St. John's University
Jamaica, NY

Core Curriculum
SYLLABUS

Science 1000C – Scientific Inquiry **Spring 2001**

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I. Course Description

This course introduces students to the fundamental processes of science through the exploration of specific topics in modern science. Students can choose from a number of different investigations (historical and logical sequences in the development of a major idea) including those into atomic theory, energy, environmental science, evolution, geoscience, and quantum mechanics.

II. Course Objectives

The objectives for the course include that students will be able to:

1. Describe the characteristics of scientific inquiry.
2. Contrast the attributes of scientific inquiry with those of other ways of knowing.
3. Plan and execute a well-designed experiment and/or simulation.
4. Analyze the historical development of a major concept in science.
5. Identify the key issues in a present-day societal issue dealing with science.
6. Apply scientific thinking to societal issues dealing with science.

III. Core Competencies and Knowledge Bases

This course will assist students in developing the following core competencies (the numbers refer to competencies as stated in the general description of the core):

- #2. Assess alternatives through data analysis and evaluation.
- #3. Use print and digitized resources of the library for research and analysis.
- #4. Use appropriate computer applications.
- #5. Read, understand, and evaluate primary texts.
- #7. Use quantitative methods appropriately.

The course will develop the following knowledge bases:

- #2. The nature and results of scientific inquiry.
- #3. The natural environment and human influences on it.

IV. Evaluation of Student Performance

Evaluation of student performance will be based upon at least three of the following assessment methods:

- Examinations
- Presentations for nonscientists
  - Oral
  - Visual
  - Poster
- Problem solving activities
- Project reports
- Writing assignments

V. Course Outline

This course will fulfill the core curriculum requirement in science. It is designed to be taught by faculty from a variety of different science disciplines. In every case, the same course outline is used, but the particular investigation to be explored will be selected by the instructor. Individual sections of the course will be designated as covering a particular investigation, so students will be able to select the area of science they wish to study.

Basic Course Outline (To be followed in all the investigations)

1. Introduction to the History of a Key Problem in Science (ONE WEEK)

2. Introduction to Science as a Way of Knowing: Characteristics of Scientific Inquiry (ONE WEEK)
   a. Observation
   b. Experimentation
   c. Comparison
   d. Model building

3. What Makes Science Different from Other Ways of Knowing (ONE WEEK)
   a. Abstraction
   b. Quantification
   c. Prediction
   d. Issues of Pseudoscience

4. The Historical Development of This Scientific Problem (THREE WEEKS)
   a. How concepts changed over time
   b. How a paradigm shift occurred
   c. The individuals and groups involved in the problem
   d. The role of technology in the development of this problem

5. The Consequences of the Solution of This Problem (THREE WEEKS)
   a. How science changed as a result
   b. How society changed as a result

6. The Relation of Science to Society (TWO WEEKS)
   a. How the culture affects the doing of science
   b. How science can both create and help solve problems
   c. How to make decisions based on scientific evidence

7. The Values of Science (TWO WEEKS)
   a. Honesty
   b. Freedom of inquiry
   c. Tolerance of different opinions
   d. Relationship of science and religion

Outlines for Each of the Specific Investigations (One of the following areas will be examined in one semester)

A. ATOMIC THEORY

Modern students are often familiar with Dalton's Atomic Theory. However, few have studied a theory in depth from its pre-history to its current conceptions and utility. Arguably the entire modern physical world is based upon the understanding brought about by the atomic theory. This course attempts to take this one theory from the beginning of time to the present. The following topics will be presented.

1. Atomic Theory
    - a. Alchemy and pre chemistry
    - b. Dalton's Atomic Theory (Theory vs Hypothesis)
    - c. Avogadro's Principle
    - d. Mendeleev and periodic table

2. Models of the atom
    - a. Atoms and continuous matter (Greeks)
    - b. Discovery of electron (Plum Pudding or Chocolate Chip Cookie Model)
    - c. Discovery of the Nucleus (Nuclear Atom)
    - d. Atomic Spectra (Bohr Model)
    - e. Wave-Particle Duality (Quantum Wave Mechanics)

3. Chemistry in the Modern World ("Better living through Chemistry")
    - a. Teflon
    - b. Nylon(polymers)
    - c. Chlorofluorocarbons(ozone hole)
    - d. Carbon dioxide(global warming)
    - e. penicillin vs Rational Drug design
    - f. Fertilizers (green revolution)
    - g. The transistor (integrated circuits and computers, nanotechnology)
    - h. Spectroscopy (atomic structure to astro-chemistry)
    - i. Health care (analytical diagnosis of the disease state)

B. ENERGY

We speak of energy in many guises. It fuels cars as petroleum, sustains life as food, lights the day as sunlight, powers our computers as electricity, warms the planet as heat, and is the coin of exchange for moving objects. What is the underlying connection between all these phenomena? We know now that energy can be converted from one form to another, but the total of all these forms never changes. With this simple knowledge, we can predict the motions of planets into the distant future, determine whether or not an untested chemical reaction will occur, or plan a diet to lose precisely ten pounds.

