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Science Writing in EEB
What is the Writing in the Disciplines Initiative?

**Goal**: The Writing in the Disciplines Initiative seeks to reinforce what you learn—and may then forget—in the Freshman Writing Seminars (FWSs). The goal is better course writing, JPs, and Senior Theses, not to mention clearer professional writing after graduation.

**Connections**: In addition to simple forgetting, many students fail to see the connection between the expository essays they wrote as frosh and the more formal and constrained lab reports and papers they write as EEBers. All are examples of academic, expository writing; they have the same essential goals, rules of evidence, and rhetorical techniques. The most basic goal of the Initiative is to make this connection perfectly clear and help hone writing skills.

**Terminology**: The first step in illustrating this connection is to use a consistent set of terms for the elements of academic writing. Even the Writing Program has a remarkable diversity in its jargon. For example, the central focus of an essay is variously referred to in different FRS sections as the Motive, the Issue, the Question, the Thesis, and the Purpose (among other things). To communicate effectively we will choose one term and stick to it across all EEB courses. For instance, EEB faculty and AIs will consistently refer to the focus of reports and essays as the **Issue**. The full set of terms is outlined below.

**Logic**: Central to making the link between FWS and EEB is showing that the underlying logic of the exposition is the same despite the differences in format (the subheads in lab reports and research papers, for example, not to mention the use of graphs, tables, and statistical tests). In academic essays, the FRSs teach that:

1) essays pose and answer a question (the **Issue**),
2) the reader needs enough **Background** to put the **Issue** into context,
3) answering a question requires a logical progression of **Evidence** plus critical **Analysis**, and
4) the **Analysis**, to be convincing, requires **Reflection** (consideration of alternative explanations that challenge the writer’s argument).

In most cases, the parallel between the FWS essay and the subheads of a simple research/lab report is straightforward:

**Essay**:  
Background → Issue → Evidence → Analysis → Reflection → Conclusion → Sources

**Report**:  
--- Introduction --- → Methods → Results → ------------- Discussion ------------- → References

For more complex essays there are iterated rounds of **Evidence/Analysis/Reflection** requiring an elaboration of the simple lab-report format:

**Essay**:  
Background → Issue → Evidence → Analysis → Reflection → Conclusion.  

For research papers and lab reports there can be problems in providing just enough **Analysis** in a Results section to maintain the narrative without actually turning it into a Discussion section. The sample research paper we read as part of our introduction to scientific writing deals with this contingency.
Target Courses: We are experimenting with 5 courses this year:
• EEB 211 (Intro biology) 3 lab reports 1 essay 1 oral report
• EEB 309 (Evolution) 4 close-reading essays
• EEB 311 (Animal Behavior) 4 close-reading essays
• EEB 312 (Marine Biology) 3 lab reports 1 oral report
• JP (fall-term papers) 1 essay draft

Assignments: We plan to focus on four types of assignments: lab reports, essays, oral reports (part of each FWS course), and close reading. You will have detailed guidelines for each kind of assignment.

Lab reports and ordinary essays (the spring-term JP, for instance) typically have the familiar format of research papers.

The close-reading essays are 500-word critical summaries of an paper. These essays will require rigorous attention to detail in the target paper. Because they will not have subheads they will need special attention to their logical flow, and thus their use of Transitions to connect paragraphs. (All forms of writing also need transitions within paragraphs to connect ideas.) This is touched on in the Rhetoric chapter in this booklet.

The oral reports have the same structure as essays, but require a written abstract as well. They are assigned in most FWSs as well to make the essay/oral-presentation link clear, and to develop this important professional skill.

Grading: The AIs will have checksheets/grading guidelines for each kind of assignment. This quick summary is returned to students with each report or essay. The checksheet are included in this booklet so you can see what the AIs will be looking for.

Sources: You need a consistent reference format for your writing. We include a Use of Sources guide in this booklet which features one version of the APA format. We chose this format because it has none of the common ambiguities seen in simpler formats. For 2009 only, EEB 211 will continue to use a simpler italics-free format (described in the course lab manual).

But first: Most of the sections in this Guide are coördinated with a target paper: Bischoff et al. (1985). This short (3pp) report was a senior thesis in 1984, and illustrates many aspects of scientific writing. It can be found in the Writing Guide folder on the BlackBoard site for your course. The best plan is to read it now, before you move on the appropriate sections of this booklet.
Scientific Writing in EEB
Overview

As you may remember (or may be about to learn) from your Freshman Writing Seminar, expository essays use evidence and logic to answer a question or resolve an issue. Ideally, the essay recapitulates the intellectual journey from question to answer. There is some variation in the terminology different instructors and disciplines use. After a quick reminder of what the elements of the academic essay are, and which names for the elements we use in EEB, we will look at how they are applied in the context of scientific writing.

Elements

Science papers and lab reports generally incorporate the same basic elements as the conventional essay, though with a somewhat different emphasis:

- Issue (aka Purpose, Motive, Question)
- Background (including Keyterms, and Orienting)
- Evidence (generally data in scientific writing)
- Analysis
- Reflection (questioning your case, considering alternatives)
- Conclusion (aka Thesis)
- Sources (where does the evidence come from?)

Your Freshman Writing Seminar may not have used exactly these terms, but this is the vocabulary we use in EEB.

Academic essays are usually structured from Question ➔ Answer. More specifically, the elements typically appear in roughly this order:

   Background ➔ Issue ➔ Evidence ➔ Analysis ➔ Reflection ➔ Conclusion.

Citation of Sources occurs throughout. This is only a basic outline. The needs of an actual essay or report might put the Issue first, use multiple cycles of Evidence ➔ Analysis, and/or put Reflection in the Conclusion:

   Background ➔ Issue ➔ Evidence ➔ Analysis ➔ Reflection ➔ Conclusion.

   ↑

One major difference between science and non-science essays is that most scientific writing does not start by giving the conclusion (the Thesis) in advance; the convention is to begin with the issue and then use evidence and analysis to reach the answer. In the humanities it is more usual to assert the conclusion at the outset. (The military does the same thing in its reports.) Another difference is that lab reports and research papers have a Methods section, describing how the evidence was gathered.

Like generic expository essays, scientific writing also has less tangible elements:

- Stance (the author’s position or attitude relative to the reader)
- Style (your use of rhetoric)
- Stitching (using Transitions to make the writing flow within paragraphs, and to make the logic of the paragraph sequence clear)
- Structure (the order of elements, which is usually highly stereotyped in scientific writing—especially research papers and lab reports)
Types of assignments

Scientific writing takes three main forms:

i) Lab reports
ii) Research papers
iii) Review papers

In many EEB courses there is a fourth type of assignment, a short essay on a target paper:

iv) Close-reading essays

In some EEB courses we assign an oral report, which has many things in common with written essays:

v) Oral reports

All of these forms have the structure of expository essays, though the relative balance of the sections differs dramatically.

Use of elements: differing emphases

As in the professional world, each of these forms requires an ability to write a clear, logical, well-structured expository essay with a crisply defined Issue, effective use of Evidence, and critical Analysis. Scientific writing can differ from generic expository essays in several ways:

a) The assumed Background in biology (the Keyterms Set as it is often called in the Writing Seminars) is enormous; the presumed audience is fairly restricted at best. The writer takes it for granted that, at a minimum, the reader knows basic physics, chemistry, and calculus; often the reader must understand the details of the author’s specialty and its jargon. A good writer attempts to define the more specialized terms in context, particularly if the intended audience includes nonspecialists. In EEB courses we assume the reader is one of the instructors.

b) The degree of Orienting may be minimal. Most specialist papers briefly recount the history of research on the question being investigated. Review papers (and the introductory chapter of your senior thesis) emphasize the historical development of knowledge to a much greater degree. For EEB courses we expect enough of a basic background to be able to understand why the Issue is important, and what is already known.

c) The reliance on apparently objective data (usually derived from direct experimental manipulations) as Evidence (rather than a subjective reading of a piece of fiction or poetry, say) is absolute. This feature is an essential component in student work, even if the “data” consist mainly of the conclusions of secondary sources (as for example in review papers). The reliability of original data is usually quantified by the use of statistical analyses; this component is not usually important in student writing other than for lab reports and the Senior Thesis. Data are almost always summarized in tables and/or graphs, with suitable stand-alone captions.

