Name______________________________________

Handbook For
NATURAL SCIENCE SEMINAR

Warren Wilson College
Spring, 2008 - draft

Contents

RESEARCH DESIGN: SCI 390

(Morse 210) TH 4:00-5:20

Spring 2008, 2 credits

Professor: Dr. Louise (Lou) Weber
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Office Hours: Tues. and Thurs. 9:30-11:30 p.m.

Date	Topic	Required by Beginning of Class
Jan 24	Course intro	
31	Topics fair	Introductory assignment due (35 pt) Read Ch. 1
Feb 7	Writing a Yarbrough	Writing assignment due (30 pt) Read Ch. 2 & 3
14	Literature searching	Literature assignment due (10 pt) Read Ch. 4
21	Statistics - null hyp., alpha and beta	Statistics assignment due (30 pt) Read Ch. 5 **Take practice test on own**
28	Statistics - anova, Chi^2, regression, corr.	Attendance at a full session of NSS due by today (10 pt) Read Ch. 5
Mar 6	Experimental Design - sampling issues	Experimental design assignment due (10 pt) Read Ch 6
13	Experimental Design - pseudorep., confounding variables	Final topic assignment (10 pt) Read Ch 6
20	**SPRING BREAK**	
28	**Date lottery** Abstracts/bibliographio - choose presentation date for 2009 - choose presentation date for later this semester	After the date lottery we will talk about the essentials of good abstract writing and good bibliographies. Lou will have examples of the good, bad, and ugly.
Apr 3	Speaking skills	**First draft Yarbrough due** (30 pts) & Ch. 7 - Lou grades this draft, but give one to advisor too
10	optional class – test review	
17	**Exam (100 pt)** - there is no review sheet. The assignments play that role.	test on Ch. 1 - 7
24	Student presentations (25 pt) - Power Point presentation covering Intro. and Methods	Second draft Yarbrough due - hand in to advisor
May 1	Student presentations	
8	Student presentations	**Final Yarbrough due** (100 pts) - advisor grades this draft **- must turn in first draft with it**
15	Student presentations	

REQUIRED MATERIALS:
Weber, Louise (ed.). Spring 2008. *Handbook for Natural Science Seminar*, Warren Wilson College, unpublished.

GRADING (beyond what is listed on above schedule):
35 points Attendance and participation. A student must sign the attendance sheet with his or her own signature and be an active and cooperative participant to receive credit for each class. No

credit is awarded on a day in which the student is late. For all assignments the late penalty is **five points for each weekday it is late.**

ATTENDANCE: Attendance at each class within Research Design is required and vital because there are only 16 sessions. If a test, class, or work session right before Research Design runs over time, you need to leave the test and come to Research Design, then make up the test later. Attendance is required even if community meetings are taking place at the same time. The only acceptable excuses are participation in an official WWC event such as athletics, attendance at a funeral, or illnesses bad enough to see a professional health care worker. If a student misses class, it is his or her responsibility to ask another student what occurred and whether any handouts were distributed.

DROPPING: Students may add/drop until Thursday, January 24 (4:30 p.m.) and withdraw until March 28.

ACCOMODATIONS: If you have specific physical, psychiatric or learning disabilities that require accommodations, please let me know early in the semester. Documentation must be on record with Deborah Braden, Educational Access Coordinator, Dodge House, ext. 3791 or dbraden@warren-wilson.edu.

ACADEMIC HONESTY: Perhaps more than any other endeavor, science research depends on objectivity and honesty on the part of the researcher. The scientific method is entirely dependent on truth. Falsification of facts and literature cited or data, and plagiarism, cheating, or other unethical behavior could result in an F for the assignment in question or an F for the course. A letter describing the incident may also be sent to the Dean as part of a student's permanent record.

OBJECTIVES AND LEARNING OUTCOMES: The overall goals of NSS are to conduct science research, understand the research of others (not just your own), and improve writing, speaking, mathematical, statistical, computer, and thinking skills.

In Research Design by the end of this semester, successful students should have:

1. decided on a suitable senior research topic.
2. chosen a research advisor.
3. completed a comprehensive search of peer-reviewed literature on their research topic.
4. prepared a research proposal in the form of a Yarbrough Grant application.
5. been assigned a date for the NSS presentation during the senior year.
6. and learned the basics of the most common statistical techniques used in science research.

Assessment for each of the above will occur through graded assignments and one exam.

Chapter 1
Natural Science Seminar Basics
by Lou Weber

"Harm is caused unconsciously by the biographers of illustrious scholars when they attribute great scientific conquests to genius rather than to hard work and patience."
- Santiago Ramon y Cajal, Advice for a Young Investigator

What's So Great About NSS?
An undergraduate research program in the sciences is not especially unique among U.S. colleges. A dozen or more schools have organized programs like ours in North Carolina. There are whole national societies with annual conferences where undergraduates can present their work in which hundreds of colleges are represented. Several states have an academy of science with a special section for undergraduates to present annually, like our North Carolina Academy of Science, although few are as active as ours and few have a peer-reviewed journal like ours. Warren Wilson's program is not the oldest in the nation, but with its start in 1982, it is in a distinguished and mature group.

Still, understand this - most colleges do not have an undergraduate research *requirement*. It would be too time-consuming and expensive. The larger the college or university, the more unrealistic it would be to manage such a thing, with each undergraduate getting personalized advising from a faculty member. The colleges with the best and most extensive undergraduate programs are generally the smallest – like us. Combine our size advantage with the lucky fate of having a farm, forest, and river for our use and a state academy of science with a journal, and you can see a natural fit. We have had a long, wonderful relationship with the N.C. Academy of Science, their grant program, and their annual spring meeting. Warren Wilson has probably won more awards and been granted more Yarbroughs than any other undergraduate institution in the state.

One unique thing about Warren Wilson's style of undergraduate science research is the way projects are chosen and financed. At most colleges, faculty members have a research requirement, which means they get grants, which means they have students work with them on one portion. At Warren Wilson, faculty suggest projects or students think of them on their own, but these are usually not funded by the advisors' grant. Because we are so land rich and so many of the projects are focused on nature, our projects can usually be undertaken with astonishingly little money.

What Students Say About Their NSS in Senior Letters

"Overall I feel I gained the most from Natural Science Seminar. It was my favorite academic experience here. It was challenging, but well worth the work because you learn so much and end up with a finished product that is meaningful. I wish that more of the classes at Wilson were like the NSS."

"My Natural Science Seminar was highly rigorous, but well worth the work. I learned what it really takes to be a research scientist, but more importantly I learned that *I* have what it takes to be a research scientist."

So what good is this research? Have we characterized any new stars, saved any endangered organisms, or discovered any new species? A review of the abstracts (go to Class Web Pages/Natural Science Seminar) reveals that there have been some surprising successes and a summary would make an interesting project. The main advantage, however, has been to the individual student.

More than any other thing, what students learn from NSS is how to put together a complex project. This is a skill that will be required of our graduates repeatedly in their professional careers. Whether the destination is graduate school, a regular job, or even a volunteer position of leadership, projects become the focus. Months of research are required both through written literature and data gathering. Extensive planning and a money-gathering are necessary. After the research is collected, data analysis often with statistics must be completed. A Power Point and a manuscript are due eventually with graphs and conclusions. This sounds like NSS.

Overall, what students gain from NSS is courage to undertake a multifaceted project, vision for organization, and confidence in knowing that complex problems can be broken down into manageable parts. Our graduates often amaze their bosses and graduate school mentors by being able to take on so much so soon after graduation. One graduate was even asked to teach a research design seminar at Yale while a graduate student because of his NSS experience.

But wait; there's more. The NSS also gives students a chance to earn Honors at WWC (see insert box on a subsequent page). It also provides a chance for publication which might be a ticket to graduate school. It also gives participants exclusive membership in the NSS Club.

Unusual Titles from Over the Years

The Efficiency of Illegal Stills

The "Whoosh Effect" the contribution of Toilet Flushing to the Spread of Fecal Coliforms

A Comparative Study of the Antibacterial Effects of Pink Soap and Blue Soap used at WWC

Ichnologically Determining Velocity of *Homo sapiens* or How Fast did that Guy Go?

Hair Straightening and Its Effect on Hair Fibers

More titles can be found at Class Web Pages/Natural Science Seminar

Membership in the NSS Club and History of the Seminar

What's the NSS Club? Yale has the Skull and Bones Society; Harvard has the Monogram Club. Maybe we should call those who have completed an NSS the members of the Wise Owl Club. It is an exclusive group with a long history, but it is not secret. From fall, 1988 through fall, 2007 there have been 525 students who presented, and there were probably at least 75 before then.

Here is the history, according to Dean Kahl. (If this were Yale you would probably be expected to memorize this and chant it on demand. We'll forgo that.) The Division of Natural Science and Mathematics initiated the Natural Science Seminar in the fall of 1982 at the suggestion of Alan Haney and himself. The seminar was an outgrowth of Bioseminar, founded by William Penfound in 1975, which included summary reports of primary literature and original student or faculty research. Participation was broadened to include chemists, ENS majors, mathematicians, and physicists in the first Natural Science Seminar presentations in 1982. They involved either a summary of published literature or laboratory and field research. However, the summary of literature option was rapidly phased out to eliminate superficial descriptions of summer travels. This launched the format in effect today.

The titles and abstracts have been stored on-line since 1996. They can be found from the Inside Page by clicking on Class Web Pages, then Natural Science Seminar. The database is maintained by Dr. Donald Collins and a copy of this manual is also at that site. In 2000 Power Point began to be used regularly, and students were required for the first time to submit a paper to accompany their presentation, a copy of which is stored in the archives.

A review of the titles shows that water quality, especially of campus waterways, has probably been the single most popular subject. Other popular topics include campus cattle, pigs, chickens and their parasites, prescribed burns, shitakes, and bittersweet, fractals, astronomy, and alternate fuels, and wild animals especially fish, birds, salamanders, frogs, sea turtles, and small mammals. There have also been hot topics that have come and gone; there was the beetle phase, the aquaculture phase, the mole salamander phase, the phthalate phase, the bluebird box phase, the Northern Cardinal phase, and the fractal phase. Now we seem to into heavy metals, GIS, tardigrades, herbal extracts, lipids in meats, and large mammals on campus.

Requirements for Honors

Students in Biology, Chemistry, and Environmental Studies may receive Honors, which entitles the awardee to wear a yellow scarf with the graduation gown during commencement and to receive this scarf at a ceremony just before commencement. Awardees also get special mention in the graduation day program and have Honors officially noted on formal records from WWC. The awardee then has the privilege of including it on future resumes and job applications. To receive Honors students must apply to their department chair during the final semester before graduation and:

1. Achieve a 3.4 QPA for courses required in the major and an overall 3.0 QPA.

2. Pursue a research project involving original laboratory or field work or an original analysis, synthesis, and evaluation of primary source material.

3. Identify the research project during the junior year by preparing a well-documented proposal which, if applicable, is submitted to the North Carolina Academy of Science (NCAS) or other source for funding.

4. Present the completed project including a formal written research report in a form suitable for publication to the Natural Science and Mathematics Research Communication class and earn a course grade of A- (90%) or better.

5. Present and defend the research report in a professional forum in addition to the Natural Science Seminar (e.g., the NCAS Conference).

6. Receive final acceptance for Graduation with Honors which is contingent on an approval vote from the faculty of the student's major.

An NSS in Four Easy Pieces

The NSS process begins with **Research Design** (SCI 390), which is a course is for juniors (at least 60 hours completed). Those who take Research Design in spring 2008 are expected to choose a research advisor (which may be separate from the academic advisor) and present their seminar in spring 2009. In other words, taking Research Design locks a student into presenting the research one year hence (unless a student goes abroad or has another unusual circumstance). That is why this course is not generally recommended for sophomores. Research Design is not a course in experimental design as much as it is a course that launches the senior project. For that reason it is probably misnamed. At any rate, sophomores do not generally have enough experience to start a senior project if they have not completed Chem. I and II or if they do not have experience in upper division courses. Research Design is graded mainly by the professor teaching the course except for the final draft of the Yarbrough proposal, which is graded by the student's, research advisor.

So what's a research design? By definition it includes (note to self, this will be on the test): identifying a research question, developing a sampling protocol, planning statistical analyses, calculating research costs, and projecting a time frame. Design of research is necessary because too many experiments have been conducted with inadequate attention to planning. Without it, enormously hard work can sometimes yield data that is unusable to test a hypothesis.

The second required course is **NSS Research** (SCI 486). It must be taken for at least 2 credits and is graded by the research advisor. It is generally taken second semester junior year and/or first semester senior year, and includes at least 80 hours (not credit hours) of real time work. One credit may be taken at a time. Students may register for more than two credit hours overall if they complete more than 80 hours, but credit hours must be awarded during a term or semester which might mean going over 18 credits. There are no summer transcripts at Warren Wilson. You *cannot* register on-line for NSS Research. Instead, a form much like an Independent Study form is available from the Registrar's Office to enroll. Students fill out the form with their advisor during the add/drop period and turn it in to the Registrar.

The third required course is **NSS Attendance** (SCI 491), which is worth 0.5 credits and graded by Don Collins. Attendance cannot be taken in the same semester as SCI 493 (Communication) when the student presents. It may be taken any other semester, even as a sophomore or first-year. All that is required is filling out forms each Monday as the student listens to the speakers and evaluates the talks.

The fourth required course is **NSS Communication** (SCI 493). During this semester a student presents his or her research on one date during a 25 minute period, speaking for 20 minutes and leaving five minutes for questions. A formal written, scientific paper describing the research is also required towards the end of SCI 493. Both the talk and the paper should include an Abstract, Introduction, Methods, Results, Discussion, Acknowledgments, and Literature Cited. The presentation itself is graded by the faculty in attendance at the talk. The median grade of the presentation is 50% of the grade for the semester. The paper is worth the other 50% and is graded by the research advisor.

Students must have a passing grade in each of the four courses to obtain a major in Biology, Chemistry, and some concentrations in Environmental Studies (Conservation Biology, Environmental Chemistry, Sustainable Forestry, Sustainable Agriculture). The four courses are required to get a minor in Chemistry. Requirements for CCII are met upon completion of all four courses.

Requirements for a topic

Topics must be original, lend themselves to a comprehensive search of current peer-reviewed literature, involve at least 80 hours of attentive research outside of class before the NSS presentation, and involve collection and interpretation of data through field study, laboratory work, or interpretation of archival data banks.

Topics should be sufficiently sophisticated to reflect a depth of learning from several college science courses, but general enough to allow an understandable explanation when presented to college seniors. The researcher must present an objective or a hypothesis to be tested or a stated problem to be investigated, and is expected to follow the scientific method or methodologies. A Warren Wilson advisor (see insert) must be selected from the official list of participating faculty. Research completed during an internship or study abroad often have an on-site advisor, but there must also be an advisor of record at Warren Wilson who will issue grades and advise the student. The participating faculty will present ideas for research to students in the second week of the semester during the Research Design course in what we call a "Topics Fair."

Participating Faculty Research Advisors

Paul Bartels – tardigrades, invertebrates, field zoology

Amy Boyd – field botany, evolution

Mark Brenner –ecology, aquatic ecology/pollution, environmental chemistry, pollution, fungi

John Brock – environment. chemistry., analytical chemistry, public health, phthalates, toxicology

Vicki Collins - chemistry, animal nutrition, environmental chemistry

Don Collins - physics, astronomy, instrument design

Bob Eckstein - animal behavior, animal welfare, veterinary medicine

Dave Ellum – forestry, herbaceous plants on the forest floor

Vicki Garlock – takes Psychology Department majors only.

Jeff Holmes - genetics, microbiology, cell biology

Karen Joslin – gardens, cultivation

Dean Kahl - environmental chemistry, organic chemistry

Laura Lengnick – sustainable agriculture, soils

Michael Torres – genetics, botany

Lou Weber - ornithology, conservation biology, wildlife management, animal ecology

Natural Science Seminars involving the WWC Farm or Garden

Projects that require cooperation or assistance from farm or garden personnel have special requirements that require the completed form below. Students should consult with farm and garden personnel early in the idea phase to get permission for an idea, then should stay in good communication with the advisor and farm/garden staff as the proposal takes shape. The completed form must be turned in with the proposal in Research Design.

Contract for Research Projects Involving Farm/Garden-*to be turned in with proposal*

Student____________________ Phone___________ CPO_________ Advisor____________________	Starting Date	Ending Date

Purpose of Research (one paragraph here plus attach proposal from Research Design)

Costs (feed, labor, fencing, plowing, etc.)	Estimated Cost	Source of Funds	Initials of Resp. Party

Resources required (area of land, number and type of animals, greenhouse use, etc.).

Preparation required (diet mixing, plowing disking, mulching, greenhouse conditions, etc.). Indicate appropriate dates needed, provisions for end of experiment, and who will be responsible for each prep (on a separate piece of paper).

Who will be responsible for data collection? Include signatures for all persons included. Attach samples of data collection forms.

Signatures Farm or Garden Work Crew

Supervisor_________________________ Student ______________________

Advisor __________________________

Timeline for the Three Semesters of NSS

Sophomore, Junior, or Senior year

- ☐ register for SCI 491 (NSS Attendance). Remember that SCI 491 and SCI 493 (NSS Communication) cannot be taken in the same semester.

Semester I of NSS (first or second semester of junior year)

- ☐ enroll in SCI 390 (Research Design).
- ☐ decide on a suitable research topic.
- ☐ choose a research advisor and begin meeting regularly.
- ☐ complete a comprehensive search of peer-reviewed literature for the research topic.
- ☐ prepare a research proposal in the form of a Yarbrough Grant application.
- ☐ acquire a date for the NSS presentation during the senior year.
- ☐ consider submitting a Yarbrough Grant application to the North Carolina Academy of Science. The deadline is in early April. Awards are announced in May or June.

Semester II of NSS (second semester of junior year or first semester of senior year).

- ☐ consider signing up for SCI 491 (NSS Attendance). Remember that SCI 491 and SCI 493 (NSS Communication) cannot be taken in the same semester.
- ☐ meet regularly with the research advisor.
- ☐ consider registering for SCI 486 (NSS Research). Two credits are required although they do not have to be taken in the same semester. Begin completing at least 80 hours of research. This could also be done in the summer between junior and senior year, but credits can only be officially registered during the academic year.
- ☐ analyze data and begin writing talk as research is completed.
- ☐ consider submitting a Yarbrough Grant application to the North Carolina Academy of Science. The deadline is in early April. Awards are announced in May or June. Awards are generally $50-200. Other grants applications may also be appropriate. See section in web edition of this book for more information on grant opportunities for undergraduates.

Semester III of NSS (first or second semester of senior year).

- ☐ sign up for SCI 493 (NSS Communication) if presenting or SCI 491 (NSS Attendance) if not already completed. Remember that SCI 491 and SCI 493 (NSS Communication) cannot be taken in the same semester.
- ☐ During the first week of the semester, discuss your title with your advisor before submitting it to Don Collins. Remove all junk words and follow the other suggestions for good titles.
- ☐ have all data analyzed and finished at least two weeks before presentation.
- ☐ talk to advisor about basic outline of presentation.

Three weeks before presentation

- ☐ prepare initial slides on Power Point and show them to the advisor.
- ☐ type up first draft of abstract and bibliography and show it to advisor.
- ☐ write a written script on paper and go through it on own.
- ☐ turn in first draft of written document to the advisor. A draft of the final paper is due to the advisor no later than Week 12 of the semester in which the student is presenting. Two copies of the final paper are due to Don Collins by the end of Week 14. One copy will go to the archives.

One week before presentation

- ☐ make slides and have speech ready .
- ☐ practice in front of faculty advisor.
- ☐ show abstract and bibliography to advisor for final approval.
- ☐ submit the abstract via e-mail (or diskette file - Microsoft Word for Windows) to Don Collins for appearance on the World Wide Web.

Three days before presentation

- ☐ redo any slides that need editing.
- ☐ practice presentation at least five times.
- ☐ make 50 copies of corrected abstract and bibliography.
- ☐ A draft of the final paper is due to the advisor no later than Week 12 of the semester in which the student is presenting. Two copies of the final paper are due to Don Collins by the end of Week 14. One copy will go to the archives.

After presentation

- ☐ submit written document to your advisor.

Spring semester of senior year

- ☐ Give presentation at North Carolina Academy of Science (generally last week in March). This is a requirement for those awarded a Yarbrough Grant.
- ☐ Consider submitting a revised final paper to the Journal of the North Carolina Academy of Sciences or another journal for possible publication.
- ☐ Consider applying for Honors.

<u>Introductory Assignment </u>***** Name**

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Read Chapter 1 and answer the questions below. Answers and hints for the basic math and science review may be found towards the back of the book.

<u>From Chapter 1</u>

1. **Have you taken NSS Attendance yet? If so which semester? If you have not taken it, which semester do you plan to enroll?** You are not going to put it off until the same semester you present your NSS are you, because that will not be allowed and will prevent graduation.

3. **When do you plan to take two credits of NSS Research?** You do not need to take both credits in the same semester, but you can only take these credits after you complete substantial work on your project. If you go over 18 hours in one semester you will pay a penalty of approximately $400 per credit hour. Forty hours of real time is equal to one credit hour of NSS Research. You will receive a letter grade for your work. If you do not put in the work, you *will* be graded appropriately.

4. Read through the requirements for Honors. **Do you plan to apply? Yes or No (circle one).**

5. **Is there a possibility that your project will be in the college vegetable garden or on the farm?** If so, read through the permission form in Chapter 1.

6. Make a list of possible topics that you are thinking about. To brainstorm ideas, consider reading through titles and abstracts of past senior research projects for Warren Wilson and UNCA or other colleges you find on-line:

---- The WWC page can be found by going to Class Web Pages, then Natural Science Seminar.

Basic math and science skill review. Use a pencil. Answers and hints are at the back of the book.

7. Circle the letter of the correct way(s) to type genus and species.

a. Homo sapiens
b. *Homo sapiens*
c. Homo sapiens
d. Homo sapiens
e. *Homo Sapiens*
f. Homo sapien

8. In longhand printing, write the genus and species epitaph for human beings using correct capitalization and nomenclature rules. Please remember that one cannot italicize in longhand. Underline properly instead.

9. What are the major divisions within the Linnaean classification system? Fill in the rest of the words.

kingdom,__________________, class,______________ ,________________, genus,___________ .

10. The genus name for mosquitoes is *Aedes*. *Aedes* spp. refers to what? *Aedes* nsp. to what?

11. Write the plural of genus.

12. Write the singular of species.

13. What is the difference among a glossary, index, and table of contents?

Fill in the blanks with the correct answers **using pencil** and **without** a calculator. (Based on Keck and Patterson 2000.)

	fraction	decimal	percentage
14.	$\frac{1}{5}$	______	________
15.	______	0.667	________
16.	______	______	33%

Metric System: fill in the blanks of the table where it is marked, "fill in."

Prefixes		Exponentials
1/1,000,000,000,000	pico (p)	10^{-12}
1/1,000,000,000	nano (n)	← **fill in**
1/1,000,000	micro (mc or um)	**fill in**
1/ ← **fill in**	milli (m)	10^{-3}
1 / 100	centi (c)	10^{-2}
1,000	kilo (k)	10^{3}
1,000,000	mega (M)	**fill in**
← **fill in**	giga (g) billion	**fill in**
1,000,000,000,000	terra (T) trillion	**fill in**
a thousand trillion	peta (P)	**fill in**
a million trillion	exa (E)	**fill in**

17. **Examine the metric conversion table below, memorize it, and notice something important** about the abbreviations for units. When using the English system, there is a period after the abbreviation as in **ac.** or **gal.** or **oz.,** but there is no period after metric units as in **kg** or **m** or **ha**, got it?

Length		
1 mm	= 1000 um	= micrometers
1 cm	= 10 mm	= millimeters
1 m	= 100 cm	= centimeters
1 km	= 1000 m	= meters
Mass		
1 mg	= 1,000,000 ng	= nanograms
1 g	= 1000 mg	= milligrams
1 kg	= 1000 g	= grams
1 metric ton	= 1000 kg	= kilograms
Volume		
1 L	= 1000 ml	= mililiters
1 m^3	= 1000 L	= liters

Conversions to memorize	
Length	**Volume**
1 in. = 2.54 cm	1 U.S. gal. = 3.8 L
1 mile = 5,280 ft.	1 U.S gal. = 4 qt.
6.2 mile = 10 km	1 barrel oil = 168 qt.
1 yd. = 3 ft.	**Mass**
Area	1 lb. = 16 oz.
2.5 ac. = 1 ha (hectare)	1 oz. = 28.4 g
640 ac. = 1 mi^2	1 ton = 2000 lbs. (pounds)
1 ac. = approximately 1 football field	1 kg = 2.2 lbs.

Convert the units in the questions below. Use the method seen below to cancel units. Put a box around your final answer and **show all work** (McConnel and Able 2008).

$$3.6\ \cancel{m^3} \times \frac{1000\ L}{\cancel{m^3}} = \boxed{3600\ L}$$

18. How many micrometers are in a meter?

19. How many centimeters are in a kilometer?

20. How many grams are in a ton?

21. Express the weight of a 135 lbs. person in kilograms.

<u>(From Keck and Patterson 2000.) Use the hints in the back of the book to check yourself.</u>

22. Write the following numbers in scientific notation (e.g., 8.95×10^3).

467000 =

0.00000034 =

410.9×10^{-4} =

23. Convert 2.76 mm to (a) nm, (b) micrometers, (c) cm, (d), m, and (e) km. Express your answers as decimals first, and then in scientific notation.

24. How many significant digits are in each of the following? Use hints the back.

6.02332×10^{23}

5.16

4.20

900

25. Calculate the answers using the correct number of significant digits and round off correctly.

$\frac{10.8 - 3.5}{2.19} =$

$3.72 + 11 + 9.3 =$

26. Compute the following by hand, showing the correct number of significant digits, of course, and show your work.

$(3.0 \times 10^8) \times (-2.0 \times 10^2) =$

27. Fill in the blanks. $a^0 =$ __________ $7.3 \times 10^0 =$ __________

28. Compute the following by hand (no calculator) and **write in scientific notation** with the correct number of significant digits and rounding. Show your work.

$\frac{1.76 \times 10^5}{1.73 \times 10^1} =$

$(4.56 \times 10^3) + (5.90 \times 10^3) =$

$(7.81 \times 10^{-2}) - (8.42 \times 10^{-2}) =$

$(6.84 \times 10^8) + (5.00 \times 10^6) =$

29. Convert the following using a method in which you cancel units. **Make sure you signify units in your final answer.**

32.87 inches to centimeters. **Show your work**.

72 miles per hour to feet per second. Show work.

7,800,000 kilograms per cubic meter to grams per cubic millimeter. Show work.

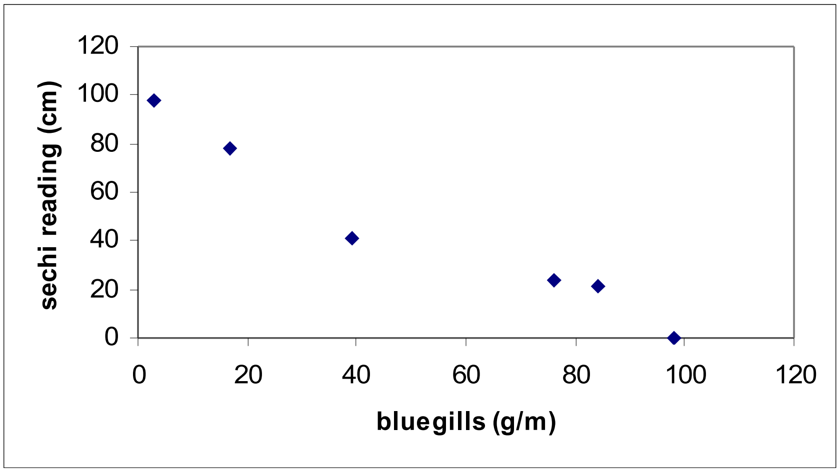
30. Calculate the following:

$\frac{11}{0} =$

$\frac{18{,}356{,}543 \times 10^{-78356}}{0} =$

Graphing Review:

31. On the line beside each graph, write whether it is a **scatter plot, bar graph, or histogram**.



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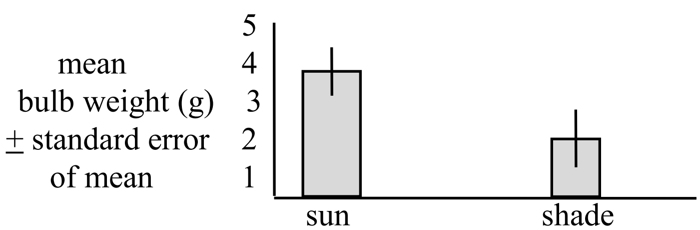

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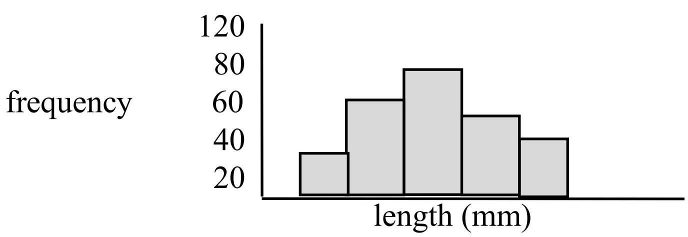

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Laws of Graphing

1. Always label the axes.

2. Always write the units on the axes.

3. Always write what the error bars indicate if there are error bars.

4. Make the graph as simple as possible while still conveying the appropriate results. Three dimensions, colors, and extraneous lines should be avoided.

5. A title on the graph is often NOT necessary and can be distracting. Sometimes the title expresses what is on the horizontal (x) axis. If this is the case, the horizontal axis label does not need to be written again.

6. Remember that many people are colorblind. Avoid using colors to indicate differences. Use hatching or line patterns instead.

7. A figure caption should be under the graph. Include if, what, when, where.

8. Indicate the number of replicates (n) somewhere on the graph or in the caption.

9. Pie charts are nothing more than bar graphs in a circle. They are used in place of bar graphs when the categories have no logical sequence and the publisher needs to save space (like in a newspaper). They are more difficult to read than bar graphs. The main problem is they cannot be read as precisely, so natural scientists use bar graphs. Leave the pie charts for the front page of *USA Today*.

10. Use these laws for every graph drawn in this course.

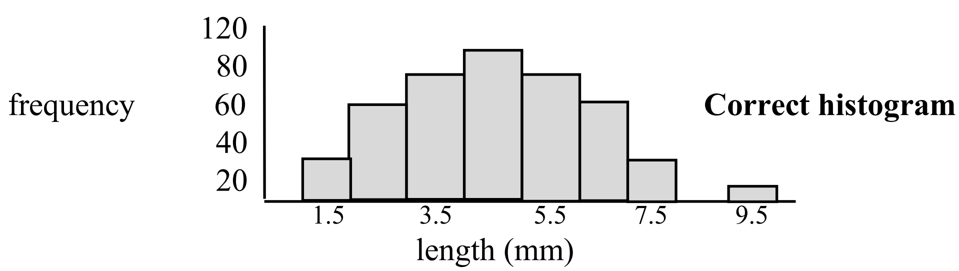
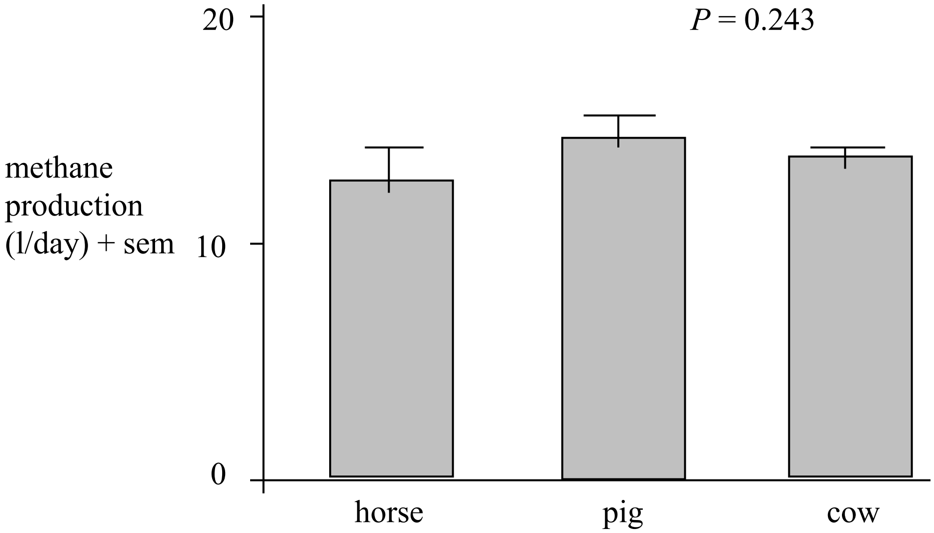


Figure 1. Frequency histogram for length of polychaete worms in exclosures at Yawkey Wildlife Center, South Carolina.