1. The originators of the energy concept included Rumford, Mayer, and Joule, all of whom advanced the idea that heat is a form of energy. Rudolf Clausius presented the modern version of the law of conservation of energy while he examined the efficiency of steam engines.

   As modern theories of quantum physics and relativity developed, new forms of energy were found. Nuclear energy and the energy vested in matter were described by Einstein's famous expression, $E=mc^2$. Light and its invisible cousins, x-rays, ultraviolet light, infrared rays, radar, microwaves, and radio, were all found to be pure energy forms and part of the conservation law.

   Our clearest idea of the role of energy came more recently. Emily Noether proved that energy must be conserved for events that unfold in a way that does not depend on the time the event started. Noether's theorem showed that time and energy are linked.

2. Energy is a premier concept in every branch of science while technology can be viewed as the practical harnessing and transforming of energy. The control of mechanical and electrical energy drove profound societal changes in the industrial revolution. Medical advances like x-rays, NMR's, ultrasound, and laser surgery are among the many uses of energy physics. Now the manipulation of molecular and radiant energy places us in the midst of a technological revolution driven by computers and communications.

3. One of the most challenging global problems today is the degradation of the environment, especially pertaining to the "greenhouse effect" where our reliance on energy threatens our climate and food sources. Excessive use of non-renewable fuels releases gas into the atmosphere that acts like a blanket to keep heat from escaping from the earth. In large part, the physics of energy is responsible for this. Most likely, it will require advances in energy physics to alleviate the danger.

C. ENVIRONMENTAL SCIENCES

The environment of planet Earth is the primary focus of inquiry in the group of sciences referred to as Environmental Sciences. Today we are only just beginning to understand the Earth as a whole an especially how human systems interact with natural systems.

Environmental science relies heavily on many sub-disciplines of the other sciences and attempts to apply that knowledge and those methods to the questions about the Earth. These include basic sciences like Ecology and Chemistry and also sub-disciplines like geomorphology and hydrology. There is also a substantial contribution from the social sciences particularly from geography, anthropology, economics and political science. There is also an important ethical dimension that may involve philosophical and moral issues.

Our understanding of "environment" has changed markedly over the last 30 years. Two of the most critical relationships to be understood by the beginning science student would be:

1. The environment of planet Earth is a highly organized system of living and non-living components. Environmental Science seeks to understand these components and how they interact with one another and especially how human systems may affect their form and function.

2. No single science or discipline is sufficient unto itself to yield a comprehensive view of the "environment". It is only through the application of knowledge and understandings acquired in many fields
that a holistic understanding of the Earth becomes possible.

Outline:

1. Presentation of the basic tenets and principles of Environmental Science

2. The major components and how we strive to achieve a systems view of the Earth environment:
   our understand of the lithosphere - landforms, soils, and processes
   our understanding of the hydrosphere-the oceans and hydrological systems
   our understandings of the atmosphere -its structure, chemistry and processes
   our understanding of energy flows within the Earth planetary system
   our understanding of the biosphere - the significance of life on Earth

3. The commanding role of humans and human systems in the evolution of the Earth

4. A look at the some of the major 21st century issues within Environmental Science

The focal issue of Scientific Inquiry - an Environmental Science Approach will be current aspects of Global Environmental Change:

1. Introduction to Earth System Science and Global Environmental Change
   a. Historical framework and the nature of environmental problems
      differences in scale - local vs. regional vs. Global
      late 20th century recognition of the nature of global change
   b. Brief functional tour of Earth systems and their key interactions
      land and soils
      hydrosphere and oceans
      atmosphere and climate
      ecological systems
      Global scale cycles

2. Development of modern scientific thinking about Global Change
   a. Changes to the Earth's surface
      terrestrial vegetation
      soils and erosion
   b. Changes to hydrological systems
      global water budgets
      coastal and oceanic systems

c. Changes within the atmosphere
    seasonality and weather events
    acid deposition and photochemical smog
    ozone depletion
    global climate change

3. Relation of Science to Society
    a. Scientific Uncertainties about the future of Global Change
    b. The need for an interdisciplinary scientific approach
    c. Efforts to build a more sustainable society and changes that must come about to achieve this end