d) The Stance is deliberately impersonal and dispassionate—usually made the more so by an unfortunate use of passive constructions in many papers. We expect you to use active voice, which makes cause-and-effect relationships clearer. The conclusions reached are always tentative (for reasons described below).

e) Enormous weight is placed on the value of skepticism (an element both of Stance and Reflection) and the testing of hypotheses (the essence of Issue in scientific
writing). In general, papers consider at least two alternative hypotheses, and seek to
test one or more by seeing if a prediction derived from the hypothesis is borne out by
the results. The hypothesis supported by the test is usually the Thesis of the paper.

f) The dependence on Style is assumed to be minimal, and great suspicion
attaches to papers that make overt use of the power of words. Students typically
describe the style of published papers as cut-and-dried at best, and deliberately boring
and obscure at worst. Ideally, you should make judicious, skillful use of rhetoric.

g) Transitions (aka Stitching) are often neglected because of the formulaic nature
of research papers. The liberal use of subheads and the highly predictable sequence of
parts (the Structure) lures many in the sciences into the mistaken assumption that
transitions are unnecessary. But transitions with paragraphs are as important as ever,
making clear why and how one idea flows from another. Good scientific writing also
links paragraphs between subheads with graceful transitions, though they frequently
take the form of questions that draw the reader along.

h) Research papers almost always have abstracts. Your senior thesis will have an
abstract, as will oral-presentation assignments (as in EEB 211 and 312); in many courses
the instructor requires that lab reports have a summary. The Title is generally
straightforward; some journals allow clever titles, but most scientists are put off by
verbal tricks. The most effective titles often involve questions, and in any event satisfy
our basic requirement that they inform and intrigue.

i) Sources (references) are essential to any professional writing. They document
where the past evidence can be found. Scientific writing usually employs an in-text
citation format with author and year [e.g., (Bischoff, et al. 1985)]. This is followed
by an alphabetical list of all the sources at the end in a References/Bibliography/Literature
Cited section.

The logic of scientific experiments

Science depends in large part on controlled experiments. Our faith-based assumption is
that the universe operates according to cause-and-effect rules, and we are smart enough
to understand them if we do the right tests or make the right comparisons.

Experiments inevitably compare two (or more) competing hypotheses. One alternative
scenario is inevitably the Null Hypothesis: changing a specific aspect of the situation—one
variable—will have absolutely no effect on the outcome. In the language of
statistics, there are two kinds of variables: dependent and independent. So, for
instance, if we were looking for a possible effect of tail size in male guppies on mating
success (measuring the preference of female guppies, for instance), it’s clear that the
cause ("independent") variable must be tail size; the effect ("dependent") variable has
to be female choice. In any single test, tail size may affect choice, but choice cannot
plausibly affect tail size; if there is any cause-and-effect connection, it is the dependent
variable that shows the effect.

This cause-and-effect relation is reflected in graphs: the independent variable is always
plotted on the X (horizontal) axis; the dependent variable is plotted on the Y (vertical)
axis. (In some cases, however, researchers look for correlation of variables with no a
priori reason to infer cause and effect. So, for instance, we might plot temperature or
rainfall at a variety of study sites as cause variables and plant growth as the effect
variable; but if we were to plot precipitation against temperature for the same sites,
there is no clear logic to choosing one over the other for the X axis. [If you are interested, cold temperatures inhibit precipitation while precipitation itself tends to lower warm temperatures.]

There may be more than one alternative hypothesis being considered. For instance, in the sample paper discussed below it might be that female guppies prefer males with larger tails (as, say, a sign of health) or instead favor males with smaller tails (better for avoiding the attention of predators). It could be that tail size is important, or the males’ display rate, or both—or neither.

A little-appreciated fact is that experiments cannot prove that a given hypothesis is correct; they can only show that a particular hypothesis is wrong (inconsistent with the results). A set of tests that exclude the obvious plausible alternatives is powerful, but not conclusive. If we could be sure we are aware of all alternative hypotheses, then proof would be possible by the process of elimination. Alas, the history of science is liberally strewn with embarrassing instances of our limited imagination and overlooked alternatives.

The argument-by-exclusion approach is the major reason for the inevitable Control measurement, which provides a basis for comparing the results of your test with data obtained when one variable (and only one variable) is different. The parameter you control is the independent variable; the one you measure is the dependent variable. It is absolutely essential that you keep in mind the logic of alternative hypotheses, hypothesis testing, the counterintuitive nature of “proof,” and the role of controls.

A research report/target paper

A short sample paper illustrates the typical Research Report. The same paper is used as a sample Lab Report, and the example for Close Reading. You can find it in the Course Materials section on BlackBoard in the Writing Initiative folder; the paper is listed as “Bischoff”:

- “Tail Size and Female Choice in the Guppy” resulted from a Senior Thesis. Alternative explanations are discussed in the introduction, and anecdotal evidence recounted that suggests the hypothesis to be tested: females prefer males with larger tails. The null hypothesis is that females do not care about tail size. Each female is her own control. She is offered a choice between males with different tail areas, and the time spent approaching each is recorded; statistical analyses show that females prefer males with larger tails. To be sure that this measure is relevant, actual mating choices are later scored.

The paper takes an unexpected turn when the student notices that display rates differ between large-tailed and short-tailed males, and thus a second variable is in play. The authors devise a clever way to circumvent this complication by warming or cooling the compartments of different males to equalize display rates. To understand this, a reader would need to know that fish are cold blooded,

As a result of this new test, the authors are able to partition the relative weightings of female preference for tail size and display rate. This paper has become a classic in the field.
Priorities

Your AI’s main concern in grading will be with structure and logic: Does the essay or report make sense? Is it clear? Are the components logically organized? He or she will look for and discourage two other rhetorical problems: 1) passive sentences and 2) clause-laden sentences. These can make the writing dull and monotonous at best, and ambiguous at worst.

This guide quickly summarizes EEB’s main rhetorical priorities.

Rhetoric

Rhetoric is the simply effective use of words. In scientific writing this mainly depends on formulating a clear, logical, and compelling argument.

Organization:
As you will recall from the Overview, the expository format taught in the Freshman Writing Seminars is (for the simplest papers):

- Background → Issue → Evidence → Analysis → Reflection → Conclusion → Sources

This Question → Answer format is what your AIs will expect for close-reading essays, though for these short assignments we anticipate truncated background and reflection. On the other hand, longer assignments like the JP should allow iterated cycles of evidence and analysis:

- Background → Issue → Evidence → Analysis → Reflection → Conclusion.

The Q → A organization provides an overall logic to EEB assignments. For lab reports, the logical burden is further eased by the inevitable subheads:

- Introduction → Methods → Results → Discussion → References

Your AI will fill out a grading guide for each assignment and return it to you. The AI will be checking for and judging each element. Is there sufficient Background? Is there a clear Issue or hypothesis? And so on.

Transitions:

The most underappreciated element in scientific writing is the Transition. In essays the opening sentence of each paragraph generally accounts for why the paragraph is in the paper at all, and why it follows the preceding paragraph. If, for example, there are three pieces of Evidence (A, B, & C) being brought to bear on the issue, you must ask yourself why A is presented first.

In any paper there should be an evident logic to the order of the argument, not just an and-another-thing approach. (If, by chance, the three instances are coequal, one can start with such a statement.) So, for instance, in an essay on learning in animals, the order of the evidence might be phylogenetic (bees, then fish, then birds). Alternatively one might choose a hierarchy of complexity (mere calibration of a sensory organ, then
rote memorization like imprinting, then complex trial-and-error learning, then apparent insight for example). The topic sentence is generally the place to make this logic clear.

Transitions within paragraphs are used to make the internal logic clear. These elements are of several familiar types:
- Sequence, chronology, addition: first, second; then, next; also, furthermore, etc.
- Similarity, contrast: likewise, in the same way; but then, however, etc.
- Exemplification: for instance, such as, etc.
- Emphasis: above all, moreover, etc.
- Conclusion: consequently, thus, so, above all, etc. Never “in conclusion”
- Reflection: even so, despite, on the other hand, etc.

Outlines:
Most students can write a short essay (up to 5pp) without an outline. All students, it seems, believe they can also write a long essay keeping everything in their heads. Experience tells us that this is rarely the case: you should work from a linear outline. Even for short assignments, some students need help identifying the logical flow (or imposing one).

