Syllabus

COURSE: NS 101 Natural Science: Principles and Practice

SEMESTER: Fall 2009

ROOM & TIME: Lecture, Shelby 150, MWF TBA; Recitation and Examinations, Shelby 250, R TBA

INSTRUCTOR: John B. Vincent, Shelby 234, 348-9203, jvincent@bama.ua.edu

PREREQUISITE: None

TEXT: To be determined. Will probably be a collection of readings chosen specifically for the course.

ADDITIONAL REQUIRED READING: (tentatively) selections from Ian Barbour, *Religion in an Age of Science*; Thomas S. Kuhn, *Structure of Scientific Revolutions*; John E. Walsh, *Unraveling Piltdown*; James Watson, *The Double Helix*; Edward J. Larson, *Summer for the Gods*; Charles Darwin, *The Origin of Species* and *The Descent of Man*; and George W. Hunter, *A Civic Biology.*

COURSE OBJECTIVES: To introduce students to the concepts and methods of the natural sciences including the scientific method, measurements, levels of organization, and equilibrium and evolution. The course is designed to prepare students to learn how to interpret information on the natural sciences they may encounter in everyday life (such as television news, newspaper, etc.).

COURSE CONTENT:

Weeks 1-4: The basics and application of the scientific method
- "hypothesis", "theory", "experiment", "law", "model", "principle", "paradigm"
- Copernican theory
- Piltdown man
- Shroud of Turin

Weeks 5-8: Measurements, constancy, and change
- metric system
- fundamental units of measure
- probability and uncertainity, accuracy and precision

Weeks 9-12: Systems and levels of organization
- subatomic particles - atoms and molecules - cells and organisms - populations and communities - planets and solar systems – the universe
- discovery of structure of DNA
- big bang theory

Weeks 13-16: Evolution and equilibrium
- Theory of evolution
- Scopes Monkey trial
- Spontaneous generation of order and entropy

LEARNING GOALS:

The goals of this course are based on the content standards for science education suggested by the National Research Council (*National Science Education Standards*, National Academy Press, Washington, D.C., 1996).

1) Students should understand how the scientific method works and comprehend concepts and terms such as "hypothesis", "theory", "experiment", "law", "model", "principle", and "paradigm".
2) Students should understand the concepts of measurements, constancy and change and comprehend the terms "metric system", "fundamental units of measure", and "probability and uncertainty".
3) Students should be able to appreciate different levels of organization, for example the relationship of fundamental particles; of elements and the periodic table; of cells, tissues, organs, organisms, populations and communities; or of plates, planets, solar systems, galaxies, and the universe.
4) Students should understand the role of ethics in science and understand the concepts of "evolution", "equilibrium", and "order and entropy".

WHO SHOULD TAKE NS 101: NS 101 is for students who are not planning to major in the natural sciences, engineering, nursing, nutrition and hospitality management, and pre-professional degree programs (including pre-medicine, pre-veterinary, etc.). Applications are pending to allow NS 101 to count as a core natural science course.

ATTENDANCE: Attendance in lecture is not required but is most strongly recommended. Attendance in laboratory is required.

GRADING: Laboratory, 100 points; Three Examinations (drop lowest grade), 2 x 100 points; Written Report, 100 points; Final Examination, 150 points. Total: 550 points. Grade scale: 90-100, A; 80-89, B; 70-79, C; 60-69, D; <60 F. +/-'s will be given at the instructor's discretion.

ACADEMIC MISCONDUCT: All acts of dishonesty in any work constitute academic misconduct. The Academic Misconduct Disciplinary Policy will be followed in the event of academic misconduct.

DISABILITY ACCOMMODATIONS: To request disability accommodations, please contact the Office of Disability Services at 348-4285. After initial arrangements are made with that office, contact your professor.

— APPENDICES NOT ATTACHED

Natural Science 101 (NS 101)

Proposed common core curriculum experience for students majoring in fields other than the natural sciences, engineering, nursing and nutrition and hospitality management.

