Syllabus *Biology 2005, fall semester 2017*

Doing science: the biology of variation meets MW 1:00-4:00 (or -5:00) in BIOL 150

Prerequisites. This is an introductory course for first-semester students who plan to major in biology or another science or engineering discipline. There are no formal prerequisites, but the course content is strongly quantitative and statistical so previous study of algebra, calculus or statistics will be helpful.

Credit hours. Three, of which two are laboratory credits, and all can be counted toward the major in Biology. Most of the course work will take place during class meetings, so *every student must attend and participate fully in every scheduled class meeting* (except for illness or other unforeseeable emergencies, of course). Please contact Prof. Seger during the first week of class if you have any questions about this. Reading and other work outside class will typically require 2-4 hours per week.

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Course description. An introduction to biology and to university life, through the practice of research in quantitative genetics. Working in small teams, students will study continuously varying traits of various kinds in natural populations of quaking aspen (*Populus tremuloides*). How do such traits vary, how do genetic and environmental factors contribute to this variation, and how does the variation affect the fitness of aspen under different environmental conditions? Each team will identify a specific trait and a set of questions about its variation, design a program of data collection, analyze their data using the statistical computing language R, and report their findings in writing and in verbal presentations to the whole class. By engaging both in the social and the technical aspects of scientific practice, students will prepare themselves to learn more easily and more deeply from their subsequent courses.

Objectives. By the end of the course, students should be able to contribute productively to the work of a scientific research team. In particular, they should be able to design and carry out simple statistical analyses using R, and they should be able to summarize, present and interpret the results of such analyses, both verbally and in writing. Clear writing depends on clear thinking, and thinking is often clarified by the process of attempting to explain a set of observations and its interpretation in writing. Thus many course activities will involve writing, critical reading, and re-writing of student-generated proposals and reports. Because the specific subject matter is quantitative-trait variation in plants, students should be able to construct data sets that allow them to estimate the genetic and environmental variance components of various phenotypic attributes of plants, and they should be able to explain the meanings and context-specific limitations of those estimates. Finally, students should be able to critically discuss the methods and conclusions of scientific papers describing studies of this kind.

Expected Learning Outcomes. The University's ELO statement for the B.S./B.A. in Biology (http://learningoutcomes.utah.edu/degree/296) lists outcomes in eight areas. Students who complete Biology 2005 will have acquired specific competencies in all eight, and especially in these four:
(1) Evolution. The principles of "trait variation and heritability" are applied in real empirical research.
(5) Process of science. The student-directed research projects demonstrate, through practice, how science depends critically on the ability to "identify knowledge gaps, formulate hypotheses, and test them against experimental and observational data to advance an understanding of the natural world".
(6) Quantitative reasoning. All of the projects "use mathematical and computational methods and tools to describe living systems and ... apply quantitative approaches such as statistics".
(7) Participation in science through clear communication and collaboration. The research teams develop their projects through written proposals, peer reviews, reports and presentations; this process gives every student the opportunity to acquire and apply effective scientific writing skills.

Content overview. Science is largely about *knowing what we don't know*, and its questions are typically quantitative. That's why we need to use statistics to assess whether, or how strongly, a given set of data supports a given conclusion. The *analysis of variance* (ANOVA) is a cornerstone of modern statistics. It was pioneered by R.A. Fisher and others in the early 20th century to help them study the inheritance of quantitative (continuously varying) traits in plants and animals. A central goal was to estimate the sizes of the genetic and environmental influences on the observed variation, and to evaluate the uncertainties of those estimates. Thus important aspects of the modern scientific outlook and some of its core methods trace back a century to the birth of the field known as quantitative genetics.

Traditionally, this subject is presented in advanced courses for upper-division and graduate students, because the theory is highly mathematical. But the central ideas are very simple, besides being fundamental to biology and to science generally. In this course we will approach quantitative genetics as a hands-on *practice* rather than as an abstract *theory*. Beginning with the sizes and shapes of aspen leaves, we will learn how to characterize the variation of quantitative traits, and then to partition or "analyze" that variation into components that can be attributed to underlying genetic and environmental causes (and to their *interaction*, an important but widely misunderstood concept).