The most useful strategy for many students is the über outline—a list of transitional sentences (or sentence fragments), one for each paragraph, alternating with one-per-paragraph entries detailing the gist of each paragraph. The introductory paragraph in each section may not need a transition; the subhead may be sufficient. The result is an enhanced road map for writing. Here is an über outline for the Bischoff et al. (1985) target paper:

Introduction
- Darwin proposed . . . ; define both kinds of sexual selection
What is known: Experiments have demonstrated . . .
- Review the female-choice literature
- Introduce the issue: is there female-choice in guppies?
Tell us about the study animal: Guppies originate . . .
- Natural history of guppies
Methods
- Equipment and subjects
- Timing and scoring of choice responses
- Scoring of actual matings
- Sizing and manipulation of male tail area
Results
- Females showed strong preferences . . .
  - Evidence
  - But there is an ambiguity
- To separate tail area from display rate . . .
  - Effect of display rate alone
  - Effect of tail area alone
Discussion
- Analysis: Apportion the blame
  - Combining the first and second sets of tests . . .
- Reflection: The curious linking of tail area and display rate . . .
References
“Style”
Two aspects of writing often classified as questions of style are particular problems in scientific writing. AIs will treat the overuse of passive voice and any excessive reliance on dependent clauses as seriously as defects in organizational logic.

**Passive and Active:** Some students seem to have been born with the idea that academic writing uses passive voice as a way of giving papers a sense of impartiality and gravitas. The major problem of passive voice is that it often obscures the distinction between the subject and object—the cause and effect. Thus passive voice can create the ultimate sin in expository writing: ambiguity. In fact, scientific writing is all about identifying cause and effect, and resolving ambiguities. Passives can also give a dead, monotonous affect to the writing. This fondness for passive voice will be mercilessly crushed.

Examples of passives abound. In one paragraph of a single paper, for instance, we can read “Until recent years it was believed that,” “it has now been shown,” “the birds were reared,” and “the conclusion to be drawn is.” Because of the passive construction, we have no idea who or what is behind the event. Saying “Smith (1998) showed,” “we conclude,” and so on makes it clear who is to blame. These are not acts of God; no one sports a bumper sticker reading “Experiments happen.”

Here is never-fail rule of thumb #1:
- Transcribe the way you would describe something to a friend. Lawyers excepted, no one actually speaks to others in the third-person passive—at least, no Princeton students do.

**Clauses and indirection:** Clauses are fragments containing a subject and verb, but not expressing a complete thought. In an effort to demonstrate the complexity and subtlety of their thinking, students are tempted to construct long, involved (often passive) sentences full of conditionals. (In this sentence “effort” was the subject, “to demonstrate” was the verb; “In an effort to demonstrate the complexity and subtlety of their thinking” is not a complete thought, and is thus a dependent clause). Dependent clauses are especially common when the writing is stream of consciousness, free of proofreading, as ideas and second thoughts pile in—that is, it’s mostly what students turn in until you put a stop to it.

Another problem with clauses is that they usually lead to indirect, roundabout ways so saying even simple things, Indirection and extra clauses sap energy and clarity from writing.

Never-fail rule of thumb #2 & 3:
- No sentence should occupy more than 2.5 lines of text unless it is (correctly) broken by a semicolon or is exquisitely written.
- No sentence should have more than two dependent clauses—and probably only one.
As a part of an initiative from the Dean of the College and the Princeton Writing Program, the EEB department emphasizes the rhetorical component of the essays and reports (both written and oral) assigned in our courses. Part of your grade depends on your expository skills. In EEB 211 we have two written lab reports (Sexual Selection, and Plant Transpiration) and one oral report (Fish Schooling). In EEB 312 we have three written reports (Plankton, Coral Feeding, and Mangrove Zonation) and one oral report.

The discussion that follows presupposes that you have read the Overview and the short research report that accompanies it. The Overview reviews the elements of the academic essay. The discussion also assumes that you have carefully read the article on female choice in guppies (Bischoff et al. 1985), which was assigned for the Sexual Selection lab.

What is a lab report?

A lab report is simply a student version of a scientific research paper. Each is a modified form of a standard expository essay. As you will remember from your Freshman Writing Seminar, the goal of an expository essay is to construct a convincing argument based on evidence. You begin with an issue (the question); you present and analyze evidence in a logical order; and you reach a conclusion relevant to your issue. In essence, a scientific paper is simply an expository essay with internal subheads and quantitative evidence (i.e., data and graphs). The order of elements in an essay is substantially the same as in a lab report:

Background → Issue → Evidence → Analysis → Reflection → Conclusion → Sources

--- Introduction ---- → Methods → Results → ------------ Discussion ------------→ References

Communication of your research findings is an essential part of the scientific process, and demands the same care and attention that you give to the design and execution of experiments. Your primary obligation is to describe accurately and clearly the scientific context and rationale for your work (Background and Issue), the methods that you used, the results that you obtained (Evidence), and your interpretation of those results (Analysis and Thesis/Conclusion).

Lab reports differ from conventional essays in that they have a stereotyped order (emphasized with subheads), and include: an Abstract or Summary, an Introduction (for background and issue), a Methods section, separate sections for evidence (Results) and analysis (Discussion), and a list of References (aka Bibliography, or Literature Cited). A formal lab report is the appropriate format for writing up investigative labs—that is, labs in which you observe, ask questions, and formulate hypotheses. You have first read the literature, and on that basis have formulated a question; you design and conduct experiments, record data, and interpret results.

This entire process is formally reflected in the conventional organization of a scientific research paper. The format of your lab report will be similar to the structure of papers submitted to scientific journals. It should include the following sections:
Although this is the order in which the sections are presented in the lab report, it is rarely the order in which they are written. See the section on Writing Tips for recommendations on the order in which it most makes sense to write the sections of your paper.

You should begin by reviewing the lab manual and writing an outline of the important points you wish to cover. As you proceed to write your report according to the format and guidelines below, constantly ask yourself

“What is the essential point of this sentence/paragraph/section?”

“What have I made the point as clearly and economically as possible?”

Problems are often exposed by the simple expedient of having a friend read your report, or even reading the report aloud to yourself.

Professional scientific research papers are written according to the format and guidelines of the scientific journal to which they are submitted. You will be expected to write your reports according to the format and guidelines provided below. Read the guidelines carefully and be sure that you understand them. Each of the report sections described below, with the exception of the Title, should be labeled with the section heading (Abstract, Introduction, etc.).

**Title**

The title should consist of a few well-chosen words indicating the subject of the report. Creativity is encouraged, as long as the title reflects the scope of your report accurately. Do not call your paper "Growth in Plants" if what you really studied was how a variety of levels of light affected the growth of pothos (*Epipremnum aureum*) plants. An ideal title intrigues (poses a question) and informs (makes it clear what the experiment was about).

The Bischoff et al. (1985) article has a very simple title: “Tail size and female choice in the guppy (*Poecilia reticulata*).” It could also have been “Female guppies (*Poecilia reticulata*) select males on the basis of tail size,” or “Do female guppies (*Poecilia reticulata*) select males on the basis of tail size?” The title “Sexual selection in fish” would have been uselessly general.

**Abstract**

The Abstract is a concise summary of your experiment; a short paragraph or five or six lines should suffice for this course. It should include the objectives of the question being investigated, the major result(s), and the most important conclusion(s). This is the part of the paper scientists read to decide whether they are interested in looking at the rest of the paper. The abstract is more easily written after the rest of the paper.
The Bischoff et al. (1985) article has a 60-word Summary—the maximum allowed in this journal for Short Reports. It outlines the main results: female guppies prefer males with larger tails and higher display rates, and such males have higher reproductive success. It then states the conclusion succinctly: guppies display female choice sexual selection. Had the journal rules been less demanding, the authors might have done well to include an issue sentence: “The existence of female-choice sexual selection is controversial.”

Introduction

The Introduction explains the purpose of the experiment—your Issue—in one or two paragraphs. It should include some Background information on the general problem or area being investigated, and explain why this problem is of interest (i.e., how your current investigation accords with what is currently known about the topic). In writing this part of your report, you should consult outside references and reread the relevant parts of your lab manual and text. Be sure to keep track of where you get this information and list all Sources used, including your lab manual and text, in the Literature Cited section at the end of the paper.

