
<tr>
<td>Practicum write up</td>
<td>Dec 2019 ~ June 2020</td>
</tr>
</tbody>
</table>

**References**


**Importance to Self, Society, and Biology**

The galls made by cynipids have always fascinated me. Working on this project centered around multiple species of galling wasps will certainly familiarize me with their life history, taxonomy, and ecology. As an aspiring ecologist hoping to specialize in plant-insect and parasite-host interactions, the cynipid-oak system provides an excellent opportunity to study these relationships. Both the host and parasites are easy to find and are accessible at Davis. The prevalence of hyperparasitism and inquilines also allow for the investigation of multiple different levels of parasite-host interactions. Further, due to the cryptic and unique nature of the cynipid biology, the potential for novel findings will likely remain robust even after decades of research. Hence, knowing the oak-cynipid system will become invaluable later in my career as I study ecological questions related to plant-insect and parasite-host interactions.

While the potential for real world application of any results found in this project is not obvious, the study would contribute to the ecological understanding of leaf phenology, its trade-offs, and the variation of cynipid population across space and time. Few authors have provided an ecological explanation for the variation in leaf abscission phenology, and even fewer have investigated leaf abscission phenology in the context of herbivory. These alternative hypotheses to the more commonly recognized ecophysiological causes of leaf abscission (Chabot and Hicks 1982) are necessary, as the ecophysiological explanations clearly insufficiently explain the appearance of deciduous trees in places with wet winters and dry summers. Indeed, where winters are wet, temperatures remain relatively warm, and day light persists reasonably, plants have no reason to abscise leaves to escape the stresses associated with winter in colder climates (Field and Mooney 1983). Clearly, there must be a different advantage at work. However, aside from the theoretical discussion offered by (Faeth et al. 1981) and the preliminary work done by Karban (2007, 2008) and Pearse and Karban (2013), much remains unknown about the generality, mechanism, cost, and benefit of overwinter leaf abscission as a herbivory defense. Accordingly, research is needed to tackle some of these questions to help the hypothesis mature.

The study also contributes to the understanding of cynipid density and distribution across space and time. In particular, I found two unintuitive phenomena: (1) there was no evidence of competitive exclusion and (2) spring and summer cynipid community shared little overlap. Few published works have examined cynipid community composition and distribution, especially in the spring. These results certainly add to our understanding of the system.

**References**


Academic Plan

Academic Interest

I am broadly interested in community and behavioral ecology; in particular, I like to study plant-insect and host-parasite interactions. My academic training in plant biology for my minor and my emphasis on insect ecology for my major will help me understand ecological relationships from multiple perspectives. I hope to continue my education in community ecology in graduate and postdoctoral research specializing in plant defenses against herbivory and plant architecture mediated interactions.
## Restricted Electives

<table>
<thead>
<tr>
<th>Course Name</th>
<th># of Units</th>
<th>Quarter Offered</th>
<th>Justification.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENT 100 - General Entomology</td>
<td>4</td>
<td>Fall 2018</td>
<td>This course provides a basic understanding of the biology, systematics, and methods in entomology. As the proposed project revolves around the family cynipidae, these skills, especially those that involve the rearing and identification of insects, are essential for conducting and making sense of the research. For instance, after taking the class, I have learned to use museum collections of insects to identify the phenology and identity of major oak feeding herbivores locally found in Davis.</td>
</tr>
<tr>
<td>ENT 105 - Insect Ecology</td>
<td>4</td>
<td>Fall 2018</td>
<td>This course provides a broad overview of the major ecological subdisciplines in the context of entomological systems. This class facilitated me in understanding the major ecological theories, particularly regarding community ecology, that apply to my research questions. My better understanding of diversity, community assembly, and plant mediated interactions greatly improved my ability to form more mature interpretations and hypotheses regarding cynipid distribution and organization.</td>
</tr>
<tr>
<td>ENT 180A - Experimental Ecology and Evolution in the Field</td>
<td>4</td>
<td>Winter 2019</td>
<td>This two-quarter series provides hands-on practical training of ecological research. Skills I learned that are of value include, programming in R, ecological statistics, methods of experimental design, methods of research question refinement and formulation, insect trapping, manuscript writing, reference management, methods of reframing questions, and methods in insect ecology. More importantly, the class taught me best practices and intuitions in ecological research, both of which are essential to the success of any ecological research project.</td>
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<tr>
<td>ENT 180B - Experimental Ecology and Evolution in the Field</td>
<td>4</td>
<td>Spring 2019</td>
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<tr>
<td>UWP 104E - Writing in Science</td>
<td>4</td>
<td>Summer Session II 2019</td>
<td>This course teaches students the best practices and pitfalls of science writing. Large emphasis is placed on coherent communication orientated towards different audiences. From this class, I learned to write a literature review for specialists and a grant proposal for a mixed audience. This class would improve my ability to write a better ABI thesis.</td>
</tr>
</tbody>
</table>
ENT 225 - Terrestrial Field Ecology  4  Spring 2020  This course provides experiential education of field ecology. Emphasis is placed on ecological hypothesis testing, data gathering, analysis, and written and oral presentation of results through an independent project. Learning how to do ecology will improve my competence in conducting my research.