D. EVOLUTION

1. Origin: First intimations of the concept in classical and biblical literature; growing recognition of changes in the planet; Linnaeus' efforts to classify animals and the recognition of variation; early interpretation of the significance of fossils.
2. Derived from ideas originated by his grandfather, Erasmus Darwin
    a. Recognition of the meaning of geological time: geologists' observations of erosion and sedimentation; recognition of ice ages; Darwin's observation of an earthquake in Chile coupled with his calculations of the age of the Andes; Lord Kelvin's calculation of the cooling of the earth; role of Malthus; Darwin's observation of the Galapagos Islands; How Wallace came to the same conclusion.
    b. Today's society, or why *Origin of the Species* is so boring: Darwin felt that he had to convince a skeptical audience with numerous examples, while a modern reader is satisfied with a few. It attests to the pervasiveness of the idea of evolution today.
3. Development of the theory of evolution from 1860 to 2000, including: rediscovery of the laws of Mendel, convergence of information leading to the same conclusion (radiocarbon and other dating, biochemical and molecular documentation of relationships, evolution, and times, mitochondrial DNA); experimental evidence for evolution (pepper moths); the dinosaur extinction hypothesis (iridium anomaly, Yucatan comet); the difference between questions of mechanisms and acceptance of the overall concept.
4. Major modification cam with the work of R.A. Fisher who synthesized the work of Darwin and the emerging school of Mendelian genetics into a coherent "genetical theory of natural selection." Modern "neodarwinists" still trace their intellectual roots to Darwin through Fisher.
5. Controversies (still raging), including conflicts with religious/creationist ideologies. Established through rancorous debate among scientists, philosophers, theologians. Universally accepted by Western science; still challenged by some theologians. What constitutes acceptable proof. *i.e.*, what is the validity of an observation by the senses; a logical and predictive experiment; the weight of evidence and independent confirmation; the words of scripture; interpretations of the words of scripture.
6. How scientists work: Definition of problems, design of experiments to answer questions. "The most difficult task of a scientist is to answer a question in such a way that it can be tested."

7. Social impact of evolution as already seen: the rise of the eugenics movement and its influence on immigration policies, nazi theory, the conflict between Lamarckian theory and modern genetics in Russia, etc.
8. Social impact of evolution today: To what extent should manipulation of genes be tolerated? What are the evolutionary implications of transgenic engineering and gene therapy? More generally, principles of evolution can be applied to any process involving information replication/transfer, including nonbiological problems such as software design.

E. GEOSCIENCES

Planet Earth is the primary focus of inquiry in the geosciences. Today we are only just beginning to understand the geology of other worlds and extending our knowledge of this planet by comparing it to other bodies in the Universe.

The geosciences include many sub-disciplines that depend on knowledge and methods from other sciences applied to the questions about the Earth. These may be divided into subjects like geophysics, geochemistry, paleontology and many more.

Our understanding of the planet has changed over the last 200 years and especially during the late 20th century. The way geoscientists see the Earth is based upon two interactive and interrelated ideas (paradigms).

> 1. The surface of the Earth is a remarkably dynamic surface. The Earth is always changing and evolving because of active processes working both within and outside the planet. Much of our modern thinking about the dynamic Earth is based in the unifying theory called "plate tectonics"
>
> 2. The history of the Earth and especially of the history of Life on Earth occurs over exceeding long periods referred to as geological time.
> The dating of Earth events (geochronology) and all of our inquiries into Earth history can only be understood within the context of geological change and evolution.

Outline:

1. Geological Thinking prior to the 20th century.
   a. Classical views. The age and permanency of the Earth
   b. A challenging idea: Wegener's hypothesis of continental drift

2. Changing views of the Earth as a dynamic system -new sources of evidence
   a. Evidence from geochronology
   b. Evidence from geophysics
   c. Evidence from the ocean floor
   d. Evidence from the fossil record
   e. Evidence from the rocks

f. Formulation of a new view of Earth

3. The rise of Plate Tectonic theory as one of the unifying idea in the Earth Sciences
   a. How plate tectonic theory helps explain the world we see
   b. What plate tectonics has yet to answer

4. The many roles of geoscientists in the 21st century.

The focus of Science Inquiry a Geoscience Approach is an analysis of the twin theoretical underpinning of the geological sciences specifically our understanding of the Earth as a dynamic system and the concept of geological time:

1. Wegener's early hypothesis of Continental Drift
   a. Converging lines of geological evidence
   b. The reaction of the scientific establishment

2. Historical development (1950-1970) of plate tectonic theory and the dynamic nature of the Earth
   a. New evidence from the sea floor
   b. Seismic evidence
   c. Evidence from geochronology
   d. Emergence of the new theory of plate tectonics.
   e. How plate tectonic theory has revolutionized our approach to Earth Science

3. Our evolving understanding of the concept of geological time
   a. Early estimates of the age of the Earth and key Earth history events
   b. Evidence from the rock record
   c. Fossils and the sequential history of life on Earth
   d. Absolute vs. Relative time scales
   e. The techniques of modern geochronology and estimates of event ages

4. The Roles of Geoscientists in the 21st Century
   a. Resource supply and protection
   b. Natural hazard risk assessment
   c. Comparative planetology
   d. Public policy roles

F. QUANTUM MECHANICS

Modern students are often familiar with Dalton's Atomic Theory. This theory led, 100 years later to the essentials of quantum mechanics. This course is designed for the student with more than a passing interest in science who wishes to delve further into modern Physics and Chemistry Theory.