Whenever you cite a source in the text, it should be according to scientific convention: (author year). So, for instance, if you refer to the paper on female choice in guppies in your sexual selection lab report, the in-text citation should be (Bischoff et al. 1985). The Literature Cited section below details how to handle a variety of different situations.

The Introduction should present the specific experimental question you posed and the hypothesis you tested; this is your Issue. For Lab Reports, we also want you to explicitly state:

- your experimental hypothesis
- your null and alternative statistical hypotheses
- the outcome you expected
- your reasoning (i.e., how the outcome would help support or refute your hypothesis)

The Bischoff et al. paper illustrates the strategy of the Introduction. The general background begins with Darwin, defining female-choice. It then notes that the existence of female-choice sexual selection was (until this paper) quite controversial. The report then presents the evidence in favor of the hypothesis, but points out that the alternative process (intrasexual combat—male-contest sexual selection) is taking place in each of these societies as well, and could be the whole story.

The introduction then presents the Issue: “The purpose of this study was to examine … whether the colorful hypertrophied tail of males attracts females and subsequently affects male reproductive success.” It makes clear why the guppy is a better choice: there is no male-contest involved. The introduction then supplies some essential natural history of the species, and states the hypothesis to be tested: “We wondered if female guppies might be discriminating among males at least in part on the basis of tail size.”
Materials and Methods

This section should include a concise description of the materials, procedures, and equipment used. It should be written in paragraph form, rather than as a list. There should be enough detail so that someone else could repeat your work. If you followed the directions in the lab manual exactly, simply cite the manual. You need not repeat the instructions unless the protocol you used differed from that outlined in the manual.

- Describe the dependent variable you measured, the independent variable you altered, and your control.
- Do not include the rationale for your work in this section; that belongs in the Introduction.
- Be sure to report your procedure as a past event rather than writing this section as a set of directions to your reader.

In the Bischoff et al. paper, the Methods are presented in sufficient detail for another researcher to repeat the tests: aquarium size, animal history, age, isolation time, sample size, testing schedule, dependant variable and scoring criterion (female choice), independent variable (tail area), and so on. The writing is in the past tense: “A single male was placed in each end compartment.” For your lab reports, only the details that differ from the lab manual (cited as a Source) need be outlined.

Results

This section consists of a verbal description of your Evidence (i.e., your results), including a presentation of your summarized data in tables and figures (graphs & drawings) where appropriate, and the results of any statistical analyses you performed. This is also where you may need to do some preliminary interpretation of the results (Analysis) if there is more than one experiment, and the results of one affect the design or logic of the next.

- Summarize your data—Do not include raw data! Organize the summarized data in figures, tables, or both, as appropriate. (In your senior thesis you may want to put the raw data in an Appendix so that future students can use it.)
- Be sure to identify the statistical test you used and the $P$ value. If your data were too few to permit statistical analysis, include the alternative quantitative or qualitative analysis (e.g., comparison of means, 10% difference, etc.).
- State the results that you obtained, not those you think you should have found.
- Organize your findings in a clear and logical order (not necessarily chronologically).
- Do not interpret or explain your results in this section. (As noted above, for a longer research paper or your senior thesis, you might need to modify this format to allow brief discussions to link one experiment to the next.)

In the Bischoff et al. paper the key result is given in the first sentence, with call-outs referring the reader to the relevant figure: “Female guppies showed strong preferences for males with conspicuous tails (Fig. 1a), and this initial preference was translated into enhanced reproductive success for the more conspicuous males (Fig. 1b).”

Some of the statistical results are given in the figure caption and some in the text, depending on where in the narrative they were needed. The type of test is identified
(binomial in Fig. 1, t-test on p. 255). Statistical methods are often given in the Methods section.

Because the initial results uncovered an uncontrolled variable (display rate, Table 1), the Results explain the logic of the follow-up test to equalize this parameter. Because the journal limits the number of figures and tables in a Short Report, these results are given in the text; you will need to put all of your results in tables and graphs.

> Tables and figures <

Be sure to:

- Include clear labels and descriptive captions, such that each can be understood without reference to the text.
- Label all axes. Include units of measurement. Remember that the independent variable is plotted on the X axis.
- Mention each table and figure somewhere in the text of your report—the “call out.” Do not include tables or figures without referring to them in the text.
- Number and provide a descriptive title for each table and figure. Number the figures in the order of reference in the text. Number the tables independently.

Example: Table 1. Effect of temperature on frequency of cricket chirps.

In the Bischoff et al. paper the data are categorical: there are discrete classes of independent variable (TT, T, and t) on the X axis; the dependent variable (female choice, with the units specified) is on the Y axis. P values and sample sizes are given on the figure for clarity. The guppy icons make the bar graphs easy to interpret.

The table summarizes the relationship between tail size and display rate. This could also have been presented as a graph (tail area as the independent X-axis variable, and rate as the dependent variable). The resulting regression plot would have had Standard Error bars to show the variability, and a P value for the relationship. In retrospect, this might have been better than the table.

Discussion

This is the most important section of your report: Analysis and Conclusion. Here you interpret the data and put them into the context you established in the Introduction. Refer to the null and alternative hypotheses outlined in the Introduction and analyze your findings in the context of your overall hypothesis and the question (Issue) you posed. In the investigative labs in this course it is not important whether your results are "right" or not; your grade depends on how well you interpret your results.

Explain your data:

- Did the results enable you to answer your specific experimental question?
- Did they support your hypothesis? Remember that in science, we cannot “prove” a hypothesis; rather we can only disprove it or support it.
- Support any conclusions you make with your data.
- What is the significance of your results in the general area you studied (i.e., How do they relate to your research question)?
- You should particularly try to relate your results to biological phenomena, where appropriate.
• How do these results fit into what we know about the topic? Cite sources of existing knowledge and relate your findings to those of others.
• Answers to any questions specifically posed by your TA or lab manual should be incorporated here.
• You should also include an analysis of possible sources of error, how important each error source might be, and ways you could have tried to eliminate them.
• If the results were not as you expected, formulate a new hypothesis and describe how you might test it.
• What further experiments could be performed to clear up discrepancies or ambiguities in your results?

The Bischoff et al. paper, given the constraints on the report length, does not walk the reader through the hypothesis (tail area affects female choice); it takes for granted that the audience will have seen this in the Results section. You are under no such limit; we expect you to remind us of the alternatives, and what you conclude from your observations. To be an acceptable 211 lab report, the paper should have said “Female guppies chose males in part on the basis of tail size, confirming our hypothesis that female-choice sexual selection is part of the reproductive strategy of this species.”

The Discussion in the guppy paper begins by combining the two experimental series (i.e., with and without temperature compensation) to derive an estimate of the relative contribution of tail area versus display rate. This is classic Analysis, going well beyond the original question. The calculation allows the authors to partition the results under these laboratory conditions: 33% tail, 67% rate.

The Discussion then attempts to relate this analysis to conditions in the wild—one of the things we meant by the reference to “biological phenomenon” above. It then considers the alternative explanations for the rate/area linkage. This Discussion suggests the “further experiments” that seem an inevitable part of any scientific paper. It might also have suggested comparing the effect on female choice of spot number, size, and color. It could have alluded back to the Introduction where alternative justifications for female choice were given: looking for indicators of health, or longevity, or generalized stimulation (the sign stimuli discussed in lecture). The guppy paper was strictly limited to 3pp of text; we will expect a less perfunctory and limited effort at Analysis and Conclusion from your reports.

**Literature Cited**

This section consists of an alphabetical list of the sources cited in the text of your report. Any information that originated from a source other than yourself must be cited as a reference, in abbreviated form in the text of your report and as a compete citation in this section. The source of authority for every statement contained in your report should be made clear to the reader. Failure to do so constitutes plagiarism, i.e., misappropriation of the ideas of others. You are responsible for understanding and abiding by all of the university’s policies on academic honesty.

> **Text citations** <

There are two ways to cite a reference in the body of your report. The first is to simply place the author's last name(s) and the year of publication in parentheses in the sentence in which the reference is made. If there are two authors, write both last names with
“and” in between. If there are more than two authors, list the first author’s name, followed by "et al." (the abbreviation for *et alia*, which means "and others"). An alternative way to cite an author is to include his or her last name (or names, as above) in the text of the sentence, and place the year of the publication in parentheses directly behind the author’s name(s).

Examples: The most recent observations of the Loch Ness monster suggest that it is a giant worm (Smith *et al.* 1985). However, Campbell (1990) presents compelling evidence that it is in fact a relict sea serpent.