ENT 198 - Directed Group Study (Gentle Intro to R/RStudio)  1  Winter 2019  This course teaches students basic programming skills in R studio. I learned basic programming operations and commands, best data management practices, methods of cleaning and manipulating data frames, and methods of producing sophisticated graphs. As my project requires multiple sophisticated data analytical methods, possessing these skills are necessary for me to properly analyze my data.

<table>
<thead>
<tr>
<th>Academic Schedule</th>
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<tr>
<th>Winter 2020</th>
<th>Spring 2020</th>
<th>Fall 2020</th>
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<tr>
<td><strong>Course</strong></td>
<td><strong>Units</strong></td>
<td><strong>Course</strong></td>
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<td>BIS 103 - Bioenergetics/Metabolism</td>
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<td>PLB 112 - Plant Growth &amp; Development</td>
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<tr>
<td>ENT 102 - Insect Physiology</td>
<td>4</td>
<td>PLB 113 - Plant Molecular &amp; Cellular Biology</td>
</tr>
<tr>
<td>PHI 031 - Scientific Reason</td>
<td>4</td>
<td>ENT 225 - Terrestrial Field Ecology</td>
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<tr>
<td>PSC 001 - General Psychology</td>
<td>4</td>
<td>ABI 189 - Senior Practicum</td>
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<td></td>
<td></td>
<td>ABI 189D - Senior Practicum Discussion</td>
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<tr>
<td><strong>Total</strong></td>
<td>15</td>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
Arnold Schwarzenegger  
Davis, CA 95616 | (997) 969-9168  
schwarzenegger@ucdavis.edu

STATEMENT OF INTEREST
I hope to pursue my passion for natural curiosities through academic research in graduate school and as a professor. I am interested in community and behavioral ecology; in particular, I study plant-insect and host-parasite interactions.

EDUCATION
University of California- Davis, Davis, CA  
Major: Animal Biology BS  
Minor: Plant Biology  
GPA: 4.00/4.00; Dean’s List all quarters  
Expected Graduation date: Dec 2020

RELEVANT SKILLS
● Programing with R  
● Advanced ecological statistics

RELEVANT COURSEWORK
Intro Ecology and Evolution  
Insect Ecology  
Plant Ecology  
Experimental Field Ecology  
General Entomology  
Writing in Science

EXPERIENCE
Verne Lab  
March 2018 ~ August 2018  
Captain Nemo, UC-Davis, One Shields Avenue, Davis, California  
● Assisted the research on remote sensing of crop quality  
● Grew and maintained test crops  
● Prepared test crops for chemical analysis  
● Operated hyperspectral camera during data collection

Tchaikovsky Lab  
June 2018 ~ Present  
Peter Tchaikovsky, UC-Davis, One Shields Avenue, Davis, California  
● Facilitated the data collection, analysis, and design of several research projects led by Dr. Eric LoPresti, Dr. Patrick Grof-Tisza, and Dr. Peter Tchaikovsky related to plant defenses  
● Completed a year long experiment and survey of valley oaks and their cynipids  
● Conducted several pilot experiments on willows and their herbivores  
● Currently working on three broad areas of research involving oak cynipids and water runoffs, foraging behavior of parasitic dodder, and structural complexity of trellis

Experimental Field Ecology and the Borodin Lab  
January 2019 ~ September 2019  
Alexander Borodin, UC-Davis, One Shields Avenue, Davis, California  
● Designed experiments, collected and analyzed data on the stripe avoidance behavior of parasitoids and fruit flies  
● Reared large quantities of caterpillars
• Extensive tachinid collection and trapping in the field and refinement of trapping methods

**PUBLICATIONS**


(In writing) Schwarzenegger, A, P.I. Tchaikovsky, Jake Goidell. Valley Oak Overwinter Leaf Retention Affects Spring Phenology, Cynipid Diversity, and density

(In writing) John Orrock, Pete Guiden, Peter Tchaikovsky, Schwarzenegger, A (Order of authors TBD). The efficacy of promoting cannibalism as a defensive strategy: plant defenses reduce herbivory as effectively as highly pathogenic herbivore pathogens

**REFERENCES**

**Peter Ilyich Tchaikovsky**

Professor in Entomology, University of California, Davis
(530) 759-2000 tchaikovsky@ucdavis.edu
* Peter Ilyich Tchaikovsky can comment on my time interning in his lab

**Alexander Borodin**

Associate Professor in Entomology, University of California, Davis
(530) 758-4130| borodin @ucdavis.edu
* Alexander Borodin can comment on my performance as a student in his class

**Alexander Konstantinovich Glazunov**

Professor in Entomology, University of California, Davis
(530) 752-4395| glazunov@ucdavis.edu
* Alexander Konstantinovich Glazunov can comment on my experience in the Research Scholars Program in Insect Biology
Opportunities Related to the Practicum

Internship

I have been working in the Tchaikovsky lab since June 1492. Much of the work for my practicum project have already been completed in early 1519, but I will continue to intern at the Tchaikovsky lab. Stemming from my practicum project, I seek to identify the role of water runoffs in affecting the cynipid load and community composition in the spring. Briefly, I suspect that water runoffs enhance the efficacy of overwinter leaf abscission and skew community composition towards the stem galling cynipids.