To do an analysis of variance we need to know how to design an experiment, gather and organize the data, and then perform the analysis. These are *skills*, combining practicality with thought. What will we measure? On how many individuals? Which ones? How will we record the data, and prevent errors? Then what computations will we do? And what do we make of the results? At every step, we have to make decisions about what to do next, with much room for creativity, and with potentially large effects on the outcome of the project. Such decision-making is better done by a group than by individuals working alone, so we will work in small teams and periodically share our plans and results with a larger community, just as professional scientists do. Here the larger community will be the rest of the class, not the whole field, but the result will be same – working together we will have more and better ideas than we would have had alone. This process is guided by rules, but it is *open-ended* – we don't know in advance where it will go, and sometimes it won't go anywhere, but in the end discoveries will be made.

Although the calculations we need to carry out are usually very simple in nature, they are tedious in practice when we are working with large amounts of data. We will use the R statistical programming language throughout the course. R has become the tool of choice for scientists in most fields because it is free, flexible, and very capable. It can be used to visualize data; to reformat and otherwise prepare data for analysis; and to carry out essentially all of the modern analytical procedures, from the simplest to the most complex. Learning R will be a challenge because it demands much attention to detail and it expects the user to tell it what to do, rather than the other way around. But when you have learned to work in this way you will be able to do anything you can think of with data – an awesome power!

Teaching and learning methods. There will be lectures by the principal instructor and his expert guests (see schedule, below). But most of the course meeting time will be devoted to exercises, open-ended research activities, tutoring and other interactions with the professor and TAs, and presentations by the research teams to the whole group. The teams will be organized by the instructional staff to maximize the diversity of skills and interests within each team, for reasons explained below.

Readings and other course materials. The textbooks are *Writing Science* by J. Schimel and *Getting started with R, 2nd edn* by A. Beckerman, D. Childs and O. Petchey. Lecture notes, articles of many kinds, and data sets will be posted on the course's web site and/or Ubox accounts. The web site's URL, login ID and password can be found on the last page of this syllabus.

Evaluation methods and grading scale. (1) The staff will evaluate each student's participation and progress in weekly meetings. Notes from these meetings will be used to construct overall participation and progress scores at the end of the semester. (2) Team "deliverables" (written proposals, written reports and live presentations) will be scored by each member of the staff. (3) Individual notebooks, short writing assignments, quizzes, and semester-end essays will also be scored by each member of the staff. These three kinds of performance measures will then be weighted equally to generate overall performance scores, which will be curved by the staff in a final meeting. The grading scale will not be competitive. If all students perform well, then all will receive high honor grades. But if not, then not.

About your notebook. People can remember a lot, but science requires Total Recall. Scientists keep ***notebooks*** to record their experiments and observations (what they *did*); to record their *interpretations* of those experiments and observations (what they *thought* of what they did); to record ideas for future experiments and observations (what they *plan to do*, and *why*); and to take notes on readings, lectures, conversations, course meetings and the like (what *other people* thought about what *they* did). Your assignment is to ***keep such a notebook*** for this course. Use it on a daily basis to keep track of your readings, class lectures and assignments, the progress of your group's research project, and any other relevant activities. ***Date every entry.*** Some of the information you record will go into your team's research report, but the larger purpose of the notebook is to help you ***understand how you think***, and how your thinking has *changed* during the semester. This is a major goal of the course. To be an effective scientist, or scholar of any kind, you need to *be aware of your own thought processes*, and those of your *colleagues*. So *study the other members of your team*, and record observations that may reveal something about how they think. The more you understand *them* (and other individual scientists), the more you'll understand *yourself*, and the more you'll *grow* intellectually, in part by adding other thinkers' habits of mind to your own repertoire. (This is why we construct the teams to be diverse.)

We will "borrow" your notebook every few weeks to read your recent entries and give some feedback, in the form of notes from the TAs and a summary score of "check", "check-minus" or "check-plus" (which you can think of as good/better/best). Among the things we'll be looking for are:
(1) Your notes on the readings from Schimel's **Writing Science.** In addition to capturing what you think are the most important points, please try to record your own *response* to each chapter. What do you feel you understood? What did you *not* understand? Where do you agree, or disagree, and why?
(2) Notes on the lectures, discussions, presentations and the like -- at least enough to remind you later what happened, and what you thought of it.
(3) Your team's work on its project. Each of you should maintain your own narrative about your discussions, the published papers you've found and read, the data you've taken and analyzed, etc.
(4) R exercises. There will typically be handouts for these, but your notebook is a good place to record many of the big ideas and little details of command syntax and other mechanics that are easy to forget.

