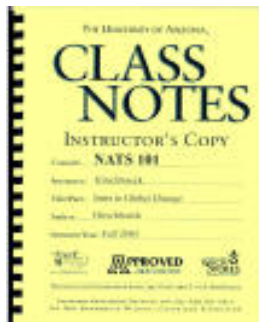
Topic #2:
ON SCIENCE & BEING A SCIENTIST

The CLASS NOTES packet is available NOW in the ASUA Bookstore

(NOTE: if they run out, you'll need to order one for yourself through the bookstore)



HINT: To find the page in the CLASS NOTES packet that corresponds with different parts of my lecture presentations, look for the box on each slide

What scientific methods do Global Change scientists use?????

Experiments?

- **Changing Earth is one unrepeatable "experiment"**
- **Can run controlled experiments on isolated parts of system, but can all the components of the system be part of an experiment?**
- **Computer models are the closest we come to running global change experiments**

Observations?

- **How to observe whole Earth? – remote sensing one important tool**
- **How to observe changing Earth over time? – paleoclimatic indicators, "natural archives" (ice cores, tree rings, etc.) are one way; combined with modeling of past environments**

➢ **ALSO: Standard "tools" of science: Hypotheses, prediction, testing, theories, and "laws of nature" all enter in.**

THE PERSONAL SIDE OF BEING A SCIENTIST . . .

Passionate Interest & Curiosity

Dedicated Work Effort

e.g. Field Work!

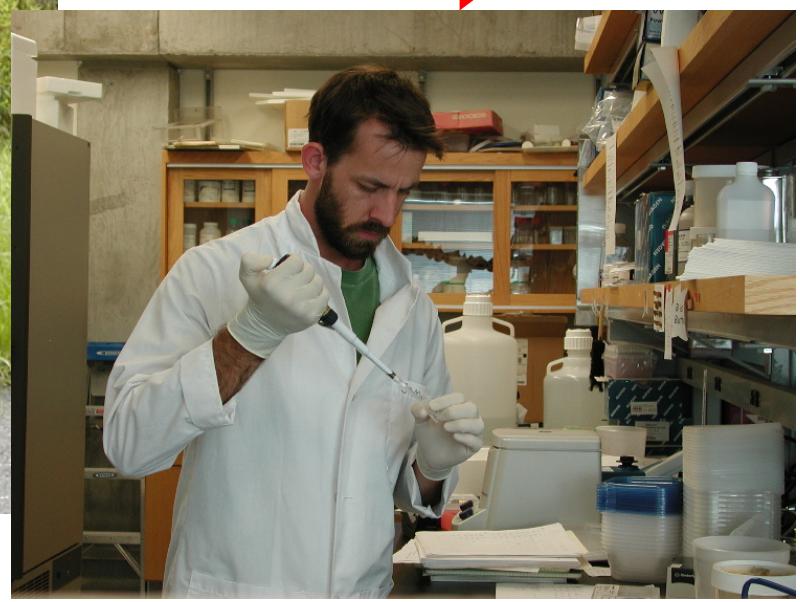
Ela up to her knees in her streamflow research in Poland!

Dedicated Work Effort

Jeff tracking the subject of his dissertation: butterflies!

. . .more Field Work!