President’s Undergraduate Fellowship

I recently submitted a proposal titled “A Modified Conceptual Framework for Habitat Structure: Trellis Structural Complexity, Heterogeneity, and Diversity Impact Climbing Plant Performance.” As such, I am ineligible to apply for my practicum project.

Annual Undergraduate Research, Scholarship and Creative Activities Conference at UC Davis

The work done for this practicum project is currently in writing for publication. My hope is to finish the manuscript by the end of 2019. With the manuscript finished, I will have enough material to present at the Undergraduate Research Conference.
Student:

<table>
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Academic Advisor:

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Master Advisor:

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Practicum Mentor:

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</table>
ABI Restricted Electives

The student’s academic plan includes a list of courses that he or she will take to fulfill the restricted electives requirement for graduation in the ABI major. This consists of 25 quarter hours of upper division courses; lower division courses generally do not qualify. Independent Research (199 units) must be approved by the mentor together with a brief written explanation about how they fit into the academic plan. The courses should fulfill one of the following criteria:

1. Teach skills needed to complete the practicum. For example, if collecting numerical data needing analysis, consider an advanced course in statistics.

2. Teach procedures required in the laboratory. For example, consider 199 research units with the mentor before the practicum begins to learn highly technical processes where training opportunities are unavailable elsewhere.

3. Provide background adding depth and breadth to the student’s knowledge about the subject area of the practicum project.

<table>
<thead>
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<th># of Units</th>
<th>Quarter Offered</th>
<th>Justification.</th>
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</table>

Mentor Signature

Printed name

Date
Appendix 4. Example of a Practicum Report written by a former ABI student. (This student traveled to the Smithsonian Conservation Biology Institute in Virginia to do her Practicum Project). Differences in the structure of this report from ABI standards are attributable to her off campus mentor. (Her name has been changed).

Myria Benner
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Davis, CA 95616
rbkimsey@ucdavis.edu

Sperm Characteristics of *Nanger dama*

**Student:**

__________________________________________ __________
Signature Printed name Date

**Academic Advisor:**

__________________________________________ __________
Signature Printed name Date

**Master Advisor and Practicum Mentor:**

__________________________________________ __________
Signature Printed name Date

**Off Campus Practicum Mentor:**

__________________________________________ __________
<table>
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<tr>
<th>Signature</th>
<th>Printed name</th>
<th>Date</th>
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</table>


Abstract:

Sperm characteristics from several male addra gazelles (*Nanger dama ruficollis*) were analyzed to generate baseline data for morphology, motility, and cryopreservation sensitivity. The addra gazelle is a critically endangered North African ungulate and sperm morphology and characteristics must be known in order to develop protocols for proper handling and cryopreservation. Sperm integrity was evaluated from four males housed at the Smithsonian Conservation Biology Institute in Front Royal, Virginia and one male from the National Zoo in Washington, D.C. using standard electroejaculation methods. Raw samples were evaluated for motility, acrosome integrity, and morphology. The samples were then treated with different additives to determine which conferred the most resistance to cryopreservation damage. These experiments showed that less than 50% of addra gazelle sperm showed normal morphology, although 80% displayed intact acrosomes. The treatment REYG appeared to be the best cryoprotectant, but post-thaw motility was not maintained past 2 hours with this treatment. This data can help develop efficient protocols for sperm cryopreservation, handling and collection, and can then ultimately apply to artificial insemination in order to maintain a viable captive population of addra gazelles.

Key terms: Dama gazelle, addra gazelle, *Nanger dama*, sperm morphology, acrosome integrity, sperm cryopreservation, REYG, electroejaculation
The Dama gazelle (*Nanger dama*, formerly *Gazella dama*) is the largest and rarest of all the gazelles (Anonymous, 2010; Villarreal and Myers, 2006). This species has two extant subspecies, known as the Mohor or Mhorr gazelle (*Nanger dama mhorr*) and the addra gazelle (*Nanger dama ruficollis*) (Dolan, 1981). As a species, the Dama gazelle is categorized as “Critically Endangered” by the International Union for the Conservation of Nature, which estimates the total wild population (of all subspecies) at less than five hundred individuals due to overhunting, drought, and habitat loss (Newby et al., 2008; Roldan et al., 2006). The worldwide captive population of Addra gazelles currently consists of around 240 individuals (Anonymous, 2011). Captive breeding coupled with habitat restoration is the best, and perhaps only, chance to save this species from extinction. However, a major problem facing the captive propagation effort is inbreeding. Captive populations generally descend from only small numbers of founder animals – for example, all captive Mohor gazelles today descend from a founder population of just four males and thirteen females, and the current Addra gazelle population descend from eight reproductive individuals within a founder population of 22 gazelles (Redus, 2010; Abagair et al., 2001). When the animals in a population are closely related, reproductive success is compromised. It has been shown in Mohor gazelles that the more inbred the male, the more abnormal sperm he will produce (Cassinello et al. 1998; Roldan et al. 2006). The average coefficient of inbreeding for Dama gazelles, a measure of how inbred an animal is, is .121, which can cause “inbreeding depression” leading to reduced fertility (Cassinello, 2005).