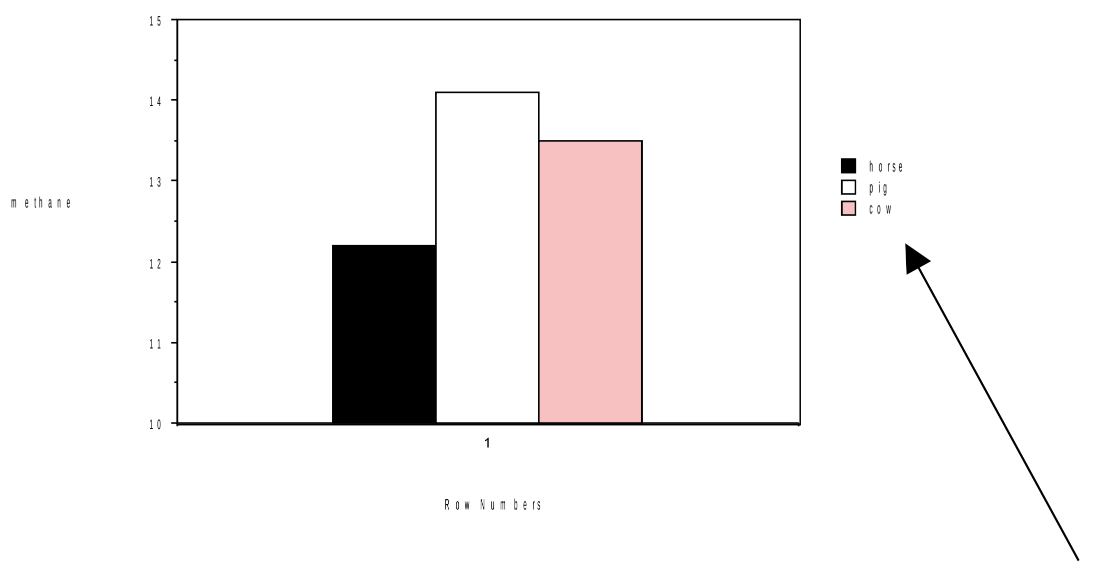
Note the following about histograms:
- each bar represent a range of values,
- there are no gaps between bars,
- values on the x-axis show the mid-points of the range.



Correct bar graph

Figure 2. Methane production by type of farm animal (n = 5) at Warren Wilson College when fed standard diets administered for six weeks during spring 2006.

Incorrect



legend

Note the following errors on the incorrect graph.

- Graphs should usually not have a legend, nor should they have separate colors or patterns under usual circumstances.
- The x-axis label makes no sense and is too small. This is due to incorrect data entry format.
- The y-axis label should be specific and have units.
- There are no error bars on the graph.
- The y-axis should always start at zero on bar graphs. Otherwise it distorts the differences between the treatments.
- There is no caption.

Correct line graph format

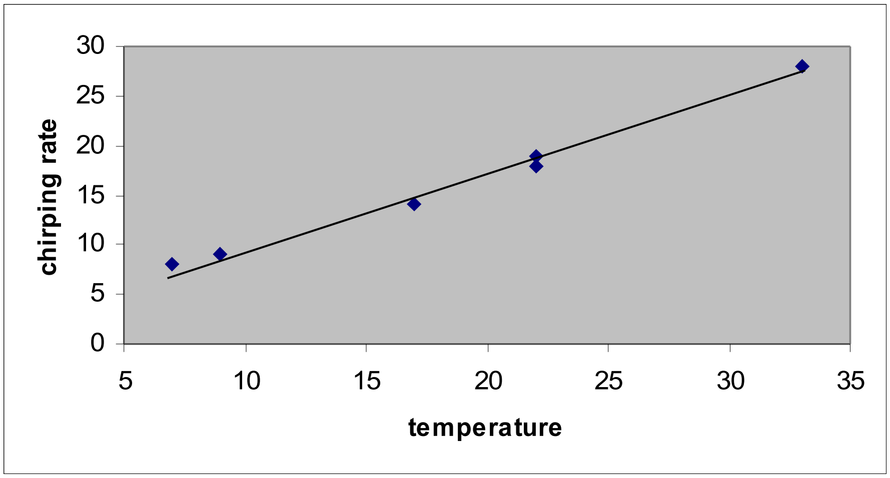
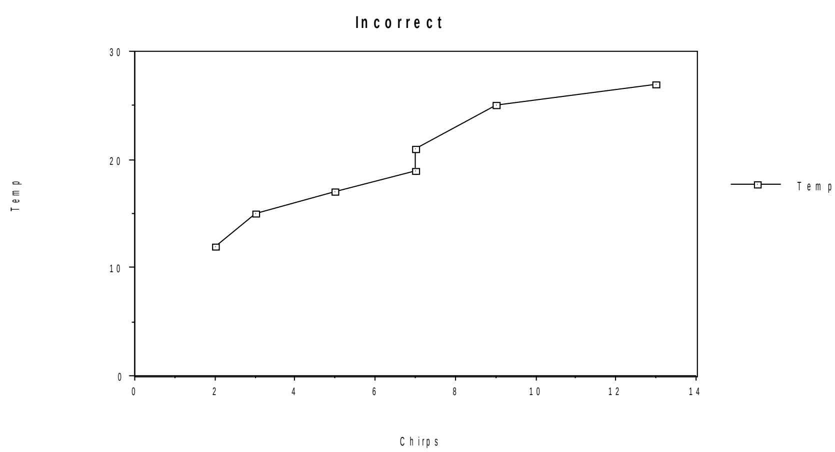


Figure 3. Chirping rate plotted against temperature for field crickets when measured in May at Warren Wilson College in Buncombe County, North Carolina.

Note the following for line graphs

- independent variable is continuous data (e.g., temperature).
- a line graph is used for showing changes with two variables as in correlation and regression.
- there is no need to start the axes at zero.



Note the following errors

- For regression and correlation, the dots should not be connected. Instead, there should be a straight line of best fit. For line graphs that are not regression or correlation, connecting the dots may be appropriate.
- The y and x axes are backwards. The dependent variable should always be on the y-axis. Because we are determining whether the number of chirps depends on temperature, chirps is the dependent variable.
- There is no need for a legend because there is only one line.
- For a line graph there is no reason to start the temperature axis at zero.
- The units should be given for each axis.

- There is no caption.

32. While adhering to the laws of graphing and correct format, draw a scatter plot with the information below, placing elk on the y (vertical) axis.

Elk seen per 10 km	Average elevation (m)
0	300
0	613
2	1294
3	1567
5	2005
5	2305
0	3700
0	3819
0	3900

33. In your scatter plot, which is the independent variable and which is the dependent variable?

34. While adhering to the laws of graphing, draw a bar graph with the information below.

Parasites per 10 cm^2	
roughed bark trees	smooth barked trees
6	3
7	0
3	0
4	1

Darren says:

- "I'll be able to learn new presentation skills and research processes in Research Design."
- "A review of grammar, writing, statistics, and presentation will teach me a few new tricks."
- "I'm looking forward to the feedback I'll get on my writing at the 300 level. My other writing course was only at the 100 level."
- "All the drafts I'm expected to do will help with my organization problems."

Dufus says:

- "This is only a two credit course. I'm not going to work hard."
- "I'm going to sign up for Research Design, even though I plan on missing every class because of basketball and community meetings."
- "I don't want to learn to write and talk like an edjucated person."
- "This course should be graded on your topic, not your abilities."
- "I don't believe in the scientific method."

Chapter 2
Choosing a Topic
by Lou Weber

"Looking back, I think it was more difficult to see what the problems were than to solve them."
Charles Darwin.

"Finding the right question is often more important than finding the right answer."
Magnusson and Mourao.

Even for Charles Darwin, one of the hardest tasks was asking a good question. Luckily, we have several ways to help Research Design students with this effort:

- get ideas from the topics fair in Research Design,
- look through the list of past NSS topics (found on NSS website under class web pages), or look at the website for projects at UNCA,
- read journals on topics that are of interest to you,
- look through textbooks and laboratory manuals,
- ask an advisor for ideas,
- participate in an Environmental Leadership Center summer internship,
- or walk around outside in nature with careful observation and ask, "I wonder why . . . ."

As you select a topic, keep in mind that it must be original and involve field study, laboratory work, or interpretation of archival data banks. Topics should be sufficiently sophisticated to reflect a depth of learning from several college science courses, but general enough to allow an understandable explanation when given to college seniors. Beyond these guidelines, students should heed the following.

Hints for selecting a good topic and being successful

1. **Realize this is not your advisor's project.** Advisors can answer questions and make suggestions, but in the end this is your project. You are the one responsible for the project's success or failure and its grade. Your advisor serves not only as a mentor but also as the primary grader. It is as if the advisor serves as both consulting attorney and presiding judge. The advisor is responsible for 35% of the grade in Research Design, 50% in NSS Communication, and 100% in NSS Research. Their grades reflect not only the final product but the initiative and hard work the student has shown throughout the yearlong process. The grades will be assigned according to a student's performance compared to other students the professor has mentored.

2. **Realize that you will need the help of an advisor and this should be someone on the officially designated list of NSS science advisors.** Occasionally students ask whether professors outside the sciences are allowed to advise. This arrangement is usually too great an imposition and impractical. NSS advising is a very large commitment. The science faculty are awarded course credit for it, want to advise students, and attend the seminars regularly. They are in the best position to advise. Faculty outside of the sciences could be consulted by students on occasion, but generally should not be expected to serve as advisor.

3. **Realize that the officially designated advisors have limitations too.** First of all, advisors can only take a maximum of five advisees per year. Second, they are limited in their expertise.

You will get the best advice on a topic that is within their expertise. Choosing a topic outside of their area is risky and may not be a great strategy for success.

4. **Realize that projects suggested during the Topics Fair (in week 2 of the course) are some of the most feasible and are within the advisors' areas of expertise.** In other words, the projects presented at the Topics Fair often lead to some of the most successful seminars, because they are ideas that have been vetted. They are the ideas the advisors think are the most feasible in their experience, and the ones for which they have the energy and expertise to advise. Students are welcome to think of their own, but they might not be as feasible.

5. **Realize that the most successful students set up regular, weekly appointments with their advisors.** Experience shows that this single practice is often worth a letter grade. Take advantage of the advisors from the earliest stages of brain-storming to advice on keyword combinations during the literature search, to drafting the final paper. Students who wait until just before topics are due without regularly seeing an advisor are getting off to a bad start, and those who do not go through drafts or plan their analyses all alone often compromise their grade.

6. **Realize that you must have the expertise to complete a project.** You do not have to know everything about a topic, but you must know the basics. One big problem is with students who want **to measure heavy metals or small quantities, but have taken very few chemistry courses and do not know how to use the chemistry instruments**. Students should not expect the chemistry professors, especially those who are not your research advisor, to provide private tutoring in using the mass spectrometer and the ICP at Western Carolina University. Those who have taken the appropriate courses in analytical or organic chemistry are best suited.

7. **Realize that you will be expected to complete this project and present it in one year.** Research Design essentially locks you into a presentation one year hence. Students should choose a topic that is appropriately scaled to a yearlong undergraduate study. It is not a master's degree project. Unlike graduate students, Warren Wilson undergraduates take more courses and have work and service requirements. NSS is worth 5.5 credits. This is approximately the equivalent of one course. Students often put too much work into their project and it diverts them from other commitments their senior year. Aim to complete 80 hours of work beyond Research Design and then stop. Try to think of a simple, testable, elegant question, then stop, without dong something open ended.

8. **Realize that your project will require far more than data collection.** According to Ratti and Garton (1996), most novice research biologists are anxious to initiate data collection because of the attractiveness of working outdoors or the pleasure of observing their study subject. Avoid rushing the design phase simply to initiate fieldwork more quickly. Many successful research biologists spend approximately 40% of their time in design and planning phases, 20% in actual fieldwork, and 40% in data analysis and writing publications. Veteran research biologists can attest that the enjoyable and rewarding portion of research comes from results after fieldwork.

9. **Realize that at some point during this project you will procrastinate, go down a dead end, make a mistake, lose something, forget something, or have a writing block.** Allow at least 25% more time than you think you will need.

10. **Realize that a myth-busters type approach can lead to a great question.** Some of the best seminars have tested wives tales, urban myths, and ideas we take for granted. Do seeds

grow better when planted under a full moon? Do seeds grow better when combined with spit and watered with fluids used to wash the feet? Listen for intriguing questions of this type among your friends and family or watch the television series, *Myth Busters*, to stimulate your thoughts.

11. **Realize that if you want to be an important scientist, do important science**. While the myth-buster approach is fun, you do not want to be flaky. Topics with practical significance for serious contemporary problems are ultimately the most interesting to most people. Seek a balance.

12. **Realize that you must be able to do a literature search on the topic to find out what has been done before.** Completing a literature search should be a serious consideration even in the brainstorming phase. Students tend to underestimate the value of accessible literature.
At least 12 recent peer-reviewed articles or books on your topic should be available. If you cannot find at least five, you are probably going to have a hard time writing an Introduction. You must have a college level topic with facts acquired from peer-reviewed sources. The scientific method depends on researchers gaining from the experience and ideas of others. Likewise, students should not depend on literature in another language or articles not easily accessible.

13. **Realize that some questions are impossible to answer at the present time.** A researcher may try so hard to answer a question that he or she may get an ulcer, end a marriage, or have a nervous breakdown, but none of this will answer the question. If funds and equipment are not available, or no known research techniques are available to answer the question, it is time to find another topic. Deep sea exploration, radioactive isotopes, and manipulation of infectious pathogens are not going to be possible at Warren Wilson. These are what I call **pitfall topics**.

14. **Realize that you must keep yourself and others safe**. Warren Wilson College is not going to allow students to use venomous snakes, explosives, or rabid dogs, although all three have been proposed - more pitfall topics.

15. **Realize that studies requiring a great deal of observations at night are impractical.**

16. **Realize that experiments involving the manipulation of human subjects are almost impossible.** There are severe legal limitations when it comes to doing experiments on humans. A legal document called an IRB must be filed although observational studies might be possible without it. Ask your advisor (or John Brock or Vicki Garlock) and take this issue very seriously.

17. **Realize that you must get permission to do a project on the college farm or garden and that large manipulations are not going to be possible**. You must fill out the farm/garden permission form before starting a project there.

18. **Realize this is Natural SCIENCE Seminar.** The topic must follow the scientific method or methodologies. We do not allow topics that are mostly politically or economically-based. Having said this, the project does not have to be an experiment. An observational study that uses the scientific method is acceptable. Any study that uses statistical tests like t-test or Chi-square has used the scientific method, but statistics are not required as long as another hypothesis has been tested. Any study that tests a hypothesis is using the scientific method. Those wishing to do a project that is not about natural science should consider Integrative Studies.

Advice for a Young Investigator

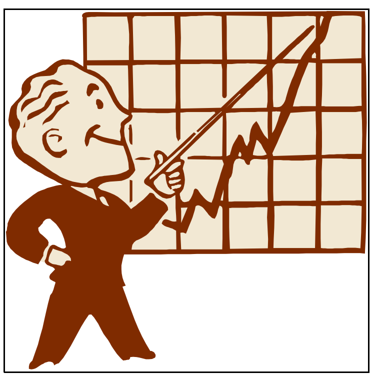
from Santiago Ramon y Cajal, Nobel Prize winner from Spain, 1897. He wrote a priceless little book with the title above, "*for serious young scientists to increase their love for laboratory work*." The book is in our library and can be read in an hour or two. Why not check it out?

The turtle may pass the hare.

Almost anyone of normal intelligence could become a productive scientist.

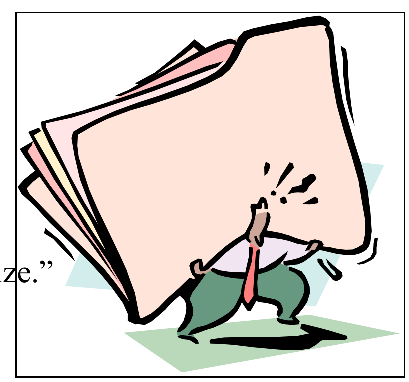
The ideal university would be a monastery with monks consecrated for life to the study of nature.

Focus one's efforts on one or two interests rather than many. Focused interest in a single research issue is like sharpening a single-edged sword until it cuts efficiently. Adding more cutting edges would progressively diminish such a sword into a dull bludgeon.



Gallant says:

- "This course in combination with NSS attendance helped me see the entire process and inspired me for my project."
- "The development of my NSS has helped me think critically about how we find things out."
- "This course took fear and pressure off of NSS."
- "I'm going to sharpen my pencil."



Gufus says:

- "I'm going to do my assignment five minutes before class and plagiarize."
- "This course should only be for those getting a B.S. The scientific method will not benefit my life."
- "I'm not going to listen to any NSS speakers during the first term. Instead, when it comes time to hand in the speaker assignment, I'm going to beg, plead, and make excuses."
- "I'm going to be messy when I do assignments."

Chapter 3

Science Writing: Grant Application, Final Research Paper

by Lou Weber

"The secret of good writing is to strip every sentence to its components. Every word that serves no function, every long word that could be a short word, every adverb which carries the same meaning that is already in the verb, every passive construction that leaves the reader unsure of who is doing what should be removed." Willian Zinsser, *On Writing Well*

Writing is not easy, and usually does not get much easier with experience because the complexities or length of the manuscript increase over time (Magnuson and Mourao 2004). The details can be annoying, but writing is one of the most powerful things an animal can do. The ability to document, synthesize, and display, transcends time when it is in writing. It creates a relationship with an audience one may never see, but may have a profound influence on them. It may teach something that will be remembered for a lifetime, or communicate with people far after the writer is dead. It is as magical as clairvoyance! The power of the web and its ever-widening audience makes this even more true – and obliges us to even more responsibility to become good writers.

Some simple rules in this chapter for science writing along with practice will improve proficiency. Writing required for the NSS includes a Yarbrough grant application due within Research Design, an abstract due just before the presentation (for publication on the course web page), and a manuscript of the student's final work. The latter is submitted during the semester of the presentation. In addition, each student should consider submitting his or her work for publication especially to the Journal of the North Carolina Academy of Science. Please note that the NCAS is *not* the only place where one may apply for money, or publish an article. Sources of grant monies can be found in a list on the Biology Department web page.

Yarbrough Grant Application

A draft of the Yarbrough grant application is required within Research Design. Three examples from past students are included in the back of this book. To actually submit a proposal to NCAS, Natasha Shipman (BIO/ENS Crew Supervisor) will collect them in early April. She will send all applications from WWC at one time. Awards will be announced by June 15 and funds will be distributed in the summer. Grants are generally $50-200. Please note that submitting a grant application is required for earning Honors (see insert) in Biology, Chemistry, and Environmental Studies.

The first draft of the Yarbrough is often the one most brutally graded during the entire NSS process and can wreck the grade in Research Design. This is harsh but students must understand that preparing a grant application is like performing surgery. Success is judged by the product, not the effort. In other words, the first draft is not a rough draft. It should be rewritten several times after reading the guidelines in this chapter several times. The second and third draft will have even higher expectations. Why not exchange papers with a friend and edit each other's to make it easier?

To be professional in each draft, the paper should be stapled or clipped in the upper left corner, and one should not ask the teacher to do so. It also means the paper should be backed up. Last minute computer problems resulting from faulty back-up procedures are not acceptable excuses for late assignments. Beyond this, other necessities for any paper that you want to look professional are that:

- all pages should be numbered, preferably in the top right corner,
- all papers should include the author's name, the date, and the title of the paper,
- all papers should have one-inch margins and double spacing.

Remember too, that good writing is good editing. At every draft, each sentence, paragraph, and word should be scrutinized for efficiency. Anything that is not essential or subjective and personal should be eliminated. The author should remove vague words (e.g., very, many, huge, recently), anything that is too obvious, and exaggerations (e.g., always, never, everybody, obviously, definitely, certainly, must, impossible, clearly). The paper should not contain clichés, trite phrases, slang, vulgarity, or obscenities. Take all of this very seriously. Some advisors take off several points every time there is a transgression. Science writing has a particular style. It is very direct, efficient and ordered. It is not the same as a feature piece in a magazine or nature writing. This is not the place to vet emotions or personal stories.

Warren Wilson students usually have sufficient grammar skills, but paragraph construction is more of a challenge. When constructing a paragraph, keep in mind that all sentences should be shorter than three typed lines, but some variation overall in sentence length improves readability. Paragraphs with short, choppy sentences should be avoided and each paragraph should have at least three sentences.

One of the most important keys to good science writing is topic sentence construction in each paragraph. Usually the topic sentence is the first in each paragraph. When the ideas in a paper seem muddy, the problem is almost always a lack of good, clean topic sentences. With attention to this single detail, the paper will begin to read like silk. The topic sentence should make the main point of the paragraph. Other sentences in the paragraph should support the topic sentence by giving more details or explaining the meaning in a fuller way. If any sentence does not do this, it is misplaced and should be removed. Topic sentences are sort of like a hanger on which the rest of the sentences in the paragraph hang. By using topic sentences in this way, each paragraph should contain a single idea that is developed. Extraneous information should be left out. Five or six of these well-hung paragraphs should make up the Introduction.

Transitional Words and Phrases (Perrin 2007)

Examples	**Relationship**
also, and, besides, equally, further, furthermore, in addition, moreover.	addition
also, likewise, moreover, similarly.	similarity
but, however, in contrast, nevertheless, on the contrary, yet.	difference
for example, for instance, in fact, specifically, to illustrate.	examples
finally, in brief, in conclusion, in other words, in short, in summary, on the whole, that is, therefore, to sum up.	restatements
accordingly, as a result, consequently, for this reason, so therefore thereupon, thus.	result

after, afterward, before, during, earlier, finally, first, immediately in the meantime, later, meanwhile, next, second, simultaneously, soon, still, then, third, when, while.	chronology

Another key element is good transition phrases from one paragraph to another. The paragraphs should be placed so they move logically from one to another but there should also be helper phrases to make the transition as in the insert box. Other matters of style are also important. For instance, gender inclusive and politically correct language should be used. Please remember that science writing means the author is presenting an argument and in doing so, the goal is to convince the reader of something. The last thing the writer wants to do is offend anyone.

Preferred Racial or Ethnic Terms (Perrin 2007)

Questionable: Arab, Hispanic, Indian, Black, White Bread, Oriental, the generic American.

Preferred: Saudi, Iraqi, Latino/Latina, Cuban, Guatamalan, Cherokee, Inuit, Mesoamerican, Ugandan, Caucasian, European American, Vietnamese, First Nation, French.

As for voice, the chemists encourage passive (it was completed) and always avoid the use of "my" (*not* "my results show," but "the results show"). In contrast, biology journals are increasingly encouraging first person (I, we, our) and active voice (I completed it) mixed with some passive voice. In doing so, papers that are single-authored should use "I" and not "we" even if your advisor or colleagues gave you an abundance of help.

Present tense is generally used in the introduction section of a science paper. Future tense is used in the Methods of a grant proposal. Past tense is generally used in Methods, Results, and Discussion of a final paper.

Use of Verbs (Perrin 2007)

Type	**Example**
Active voice	Respondents completed the questionnaire in 15 minutes. (*Not*: The questionnaire was completed in 15 minutes by the respondents.)
Passive voice	Traditional IQ tests were administered as part of the admissions process.
Past tense	They summarized their results in one incisive paragraph.
Present perfect tense	In the years since, researchers have incorporated Piaget's methods.
Subjunctive mood (conditional situation or one contrary to fact)	If the sampling were larger, the results might be different. (*Not*: If the sampling was larger, the results might be different.)

Regulations from the North Carolina Academy of Science
(ncacadsci.org/cancas.htm)

1. Research is to be carried out during the summer of 2008 and/or 2008-2009 academic year.

2. Applicants must be freshmen, sophomores, or juniors in good standing at any North Carolina college, and who plan to be enrolled next year. The research advisor is responsible for administrating the funds.

3. Recipients must present their research paper at the 2009 spring meeting and submit a brief financial report to the chairman of the Research Grants Committee upon project completion. Award winners are highly encouraged to submit a manuscript to the J. of the N.C. Acad. of Sci. for publication.

4. Any researcher requiring special permits (animal use, banding, human subjects) should indicate that permits are in hand.

5. Applicants must include the following:
   a. from the student, one copy of
      - a NCAS proposal cover sheet (from NCAS web site),
      - a narrative description of the research (four pages),
      - a one page budget summary (separate page),
   b. from the faculty sponsor, one copy of a supporting letter,
   c. from two other professors, one copy of general letters of recommendation.

The Narrative section of the Yarbrough Application **must not exceed four pages** and must include Introduction, Methods, and Literature Cited. All pages should be numbered in the top right corner and the first page should have the title, author's name, and date at the top. On the first page there should be a section titled, Introduction, which should include a brief literature search and a clear statement of objective. No abstract is required. After the Introduction, there should be a section titled, Methods, which should include a summary of statistical analyses that are planned along with other methods. After Methods, there should be a section titled, Literature Cited, which lists only those sources that were cited in order of the first author's last name. The precise format for literature cited is in this chapter and must be followed.

After the narrative, **a fifth page** must be included, which lists the budget for the research and must follow **exactly** the format on the next page. If funding exceeds $200 a statement of additional funding should be included. The student should propose a plan of how other funds will be sought through the department, Sigma Xi, or other granting agencies.

The budget for the Yarbrough should be on its own page and follow the format in the box below *exactly*.

TITLE OF RESEARCH PROJECT

PROPOSED BUDGET

ITEM	QUANTITY	SOURCE	UNIT PRICE
MAGENTA GA 7 VESSELS	25	SIGMA V-8380	$ 46.90
MAGENTA GA 7 VESSEL COVERS	25	SIGMA C-0542	17.25
SEPHADEX G-10	50g	SIGMA G-10-120	56.00
SEPHADEX G-15	50g	SIGMA G-15-120	82.50
SPHAGNUM	5 cases of 12	CAR. BIOLOGICAL	35.92
		TOTAL	**$253.57**

THE ESTIMATED TOTAL COST OF THE PROJECT WILL BE $253.57

Note: the entire budget should be submitted, even though it exceeds the maximum amount available per grant to be determined by the NCAS Board.

"Every wasted research dollar could have otherwise been used to save the lives of underprivileged children." Magnusson and Mourao, Statistics without Math

Sections of a Science Research Paper

Science research papers usually consist of the sections detailed below. Most authors find that the easiest way to begin, is to write methods and results first, introduction and discussion second, and title and abstract third. The introduction and discussion should be thought of as the first and last parts of a good mystery. The introduction gets the reader interested and sets the stage. The discussion answers the questions presented in the introduction and delivers the punch line.

Title

It is best to write the title after at least one draft is complete. To write a title, one should first make a list of key words for the study and write them in decreasing order of importance. The most important of the important should be in the title. Another good way is to answer or ask a question as in, "Does rainfall determine coyote predation rates on frogs?" or "Rainfall determines coyote predation."

In a title, every word must count. The title should consist of as few words as possible, but enough to adequately describe the content and allow someone not familiar with your work to decide if the paper will be relevant to their investigation. Wordiness should be avoided such as "Preliminary study of . . .", "Description of . . .", "Notes on . . .", "Ecological study of . . .", "The behavior of . . ," "The effects of . . . ." Specialized terminology, coined words, and most abbreviations should be avoided. Let "of" serve as a red flag to be avoided. If a species name is in the title, general readers will need to know what type of organism this species is. For instance if you include the species name for a true bug, make sure the common name, "bug," or Hemiptera is in the title too.

Abstract

An abstract is not required in the Yarbrough Grant application, but it is for the talk and the final NSS paper. The abstract is generally written after the rest of the paper. Although it is intended to summarize the paper, it should not simply be a patchwork of sentences lifted from the text. **The most important principle in abstract writing is that** each of the four main sections, introduction, methods, results, and discussion, must be summarized. Two or three sentences from each section should be written as a cohesive paragraph without separate headings.

The abstract should generally be one paragraph and less than 250 words. There should be no citations. The objective should be included. The summary of the results should be very detailed and include P values, correlation coefficients, Chi-square values, and means. The final line should be a strong conclusion statement that summarizes the entire project. Overall, the greatest mistake students have made is failure to summarize the discussion or to indicate what the implications of the results are to the wider world.

Introduction

The introduction should contain only what is necessary to adequately provide background for the objective. It should move from general to specific, with the objective generally the last sentence. In working towards this objective, the introduction should answer, what is the existing state of knowledge about the topic; why did the author undertake this study. The author should be careful about restricting the background to only what is pertinent. Students often over-emphasize taxonomy and natural history, presenting too many facts that are extraneous. Students tend to *under*-emphasize hypotheses and previous explanations for the issue at hand. Overall, the literature summary should orient the reader to what is pertinent. It should also note similarities and differences between previous studies and the work the author is about to describe.

Every fact stated should include a citation using the name-year method preferably at the end of the sentence, like this (Smith 1999). Whole paragraphs should not be cited just once at the end of a paragraph to attribute the whole paragraph to a single source. Footnotes and quotation marks should never be used in science writing except for footnotes in tables. More on citations is included in a subsequent section.

Each paragraph should have a topic sentence and in science writing this is generally the first sentence in the paragraph. The various paragraphs should stand in a logical relationship (1 leads to 2 and 2 leads to 3, *etc*.). Ideally, the reader should be able to read only the topic sentences and still understand the logical progression to the objective statement.

A statement of objective is imperative for the Yarbrough Grant Application, the Abstract, the NSS presentation, and the final paper. It usually comes at the end of the Introduction and should include **an if, why, or whether phrase**, or direct explanation of why the study was undertaken. It should not just report *what* will be done; it should explain *why* it is being done. It may also help to include:

- the full species or chemical name that will be investigated,
- the location or geographic area that will be studied,
- the attribute of the species or chemical that will be studied (e.g., size, density, cover).

A hypothesis or prediction of the results could be included along with the objective as long as it does not bias results. For example, one should *not* write, "my objective is to determine whether the addition of calcium in soil will grow better watermelons. I hypothesize that it will so I am going to spend most of my effort sampling that treatment." After writing the objective, one should review it several times, keeping the paper's purpose in mind. Does it really capture the major idea? Does it explain why? Is it cluttered with junk words?

Inefficient, redundant words

Instead of	*use*
at this point in time	now
due to the fact that	because
utilize	use
high degree of accuracy	accurate
end result	result
prior to	before
a sufficient number of	enough

Methods - (no longer called Materials and Methods in most biology journals)

In a paper, methods should include enough information so that someone could repeat the research. This should be in paragraph, narrative form and not written in the style of a recipe. In a talk however, it is often better to show diagrams, photos, or flowcharts to describe the steps in the procedures rather than having bullets with long wordy sentences. Because of this, students should remember to take photographs of their experimental setup and of themselves in action while doing their research.

Appropriate for inclusion in Methods is the time of year the study was completed, how samples were collected and preserved, how organisms were identified, how many samples were taken. A subsection called "Study Site" is sometimes appropriate for field studies. For chemistry, materials should be described within the narrative rather than in a list and could include the degree of purity (e.g., Reagent Grade) and source (company, city, state, country).

In a grant proposal, statistical procedures that will be used to analyze the results should be included in Methods. The null hypothesis *could be* included, but is not always necessary if other wording is specific enough, e.g., "I will compare the mean of the burned treatment to the mean of the unburned treatment in a t-test." It is *not* appropriate just to write "I will analyze my data with a t-test," or "I will run a correlation."

Results

Results should summarize the data but be without implications, speculation, management recommendations, or interpretations. If the project involved a number of experiments, the results should be reported in the same sequence as they were introduced in the methods. In a paper, the results should be in narrative form and not simply a collection of figures and tables. Tables and figures should not replicate each other.

Every graph, figure, map, or table should be referenced within the text like this (Fig. 3) or this (Table 1) using Arabic (1, 2, 3 . . .) numbers. When making conclusions about statistical differences, word precision is essential as in, "there was no significant difference in the means of Treatment A and B" rather than, "The treatments were not significant."

Discussion

The biggest mistake young authors make in discussion is that they simply rehash results rather than interpret them. A second tendency is to dismiss the results because of errors and inadequacies. While it might be appropriate to suggest improved techniques, most students are too quick to dismiss their results entirely. No one has ever done a perfect study. If all the studies that had weaknesses were dismissed, we would have no science literature.

To write a good discussion, the first step is to examine the results of the study and **write down the major conclusions** (Magnusun and Moreao 2003). For instance, the conclusion might be "The quantity of frogs in the diet of some coyotes is related to the amount of rainfall." This is the only part that might be a slight rehashing. Beyond that, if one is having trouble writing the discussion or if there seem to be too many conclusions, it may be because nothing exciting was discovered, or because the writer has not yet identified the major scientific conclusion. Keep in mind that methodological results should *not* be confused with scientific conclusions. Even very complex papers rarely have more than two or three major conclusions.

The discussion must address the questions introduced in the objective and should usually move from specific to general or proceed in a logical order, paralleling the order in the results section. The discussion should interpret the data and draw conclusions, not just repeat the results. At least some of the citations in the introduction should be cited again in the discussion to compare and contrast the results and conclusions to those of others. Interpretations to the present state of knowledge should be related.

Theoretical implications of the study should be identified, but wild extrapolation beyond the data should be avoided. The speaker should consider alternative explanations of data but the strengths of the study should be emphasized. Certainly, inconsistencies and unsettled points should be identified, but not dwelled upon. Negative results should not be dismissed, but they should be explained and then the strengths emphasized. If the experiments cannot resolve which explanation is correct, additional experiments should be suggested, but vague or general additional experiments (such as additional replicates) that do not directly follow from the results should *not* be suggested.

The discussion should have a conclusion that represents the student's informed opinion about what the results do and do not suggest. Management implications might be included if they are appropriate. The discussion should end with a firm take-home message or conclusion that brings the reader back to the issues in the introduction. There is no requirement for a Future Research section and in fact too much emphasis on future research sounds like an excuse. If the author has so many great ideas for future research, why didn't he or she attempt them in the first place?

Acknowledgments

Acknowledgments should give credit to those who contributed:

- equipment,
- transportation,
- housing,
- grants,
- internship funding,
- major ideas,
- literature searching,
- technical assistance,
- statistical advice,
- computer advice,
- permissions,
- access to study sites,
- or help with preparation of the manuscript.

The Environmental Leadership Center and the NCAS should get acknowledged for any part they played. Any faculty member who helped, beyond the major advisor, should be acknowledged. Please remember, however that the **NSS is not the Academy Awards**. Keep private jokes, personal thanks, and gushy emotions to a minimum. Authors should include only professional acknowledgments. Personal references (Elvis, God, Mom, pets) should be thanked in some other way. Remember too that acknowledgment does not have to mean the same thing as gratitude. Occasionally, hard feelings develop between a major contributor and the author. The writer does not have to give thanks to this person, but he or she should be acknowledged.