ADA statement. The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability Services. http://disability.utah.edu/currentprospective.html

Statement of student and faculty rights and responsibilities. Everyone is expected to maintain professional behavior in the classroom, according to the Student Code, as spelled out in the Student Handbook. Students have specific rights as detailed in Article III of the Code, which also specifies proscribed conduct (Article XI) such as cheating on tests, plagiarism and/or collusion, as well as fraud, theft, etc. Students should read the Code carefully and know they are responsible for the content. Faculty are responsible for enforcing responsible classroom behaviors, and we will do so, beginning with verbal warnings and progressing to dismissal from the class and a failing grade, should that be necessary. (Heaven forbid!) Students have the right to appeal such action to the Student Behavior Committee. To maintain a productive learning environment for everyone, there will be no phoning, texting, e-mailing, web surfing or other distracting activities during class (except during breaks).

Sexual harassment and assault. Title IX establishes clearly that harassment or violence based on sex and gender (which includes sexual orientation and gender identity/expression) is a civil rights offense subject to the same kinds of accountability and the same kinds of support as are applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran's status or genetic information. If you or someone you know has been harassed or assaulted, you are encouraged to report it to the Title IX Coordinator in the Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, or to the Office of the Dean of Students, 270 Union Building, 801-581-7066. For support and confidential consultation contact the Center for Student Wellness, 426 SSB, 801-581-7776. To report an incident to the police, contact the Department of Public Safety, 801-585-2677 (COPS).

Wellness statement. Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student's ability to succeed and thrive at the University of Utah. For helpful resources you may contact the Center for Student Wellness, www.wellness.utah.edu, 801-581-7776.

Schedule of class meetings (***approximate*** and ***always subject to change!***) ... as of 20 August 2017

Abbreviations: WS = *Writing Science* by Josh Schimel**;** SSR = simple-sequence repeat (microsatellite)

Access to course web site at http://courses.biology.utah.edu (id = 2005.student, password = genchngs)

Aug 21	introduction to the course and to each other; "cool research projects slam" on reports from previous years
Aug 23	form research groups; discuss proposal rubric and potential topics; prepare for Field Trip 1; talk by **Bill Anderegg**
Aug 28	**FIELD TRIP 1**: meet the trees at Silver Lake, study their variation, collect samples for phenotyping and genetics
Aug 30	mount and scan leaves collected on August 28; begin work on proposals
Sept 6	**statistics #1:** intro to quantitative traits; **R #1:** basics, scripts, mean, variance, histograms; prepare for Field Trip 2
Sept 11	**FIELD TRIP 2**
Sept 13	aftermath of Field Trip 2; keep working on proposals
Sept 18	talk by **John Sperry**; finish first drafts of proposals and present them to the class for discussion
Sept 20	**statistics #2:** associations and significance tests; **R #2:** data visualization; threshold (black-and-white) leaf sheets
Sept 25	**FIELD TRIP 3**
Sept 27	consolidate proposals and submit written versions; finish thresholding, start making leaf-data spreadsheets
Oct 2	**statistics #3:** ANOVA; **R #3:** ANOVA; **background on genetics** to prepare for DNA extraction lab, SSRs
Oct 4	DNA extraction lab
	(***fall break***)
Oct 16	**scholarship:** finding and using the scientific literature (lecture + project-oriented practice); assign Schimel #1 (WS)
Oct 18	discuss Schimel #1 (WS); **statistics #4**: linear regression; **R #4**: linear models
Oct 23	SSR genotyping lab; finish leaf-data spreadsheets; work on projects; assign Schimel #2
Oct 25	discuss Schimel #2; **genetics of quantitative traits**
Oct 30	talk by **Karen Mock**; consult with Prof. Mock on projects; assign Schimel #3
Nov 1	discuss Schimel #3; work on projects
Nov 6	**statistics and R #5:** genetic and environmental variance components; work on projects; assign Schimel #4
Nov 8	discuss Schimel #4; work on projects
Nov 13	**statistics and R #6:** making figures that look good and tell your story truthfully; assign Schimel #5
Nov 15	discuss Schimel #5; work on projects, begin writing first drafts of reports
Nov 20	work on projects, keep writing
Nov 22	discuss Schimel #6; finish first drafts, assign and distribute drafts to peer reviewers (write reviews over weekend)
Nov 27	distribute peer reviews; teams read and respond to reviews; keep working
Nov 29	finishing projects and revising reports
Dec 4	finish revising reports; work up presentations
Dec 6	teams ***present projects***; group reflection on course; review for final exam
Dec 12	final exam and celebration (1:00 - 3:00, ***Tuesday***)