In one study, only 64.7% of Mohor gazelle sperm counted had intact acrosomes, and 80% of those were motile (Abagair et al., 2001). In another study, the most frequently observed
abnormalities for Mohor gazelle sperm were abnormal tails (13.8%), cytoplasmic droplets (12.1%), and abnormal heads (10.5%), with 59.5% normal sperm observed (Cassinello 1998). However, due to the lack of data about Addra gazelle reproduction, it is unknown whether these values would be similar for Addra gazelle sperm.

In small managed populations, inbreeding leading to poor sperm quality is a major problem and has been shown to detrimentally affect Mohor gazelles. In this study, spermatozoa of the *N. ruficollis* subspecies – known as the Addra gazelle – were evaluated to determine morphological and motility characteristics as well as the best cryopreservation protocols. This information can be compared to the data acquired in previous studies of the *N. mhorr* subspecies, and ultimately applied to the development of effective artificial reproductive technologies that will assist in conserving this species.

**MATERIALS AND METHODS**

*Study Animals*

Four addra gazelle males from the Smithsonian Conservation Biology Institute in Front Royal, Virginia and one from the National Zoo in Washington, D.C. were used for this study. Three of the males at SCBI were housed together, and one individually. The male at the National Zoo was housed with three females. Sperm collections took place in the animals’ barns.

*Electroejaculation*

The males were anesthetized with 3.5 mg etorphine from a dart gun. Once in place, they were given sedatives (35 mg Xylazine and 50 mg Ketamine) and their annual vaccinations. Feces were cleared from the rectum and a 2.6 cm rectal probe inserted. Stimulations were
applied in three separate series of increasing voltages with a rest in between – series I consisted of stimulations of 2, 3, and 4 volts, series II of 3, 4, and 5 volts, and series III of 4, 5, and 6 volts (Holt, 1996; Abragair, 2001). Separate collection cups were used for each stimulation and sperm motility was immediately estimated for each sample. Aliquots of each sample were also immediately fixed using 4% paraformaldehyde in a 2:1 PFA:sperm ratio. The samples were brought to the lab after each male had received three series of stimulations. Once this was complete, the animals were given the anesthetic reversal drug diprenorphin (Plotka 1987).

**Sperm Evaluation – Acrosome Integrity and Morphology**

We evaluated the sperm samples that had been fixed in 4% paraformaldehyde immediately post-collection for morphology and acrosome integrity. We assessed morphology for 200 randomly selected spermatozoa using a form of common abnormalities, and tallied using both a counter and making manual tally marks. The possible categories were: normal sperm, macrocephalic, microcephalic, bicephalic, abnormal acrosome, abnormal midpiece, no midpiece, tightly coiled tail, biflagellate, bent midpiece with cytoplasmic droplet, bent midpiece without cytoplasmic droplet, bent tail with cytoplasmic droplet, bent tail without cytoplasmic droplet, proximal cytoplasmic droplet, distal cytoplasmic droplet, bent neck, spermatid, cells, detached head, detached tail, and abnormal head (see Fig. 1). Then we stained the fixed samples using a Coomassie stain for 90 seconds. 200 spermatozoa on each stained slide were evaluated and classified by whether their acrosome was intact, damaged, or missing (Larson and Miller, 1999). We included previously collected samples from the same individuals in this study.

**Sperm Evaluation – Cryopreservation**
We treated the raw sperm with one of EQ, TEST, or REYG (egg yolk with added sugars and glycerol). We diluted half of the samples 1:2 by volume in SP-TL media and half were raw plus the cryoprotectant treatment (Rivera and Hansen, 2010). The sperm plus various treatments were drawn into ¼ cc straws, sealed with a heat sealer, labeled, and sealed into a plastic bag. The bag was then placed in a container of water at room temperature which was moved to a walk-in cooler to cool to 4 degrees Celsius. After the samples were cooled, they were removed from the plastic bag and placed on a rack sitting in 4cm of liquid nitrogen in a Styrofoam container. The straws were then packed into a cane, and the cane replaced in the canister in the tank of liquid nitrogen. To evaluate resistance to cryopreservation damage, samples were thawed for 30 seconds in water at 37 degrees then emptied into Eppendorf tubes. Motility and forward progression were assessed at various post-thaw time points, using a percentage and 1 – 5 scale, respectively (Garde, 2003).