Literature cited

Literature cited is not the same thing as a bibliography (which lists every literature source consulted during any phase of the project). Literature cited is required for the final paper. A bibliography is required for the presentation on the back of the abstract. Literature cited should include only those sources actually cited in the manuscript and is literature only, not personal communications. Citations for web sites should be kept to a minimum or not used at all. Instead, peer-reviewed literature should take up most of the space. In both literature cited and a bibliography, the citations should be in alphabetical order by the first author's last name. Examples are given in a subsequent section.

Tables

Tables should be numbered consecutively using Arabic numerals and each should have a caption above it, separated from the table by a line. Notice that the first sentence of the caption does not have to be a complete sentence. Notice too that it is appropriate to have footnotes in a table even though they are not allowed in other sections of science writing. In tables, the appropriate number of decimal places should be used – no more than you need or are significant. The column headings should be easily understood. In the final paper, tables and figures should be placed on pages separate from the text, one table or figure per page.

Correct table format

Table 1. Relationship between the number of herbivorous marsupials and area of land on Australian islands.

Island	Area (km^2)	Observed species	Expected species
Tasmania	67,900	10	12.6
Finders	1,330	7	6.3
King	1,100	6	6.0
Cape Barren*	445	6	5.1
Clarke	115	4	4.0

*Number of species as of AD 1800.

Figures

Graphs, maps, drawings, and photos are called figures. In graphs, simple is best. A font type such as ariel, century gothic, or sans serif is the easiest to read on a graph or map because they have no cross marks. Two-dimensional graphs are preferable to graphs with shadowing, bars or pies with 3D, or colors which only add unnecessary complexity. Only graphs that require three axes should be 3D. The graph should include everything it needs, but remain as uncluttered as possible. During the talk a title on a graph is often not necessary and should be avoided if the axes clearly identify the graph. Sometimes a caption under the graph or photo during a talk is helpful and appropriate, but sometimes not. For any graph, axes should be clearly labeled and error bars should be accompanied by some explanation of what they represent either on the axis label or in a caption (e.g., standard error of the mean).

Although graphs within a talk may or may not have a caption, in a paper, each figure should have one that begins with a label as in "Fig. 1." The caption should give enough information so that it can be understood by itself without further reference to the text. Data should not be interpreted in the caption, but the caption should explain what the symbols represent if there is no legend.

There is usually no need to present the t-value or chi-square values on a graph, but the *P* value should be typed above the bars on the bar graph. It is also a good idea to indicate the sample size for each treatment on the graph (e.g., n=5) above the bars as long as this does not look too cluttered. Best-fit lines should not be drawn unless the data are suitable for regression, but even then these best-fit lines should not be extended beyond the data. A photo or drawing that is cut and pasted from a web site should not be included if it is copyrighted, but an uncopyrighted photo still needs to be cited in small letters under the photo.

Figures and tables for manuscripts

For manuscripts, figures and tables should not be imbedded in the text. They must come at the end of the manuscript after literature cited. Tables should come before figures, each table on a separate piece of paper. After tables, the figure legends should be together all on one page. Figures should follow figure legends, each figure on a separate page, so they can be photographed for a journal. In pencil on the back of each page, "Fig. X" should be written lightly.

General Manuscript Guidelines

Latin bionomials

Genus names should always begin with a capital letter and be italicized or underlined. Species names should never begin with a capital letter and should be italicized or underlined as in *Homo sapiens* and not Homo sapiens or *Homo Sapiens* or Homo Sapiens. At the first occurrence of the common name of a species, the genus and species name should appear in parentheses as in Bonobo (*Pan paniscus*). At subsequent occurrences, the common name alone could be used or the abbreviated *P. paniscus*. The same process should be used for general abbreviations.

Line spacing, fonts, and word use

To be courteous to your editor or professor and leave room for them to edit, one should double-space all elements of the paper, use one-inch margins, and use 11 or 12 pt. font. If the default margins for your software are not one inch, reset them. Do not right justify the right margin, i.e., create a straight text edge on the right. Please review every line of the table that follows to improve word choice.

Word Choice

Practices to avoid in science writing	**Example and/or explanation**
Ending a sentence with a preposition.	Where did she go to? Who did she go with? (Of, with, on, for, to, up, through, from, over, and by are examples of prepositions.)
Beginning a sentence with "and" or "but."	But he had another filter in the drawer.
Using contractions in science writing.	there's, it's, don't, wouldn't, we'll
Frequently using "however."	(Young writers use it too frequently.)
Using prove, proved, proven, or proving.	(These words should almost never be used. Outside of mathematics almost nothing can be proved.)
Inappropriately using "significantly."	(Significantly should not be used unless there is a statistically significant difference.)
Using colloquialisms, slang, and generalizations.	Write-up (instead of report), only a few (instead of 7%), get-together.
Using English measurements without metric equivalents.	14 acres. (All measurements should be in metric.)
Being anthropomorphic	The pair of ducks divorced.
Being teleological	The bittersweet tried to cover the forest canopy.
Asking questions of the reader or using other methods that sound didactic (preachy) or sardonic (mocking, cynical).	What method shall we use, then, if our choices are limited?
Interchanging the following:	
- specie and species	Only one species was present, *not* One specie was present. (Species is both the singular and plural form of the word. Specie is not a word.)
- it's and its	It's about time. Its limb was reattached. (It's should never be used in science writing because it is a contraction.)
- there, their, they're	There she goes. Their car was parked. They're going to the park.

- to and too	I went to the store. I bought shoes too.
- lie and lay	The chicken will lie on the straw. The chicken lays an egg. (Lay must always have an object when used in the present tense, for instance, a chicken does not lie an egg.) I lay the book on the table. (I do not lie the book on the table. The confusion arises because forms of lay are also the past tense of lie.) The chickens laid down after a hard day.
- approximately and about or roughly	Approximately 15 comets passed that night. *not* About 15 comets passed that night.
- since and because	Because she was sick, there was no talk. *not* Since she was sick, there was no talk. Since yesterday . . . . (Since refers to time.)
- due to and because	("due to" is slang and should not be used. A library book is due and so is a the assignment for this chapter, but it is not due to something.)
- effect and affect	The main effect . . . . This will not affect me. (Effect is a noun and affect is a verb.)
- further and farther	We will go no further with this idea. I ran farther than anyone else. (Farther always refers to distance. Further refers to hypothetical ideas.)
- this data and those data.	data were collected, *not* data was collected (Data is a plural noun always, always. Do like I do and avoid using the whole noun. Then you will not have to worry about it.)
- who and whom	Who is responsible for this? *not* Whom is responsible for this? To whom are you referring? *not* To who are you referring? I was wondering with whom I am speaking, *not* with who. . . . Who's who of language geniuses, *not* who's whom of language geniuses. (Who is in a subject position. Whom is in an object position following a preposition.)

- utilize and use	(Utilize should never be used, not ever.)
- alot and a lot	(Alot is not a word. If you must, use the phrase "a lot" instead, but realize it is not a college-level phrase. Think about using "considerable" instead.)
- among and between	What is the difference among these three treatment? What is the difference between these two treatments?
- *etc.* and ect.	(*etc.* is short for *et cetera*, but it should not be used in science writing because it is too vague. If one insists on using it, then it should be configured properly. The abbreviation is *etc*., not *ect*.,. Many editors will also insist on italics.)
- e.g., i.e., and N.B.	(e.g. means "for example," i.e. means "that is," and N.B. means "note well.")
- p.m. and pm	(There should be periods after each letter.)

Punctuation

In general, words should *not* be underlined, made bold, or placed within quotation marks in science writing. No exclamation marks should be used, and there should be two spaces after every period and colon. There should be spaces before and after parentheses (like this) not(like this). There should be a space after a numeral and before the units like this 12 mm and not like this 12mm. Please review the table on punctuation that follows.

Punctuation (from Perrin 2007)

Uses of commas	**Examples**
Three or more items in a series	men, women, and children.
Set off nonessential	The room, which was well lighted, was on the south corridor.
Clauses of a compound sentence	The first survey was a failure, but the second one was not.
Years with exact dates	May 25, 2005, the experiment began *(but* May 2005).
Numbers of 1,000 or or larger (every three	11,205 students, 1,934 books

numbers)	
unless page numbers,	page 1287, pages 1002-1021
or temperature,	2044 F
or serial numbers,	033776901
or to right of decimal,	2.09986
or degrees of freedom.	d.f. was 1000.
Uses of semicolons	**Examples**
Joins clauses of a compound sentence when no coordinating conjunction is used.	Males responded positively; females responded negatively.
Separate elements in a series when there are commas.	Fresno, California; St. Louis, Missouri.
Uses of colons	**Examples**
Introduce a phrase or clause that serves as an explanation or illustration.	Two words triggered the reactions: preferential and special.
A ratio.	The sex ratio was 3:10.
Separate volume from page numbers in a citation.	J. of N.C. Acad. of Sci. 72:204-207.
Uses of dashes	**Examples**
Indicate a break in the thought of the sentence.	The national heritage of participants – they identified themselves – this proved less important than researchers expected.
Uses of quotation marks	**Examples**
Words used counter to their intended meaning.	Her so-called “normal” parents visited one day. His behavior was “abnormal.” In fact, it seemed normal to me. (N.B., in the U.S. punctuation belongs within the quotation marks. In Britain, punctuation is placed outside of the marks as in; his behavior was “abnormal”.)
Uses of parentheses	**Examples**
Set off clarifying information.	We provided parents with four samples (Fig. 1-4). First-time offenders respond (Gillium and Sparks 2004).
Introduce an abbreviation.	Roadkill on the Blue Ridge Parkway (BRP) was counted . . . .
Set off numbers that indicate divisions.	The test included sections on (1) math, (2) reading, and (3) logic.

Uses of capitalization	Examples
Proper nouns/adjectives	Robert Coles, Chinese students, Elizabethan drama.
Specific departments or courses.	Department of Psychology, Warren Wilson College Blacksmith Crew, Criminology 235.
Trade and brand names.	Prozac, Xerox, WordPerfect 12.0.
Nouns used describing sequenced methods or examples.	Day 4, Experiment 6, Table 1, Figure 3A (*but* column 2, row 6).
Common names of species.	Red-winged Blackbird (*but* blackbirds with red wings), Northern Flicker, Least Shrew, Fraser Fir (*but* firs of several species).
Taxonomic categories.	Phylum Chordata (*but* chordate phylum or chordates). Family Elaphidae (*but* elaphid family or elaphids).
No capitalization	**Examples**
Hyphenated second word.	Introduction to Short-term Memory Loss, Red-winged Blackbird.
In figure captions.	Figure 1. Percentages of students by country.
General references to departments and courses.	a number of departments of sociology, the college blacksmith crews, a speech pathology course.
Chemicals	fluoxentine hydrochloride (*but* Prozac).
General names of laws or theories.	the empirical law of effect, the theory of natural selection, the second law of thermodynamics.
Uses of Italics	**Examples**
Genus, species.	*Pan troglodytes* (but common chimpanzee).
Latin words.	*et cetera*
Words that could be misread.	Which answer below is *not* true?
Letters used as standard algebraic symbols.	*P, F*-test
Uses of numerals	**Examples**
Numbers of 10 or larger *unless* they start a sentence,	14 respondents, 26 chapters, 11th article (*but* two respondents, fourth article, zero animals, one topic). Sixteen authors contributed. Thirteen others approved.
are in a fraction,	two-thirds of teachers, and three-fourths of students.
or are in common phrases.	the Ten Commandments, the Seven Wonders of the World.

Numbers smaller than 10 when compared with numbers larger than 10.	the 4th chapter of 20, 2 of 30 research subjects.
Numbers preceding units.	6 in. mark, 300 mg capsule.
Numbers used as decimals.	7.5 of respondents.
Numbers used in ratios.	a ratio of 5:2.
Numbers used in percentages.	9% *but* zero percent (confusion is likely when zero is involved, note also that the percent symbol is used in science and is not spelled out in most cases).
Numbers that represent time.	6 years, 5 months, 1 week, 3 hr., 15 min., 7:15 p.m.
Numbers that represent dates.	April 1, 2001; November 2007.
Numbers that represent ages.	4-year olds, students who are 8-years old.
Money.	The cost of the test was $4.35, a $5 fee.
Numbers that refer to placement in a series or parts of books.	Exam 4, Figure 9, page 6, chapter 2.

Citing Sources within the Narrative

You must cite every fact you state that is not your own observation. If you fail to give credit to your reference, you are committing plagiarism. Quotation marks should not be used in science writing. Instead, citations using the author's last name and year of publication should be in parentheses at the end of the sentence. Long sections from other papers should not be included in your paper, but short phrases and paraphrases can be if they are cited.

With one author this looks like:

> The spruce-fir coniferous forest occupies the high Appalachians in North Carolina (Smith 1996).

For two authors of one publication, they should both be included in the parentheses:

> The spruce-fir coniferous forest occupies the high Appalachians in North Carolina (Smith and Jones 1996).

If there are more than two authors of one publication, then "et al." should be used after the first author's name which is Latin for "and others." Please note the correct punctuation and spelling for et al.

> The spruce-fir coniferous forest occupies the high Appalachians in North Carolina (Smith et al. 1996).

If there is more than one reference showing similar results, the references should be listed chronologically, separated by a comma:

> The spruce-fir coniferous forest occupies the high Appalachians in North Carolina (Smith 1996, Jones 1998, Jones and Doe 2003).

For more than one reference by the same author in the same year, lower case letters should be used to differentiate them:

> The spruce-fir coniferous forest occupies the high Appalachians in North Carolina (Smith 1996 a, b).
>
> Whereas the spruce-fir coniferous forest occupies the high Appalachians (Smith 1996a), the dreadlock-white pine dominates the Warren Wilson forests (Smith 1996b).

Occasionally in science writing, the citation comes at the beginning of the sentence as in the example:

> Smith (1996) stated that the hemlock-white pine hardwood forest occupies the high Appalachians in North Carolina.

This format is less preferable than the citation at the end of the sentence because the citation distracts the reader from the main point of the sentence. This format should only be used when the author's name is the main point of the sentence because of conflicting views, for example:

> Smith (1996) stated that the hemlock-white pine hardwood forest occupies the high Appalachians in North Carolina. In contrast, Jones (1998) argued that dreadlock-white pine dominates the forests in the Appalachians.

Citing at the end of a paragraph

Some students include a whole paragraph of information from another source and dutifully cite every sentence in the paragraph with the authors last name and date, or to save paper they cite it once at the end of the paragraph. Both methods should be avoided at all times. First, if you are citing everything in a long paragraph, you are including too much information from the other source. The reader can obtain the other paper if they want all of that information. The purpose of your writing is to say something new. Secondly, a listing of the author's name and date from the same source after every sentence in a long paragraph is monotonous. Try never to cite more than three sentences in a row from the same source. Even three in a row can be monotonous, so I suggest the following type of arrangement or something else creative to get around the problem:

> Shimper (1986) makes the following three observations about tropical rain forest. There are 30-40 types that include the monsoon forest and the evergreen savanna. These once formed a worldwide belt around the equator that are now subject to mercury outfall that is rapidly affecting the native communities. Of all these forest stands, the largest continuous rain forest was in the Amazon basin.

By this format the reader was warned that there would be three observations by Shimper, thus the reader easily can attribute the three uncited facts in a row to that author.

Another reason why a paragraph should never be cited just once at the end of the paragraph is that there is too much ambiguity in that method. The reader does not know if only the last sentence in the paragraph is attributed to the author and all the rest of the facts are uncited, or the whole paragraph is attributed to that citation. As already stated, there is rarely a good reason to include a whole paragraph as a citation, so this problem should not arise in the first place.

Problems and ethics in citing facts
One common problem is that a student wants to cite a fact not stated directly by the author, but only cited by the author. For example you might read from a book by Smith:

> Scavenging is accomplished by algae and lichens, which occupy canopy leaves in balsam fir forests (Lang et al. 1976).

You may want to cite this fact in your paper but in doing so you should cite Lang et al. and not Smith for this fact. You should do so, however, only if you have read the paper of Lang et al. If you have not read their paper you have not verified that indeed they actually made that statement. Without verification you are relying on the interpretation of Smith who may not have made an accurate interpretation.

In other words, you should never cite a source that you have not read.

This may seem picky and it means a lot of work, but many young (and old) authors have gotten themselves in trouble by not verifying their citations. Teachers can tell if students are making this mistake if, for instance, a student cites several Russian journals, but the teacher knows that the local library does not carry Russian journals and the student does not speak Russian. It is worth repeating that the most important rule in citing facts is to only cite sources you have read. Never cite a source you have not read and verified.

Common knowledge facts
While it is generally true that every fact you state should be cited, some facts are common knowledge and do not need a citation. Stating that the sky is blue should need no citation. Most students, however, regard far too much as common knowledge. Typically, students spend several hours reading sources to gain information about a topic. A certain fact is mentioned several times in more than one source, so the student regards the fact as common knowledge. The fact that six species of sandpipers have partial webbing on their hind feet may be mentioned in several sources. It becomes common knowledge to the student, but it was not before reading the books and is not to most other students.

Footnotes and quotation marks
Footnotes and quotation marks are almost never used in science writing except occasionally footnotes in tables.

Citing personal communication
Occasionally, an author may want to cite a fact stated during a conversation with an authority. The way to do this is with “pers. comm.” the abbreviation for “personal communication:”

In the tropics 52% of the parrot species are rare (Wilson, pers. comm.).

Use "personal communication" (or pers. comm.) sparingly because this is an extremely weak way to provide evidence for a fact. You will always make a stronger argument by citing a peer reviewed resource. Do not cite this person in Literature Cited which is for literature cited only.

Citing unpublished work
Unpublished papers should generally not be used for citations, although papers that have been accepted for publication, but not yet in print, can be used:

The spruce-fir coniferous forest occupies the high Appalachians in North Carolina (Smith, in press).

Citing from the World Wide Web
You should be cautious when citing sources from the internet. Only reputable, peer reviewed web sites should be cited. Any Billy Bob can put anything, information or misinformation, on the web. Articles that are accessed online from journals that are also available in print (e.g., Ecology, Conservation Biology, Molecular Biology of the Cell) should be cited according to the printed journal format given above and not as a web document. Only periodicals that are available only as electronic sources should be cited as a web journal. When citing the web, include the author and year as in a regular citation.

Literature Cited Format

JOURNAL ARTICLE WITH SINGLE AUTHOR
Sachar, D.B. 1994. Budesonide for inflammatory bowel disease: is it a magic bullet? New England Journal of Medicine 331:873-874.

JOURNAL ARTICLE WITH TWO AUTHORS
Lee, T.D. and F.A. Bazzaz. 1982. Regulation of fruit and seed production in an annual legume, *Cassia fasciculata*. Ecology 63:1363-1373.

JOURNAL ARTICLE WITH THREE OR MORE AUTHORS
Auerbach, S., F.C. Zhou, B.L. Jacobs, and E. Azmitia. 1985. Serotonin turnover in raphe nuerons transplanted into rat hippocampus. Neuroscience Letters 61:147-152.

BOOK BY TWO AUTHORS
Sokal, R.R. and F.J. Rohlf. 1981. Biometry: the principles and practice of statistics in biological research. 2nd ed. WH Freeman, San Francisco, CA, U.S.A. 859 p.

CHAPTER IN AN EDITED VOLUME
Petter, J.J. 1965. The lemurs of Madagascar. In: DeVore, M. (ed.). Primate behavior of monkeys and apes. Holt, Rinehart, and Winston, New York, NY, U.S.A. p. 292-319.

TWO ARTICLES PUBLISHED IN SAME YEAR BY ONE AUTHOR
Sachar, D.B. 1994a. Budesonide for inflammatory bowel disease: is it a magic bullet? New England Journal of Medicine 331:873-874.

Sachar, D.B. 1994b. Inflammatory towel disease as a result of magic bullets. Journal of the American Medical Association 435:192-339.

WEB SITE – For more on this go to Painless Library Research on the college's library web site.
Important elements when citing web resources: author (if given), date site was last updated, title of work, group responsible for the site (if applicable), date of access, address of the site.

National Park Service. 2003, February 11. Abraham Lincoln Birthplace National Historic Site. Retrieved February 13, 2003, from http://www.nps.gov/abli/.

> "I find this literary business very irksome. It is like the life of a glacier, one eternal grind."
> *J. Muir*

Publishing Results and Deciding on Authorship

Students are highly encouraged to publish the results of their NSS. A publication can provide a ticket to graduate school or round out a resume. Few students pursue publication even though, once the final paper is drafted, there is little more to do. Strict formatting rules must be followed and these are found in the back of the targeted peer-reviewed journal. Students are especially encouraged to submit to the *Journal of the North Carolina Academy of Science*. It was formally known as *Journal of the Elisha Mitchell Scientific Society* and is available in our library.

The topic of who should be listed as an author in scientific publications has always been delicate and authorship policy remains loose, informal, and idiosyncratic. In the old days, there was little discussion between students and their advisors about this because scientists rarely published until well after they received a graduate degree. Today, many undergraduates and even high school students publish. Conflict can develop between colleagues or students and their supervisors when the time comes for submitting.

Ideally, students and their faculty mentor should decide on authorship before the first draft of the manuscript is written. In the first discussion of publication, the subject of authorship should be addressed. Participants should have a serious discussion to decide on the exact order of authors and the tasks of each. Once an agreement is made, the order should not be changed without further discussion. Participants should also decide on a target journal at the first meeting. Galindo-Leal (1996) provides guidelines for determining authorship (Table 1). The required score for authorship is 25%. Any participant who does not achieve it should not be an author.

Table 1. Guidelines for determining authorship.

Activity	*Contribution*	*%*	*Student*	*Supervisor*
Planning	None	0		
	Minor	5		
	Moderate	10		
	Major	20		
Executing	None	0		
	Minor	5		
	Moderate	10		
	Major	20		
Analyzing	None	0		
	Minor	5		
	Moderate	10		
	Major	20		
Interpreting	None	0		
	Minor	5		
	Moderate	10		
	Major	20		
Writing	None	0		
	Minor	5		
	Moderate	10		
	Major	20		
Total				

<u>Most common mistakes on the Yarbrough Grant applications</u>

- weak or no evidence of a peer-reviewed literature search.
- not all facts are cited.
- name-year method of citation is not used.
- paragraphs do not have topic sentences or do not transition well from one to another.
- paragraphs do not follow each other logically.
- objective is missing, weak, or does not include an if, why, or whether statement.
- methods are not detailed enough.
- Literature Cited section is missing or not done correctly.
- budget is missing.
- pages are not numbered, or there is no title, the author's name is not included, or there is no date.
- English units of measurement are used instead of metric.

Advice about punctuation from Lynne Truss

from *Eats, Shoots and Leaves,* a book about punctuation, and a number-one best seller in Britain.

"Don't use commas like a stupid person. I mean it. Only do it if you're famous. Done ignorantly by ignorant people, it's awful."

"Shaw explains that having worked out his own system for colons and semicolons, he has checked it against the Bible, and seen that the Bible almost got it right."

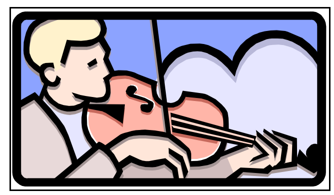
"*Punctuation directs you how to read, in the way musical notation directs a musician how to play*."

Winney says:

- "This chapter really pushed me to learn new skills."
- "I'm going to staple my assignment before class by using the stapler in the copy room."
- "I better do this assignment well before class. I might need more time than I expect."
- "I see now how punctuation and capitalization are important. I better pay more attention to it in my writing."

Ninny says:

- "Why do we have to know where prepositions are supposed to be at?"
- "I'm going to come late to class, then just after the teacher asks us to hand in our assignments, I'm going to call out, 'do you have a stapler?'"



- "Who cares about the difference between further and farther."
- "I didn't learn alot in this course."
- "This writing crap is anal."

staple this BEFORE CLASS

Writing Assignment ****** worth 30 points Name___________________________

Read carefully through Chapter 3 and use its information to complete the assignment below.

1. T or F For Yarbrough, all pages should be numbered, preferably in bottom left corner.

2. T or F The Yarbrough should be three pages long at maximum.

3. T or F An abstract should be included for Yarbrough.

4. T or F For Yarbrough, a budget is required.

5. T or F All sentences should be shorter than three typed lines.

6. T or F Each paragraph should have at least three sentences.

7. T or F Authors should try to sound didactic.

8-10. Rewrite the following paragraph using less choppy sentences and correcting all mistakes.

> Golden hamsters (Mesocricetus auratus) used for this research were adult males. Temperature conditions were kept at 22-24 C. Amimals were fed Purina Chow. Hormonal Studies were performed on 23 individuals. The photoperiod was 16 h. Animals were housed with littermates of thes same sex and feeding was once each day. All Hamsters had been weaned at three weeks.

Make corrections or improvements to the following sentences according to the guidelines in this chapter.

11. The grassland was huge.

12. The crabs were fit as a fiddle.

13. The strawberries turned blue!

14. I checked to see where the duck flew to.

15. And after mixing, the tritium was added.

16. She could not walk any further, ect.

17. These data may be utilized.

18. I collected 5 replicates.

19. 157 insects were found in the sample.

20. The insect was 0.45 inches long.

21. During the second sampling period we noticed a significant number of geese at the collection site.

22. The results of the t-test proved our hypothesis.

23. The data was collected using an Orion pH probe.

24. Which is/are correct?
(a) 12mg (b) 12 mg (c) 12 Mg (d) 12 mg. (e) 12 Mg.

25. Which is/are correct?

(a) Daphnia magna (b) Daphnia magna (c) *Daphnia magna* (d) Daphnia magna
(e) *Daphnia Magna* (f) Daphnia Magna

Rewrite the following sentences using more efficient phrases and words.

26. We used a 60 ml syringe in order to increase the volume of sample collected.

27. The pH of the soil at the second site was probably higher due to the fact that lime had been added the previous year.

28. Combustion of the material can be carried out in an atmosphere of oxygen.

Correct the following titles by taking out junk words and improving them.

29. A Study of Methanotrophic Activity in the Beaufort Sea

30. The Determination of the Capacities of an Indirect, Through-Pass Solar Dryer

31. Studies on the Reproductive Biology of *Actinia*, Including Sperm Transfer, Sperm Storage, and Sperm Utilization.

32. Report of new health data results from the 2006 national ASAP-FYI-ERGO health study: lung cancer in women mushrooms

Underline the topic sentences in the following paragraphs taken from introductions.

33. The fat body is a loose network of cells associated with the connective tissues of the body. It is located around the gut and other organs and may account for up to 65% of the total body weight in some larvae. The primary function appears to be activities of storage.

34. Pausing the cell cycle to repair DNA is a cellular-level protection from ultraviolet damage. Killing off damaged cells is a tissue-level strategy. Clearly, cells and tissues are necessary for functioning of a multicellular organism.

35. The U.S. population spend $33 billion a year on weight loss products. Many people try to lose weight to improve their appearance, but obesity is a bona-fide and serious medical condition, and a major part of the economy. Obesity raises the risk of developing certain chronic illnesses, including hypertension, diabetes, heart disease, and some cancers. The discrimination directed at overweight people can result in depression, low self-esteem, and eating disorders.

36. T or F (circle one). In science writing, the topic sentence is usually at the beginning of the paragraph.

37. T or F (circle one). A topic sentence can be at the beginning or end of a paragraph, but is never in the middle.

38. T or F (circle one). For long citations, it is okay to cite a paragraph once at the end of the paragraph.

Critique the objective statements and remove junk words.

39. The objective of this study is to determine whether the surrogate light chain (VpreB) affects the autoreactivity of the heavy chain.

40. My objective is to determine if individual raccoons show a paw preference in a food/toy-reaching task.

41. This research determined that methane did not occur on the ocean floor in the Beaufort Sea of Alaska.

42. T or F. The methods section does not need to include complete sentences.

43. T or F. Each figure in results should have a caption.

44. T or F. Footnotes are allowed in science writing as long as they are not in tables.

45. T or F. The discussion section should address the questions brought up in the objective.

46. T or F. A Future Research section is required for NSS.

47. T or F. In Acknowledgments, you should forget to mention the ELC and The North Carolina Academy of Sciences if you were awarded something from them.

Identify the mistakes in citation format:

48. Phosphorus was analyzed using the ascorbic acid method described by Strickland and Parsons (19).

49. Rayle (pg. 30) conjugated the linoleic acid in the eggs from Warren Wilson roosters.

50. Such waste explains why landfills are closing(Miller 2006).

51. "The plant species all grew exponentially." (Kindler 2003)

52. T or F. It is okay to cite a source you have not read.

53-55. **Correct the mistakes for the Literature Cited section of the following Yarbrough application.**

Bibliography

1. Weisenheimer, 1992. Transgendered rhino cloning in Namibia. Interview on May 7, 2006.

2. Griffith, Andy and F., Barney. 1959. GC/MS tripoletic multi-mulberry recipe for Aunt Bea's favorite pie. Conservation Biology vol. 123(4) pages 45-89.

3. Wilson, Warren. 1902. No future for work colleges; early hippi behavior in farm students from Appalachia and vegetarian diets. Annuls of Social Behavior 78:2-56

56-57. List two citations from your own research and use proper citation format as if writing in the Literature Cited section. If you do not have any citations yet, use another topic showing me you understand the format.

58. How is your progress on research? Summarize meetings with faculty, phone calls, progress on your literature search, and other achievements of the last week.

59-60. What are your two chief NSS goals for the coming week?

Chapter 4

Searching the Science Literature

by David O. Bradshaw, Louise Weber, and Mark Brenner

Some student research projects are undermined from the start by weak literature searches of peer-reviewed journals and books. Without a thorough search, students tend to have half-hearted Introduction and Discussion sections and their statement of objective is often diffuse. Students may also discover too late in the process that standard methods they want to use cannot be completed at WWC or that most of the literature they need is written in a language other than English or in journals that are not accessible. Students are also sometimes embarrassed, late in the process, to discover that their research question has already been answered.

The only way to have strong Introduction and Discussion sections in the NSS is to complete a thorough search of peer reviewed science literature. Each student should find at least 12 good articles or books. If less than five are found, the student should find a different topic. The search should include:

1. electronic databases in the WWC Library to find titles and abstracts of peer reviewed journals.

2. the library's electronic catalog to find books within the MCLN system, and the *WorldCat* database to find books in libraries all over the world.

3. the World Wide Web to find general information and web sites from respectable agencies and institutions that provide information on the topic.

Using Electronic Databases

Most of a student's literature search should be from peer reviewed books and journals. The ideal in literature searching is to read all the peer reviewed literature that has been written on the topic or at least the most important and recent pieces. The easiest way to access journal titles on a topic is to use the library's electronic databases. While many of these databases provide access to older journal literature, please note that some databases cover journals only from the last 5-10 years. There are various ways to get at this older literature. For example, WWC students may use the UNCA library for the full BIOSIS database. Students should check with a librarian for details and hints for literature searching within their field.

To access our library's electronic databases:

- Access the Library web page.
- Mouse over "Articles & Databases" (then select "On-Campus Users" or "Off-Campus Users"). If you want to use the databases from off-campus, you may contact the library for the login information.
- Look in either the alphabetical list or in the subject category of "Sciences."
- Click on the title of the database to access the desired database.
- Once in the database, type in keywords that will bring up hits of titles in peer reviewed journal articles. Some databases provide full text of the articles. Others provide abstracts as well as titles. Some are titles only.

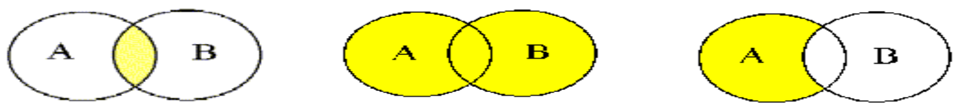
- If an article you find is not available full-text, you need to take an additional step. From the library home page, select the link "Magazines & Journals," then "WWC Periodical Holdings." Here, you can search for the title of the journal to see if it is available full-text in another database or physically present in the library. If you find that the journal is not available at all, then you can request the article through our interlibrary loan service. There is an online form on the library web pages for doing this.

General searching tips are listed below. In addition, each of the different databases provides an extensive Help section online.

- type + or ? at the end of a word to include singular or plural forms of the word,
  e.g., poliovirus+ finds poliovirus, polioviruss, polioviruses
- type **and** between two words to specify records containing both words regardless of how many other words are between them.
- type **or** between two words to specify that records found contain either words.
- type **not** between two words to specify that records contain the first word but not the second.
- if you want to include **and** or **or** as part of a title, type them in quotation marks
  e.g., war "and" peace.
- generally, put quotation marks around terms that you want to search as a phrase.
- use parentheses to indicate which items should be searched first.
  e.g., baseball and (brewers or twins), otherwise databases find brewers or twins first and then looks for records that also include baseball.

<u>Boolean Search Tips</u>

Boolean searching is a way to combine your search terms to broaden or narrow your search. The three basic boolean search terms are AND, OR, and NOT. Below, A and B represent your search words, and the shaded areas indicate the results.



AND OR NOT

Linking terms with these words will give the results specified below.

OR: will find references that include <u>either</u> of the terms you specify.

Example: Linking Global Warming OR Greenhouse Effect will find all references with either of these terms. This broadens your search and is useful for terms which are synonyms so you don't miss important references

AND: will only find references that include <u>both</u> of the terms you specify.

Example: Linking Wolves AND Moose will only select references which include both of the terms wolves and moose. If a reference has only one of the terms, the it will not be listed. This is a good way to narrow a search.

NOT: allows you to find only references that include one of the terms but not the other.

Example: Linking Wolves NOT Moose will find all references with Wolves except those which also contain moose. It can be handy for limiting your search by excluding terms that you are not interested in.