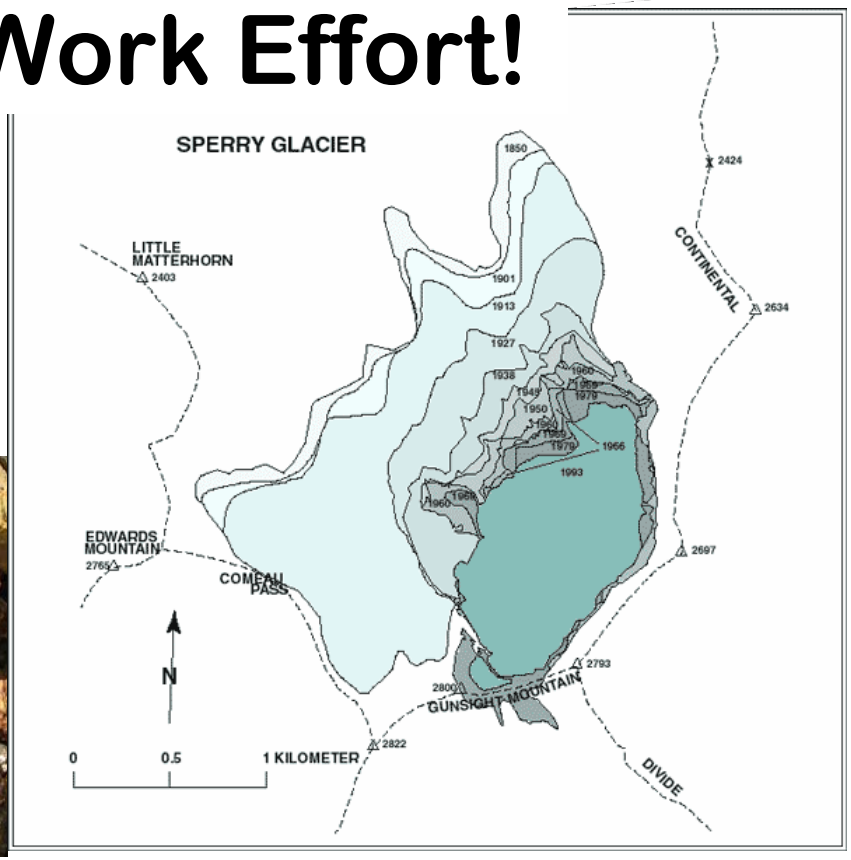
. . . and in the Lab doing analysis



Sperry Glacier, Glacier National Park, Montana 2006

Dedicated Work Effort!

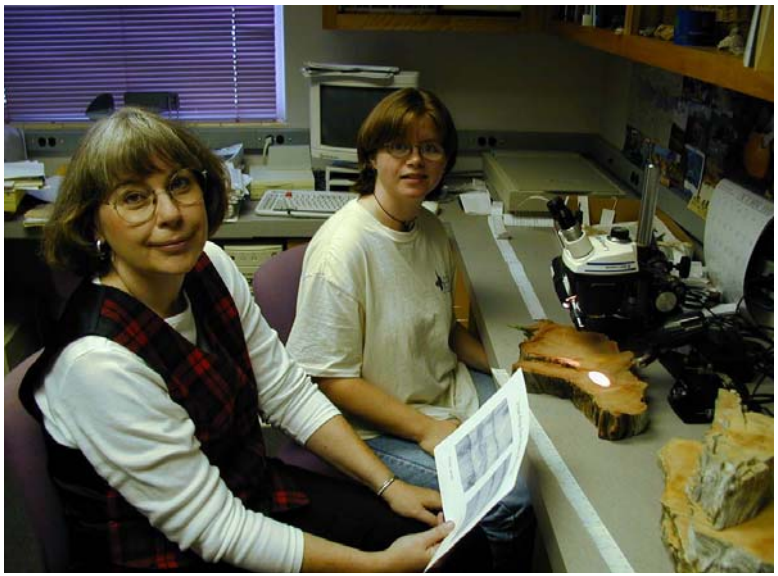
Rebecca



Dedicated Work Effort!

Adam immersed in field work

Analysis, Collaboration, Discovery: Dr H's Lab



Wonder, Awe, & Contemplation of Nature

Persistence, persistence, persistence . . .

ON SCIENTIFIC METHOD (s?) & the Nature of Scientific Research

Is there “a” scientific method?

Many scientists regard such blanket descriptions of what they do with suspicion.

Rather than following a single scientific method, scientists use a *body of methods* particular to their work.

Traditional outline of "the" scientific method:

a. **OBSERVATION**

b. **HYPOTHESIS**

c. **PREDICTION**

d. **TESTING**

a. OBSERVATION (vs. Experiment):

Observation -- observe nature without manipulating it

Experiments -- manipulate some aspect of nature and observe the outcome

Then identify **patterns** and **regularities** in one's observational and experimental results.