Introduction

NS 101 is to be a one semester course comprised of three hours of lecture, an hour of recitation, and three hours of laboratory a week for four hours credit for students majoring outside the natural sciences and certain professional and pre-professional programs. The laboratory component is essential for this course to count toward the State of Alabama's General Studies and Articulation agreement. The remaining four hours of natural science credit for the core curriculum requirement would come from a traditional non-majors natural science course such as BSC 110/111; CH 107; PH 115; etc. This course is designed to complement the more discipline-based perspective of science provided by standard science courses. The concepts covered will provide connections between and among traditional scientific disciplines, be fundamental, and be comprehensive within the appropriate level of scientific development of the students. The course is also modular in design, allowing flexibility to instructors, freedom for sections (modules) to be replaced or changed, and the ability for aspects of the course to be incorporated into the traditional natural science courses as desired. Course size for the pilot program in Fall 2008 or 2009 is to be limited to 48 students; however, this is the preferred class size for future offerings, allowing for some discussion-based learning. Each class of 48 students would also be registered in two laboratory sections of twenty-four, giving them a closer association between laboratory and lecture. Additionally, twenty-four students can easily be broken into groups of four or six for group-based laboratory experiments; this size is also right at the maximum number of students recommended for laboratory sections by such organizations as the National Science

Teachers Association and the American Chemical Society.

The course will focus on the scientific method and examine the structure of the scientific method, how it works, what happens when the method is not used properly, and the implications of the method for society, both past and present. To accomplish this, events in the history of science that had or have particularly great impacts on society are to be emphasized and even recreated in the laboratory. Laboratories will be inquiry-based whenever possible (for example see Shroud of Turin experiment, appendix A). Group discussions will be a major component of lecture and recitation. Students will also have to give a written or oral report on a problem, historical event, etc. in the natural sciences and discuss its significance in light of the scientific method and society at the end of the course. Lectures could be areas for the use of recent advances in teaching technologies. Note that this course is not a survey of the physical sciences as in a traditional natural science for students in certain two-year degree programs.

Justification

This course is designed with the view that a scientifically literate populace represents a important goal for higher education and that baccalaureate students at The University of Alabama should be able to understand the points of intersection between science and other aspects of society and culture and comprehend the investigative and analytical methods used to probe the natural world and develop models based on that evidence. Additionally it is believed that the way for students to understand such methods is not by just hearing about them but by also experiencing them and having to express their understanding of them. The course should not be one where students are simply receivers of information, but one that strives to instill a desire for inquiry and provides a climate for adventure and discovery. As such the course should be targeted towards freshman. The methods of scientific inquiry can be applied into other fields; thus, this course is not designed as a recruiting tool for attracting natural science majors. It is hoped that this course could be combined with a structured freshman year program which throughout could emphasize inquiry-based learning and prepare students for inquiry-based core courses in other disciplines such as the humanities and fine arts and in the students' advanced courses in their chosen field of endeavor. (For a plea for this type of curriculum development, see the report of the Boyer Commission on Educating Undergraduates in the Research University, *Reinventing Undergraduate Education*, http://notes.cc.sunysb.edu/Pres/boyer.nsf). The common experience such a course offers to non-science majors (and if some of the modules are used in freshman courses for natural science majors to these students as well) provides significant benefit to students. First it helps to provide a sense of community, an important feeling for entering students (leaving their communities and entering the University where they may not yet have made connections with students sharing their intellectual interests). At the same time, a core course such as this must be taught to audiences of limited size, helping the student not to lose his/her personal sense of identity amongst the masses. Also common courses expose students to a diversity of backgrounds, not only through interactions with other undergraduate students but with faculty and graduate students as well. Such diversity can allow students to visualize approaches to problems from different perspectives, enriching the inquiry and discovery process.

Course Philosophy

While this proposed course is innovative, especially with its emphasis on ethics and most importantly laboratory experiments, it is not without precedent. The late President of Harvard University James B. Conant emphasized the importance of a case history-based science course for non-science majors over five decades ago (James Bryant Conant, Leonard K. Nash, Duane Roller, and Duane H. D. Roller, *Harvard Case*

Histories in Experimental Science, Harvard University Press, Cambridge, 1957; James B. Conant, *On Understanding Science: An Historical Approach*, Yale University Press, New Haven, 1947). The philosophy of this course rests upon recapturing the experience of scientists who participated in influential and from a scientist's point of view exciting events in the history of scientific research. While lecture provides the understanding of the terms and to some degree the procedure of science, nothing provides an understanding of science like experiencing a scientific discovery. Non-science majors

