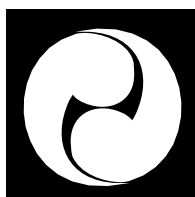


Syllabus - Geology 200

<http://www.jmu.edu/geology/evolutionarysystems/>

EVOLUTIONARY SYSTEMS

Spring, 2010



CLASS NUMBER:	21287; Section 0001	
CREDIT HOURS:	04	
LECTURE:	Memorial, Room 7320, MW 12:20 -2:15; F 12:20-1:10	
LAB:	<i>(Lab/lecture sessions are irregularly scheduled; we go to lab when it is time for lab, and return to class when it is time for class)</i>	
INSTRUCTORS:	Lynn S. Fichter	
OFFICE:	Memorial, Rm 7100 E	
OFFICE PHONE:	568-6531	
E-MAIL:	Fichtels@jmu.edu	
OFFICE HOURS:	MW 8-9; T/Th 8-10	
FINAL EXAM:	Friday, May 7, 8:00 - 10:00	
TEXTS:	Notebook of Lecture Illustrations (JMU Copy Center) Notebook of Laboratory Experiments (JMU Copy Center) The Death and Life of Great American Cities by Jane Jacobs: 458 pages; Publisher: Vintage Books; ISBN: 067974195X Nonzero: The Logic of Human Destiny by Robert Wright: 435 pages; her: Vintage Books; ISBN: 0679758941	

THERE ARE THINGS ABOUT THE UNIVERSE WE DON'T UNDERSTAND

"Life is often complicated, sometimes exceedingly so. Much of our everyday experience is unexpected, apparently whimsical, seemingly beyond our control. On the other hand, we also commonly take for granted the long-term, reliable functioning of refrigerators, computers, and communication satellites. How is it that some aspects of our experience are regular, predictable, tamable, while others appear to be the outcomes of some cosmic game of chance? Is the universe a crazy patchwork of phenomena, some understandable, some beyond explanation?"¹

Most of intellectual and scientific history are attempts to bring order and predictability to a world seen as chaotic and ungovernable, even frightening or horrifying. Ancient myths and epic poems are explorations of how a hero can overcome the dark forces of chaos. Socrates tried to escape the chaos by creating a world of absolute equality, beauty, goodness, justice, and holiness. Plato's solution was his theory of ideal forms—forms that existed as an absolute and eternal reality, relegating the natural world to a transitory and imperfect poor copy. Thomas Aquinas required a logical and certain proof of God. Descartes and Newton tried to hold the universe together with mathematical and logical purity. And Einstein stated that God does not play dice with the universe.

Humans have always struggled to make sense of this sometime capricious universe, but for most of history we have been stunningly unable to do it. Even today there are powerful urges to keep the world from flying apart. Fundamentalist religion and absolutist regimes (whether political, or intellectual) with their rigid rules and intolerance for dissent are attempts to restrain what the believers experience as chaos.

Yet, throughout history the evidence all around is that the world is not under our control, and that security and predictability are an illusion. Exhibit some mundane examples, our attempts to predict the weather and the stock market. Even with powerful computers and sophisticated intellectual tools these systems, one natural and one human, continue to defy our attempts to reign them in—and sometimes they just bite us in the butt.

Or, imagine a large city, like New York, or London, or Paris: millions of customers, tens of thousands of merchants, thousands of suppliers, all working more or less independently, each looking after their own selfish interests. The suppliers and merchants just want to make as much money as they can, as fast as they can. And the customers just want to buy what they want to buy when they want it, at the lowest price possible. And they can! The shelves are always full, and the prices are always low. Instead of the chaos we might expect, it all just seems to work smoothly. But how? Who is in charge? Who has organized this marvelous system?

The not so simple answer is, No One!

The truth is, until recently we have not had the means to explore and understand the world in all its complex and chaotic behavior. The sheer number-crunching necessary was not available until the advent of computers. But clearly there is also a powerful psychological force working here. Fear of the unknown makes us feel weak and vulnerable, out of control, careening down a dark passage to oblivion.