<u>Misplaced Words and Punctuation</u>

Iraqi Head Seeks Arms
Kids Make Nutritious Snacks
Red Tape Holds Up New Bridges
Enraged Cow Injures Farmer With Ax
Hospitals are Sued by 7 Foot Doctors
Those old things over there are my husbands.
Plane Too Close to Ground, Crash Probe Told
Man Struck By Lightning: Faces Battery Charge
Police Begin Campaign to Run Down Jaywalkers
Typhoon Rips Through Cemetery; Hundreds Dead
To protect yourself from purse snatchers, use purse hook.
Two Sisters Reunited After 18 Years in Checkout Counter
Darwin discovered the theory of natural selection on a ship.
Tubers were eaten by ancient peoples after they were cooked.

The WWC Library's List of Electronic Databases in the Sciences

Academic Search Premier, 1984 to the present
Academic Search Premier provides abstracts and indexing for over 8,200 scholarly journals covering the sciences, social sciences, humanities, education and more. Also offers full text for over 4,700 journals with many dating back to 1990. Includes coverage of over 1,700 peer-reviewed journals.

Agricola, 1970 to the present (updated monthly)
The *AGRICOLA* database indexes 2,500 journals, USDA publications, state agricultural experiment station and extension services documents, FAO publications, foreign documents, conference proceedings, books, and audio-visual materials. Its subject matter covers agriculture economics and rural sociology, animal industries, animal nutrition, botany, chemistry, entomology, food and human nutrition, natural resources, plant science, soil science, veterinary medicine, and water management. Approximately 10% of the citations include abstracts.

American Chemical Society Journal Search
You can search the journal collection of the American Chemical Society by title or author. You will be able to get the full text of these journals online back to 1996.

Annual Reviews
Full-text articles that synthesize the primary research literature in 32 focused disciplines within the Biomedical, Physical, and Social Sciences. Our coverage extends back to 1996.

Applied Science and Technology Index, 1983 to the present (updated monthly)
Applied Science & Technology Index covers more than 400 English language scholarly and trade journals in the general fields of engineering, computers, chemistry, applied mathematics, energy, and a wide variety of applied sciences.

Basic BIOSIS, 1994 to the present. Index of core life science journals.

Biological & Agricultural Index, 7/1983 to the present
Indexes English-language periodicals in life sciences and agricultural subjects, published in the U.S. and elsewhere. Includes book reviews.

Biology Digest, 1989 to the present (updated monthly from Sept. to May)
Biology Digest provides lengthy abstracts written in a non-technical style to over 300 journals covering the life sciences. Subjects covered include botany, health, medicine, environmental science, life sciences and zoology.

BioOne A full-text aggregation of bioscience research journals focusing on the biological, ecological and environmental sciences.

Chemical Abstracts
The world's largest and most comprehensive collection of chemical information. 1966-present. See a librarian if you think you need to search this database.

Dissertation Abstracts Online, 1861 to the present
Index of the complete range of academic subjects appearing in dissertations accepted at accredited institutions. Began abstracting dissertations in 1980 and theses in 1988.

Earthscape
"An online resource of the global environment," Earthscape provides a wide range of information in the Earth sciences and environmental policy. The database contains hundreds of curriculum-related materials, conference proceedings, video clips, web links & resources, plus journals and books.

Encyclopedia of Life Sciences
"The most ambitious reference work ever to be published in the biological sciences," with over 3,000 specially commissioned, peer-reviewed and continually updated articles.

General Science Index, 5/1984 to the present
Journals and magazines from the U.S. and Great Britain, covering such subjects as anthropology, astronomy, biology, computers, earth sciences, medicine and health, and much more. Includes articles, reviews, biographical sketches, and letters to the editor.

GEOBASE, 1980 to the present
Index of records covering the worldwide literature on geology, geography, and ecology.

JSTOR - The Scholarly Journal Archive
This database provides complete archives of core scholarly journals, many of which date from the 1800s (and some earlier), covering the following disciplines: general science, botany, ecology, and history of science. The most recent issues of journals are not included (typically, there is a 2-5 year gap).

Kirk-Othmer Encyclopedia of Chemical Technology
“the bible of chemical technology," this is the online version of the classic reference that was first published in 1949. Covers properties, manufacturing, and uses of chemicals and materials, processes, and engineering principles combined with insights into current research, emerging technologies, economic aspects, and environmental and health concerns.

Medline, 1965 to the present (updated monthly)
MEDLINE is the source for clinical medical information covering all aspects of biomedicine, including the allied health fields; biological and physical sciences; and humanities and information science as they relate to medicine and health care. Citations are available for documents from over 3,600 journals published throughout the world, plus selected monographs of congresses or symposia (1976-1981). The majority of records from 1975 to the present include abstracts.

NetLibrary
A large collection of about 45,00 full-text books, some of which cover the sciences.

Proquest Research Library
Provides comprehensive indexing and abstracting to articles from over 1,800 periodicals covering a variety of subject areas, plus current coverage of articles from The New York Times

and The Wall Street Journal. Also includes full text and/or page image for over 600 of these titles. Can limit to peer-reviewed articles.

ScienceDirect
Provides indexing for over 2,000 journals in the science, technology and medicine fields. Full text is not available for "guest" users.

Wiley Interscience E-Books
A small full-text collection of electronic books covering biology, chemistry, physics, genetics, mathematics, statistics, etc.

WorldCat (OCLC Union Catalog), 11th Century to the present (updated daily)
WorldCat is a catalog of nearly 40 million books, serials, audiovisual media, maps, archives/manuscripts, scores, and computer files owned by libraries around the world. Since March 1997, links to Internet sources have been added to the Web interface.

Glossary of Library-ese

Abstract - a summary of a work (article, book, etc.). It should summarize Introduction, Methods, Results, Discussion.

Annual Reviews - These are books or journals that summarize articles in a specific subject area. They are peer reviewed by other scientists in that field and have an extensive citation section. Examples are *Annual Review of Biochemistry, Annual Review of Ecology and Systematics,* and *Accounts of Chemical Research* (online). There are several others that begin with the words, "Annual Review . . ."

Bibliography - A list of works (books, journal articles, etc.) usually listed in alphabetical order by author and title and usually supporting a specific topic or interest.

Citation - Information identifying a book or article. Book information includes author, title, publisher and date of publication. Article information includes author, title of article, volume, pages and date.

Full-Text - All the words of the article are available in the record. You can read, print, or download the article from your computer. Illustrations, photos and graphs are sometimes not included.

Interlibrary Loan (ILL) - The process by which a library requests materials from, or supplies materials to, another library. To obtain books or articles not available in your library, check with your librarians about your library's interlibrary loan policies.

ISBN (International Standard Book Number) - A unique 10-digit number that identifies a specific book.

ISSN (International Standard Serial Number) - A unique 8-digit number that identifies a specific serial (journal, magazine, newspaper, etc.).

Journal - A periodical containing scholarly articles and/or disseminating current information on research and development in a particular subject field. A **refereed journal** has a structured reviewing system in which at least two reviewers, excluding in-house editors, evaluate each unsolicited manuscript and advise the editor as to acceptance or rejection. **Magazines** differ in that they are for general reading and contain articles, stories, photographs, and advertisements on a variety of subjects.

Keyword searching - Looks in the entire record for the term(s), which increases the number of records retrieved. If you are unsure of the vocabulary used in the database, start with keyword searching.

Library catalog - A searchable index of the materials owned by a library (or a group of libraries if they share a catalog). Most "card catalogs" have been replaced by computerized catalogs (also know as "online catalogs" or OPACs—Online Public Access Catalogs). Usually, these catalogs primarily contain information about the library's book collection; most also include other items the library owns such as audiovisual materials. While they may show what magazines and journals the library subscribes to, they usually do not provide access to individual journal articles.

Peer reviewed – This is a book or journal that has submitted its contents for review by experts who are not part of the paid editorial staff. The reviewers are usually college professors and researchers who have previous experience with the topic of the article and give the editor a recommendation on whether the article is sound and important enough to be published. Each journal discloses its policies in its *Instructions to Authors* about its peer review policies, but a quicker way to determine if an article is peer reviewed is to see whether the article has Introduction, Methods, Results, Discussion, and Literature Cited. If it has these sections, it is almost surely peer reviewed.

Primary Literature - As opposed to secondary literature, this is a book or journal that presents results of original research conducted by the authors. The format is Introduction, Methods, Results, Discussion. Most importantly, the literature is refereed (peer reviewed) by other scientists in that field. Some of these journals publish papers from many scientific disciplines (e.g., *Science, Nature*) but they are still peer reviewed. Others (e.g., *Agronomy Journal, American Midland Naturalist*) publish from one area only.

Reference book - A book or work compiled for consultation (reference) on specific information rather than for continuous reading. Usually these titles are shelved separately in a library reference section and designated with "Reference" or "R" above the call number. Examples include dictionaries and encyclopedias, both general and specialized.

Reference librarian - Librarian who, at the reference desk or by appointment, assists library users in their search for information. This professional librarian holds a graduate degree in library or information science and often has an additional graduate degree in another subject field.

Secondary Literature - As opposed to primary literature, this is a book or journal that does not present results of original research. It consists of review articles (which can be peer reviewed), magazines, or trade journals. These often tie together results from many studies on one subject. They may either be technical and targeted at scientists but they are not primary literature (e.g., *Bioscience, Trends in Ecology and Evolution, Chemical and Engineering News, American Scientist*). They may also be targeted at a general audience (e.g., *Discover, Popular Science, Science News, Scientific American*).

Subject searching - Looks in the subject field for the term(s), which results in a narrower, more specific search. Use subject searching when you are familiar with the vocabulary of the database.

COMMONLY USED SCIENCE JOURNALS

Primary Literature

Present results of original research conducted by the authors.
Include the format: Introduction, Methods, Results, Discussion.
Are refereed (peer reviewed) by other scientists in that field.

Examples which publish papers from many scientific disciplines:

- *Science*
- *Nature*

Examples of journals that publish from one area:

- *Agronomy Journal*
- *American Journal of Alternative Agriculture*
- *American Journal of Botany*
- *American Naturalist*
- *American Midland Naturalist*
- *Animal Behavior*
- *Analytical Chemistry*
- *Applied Entomology and Zoology*
- *Canadian Journal of Forest Research*
- *Canadian Journal of Zoology*
- *Conservation Biology*
- *Ecology*
- *Ecological Applications*
- *Environmental Science and Technology*
- *Experimental Agriculture*
- *Freshwater Biology*
- *Herpetological Review*
- *Hortscience*
- *International Journal of Pest Management*
- *Journal of Animal Science*
- *Journal of Bacteriology*
- *Journal of the American Chemical Society*
- *Journal of Herpetology*
- *Journal of Sustainable Agriculture*
- *Journal of Wildlife Management*
- *Plant Physiology*
- *Wildlife Monographs*
- *Wilson Bulletin*
- *Biochemistry (on-line)*
- *Inorganic Chemistry (on-line)*
- *Journal of Animal Ecology (on-line)*
- *Journal of Applied Ecology (on-line)*
- *Journal of Physical Chemistry (on-line)*
- *Chemical Research in Toxicology (on-line)*
- *Journal of Agricultural and Food Chemistry (on-line)*

Secondary Literature (some may be peer reviewed and some not)

Review Periodicals
Summarizes articles published in the previous year in a specific subject area.
Are refereed (peer reviewed) by other scientists in that field.
Have large bibliography.

Examples

Accounts of Chemical Research (on-line)
Annual Review of Biochemistry
Annual Review of Ecology and Systematics
Annual Review of Genetics
Annual Review of Microbiology
Annual Review of Physiology
Chemical Reviews (on-line)

Synthesis Periodicals/Trade Journals
Ties together results from many studies on one subject.
Often presents data.
May or may not be refereed (peer reviewed) by other scientists in that field.
Target audience is scientists.

Examples

Bioscience
Trends in Ecology and Evolution
Chemical and Engineering News
American Scientist

General Science Periodicals
General Interest.
Accessible by non-scientists.
Not refereed (peer reviewed) by other scientists in field.

Examples

Discover
Popular Science
Science News
Scientific American

Using the Internet

Only scholarly web sites should be used as resources for NSS. Examples of appropriate web sites include the *Environmental Protection Agency, Centers for Disease Control*, the *National Institute of Health*, and the *Carter Center*. If you have doubts about whether the site is appropriate, consider the following questions:

- what is the purpose of the site?
- who developed/sponsored the site?
- is there a bias to the site?
- what are the goals and objectives of the developer/sponsor?
- is the information well documented and are there links to sources?
- is the author of the page identified?
- can you contact the developer of the page?
- when was the site last updated?
- what are the author's credentials?

For info on evaluating web sites, try these pages:

Evaluating Web Resources
http://www.widener.edu/Tools_Resources/Libraries/Wolfgram_Memorial_Library/Evaluate_Web_Pages/659

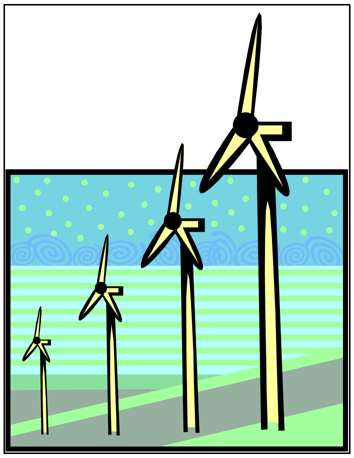
ICYouSee:T is for Thinking
http://www.ithaca.edu/library/training/think.html

Thinking Critically About World Wide Web Resources
http://www.library.ucla.edu/libraries/college/help/critical/index.htm

Library Overview

For a quick, easy-to-understand overview of using the library's resources, consult "Painless Library Research" on the library home page at http://www.warren-wilson.edu/~library/painless2.htm. There, you will find more information on things such as interlibrary loan, documenting sources, and more.

"One must labor for beauty as for bread." *J. Muir*



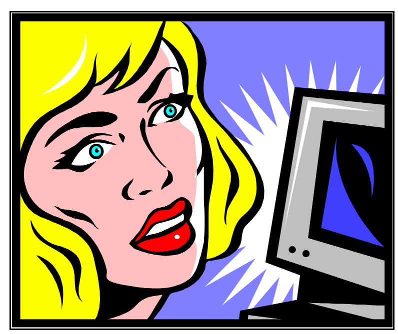
Carin says:

- "I try to be really considerate of the interlibrary loan workers because I know they're busy at our library and others. I only ask for those papers I think I'll really read."
- "I set up weekly appointments with my research advisor. To prepare I keep a little notepad in my backpack and write down ideas and question as they occur to me during the week."
- "I get free notepads at the College Press. They make notepads out of scrap paper and give them to anyone who asks."
- "It's neat to be organized."

Clutz says:

- "I've never bothered to get my own office supplies. When I need something I just go to the office of a really busy professor, interrupt her and ask, 'do you have a paper clip?'"

- "The reference librarian really helped me one day even though he was busy. He listened to me describe my project and gave me several ideas for keywords and suggested I try different combinations.'" I never followed through and lost the piece of paper. Now I have go ask him again."



- "Then when I'm in the office of the really busy professor borrowing the paper clip, I ask, 'why haven't you graded my test yet?'"

- "I can't be bothered with recycling. It wastes my time."

staple this BEFORE CLASS or lose 5 points.

Literature Searching Assignment***** Name_________________________

Now is the time to begin searching literature if you have not already. Use Chapter 4 to complete the following exercises.

1. What is the difference between primary (peer reviewed) and secondary (popular) literature? What is the difference between a journal and magazine?

2. How do you know if an article is peer reviewed?

3. What is the difference between annual reviews and regular journals? Are review articles primary or secondary literature?

4. Use at least one or two electronic databases to search for a topic related to your NSS.

Google Scholar, Basic BIOSIS, JSTOR and Agricola are some of the most productive for NSS students.

Which databases did you use?

What is your topic?

Which key words did you use and how did you type them in for your best search?

How many records did you find?

Give the title of the best item that you found.

Does the library have the journal article?

5. For the best article, do an additional search on the first author. Cite below any other related articles written by this author that may be helpful.

6. Use the MCLN computer catalog to pursue a topic related to your NSS. Answer the questions below.

Did you search by subject, author, title, or keyword?

Give the title of the best item that you found.

Does our library have the book? If not, did you order it through interlibrary loan?

7. Go to the library home page and click on "Search the Net." Using a search engine of your choice, search for a topic related to your NSS.

Which key words did you use?

Give the address of a site you found.

Briefly evaluate this site based on the criteria listed in this chapter.

8. Talk to your advisor this week about your progress and ask for some advice on searching the literature or any other sources you should be reading. Summarize your meeting here.

9. What goals for your project do you have during the coming week?

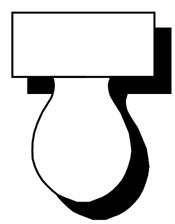
10. What is your topic?

Trina says:

- "I'm going to keep my copy of the NSS Handbook for next year."
- "I actually know how to write a grant application now."
- "I feel ready to consider graduate school."
- "The pace of the course is rapid and exciting."

Latrina says:

- "There should be a required statistics course, but not till after I leave."
- "They can't possibly expect us to pay attention for a 4:00 class, can they? I'm like, hello, it's not like this in the real world."
- "This course was remedial. That's why it's not fair that I'm getting a C."
- "I felt rushed. How is anyone supposed to come up with a research idea in just half a semester?"
- "This course should be optional based on self advisement."
- "Ya, well screw it."



SCI 390 Research Design Practice Test

Fill in the blank.

1. The process by which a library requests materials from, or supplies materials to, another library is ____________________________________.

2. Write the name of the electronic database accessible through the campus library website that is a catalog of nearly 40 million books owned by libraries around the world ___________________________.

3. When searching a library record or database, one may increase the number of records retrieved by starting with a _________________________ search before moving to a title, author, or subject search.

4. Books that have an R above the call number can be found in the _______________________ section.

5. If you wanted to include the singular or plural form of a search term with several endings, such as poliovirus, polioviruss, polioviruses, write the shorthand way of writing this for most databases? ___________________________________

6. How is a bibliography different from literature cited?

7. How do you know if a journal is peer reviewed?

Mark T or F for true of false.

8. The phrase “et al.” stands for “third author.”________

9. You should cite only those sources you have read.________

10. In science writing, each word should be scrutinized for its efficiency. Anything that is not essential should be eliminated.________

11. In science writing and in NSS, all measurements should be in English units (such as feet and miles) not in metric.______

12. Objectives should include an if, why, or whether. ________

13. Citations should be included in an abstract. _________

14. It is ok to take NSS Communication and NSS Attendance during the same semester. _____

15. In the NSS presentation, you must include a section called Future Research. _________

16. In an abstract, the summary of results should be very detailed including perhaps P values, correlation coefficients, and Chi-squared. _______

17. In the final paper, methods and results should be presented in the past tense._______

18. You should always make your teacher staple your assignments for you.______

19. In biology, students should use "we" (to include the advisor) and active voice ________

20. Which is (are) correct?
a. *Pan paniscus* b. Pan Paniscus c. pan paniscus d. <u>Pan</u> <u>Paniscus</u>

21. Which are (is) correct?
a. ect. b. ect c. et cet. d. etc.
e. you should not use this phrase in science writing.

22. What is the difference between further and farther?

<u>Correct the following title.</u>

23. The role of hemal tissue in moving nutritive substances to the gonads of the marine mussel *Mytilus galloprovincialis*

<u>Revise and correct the following</u>

24. 12 out of 55 piglets had low iron concentrations.

25. This data shows some interesting trends from small concentrations to large.

26. Each species belong to the genus, trichanovi.

27. Ferguson examined autoradiographs of sea star digestive tissue after being fed radioactive clams (1989).

28. Like flatworms and earthworms, leeches have proven useful to neurophysiologists.

29. Its ventricular orifice had nowhere to go to.

30. Gas chromatography was utilized.

31. During the second sampling we noticed alot of geese.

32. Hormones effect the pathways that allow chlorophyll to make energy.

33. According to Johnson, "Plants provide a constant supply of oxygen to our atmosphere."

34. Its generally known that carbon dioxide is important to.

Substitute **one** word for each phrase below.

35. continue on -

36. due to the fact that –

37. Of the sentences below, circle the letter of the topic sentence.

a) It is becoming clear, however, that although wave propagation is a common feature of activation, there are both subtle and significant differences in this response when comparing eggs from different species.

b) It appears that all vertebrate, invertebrate, and perhaps even some plant eggs are activated by the generation of calcium transients in their cytoplasm (Roberts et al. 1994, Lawrence et al. 1997).

c) In contrast, activation triggers a series of repetitive calcium waves or oscillations in annelids (Stinker 1996), ascidians (Albrieux et al. 1997), and mammals (Kline and Kline 1992).

d) For example, in fish (Kilkey et al 1978), echinoderms (Stinker et al, 1992, and frogs (Busa and Nuccitelli 1985, Kubota et al. 1987), a single calcium wave is propagated across the activating egg.

e) In most cases these transients take the form of propagating calcium waves (Jaffe 1985, Epel 1990, Whitaker and Swamm 1993), which appear to be essential for activating the eggs.

Define

38. research design -

39. pseudoreplication -

Short answer:

40. What should one do **first** if the assumptions of a t-test have not been met?

41. Which is correct? Choose only the best one.

a. The treatments were not significant.
b. There was no significant difference among the means of Treatment A and B.
c. There was no significant difference between the means of Treatment A and B.
d. I will use a diversity index to determine if there is significance.
e. There was no significant difference in means, but Treatment A was greater.

42-43. Below is a chart showing the null hypothesis for each test. Fill in the blanks

t-test	ANOVA	Chi^2
$\bar{x}_1 = \bar{x}_2$	________	___________

44. Should one reject or fail to reject the null for the ANOVA in the box below? ________

45. Write the *P* value that told you whether to reject or not.__________________

46. Can we accept this value? Why or why not?

47. Which treatments would be different from which?

Levine Test for Homogeneity of Variances

statistic	df1	df2	2-tail Sig.
0.7616	1	8	0.0230

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	*P*
Between	1	16.3840	16.3840	15.36240.089	
Within	8	8.5320	8.5320	1.0665	
Total	9	24.9160			

Tukey-Kramer pairwise comparisons 2-tail Sig.

	horse	pig	cow
horse	0.00		
pig	0.072	0.00	
cow	0.099	0.124	0.00

Mark T or F (for true or false).

48. Rather than citing every sentence in a long paragraph that is all from one source, the paragraph should be cited once at the end of the paragraph.________

49. In science writing, sentences should be less than three typed lines._______

50. Graphs often provide convincing results even without statistics.________

51. In NSS if there is a choice between using a table and a bar graph, the table should always be used._______

52. In a Yarbrough Grant application or the final paper, pages should be numbered. ________

53. Experiments involving human subjects require special permission. _________

54. Didactic means preachy. ________

55. When writing the Introduction, one should generally move from specific to general. ______

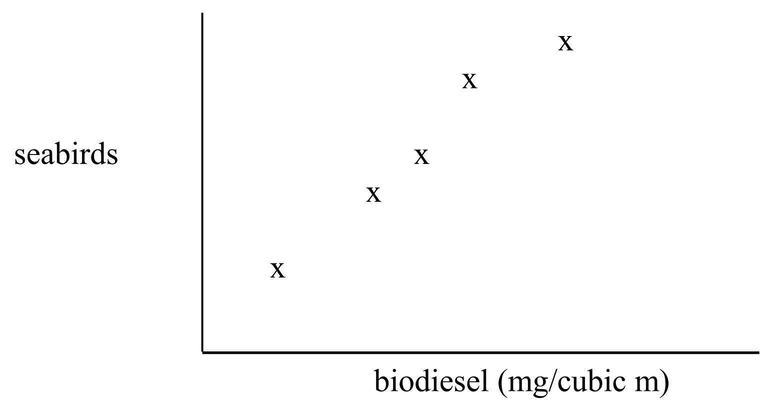
56. Every graph, figure, map, or table should be referenced within the text like this (Fig. 3) or this (Table 1). _____

57. Citing at the beginning of a sentence (e.g., Wilson (1932) found the Asheville Farm School to be the top cool school) is preferable over citing at the end. ______

58. In the NSS presentation, you should begin by reading the title. _________

59. In the NSS presentation, your final slide must be Literature Cited, which has a very tiny font and is flashed on the screen for one second or less. ________

60. Duncan's Multiple Range is the best post-hoc test. _________



61. If this is regression in the graph above, which is the dependent variable? _______________

62. What r value would you expect the graph to have? _________________

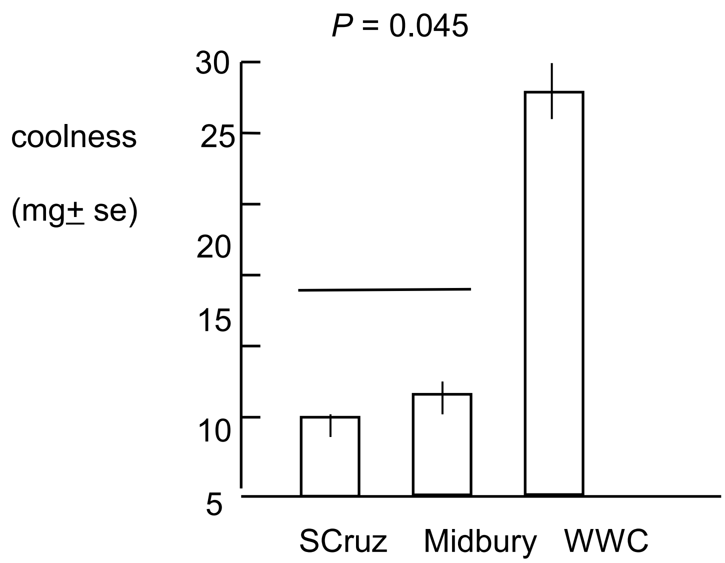
63. Which phrase describes the situation best?
a. the less the biodiesel, the greater the seabirds.
b. the less the seabirds, the greater the biodiesel.
c. the greater the seabirds, the greater the biodiesel.
d. the greater the biodiesel, the less the seabirds.
e. there is no correlation between seabirds and biodiesel.

64-65. Indicate which of the following sentences are facts rather than opinions and therefore need a citation.

The late nineteenth century was a time when much needed to be reformed. opinion or fact?

On one occasion, Bly posed as a maid for a story on employment agencies that took advantage of poor, uneducated women. opinion or fact?

66. In the graph below, should you reject or fail to reject the null hypothesis?_____________



67. In the graph above, which treatments are significantly different from which? How did you know for sure?

68. Which statistical test(s) was/were used to make the conclusion in 67?

69-70. An experimenter measures an observer's ability to detect very dim lights and discovers a positive correlation between ability and minutes in the dark. Draw a graph showing the relationship using good graphing form.

71. A type I error is
a. Psuedoreplication.
b. Confounding variables.
c. Confusing the *P* value with the t of F value.
d. The researcher has rejected the null hypothesis when it was really true.
e. The researcher has failed to reject the null hypothesis when it was really false.

72. T or F Statistics are required in the NSS.

73. T or F It is when we go graphless that the statistical world can become murky. _______

74. T or F Approximately 67% of the observations occur within $\pm$ one standard deviation of the mean.

75. T or F In most cases one should put more effort into sub-samples than true samples.

76. T or F If we compare foods or products purchased at a store, we must be careful about whether the samples came from the same lot, brand, delivery route, or manufacturing plant.

77. T or F Nonparametric tests are preferred over parametric.

78. Define median.

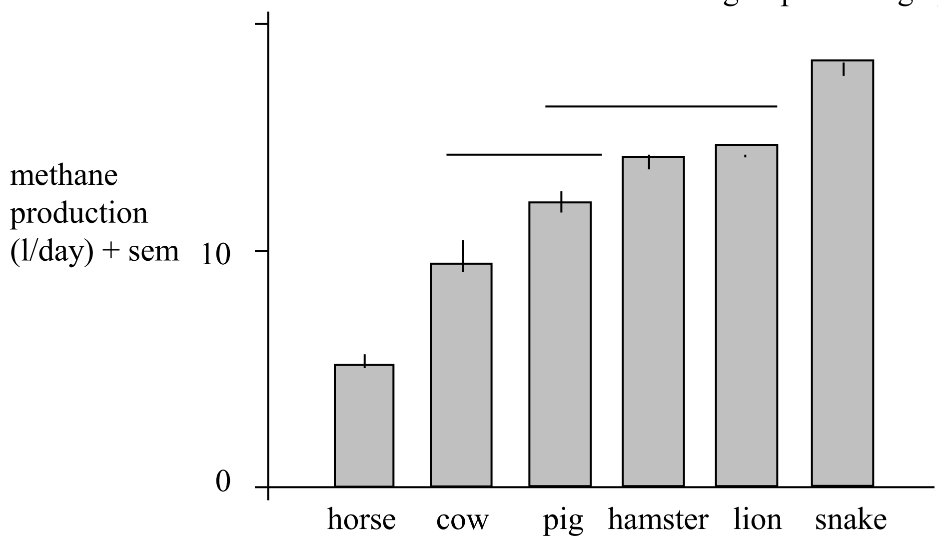
79. Define haphazard and contrast it with randomness.

80-81. Use examples to describe the difference between random and systematic sampling.

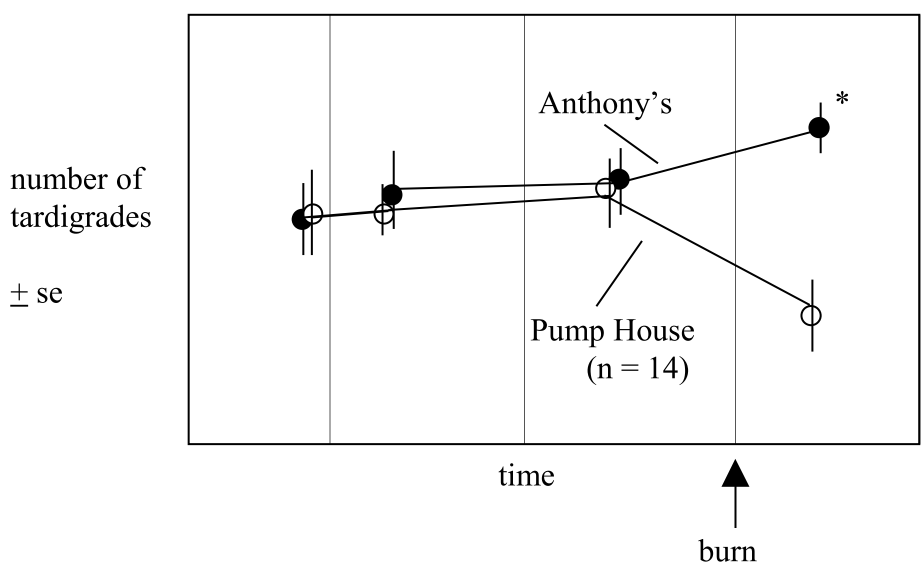
82-83. Should samples be taken randomly or systematically? Explain your answer.

84-85. Describe an example of temporal pseudoreplication.

86-87. There are 11 differences between treatment groups in the graph below. Identify four here.



Students used a random numbers generator to find 30 random sampling sites in the forest stand known as Pump House and 30 more in the forest stand known as Anthony's. They took a core sample at each random site within each stand and counted the number of tardigrades found in each. They sampled three times, then performed a prescribed burn in Anthony's and repeated the sampling in both sites. Their results are below with a * indicating any significant difference.



88. What is the sample size?

89-91. They concluded that burning had a positive effect on the number of tardigrades. Critique their conclusion based on their experimental design.

92. If they were to perform a BACI design instead, describe how it would be different?

Researchers would like to know if parasites on the scales of fish are clumped or occur at random. They caught 98 fish and counted the number of parasites on each. They found 38 fish with no parasites, 44 with one parasite, 14 with two parasites, and 2 with three parasites or more.

93-94. Which statistical test would be most appropriate for this design? Explain your answer.

95. There are four scores in a distribution with a mean score of 36 and a variance of 16. What is the standard deviation? What is the standard error of the mean?

Methane can be produced by letting bacteria break down rich organic matter such as animal feces in an anaerobic (no oxygen) environment. The objective of a student's research was to determine which type of dung produced the most methane, cow, pig, or horse. A sample of each type of manure was obtained from the WWC farm. Flasks were constructed to create anaerobic conditions and collect the methane produced. For each type of manure, four flasks were set up (12 total). Into each flask 100 grams of the appropriate manure were added. All flasks were inoculated with the same amount of methane producing bacteria and placed in the same incubating chamber at 40 C. The gas produced was collected and the volumes were determined and compared.

96. What statistical test should be used?

97-100. If the test showed a *P* value of 0.001, can the student conclude that there is a significant difference in the production of methane from each type of manure?

Extra Credit!!!

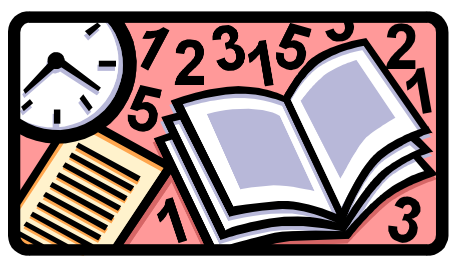
102-105. On the next page explain the principle behind multivariate analysis, multiple regression, or experimental regression.

Sally Savvy says:

- "To protect my clothes in the chem. lab, I'm going to get an old shirt at the Free Store to wear like a big smock."
- Work creates talent.
- "I think I'll eat an apple for my dessert today."

Sally Slacker says:

- "After I finish my seminar, I'm going to leave all my NSS junk in the research lab so someone else will have to clean it up.'"
- "I don't wear goggles in the chem. lab."



- "I'm too lazy to submit my Yarbrough, but I expect the college to pay for all my research supplies. If it drains the budget and there's nothing left for the students in the second semester, that's their problem."

- "I'm going to eat a big bowl of gravy for my dinner."

Chapter 5
Statistical Analysis
by Lou Weber

"Statistics should simplify not complicate biological interpretation."