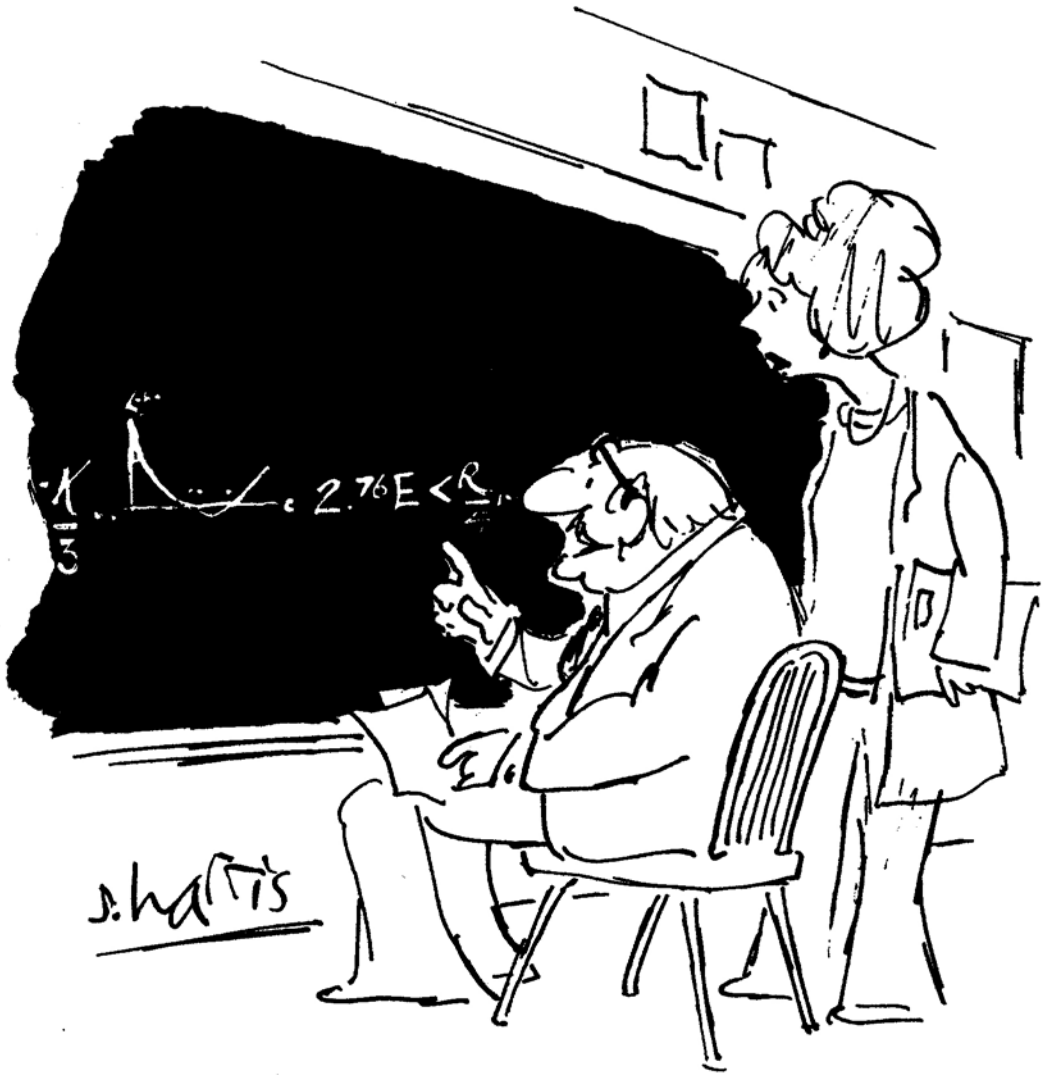
b. HYPOTHESIS

Form a **HYPOTHESIS**

-- a “tentative guess” about how the world works
-- often several hypotheses are formed at once
"multiple working hypotheses"
(scientists want to avoid "ruling hypothesis")

THEORY -- refers to a description of the world that covers relatively large numbers of phenomena and has met observational and experimental tests.

Not all theories are useful!!



"THE BEAUTY OF THIS IS THAT IT IS ONLY OF THEORETICAL IMPORTANCE, AND THERE IS NO WAY IT CAN BE OF ANY PRACTICAL USE WHATSOEVER."

c. & d. PREDICTION AND TESTING

-- **Test** hypotheses and theories by using them to **make predictions** about how a particular system will behave . . .

-- Then **observe** nature to see if the system behaves as predicted.

PREDICTION AND TESTING???

"THEN, AS YOU CAN SEE, WE GIVE THEM SOME MULTIPLE CHOICE TESTS."

When does a Theory become a "Law of nature?"

-- when a theory or group of related theories has been tested extensively and seems to apply everywhere in the universe

-- when we have had enough experience with it and have a lot of confidence that it is true

-- we elevate the theory to a new status & call it a law of nature

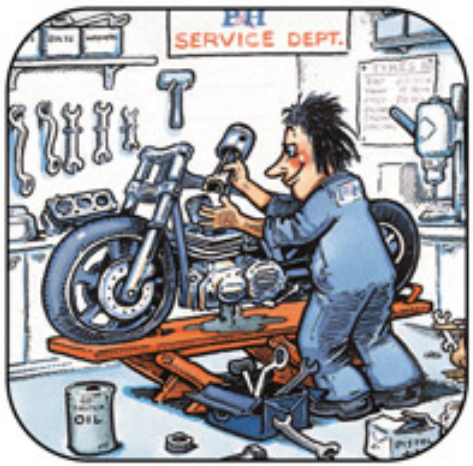
-- an overarching statement of how the universe works.

e.g. GRAVITY

Other presentations of "Scientific Method". . .