Yes, the world is chaotic, but not as we once understood the term (*utter disorder and confusion*). And yes, the really interesting phenomena in this world (cities, economies, political systems, brains) are inherently unpredictable. But, where we used to think this chaos and unpredictability hovered precariously on the edge of dissolution and decay, we now understand that it instead lies as much if not more on the edge of creativity and wonder, of beauty. The purpose of this course is to explore this new, and relatively recent view, to come to understand those things we don't understand.

¹ Chaos Under Control, 1994, The Art and Science of Complexity by David Peak, Michael Frame, Rhonda Roland Shearer, Benoit B. Mandelbrot: 408 pages, W H Freeman & Co.; ISBN: 0716724294 quote on p 1

WHAT IS/ARE EVOLUTIONARY SYSTEMS ALL ABOUT?

Catalog Description

An investigation of the theoretical principle behind evolutionary systems of all types based on mathematical modeling in chaos, complexity theory and artificial life studies with extensive computer experimentation and examples drawn from physical, chemical, biological, economic and social systems. The purpose is to explore what is common and universal to all evolutionary processes.

Nature of the Subject

In seeming defiance of the 2nd law of thermodynamics (everything is decaying, going to the lowest energy state; a disordered gooey mess) our world is not decaying to disorder. Quite the contrary. It continues to increase in complexity, diversity, order, and/or interconnectedness with time—that is, it is evolving. This fact seems to defy everything about the universe that classical science (the science all of you have been taught) teaches us. How to resolve this contradiction is the central question of this course. But, think about it, virtually every system we see in the world around us—technological, social, the world wide web, the economy, etc.—is evolving to greater complexity.

Unlike most other sciences which can trace their history back hundreds or thousands of years, chaos/complex systems theory is only about 50 years old. The phenomena that are now included in this subject have been evolving independently, piecemeal, and ever more rapidly in a wide diversity of disciplines: mathematics, physics, chemistry, biology, economics, etc. Historically, the concepts or principles were often developed simultaneously by individuals in different disciplines, who saw them as a curiosity, without being aware of parallel work in other disciplines, and thereby giving the phenomena a different name. Today concepts in complex systems theory still tend to be diffuse, scattered in many disciplines and a wide diversity of literature sources, with a confusing vocabulary.

In this class we will develop chaos and complex systems theories in a deliberate and systematic progression that makes everything fit together in a seemingly natural and logical manner. But, this is not how the science developed. The chart on the next page illustrates the historical complexity and rapidity of the development of the discipline. Take a moment to peruse the chart. Most of the concepts on that chart will show up in one form or another this semester.