"The ability to interpret statistics is not as important as the ability to interpret graphs."
both quotes above from Magnusson and Mourao, Statistics without Math

Undergraduates come to research with a great deal of logic, which is why it is often refreshing for faculty to work with young students. They sometimes offer ingenious answers to *why* questions with simple, uncluttered reasoning. When asked to access this on command, however (as in Research Design), students often have a difficult and frustrating time expressing themselves. Their vocabulary and library of concepts seems imprecise and subjective. A student's job then, is to learn a new vocabulary, reach a deeper level of understanding, see the world more clearly, organize knowledge more cleanly, and be able to express language with more accuracy and precision. In science this often means taking the subjective and turning it into measurable quantities and categories.

Take color, for instance (Magnusson and Mourao 2004). We all know what it is, but how do we express it rationally? A rich vocabulary categorizes it. Scientists take the approach of understanding the human eye, and also how red, green, blue, and black dots from a printer can make all the other colors, and how electromagnetic wave lengths can be quantified and measured. Take sex, another interesting topic. The scientific approach is to quantify hormone levels, metabolic rates, various cycles, chromosomal changes, hydraulic processes, and behavioral consistencies. Science means categorizing and quantifying, putting the world into boxes and becoming evermore precise at differentiating one box from another. Welcome to statistics as a major tool for this purpose.

Graphing, in particular, is a chief way we organize and express rational and quantitative thoughts into boxes. The ideas in our heads may be a jumble of words, pictures, and memories, but when we want to express a scientific idea to others, graphing is one of the most elegant ways to categorize and quantify. The next step after graphing is statistical analysis, using mathematical formulas, definitions, and computer programs to predict, define, and tell exactly how different one box is from another.

The problem is that the formulas, definitions, symbols, and ever-changing computer complexities (and fickleness) get in the way of learning the basics. One hour spent on concepts entails 10 hours dealing with mathematics and bandwidth. This bogs down understanding, when the main idea in the first place may be a scientific question or experimental design, not statistics.

Attempts to teach statistics becomes, all too often, time spent on ideas too abstract to stick, and detail too trivial to be useful (Magnusson and Mourao 2004). There are students at different levels in every college statistics class. The teacher has to cover the material at different levels and knows it usually takes two or three good runs at it to gain an appreciation, sense of confidence, and that level of understanding where a student thinks, "Oh so this is all they're talking about." It is like pealing layers of an onion. Each effort exposes a deeper layer of understanding – and makes people cry. The other thing about statistics, and this seems truer than for other subjects, is that one has to teach oneself. The teacher may write on the board and talk about things, but it is the student's own mental elbow grease that makes sense of what is being said and files away a library of ideas for future use.

It is not easy for beginners. If you wanted to learn to use a gun, the gun manufacturing brochures may not be the best place to learn the practical and ethical issues that need to be considered first - that guns are designed to kill things (Magnusson and Mourao 2004). So too, a mathematical treatise on statistics is not the best place to begin to gain a practical understanding of experimental design. One problem is that many statistics courses are taught by mathematicians, and their job is to emphasize theory. It may get too deep, too fast, and never cover examples in your field. Another problem is that practitioners, the biologists, chemists, and physicists who advise you, may have years of experience and tricks of the trade using the statistical techniques they need, but their theory is absent and the language may be inconsistent. How are you expected to learn anything and where do you go for advice?

A good place to start is with graphs and maybe the first page of each chapter in a statistics book. After that, one can peel through to the next layer with more complex graphs, experiments, and examples within your field. The perfect class, book, or teacher will never emerge for something so personal and complex. You are going to have to peel this onion for yourself.

There are books at the library about statistics and you might have to read them. The book you are reading now is written from a practitioner's standpoint and makes an attempt to remain uncluttered with mathematics. If a Research Design student cannot understand the simple review in this chapter, he or she will probably not be able to understand the science literature. Even if you do not plan to use statistics yourself, you must be able to understand scientific papers and the work of other students during NSS. For this course you are going to need to read through this chapter in enough depth to take a test on it.

Then again, you may not need to read the chapter if you are confident in your skills. Feel free to move directly to the practice test and assignment at the end of this chapter and see how many questions you can get through, then go back as needed. Once the concepts in this chapter are under control, investigate the results sections of science journals and the statistics and experimental design books from the library to find specific examples that interest you. Even if you have had a statistics course, you may need to review experimental design concepts in this chapter and the next.

There is no requirement for using statistics in the NSS. The faculty would rather a student use graphs and really understand the implications, rather than misunderstand statistics. **Graphs often provide convincing results even without statistics**, and if a student can get to the point of putting results in a graph, it often dictates the statistical method**. It is only when we go graphless that the statistical world becomes dark and complex**. I have tried to be graph-based in the following summary and to use common sense text. You should try to do the same in your project.

<u>Recommended statistics books</u>:
Dytham, C. 1999. Choosing and using statistics. Blackwell Science. Malden, MA, 218 p.

Magnusson, W.E. and G. Mourao. 2004. Statistics without math. Sinauer. Sunderland, MA, 345 p.

Gotelli, N.J. and A.M. Ellison. 2004. A primer of ecological statistics. Sinauer. Sunderland, MA, 510 p.

<u>The Basics of Statistics</u>

Null Hypothesis

"Null" means no, nothing, none, non-existent. It does not mean zero. Depending on the type of experiment conducted, a null hypothesis states that there is:

- no difference between means being compared (t-test and ANOVA)
- no difference between observed values and those expected by chance (Chi-square)
- no relationship between two variables (correlation and regression)

Corresponding to each of these, the alternative hypothesis is the opposite:

- there is a significant difference between means being compared.
- there is a significant difference between observed values and those expected by chance.
- there is a significant relationship between two variables.

For instance, in an experiment in which one is comparing weight of flower bulbs in different beds, some with sun and others with shade, the researcher would want to know if there is a statistically significant difference between means (Fig. 1).

The null hypothesis (H_0) for the comparison is that there is **no difference** in the mean weights of the two **treatments**. In short, $\bar{x}_1 = \bar{x}_2$ (read this as the mean of treatment one equals the mean of treatment two).

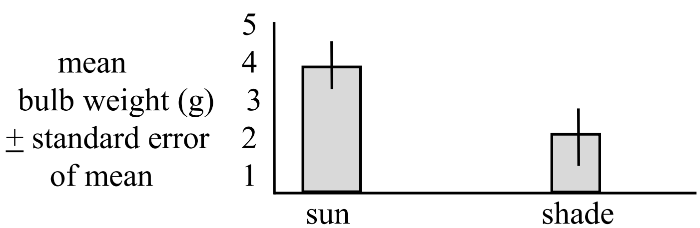


Figure 1. Bar graph showing the mean bulb weights between samples in the sun or shade.

A t-test would be used to compare two means statistically. The test could be completed by using the t-test formulas and charts in a statistical text, or by using computer software such as Excel, Instat, SPSS, Minitab, or others. The result of the test will provide a *P* value.

P values

- *P* is difficult to define, but beginners can think of it as **the probability that the null is true** **(H_0: $\bar{x}_1 = \bar{x}_2$).**

- if $P < 0.05$, reject it. The data supports the alternative hypothesis and one can conclude that the means are significantly different.
- if $P > 0.05$, fail to reject. There is not enough support for the alternative hypothesis.

When $P < 0.05$, it is sometimes thought of as having less than a 5% chance that the null is true (and that explanation is ok for beginners). Actually, a more accurate way to express it is that a difference as great as what we found between treatments would only be expected less than 5 out of 100 times (Gotelli and Ellison 2004).

Why do we use $P = 0.05$ as the cut off point? This seems stringent if we reject only when there is less than 5% chance that the null is true. If you used this rule in your everyday life, you would never take an umbrella unless the forecast for rain was at least 95% (Gotelli and Ellison 2004). It implies that when we are 94% sure the null is false, we still do not reject, or carry an umbrella. This requires evidence to be exceedingly strong in order to reject the null hypothesis. We would all certainly take precautions if we knew there was a 95% chance of a tornado.

- The convention is based on probability. We do not measure the whole population, only a sample, and sometimes our analysis is wrong. We could be making an error and so we need to be conservative.
- There are two types of errors we could make as illustrated in Table 1.

Table 1. Deliniation of Type I and II errors.

	analysis indicated that we should *fail to reject* H_0	analysis indicated that we should *reject* H_0
H_0 *true* = in reality there is no difference $x_1 = x_2$	our analysis is correct	**type I error (alpha)**
H_0 *false* = in reality there is a difference $x_1 \neq x_2$	**type II error (beta)**	our analysis is correct

The higher P you choose, the more you increase your chance of making a **type I error**. A type I error is the worse type because it is a false positive. **The researcher has rejected the null hypothesis when it was really true**. More significant differences were declared than were actually there.

- If you use a lower P than 0.05, you increase the chance of making a **type II error**.
- Experience has shown that $P = 0.05$ is about the right balance between Type I and II errors for most situations.

An important thing:
Be careful about using the word "prove." Just because $P < 0.05$ and you reject the null, it does not prove that the null hypothesis is false. It just indicates that it is probably not true.

Another important thing:
Three things lower the value of P: the difference betweens the means of the treatments, the **number of replicates** in the sample (**n**), and the **variation among individuals** (**variance = s^2**). This makes intuitive sense. Think about it. If there are a large number of samples and their values are all close to the mean in each treatment, it does not require as large of a difference between means to be sure there is a difference. In other words, having a higher sample size gives us more power to detect a difference if there is one. On the other hand, if the means are exactly the same, more samples will not find a difference.

<u>Measures of spread</u>

Measures of variability may include range, variance, standard deviation, or standard error (Fig. 2). They are plotted as "error bars" when displayed symmetrically about a mean on a graph.

- **Range** = highest value within the treatment – lowest value, in other words the maximum and minimum are displayed. Despite its conceptual simplicity, it is rarely used to create error bars because it does not help us know whether means are significantly different the way standard deviation and standard error help us.
- **Variance** (s^2) = sum of $(x_i - \bar{x}_i)$. This is rarely used to create error bars because it is not in the same units as the original observation.
- **Standard deviation** (s or sd) = square root of s^2. This is often used to create error bars because it is in the same units as the mean. Technically, standard deviation is an estimate of the population standard deviation. The true standard deviation (symbolized by the Greek letter omega) can never be known.
- **Standard error** (se or sem for standard error of the mean) = s/square root of n. This is often used to create error bars because it is in the same units as the mean. Researchers like to use it because it is always smaller than the standard deviation and therefore easier to depict on a graph. Technically, standard error is the standard deviation of a distribution of means for repeated samples from a population.
  - n = sample size.

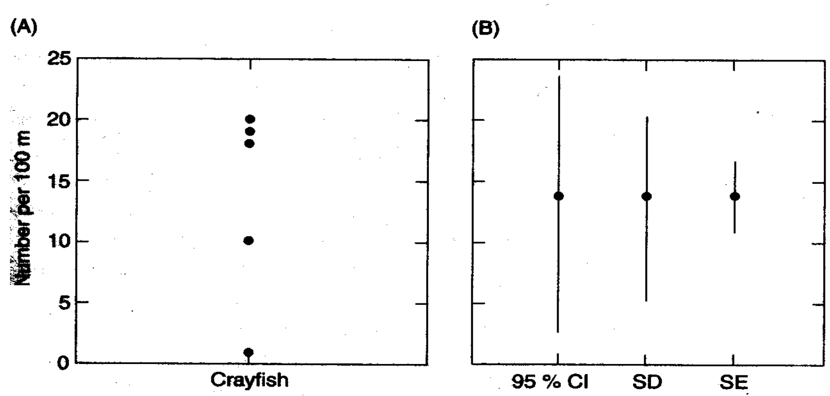


Figure 2. A. a dispersion graph showing number of crayfish in a 100 m stretch of stream. B. statistical summaries from the dispersion graph (Magnusson and Mourao 2004).

In addition it may occasionally be helpful to express some of these measures as a percentage of the mean such as the coefficient of variation (standard deviation/mean) or coefficient of dispersion (variance/mean) (Gotelli and Ellison 2004).

The standard deviation is often used to construct a confidence interval around the mean. For a normally distributed random variable (Gotteli and Ellison 2004):

- approximately **67%** of the observations occur within $\pm$ **one standard deviation** of the mean.
- approximately **96%** of the observations occur within $\pm$ **two standard deviations** of the mean.

We could use this observation to create a 95% confidence interval, or more specifically ($\overline{x}_1$ - 1.96 s and $\overline{x}_1$ + 1.96 s). This is helpful because it shows the size of the normal curve around a mean. If the confidence interval is large, it indicates the mean is less reliable.

What is means is that if we were to repeatedly sample our population (with the same number of samples each time), we would expect the true population mean to lie outside this confidence interval 5% of the time. If we were to increase the sample size, the confidence interval would have to be recalculated.

Students should get into the habit of quickly estimating rough confidence intervals (CI) around the mean when they see a standard deviation on a graph or in text (Gotteli and Ellison 2004, Dytham 1999). For instance if the mean and standard deviation are reported as 2.57 g ± 0.3 se, the 95% CI is approximately ± 0.6. This creates a good way to check reported statistical differences among means.

Measures of average (Dytham 1999)

- **Arithmetic mean** (or mean) = sum of all the values within a treatment/n. It is the most common average and is symbolized by x with a line (bar) over it when it is an estimate of the true mean (symbolized by the Greek letter mu which can never be known).

- **Median** = the middle value of a ranked data set. It is the second most often used average and useful when there are known outliers, or when a researcher would like a quick estimate of the mean and does not have a calculator handy. Numbers do not have to be summed; they only have to be ranked.

- **Mode** = the value that occurs most frequently in a data set. Mode is rarely used as an average, but the term is useful for describing distribution. For instance a unimodel distribution has one peak, a bimodal distribution has two, and a multimodal has three or more. A trough between two peaks is the antimode.

- Geometric mean = the antilog of the mean of the logged data. When we want to compare data sets that are right skewed, the data are log transformed to unskew the distribution. This value is always smaller than the arithmetic mean.

- Harmonic mean = the reciprocal of the mean of the reciprocals.

Comparing Means: t-test and ANOVA

T-tests are used to determine if there is a statistical difference between two means. There is a difference between independent and paired t-tests. Paired t-tests have more power to detect change and should be used whenever appropriate, but most comparisons are independent and not paired. Paired t-tests can be used when pairs of sampling units are correlated. In other words, a plot with a large value the first year is likely to have a large value the second year and so they are correlated. Some examples include when:

- the right side of bilateral animals is compared to the left.
- the same plots are compared this year versus last year.
- identical twins are compared.

If you are not sure whether a t-test is paired or not, it probably is *not*. Proceed as if it is *not*. A t-test can be either one tailed or two. If you are not sure, assume it is two tailed.

T-tests have assumptions that must be met, otherwise the results are invalid. These are:
I. data are normally distributed – frequency histogram forms a bell shaped curve (Fig. 3). This will almost always be true if there is a sample size of 30 because of the Central Limit Theorem.

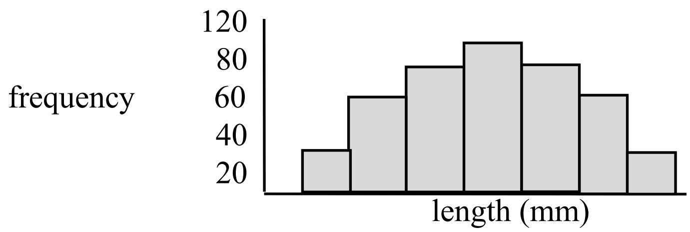


Figure 3. A bell-shaped curve in a frequency histogram. Each bar represent a range of values and there are no gaps between the bars. Values on the x-axis show the mid-points of the range.

II. the variances of each treatment are approximately equal to each other. This is the more important of the two assumptions. Variance refers to how much variation there is among the samples in one treatment. There is a formula to calculate it.

III. observations are independent. In other words, there is true replication, not pseudoreplication, and there has been randomization.

During the seminar, you should state whether the assumptions have been met. If you do not, faculty might subtract points or ask you pointed, annoying questions. To test for the first two assumptions, Instat will automatically check them for you, and in fact will not let you proceed if you have violated an assumption. The other statistical packages have other ways to check, although they might be more complicated than in Instat. In an emergency you can use some seat of the pants rules from below:

To test Assumption I:
1. if you have 30 samples or more, assume the assumption is met,
2. if you have less than 30 samples, plot the mean and individual values for each treatment on a number line. If the individual values are evenly distributed around the mean, assume the distribution is normal.
3. read the print-out from a computerized statistical analysis and see the results for a normalicy test.

To test Assumption II:
1. calculate the variance or standard deviation for each treatment. (Excel can calculate this for you.) If the standard deviations are roughly equal (within 30%), assume the assumption has been met.
2. check the Levine's test or other computerized test on the printout for results of the equal variance assumption.

To test Assumption III: use common sense and judgment. There is no computer program that can tell you this. Was there true replication, or is it psedoreplicated? If this assumption is not met, the analysis must be abandoned. There is no other choice.

What if the first two assumptions are *not* met? There are three choices.

- Some statistical packages make corrections for unequal variances such as using the Welch correction within Instat.
- Each number in the data sets can be transformed by ln x, sqr root of x , or ln (x + 0.1). This is like changing units from miles to km. The natural log transformation is the most common and has the particular effect of making the standard deviations relatively smaller and therefore more equal. This seems like a magic trick, but it is as valid as changing units from miles to km.

    - Please note that when dealing with percentages, the assumptions are almost always violated. The best transformation to use with percentages is to take the arcsin square root of each of the data points.
    - Note also that although you may transform the data for analysis, you should **report the results in the original units** when making graphs or tables**.**

- If the problem is not corrected when the test is run on the transformed data, the researcher should use a **non-parametric test**. These have fewer assumptions. **Parametric** means that the probability fits a specific distribution, almost always this implies a bell-shaped (normal) curve. Note however, that non-parametric tests are usually based on ranks, a far less accurate way to assess differences. The non-parametric alternative for comparing two means is a Wilcoxon signed rank test or Mann-Whitney U test. The alternative for comparing more than two means is a Mann-Whitney U test or Kruskal-Wallis.

Which is the best choice, parametric or non-parametric?

You should always try to use parametric tests if at all possible. Non-parametric should be used only if a correction or transformation will not fix the problem. Parametric tests are far more accurate and do the most to reduce both type I and II errors. The difference is as dramatic as using a laser scalpel to do brain surgery rather than a dull, unsterilized axe for the same surgery. If you use a non-parametric test for NSS, you should justify your use of it during the seminar, otherwise some faculty members may subtract points or make comments on the evaluation.

What if the researcher is comparing more than two means (Fig. 4)?

An analysis of variance (ANOVA) is used when comparing the means of more than two treatments. The basis of an ANOVA is different from a t-test. An *F* test is used instead. The idea is that if the variance among groups is much greater than the variance within, the treatments must be significantly different. This makes intuitive sense. Think about it.

To do this in practice, the sum of the squared deviations among treatments $\sum (\bar{x}_1 - \bar{\bar{x}})^2$ is divided by the sum of the squared deviations within treatments $\sum (\bar{x} - x_1)^2$ to produce an F value. The F value is checked against a table of values to determine *P*.

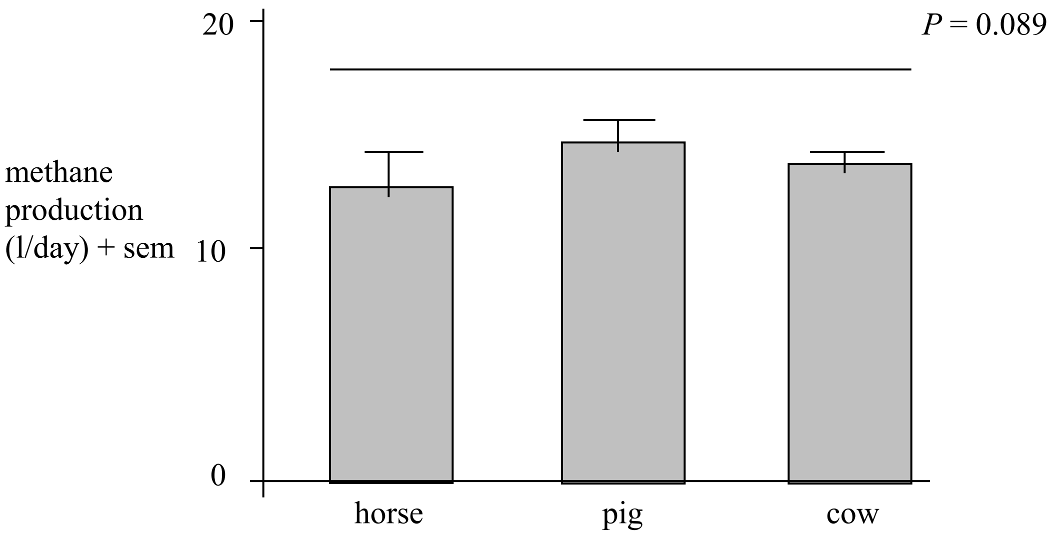


Figure 4. Methane production by type of farm animal (n = 5) at Warren Wilson College when fed standard diets administered for six weeks during spring 2006.

The computer output for an ANOVA is in a table format (Table 2) (Dytham 1999):

Table 2. The standard ANOVA table produced in computer output.

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	*P*
Between	1	16.3840	16.3840	15.36240.089	
Within	8	8.5320	8.5320	1.0665	
Total	9	24.9160			

The business end of the table, of course, is the *P* value. In this case $P > 0.05$ and so there is no significant difference among treatment means. We fail to reject the null hypothesis. Please note that when we refer to differences between two means we use between. When we refer to differences among more than two means we use among.

What are the assumptions of ANOVA?
1. observations are independent. If the researcher has randomized and replicated and there is no pseudoreplication this assumption is met.

2. variances are equal among treatments. This is the most important of the assumptions and usually a problem. Usually the higher mean has a larger variance. Lavene's test on a computer can be used to check this assumption. If Levene's test is not available then Lou's rule of thumb is that if all variances are within 30% of each other, the assumption is met.

- if not met, then transform, usually ln (x + 0.1).
- if still not met then use a non-parametric test, in this case Kruskal-Wallis. The assumption for K-W is that there are few ties.

3. data are normally distributed - do frequency histogram or use statistical packages to test for this (or if sample size is at least 30, the researcher generally does not need to worry about this).

When adding the Levene's test, the computer output will now look something like Table 3 (Dytham 1999):

Table 3. ANOVA table with output for Levine's test.

Levine Test for Homogeneity of Variances

statistic	df1	df2	2-tail Sig.
0.7616	1	8	0.408

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	*P*
Between	1	16.3840	16.3840	15.36240.089	
Within	8	8.5320	8.5320	1.0665	
Total	9	24.9160			

The 2-tail Sig. value is the *P* value for the Levine's Test. It tells us that there is no significant difference in the variances among treatments, thus we have met the equal variance assumption. That is good and means we can proceed to validly accept the information in the analysis of variance table. If the *P* value for the Levine's test were less than 0.05, we would have to take corrective action such as transforming the data. It would not be valid for us to accept the results in the ANOVA table.

The *P* value for our ANOVA results tell us that some of treatment means are different from each other, but it does not tell us which mean is different from which?
To determine this we need a "**post-hoc" test**. Post-hoc = after the fact. This is also sometimes called *a posteriori* = after the fact. This is also called means-comparison test. These compare every mean to every other mean and provide *P* values for every pair-wise comparison if our overall ANOVA table tells us there is a significant difference somewhere among our treatments. The one thing that is NOT VALID is to complete multiple t-tests to compare every mean to every other mean. This compounds the probabilities and renders the tests invalid.

There are several post-hoc tests available, Least Significant Difference (LSD), Student Newman Keuls (SNK), Sheffe, Tukeys, Duncan Multiple Range. Mathematical research shows that the best one to use is Tukey's. Here is why:

- LSD uses multiple t-tests which is invalid because it produces a result that is too conservative - too many type IIs.
- Duncan's Multiple Range is too liberal - too many type I = worst kind of error. Thus, Duncan's Multiple Range test should **NEVER** be used.
- Tukeys has fewest type II or type I errors – use this.

The computer output with Levine's test, the ANOVA table and the post-hoc test would look like Table 4:

Table 4. ANOVA table with output for Levine's test and post-hoc tests.

Levine Test for Homogeneity of Variances

statistic	df1	df2	2-tail Sig.
0.7616	1	8	0.408

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	*P*
Between	1	16.3840	16.3840	15.36240.089	
Within	8	8.5320	8.5320	1.0665	
Total	9	24.9160			

Tukey-Kramer pairwise comparisons 2-tail Sig.

	horse	pig	cow
horse	0.00		
pig	0.072	0.00	
cow	0.099	0.124	0.00

There are no significant differences between any of our pairwise comparisons among means. None of the *P* values are less than 0.05. Actually, we would probably not have run the post-hoc tests on this analysis in the first place because we did not find a significant *P* value when the overall ANOVA was run.

How do I signify pair-wise significant differences on my graph?

Look again at Figure 4. There is a horizontal line over all three bars. The conventional rule is that this horizontal line is placed over the top of all treatments that are *not* significantly different. In this case the original *P* = 0.089. Because it was not less than 0.05, there were no significant differences. A post-hoc test did not need to be completed.

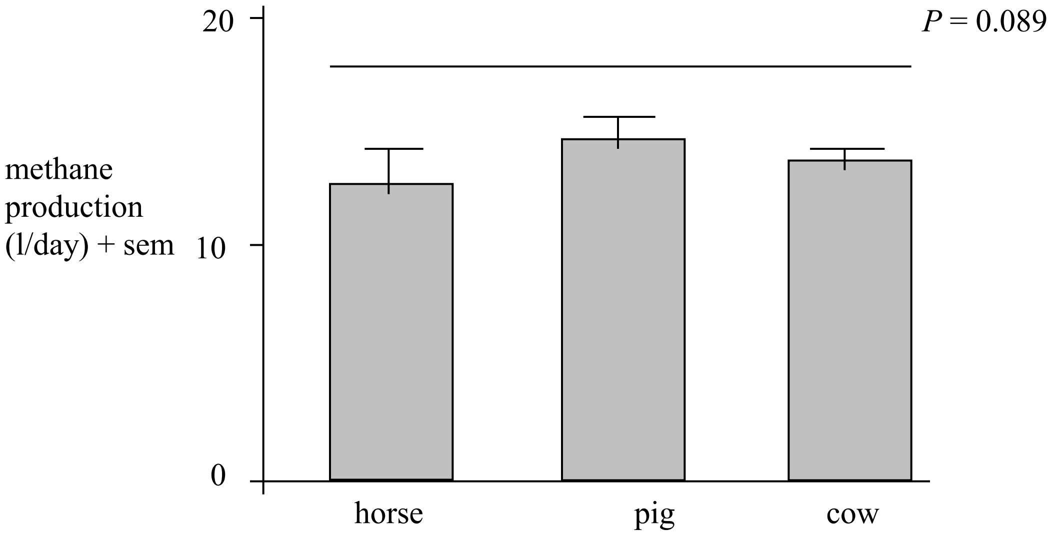


Figure 4. Methane production by type of farm animal (n = 5) at Warren Wilson College when fed standard diets administered for six weeks during spring 2006.

Consider an example when there is a significant difference among one of the means (Fig. 5). The mean for horse is significantly different from the means for pig and cow, but pig and cow are not significantly different from each other. Notice that the graph has a line over the treatments that are *not* significantly different. Notice too that to make this convention work, the means must be placed in order from lowest to highest or highest to lowest on the graph, thus the order of the bars has been rearranged. The computer output is provided in Table 5.

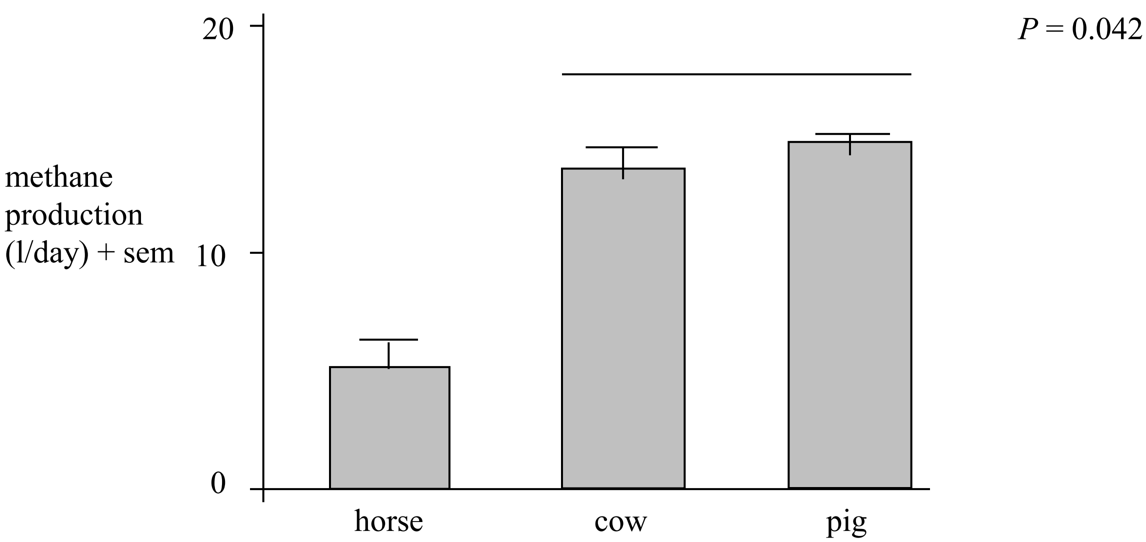


Figure 5. Methane production by type of farm animal (n = 5) at Warren Wilson College when fed standard diets administered for six weeks during spring 2007.

Table 5. ANOVA table for methane experiment in 2007.

Levine Test for Homogeneity of Variances

statistic	df1	df2	2-tail Sig.
0.7616	1	8	0.408

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	*P*
Between	1	16.3840	16.3840	15.3624	0.042
Within	8	8.5320	8.5320	1.0665	
Total	9	24.9160			

Tukey-Kramer pairwise comparisons 2-tail Sig.

	horse	pig	cow
horse	0.00		
pig	0.033	0.00	
cow	0.039	0.124	0.00

The convention of placing a line above the treatments that are not significantly different can be used for some very sophisticated differences (Fig. 6). In Figure 6 the lines tell us that the mean for horse is significantly different from every other mean. The mean for snake is different from every other mean. Cow and pig are not different from each other. Pig, hamster, and lion are not different from each other. Remember, this convention will only work when you order your means from lowest to highest or highest to lowest. All together there are 11 significant pairwise differences depicted in Figure 6. Can you name them all?

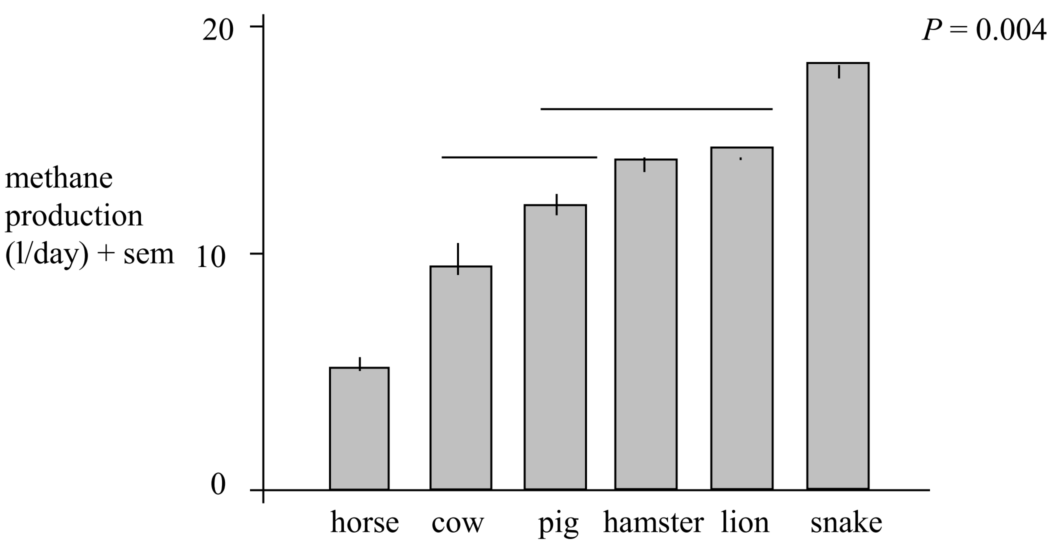


Figure 6. Methane production by type of farm animal (n = 5) at Warren Wilson College when fed standard diets administered for six weeks during spring 2006. Lines above bars indicate no significant difference in pairwise comparisons.

Let us review the main ideas covered so far by forming the table below.

	t-test	ANOVA	chi-squared
what is being compared	two means	more than two means	two or more frequencies
null hypothesis	H_o: $x_1 = x_2$	H_o: $x_1 = x_2 = x_3$	$freq_1 = freq_2$
type of variable	continuous	continuous	categorical

Comparing Frequencies: Chi-squared

When is it appropriate to use a chi-square test?

- when frequencies are being compared, not means.
- when categorical data are being used, not continuous data.
- when the null is that **the observed and expected frequencies are not different.**

Frequencies are not means. They are the number of each organism in a unitless dimension and can only occur as a whole number, not a decimal as is possible for a mean. They count, for instance, how many times a coin lands heads or tails, whether individual beetles reproduce or not, or whether organisms are present or not.

Hypotheses tested in chi-square:

- is the observed and expected frequency the same?
- are phenotypic ratios in a monohybrid cross the same as the expected 3:1 frequency?
- are sex ratios the same as what we would expect?

Comparisons among frequencies are useful in genetic analysis and some chemistry research, but with a few exceptions they are rarely appropriate for answering ecological questions (Magnusson and Mourao 2004). Too many individuals or plots have to be sampled to record something like presence and absence. It ends up being too expensive and time consuming to visit 1,000 trees. A thousand test tubes, however, may be reasonable. Ecologists often find means and the variation among samples to be more appropriate and more enlightening for small sample sizes. Another problem is that chi-squared tests are very sensitive. They almost always show statistical significance to the point where the results become meaningless. If you are doing an ecological project and you find yourself using frequencies, see if you can turn your question into something using a mean. This is almost always possible.