1. Preliminaries:
    a. Alchemy
    b. Atomic Theory
    c. Subatomic Particles

2. Precepts of Quantum Mechanics
    a. The Bohr Atom
    b. Wave Equations
    c. Heisenberg's Uncertainty Principle

3. Results of the theory
    a. Nuclear Physics
    b. Molecular Modeling
    c. Understanding Cosmology

VI. Regulations

The conventional 120 hours of work associated with meeting the New York State standards required of the three-credit undergraduate course is met by in-class work, outside reading, study, and other assignments as outlined in part IV.

VII Select Bibliography

General

American Association for the Advancement of Science. (1990). *The Liberal Art of Science: Agenda for Action*. Washington, DC: AAAS.

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Conant, James. (1947). *On Understanding Science*. New Haven, CT: Yale University Press.

Cromer, Alan. (1993). *Uncommon Sense: The Heretical Nature of Science*. New York: Oxford University Press.

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Wilson, Edward O. (1998). *Consilience: The Unity of Knowledge*. New York: Knopf.

Brooklyn College has a science education Web site with links to many relevant resources: http://academic.brooklyn.cuny.edu/education/miele/ScienceEducation.htm

WWW Virtual Library for the History of Science, Technology & Medicine: http://www.asap.unimelb.edu.au/hstm/hstm_ove.htm

Biology

Browne, E. Janet. (1995). *Charles Darwin: A Biography*. New York: Knopf.

Dawkins, Richard. (1999). *The Extended Phenotype: The Long Reach of the Gene*. New York: Oxford University Press.

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The Access Excellence is a site with many resources for life sciences education: http://www.accessexcellence.com

The BioQUEST Curriculum Consortium Web page has information on computer simulations and on case-based learning in biology: http://www.bioquest.org

The Tree of Life homepage is a rich source of information on organisms: http://ag.arizona.edu/tree/phylogeny.html

http://www.talkorigins.org. Several nice pages, including history of evolution theory, the seven main hypotheses of the theory of evolution, etc.

http://www.harvard-magazine.com/issues/so98/darwin.html. "A wrangle over Darwin". An excellent summary of the controversy in the correspondence between Darwin and Asa Gray, a botanist who was one of his main supporters in the US, and Louis Agassiz, who first brought the attention of the world to the concept of glacial eras but who rejected the idea of evolution.

http://bob.nap.edu/readingroom/books/creationism/index.html. The National Academy of Sciences weighs in on the issue of science and creationism. A good summary of the consensus of scientists about the subject and the evidence supporting the concept of evolution. Also available as a book: *Science and Creationism*, available through the Web site (http://www.nap.edu/catalog/5787.html). The site also offers an extensive reading list (http://bob.nap.edu/readingroom/books/creationism/readings.html).

Chemistry

Dalton, John. (1960). *A New System of Chemical Philosophy*. London: Dawson (facsimile of 1808 edition).

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Videotape: *Creation of the University*. A1238. Public Broadcasting Service.

Videotape: *Life Beyond Earth*. A3787. Public Broadcasting Service.

Videotape: *Mysteries of Deep Space*. A2481. Public Broadcasting Service.

Videotape: *Stephen Hawking's Universe*. A2769. Public Broadcasting Service.

Atomic Models, http://web.jjay.cuny.edu/~acarpi/NSC/indes.htm

Avogadro's Hypothesis, http://maple.lemoyne.edu/~giunta/avogadro.html

Chemist's Art Gallery provides many images of atoms and molecules: http://www.csc.fi/lul/chem/graphics.html

Classic Chemistry, http://maple.lemoyne.edu/~giunta/index.html

Dalton's Atomic Theory, http://antoine.fsu.umd.edu/chem/senese/101/atoms/dalton.shtml

Dalton's Original Paper, http://maple.lemoyne.edu/~giunta/dalton.html

Physics

Arons, Arnold, & Bork, Alfred (Ed.). (1964). *Science and Ideas*. Englewood Cliffs, NJ: Prentice-Hall.

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Pagels, Heinz. (1982). *The Cosmic Code: Quantum Physics as the Language of Nature*. New York: Bantam.

Science and Ideas, Arons, Arnold B. & Alfred M. Bork ed., Prentice-Hall 1964
Highly regarded collection of enlightening essays.

http://www.emmynoether.com, a Web site describing the work of Emmy Noether, who developed the current view of energy and its conservation.