RESULTS

Morphological Abnormalities

The addra gazelle sperm assessed varied significantly in their morphological characteristics between individuals. Table 1 combines data from multiple collections and includes average percentage of normal sperm as well as the most common abnormalities (Table 1).

Most abnormalities involve cytoplasmic droplets but acrosome abnormalities (including microcephaly) are also common. To compare this to previous data on Mohor gazelles, Cassinello’s 1998 data shows that primary abnormalities include an abnormal tail (a condition hardly seen with the N. ruficollis samples). However, cytoplasmic droplets were also common
in Cassinello’s study, similar to what was seen in this study. In total, this study of morphology found 42.8% normal sperm, although that varied wildly and may make a comparison to Cassinello’s value of 59.5% normal sperm difficult.

**Acrosome Integrity**

Raw samples that were fixed, Coomassie stained and evaluated for acrosome integrity show roughly 20% having damaged or missing acrosomes — indicating that they may be incapable of fertilization (see Table 2). Cassinello’s study showed 68.3% of sperm had intact acrosomes, and Abagair’s 2001 study showed 64.7% intact. These results, obtained from Mohor gazelles, are lower than our 79.4% intact figure for Addra gazelle acrosomes (see Table 2).

**Cryopreservation Sensitivity**

We evaluated three treatments to determine how well they contributed to the resilience of sperm after cryopreservation. Half the samples were diluted in SP-TL — those that were not diluted we called “post-thaw.” REYG treatment increased post-thaw motility and progression, although the effects of dilution are inconclusive. None of the treatments were able to maintain sperm motility past 2 hours after thawing (Fig. 2 and 3).

While REYG showed its ability to protect spermatozoa from cryopreservation damage, its inability to keep any significant quantities of sperm alive past 2 hours post-thaw indicate room for improvement.

**DISCUSSION**

In this study, we gathered basic data about Addra gazelle (*N. dama ruficollis*) sperm morphology, acrosome integrity, and cryopreservation sensitivity. For informational purposes,
these data were compared to the closely related gazelle, the Mohor gazelle (*N. dama mhorr*).

In this study, a rough correlation appeared between morphological abnormalities and acrosome integrity data between the two subspecies but there was not a clear comparison. This may imply a difference in sperm collection, handling, processing, and evaluation techniques, or it may represent a genuine different in sperm characteristics between these two closely related taxa. Even within this data, there was significant variation inter- and intra-individual: some collections yielded a much greater proportion of sperm with intact acrosomes than collections on the same individual a year prior. With such a small sample size (n = 5) for this study, it is difficult to determine why the Addra and Mohor gazelle data contain so little overlap. Therefore, findings regarding sperm abnormalities in *N. dama mhorr* do not necessarily apply to *N. dama ruficollis*.

Nevertheless, this study represents the first time genetic material from Addra gazelles has been evaluated and so this information may be valuable in the development of assisted reproductive techniques (ARTs). Most ARTs, such as sperm cryopreservation, in vitro fertilization, artificial insemination, etc. have only been tested on Mohor gazelles, so while they likely will have the same results on addra gazelles, we cannot be positive. Often it is too difficult or stressful to move animals around the world to breed, so transporting sperm and eggs is a promising alternative. By developing technologies such as artificial insemination, scientists can promote gene flow among captive populations. This depends on the proper collection, handling, storage and transportation of gametes, especially sperm, and these technologies are only in their infancy in Dama gazelles. The first Dama gazelle calf from an
artificial insemination was a Mohor gazelle born in 2005, so ARTs have promise but have a long way to go to be viable (Roldan et al., 2006).

Most data on the sperm characteristics of endangered gazelles, and certainly of *Nanger dama*, has come from studies of the Mohor gazelle, primarily because of the length of time they have been in captivity as compared to the Addra gazelle (Redus, 2010). However, in 2009, the Antelope Taxon Advisory Group recommended that North American zoos and other institutions reduce their populations of Mohor gazelles to free space for a target population of 200 Addra gazelles (currently there are less than 130 in North America). This implies that the Addra gazelle captive breeding program is having some success and a reintroduction effort, similar to the one already underway for Mohor gazelles, is on the horizon (Petric, 2009). In order to continue and enhance such breeding success and maintain maximum genetic diversity in a small managed population, assisted reproductive technologies must be employed. Studies like this one, intended to characterize the “normal” states of spermatozoa, are necessary in order to accurately develop ARTs that will be effective for the species in question.

**References**


http://animaldiversity.ummz.umich.edu/site/accounts/information/Nanger_dama.html.
Figure 1. Diagram of commonly observed sperm abnormalities.

- Normal morphology
- Distal droplet
- Proximal droplet
- Disconnected head
- Abnormal acrosome (could present multiple ways)
- Bent midpiece with droplet
- Bent midpiece without droplet
- Bent tail
- Microcephalic
- Tightly coiled tail
Table 1. Addra gazelle sperm abnormalities.

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<th>Primary Abnormalities</th>
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<td>TX 12</td>
<td>10/14/2010</td>
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<td>Variance</td>
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Table 2. Addra gazelle acrosome integrity.