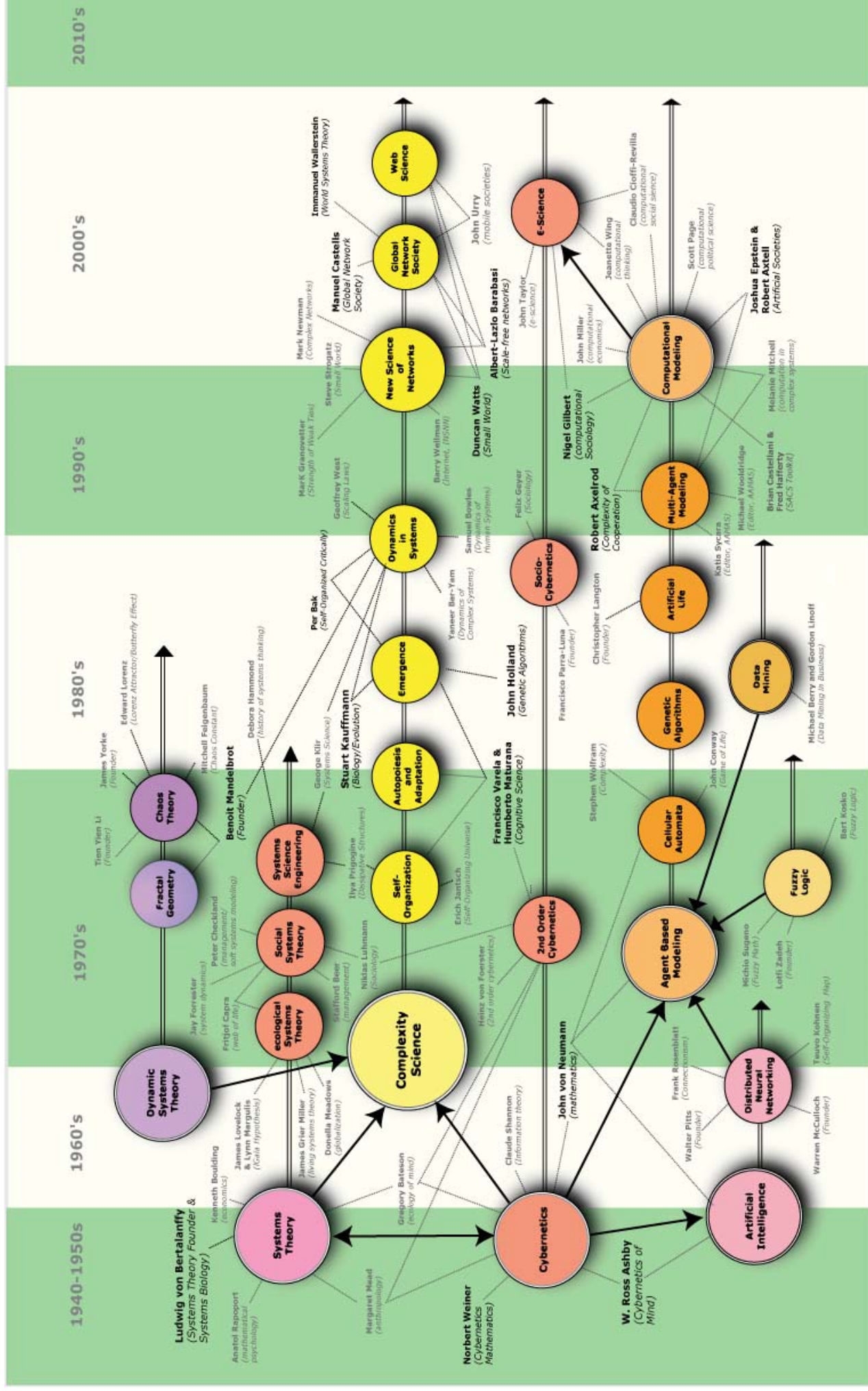
SEMESTER ORGANIZATION

First Half of Semester

Chaos theory studies why and how the behavior of simple systems—simple algorithms—becomes more complex and unpredictable as the energy/information the system dissipates increases. Complex systems theory (or simply complexity theory) studies how systems with many "agents" that are already at high energy/information dissipation—such as ants, or cars, or businesses in an economy—interact and behave. Chaos and complex systems theories lead then to artificial life, modeling how "living" systems behave.

Chaos/complex systems have their own set of assumptions, approaches, cognitive tools, and models that are different from those normally taught in science and mathematics class rooms. The first half of the semester is about becoming familiar with these 19 properties listed below. The first two tests are about these ideas.

History of Chaos and Complex Systems Theories and Related Disciplines



Chaos Theory

1. Computational viewpoint
2. Positive & Negative Feedback
3. “r” values - rate of growth
4. Bifurcation
5. Sensitive Dependence
6. Self Similarity
7. Attractors

Complex Systems Theory

8. Avalanche Behavior
9. Power Law Distributions
10. 1/f Noise
11. Fractals

Artificial Life

12. Universal Computers
13. Local Rules/Global Behavior
14. Self Organization
15. Emergence
16. Flocking Behavior
17. Natural Selection
18. Red Queen Effect
19. Artificial Ecosystems
 - Complex Adaptive Agents
 - Adaptive Landscapes
 - Selecting Agents

Second Half of Semester

The second half of the semester applies the concepts and principles from the first half to a variety of evolutionary systems. We want to explore as many systems as possible, including:

1. Biological evolution through the lens of complex systems and artificial life.
2. Swarm behavior and swarm intelligence from ants to humans.
3. Game theory—the prisoner’s dilemma—and the best strategies in both interpersonal as well as international relations.
4. Economic and social systems.
5. The evolution of culture and the question of progress in evolution and human civilization.