Poisson distributions

The one frequent ecological use of chi-square involves Poisson distributions. For instance to determine mathematically whether the dispersion pattern is random, the data could be compared to a Poisson distribution through the use of the chi-square test. If events are truly random, they should follow the distribution (Dytham 1999). Observed frequencies, not means, are compared to expected values from the Poisson distribution with the same mean.

To determine the dispersion of soil organisms that live under decomposing logs, you could count the number of organisms under standard-sized boards (Table 9). The null hypothesis is that there is no difference between the observed and Poisson frequency. In this case the $P > 0.5$. We fail to reject the null. The spiders appear to be randomly distributed.

Table 9. Distribution of Spiders under boards (Allee et al. 1949).

	Number of Spiders per Board				
	0	1	2	3	More
Observed frequencies	159	64	13	4	0
Expected frequencies (Poisson). . . .	157.0	66.5	14.2	2	0.3

In Poisson distributions the mean and variance are equal (Dytham 1999). If variance > mean, the population is more clumped than random. If variance < mean then it is more uniform than random. This serves as an easy way to analyze dispersion.

The Poisson distribution is different than the bell-shaped normal curve we are usually used to considering on both sides of a mean because the frequency of something cannot be less than zero and must be a whole number. The Poisson distribution is asymmetric (Fig. 7) and varies from 0 to positive infinity, unlike the normal curve symmetrically placed about a mean. Even if the mean number of spiders were 0.1/cm3, we could draw a bell-shaped confidence interval even if part of it was less than zero. This is not possible with frequencies. Luckily Poisson distribution have been developed, based on the idea that a frequency distribution is not likely to have equal sized confidence intervals like a mean. If the mean is 0.1/cm3, it indicates the most common frequency reported would be zero. The next most likely frequency is one. There is less likely chance of a frequency of two or more. Thus, the Poisson is a hump-shaped distribution based on the mean and the overall number in the population even if it cannot be less than zero. The hump shape of the distribution reflects the increased likelihood of finding zero spiders as the most common frequency

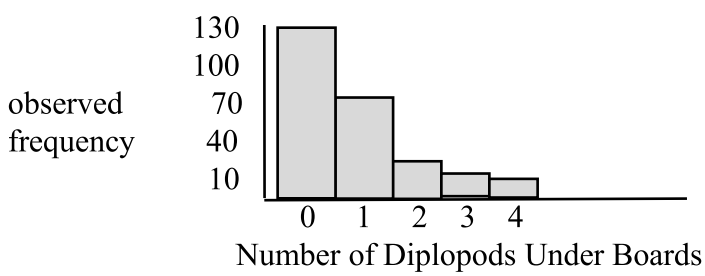


Figure 7. The hump-shaped distribution of a Poisson distribution, is different from a normal curve, which is symmetrically shaped around a mean. The Poisson is not symmetrical because values cannot be less than zero.

In the case of the diplopod, *Scytonotus granulatus*, a millipede, no such randomness occurred because P < 0.05 (Table 10). The table shows that there are more instances of groups of four or five than what was predicted by Poisson. The diplopods are not distributed randomly; they are clumped. A larger number of organisms occurs more frequently under boards than would be expected if the dispersion were random.

Table 10. Distribution of Diplopods *(Scytonotus granulatus)* under boards (Allee et al. 1949.

	Number of Diplopods per Board						
	0	1	2	3	4	5	More
Observed frequencies	128	71	34	11	8	5	3
Expected frequencies (Poisson). . . .	100.5	94.5	45.5	14,4	3.4	0.7	0.1

A key point is that dispersion patterns depend on scale. For example, aphids are tiny insects that suck sap and are transported by the wind. At the scale of a whole cornfield their distribution may be random. At the scale of one corn stalk, their distribution may be regular. At the scale of one leaf, their distribution may be clumped.

Correlation and Regression

For both correlation and regression we usually draw a graph with two axes, and plot points. This is called a scatter plot (Fig. 8) or if it has a line with it, a line graph.

- if the two variables are correlated the data set will slope either one way or the other, positive correlation, or negative.
  - we interpret a positive correlation as "**the greater the volume, the greater the peanut growth**"
  - we interpret a negative correlation as **"the less the volume, the greater the peanut growth"** or **"the more the peanut growth, the less the volume".**

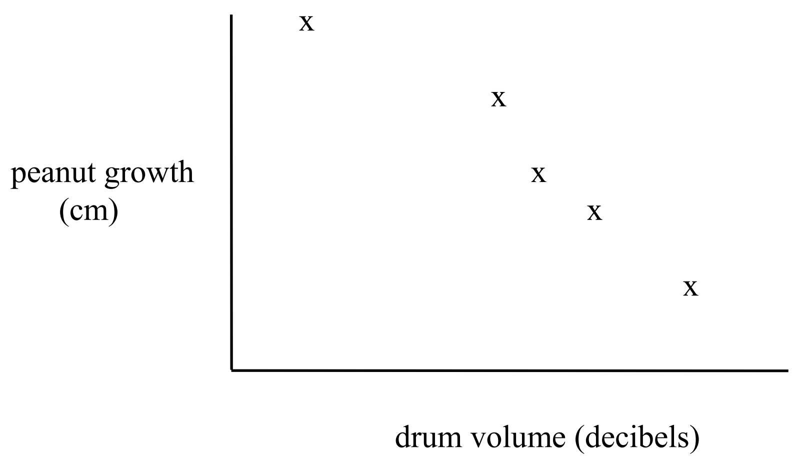


Figure 8. Peanut growth versus drum volume at Warren Wilson College.

The difference between regression and correlation How are they different?

- correlation is plotting two variables and looking for a pattern. The researcher did not specify which variable is on the x axis and which is on y. There is no predictor and response variable.

- regression *does* specify cause (independent (x) variable) and effect (dependent variable) because the researcher knows which is causing which.

- a best-fit line can be added to correlation or regression. This is done to minimize the average distance of the points from the line and can be done mathematically or by eyeball.

- for linear regression, the squared *vertical* distances from a line are generally minimized (Magnusson and Mourao 2004).

- for correlation, the horizontal and vertical distance of each point is minimized and this is called least-squares (also referred to as Model II regression) (Gotelli and Ellison 2004).

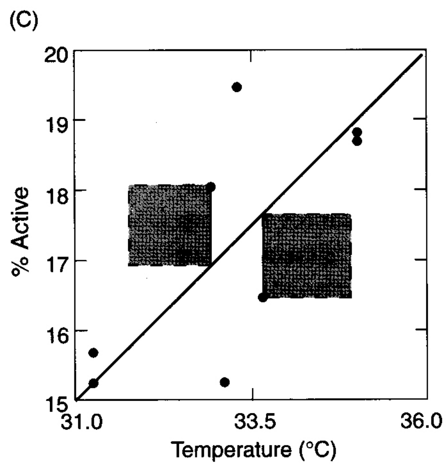


Figure 9. Minimizing the vertical and horizontal distance from each point to the line produces the best fitting line. For obvious reasons this is called least-squares regression (Magnusson and Mourao 2004).

More advanced students may be interested to know that least squares regression is logically and mathematically the very same thing as ANOVA. The distances to the best-fit line are "residuals." The variation about the line is the residual variation not explained by our model (the line). A plot of residuals after an ANOVA can be enlightening to establish how much variation exists within or between treatments. It is also used to calculate r^2.

- in regression one can draw a line in the form y = mx + b to predict y values based on x. A prediction is not appropriate in correlation.

- in regression one can obtain a *P* value and do a significance test. It tests the null that one variable does not depend on the other. Or in other words, ***P* is probability that the best-fit line has a slope of zero.** In correlation this is not appropriate.

The strength of the correlation can be measured.
- This is signified as **r** which usually stands for the Pearson's product-moment correlation. It varies from -1(negative) to +1 (positive). If it is 0, it means there is no correlation present at all.
- We can also do a test of significance on it, and get a *P* value that tests the H_0: one variable is not correlated with the other. This tells something about the strength of relationship but not the slope.
- Probably the most telling statistic in correlation is the r^2 value. This represents the % variation in one variable explained by the other. In other words, how consistent are the data? Is there a lot of error, or do the data points make a straight line?

Words of caution about correlation:
- to do a Pearson's correlation, it assumes that both variables are normally distributed
    - this consideration is hardly ever heeded.
    - one sees correlations frequently, widely used, *USA Today*, but there is little consideration of assumptions.

- even if there is a correlation, it does not imply cause or effect. It does not mean that one variable causes the other - consider "**the more tattoos worn at WWC, the more hurricanes occur in North Carolina.**" All correlation can do is establish a possible pattern, which is sometimes useful.

What statistical software should one use?

The statistical software available to students on WWC computers includes:

- Excel - A spreadsheet, but can be used for simple statistics and has graphing capabilities.
- Instat - Easy to use; can do most statistics for NSS projects, but results are difficult to print on our computers.
- Minitab - More powerful, used in our statistics courses, but more difficult to learn than Instat.
- SPSS - Most powerful, but difficult to learn and use.
- programming calculator

Instat is a program that was written for novice users who wish to do minor to intermediately sophisticated analyses. It is easy to use and will allow one to proceed only if assumptions of the tests are checked first. It walks the user through these tests and provides help with interpreting results. It is available on the iMac computers in the Biology Computer Laboratory. Instat manuals are available (from Lou or in the Bio. Computer Lab) but most students find that they can use the software without a manual. To access Instat:

- click on Instat
- at every step within Instat, click on the arrow at the bottom right corner of the screen to go to the next screen.

Choosing a Statistical Test – Overview

The statistical analyses you use depends on the question you want to answer and the type of data you gather. Use the following outline to help you decide which test to use:

Comparing means
- Two means
  - two groups are totally independent
    - data distributed normally and standard deviations not different
      - **unpaired t-test**
    - data not distributed normally and/or SD's different
    - try a log transformation first to equalize SD's
      - **unpaired t-test**
    - if SD's still different
      - **Mann Whitney test**
  - two groups are not independent
    - data distributed normally and standard deviations not different
      - **paired t-test**
    - data not distributed normally and/or SD's different
    - try a log transformation first to equalize SD's
      - **paired t-test**
    - if SD's still different
      - **Wilcoxen test**
- Three or more means
  - data distributed normally and standard deviations not different
    - **ANOVA (followed by a paired comparison test)**
  - data not distributed normally and/or SD's significantly different
  - try a log transformation first to equalize SD's
    - **ANOVA (followed by a paired comparison test)**
  - if SD's still different **Welch's correction or**
    - **Kruskal-Wallis (followed by a paired comparison test)**

Correlation between two or more variables (i.e., as one increases so does the other)
- Neither variable is the clearly the independent or dependent variable
  - **Correlation Analysis**
- One variable is clearly the dependent variable
  - One independent variable
    - **Regression Analysis**
  - Two or more independent variables
    - **Multiple Regression Analysis**
  - Two or more independent variables and two or more dependent variables.
    - **Multivariate Analysis**

Comparing frequencies
- Goodness of Fit (do observed frequencies differ significantly from that expected by chance)
  - **Chi Square Analysis**

Green's Principles Of Good Experimental Design for Field Studies

(taken from: Green R. 1979. Sampling and Statistical Analysis for the Environmental Sciences. J. Wiley Publ.)

1. **Clearly ID the question you are seeking to answer**
Your results will only be as coherent and as comprehensible as your initial conception of the question.

2. **Take replicate samples**
Do this within each combination of time, location, and any other controlled variable. Differences among can only be demonstrated by comparison to differences within.

3. **Take random samples**
Taking "representative," "typical," or haphazard samples in is not random sampling.

4. **Have a true control whenever possible**
Make sure all other conditions other than the independent variable are the same. Before and after sampling does not provide a true control because any observed effects are confounded by time.

5. **Conduct Preliminary sampling**
Those who skip this step because they "do not have enough time" usually end up losing time.

6. **Use stratified random sampling if appropriate**
If the area has wide scaled environmental pattern, break up the area to be sampled into relatively homogenous subareas, and allocate samples proportionally in each of the subareas.

7. **Make sure the sample size is appropriate to population you sample**
This can be determined by preliminary sampling mentioned in step 5. Too large a sample size will be too time consuming and too small will not give you statistical power.

8. **Use proper statistical tests**
Know what statistical tests you will conduct <u>before</u> collecting your data. Make sure that you check the assumptions of all statistical tests

9. **Accept your result**
An unexpected or undesired result is not a valid reason for rejecting the method and hunting for a "better" one.

Statistics Assignment ******** Name________________________________

Read through Chapter 5.

1. What does null mean and what is a null hypothesis?

2. Which statistical test should be used when comparing two means?

3. Certain words and symbols are fundamental in statistics. What do the following mean: n, $\bar{x}_1$, s, s_2, sem, sd, d.f., treatment?

4. What is the definition of *P*?

5. Why is *P* usually set at 0.05 and why is it so stringent?

6. In a t-test, should one reject or fail to reject the null if $P < 0.05$?

7. Does a significant result "prove" anything? Explain.

8. What are alpha and beta? What is their meaning?

9. What is the difference between a parametric and non-parametric test? What does parametric mean?

10. What is a post-hoc test and when is it necessary? What does post-hoc mean? Which is the best post-hoc test?

11. What are the two main assumptions of t-tests and ANOVAS?

12. What should be done if the assumptions are not met?

13. What is the difference between a t-test and an ANOVA?

14. Why are standard errors preferred over the use of standard deviations when drawing bar graphs?

15. When is it appropriate to use a chi-square test?

16. What is the difference between correlation and regression?

17. Does correlation imply cause and effect? Explain.

18. Should one reject or fail to reject the null in the situation described in the box below? ________

Why did you make the decision to reject or fail to reject?________________________________

Write the null hypothesis in this situation that you rejected or failed to reject.____

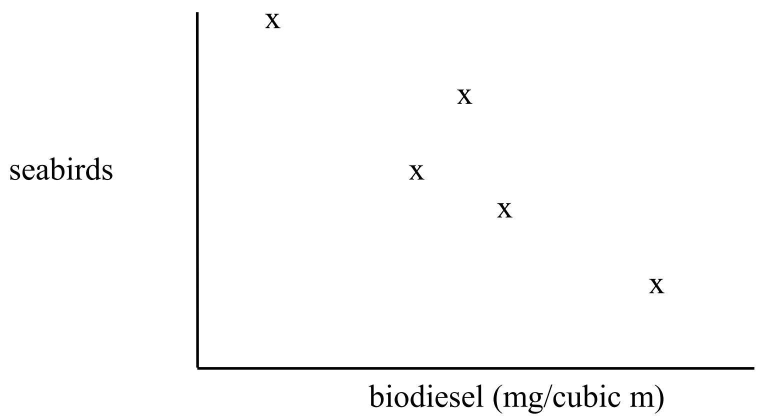
Unpaired t-test
P-value The two-tailed P value is 0.5507, considered not significant. t=0.6229 with 8 degrees of freedom. 95% confidence interval Mean difference = -4.140 (mean of Column B minus mean of Column A) The 95% confidence interval of the difference: -19.467 to 11.187 Assumption test: Are the standard deviations equal? The t test assumes that the columns come from populations with equal SDs. The following calculations test that assumption. F = 338.83 The P value is < 0.0001

19-20. Write the null for each test below.

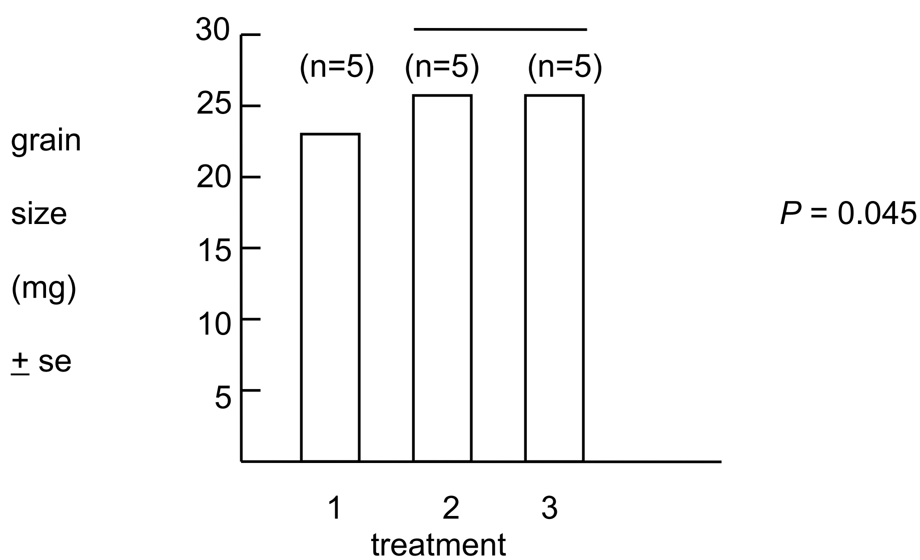
t-test	ANOVA	Chi[2]
$\bar{x}_1 = \bar{x}_2$	_______	__________

21. If this is regression, which is the dependent variable on the graph below? _______________

22. What r value would you expect the graph to have? _________________



23. In the graph below, which treatments are significantly different from which?



24. In the graph for question 24, which statistical test(s) was/were used to make this conclusion?

25. In a study of 500 high school students, the correlation between IQ test scores and scores on a standardized test of academic achievement was 0.55. From this information, it can be correctly concluded that

a. low IQ scores generally are associated with high achievement test scores.
b. an inverse relationship exists between the two variables.
c. a moderate positive relationship exists between the two variables.
d. a correlation cannot be less than 1.

26. While doing an ANOVA a researcher notices that the means of all the treatments are positively correlated with the size of the standard deviation. Which of the following transformations made on the data might correct this problem without having an effect on the original data?
a. adding a constant to all scores.
b. taking the reciprocal of all scores.
c. multiplying all scores by a positive constant.
d. taking the square root of all scores.
e. taking the logarithm of all scores.

29. An F-ratio is a ratio of
a. variance measurements
b. alpha levels
c. degrees of freedom
d. observed means
e. sample sizes

30. In an experiment group X performed a task better than group Y and group Z was better than X and Y. The investigator wishes to use an ANOVA to determine whether the mean difference is statistically significant. To do so, the investigator needs to know all the following EXCEPT:
a. the number of individuals in X
b. the number of individuals in Y and Z
c. whether both groups were equally motivated
d. the amount of variation in performance within each group
e. the amount of variation among the groups

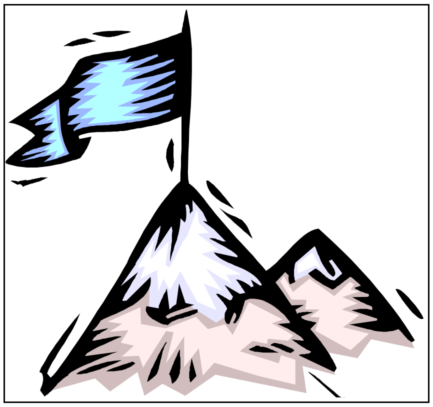
31. Draw a graph with the results from the question above.

Attending an NSS Assignment *****

Name______________________________

1. By this week students should have attended a Monday (4:00 p.m.) NSS session and listened to two speakers. Please list the two speakers you listened to and briefly critique their talks.

2. Students should continue to meet regularly with their advisor and make progress on their literature searches. Literature searching should be an ongoing effort as the research topic evolves.



Freddy the Forester says,

- "I'm going to ask my friend on the Recycling Crew to keep a lookout for a nice pair of black shoes from the Free Store that I can wear during my seminar. Even if they are a little big, no one will notice under my pants."

- "It's late, but I better go check for smoldering embers in the area of my prescribed burn from earlier today."

- "It's time for my daily multivitamin."

Flunky the Forester says,

- "It's not my fault if I pseudoreplicated."

- "I'm going to plan a prescribed burn during a burn ban."

- "Oops. I spilled a big bucket of Garlon."

- "I have motor oil on my good skirt."

Chapter 6

Experimental Design

by Lou Weber

Sampling

Why should one take samples?

It is usually impossible or impractical to monitor the entire habitat or to measure all the organisms in a given area. If you could, you would say you were measuring the whole population or universe. In most cases there is not the time or money to sample the whole population. Statistics is about taking samples and then using the process of **induction** to draw general conclusions, that is, going from specific to general.

Golden rules of sampling

1. *Independence* - Samples must always be independent of each other.

In other words, no sample can be used more than once and there should be no pseudoreplication.

2. *Replication* – One should have adequate replication when sampling, in other words $n \geq 2$.

3. *Randomization* – statistical techniques require random samples within the universe.

How do you obtain random numbers?

- role dice
- draw out of a hat.
- toss a coin.
- use a deck of cards.
- take random numbers from a random numbers table.
- start a stop watch, then stop it without looking and take the last digit on the readout.

Once you have random numbers in hand how do you apply them?

- use them to find a plot that is a random distance from the trailhead,
- choose numbered plots randomly within a 100 x 100 m grid,
- choose random coordinates on a map,
- choose one of four directions.

Please note that a random numbers table is only useful, when **a sampling frame** can be developed first. In other words, a map or spatial configuration of some type must first be laid out showing all the possible areas available to sample, then a random numbers table is used to choose among the possibilities.

What is the difference between haphazard and random?

Oftentimes, randomness is confused with **haphazardness**. Anything that might inflict bias is haphazard. Examples of haphazard sampling would include:

- throwing something into the sampling area and taking the sample where the object lands.
- having a dog sniff around the sampling area and taking the sample from where it lies down.

- closing one's eyes, spinning around, and choosing the sampling area where one stops.
- walking down the trail and choosing trees that are conveniently located or that look interesting.

Systematic sampling is yet another thing. It could include, for instance:

- sampling every fifth tree,
- sampling every other row of corn,
- taking a sample every ten meters of a transect,
- scanning the plot every 30 seconds and recording behavior.

Should samples be taken randomly or systematically?
One of the major assumptions of most common statistical techniques is random sampling, but systematic sampling has some distinct advantages, and in practice can often produce more accurate measures. One consideration involves sample size. If only 2-5 plots can be sampled, systematic sampling is generally encouraged because it provides wider coverage over a geographic area. With a small number of random samples, bad luck may place all the samples on one end of a gradient rather than spacing them out over the entire area. For sample sizes approaching 30 or more, bad luck in drawing clustered sites is less likely. The answer for situations with limited accessibility and size, like this, is to use a **randomized block design**. A geographic or temporal block is selected with relatively homogenous conditions, but within the block random samples are chosen.

Why can't I make conclusions by taking just one sample?
There is some deviation, bias, or error in every sample when comparing it to the mean. If Martians visited earth to determine the mean number of calories consumed per day by humans, you would not expect an accurate answer if they observed only one human, would you? What if by chance they selected a high school male football player, or a three year old girl?

What is the source of other error?

- when sampling a field, one part of the sampling area may have had an insect outbreak or had been burned recently.
- one family of mice may have a mutation not found in other families.
- the measuring device may be erratic or inaccurate.

How many samples should be taken?

- There are statistical methods for determining how many samples one should take, but these are often *not* very reliable or helpful.
- Instead, these rules of thumb are suggested:
    - **take as many samples as you can afford time-wise and money-wise.**
    - **try to have at least 30 samples.**

Most statistical tests (t-test, chi-square, ANOVA) were developed to work with 30 samples in mind. They give the most accurate results when at least this many are analyzed (Dytham 1999). The greater the sample size, the lower the chance of an error. In other words, there is greater power in your analysis to detect significant differences. However, researchers do not always have this luxury. If your study involves whole lake manipulations or large geographic regions, this will be impractical and expensive. Testing two lakes will be enough of a challenge; thirty lakes will be impossible. Other methods must be employed in these types of situations.

Should sub-samples be taken to improve accuracy?
The goal within statistical analyses is generally to have as many degrees of freedom as possible to improve the likelihood of finding a significant difference if one is there. In statistical terms, this maximizes the "power" of a procedure. Therefore, true samples and not subsamples are more valuable in scientific work if the goal is to maximize power. While accuracy can sometimes be slightly improved by taking subsamples, generally money and time are better spent by taking as many true samples as possible.

- **Put more effort into true samples than sub-samples.**

- **Try to have the same number of samples in each treatment.** This is the optimal situation and will lead to more statistical power and accuracy, but not always a requirement.

What is pseudoreplication?

In the early 1980s, Stuart Hurlbert alerted the world to errors in most ecological analyses and called these pseudoreplication (Magnusson and Mourao 2004). If five sections of a stream without predatory fish were compared to five sections of a stream with predatory fish, the sample size would usually be considered one in each treatment, not five. If the researcher claimed the sample size was five, it would be considered psuedoreplication. This simple error pervades scientific literature.

Psuedoreplication, however, depends on the question being asked. If the question is, "do predatory fish have an effect on the number of crayfish in streams," the number in each treatment is one. If the question is, "do predatory fish in this particular stream have an effect on the number of crayfish compared to a particular similar stream that is nearby and does not have predatory fish," then the sample size is five. The difference is whether a universal or specific question is asked. If asking a specific question, the researcher must be very careful not to extrapolate to universal truths during the Discussion. No computer can be used to detect the error. The researcher must use judgment.

Psuedoreplication can be **spatial** or **temporal** (time related) and temporal is often harder to detect (Magnusson and Mourao 2004). If a tree produces fruit during a month with high rainfall, it will probably continue to produce fruit a month later. The error comes from using the same tree in two cases to show causality between moisture and production of fruit.

In another example, what if we counted the number of geese each evening at the Owens Ponds and took the temperature of the water in an effort to relate flock size with water temperature. If we count at the same pond more than two evenings and called each a replicate, we commit psuedoreplication. To obtain true replicates we would need to count the geese and measure the temperature at different ponds with different geese.

Psuedoreplication can even happen phylogenetically (Magnusson and Mourao 2004). If we sample tadpoles from a single egg clutch, seeds from the same tree, or insect larvae from the same geographic area, then try to relate our findings to the whole species, we have psuedoreplicated. The organisms are too genetically related. We have violated the assumption of independence. Similarly, if we are comparing foods or products purchased at a store, we must be careful about whether the samples came from the same lot, brand, delivery route, or manufacturing plant.

Consider a final example for **spatial psuedoreplication**. Thirty male guppies were placed in one tank and given 0.05 mg/L of estrogen in their water per day. Thirty male guppies in a second tank were treated the same way except for the estrogen. After 30 days the color of the fish was graded by each of 10 observers on a scale of 1-5 and means were derived by tank and compared. The fish in the estrogen were less red, indicating that they had become feminized. According to the researcher, the sample size was 30 and he concluded that wild fish might be feminized by the excess estrogen compounds coming out of sewage treatments plants. Unfortunately, the experiment was psuedoreplicated if he wanted to make this claim. Although the effect might of come from estrogen, all the fish receiving the treatment were in one tank. The effect could have been caused by something other than estrogen found only in that tank, like glue used to repair a leak. If we wanted to actually ask this question, we should have put all the fish in individual tanks.

What does it mean to have confounding variables?

It means that more than one variable may explain the result. Consider this problem:

> A student is studying the populations of zooplankton (very tiny aquatic animals) in the farm pond. She takes 10 random samples from various locations in the pond in early summer when fish were not present and determines that there are 12 species of zooplankton and a mean of 110 organisms per liter. Fish were either added by people or dispersed by other animals into the pond over the summer. A month after the initial sampling she uses the same techniques. There are now five species of zooplankton present with a mean of 40 organisms per liter. The student concludes that fish reduced both the number of zooplankton species and the total number of zooplankton in this pond. **Critique her conclusions**.

You should point out that her results are **confounded by time**. The change in the number of species and concentration of zooplankton may be a result of added fish, or may be the result of seasonal change, or something else. Perhaps some of the species are in a resting phase at the bottom of the pond as always happens late in summer. Here is another problem:

> An ecologist wants to see if bee foraging is affected by nectar volume. Optimal foraging theory predicts that, all else being equal, time per patch should increase as energy per patch declines. So, he goes out and finds a field with lots of flowers. He divides the field into two sections, and then flips a coin to choose one side. He adds 0.1 ml of 30% nectar to all the flowers on that side and follows ten bees each for 15 minutes, counting and timing their visits to each flower. He then goes to the other side of the field and adds 0.5 ml of 30% nectar to each flower and again counts and times ten bees as they visit flowers for 15 minutes each. He finds no difference in the mean time bees spend on flowers in the two areas. **Critique the conclusion**.

His results are **confounded by both space and time and there was no control**. Bees may spend more time on one end of the field for a reason other than the nectar added to the flowers, or more time late in the day than earlier. He also failed to measure a baseline concentration of nectar in the flowers he manipulated and thus had no control to serve as a basis for comparison.

Before-After-Control-Impact (BACI)

To control for the confounding effects of time and space, controls can be put in place through the use of a BACI design. It comes from impact analysis in which measurements are taken before and after the impact occurs (Gotteli and Ellison 2004). There should be replication of control and treatment plots as well as temporal replication before and after treatment application.

In our zooplankton study a second pond with similar characteristics and geographic location would be required to serve as a fishless control. Both ponds would be sampled in the same way at the same times before fish were added to one pond. In the pond without fish, efforts would have to be made throughout the summer to keep fish out or get rid of any fish that might be introduced. At the end of the summer both ponds would be measured in the same way at the same times. Any difference in zooplankton can now be more fairly attributed to the presence of fish.

What if I want to compare the difference in treatments over time?

Psudoreplication over time (temporal pseudoreplication) occurs if the same population is sampled repeatedly and each date is treated as an independent replicate. What if I am doing something different; I want to compare two treatments several times? The dates are not treated as replicates; instead the replicates occur in space and are legitimate. Consider Figure 7:

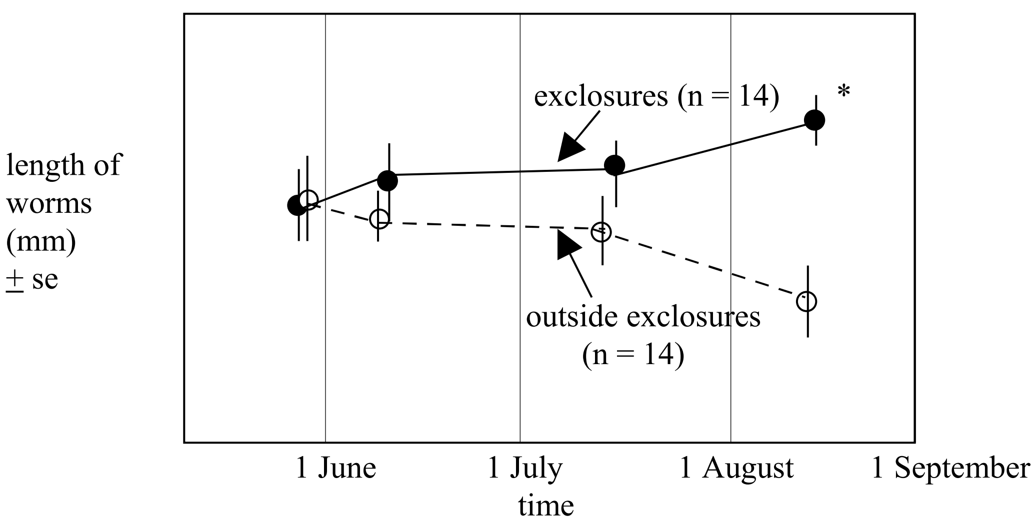


Figure 7. Length of worms in the sediment within shorebird exclosures compared to a nearby areas outside of exclosures. In the August sampling period the means were significantly different at *P* < 0.05 signified by *.

From late May to mid-August the researcher measured the length of worms commonly eaten by shorebirds in the sediments of wetlands. She measured within 14 exclosures (netted areas where shorebirds were excluded) and 14 areas 10 meters away from each exclosure in the same wetland where shorebirds foraged. For the fourth and final sampling period she completed a t-test on the mean lengths between the two treatments and found significantly longer worms within the exclosures. This indicated that shorebird predation was having an effect on worm length.

The researcher wanted to watch the change over time and show this to the audience. She measured four times and plotted the means and standard errors on the graph. However, she only completed one t-test – and this was on the final values.

This sort of analysis over time is a common scenario. Students often think they would like to statistically analyze the difference at every date, but this is usually not necessary and may not be legitimate. Even though dates are not being used as replicates (the exclosures are replicates), the same replicates are being sampled for multiple tests. This compounds the probabilities within the statistical test, rendering individual tests invalid. A **repeated measures** analysis readjusts the probabilities and will provide results at every date, but this procedure is power hungry. In other words it requires large sample sizes to detect a significant difference between treatments. Each date in a repeated measures analysis uses some of the degrees of freedom; thus fewer are available for analyzing the difference in treatment means. We hate that because when sample sizes are small as in this case, we need all the power we can get to compare treatment means. Completing just one test on the final date is a good solution. Why do we need a statistical comparison on every date anyway? The audience can clearly see the trend over time just from the graph.

Different types of ANOVA

In a **one-way ANOVA**, each of the treatments represents variation in a single factor as in the example of methane production. The horse, cow, pig, hamster, lion, and snake were each treatments (categories) within one factor. A one-way ANOVA could therefore be called a single-factor ANOVA.

One common variation of the one-way design is the **randomized block design**. It is exactly the equivalent of a paired t-test, except instead of pairs, replicates are "blocked". When environments are patchy or when samples need to be collected in a somewhat systematic rather than completely random way, the randomized block design is a lifesaver. A **block** is a delineated area or time period within which the environmental conditions are relatively homogenous (Gottelli and Ellison 2004).

This might even apply in a laboratory setting. Perhaps 1000 test tubes will not fit on the counter space in one chemistry lab, but there is a little room on the counters in two other rooms. The three rooms then become three blocks. All the test tubes in one block have something special in common and are not at random in the universe just as identical twins are not just random people. The block members are then treated specially in the mathematical formulations just as in a paired analysis. Alternatively, you use only one room, but use 333 test tubes on three different days. In this case, days are the blocks. Perhaps it is organisms that are in short supply. This week 12 guppies are sexually mature and ready to be tested. Three months from now their offspring will be sexually mature and ready for a second block of testing. In a wetland complex, each semi-isolated marsh could become a block. Although the marshes are a little different from each other, within the marsh there is relative consistency. Each block has one of each treatment. These are placed randomly and they must be independent of each other. In your spreadsheet your columns would be arranged like Table 6.