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<th>Intact</th>
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<td>89%</td>
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<td>TX 12</td>
<td>96.00%</td>
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<td>73.50%</td>
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<td>90%</td>
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59
Figure 2. Percentage of post-thaw motile sperm from male SB 2096.
Figure 3. Post-thaw progression scores for male SB 2096.
Appendix 5. Suggested Formatting Procedures

Uniform Requirements for Manuscripts Submitted to Biomedical Journals: Writing and Editing for Biomedical Publication¹

Updated April 2010

Publication Ethics: Sponsorship, Authorship, and Accountability
International Committee of Medical Journal Editors
http://www.icmje.org/urm_full.pdf

IV. MANUSCRIPT PREPARATION AND SUBMISSION

IV. A. Preparing a Manuscript for Submission to a Biomedical Journal

Editors and reviewers spend many hours reading manuscripts, and therefore appreciate receiving manuscripts that are easy to read and edit. Much of the information in a journal’s Instructions to Authors is designed to accomplish that goal in ways that meet each journal's particular editorial needs. The following information provides guidance in preparing manuscripts for any journal.

IV. A. 1. a. General Principles

The text of observational and experimental articles is usually (but not necessarily) divided into the following sections: Introduction, Methods, Results, and Discussion. This so-called “IMRAD” structure is not an arbitrary publication format but rather a direct reflection of the process of scientific discovery. Long articles may need subheadings within some sections (especially Results and Discussion) to clarify their content. Other types of articles, such as case reports, reviews, and editorials, probably need to be formatted differently. Electronic formats have created opportunities for adding details or whole sections, layering information, crosslinking or extracting portions of articles, and the like only in the electronic version. Authors need to work closely with editors in developing or using such new publication formats and should submit supplementary electronic material for peer review.

Double-spacing all portions of the manuscript—including the title page, abstract, text, acknowledgments, references, individual tables, and legends—and generous margins make it possible for editors and reviewers to edit the text line by line and add comments and queries directly on the paper copy. If manuscripts are submitted electronically, the files should be double-spaced to facilitate printing for reviewing and editing. Authors should number all of the pages of the manuscript consecutively, beginning with the title page, to facilitate the editorial process.

IV. A. 1. b. Reporting Guidelines for Specific Study Designs

Research reports frequently omit important information. Reporting guidelines have been developed for a number of study designs that some journals may ask authors to follow. Authors should consult the information for Authors of the journal they have chosen. The general requirements listed in the next section relate to reporting essential elements for all study designs. Authors are encouraged also to consult reporting guidelines relevant to their specific research design. A good source of reporting guidelines is the EQUATOR Network (http://www.equator-network.org/home/).

IV. A .2. Title Page

The title page should have the following information:

1. Article title. Concise titles are easier to read than long, convoluted ones. Titles that are too short may, ¹ This document is extracted from and derives almost entirely from: http://www.icmje.org/urm_full.pdf  Publication Ethics: Sponsorship, Authorship, and Accountability, International Committee of Medical Journal Editors Updated April 2010:
however, lack important information, such as study design (which is particularly important in identifying randomized, controlled trials). Authors should include all information in the title that will make electronic retrieval of the article both sensitive and specific.

2. Authors’ names and institutional affiliations. Some journals publish each author’s highest academic degree(s), while others do not.

3. The name of the department(s) and institution(s) to which the work should be attributed.

4. Disclaimers, if any.

5. Contact information for corresponding authors.

The name, mailing address, telephone and fax numbers, and e-mail address of the author responsible for correspondence about the manuscript (the “corresponding author;” this author may or may not be the “guarantor” for the integrity of the study). The corresponding author should indicate clearly whether his or her e-mail address can be published.

6. The name and address of the author to whom requests for reprints should be addressed or a statement that reprints are not available from the authors.

7. Source(s) of support in the form of grants, equipment, drugs, or all of these.

8. A running head. Some journals request a short running head or footline, usually no more than 40 characters (including letters and spaces) at the foot of the title page. Running heads are published in most journals, but are also sometimes used within the editorial office for filing and locating manuscripts.

9. Word counts. A word count for the text only (excluding abstract, acknowledgments, figure legends, and references) allows editors and reviewers to assess whether the information contained in the paper warrants the amount of space devoted to it, and whether the submitted manuscript fits within the journal’s word limits. A separate word count for the Abstract is useful for the same reason.

10. The number of figures and tables. It is difficult for editorial staff and reviewers to determine whether the figures and tables that should have accompanied a manuscript were actually included unless the numbers of figures and tables are noted on the title page.

IV. A. 3. Conflict-of-Interest Notification Page

To prevent potential conflicts of interest from being overlooked or misplaced, this information needs to be part of the manuscript. The ICMJE has developed a uniform disclosure form for use by ICMJE member journals (http://www.icmje.org/coi_disclosure.pdf). Other journals are welcome to adopt this form. Individual journals may differ in where they include this information, and some journals do not send information on conflicts of interest to reviewers. (See Section II. D. Conflicts of Interest.