> require an understanding of science that will help them to relate to developments in the natural science to those in the other fields of human activity. To do so demands an understanding of both of the methods of experimental science and of the growth of scientific research as an organized activity of society. Experience shows that a man who has been a successful investigator in any field of experimental science approaches a problem in pure or applied science, even in an area in which he is quite ignorant, with a special point of view....Even a highly educated and intelligent citizen without research experience will almost always fail to grasp the essentials in a discussion that takes place among scientists concerned with a projected inquiry. This will be so not because of the layman's lack of scientific knowledge or his failure to comprehend the technical jargon of the scientist; it will be to a large degree because of his fundamental ignorance of what science can or cannot accomplish....He has no "feel" for what we may call "the tactics and strategy and strategy of science". (Conant, et al., 1957, p. vii).

Yet, while Conant and others have emphasized the importance of case studies and understanding the process of scientific discovery, it is the belief of this proposal that science is a "hands-on" experience which is not truly understood and appreciated without a laboratory experience, including the experience of experiments which fail to work successfully or give an answer other than that expected. Additionally, pre-laboratory questions, which students are required to master before entering the laboratory every week) will be delivered using MasteringChemistry as will be tested shortly for CH 101/102 and CH 117/118.

Course Content

The course will be divided into four four-week units: 1) the basics and application of the scientific method, 2) measurements, constancy and change, and systems, 3) levels of organization and 4) evolution and equilibrium. Each unit will have three laboratory experiments. A proposed outline of the course is given below. The breakdown of the course is in part based on the content standards for science education suggested by the National Research Council (*National Science Education Standards*, National Academy Press, Washington, D.C., 1996).

1) The basics and application of the scientific method.

Lectures will describe how the scientific method works and introduce concepts and terms such as "hypothesis", "theory", "experiment", "law", "model", "principle", and "paradigm". Lectures will be based around the Copernican theory as a model of how the method works and its implications on society. This will be supplemented with discussion of what happens when the method is intentionally or unintentionally bypassed using modules on Piltdown Man (a scientific forgery which demonstrates the failure and then ultimate success of the scientific method) and the Shroud of Turin (possible self-deception of scientists on both sides of an issue and the effects of bias on the scientific method). Textbooks and readings for this section could include all or portions of Thomas S. Kuhn (*The Structure of Scientific Revolutions*, 3rd edition and *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*), Karl R. Popper (*The Logic of Scientific Discovery*), Norman Campbell (*What is Science?*), Carl G. Hempel (*Philosophy of Natural Science*), and Ian Barbour (*Religion in an Age of Science*), as well as specific articles and books on Piltdown Man (e.g. John Evangelist Walsh, *Unraveling Piltdown*) and the Shroud of Turin. There are also excellent web sites on Piltdown Man (e.g. http://www.tiac.net/users/cri/piltdown.html and http://www.tiac.net/users/cri/piltref.html) and the Shroud of Turin which students could access. Laboratories will include one to demonstrate how the scientific method should work (yet to be chosen but a possibility would be estimating the diameter of the earth using one of the methods of the Greek scientists/philosophers) and experiments recently designed in the Department of Chemistry on forging Piltdown Man and simulating the Shroud of Turin. In the Shroud example, students take pieces of natural cloth and plastic baby dolls and attempt to transfer a three-dimensional image of the doll onto the cloth using only items available in the 14th century. This is an inquiry-based laboratory as students are given the supplies and told of the proposal in the scientific literature about how the Shroud might have been produced but then have to figure out how to accomplish this on their own. This experiment has been well tested, and a description has been published (see appendix A). In the case of Piltdown man, students take pieces of simulated fossil bone and determine through the use of a logic tree and qualitative elemental analysis (quantitative chemical analysis was used in the exposure of the fraud) whether the "bones" are faked in one of the manners used in the Piltdown forgeries or appear "real". A description of this laboratory appeared in the *Journal of Chemical Education* (see Appendix B).

2) Measurements, constancy and change.