Table 6. Spreadsheet layout for a randomized block design.

Number	Treatment	Block	Number of worms
1	Exclosure	1	14
2	Open area	1	3
3	Cage control	1	4
4	Exclosure	2	16
5	Open area	2	5
6	Cage control	2	2
7	Exclosure	3	22
8	Open area	3	5
9	Cage control	3	3

One disadvantages of the block design is that it is power hungry and requires the use of some of your degrees of freedom to determine whether there is an effect by block. A second disadvantage is that there is only one replicate of each treatment in each block. If one of the samples is lost, the whole block must be discarded.

A **nested design** is another variation of a one-way ANOVA and refers to any design in which there is subsampling within each replicate (Table 7) (Gotelli and Ellison 2004). The subsamples, of course are not independent of each other and so are not true replicates. This seems like a waste of observations, but sometimes there is a need to increase precision within each replicate. A second reason it might be done is to investigate several scales at once and measure the variation within each scale. It allows you to ask two questions; is there variation among the replicates, and is there variation among the treatments? In fact, several hierarchical levels could be designated: replicates within marshes, marshes within intertidal zones, intertidal zones within regions, regions within continents. The variation in the data can be partitioned into each level. It might tell us that 80% of the variation occurs at the level of intertidal zones within regions, but only 2% within neighboring marshes.

The disadvantage of a nested design is that one must keep track of whether one is working with replicates or subsamples at each level (Gotelli and Ellison 2004). If you want to compare the difference between treatments, you will probably want to pool the subsamples into true replicates and use a conventional one-way design. Another problem is the analysis can be tricky or impossible to analyze unless there are equal numbers of samples and subsamples at each level.

Table 7. Spreadsheet layout for a nested design.

Number	Treatment	Replicate	Subsample	Number of worms
1	Exclosure	1	1	14
2	Exclosure	1	2	11
3	Open area	1	1	3
4	Open area	1	2	8
5	Cage control	1	1	4
6	Cage control	1	2	4
7	Exclosure	2	1	16
8	Exclosure	2	2	21
.	.	.	.	.
.	.	.	.	.
	Cage control	3	2	3

Two-way designs

In a **two-way** or multifactor ANOVA, the treatments cover two or more different factors and each factor is applied in combination with the different treatments (Gottelli and Ellison 2004). For instance, you could test different levels of nitrogen and different levels of phosphorus all in the same experiment. What is the advantage compared to running two separate experiments? One advantage is to test for **interaction effects**. In other words perhaps nitrogen and phosphorus interact and create a different effect together than when alone. The two-way design will parse out the **main effects** of just nitrogen or phosphorus, but also the interaction effect. Another advantage is that it could save time, money, and tractor time to run a single experiment with 16 treatments than two experiments with four treatments each. Two-way ANOVAs are common in agriculture and social sciences.

If all the treatments are fully crossed, the design is known as a **factorial** arrangement, also said to be orthogonal; every treatment level of the first factor must be represented with every treatment level of the second factor (Gotelli and Ellison 2004). Thus, if nitrogen has three treatment levels and phosphorus has four, we would call this a 3 x 4 factorial design and it would have 12 distinct treatment combinations. Each treatment level must have replicates (Table 8). Deviations include split-plot designs and randomized block designs within the two-way structure. A repeated measures design is actually a split-plot design.

One disadvantage is that if any of the treatment combinations are missing, we end up with a confounded design. Thus, this type of design is something that is only used for manipulative experiments. Observational studies do not provide every combination that we may want to examine. Another disadvantage is the large number of replicates required. Even if there are only 10 replicates of each combination, the 3 x 4 design requires 120 plots.

Table 8. Treatment combinations for a 3 x 4 factorial experiment with 10 replicates of each combination.

		Phosphorus			
		0.1 g	0.2 g	0.3 g	0.4 g
Nitrogen	0.4 g	10	10	10	10
	0.6 g	10	10	10	10
	0.8 g	10	10	10	10

What is experimental regression?

Factorial experiments using two-way ANOVA designs can get unwieldy because of the number of replicates that must be used for each treatment combination. An alternative is experimental regression in which there is only one replicate for each treatment combination and the results are analyzed using regression (Table 9) (Gotelli and Ellison 2004)

Table 9. Two-way experimental regression design with one replicate in each combination.

		Phosphorus					
		0.1 g	0.2 g	0.3 g	0.4 g	0.5 g0.6	g
Nitrogen	0.4 g	1	1	1	1	1	1
	0.6 g	1	1	1	1	1	1
	0.8 g	1	1	1	1	1	1

What is logistic regression and non-linear regression?

Logistic regression is a special form of regression in which the independent variable is categorical rather than continuous (Gotteli and Ellison 2004). Rather than forcing a straight line through the results, an S shaped curves is a better fit and therefore a better predictor of the probablility of wasp visits (Fig. 12). The conclusion that can be reached from instant inspection of the curve in the graph below is that the probability of wasp visitation increase with leaf height. Logistic regression is an example of non-linear regression, a type of regression in which the best fit line is not a line but a curve.

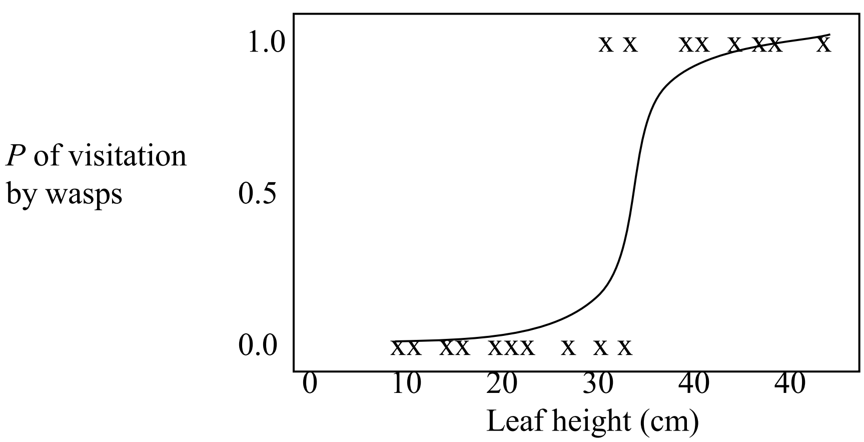


Figure 12. Probablility of wasp visits versus leaf height using logistic regression to form an S shaped curved model.

What is multiple regression?

Multiple regression is when there are two or more independent variables for each replicate, and one dependent variable. In other words, two or more distinct variables are measured for each replicate (Gotelli and Ellison 2004). For instance, latitude and elevation are measured at each site in which we are measuring species diversity of ants.

If we regress ant species diversity on latitude only, the result is:

species diversity = 5.447 – 0.105(*latitude*)

If we regress ant species diversity on elevation only, the result is:

species diversity = 1.087 – 0.001(*elevation*)

With multiple regression we can develop a more accurate predictor equation:

species diversity = 4.879 – 0.089(*latitude*) – 0.001(*elevation*)

This combined equation can now be graphed three-dimensionally. With only two variables linear regression can be plotted in two dimensions. With three variables it takes three dimensions. Multiple regression can develop equations with more than three variables, but they can not be graphed.

For multiple regression the assumption must be met that the cause variables are independent of each other, an assumption that is too often ignored. If they are correlated we say there is multicollinearity (Gotelli and Ellison 2004). A conventional printout is shown below relating the density of crayfish to 10 potential independent variables.

Table 9.1

Dep Var: CRAYFISH N: 14 Multiple R: 0.928 Squared multiple R: 0.860
Adjusted squared multiple R: 0.395 Standard error of estimate: 0.235

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	0.941	0.627	0.000	.	1.500	0.231
VELOCITY	–0.131	0.520	–0.108	0.256	–0.253	0.817
TEMPERATURE	–0.122	0.401	–0.109	0.361	–0.304	0.781
DEPTH	0.320	0.345	0.289	0.477	0.926	0.423
WIDTH	–0.428	0.328	–0.421	0.448	–1.305	0.283
COVER	0.140	0.482	0.134	0.221	0.291	0.790
SNAGS	–0.645	0.308	–0.732	0.380	–2.092	0.128
ROCKS	0.069	0.378	0.071	0.311	0.184	0.866
HERONS	–0.057	0.454	–0.056	0.236	–0.126	0.907
CARNFISH	–0.212	0.438	–0.177	0.347	–0.484	0.661
HERBFISH	0.359	0.263	0.368	0.640	1.363	0.266

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1.024	10	0.102	1.848	0.335
Residual	0.166	3	0.055		

Multivariate analysis

What if there is more than one response variable? In other words, multiple regression accounted for more than one independent variables, but only one dependent variable. What if there are several independent and dependent variables? Now we are in the realm of multivariate analysis (Gotelli and Ellison 2004). The mathematics for multivariate analysis is best expressed through matrix algebra, something that can now be done through spreadsheets tables. Once organized, an ANOVA can be completed on a multivariate data set in what is called a MANOVA. The sums of squares become sums of squares and cross-products matrices (SSCP). These are used in place of the among and within sums of squares.

Ordination is a different type of multivariate analysis that creates new variables (called principal axes) out of some of the best variables measured and scores (orders) the samples according to how well they fit (Gotelli and Ellison 2004). It is a data reduction technique that generates a smaller number of variables that still illustrate important patterns. It can also be used to discriminate or separate samples along the axis that are subtly different. Types of ordination include principal component analysis, factor analysis, correspondence analysis, principal coordinates analysis, and non-metric multidimensional scaling. Wow!

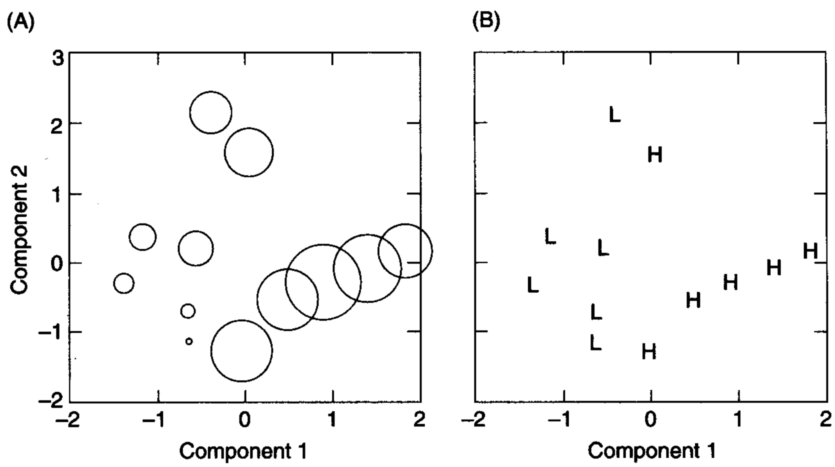
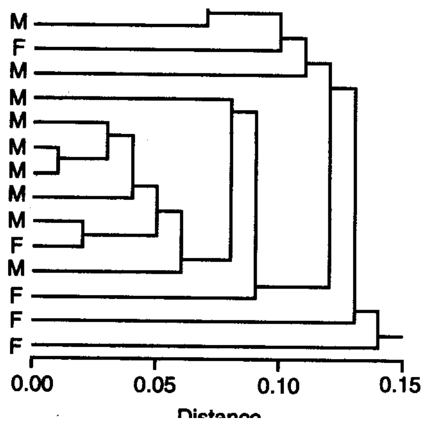


Figure 13. Principle components analysis (Magnusson and Mourao 2004).

The disadvantages of ordination are that most scientists are not well educated in matrix algebra and few know how to interpret the ordination plots that appear in scientific journals. Most scientists probably skip the articles in which they see an ordination plot. That is the reality.

The most common use for ordination is for classification, cluster analysis, and discriminate analysis. The ordination separates the observations into groups (Gotelli and Ellison 2004). The goal is to form clusters of sites on the basis of similarity in shell shape (Fig. 14). It can be used to group organisms on the basis of morphology or DNA sequences and is especially helpful within the growing interest in cladistics.



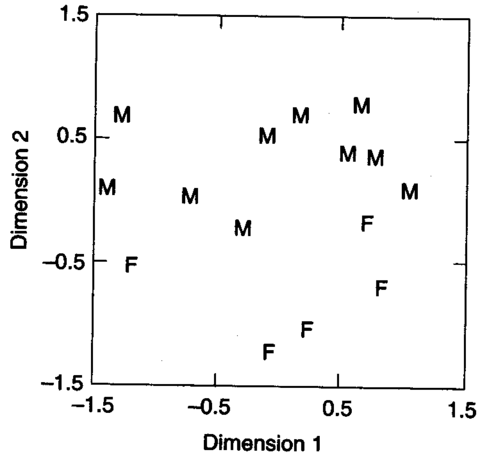


Figure 14. A. example of a cluster analysis. The longer the lines between categories, the less closely related they are to each other. B. two dimensional gradient analysis plotting differences between male and female humans.

<u>Worst lines ever heard at WWC</u>

I think I deserve an A for the course because for the work I did turn in, it was above average.
I didn't miss the deadline; I just waited too long.
I don't know where Old Farm School Road is, but I know it's not hard to find.
Way down deep inside, I'm really a shallow person.
What's beef jerky made of?
I'm not going to change, but I will compromise.
If I had wanted a C, I wouldn't have done the assignment at all.
The one most important thing in all the world is two things. . . .
You know, you never know, you know?
I'm not on a diet, I'm just trying to get down to my original weight.
It bugs me bad, a lot.

Experimental Design Assignment****

Name______________________

1. Randomization, independence, and replication are essential if statistics are going to be used. How does one achieve true randomization?

2. How many samples should a researcher collect? Hint: there are two answers to this question.

3. Define pseudoreplication.

4. T or F In most cases one should put more effort into sub-samples than true samples.

5. T or F If we compare foods or products purchased at a store, we must be careful about whether the samples came from the same lot, brand, delivery route, or manufacturing plant.

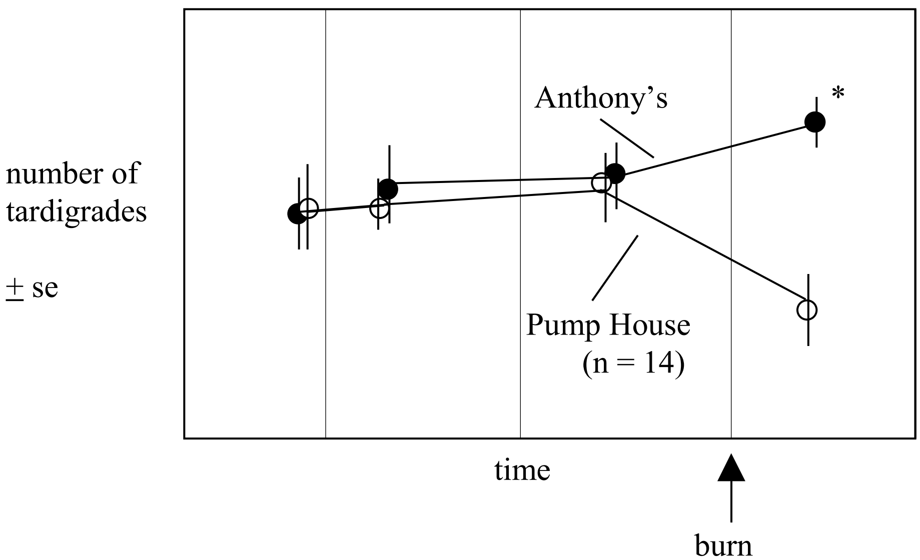
6. Define haphazard and contrast it with randomness.

7-8. Use examples to describe the difference between random and systematic sampling.

9-10. Should samples be taken randomly or systematically? Explain your answer.

11-12. Describe an example of temporal pseudoreplication.

Students used a random numbers generator to find 30 random sampling sites in the forest stand known as Pump House and 30 more in the forest stand known as Anthony's. They took a core sample at each random site within each stand and counted the number of tardigrades found in each. They sampled three times, then performed a prescribed burn in Anthony's and repeated the sampling in both sites. Their results are below with a * indicating any significant difference.



13. What is the sample size?

14-15. They concluded that burning had a positive effect on the number of tardigrades. Critique their conclusion based on their experimental design.

16. If they were to perform a BACI design instead, describe how it would be different?

Researchers would like to know if parasites on the scales of fish are clumped or occur at random. They caught 98 fish and counted the number of parasites on each. They found 38 fish with no parasites, 44 with one parasite, 14 with two parasites, and 2 with three parasites or more.

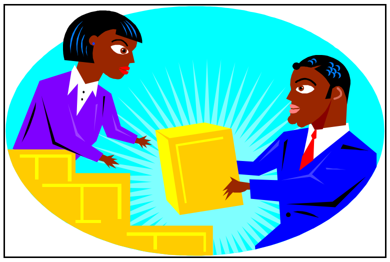
17. Which statistical test would be most appropriate for this design? Explain your answer.

18. There are four scores in a distribution with a mean score of 36 and a variance of 16. What is the standard deviation? What is the standard error of the mean?

Methane can be produced by letting bacteria break down rich organic matter such as animal feces in an anaerobic (no oxygen) environment. The objective of a student's research was to determine which type of dung produced the most methane, cow, pig, or horse. A sample of each type of manure was obtained from the WWC farm. Flasks were constructed to create anaerobic conditions and collect the methane produced. For each type of manure, four flasks were set up (12 total). Into each flask 100 grams of the appropriate manure were added. All flasks were inoculated with the same amount of methane producing bacteria and placed in the same incubating chamber at 40 C. The gas produced was collected and the volumes were determined and compared.

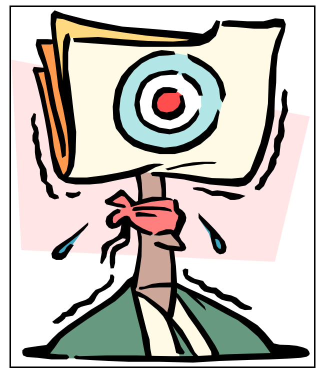
19. What statistical test should be used?

20. If the test showed a P value of 0.001, can the student conclude that there is a significant difference in the production of methane from each type of manure?



Lexi says:

- "This course is getting me rolling on my project."
- "I'm learning a great sense of work ethic, how to deeply research a topic, make a realistic project, and how to put it all together in a presentable manner."



Loser says:

- "It is a horrible thing to grade science majors on grammar."
- "I'm going to waste a lot of paper when I write my drafts."
- "I **am** using metric; I measured in acres."
- "I've known how to write since dawn's crack."

Final Topic Assignment******

Name___________________________________

Advisor's signature ____________________________________
sign only after inspecting all work below

This assignment requires a final decision on choosing an advisor and topic.

1. **Before your advisor signs this, write your objective**. Do not make any of the pitfalls identified in Chapter 2. Look back in your notes on what makes a good efficient objective statement. Avoid needless words. Include an if, why, or whether in the objective. Explain within the objective why you are completing this research, not just what you are going.

2. **Have your advisor read your answers to the questions below:**

a. which databases did you use for finding peer-reviewed journal articles?

b. which key words did you use within the databases?

c. what is the best peer-reviewed journal article that you found? Use proper format for citing articles and write neatly.

Riddle says:

- "I'm going to work-out on a regular basis so I improve oxygen flow to my brain."
- "I need to watch my junk food intake so I can think clearly when I sit down to study."

Piddle says:

- "I'm going to increase the carbon monoxide flow to my brain by smoking things. Then I'm going to poison the wildlife by throwing my butts on the ground."
- "I don't like vegetables."
- "I want my liver to congeal."

Chapter 7

Guidelines for Speaking in Natural Science Seminar

by Lou Weber

"Tell your audience what you're going to tell them, tell them, then tell them what you told them."

It is natural to be nervous about an oral presentation, but it can also be fun to strut your good work in front of an attentive audience. Some things make the NSS presentation easier than others – an established format, a strict time limit, and the use of Power Point. I will give more detail about each, then give some hints for preparing, but students should also go through the check-off list in this chapter and follow its advice strictly. It reflects what faculty grade most harshly. Please also be aware of the award criteria used at the NCAS annual meeting found in this chapter if you will be attending the conference.

The established format in NSS is Introduction, Methods, Results, Discussion, Questions, Acknowledgements. There is no need for Literature Cited or Future Research. Other formats may be used if appropriate, for instance if a mathematical proof is being established. Other sections are added on occasion. Study Site is sometimes added as a subsection of Methods and Management Implications is sometimes added within Discussion. When multiple experiments are done, it sometimes flows better to go through Methods and Results for each experiment rather than having one big section of each. Still, students should be conservative about diverging from the usual format. Students new to this are often tempted to have one big section called Results and Discussion. This is usually just a lazy way of dodging something.

Be very careful about Discussion. Do not forgo it or replace it with a section called Future Research or Conclusions. Think of it mainly as a way to answer the questions and objectives brought up in Introduction. Tell us how this fits with the literature you summarized in Introduction. Most of all, give a conclusion that represents your informed opinion about what the results do and do not suggest. Do not just tell us what you did wrong or could have done better. Tell us what the results mean. Do not fade out with weak phrases such as, "Well, that's about it." You should memorize a good conclusion line, then transition to final questions.

As for other sections, recently a myth has circulated that there has to be a Future Research section. Only some speakers will find it appropriate to suggest future studies. In any case it should be within Discussion if done at all. As for Methods, this will be very different in appearance than what you write in your paper. Show methods in diagrams, flow charts, and photos, rather than writing it out in bullets.

You should plan a 20-minute presentation with an additional four minutes for questions, then go quickly through acknowledgements. Be aware that some faculty are strict about the time and will begin subtracting points with every 30 seconds over the limit. Be aware that the speaker is in charge of the clock and not the advisor or Don Collins. Even if it seems like it is the fault of the audience for going over time – because they are asking too many questions – the speaker must control the time. Be ready to use phrases like, "I can take just one more question." The speaker must also control the questions after each main section. As a rule, it is generally not good to take more than 2-3 questions after each section. As for acknowledgements, it is good to say why you are acknowledging each entity, for instance, "I want to thank NRC for use of a truck." You will need to keep these explanations short, however, especially if you are running long.

While Power Point can greatly enhance presentations, it is only a tool. Clear presentation of the research should be the most important thing. Too often what the speaker says is overshadowed by the glitz of Power Point, or even more often, the speaker uses it as a crutch instead of a tool. The bullets and pictures should not be the primary script for the speaker, but should serve as a device to help the audience gain greater understanding. Many speakers make the mistake of adding too much glitz and it becomes distracting. For instance, graphs should not be in three dimensions unless there are three bona fide axes that need to be presented. Otherwise, it provides unnecessary complexity which makes the graph hard to read.

Backgrounds should be simple enough so they do not interfere with the font in the foreground. The font, Arial, **when it is bolded is the clearest one, as can be seen in this sentence, and is preferred over** New Times Roman. Another thing to keep in mind is that the network goes down frequently. To prevent surprises speakers should download their presentations to the desktop of the computer in the Jensen auditorium well before the presentation. A bibliography and abstract should be typed and 50 copies should be made and distributed at the seminar.

Keep in mind that students usually prepare only 20-30 slides for their NSS, approximately one per minute. Any slide shown for less than 20 seconds is generally useless. Dean Kahl suggests the following as general guidelines, but they are only approximate and must be modified to fit your situation.

- Introduction --- 6 slides (one should be a list of objectives)
- Methods --- 5 slides
- Results --- 5 slides
- Discussion --- 4 slides

Each slide should have no more than 3 or 4 ideas or bullets. Do not talk about material that does not appear on a slide; it is difficult for the audience to reconcile a presentation that does not match your slide. Remember that you are trying to teach us – clarity is critical. Avoid "Oh No!" slides. These slides/graphs/diagrams contain so much information that the audience cannot follow. Simplify.

As for preparation of the speech, expect it to take more time than writing. D'Arcy (1998) even suggests that you budget 25% just for procrastination. If you have done other Power Point shows, you already know that simple slides can take an enormous amount of time. Getting good photos to load in from the web or your own camera on the same slide with well-placed short bullets can take a long time. Scanning and preparation of graphs also takes longer than one thinks.

Leave plenty of time for practicing your spoken word after the slides are complete. Run through your presentation several times and include out-loud readings. Pay attention to the organization as you read it aloud. Creating Power Point slides as separate entities is very different from preparing a speech that transition through a captivating story. You will almost certainly need to rearrange some slides to avoid awkward transitions once you hear it out loud.

Try to use an extemporaneous style rather than memorizing or using a script. Extemporaneous means that one improvises – but only to an extent. In this case the speech and slides should be well prepared and rehearsed, but the words should be slightly different each time it is presented. The speaker is using the slides as a prompt to know what to talk about next, but most of the lines are not memorized. This gives the speech a fresh sound rather than something that sounds like reading. Occasionally a speaker will feel better reading a script or memorizing, and that is all right too as long as it does not sound like reading. It is possible to read with quite a natural sound, even including jokes and pauses to think, but for some people this is harder than speaking extemporaneously.

Remember too that the delivery is extremely important. Listeners pay a great deal of attention to body language, voice, facial expression, and rapport established with the audience. Some authors think that as much as 80% of the judgment of a speech is based on things other than content (Knisely 2005).

Finally, take your job as a listener in NSS seriously. Give the kind of real feedback you would want as a speaker. Do this in an atmosphere of mutual respect, but think intently about your responsibility.

Public Speaking

Appearence

1. Dress professionally (optimally, ties for men, skirts or dress pants for women).
2. Wear no ballcap, jeans, sneakers, or sunglasses.
3. Wear no tee shirt or any shirt with printed words.
4. Tuck in shirt.
5. Keep beard and hair neat and washed.
6. Appear appropriately interested, enthusiastic, and energetic.

Voice

7. A well prepared extemporaneous speech is generally better than something memorized or read. Speech should not sound like reading. Note cards or a script can be used, but generally, for a 20 minute speech, most college seniors can remember all their ideas once they take their cues from the Power Point slides.
8. Use appropriate speed.
9. Have good inflection. Do not let the voice drone.
10. Talk distinctly (no mumbling).
11. Do not let the voice rise at the end of a statement as if asking a question.
12. Do not drop volume at the end of a sentence.
13. Speak loud enough.
14. Do not sniff or burp and have a tissue ready in case of a runny nose or sneeze.

Words

15. Do not use *like* as a connecting word.
16. Do not use slang, profanity, trite phrases, clichés, and avoid “you guys,” “stuff,” “crap.”
17. Avoid frequent use of *um, and a, ok.*
18. Make effective use of pauses and silence.
19. Do not fill every pause with “and.”

Body language

20. Make good eye contact with all members of the audience, not just the faculty.
21. Engage and be attentive to audience.
22. Use gestures appropriately and effectively and do not make excessive hand gestures.
23. Do not fidget or touch face, armpits, beard, hair, or put hands in pockets during speech. Do not slap the screen with the pointer.
24. Do not lean on lectern or put elbows on lectern.
25. Do not jump, leap, shift weight from foot to foot, rock back and forth, or cross legs.
26. It is okay to walk around a little when speaking and it can add life to a talk.
27. Do not rest your hands on your hips.
28. Appear poised.
29. Have a confident posture and avoid slouching over your notes.

Content

30. Have a title, Introduction, Methods, Results, Discussion, and Acknowledgments. All images taken from web sites should be cited.
33. Make sure the speech is informative and useful for the greater audience and not overly detailed, long, or boring.
34. Make sentences short (most less than 15 words). Speakers should use shorter sentences than in writing.
35. Use gender and culturally inclusive language.
36. Try to use a little humor or personal story telling but be aware that joke slides and inside jokes are offensive to many.
37. Sound bites and repetition are sometimes effective ways of influencing the audience.
38. Substantiate opinions with facts.
39. Avoid the use of slides or overheads that are too simple and needless. For example, there is no need to have a slide that reads "Introduction" or "Results." Each slide or overhead should remain on the screen for at least 20 seconds.
40. Incorporate for-instance examples that turn "so what" moments into "Aha!" moments.
41. In the acknowledgments, only professional acknowledgments should be made and the speaker should explain why he or she is acknowledging each person or institution (e.g., I thank the Warren Wilson College Farm for use of a truck). In most cases you should save personal acknowledgments (God, your mother, your moral supporters, Elvis, your stuffed bear) for after the seminar. Natural Science Seminar is not the Grammies.
42. There is no need to include a Literature Cited slide at the end.

Process

44. Avoid merely reading the slides or overheads to the audience. Not even the title slide should be read to the audience. The title slide could be displayed as the audience is filing into the auditorium or while the speaker is being introduced.
45. When talking, face the audience and not the projection screen or chalkboard.
46. If there are notes or note cards they should be well prepared. Do not rattle papers.
47. Hold notes or note cards away from the face and chest.
48. The speech should last about 20 minutes with five minutes for questions and acknowledgments.

Statistical Analysis

49. Graphs should be discussed before the results of the statistical analysis.

50. Null hypotheses can be rejected or one can fail to reject them, BUT THEY CAN NEVER BE ACCEPTED. The null hypothesis for any t-test is that the means of the treatments are equal.
51. For every t-test or ANOVA, the equal variance assumption and the normal distribution assumption should be tested. If an assumption is violated, converting the data to *ln x* can sometimes fix the problem. If the assumptions are still not met, non-parametric statistics should be used. In your talk you should say whether you have tested your assumptions.

Introduction

- Do not start the talk with "Thank you for attending this seminar" and do not read the title slide. Instead begin with your own version of
  - "Thank you for your kind introduction"
  - "Ladies and gentlemen, I would like to describe my work involving…"
  - "Let me tell you about . . . ."
  - "I became fascinated with this subject last summer when . . . ."
- Should move from general to specific.

Methods

- Consider using illustrations, flowcharts, photos (cite sources) to explain your methods and discussion. Bulleted lists should be a last resort.
- Explain the reasoning behind your choice of methods, sampling protocol, and experimental system.

Results

- When describing results, indicate whether they fit with expectations or not.

Discussion

- Should move from the specific to general.
- Consider alternative explanations of data.
- Do not claim that you have proved anything. Only mathematicians can create proofs. Scientific knowledge is always conditional and may be revised at a later date
  - Use, "These results suggest that……."
- If your experiments cannot resolve which explanation is correct, then suggest additional experiments that might resolve the question.
- Do not suggest vague or general additional experiments (such as additional replicates) that do not directly follow from your results.
- The discussion should have a conclusion that represents your informed opinion about what the results do and do not suggest about the question(s) you outlined in your introduction.
- Do not dismiss negative results - explain them.
- Be explicit about how your results support your conclusions.
- Make connections between your results and those of others.

Acknowledgements

- If you have a grant or internship, acknowledge the foundation or internship agency.
- If the Environmental Leadership Center has been involved, do not forget them.
- Do not forget to thank the librarians by name – they work really hard for us.

Questions

- Stay within the time limit, cutting off questions if necessary.

- Invite questions where appropriate.
- You must make it clear when you are through with your presentation and it is time for the audience to ask final questions.
- Make it clear when it is time to clap.

Using Power Point **-** ask at Bannerman if you have trouble

- open Power Point.
- choose blank presentation.
- choose the blank page (lower right corner) of the auto layout,
- use *format/slide color scheme* to create a color scheme for the background and font,
- use *custom* to create your colors, and apply to all,
- once the color scheme is chosen, use the Microsoft menus to create the first slide. For text you will need to create a "text box" found on the options at the bottom of the screen,
- click on *insert/new slide* to create the second, third, fourth, etc. slide. Do not create a new file for each new slide,
- keep the slides simple and readable. Error on the side of conservatism in this case rather than creating 3-D words, graphs, pastel colors, and borders that cause distraction. The focal point should be neither the presenter, nor the Power Point gadgets, but the story, its science, and what the world can learn from this. Realize also, that some members of any audience may be color-blind. To distinguish differences use different cross-hatching patterns rather than colors, or contrast light colors against dark such as yellow against blue. Even those with color blindness can contrast yellow against a dark background.
- While keeping slides simple overall, consider importing photographs or drawings of the molecule or organism being discussed. A figure in one corner of a Power Point screen with narrative on the rest can be helpful.
  - To import a picture from another source on the computer, find a non-copyrighted picture, use the right clicker on the mouse (only Window's based computers have it) to copy the image onto the clipboard, then paste it into your document.
  - If you wish to use an image from a book or journal, you will need to scan it in to your document. Crew members in Bannerman can help. Make sure you include a citation under each image you use from other sources.
- the network goes down frequently. To prevent surprises speakers should download their presentations to the desktop of the computer in the auditorium before the presentation**.** Running the presentation off a Flash Drive or Thumb Nail or any plug-in drive will also work, but you will want to try it and make sure it is compatible with our laptop.
- save your file on your M drive before class. To do this:
  - log on to the M drive by going to the My Computer icon.

- in My Computer go to *Tools/Map Network Drive*. On the top line pull down *M*. On the bottom line pull down and click on *\\raptor\homes*
- click on *finish*. Put in login and password. Save your file on *Homes on Raptor*.

Purpose and Learning Objectives for Other Courses in NSS

<u>SCI 491, 492, 493</u>
This seminar provides students and staff with opportunities to interact professionally in a formal setting, exchange news, ideas and theories, and explore the interrelationships among various disciplines. Students are further given the opportunity and motivation to participate in scientific research: choosing and delimiting a suitable topic, defining the problem and forming a hypothesis where appropriate, discovering and evaluating the work of others, conducting their own investigation, evaluating the data and results, and organizing and communicating their results to others. Discussion, questions and argument will sharpen communication and logic skills, as well as increase understanding, both for those presenting seminars as well as those attending. An informal learning outcome is the self-confidence that students obtain presenting their research to an audience of peers and superiors for future settings.