> Complete reference listing in Literature Cited section <

There are several formats used in scientific papers. All have the goal of providing a clear, consistent way to guide the reader to the original source. Other courses may use slightly different formats. For EEB majors: you will receive a departmental writing guide in the fall of junior year (or before if you take 309, 311, 312, or 321 before that); that guide and our upper-level course use the more complex APA format.

- For a journal article:

  **Examples:**

- For a book:
  Author's last name(s), Initials. Year. Book title. Publishing company, location.

  **Examples:**

**Writing Tips**

Your report will be easier to read and understand if you follow these tips and try to conform to the accepted style of scientific writing that is required for scientific papers. Conformity can be a good thing if it increases communication!

- Write in the past tense, not present or future, in the Abstract, Materials and Methods, and Results sections. In the Introduction and the Discussion sections, use past tense when referring to your experiment; however, present tense may be more appropriate when referring to generally accepted knowledge as well as in discussing the relevance of your work.
- Use the active voice rather than the passive. This will decrease verbosity and increase clarity. For example, write, "We performed a behavior experiment..." rather than "A behavior experiment was performed..." The passive obscures cause and effect; everything seems to have been done by an unknown actor—presumably God.
• Since all experiments in this course are performed in groups, use “we” rather than “I.”
• Refer to animals and plants by their scientific names. Always italicize the scientific names of organisms (e.g., Acheta domestica). For the first mention of a particular organism, write out both genus and species (the genus should be capitalized and the species name in lower case); however, for subsequent mentions it is acceptable to abbreviate the genus to its first initial followed by a period (e.g., A. domestica). Be as specific as you can in naming the organism, but when the name is not known completely, write sp. after the generic name (e.g., Oscillatoria sp.).
• Use metric units (gram, meter, liter, second) and degrees Celsius (ºC).
• If you begin a sentence with a number, write out the number. Numerals are appropriate in any other position.
• Avoid boring the reader with copious verbiage and excessively formal writing. Write as you would describe things to an interested friend in conversation.

> Battle plan: order in which to write the sections <
• Begin your writing with the Materials and Methods section. This is normally an easy section to compose because you simply have to summarize a procedure that you have already performed.
• Next tackle the Results section. Summarize your findings, but do not interpret them.
• Write the Discussion.
• Write the Introduction.
• Write the Abstract.
• Decide on the Title.
• Organize your list of cited literature alphabetically by the (first) author’s last name.
• Proof-read the entire paper, looking for grammatical and spelling mistakes. Don’t rely solely on a spell-checker!
• Take a break. Read the draft with fresh eyes—preferably the next day. Does it flow logically? Is it obvious why each sentence is where it is?
• If possible, have a friend read it. Does it make sense to someone besides you?

References


Critical reading:
Close reading—the critical and detailed review of papers—is a key ability in all professions. It is particularly important in the sciences, where quantitative and statistical analyses often underlie conclusions and alternative research reports sometimes report contradictory findings. Scientific understanding comes from readers imposing their own critical analysis upon the published literature. The Freshman Writing Seminars provide an introduction to close reading, and these EEB assignments we help you to hone this valuable skill.

Tucked away inside each paper are the standard elements of expository writing your students encountered in the Freshman Writing Seminars, and which are covered in detail earlier in this Guide: Background, Assumptions (often hidden), Issue, Evidence, Analysis, Reflection (sometimes!), and Conclusion. Largely unique to science is the Methods section, as well as the quantitative data and statistics that are part of the Evidence. Many people do not understand the logic of research papers, and how scientific writing is similar to an expository essay in most ways but somewhat different in others.

Perhaps the most common misunderstanding about scientific writing is that the value of scientific papers lies not in the grand conclusions, but in the gritty details. Those new to science typically start off reading papers for the “ending”: What does the author conclude, does Red October successfully defect, does Ahab catch Moby Dick, do Elizabeth and Darcy finally get married? New readers of standard literature often fail to recognize the plot (how the story develops) or follow its logic. Likewise, new readers of the scientific literature frequently do not see (or do not correctly identify) the Issue, they miss how the Background material forms the hypothesis, they sometimes miss the alternative predictions and whether they are sensible predictions, and—perhaps most importantly—they fail to recognize how the Analysis synthesizes the chain of Evidence.

Close-reading essays:
The purpose of the close-reading essays in EEB 309, 311, and (beginning in 2010) 321 is to teach how read research papers closely, and to write crisp, critical summaries of the context and process, as well as the conclusion reached. Our goal for these assignments is not for the you to search for a paper’s possible flaws (though that is fine if you spot any); instead it is to trace the logic of the experiment and analysis.

The essays will be 500 words (two double-spaced pages); each of you will write four over the course of the term. Your AIs will have a checksheet to make the grading easier and more uniform. They are scoring two quite separate things: The essay as a careful and insightful summary of the target paper, and the essay as a piece of expository writing.

What follows is a sample of a satisfactory close-reading treatment of the Bischoff et al. (1985) paper on female choice in guppies.
Sample close-reading essay:

Darwin posited two kinds of sexual selection: contest and choice. In contest systems individuals of one sex fight for control of resources; a member of the other sex goes to the resources and mates with the individual possessing them. In choice systems, on the other hand, members of one sex display and individuals of the other sex choose among the displayers for no overt material reward. Sexual selection based on choice has been a controversial idea, and evidence for female choice has been equivocal because most previous studies have inadvertently included a component of male contest.

To determine the importance of female choice without the confounding effects of male contest, Bischoff et al. (1985) chose a species (guppies) that has no male-contest component in its mating system. Males display in front of females, flashing their large tails. The authors examined whether females select males on the basis of tail size, a trait that is highly polymorphic.

The authors first used a three-compartment tank with a female in the center and one male at each end. The tank contained one-way mirrors that allowed the female to observe the spontaneously displaying males, but neither male could see the female or the other male. The authors then scored the number of times the female approached each male as a proxy for female choice. In a second series, the authors removed the mirror barriers and counted matings. The authors used a combination of natural variation and surgical shortening to generate variation in tail size. The authors claimed that naturally small-tailed males and surgically shortened males acted in similar ways.

Females significantly preferred males with larger tails, both in the choice experiment with one-way mirrors and in subsequent matings. However, males with larger tails also displayed more often than did males with shorter tails. To separate the possible effects of tail size versus display rate, the authors tested males with equal tail area in either end of the one-
way mirror tank, heating one end of the tank to increase the display rate of males. In this experiment, females preferred males with a higher display frequency. Next the authors tested males with different tail sizes and adjusted the temperatures in the two end chambers until smaller-tailed males and larger-tailed males displayed at the same rate. In this experiment, females preferred the males with larger tails, but not to the same extent as observed in the original experiment when display rate was not controlled.

Since the authors could separate the effects of tail size and display rate, they calculated that display rate is roughly twice as important as tail area for female choice. Females were apparently considering both tail size and display rate in their choice. Thus, in a species with no male-contest component to the mating system, female choice occurs, at least under laboratory conditions.

(470 words)
Purpose of a scientific essay
Research reports, as we have seen, take a specific Issue and try to resolve it with experiments. But scientists also write non-experimental papers—standard academic essays. In general, scientific essays fall into two categories: a broad critical review, or a narrower literature-based evaluation of a specific topic. Regardless of the scope of the particular essay, all scientific writing is devoted to critical evaluation—Analysis and Reflection. As Dunski et al. (1995) put it:

Even if you are predominantly concerned with compiling a summary of literature upon a subject, you should also assess the value of the works that you read. Just because something is published—even in a peer-reviewed scientific journal—does not make it “good” science, and conclusions made from the data are not always valid.

The following guidelines may help you structure your essay. Unlike scientific reports, essays do not require explicit subheadings and certainly have no Methods section. Nevertheless, a scientific essay should follow the same general format we’ve seen in conventional expository essays:

- Always keep the purpose (Issue) in mind; ask yourself how each paragraph is relevant to your Issue.
- Each paragraph should focus around a topic sentence or phrase—an element that usually opens the paragraph. Since you will not have subheads to impose an organization on your essay, it is crucial that you employ paragraph-to-paragraph transitions.
- The topic sentence/phrase is usually the best place to make clear why the paragraph is even in your essay in the first place, and then why it is positioned where it is—that is, why it is the logical next thing to go into.
- Transitions within paragraphs should make clear how the sentences are related, and ensure that the writing flows smoothly.
- For short essays, consider using an outline. For JPs, don’t even think about foregoing the organizational help an outline provides. See the Rhetoric chapter for a discussion of the transitions-focused über outline.