Lectures could be based on subjects such as the theory of relativity, development of quantum mechanics (non-mathematical discussion), or plate tectonics. The metric system, the fundamental units of measure, and probability and uncertainty will also be introduced. One laboratory will involve firing a projectile by some means at a target (the bigger the better) several times and determining the accuracy and precision of the shots (see Appendix C). Others could include measuring some fundamental physical constant (e.g. electron charge or speed of light for which specialized equipment for teaching laboratories is available commercially) and measuring some type of rate of change (e.g. nuclear decay (see Appendix D which would require rewriting for a non-majors experiment) or an inquiry-based experiment such as optimizing reaction rates with Mentos candy and diet Coke (see Appendix E))..

3) Systems and levels of organization.

Lectures will focus on different levels of organization, for example the relationship of fundamental particles; of elements and the periodic table; of cells, tissues, organs, organisms, populations and communities; or of plates, planets, solar systems, galaxies, and the universe. Discussions on cosmology could be used to reinforce the Copernican revolution. For scale at the molecular level, a module using Watson and Crick's discovery of the structure of DNA will be used. Discussions would include a reinforcement of the scientific method and scientific ethics, with a module examining whether Watson and Crick bypassed the conventional code of scientific research and disclosure. Reading materials would include Watson's (*The Double Helix*) and Crick's (*What Mad Pursuit: A Personal View of Scientific Discovery*) accounts of the events and secondary sources such as Robert Olby's *The Path to the Double Helix* and Horace Freeland Judson's *The Eighth Day of Creation.* The made-for-television movie *Race for the Double Helix* (American Title), for which Crick and Maurice Wilkins (one of the investigators who collected the X-ray data) were consultants, could also be shown. As a laboratory experiment, DNA would be isolated from yeast. This has been done previously in the freshman chemistry course for nursing and nutrition and hospitality management majors, CH 104. For experiments at other levels, passing a laser through slits and light over diffraction gratings, etc. could be used to demonstrate quantum effects. Similarly experiments using radioactivity could be used to demonstrate principles on the atomic scale. A third experiment would need to involve a subject from a field such as geology, cosmology or ecology.

4) Evolution and equilibrium

This section will focus on the Scopes Monkey trial. This unit has been tested at a more advanced level in the Department of Chemistry during an interim period as CH 409, Scientific Ethics. Text will be Edward J. Larson's *Summer for the Gods: the Scopes trial and America's continuing debate over science and religion*, BasicBooks, New York, 1997 with additional reading including excerpts from the King James Version of the *Bible*, Charles Darwin's *The Origin of Species by Means of Natural Selection* and *The Descent of Man*, George William Hunter's *A Civic Biology* (the textbook being used at the high school where Scopes was an instructor), and period newspaper and magazine articles. The trial will be examined from several perspectives --- the background of the principal players, the town, Tennessee politics, and national politics; the events of the trial itself and public opinion as the trial proceeded; and the aftermath in terms of the final outcome of the case, public opinion (including the film *Inherit the Wind*), high school and college biology textbooks, and subsequent laws and trials. Mixed into the trial discussion as scientific evidence is presented in the case will be classroom lectures and discussions of the evidence for evolutionary theory and a module on the concept of equilibrium and far from equilibrium systems (the spontaneous generation of order). Laboratory experiments will include the demonstration of an equilibrium system using $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$ (Appendix F, although this will be modified for a non-science major) and the spontaneous generation of complexity using the Belovsov-Zhabotinsky reaction (Appendix G). The first involves the interconversion of two cobalt complexes (one pink and one blue used in some relative humidity devices) demonstrating that equilibrium systems are dynamic and not static and are affected by changing concentrations and temperature. The latter takes a well stirred and, thus, homogeneous system which oscillates repetitively from one color to another and back; all the molecules appear to communicate with each other across the container (which is impossible) informing each other when to react so that the reaction occurs at the same instant throughout the container. The rapid changing back and forth of color uniformly at a instant throughout the entire system is only possible through the production of complexity and higher order in the system and possesses many properties of a living system. Another possible laboratory experiment could be the production of amino acids and nucleic acid bases from simple precursor molecules believed to be present on the primitive earth; attempts to develop such a laboratory are currently underway in the Department of Chemistry.

Given the history of instruction of evolution in the State of Alabama this unit will be most interesting and will require well-qualified instructors and laboratory assistants. The need of teaching evolutionary theory in such a course cannot be understated, for example see *Teaching about Evolution and the Nature of Science*, National Academy of Sciences, National Academy Press, Washington, D. C., 1998.

If you need more information please contact the STARS Office at 334-670-3690.