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Morphological and Genetic Characterization of a new tardigrade from Great Smoky Mountains National Park (*Bryodelphax nsp)*

Veronica Anderson April 3, 2007

Tardigrada is a relatively unknown phylum of meiofauna discovered in the 18th century (Nelson and Higgins 1990). These invertebrates inhabit marine, aquatic and terrestrial habitats around the world and have for millions of years (Nelson and McInnes 2002, McInnes and Pugh 1998). Recently, Tardigrada has been determined to be a sister group of Arthropoda, however the phylogeny below the class level is less distinct (Nelson and Higgins 1990). Tardigrades have been divided into two classes, the Eutardigrades and the Heterotardigrades based on the presence or absence of armor plates (Nelson and McInnes 2002). Historically, tardigrade taxonomy was based on morphological differences in the cuticle, claws and buccal apparatus (Nelson and Higgins 1990). In recent years, this morphological description is being supplemented with genetic analysis (Blaxter 2003). Currently, there are less than a thousand described species of tardigrades, some of which are thought to be globally distributed, although this is most likely a low estimate of tardigrade diversity (Nelson and McInnes 2002, Blaxter 2003).

One genus in particular, *Bryodelphax* has been found in moss and lichens on every continent excluding Antarctica (Kristensen 1987). The genus *Bryodelphax,* within the class Heterotardigrada, contains only 11 species to date (Kaczamarek and Michalcyzk 2004). One morphological characteristic unique to this genus is the presence of 10 small buccal papillae around the mouth (Kristensen 1987). Possible specimens of *Bryodelphax parvulus* have been found in Great Smoky Mountains National Park as part of the ongoing All Taxa Biodiversity Index (ATBI), a collaborative effort to catalog every species present in the park. Thus far, the ATBI efforts have revealed a wider range of tardigrade diversity than previously observed (Bartels and Nelson 2006). Many species new to the park, and some new to science, have been discovered, now they must be analyzed and placed on the phylogenetic tree (Bartels and Nelson 2006).

A new and exciting development in the field of taxonomy is the technology to analyze and compare gene sequences to determine phylogenetic relationships between organisms. This technique, known as DNA barcoding, may well revolutionize the field of taxonomy and redefine many taxonomic divisions. Hebert et al. (2003b) believe that mitochondrial, rather than the nuclear DNA, is more appropriate for DNA barcoding for several reasons. These include the lack of introns commonly found in nuclear DNA, a limited amount of recombination and the fact that mitochondrial DNA comes only from the mother (haploid inheritance). The existence of primers that reliably allow for the recovery of specific genes also makes mitochondrial DNA a logical choice. Within the mitochondrial genome the main gene that has been suggested for use as a DNA barcode is cytochrome *c* oxidase I (COI) which has two distinct advantages over other possibilities, according to Hebert et al. (2003b). These are the fact that robust primers are available for that genes and that it has a good range of 'phylogenetic signal.' This means that two species geographically isolated from each other for several million years will have enough differences that they can be told apart, but still maintain much of the same sequence (Hebert et al. 2003a). These differences will be quantified as the number of base pairs that differ divided by the total number of base pairs in a given sequence (Hebert et al. 2003a). This technique can be applied at nearly all taxonomic levels, not merely the species level, making it a labor-saving tool for the dwindling number of taxonomists left with the daunting numbers of organisms to be catalogued (Blaxter et al 2004). Critics of this technique, including Rubinoff (2006), claim that this will cause some definitions of 'species' to become obsolete, replacing them with a purely genetic definition that will create new species and eliminate others. DNA barcoding when combined with morphological analyses can lead to a new understanding of how specis relate to one another. My objective is to determine whether the population of *Bryodelphax* living in Great Smoky Mountain National Park is *Bryodelphax parvulus* or a distinct species, based on morphological and DNA analysis.

Methods:

This study will be conducted in the fall of 2007 and spring of 2008, in a collaborative effort between Warren Wilson College and Western Carolina University. The microscopy will be performed at Warren Wilson College with the assistance of Dr. Paul Bartels. The genetics will be performed at Western Carolina University with the help of Dr. Sean O'Connell.

Fresh tardigrade specimens will be collected from a known population in Great Smoky Mountains National Park, according to the method presented in Bartels and Nelson (2006). I will mount some of these specimens according to the same methods. I will then examine the slides with an Olympus BX 60 microscope housed at Warren Wilson College. Using iSolutions Digital Image software, I will be able to measure morphological characteristics such as stylets, buccal apparatus and claws. These data will be compared, with multivariate analysis, to specimens of *Bryodelphax parvulus* from Europe using JMP software.

A portion of the fresh specimens will be analyzed with the gene sequencer at Western Carolina University. Literature searches revealed no protocols for comparing tardigrades COI gene sequences, so developing such a protocol, including identifying the appropriate primers, is a secondary objective of this study. Blaxter et al (2004) present a method for tardigrade taxonomy using another mitochondrial gene, so perhaps this method can be modified. Once I have the gene sequences of the Great Smoky Mountains *Bryodelphax* and the European *Bryodelphax*, they can be compared using an unpaired t-test to determine whether they are indeed the same species.

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Morphological and Genetic Characterization of a new tardigrade from Great Smoky Mountain National Park (*Bryodelphax nsp)*

PROPOSED BUDGET

ITEM	QUANTITY	SOURCE	UNIT PRICE
MICROSCOPE SLIDES	144	VWR	$ 18.85
COVERSLIPS	1 oz.	VWR	13.13
RESOVLE IMMERSION OIL	1 oz.	VWR	7.70
PCR TUBES	1000	VWR	87.42
DNA PRIMERS		VWR	300.00
		TOTAL	**$420.17**

THE ESTIMATED TOTAL COST OF THE PROJECT WILL BE $ 420.17

Nitrate and Phosphate Levels Upstream and Downstream of the Asheville Country Club Golf Course

Ryan Morra
May 9, 2007

As urbanized areas increase in size and population, streams in these landscapes are at greater risk of contamination by a number of pollutants. In particular, use of fertilizers in landscaping can increase surface water levels of nitrogen and phosphorous in the forms of nitrate (NO_3^-) and phosphate (PO_4^{3-}), as well as contribute to increased groundwater levels of nitrogen (Spruill et al. 2002). Nitrogen and phosphorous are commonly added to fertilizers as two of the most common limiting nutrients in plant growth (Taiz and Zeiger 2004). When compared to households, golf courses present a particular greater risk for contamination. This is because of the intensity with which fertilizers are applied to increase turfgrass growth on fairways and putting greens.

Many types of fertilizers exist, but most can be grouped into two general categories: quick-release and slow-release forms (Schlossberg and Schmidt 2007). Quick-release forms are highly water-soluble and must be applied at frequent intervals to correct nutrient deficiencies. Slow-release fertilizers are water-insoluble and less susceptible to leaching (Schlossberg and Schmidt 2007). However, the slow-release, water-insoluble fertilizers cannot be applied through foliar applications, and this has made use of quick-release, water-soluble fertilizers more desirable. Use of these quick-release fertilizers has led to and increased interest in assessing the water quality impact of golf courses in the United States (Cohen et al. 1999).

Nitrogen and phosphorous levels are used in water quality assessment to indicate the trophic status of freshwater bodies (Mackie 2004). Nitrogen is a key nutrient for many processes in freshwater organisms, and phosphorous has been shown to be the most common limiting nutrient responsible for algal blooms (Mackie 2004). High levels of nitrates and phosphates in the feeding waters of a lake can lead to the eutrophication of the lake if phosphate is taken up by algae in such quantities as to produce an algal bloom.

Results for the testing of nitrogen and phosphorous levels in groundwater and lakes near golf courses have varied. Studies have shown that phosphorous concentrations in urban catchments have increased since 1990, and this has been attributed to use of fertilizers on lawns and golf courses (Paul and Meyer 2001). Nitrogen levels have not yielded consistent results, with some studies detecting total nitrogen levels that did constitute a water quality issue, while many others found no impact of water quality (King et al. 2006). Moreover, most of these studies have solely tested the surrounding groundwater or a lake within the golf course area; few studies have occurred on streams near golf courses.

Similarly, ecology students from Warren Wilson College have previously conducted class work to assess nitrogen and phosphorous levels of Beaver Lake, but not of the streams that feed into the lake. The Asheville Country Club Golf Course is located in Asheville, North Carolina, and is within the Beaver Lake watershed just north and east of the lake. There is one stream that runs directly through the golf course before meeting another stream just south of the golf course. The objective of this study is to determine whether there is a difference in nitrate and phosphate levels upstream of the Asheville Country Club golf course from downstream.

Methods

This study will be conducted during the months of April through July 2007. These dates were chosen because the Country Club indicated that the first application of fertilizer by the Country Club would be in the early spring. Nutrient levels can then be monitored through the summer. The first sampling will occur before fertilizer is applied to the grass, and then samples will be taken every two weeks for four months, leading to a total of nine sampling dates. Up to three additional sampling days will be added following a large rainstorm in order to compare the nutrient levels in the stream after such events.

Water samples will be collected from the stream in one-liter LDPE bottles at three sites upstream and three sites downstream on each sampling day. The sites will remain consistent for each sampling day. The bottles will be taken immediately to the laboratory, refrigerated at 4˚C, and then analyzed within one day of collection. Between sampling, bottles will be cleaned with 1:1 hydrochloric acid solution and rinsed with deionized water.

Samples will first be analyzed for phosphorous in the form of phosphate using the ascorbic acid spectrophotometer method for low range detection levels (Hach Company 2000). Previous studies indicate that phosphorous levels should only be expected to occur in low ranges (Kaufmann III and Watschke 2007). The samples that will be analyzed for nitrogen in the form of nitrate will be allowed to rise to room temperature until ready for analysis using the cadmium-reduction spectrophotometer method for low range detection levels (Hach Company 2000). Again, previous studies did not indicate that detections should be found in the mid-and high-ranges (King et al. 2006, Lee 2003, Valiela et al. 1997). Mean nitrate and phosphate levels will be compared with a paired t-test using upstream and downstream samples as the treatments.

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Proposed Budget

Item	Quantity	Source	Price
PhosVer 3 Reagent Powder Pillows	1 package (100 pillows)	Hach Company	$23.30
NitriVer 3 Reagent Powder Pillows	1 package (100 pillows)	Hach Company	$31.20
NitraVer 6 Reagent Powder Pillows	1 package (100 pillows)	Hach Company	$41.40
1L LDPE Bottles	6	WWC	
250mL LDPE Bottles	12	WWC	
Cell Riser – 10mL	60	WWC	
Graduated cylinder – 50mL	6	WWC	
Sample Cell – 25mL	6	WWC	
Beaker – 50 mL	6	WWC	
		TOTAL	**$95.90**

THE ESTIMATED TOTAL COST OF THE PROJECT WILL BE $95.90

Heavy Metal Concentrations in Soil Surrounding New Orleans Construction & Demolition Landfills

Julia Mead, May 10, 2007

Hurricane Katrina stands as the largest and most costly natural disaster in U.S. history (LDEQ 2007c). On August 29, 2005, the hurricane struck the Louisiana-Mississippi Gulf Coast with 218 billion kilograms of water, flooding eighty percent of the New Orleans area for almost a month (Presley et al. 2006). The property damaged by the floods generated an estimated 72 million cubic meters of disaster debris, of which about fifty percent constitutes as construction and demolition (C&D) waste (Dubey 2007). Construction and demolition waste includes non-hazardous debris such as concrete, roofing materials, drywall and wood, and the State and Federal Government must regulate the disposal of such materials (LDEQ 2007a).

The design of each landfill dictates the kinds of wastes admitted to each facility. For example, Type III (C&D) landfills differ from Type I (industrial) and Type II (residential and commercial) landfills in several ways, most notably in that the facilities have no lining to prevent leaching of landfill contents (LDEQ 2007a). After Hurricane Katrina, waste management-related permits relaxed considerably and the scope of Type III landfills expanded through a series of emergency declarations (LDEQ 2007b). Items such as furniture, trash, and treated lumber could now enter Type III facilities legitimately when mixed with actual C&D debris (LDEQ 2007b). However, the environmental impacts of these new waste management strategies are not yet clear (Dubey 2007).

One potential source of environmental contamination in the New Orleans area may arise from the disposal of treated lumber in Type III landfills. This type of wood contains a coating of preservatives meant to prevent fungi and termite damage (Khan, et al. 2006). Chromated copper arsentate (CCA), formerly the most commonly used chemical preservative until banned in 2003, leaches arsenic into soils during both service and disposal (Khan et al. 2006a, b). Previous studies have shown that between eight and twenty-two percent of wood found in post-Katrina debris has been treated with CCA (Dubey et al. 2007). Based on this figure and the estimated 12 million metric tons of construction-based wood debris generated by the storm, approximately 1740 metric tons of arsenic has been deposited into Type III C&D landfills around the New Orleans area since August 2005 (Dubey 2007).

Due to the magnitude of damage caused by the storm and the subsequent flooding, the origin of other contaminants remains unclear. Elevated concentrations of lead have been found in soil samples taken from various locations around the city (Presley et al. 2007). Certain samples exceeded both human health specific screening levels (HHSSL) and high priority bright line screening table (HPBLS) values for lead established by the U.S. Environmental Protection Agency (USEPA) (Presley et al. 2006). Soil remains the most common As and Pb exposure pathway for humans, especially children (Basta et al. 2002, Ruby et al. 1999) which could pose a health hazard to children returning to contaminated areas (Presley et al. 2006).

Because Hurricane Katrina was such an unprecedented disaster, a critical need exists to examine areas of possible contamination. Establishing baseline data will assist in assessing potential long-term damage and creating effective management strategies for future disasters (Presley et al. 2006, Dubey et al. 2007). My objective is to determine whether soil surrounding New Orleans landfills contains elevated arsenic (As) or lead (Pb) concentrations, compared to soil around landfills of similar design in Western North Carolina.

Methods

This study will be conducted in the region surrounding New Orleans, Louisiana, and Buncombe County, North Carolina, which will act as the control. The data collection will occur during the summer of 2007 from five Type III C&D landfills identified as receiving Hurricane Katrina disaster debris on a regular basis beginning in September 2005. From each landfill, soil samples will be taken from five systematically chosen locations surrounding the landfill, in order to insure a representative sample. Analysis will also be performed on soil taken from landfills around Western North Carolina, and control samples will be taken from areas around Warren Wilson College with no known heavy metal exposure.

Soil samples of 20 g will be collected in 30 mL plastic tubes as outlined in USEPA SW-846 protocol for inorganic analyte analysis in soil (USEPA 1996). The samples will then be dried and transported on ice back to Warren Wilson College, where they will be analyzed using the inductively coupled plasma atomic emission spectrophotometer (ICP-AES). Before measuring absorbance of the samples, the soil must be weighed and ground to remove large particulates. Two mL of each ground soil sample will then be digested with concentrated nitric acid and heated (USEPA 1996). Before the absorbance can be measured, the digested sample must be filtered and diluted (USEPA 1996).

The absorbances of the samples will then be compared to standard As and Pb concentrations using a Beer-Lambert Plot. Statistical analysis using an ANOVA test will be performed, comparing mean heavy metal concentrations in samples from New Orleans to mean heavy metal concentrations in samples from Western North Carolina. This test will determine if a significant difference exists between the mean heavy metal concentrations in the soil from each region.

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Heavy Metal Concentrations in Soil Surrounding New Orleans
Construction & Demolition Landfills

PROPOSED BUDGET

ITEM	QUANTITY	SOURCE	UNIT PRICE ($)
1 M CONCENTRATED NITRIC ACID	1 L	CAROLINA BIOLOGICAL, 87-7653	$9.30
ICE	4 kg	SAFEWAY MARKET	$0.70
50 mL PYREX CENTRIFUGE TUBES	25	AVAILABLE AT WARREN WILSON COLLEGE	
HARD SIDED COOLER	1	AVAILABLE AT WARREN WILSON COLLEGE	
GLASS DRYING TRAY	1	AVAILABLE AT WARREN WILSON COLLEGE	
MICROPIPETS	1	AVAILABLE AT WARREN WILSON COLLEGE	
FILTERING SCREEN	1	AVAILABLE AT WARREN WILSON COLLEGE	

TOTAL: $12.10

THE ESTIMATED TOTAL COST OF THIS PROJECT WILL BE $12.10

Example of a good final paper, in the form necessary to submit to the Journal of the North Carolina Academy of Sciences

A SURVEY OF ROAD-KILL ALONG THE BLUE RIDGE PARKWAY

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ABSTRACT: The Blue Ridge Parkway is a federal parkway administered by the National Park Service (NPS), which stretches 469 miles (757 km) from Shenandoah National Park in Virginia to the Great Smoky Mountains National Park in North Carolina. The NPS has the primary responsibility of conserving all of the park's resources for the enjoyment of visitors. One of these resources is wildlife. This study is an attempt to better understand which species of wildlife are being directly affected by vehicular traffic along a specific road segment as well as what might be the cause of the high road-kill rate. Driving surveys were conducted twice a day for 20 days from mid-October to mid-November along the Parkway between the Folk Art Center (mile marker 382.2) and the intersection of N.C. Hwy 191 (mile marker 393.6). Each survey consisted of locating and identifying those individuals which had died as a result of being hit by a motor vehicle. The first survey occurred between 1600-1700 hr and the second survey took place between 2000-2100 hr finding a significantly higher frequency of road-kill between 1700-2000 hr than expected by chance (Chi-square $P < 0.025$). The eastern gray squirrel (Sciurus carolinensis) was the species found most often followed by the opossum (Didelphis marsupialis). The results suggest that road-kill was occurring at an unusually high rate between 1700-2000 hr which may be because of commuter traffic from nearby Asheville. Traffic counts at the four intersections in the study section were higher than at any other point along the Parkway. A number of different mitigation techniques were suggested to reduce the amount of road-kill in an effort to better conserve wildlife as a resource.

KEYWORDS: Road Ecology, National Park Service, Road Mortality, Southern Appalachians

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INTRODUCTION

The Blue Ridge Parkway is a 469-mile (757 km) scenic road that stretches from Shenandoah National Park in Virginia to the Great Smoky Mountains National Park in western North Carolina (Jolley 1969). Twenty million people visit the Parkway each year. The great majority of these visitors experience the grandeur of the Southern Appalachians from behind the windshield of their automobile. The National Park Service administers the Parkway and its primary responsibility is to conserve all of the Parkway's resources for the enjoyment of visitors and future generations (Organic Act of 1916). An important Parkway resource is wildlife, and it has recently come to the attention of park officials that automobiles may be adversely affecting wildlife in areas protected by the NPS.

A variety of factors contribute to high rates of road-kill in and around protected lands. Researchers in Saguaro National Park calculated that some 22,000 vertebrates are killed on roads in and adjacent to the park every year (Kline & Swann 1998). They noted the presence of road-kill hotspots, which are areas rich in resources and at the intersection of busy roads (Kline & Swann 1998). Officials in Banff National Park in Alberta, Canada conducted extensive research along the Trans-Canada Highway which bisects the park (Forman et al. 2003). These studies identify high road-kill counts as a result of high traffic volume and increased vehicle speeds. National Park Service officials conducted a study of road mortalities along the entire Blue Ridge Parkway in 2003 suggesting that mortalities were occurring in the greatest abundance near Asheville (Halligan 2004). As a result of this last study, we decided to take a closer look at what might be influencing these high rates of road-kill along this particular section of the Parkway.

We identified which species of wildlife were affected by traffic along the section of Parkway which stretches from mile marker 382 to mile marker 393. Secondly, we identified any potential road-kill hotspots along that road segment. Thirdly, we examined the relationship between road-kill, time of day, and Parkway intersections.

METHODS

The survey section was along the Blue Ridge Parkway from mile marker 382.2 to mile-marker 393.6. English measurements were used because the NPS places signs at every mile, and they were the measurements used in the companion study (Halligan 2004). This segment was shown to have the highest quantity of road mortality on all of the Blue Ridge Parkway (Halligan 2004). Driving surveys were conducted twice per day on 20 separate days between 16 October and 19 November 2003. The first survey each day occurred between 1600-1700 hr and the second between 2000-2100 hr which allowed us to determine the number of kills in a three hour period between 1700-2000. The starting point of each survey was the Folk Art Center entrance and the end point was the turnoff onto N.C. HWY 191. Driving speed for each survey was 30 m.p.h. (48 km/hr). All individual mortalities visible to the naked eye that were on the Parkway itself or in close proximity (i.e., the shoulder) were counted as road-kill. Whenever an individual was discovered, the species was identified, and the time of discovery was logged. A piece of orange flagging was placed on the roadside vegetation in closest proximity to that individual so that it would not be counted again in a subsequent survey. Location of each individual was recorded to the nearest 0.1 mile (0.16 km). Chi-square was used to test the hypothesis that mortality rates were the same between 1700-2000 hr as expected by chance.

RESULTS

Fifty-eight individuals were identified and recorded at the end of the 20 survey days including forty-three eastern gray squirrels (Sciurus carolinensis), eight opossums (Didelphis marsupialis), three red squirrels (Tamiasciurus hudsonicus), one chipmunk (Tamias striatus), one vole (Microtus sp.), one unidentifiable bird, and one domestic black cat. The greatest number of individual mortalities, 10, occurred along the one mile section designated by mile marker 388, followed by mile marker 384 with a total of eight individuals (Fig. 1). Fewest mortalities occurred at mile marker 391. Thirteen of the 58 individuals occurred between 1700-2100 hr which was a higher mortality rate than expected by chance (x^2 = 0.025). The expected number of individuals killed in any three hour time period throughout the day would be approximately seven if kills were occurring randomly.

DISCUSSION

There were two species that were being affected by vehicles on the Blue Ridge Parkway. The eastern gray squirrel and opossum were both generalist species whose habitats match that created by the narrow Blue Ridge Parkway with its surrounding housing/commercial development that exists along the road segment surveyed. Because opossums are usually active only at night when traffic volume is low, they face less of a risk than squirrels which are active mostly during dawn and dusk. Peak activity for squirrels is during those times when one would expect Asheville-area commuters using the Parkway as a commuter highway to get to and from work. Eastern gray squirrel populations tend to thrive in the oak-hickory forest habitat that is adjacent to the Parkway. It was not known whether squirrel populations were being affected to a degree that might necessitate new conservation efforts from the NPS.

Thus, there are a few places along the 11.4-mile (18.4 km) road segment which might be deemed road-kill hotspots. These hotspots occur at the intersection of major roadways. The mile marker with the greatest number of mortalities was mile marker 388 where U.S. Hwy 25 intersects the Parkway. Mile marker 384, which includes the intersection of U.S. Hwy 74, accounted for the second largest number of road-kill. Traffic statistics from the NPS indicate that the intersections along this road segment experience the highest traffic volume on the Parkway (NPS website). This evidence supports the idea that high rates of road-kill are directly proportional to increased rates in traffic volume.

Results indicate that road mortalities were occurring more frequently between 1700-2000 hr than would be expected by chance suggesting that animals were more at risk then. This may be attributed to increased traffic volume at this time or to increased amounts of animal activity during this time period.

NPS officials might want to consider restricting access to the Parkway from area commuters by requiring drivers to pay a toll at the intersections that are experiencing the greatest amounts of road-kill. This would dramatically cut down the volume of traffic and would allow the Parkway to continue serving visitors as the scenic roadway it was initially established to be (Jolley 1969). Other management might include decreasing Parkway speed limits, increasing enforcement of existing speed limits, and issuing public service announcements to increase driver awareness of animal activity during different times of the year (i.e., during mating seasons).

ACKNOWLEDGEMENTS: We acknowledge Mr. Bob Cherry and Mr. Mike Ryan of the National Park Service who provided us with answers to questions concerning the maintenance of the Parkway as well as directions on how the study might be directed towards the conservation efforts of the NPS. Zac Ispa-Landa, Jackson Fields, Anna Halligan, Matt Heller, Charlotte Litjens, Will Pierzala, and Rob Wiley provided automobiles during surveys.

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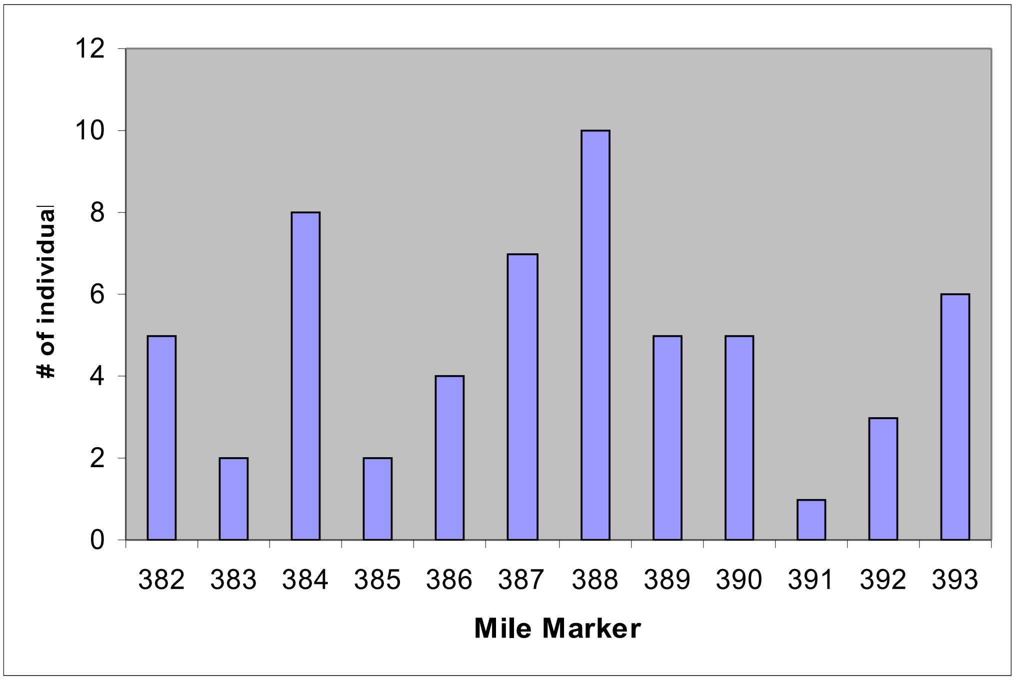
Blue Ridge Parkway traffic counts located at:
http://www2.nature.nps.gov/mpur/Reports/reportlist.cfm

Fig. 1. Number of mortalities in relation to the location of their discovery on the Blue Ridge Parkway during fall 2003. Each mile-marker contains individuals that were found along that one-mile segment. For example, mile marker 382 included five individuals that were found between 382.0 and 382.9.



Assignment 1 – Answers/Hints to Science and Mathematics Review

Nomenclature Rules for Taxonomy –

1. Genus always begin with a capital letter. Species always begins with a small letter.
2. Genus and species should be italicized or underlined when typed.
3. When writing in longhand, genus and species should always be underlined.
4. When underlining, the genus and species should have separate lines under them. There should not be one continuous line under them like Homo sapiens. It should be Homo sapiens.
5. The names for all the other categories in the taxonomic system except species should be capitalized only when they are proper as in the examples below:
   - Kingdom Animalia, but animal kingdom, not Animal Kingdom.
   - Phylum Chordata, but chordate phylum, not Chordate Phylum.
6. All family names end in -idae and not –idea. It is not idea like a thought. The a comes before e.

Rules of mathematics – (based on Keck and Patterson 2000)

1. When turning a fraction into a decimal, you must do division.

$$= \frac{\text{numerator}}{\text{denominator}}$$

The hard part is remembering which one is the divisor. Try this simple rule of thumb:

$\frac{1}{4}$ 1 is up on a wall and falls off. He has to go to the hospital. The hospital is inside the brackets (hospital) like what you see below.

$$4\,\overline{)\,1.00}$$

Now we can compute the answer:

$$\begin{array}{r} 0.25 \\ 4\,\overline{)\,1.00} \end{array}$$

2. To turn a decimal into a percentage, multiply by 100.

$$0.25 \times 100 = 25\%$$

3. Alternatively, turn the denominator into 100:

$$\frac{1}{4} = \frac{25}{100}$$

Scientific notation

1. A number in scientific notation has exactly one digit, other than 0, to the left of the decimal point.

23600 is $\mathbf{2.36 \times 10^5}$

0.00000078 is $\mathbf{7.8 \times 10^{-7}}$

590.8×10^4 is $\mathbf{5.908 \times 10^6}$

2. To create scientific notation on a calculator, most have some variation of the following procedure:

To enter 6.02×10^{23} press 6.02, press Exp, press 23

Rounding and significant digits

1. In the course of a long computation, save the rounding off until the last step which will avoid compounding the round-off error.

2. The number of digits indicates the accuracy of a measurement.

6.02332×10^{23} has **six** significant digits

3. If a number is written with a decimal point, then zeros on the right indicate significance.

5.80 indicates a total of **three** significant digits.

700. has **three** significant digits.

700 without a decimal point may have one, two, or three significant digits. It is ambiguous. Assume it **has one** if you do not know for sure.

4. When multiplying or dividing, the number of significant digits in the answer should be the smallest of the number of significant digits of any number in the equation.

$\frac{10.6 - 4.5}{3.13} = 1.9488818$ must be rounded to **1.9** because 4.5 has only two digits.

5. When adding or subtracting, the answer cannot have more digits to the right of the decimal point than any number in the equation.

4.61 + 11 + 8.2 = 23.81 must be rounded to **24** because 11. has no digits to the right of the decimal.

Multiplication and division of numbers in scientific notation

1. $a^m \times a^n = a^{m+n}$

$(3.0 \times 10^8) \times (-2.0 \times 10^2) =$

regroup to $(3.0 \times -2.0) \times (10^8 \times 10^2) =$

$\mathbf{-6.0 \times 10^{10}}$

2. $a^0 = 1$ for any number a other than zero.

$5.2 \times 10^0 =$ **5.2**

3. . $\frac{a^m}{a^n} = a^{m-n}$

$\frac{1.76 \times 10^5}{2.2 \times 10^{-2}} = 0.8 \times 10^{5-(-2)} = 0.8 \times 10^7 = 8.0 \times 10^6$

Addition and subtraction of numbers in scientific notation

Use the distributive law:

$(4.56 \times 10^3) + (5.90 \times 10^3) = (4.56 + 5.90) \times 10^3 =$

$10.46 \times 10^3 = 1.046 \times 10^4 =$ $\mathbf{1.05 \times 10^4}$

$(6.84 \times 10^8) + (5.00 \times 10^6) = (684 + 5.90) \times 10^6 =$

689×10^6 $\mathbf{= 6.89 \times 10^8}$

Conversion of units

1. The easiest and most accurate way to convert units is to cancel like units. **This is why it is essential to keep track of all units.**

2. When signifying units remember that English units are abbreviated using a period as in ft. and mi. Metric units are signified without a period as in g and km which makes it easy.

example: convert 36.79 inches to centimeters. Use 1 inch = 2.54 cm.

$$36.79\ \text{in.} \times \frac{2.54\ \text{cm}}{1\ \text{in.}} = \mathbf{93.4\ cm}$$

convert 60 miles per hour to feet per second. Use 5280 feet in a mile and 3600 seconds in an hour.

$$\frac{60\ \text{mi.}}{\text{hr.}} \times \frac{5280\ \text{ft.}}{\text{mi.}} \times \frac{1\ \text{hr.}}{3600\ \text{sec}} = \mathbf{\frac{88\ ft.}{sec}}$$

convert 6,800,000 kilograms per cubic meter to grams per cubic millimeter.

$$\frac{6{,}800{,}000\ \text{kg}}{\text{m}^3} \times \frac{1\ \text{m}^3}{1000^3\ \text{mm}^3} \times \frac{1000\ \text{g}}{1\ \text{kg}} = \frac{6{,}800{,}000\ \text{g}}{1000^3\ \text{mm}^3} = \mathbf{\frac{6.8\ g}{mm^3}}$$

Division by zero

Any number divided by zero is an error.

$$\frac{11}{0} = \textbf{error}$$

$$\frac{18{,}356{,}678 \times 10^{-78356}}{0} = \textbf{error}$$

Graphing:

Scatter plots are used to show trends between two variables**.**
Bar graphs are used to compare means of treatments**.**

Summary of Guidelines for the Talk

Title-
- should be descriptive and specific with all the main key words, but have no unnecessary words.

Abstract -
- should be all one paragraph, no longer than 250 words and have no citations.
- each of the four main sections of the talk should be summarized, Introduction, Methods, Results, Discussion.
- the objective should be included and written clearly.
- the summary of the results should be very detailed.
- the final line should be a strong conclusion statement that summarizes the entire project.

Introduction –
- opening line should be interesting and not just a reading of the title or a name.
- should proceed from general to specific.
- should answer the questions, what is the existing state of knowledge about the topic, and why did the author undertake this study?
- every fact that is written in a bullet on a slide should include a citation.
- a statement of objective is imperative.

Methods - (should not be called Materials and Methods in Biology)
- in a talk it is generally better to show diagrams, pictures, or a flowchart of the procedures rather than long, wordy bullets.
- randomization and replication should be appropriate.

Results -
- should not include implications, speculation, management recommendations, or interpretations.
- tables and figures should not duplicate each other. They should be prepared according to the format shown in the J. of North Carolina Academy of Science or another journal.
- for every t-test or ANOVA, the equal variance assumption and the normal distribution assumption should be tested. If an assumption is violated, converting the data can sometimes fix the problem. If the assumptions are still not met, non-parametric statistics should be used.
- the student should say whether the assumptions have been tested.

Discussion -
- should interpret the data in relation to the original objective and compare conclusions to those of others, but not overextend the results.
- should end with a firm take-home message or conclusion statement.

Acknowledgments -
- should give credit to those who contributed equipment, transportation, housing, grants, internship funding, major ideas, work, technical assistance, statistical advice, computer advice. Any faculty member who helped beyond the major advisor should be acknowledged.
- the NSS is not the Academy Awards. Minimize private jokes and personal thanks.

Literature Cited - Required for the final paper. A bibliography is required for the presentation on the back of the piece of paper that has the abstract.