IV. A. 4. Abstract

Structured abstracts are preferred for original research and systematic reviews. The abstract should provide the context or background for the study and should state the study’s purpose, basic procedures (selection of study subjects or laboratory animals, observational and analytical methods), main findings (giving specific effect sizes and their statistical significance, if possible), principal conclusions, and funding sources. It should emphasize new and important aspects of the study or observations. Articles on clinical trials should contain abstracts that include the items that the CONSORT group has identified as essential (http://www.consort-statement.org/?_1190 ).

Because abstracts are the only substantive portion of the article indexed in many electronic databases, and the only portion many readers read, authors need to be careful that they accurately reflect the content of the article. Unfortunately, the information contained in many abstracts differs from that in the text (7). The format required for structured abstracts differs from journal to journal, and some journals use more than one format; authors need to prepare their abstracts in the format specified by the journal they have chosen.

The ICMJE recommends that journals publish the trial registration number at the end of the abstract. The ICMJE also recommends that, whenever a registration number is available, authors list that number the first time they use a trial acronym to refer to either the trial they are reporting or to other trials that
they mention in the manuscript.

IV. A. 5. Introduction

Provide a context or background for the study (that is, the nature of the problem and its significance). State the specific purpose or research objective of, or hypothesis tested by, the study or observation; the research objective is often more sharply focused when stated as a question. Both the main and secondary objectives should be clear, and any prespecified subgroup analyses should be described. Provide only directly pertinent references, and do not include data or conclusions from the work being reported.

IV. A. 6. Methods

The Methods section should include only information that was available at the time the plan or protocol for the study was being written; all information obtained during the study belongs in the Results section.

IV. A. 6. a. Selection and Description of Participants

Describe your selection of the observational or experimental participants (patients or laboratory animals, including controls) clearly, including eligibility and exclusion criteria and a description of the source population. Because the relevance of such variables as age and sex to the object of research is not always clear, authors should explain their use when they are included in a study report—for example, authors should explain why only participants of certain ages were included or why women were excluded. The guiding principle should be clarity about how and why a study was done in a particular way. When authors use such variables as race or ethnicity, they should define how they measured these variables and justify their relevance.

IV. A. 6. b. Technical Information

Identify the methods, apparatus (give the manufacturer’s name and address in parentheses), and procedures in sufficient detail to allow others to reproduce the results. Give references to established methods, including statistical methods (see below); provide references and brief descriptions for methods that have been published but are not well-known; describe new or substantially modified methods, give the reasons for using them, and evaluate their limitations. Identify precisely all drugs and chemicals used, including generic name(s), dose(s), and route(s) of administration.

Authors submitting review manuscripts should include a section describing the methods used for locating, selecting, extracting, and synthesizing data. These methods should also be summarized in the abstract.

IV. A. 6. c. Statistics

Describe statistical methods with enough detail to enable a knowledgeable reader with access to the original data to verify the reported results. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Avoid relying solely on statistical hypothesis testing, such as P values, which fail to convey important information about effect size. References for the design of the study and statistical methods should be to standard works when possible (with pages stated). Define statistical terms, abbreviations, and most symbols. Specify the computer software used.

IV. A. 7. Results

Present your results in logical sequence in the text, tables, and illustrations, giving the main or most important findings first. Do not repeat all the data in the tables or illustrations in the text; emphasize or summarize only the most important observations. Extra or supplementary materials and technical detail can be placed in an appendix where they will be accessible but will not interrupt the flow of the text, or they can be published solely in the electronic version of the journal.

When data are summarized in the Results section, give numeric results not only as derivatives (for example, percentages) but also as the absolute numbers from which the derivatives were calculated, and specify the statistical methods used to analyze them. Restrict tables and figures to those needed to explain the argument of the paper and to assess supporting data. Use graphs as an alternative to tables with many entries; do not duplicate data in graphs and tables. Avoid nontechnical uses of technical
terms in statistics, such as “random” (which implies a randomizing device), “normal,” “significant,” “correlations,” and “sample.” Where scientifically appropriate, analyses of the data by such variables as age and sex should be included.

IV. A. 8. Discussion

Emphasize the new and important aspects of the study and the conclusions that follow from them in the context of the totality of the best available evidence. Do not repeat in detail data or other information given in the Introduction or the Results section. For experimental studies, it is useful to begin the discussion by briefly summarizing the main findings, then explore possible mechanisms or explanations for these findings, compare and contrast the results with other relevant studies, state the limitations of the study, and explore the implications of the findings for future research and for clinical practice. Link the conclusions with the goals of the study but avoid unqualified statements and conclusions not adequately supported by the data. In particular, avoid making statements on economic benefits and costs unless the manuscript includes the appropriate economic data and analyses. Avoid claiming priority or alluding to work that has not been completed. State new hypotheses when warranted, but label them clearly as such.