Title
Readers often decide whether to read an essay based on its title, so make it concise but informative and (if possible) intriguing.

Introduction
State the Issue of the essay clearly to help convince your audience that the article is worth reading. Provide Background information to establish a framework for your essay and bring the reader up to speed. The order of presentation is often: general background, issue, more-specific background.
Body

Your Evidence and Analysis should be presented logically so readers can follow them easily. The paragraph-level transitions should make it clear why example A necessarily precedes example B—why it’s bigger and better, or moves you deeper into the Issue. Don’t leave the reader wondering if you just alphabetized the evidence.

When you encounter apparently contradictory information from two sources, evaluate whether the conflict is real or whether the conclusions are based on different circumstances. This is one of the key goals of Reflection. Reading more literature on the subject is often helpful in coming to a resolution. Point out trends, but be wary about making generalizations from specific data: that ducklings will imprint on toy trains may not settle the question of bird-song learning.

Conclusions

Your final paragraph(s) should provide closure to your essay. Remind the reader of the Issue and be sure that the Conclusion—the take-home message—is clear. This is a good place for broad Reflection. Try to end on an optimistic note if possible: the reader has invested time and effort in your paper, and would prefer not to learn now that it was a waste. Good essays often end with an extrapolation: what might these results mean for the future, for casting light on broader issues, or some other uplifting note.

Sources

All sources used should be cited within the text in proper citation format for scientific writing (author year). Full citations are included at the end of the essay, again in proper style for scientific writing. See the entry on Sources for specifics.
Check your essay to ensure that you have considered all of these components.

<table>
<thead>
<tr>
<th>Section</th>
<th>Components</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>In general, the essay:</td>
<td>Fulfills a specific purpose: evaluating an Issue by bringing to bear Evidence, Analysis, and Reflection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintains an appropriate: Level of writing for the intended audience</td>
<td></td>
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<tr>
<td></td>
<td>Length for each section</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depth for each section</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uses correct grammar and spelling</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Concisely describes the subject; intrigues and informs</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>States the Issue that motivates the essay</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gives the reader Background information to orient and provide context</td>
<td></td>
</tr>
<tr>
<td>Body</td>
<td>Presents Evidence in a logical progression</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provides critical Analysis of the evidence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provides Reflection (consideration of anomalies and Alternatives)</td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td>Resolves the Issue to the extent the Evidence allows</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emphasizes the “take-home” message</td>
<td></td>
</tr>
<tr>
<td>References</td>
<td>Cites all sources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lists references alphabetically by author</td>
<td></td>
</tr>
<tr>
<td>Transitions</td>
<td>Each paragraph flows logically from the previous one:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the first (topic) sentence should make it perfectly clear to the reader why this paragraph is in your essay at all, and in particular why it comes after the preceding one (and thus is part of the logical flow)</td>
<td></td>
</tr>
</tbody>
</table>

Science Writing in EEB  
Guidelines for Oral presentations

An oral presentation assignment is incorporated into most Freshman Writing Seminars because it requires most of the same expository techniques found in essay writing, and is an important professional skill in most post-Princeton careers. Both EEB 211 and 312 have an oral presentation component near the end of the course.

Compared with essays, an oral presentation is time-limited and thus involves using many fewer words. In EEB 211 the presentations are 8 minutes long; in EEB 312 they have a 15-minute limit. This pushes much of the expository burden onto well-designed, information-rich, readily comprehended visuals. The oral presentation in EEB 312 also requires a written summary or abstract—the usual case for professional presentations. Preparing an abstract with just the right scope and level of detail is a skill all its own.

You will also be graded on the questions you ask of other presenters, as well as the answers you give to the queries posed by your peers. If possible, try to anticipate questions.

**Content:** Here are the elements of a typical oral presentation.

**Introduction:**
The introduction sets the stage for what will follow. The introduction should therefore begin with a discussion of prior work in this area with reference to published articles so that the reader is clear, when you state your Issue, just why you bothered with this research. The null and alternate hypotheses should be outlined as well. Make it clear why your Issue is both important and biologically relevant.

**Methods:**
This section is brief and outlines the experimental design and methods used. Pay special attention to sample sizes, but do not get bogged down in details. Well-designed visuals can make this go quickly.

**Results and Discussion:**
This is where you present your Evidence and Analysis. However, unlike a lab report or research paper, the results in an oral presentation are usually presented along with discussion points. This is because the audience will often forget the key points from a graph, table, or figure if you refer back to it after presenting all the results first. The visual elements you use—graphs, tables, summary lists—should clearly tell the audience what is important in your data, including P-values. The discussion should weave together the story, describe the patterns observed in the data, and relate your results to other studies.

**Conclusion:**
Draw the talk to a close by answering the question posed in your introduction. Were your hypotheses confirmed or rejected? If not suggest an explanation. If the results were consistent with the hypotheses, where do we go from here? How is any of this biologically relevant? This is the place for Reflection.

**Abstract and References:**
EEB 312 requires a 200-word abstract and list of sources (at least 4-5 references from peer-reviewed journals). The abstract must outline Issue, the basic methods used, the key Evidence obtained, and enough Analysis to justify the conclusions you draw. This is difficult in 200 words.
**Presentation:**
You can use either PowerPoint or overhead transparencies for your presentation.

**Time:**
Remember you have a time limit, and an audience sitting in the dark ready to nod off if you become boring. You do not need to discuss everything, nor can you (no matter how quickly you talk). Focus on the main features, where there is enough data to give you some confidence in your result. Practice your talk (using your laptop if you are using PowerPoint).

**The oral part:**
It is also critical that you be clearly understood. This generally means standing, speaking slowly and clearly facing the audience rather than the projector screen. Schematic notes work better than a full-fledged script; reading off a script produces a tedious canned effect.

**Visuals:**
It is critical that the font on your slides/overheads be legible. For summary points, 16- or 18-point text as it appears in a 720-pixel window is a reasonable minimum. For Tables, 12 or 14 point is about right. For the axes on graphs (the most common problem in visibility for audiences) 12-14 is again a good minimum to shoot for. Graphs and other illustrations need to be simple—readily comprehended at a glance. For calibration, the graphs in the Bischoff et al. (1985) paper have useful male-guppy icons, but are too complex to be displayed together.

Do not act as though your audience is deaf: minimize the use of text; nothing is more tedious than a word-for-word slide of what you are saying. Demonstrating your expertise in creating distracting background or having your text cavort on the screen is counterproductive.

**Sample presentation:**
Here is one possible way to turn the Bischoff et al. (1985) paper into an oral presentation.

<table>
<thead>
<tr>
<th>Outline</th>
<th>Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction: Background &amp; Issue</td>
<td>Mountain sheep fighting</td>
</tr>
<tr>
<td>Sexual selection</td>
<td>Male peacock displaying</td>
</tr>
<tr>
<td>Male-contest</td>
<td>Male widowbirds</td>
</tr>
<tr>
<td>Female-choice</td>
<td>Alternative hypotheses</td>
</tr>
<tr>
<td>Controversy</td>
<td>Male polymorphism</td>
</tr>
<tr>
<td>Both elements in most cases</td>
<td>Three-compartment tank</td>
</tr>
<tr>
<td>Issue</td>
<td></td>
</tr>
<tr>
<td>Guppies</td>
<td></td>
</tr>
<tr>
<td>Methods</td>
<td></td>
</tr>
<tr>
<td>Tank</td>
<td></td>
</tr>
<tr>
<td>Scoring criteria</td>
<td></td>
</tr>
<tr>
<td>Results and discussion: Evidence &amp; Analysis</td>
<td></td>
</tr>
<tr>
<td>Choice tests</td>
<td>Figure 1a</td>
</tr>
<tr>
<td>Mating tests</td>
<td>Figure 1b</td>
</tr>
<tr>
<td>Display-rate problem</td>
<td>Table 1</td>
</tr>
<tr>
<td>Warm/cool tests</td>
<td>New table or graph</td>
</tr>
<tr>
<td>Relative role of display rate and tail area</td>
<td></td>
</tr>
<tr>
<td>Conclusion and Reflection</td>
<td></td>
</tr>
<tr>
<td>Female-choice sexual selection is real</td>
<td>Use your imagination</td>
</tr>
<tr>
<td>Possible logic of area/rate correlation</td>
<td></td>
</tr>
<tr>
<td>Future work: what other features of males might matter?</td>
<td></td>
</tr>
<tr>
<td>What is the adaptive logic of caring about tail size and display rate?</td>
<td></td>
</tr>
</tbody>
</table>
# Science Writing in EEB
## Lab Report Evaluation Criteria