Along the way we will add other principles such as hysteresis and bistable behavior on the one hand (including patterns of crime and marriage, and their social/political implications), and ethical and moral issues on the other hand.

THE STRATEGIES OF EVOLUTIONARY SYSTEMS

Our study of Evolutionary Systems seeks to explain how all complex systems—such as economies, social systems, political systems, atmospheric systems, chemical systems, biological systems—organize, grow, and evolve by bottom-up processes; that is, without central planning or control.

The experimental methods include mathematical modeling in a wide range of computer and real world systems. All of these are based on the computational viewpoint which argues that the behavior and evolution of complex systems cannot be deduced from first principles—deductively derived from a set of premises—but must be empirically discovered by watching systems evolve in real time—the computer models.

The heart of the course, and the heart of our strategy, is the logistic system— $X_{\text{next}} = rX(1-X)$ —a simple population model first published by Pierre François Verhulst in 1838, and popularized by Robert May in 1976, and serving as one definition of chaos. This deceptively simple equation exhibits the most amazing and wonderful behavior. We will spend about two weeks exploring it.

But, we believe it is important you *not just be told*—lectured to about—how these systems behave. Rather you need to experience them for yourself by experimenting with and experiencing them in the lab—what is called **bottom-up** learning. Thus, the semester starts off by us all marching into the lab, without preconceived notions, to run experiments and observe the behaviors.

Each experiment is then followed by seminar and/or lecture where we explore what we have observed, and what it all might mean, and logically turn it into theory—**top-down** knowledge. With the principles we have learned in mind we then move onto the next experiment, experiencing it bottom-up, followed by debate and discussion to turn it into top-down theory.

COURSE PROCEDURES

The course is an interplay of three activities. **First**, lectures that introduce ideas and present their theoretical frameworks. **Second**, computer modeling of various kinds of systems, exploring how they behave, and the implications of that behavior. **Third**, Socratic seminars focusing on the results of the models, or readings concerning environmental questions and issues. We will fluidly move back and forth among these.

Some of the issues we explore are philosophically deep, tend to be religiously and/or politically controversial, and yet have everything to do with how civilizations rise and fall. We explore these ideas through readings and Socratic seminars.

What is a Socratic Seminar?

The purpose of a Socratic seminar is to discuss some work we have all read or examined. A seminar is not for the professors to tell you anything; that is what lectures are for. In a seminar the job of the seminar leader is only to ask question after question after question—until all ideas have been expressed, and all controversies brought to the surface, and perhaps resolved.

What questions do we ask? First, what is the author saying. Not what we think they are saying. Or want then to say. But what they *are* saying. Then, second, we ask questions about the meaning and implications of the author's ideas; how these ideas relate to other ideas we are exploring. Finally, we explore what we think and feel about those ideas. More specific instructions are provided with the first seminar.

TEXTS

There are four texts for the course, listed on the front page. The first two come from the JMU Copy Center and are available in the bookstore (see note below on availability). The second two are for two of the Socratic seminars conducted in the second half of the semester.

Each subject we examine this semester in Evolutionary Systems is an enormous subject all its own with entire books, or college courses devoted to it. In some areas you can even get a degree studying it. Plus, these higher degrees are spread across the disciplines: math, economics, biology, etc.

Hundreds of books and articles have been written dealing with the subjects of chaos theory, complexity theory and evolutionary systems, including both general explorations and highly technical treatises. We have read and incorporated in this course ideas from many of these books, but none of them by themselves make a good textbook. All of the books either explore a subject in more detail than we have time for, or they do not begin to explore the breadth of the subject matter we have in mind. During the semester we recommend many books to you as good explorations of some deeper aspect of what we are studying, but if you were to buy every book worth reading to understand evolutionary systems you would purchase a small library.