IV. A. 9. References

IV. A. 9. a. General Considerations Related to References

Although references to review articles can be an efficient way to guide readers to a body of literature, review articles do not always reflect original work accurately. Readers should therefore be provided with direct references to original research sources whenever possible. On the other hand, extensive lists of references to original work on a topic can use excessive space on the printed page. Small numbers of references to key original papers often serve as well as more exhaustive lists, particularly since references can now be added to the electronic version of published papers, and since electronic literature searching allows readers to retrieve published literature efficiently.

Avoid using abstracts as references. References to papers accepted but not yet published should be designated as “in press” or “forthcoming”; authors should obtain written permission to cite such papers as well as verification that they have been accepted for publication. Information from manuscripts submitted but not accepted should be cited in the text as “unpublished observations” with written permission from the source. Avoid citing a “personal communication” unless it provides essential information not available from a public source, in which case the name of the person and date of communication should be cited in parentheses in the text.

For scientific articles, obtain written permission and confirmation of accuracy from the source of a personal communication. Some but not all journals check the accuracy of all reference citations; thus, citation errors sometimes appear in the published version of articles. To minimize such errors, references should be verified using either an electronic bibliographic source, such as PubMed or print copies from original sources. Authors are responsible for checking that none of the references cite retracted articles except in the context of referring to the retraction. For articles published in journals indexed in MEDLINE, the ICMJE considers PubMed the authoritative source for information about retractions. Authors can identify retracted articles in MEDLINE by using the following search term, where pt in square brackets stands for publication type: Retracted publication [pt] in PubMed.

IV. A. 9. b. Reference Style and Format

The Uniform Requirements style for references is based largely on an American National Standards Institute style adapted by the NLM for its databases. Authors should consult NLM’s Citing Medicine for information on its recommended formats for a variety of reference types. Authors may also consult sample references, a list of examples extracted from or based on Citing Medicine for easy use by the ICMJE audience; these sample references are maintained by NLM.

References should be numbered consecutively in the order in which they are first mentioned in the text. Identify references in text, tables, and legends by Arabic numerals in parentheses. References cited only in tables or figure legends should be numbered in accordance with the sequence established by
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abbreviated according to the style used in the list of Journals Indexed for MEDLINE, posted by the NLM
on the Library's Web site. Journals vary on whether they ask authors to cite electronic references within
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journal to which they plan to submit their work.

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Tables capture information concisely and display it efficiently; they also provide information at any
desired level of detail and precision. Including data in tables rather than text frequently makes it possible
to reduce the length of the text.

Type or print each table with double-spacing on a separate sheet of paper. Number tables consecutively
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or vertical lines. Give each column a short or an abbreviated heading.

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Identify statistical measures of variations, such as standard deviation and standard error of the mean.
Be sure that each table is cited in the text. If you use data from another published or unpublished
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Additional tables containing backup data too extensive to publish in print may be appropriate for
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to readers directly by the authors. An appropriate statement should be added to the text to inform
readers that this additional information is available and where it is located. Submit such tables for
consideration with the paper so that they will be available to the peer reviewers.

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Figures should be either professionally drawn and photographed, or submitted as photographic-quality
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Type or print out legends for illustrations using double spacing, starting on a separate page, with Arabic
numerals corresponding to the illustrations. When symbols, arrows, numbers, or letters are used to identify parts of the illustrations, identify and explain each one clearly in the legend. Explain the internal scale and identify the method of staining in photomicrographs.

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Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples. Temperatures should be in degrees Celsius. Blood pressures should be in millimeters of mercury, unless other units are specifically required by the journal. Journals vary in the units they use for reporting hematologic, clinical chemistry, and other measurements. Authors must consult the Information for Authors of the particular journal and should report laboratory information in both local and International System of Units (SI). Editors may request that authors add alternative or non-SI units, since SI units are not universally used. Drug concentrations may be reported in either SI or mass units, but the alternative should be provided in parentheses where appropriate.

IV. A. 14. Abbreviations and Symbols

Use only standard abbreviations; use of nonstandard abbreviations can be confusing to readers. Avoid abbreviations in the title of the manuscript. The spelled-out abbreviation followed by the abbreviation in parenthesis should be used on first mention unless the abbreviation is a standard unit of measurement.

IV. B. Sending the Manuscript to the Journal

An increasing number of journals now accept electronic submission of manuscripts, whether on disk, as an e-mail attachment, or by downloading directly onto the journal’s Web site. Electronic submission saves time and money and allows the manuscript to be handled in electronic form throughout the editorial process (for example, when it is sent out for review). For specific instructions on electronic submission, authors should consult the journal’s Instructions for Authors.

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● A full statement to the editor about all submissions and previous reports that might be regarded as redundant publication of the same or very similar work. Any such work should be referred to specifically and referenced in the new paper. Copies of such material should be included with the submitted paper to help the editor address the situation.

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● A statement that the manuscript has been read and approved by all the authors, that the requirements for authorship as stated earlier in this document have been met, and that each author believes that the manuscript represents honest work if that information is not provided in another form (see below).

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