<table>
<thead>
<tr>
<th>Points</th>
<th>Earned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract (6)</strong></td>
<td>Concise summary of relevant information</td>
</tr>
<tr>
<td><strong>Introduction (28)</strong></td>
<td>Background: Brief and general introduction; rhetorical logic of writing</td>
</tr>
<tr>
<td><strong>Issue</strong>: Purpose of experiment; specific experimental question posed</td>
<td>___/8</td>
</tr>
<tr>
<td><strong>Issue</strong>: Statement of hypothesis and prediction; explanation of prediction</td>
<td>___/6</td>
</tr>
<tr>
<td><strong>Issue</strong>: Statement of null and alternative hypotheses</td>
<td>___/6</td>
</tr>
<tr>
<td><strong>Methods (12)</strong></td>
<td>Ref. to manual; Description of procedures where they differ from/are more specific than manual</td>
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<tr>
<td><strong>Results (20)</strong></td>
<td>Evidence: Written summary of results</td>
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<td>(including statistics, if data permit, or comparison of averages)</td>
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<td></td>
<td>(including Tables/Graphs appropriately ref’d and labeled, if appropriate)</td>
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<td></td>
<td>(including good transitions to lead the reader through the logic)</td>
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<tr>
<td><strong>Discussion (30)</strong></td>
<td>Analysis: Summary addressing specific questions and hypotheses; rhetorical logic</td>
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<tr>
<td></td>
<td>Analysis/Conclusion: Data interpretation/Conclusions; rhetorical logic of writing</td>
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<tr>
<td></td>
<td>Analysis: Identification of possible sources of error</td>
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<tr>
<td><strong>Conclusion/Reflection</strong>: Further experiments suggested</td>
<td>___/5</td>
</tr>
<tr>
<td><strong>Literature Cited (4)</strong></td>
<td>Sources: References properly cited and listed (e.g. scientific articles, resource packet, text)</td>
</tr>
<tr>
<td><strong>Rhetoric and Style (10)</strong></td>
<td>Rhetoric: No passives or overly complex clause-laden sentences</td>
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</tbody>
</table>

**Total ___/100 (+ 10 extra credit)**
### Science Writing in EEB
#### Checksheet Grading Guide for Close-Reading Essays

<table>
<thead>
<tr>
<th></th>
<th>Seriously flawed</th>
<th>Less than adequate</th>
<th>Adequate</th>
<th>More than adequate</th>
<th>Outstanding</th>
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<tbody>
<tr>
<td>As a critical summary, the essay:</td>
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<tr>
<td>clearly identifies the Issue</td>
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<td>captures the key elements</td>
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<td>of the Background</td>
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<td>identifies the key pieces of</td>
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<td>Evidence</td>
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<td>clearly summarizes the Analysis</td>
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<td>accurately summarizes the</td>
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<td>the gist of the Conclusion</td>
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<td>As a piece of expository writing, the essay:</td>
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<td>has a logical order, with clear inter-paragraph Transitions</td>
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<tr>
<td>is clearly written, with clear intra-paragraph Transitions</td>
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<td>is mercifully free of Passives</td>
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<td>uses direct sentences without excessive use of Clauses</td>
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<td>is a pleasure to read because of the quality of its Writing</td>
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**Summary:**

|                                |          |          |          |          |             |

EEB 311 grading scale

2  4  6  8  10

EEB 309 uses a 3-category scoring scale (Less than adequate, Adequate, More than adequate); EEB 311 uses the full 5-category scale (including Seriously flawed and Outstanding)
Science Writing in EEB
Checksheat Grading Guide for Essays

This essay:

Has a clearly identified Issue ______ ______ ______ ______ ______

Has a broad, deep, relevant Background ______ ______ ______ ______ ______

By way of text, clearly presents the Evidence ______ ______ ______ ______ ______

Through figures and tables, clearly presents the Evidence ______ ______ ______ ______ ______

Has clear and insightful Analysis ______ ______ ______ ______ ______

Comes to a clear and well-justified Conclusion ______ ______ ______ ______ ______

As a piece of rhetoric, the Introduction (Issue and Background):

has a logical order, with clear Transitions ______ ______ ______ ______ ______

As a piece of rhetoric, the Evidence (and, if appropriate here, Analysis):

Has a logical order, with clear Transitions ______ ______ ______ ______ ______

As a piece of rhetoric, the Conclusion (and, if appropriate here, Analysis):

Has a logical order, with clear Transitions ______ ______ ______ ______ ______

As a piece of rhetoric, the Essay as a whole:

is mercifully free of Passives ______ ______ ______ ______ ______

uses direct sentences without excessive use of Clauses ______ ______ ______ ______ ______

is a pleasure to read because of the quality of its Writing ______ ______ ______ ______ ______

Summary: ______ ______ ______ ______ ______

EEB 211 grading scale: 1 2 3 4 5
5pts/item, 60pts total 12 24 36 48 60
Science Writing in EEB
Grading Checksheet for EEB 211 Oral presentations

Introduction (15 points)
- Background: general discussion of schooling/behavior _____/5
- Issue: statement of hypothesis _____/5
- Issue: why the hypothesis is biologically relevant _____/5

Methods (10 points)
- concise/clear description of design _____/5
- logical sequence of experiments _____/5

Results (15 points)
- Evidence: clear/concise explanation _____/5
- Evidence: statistics (P-value) _____/5
- Evidence: graphs _____/5

Discussion (15 points)
- Analysis: interpret results (what do stats mean biologically?) _____/5
- Conclusion: relate to broader scientific concepts _____/5
- Conclusion: follow up experiment _____/5

Group Total _____/55

+ 5 points for each individual’s participation = _____/5

Individual Total _____/60
Science Writing in EEB
Citing sources

It is critical that the reader be able to locate the sources you cite in a student’s presentation of his or her evidence. This involves brief in-text citations and a full listing of publication information in a References (aka Bibliography or Literature Cited) section at the end of the essay, paper, or report.

Formats:
There are a variety of different citation formats used in scientific writing. All are designed to avoid ambiguity while preserving the essential information needed to locate the original publication. In EEB we will use a version of the APA style. APA uses italics to distinguish between books/journals and article/chapter titles. If you set your e-mail program preferences to use Monaco or Geneva as your message font, you will not be able to send italic-formatted citations except in attachments. Common e-mail fonts with italics include Arial (a sans serif font) and Helvetica (also sans serif) as well as Times (a font with serifs); this text is in Palatino.

The basic APA bibliography format is: Author (year). Title. Journal volume, pages. Most journal names are abbreviated: Anim. Behav. and Amer. Nat. (Animal Behaviour and American Naturalist, for instance). Some are not: Science and Nature for example). If unsure check the reference in a published paper, or look in the top margin of the first page of the paper in question; if all else fails, don’t abbreviate.

Call outs:
The in-text citation call-out is either (Author year) or Author (year) depending on whether the author’s name is used in the text itself [as in “On the other hand, Herman (1991) reports that dolphins learn auditory cues faster than visual ones.”]. Article and chapter titles capitalize the first letter of the first word; the first letter of each major word in Journal and Book titles are capitalized. Sounds simple enough . . .

Complications:
In documenting sources, your students will discover a number of potentially ambiguous variants. Citations can be of single-author papers or ones with multiple authors. The publication may be a journal or a book. If a book, the author cited may only have written one chapter of many. In citing evidence there may be two or more sources, which your students will want to refer to together in some way. They may find that two of your sources are by the same author, which they need to distinguish in the text (so that the reader knows which Bibliography entry is correct). And, as they will find, there are other amusing contingencies to deal with.

We have organized these examples to illustrate the most common challenges. In each instance we list the in-text citation followed by the corresponding Bibliography entry.