- ✧ Lecture and Lab Book Availability: The JMU Copy Center has a policy of not initially producing enough notebooks for every student in the class. Or, as they said in a recent e-mail:

“We have produced your coursepack. You requested 20 copies each, however we always produce a percentage on the first printing. We produced 16 copies each based on the enrollment on e-campus. We will review the e-campus totals before the semester starts.

“If your student goes to the bookstore and they are out, here is what they need to do. They will request that course, pay for it. The next morning the bookstore will fax us the request as a 24 hour. We have it in the bookstore by that evening.”

- ✧ Seminar Book Availability: Although we will not read Jacob's and Wright's books until the second half of the semester, get them now. About half way through the semester the book store returns to the publisher any books not bought.

LECTURE/LAB POWER POINTS

S:/Geol200Evolutionary Systems

Copies of all the power points used in the course are available on the S: drive on the Geology/Environmental Science server. This server is accessible from any computer in the department computer labs, or from any computer in any of the geology class rooms. If you are not familiar with the S:\ drive go check it out. It is a drive where you can create a folder of your own, and store files associated with geology courses and projects.

All the Geol 200 lecture/lab power points will be placed there so you can review lectures, and study for tests. I try to have copies of the power points available before the class we talk about them, but I also often revise lectures right up until I walk into class, so they may show up later.

Feel free to bring a memory stick and download any of these files and put them on your own computer for studying. Most of the computer programs are also available to put on your personal computer.

EVOLUTIONARY SYSTEMS REQUIREMENTS, EXAMS AND GRADING

GRADING:

There are three lecture exams, the third being the final. Grading is based upon the following schedule. Because this course is actively developing the system below may change, but any changes will be discussed with the class and decided by majority vote.

- | | |
|---|-------------|
| 1. 1 st Midterm: Principles of Chaos Theory (scantron; about 5-6 weeks in) | 25 % |
| 2. 2 nd Midterm: Principles of Complexity Theory (scantron; about 11 weeks in) | 30 % |
| 3. Final: Evolutionary Systems (essay; questions provided ahead of time) | 35 % |
| 4. Self Evaluation | <u>10 %</u> |
| | 100% |

MIDTERMS: The midterms evaluate your understanding of basic concepts in chaos and complexity theory. They are computer graded and consists of multiple choice and True/False questions dealing with understanding of definitions, concepts, and the great variety of charts, diagrams, and graphs used to illustrate or demonstrate these phenomena. Also 1 or 2 short essay questions. A study guide is provided to prepare for the tests.

FINAL: The final deals with the application of chaos/complexity principles to evolutionary systems - such as biological evolution, economic systems, social systems, game theory, etc. It will be essay in format. A study guide is provided.

FINAL GRADES - Final grades are based on the percent scale, with plus and minus grades distributed as follows:

94-100 = A	87- 89 = B+	77- 79 = C+	67-69 = D+
90- 93 = A -	84- 86 = B	74- 76 = C	60-66 = D
	80- 83 = B -	70- 73 = C -	NO D- GRADES EXIST

SELF EVALUATION: Evolutionary Systems is about thinking scientifically about complex systems that are unpredictable, and defy simple explanation. For example, what *is* Adam Smith's *Invisible Hand of Commerce*.

So, there are two problems here, (1) thinking about complex systems, and (2) thinking about how well we are able to think about complex systems.

Good thinking is thinking that (effectively) assesses itself. As a critical thinker, one does not simply state a problem; s(he) assesses the clarity of his/her own understanding of the problem. Information is

not simply gathered; it is checked for its relevance and significance. Interpretations are not simply formed; they are checked to make sure they have adequate support.

Therefore, 10% of your final grade is a self-evaluation of how well you have learned and been able to grapple with your own mind grappling with the struggle to understand evolutionary systems. This self-assessed grade will not be questioned by the faculty of the class, it will be taken as a matter of fact. You will, however, have to provide the reasoning and criteria you used to decide that 10%.

Since self-assessment may be an unfamiliar task, through the semester you will have opportunities to do small self-assessments as part of the writing assignments. And, of course, to do a self-assessment you must have some criteria to base your assessment on. We use a couple of self-evaluation criteria which we introduce at appropriate times during the semester.