Original papers

Single author:
(Higuchi 1986)

Two authors:
(Marler & Tamura 1964)
Three or four authors:
(Curio, et al. 1978)

Five or more authors:
(Margolis, et al. 1987)

Citations of books (tell us where in the book to look)

Single-author books
(Watson 1924, pp. 12-15; 74-81)

Multiple-author books (same et al. rules as for articles)
(Cheney & Seyfarth 1990, pp. 34-43)

Edited volumes (citing just one chapter in a compilation; same et al. rules)
(Kavanau 1969)

Multiple papers
Two references for a single citation (separate, standard Bibliography entries)

Different authors (chronological order)
(Skinner 1960, Higuchi 1988)

Same author(s) (chronological order)
(Hess 1956, 1972)

Same first author (chronological in text, alphabetical order by second author in bibliography)
(Gould et al. 1978, Gould & Able 1982)

Two references with same author(s), same year (cited together or separately; if separate, first mentioned is “a”)
(Dyer & Gould 1981a, 1981b)
Sample Bibliography
[(alphabetically by author(s), chronologically for same exact author(s)]


Breland, K., & M. Breland (1961). The misbehavior of animals. Amer. Psychol. 16, 28-37.


Science Writing in EEB
Notes on grammar & style

Priorities:
Our main concern in grading your writing will be with structure and logic: does the essay or report make sense? Is it clear? Are the components logically organized?

This is not to say that style and grammar are not important. If, in fact, your writing is difficult to read, your AI will attempt to identify the key problem. If the difficulty is in ambiguous use of grammar, this guide may help. Equally critical is to take advantage of the Writing Center. The well-trained advisors there can look over the draft or assignment your AI has marked and help with the specific problem.

Certain grammatical problems almost never arise in scientific writing—the use of pronouns, for instance. This guide focuses on just a few potential trouble spots.

Grammar
“Grammar” has an arbitrary and prescriptive sense attached to it in the minds of many. In fact, all legitimate grammatical rules serve merely to resolve potential ambiguities. (Illegitimate rules—like the Victorian prohibitions against double negatives, or ending sentences with prepositions, or splitting infinitives—were invented by pedants; they largely serve to enforce regional or class distinctions.) Only a few grammatical distinctions are relevant to scientific writing.

Terms: Here is a quick review of terminology. Except in special cases, English sentences have a subject, a verb, and an object, and they appear in that order. (Special cases mainly involve either inferred subjects/objects that are evident from the context, or intransitive verbs that require no object—as in “flowers die”—since the implied object of the verb is the subject itself) If the verb is transitive, the verb tells us what the subject did to the object: “John bit the dog” means something quite different than “the dog bit John.”

Adjectives modify (describe) the nouns, while adverbs modify the verbs (and some adjectives). Clauses can sometimes substitute for subjects or objects, or provide stand-alone supplementary information, or modify subjects/objects. Prepositional phrases can modify almost anything. Nouns in prepositional phrases are inevitably objects, not subjects; this is important mainly when you are using pronouns: “I” is a subject while “me” is an object; on the other hand, this almost never turns up in scientific writing.

Parallel and Obtuse: English requires that compound sentences have parallel structures (though sufficiently complex sentences—ones that should have been divided into two for clarity in the first place—can violate this stricture in certain cases). Thus if one part of the sentence is in the present tense, a parallel part cannot be in another tense. If I say that “the dog lies on the ground and slept,” you must wonder whether I meant to talk about now (“lies”) or then (“slept”). As with most grammatical rules, the object is clarity. The difficulty arises with surprising frequency given the tendency of many or our students to add a level of pedantic formality to their scientific writing, leading to ponderous clause-laden sentences.
Singular and Plural: English requires that the verb and the subject agree as to number; whether the object is singular or plural is of no importance whatsoever. Thus “the dogs barks for the stranger” is clearly wrong because the subject is plural while the verb is singular; it does not matter how many strangers were barked at. Ambiguity here is generally restricted to a few classes of cases. In one, the subject has two singular nouns conjoined by “or”: “the dog or the cat eats the food first.” A surprising number of writers treat “or” as “and”: “the dog or the cat eat the food first.”

In the second category, the singular subject is modified by a plural adjective or phrase, and we are tempted to match the modifier: “the gist of the 100 articles is that the planet is warming” (correct), versus “the gist of the 100 articles are that the planet is warming” (wrong).

Then there is the all too common case of taking all verb conjunctions to be plural: “there’s a dozen students in this class” as opposed to “there are a dozen students in this class.” This is a somewhat rare problem in scientific writing.

Compound Adjectives: English distinguishes between two instances of multiple adjectives: those in which each adjective separately modifies (describes) the noun (“the round felt hat”), and those in which one adjective modifies another adjective (“the moth-eaten hat”). The potential for ambiguity is obvious (and thus the evolution of the distinction). The choice is easy to make: do the adjectives separately describe the noun (“round hat” and “felt hat”), or does the first adjective modify the subsequent adjective (“moth hat” and “eaten hat” versus “moth-eaten hat”). Where an adverb modifies an adjective that modifies a noun (“the building was astonishingly beautiful”), there is no hyphen (because there is no ambiguity). Given the level of detail in scientific writing, few lab reports or essays manage to restrict themselves to one adjective per sentence, so there is a potential for ambiguity fairly often.

Number versus Amount: English distinguishes between things that can be counted and things that can be continuously measured. Thus Princeton has a certain discrete number of students (6103, say), but spends an astonishing amount of money annually (perhaps $201,236,421.36). Another side of this distinction is seen in the use of “fewer” versus “less.” “Fewer” refers to things are individually counted, and thus can take a plural form when the number is more than one (as in “raindrops”); “less” indicates something that is not being counted, as in the case of “rain.” “Less calories,” despite its prevalence, is never, ever, correct. Scientific writing is so quantitative that it is almost impossible to write a paper without the question of number versus amount arising.

Was and Were: The failure to distinguish between “was” and “were” when talking about a conditional event (“I wish I were in Dixie”) removes a distinction that gives English power and grace. Though not an error that inevitably generates ambiguity, it is nevertheless unfortunate. Obviously “was” is the past tense of “is,” while “were” is the past tense of “are.” But “were” is also the conditional form of “was.” Thus we say “if I were interested, then…” for a potential situation, but “I was interested, so…” for a case of fact. Science is full of conditionals, so this is important for the writers to get right.
Style:

Rhetoric is the art of using words effectively. Without some sense of rhetoric, scientific writing is often boring and (worse yet) unconvincing. Much of rhetoric consists of organization, logic, and choice of evidence. Most of the rest depends on “style”: making wise choices in how to write. This is not a question of grammar, though grammatical terms are needed to talk about it.

Two other elements often considered matters of style (the over use of passives on the one hand and dependent clauses on the other) are frequently serious problem; they are analyzed on the separate rhetoric guide.

Punctuation:  Punctuation is to some degree an art. We can all agree that expository sentences must be complete, and that separate sentences joined at the hip by a comma (the infamous comma splice) are anathema—as, for instance, “she and her lab group performed the experiment, the tests showed that even plants need oxygen.” Each of the two sections is an independent clause—a complete sentence, with subject, verb, and object; to coexist in the same sentence they need to be connected by a conjunction.

There is a continuum of punctuational tools, ranging from commas to parentheses to dashes to semicolons to colons to periods.

Commas are used for clarity and to pace the sentence so as to recreate the spoken rhythm and emphasis you want your reader to hear.

Dashes and parentheses set off the kinds of asides or interjections you would normally indicate by a change in intonation of your voice in speech. For most experienced writers a parenthetical insertion is afforded less emphasis than one dignified with dashes—hardly a level of detail we should be worrying about.

Semicolons are the legitimate form of the comma splice, useful when the two sentences are intimately connected.

Colons usually introduce a list or a conclusion.

Punctuation is a powerful way to manipulate your listener’s ear and mind; poorly handled, however, it creates confusion. If the writing is hard to follow, check to see that the punctuation is not actively misleading.

Danglers: Clauses that do not modify what they appear to modify are another source of potential confusion. They are usually illustrated with examples in which there is no ambiguity, and so the error is painfully obvious: “Born at the age of 45, Sally was a wonderful comfort to her mother.” The dangling clause cannot modify the object of a prepositional phrase, leading us to conclude that Sally was a long time in the womb. The danger lies in danglers that are not self-evidently absurd, and thus can be taken to describe the wrong thing.

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