The Responsibility of Grading Yourself

Asking you to evaluate a portion of your own grade clearly puts a lot of responsibility on you. One of the skills we ask you to practice this semester is the ability to honestly assess your own thinking ability; to bring your internal standards in line with the best of external standards. It is a responsibility that can be abused by dishonestly representing your effort in this class. Typically, the honesty issue is addressed with quotes from Honor Codes (see, for example JMU's code at <http://www.jmu.edu/honor/code.html>). However we believe that honor codes are only as good as the integrity of the people working under them; i.e. if people have integrity they don't need honor codes; if they don't have integrity they will follow the code only when it suits them.

The issue at hand is much deeper because what we are after is the search for true knowledge of the world; not what we wish it to be, or need it to be, or have been told it is, but what it really is. Dishonesty is very detrimental to this discovery. Not only does it lead us down wrong paths, but actions taken on the basis of false knowledge can have serious consequences.

Besides, good ideas are hard enough to discover when struggling honestly. Dishonesty in science and other disciplines, when discovered, destroys a career, and ruins a reputation. And, because the goal of research is not so much to discover Truth (capital T), philosophically impossible anyway, but to discover what is not true (whatever *is* true, this is not), dishonest is always uncovered eventually.

Or, to take a quote from Sir Walter Scott's "Lay of the Last Minstrel":

"Oh what a tangled web we weave, when first we practice to deceive."

On the other hand, self-deception, or the inability to know when we are being deceptive, may be more damaging than deliberate deception, just because we have no real idea who we are, or what we know, or how to act.

"Love of the Truth puts you on the spot."

But, trust and respect are cornerstones in the development and acquisition of wisdom. And just as we hope you will trust us to be honest in our presentation of material in this class and will respect us as faculty, we will simply assume that you will be honest in all matters related to this class, and respect your self-assessment used to determine 10% of your grade.

STUDYING AND GETTING THROUGH THE COURSE PAINLESSLY AND DOING WELL

The ideas we develop are often quite simple—but not simplistic. Many of the models are logical, and their implications almost intuitive. On the other hand, these simple models and ideas feed into, and support, and build on each other in ways of increasing subtlety and complexity. Many of these ideas and models even though empirically straight forward, almost defy deterministic analysis—like how a bunch of non-intelligent ants, without any plans, guidance, or leadership can build a complex colony.

We develop all our ideas logically and systematically, and try to make sure you each understand them at each step. But, slowly, creepingly, imperceptibly, the ideas accumulate and build, and this is where you will be most challenged. It can sneak up on you, and pass you by before you even are aware of it, and then you will have to scramble to make sense of the ideas and their complexity that is beginning to dawn on you. We can help, we can get you through it, but you must be enough aware and in touch with the ideas fermenting in your own mind that you can catch yourself when you see it beginning to happen—and stop us to question us, probe your own growing but yet incomplete awareness—and learn some of the most fascinating ideas you will encounter. Some strategies to get through.

1. **Power Point Presentations:** Most of the course is on Power Point presentations. You may have these files to take to your own computer. The files are available on the class room computer or in the geology computer labs; bring a memory stick. Go to S:\GEOL200-EnvironmentalSystems. These files tend to be large and in the past some have not been able to down load them. Ask if you have problems.
2. **Use the Power Points as study guides.** When we make up a test we go through the power points slide by slide, reminding ourselves what we discussed and emphasized, and compose questions from that. My tests follow the order and logic of the power points almost exactly. There is a story and logic to everything we study, and if you get in the rhythm of the stories and logic it will all flow more smoothly.
3. **Take good notes.** Because there is no formal text, good note taking is important. It is very hard to miss classes and get through the class well. Find a good partner whose academic abilities you trust to exchange notes with if you do have to miss class.
4. **Create a Study group.** Perhaps the most efficacious thing you can do. Find 1, or 2, or 3 people to study with. Go through the power points together, and talk about the logic of the ideas as they develop. Try to explain to each other what you know; saying it out loud sets it in your mind, and if you misunderstand something your partners will quickly correct it so you do not learn it wrong.