. . . the reading assignment for today:

Robert Pirsig's article from *Zen and the Art of Motorcycle Maintenance* outlines a 6-part "Formal Scientific Method":



1. statement of problem
2. hypotheses about the cause of the problem
3. experiments designed to test each hypothesis
4. predicted results of experiments
5. observed results of experiments
6. conclusions from the results of experiments

Pirsig also describes two types of reasoning processes that go into observations, hypotheses, and predictions:

Induction (inductive reasoning) = generalizing from individual observations to general conclusions

Deduction (deductive reasoning) = start with general knowledge (first principles, established theory) and predict a specific observation.

INDUCTION:

INdividual observations ➔

General conclusion

DEDUCTION:

DE (“the”) big picture (theory) ➔

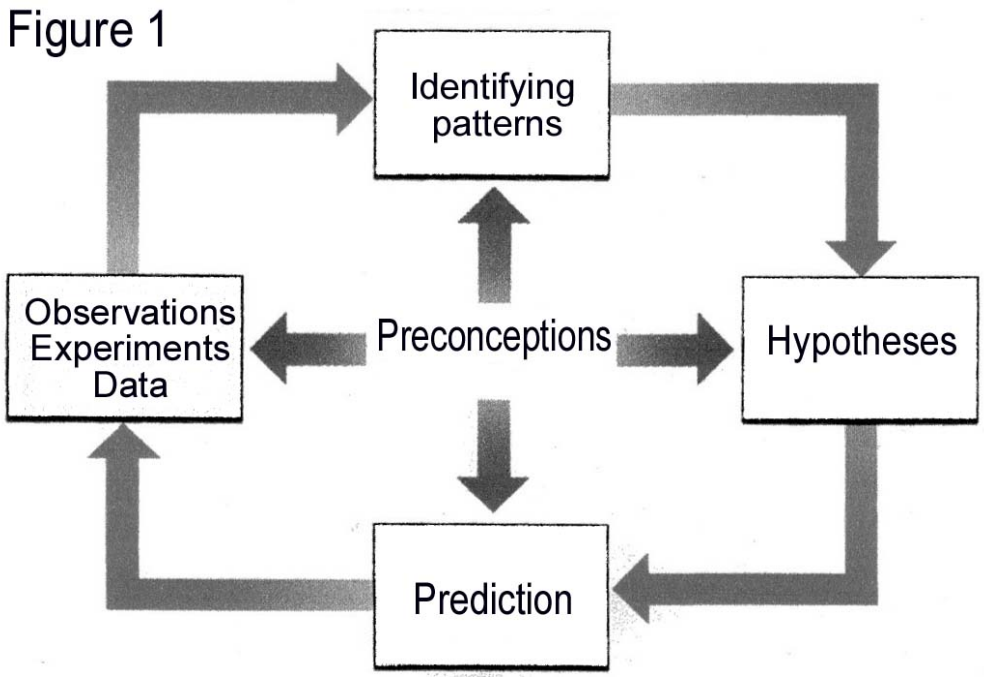
conclusion / prediction about a specific observation

Pirsig suggests:

. . . in actual science, problem solving takes place by long strings of mixed inductive and deductive inferences that weave back and forth between observations and theory . . .

Interconnectivity of methodological steps!

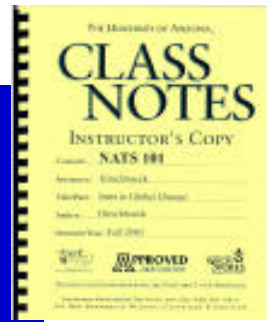
Other presentations of "Scientific Method". . .



- No "right" place to enter cycle
- Usually a specific hypothesis is under consideration
- KEY POINT: Scientists must believe the results of their experiments and observations whether or not they fit the hypothesis or preconceived notion.

- Observations & experiments must be verifiable, i.e. the results must be reproducible
- Science does not provide final answers . . .or ultimate truth . . . It attempts to produce successively more detailed and exact descriptions and models for understanding +/or predicting the behavior of processes and phenomena in the world

CLASS ACTIVITY:
QUOTES FROM SCIENTISTS ABOUT DOING SCIENCE



If you HAVE your CLASS NOTES with you today – great!

If you DON'T . . . Raise your hand to get a green handout for use in class today & return it at the end of class.

p 15

DIRECTIONS: Take out a piece of paper, write your name on it and set it up:

A) #_____ **B) #_____**

NOW READ THROUGH THE 26 QUOTES on pp 15 -16 (or the green sheet) and SELECT THE QUOTE:

A) # _____ that you like best and/or most resonates with YOU

and

B) #_____ that surprises you the most (as coming from a scientist)

Then write out a couple of sentences explaining why you made your selections for (A) & (B)

CLASS DISCUSSION TIME

SHARE YOUR SELECTIONS WITH YOUR NEIGHBOR

Some critiques of scientific methodologies:

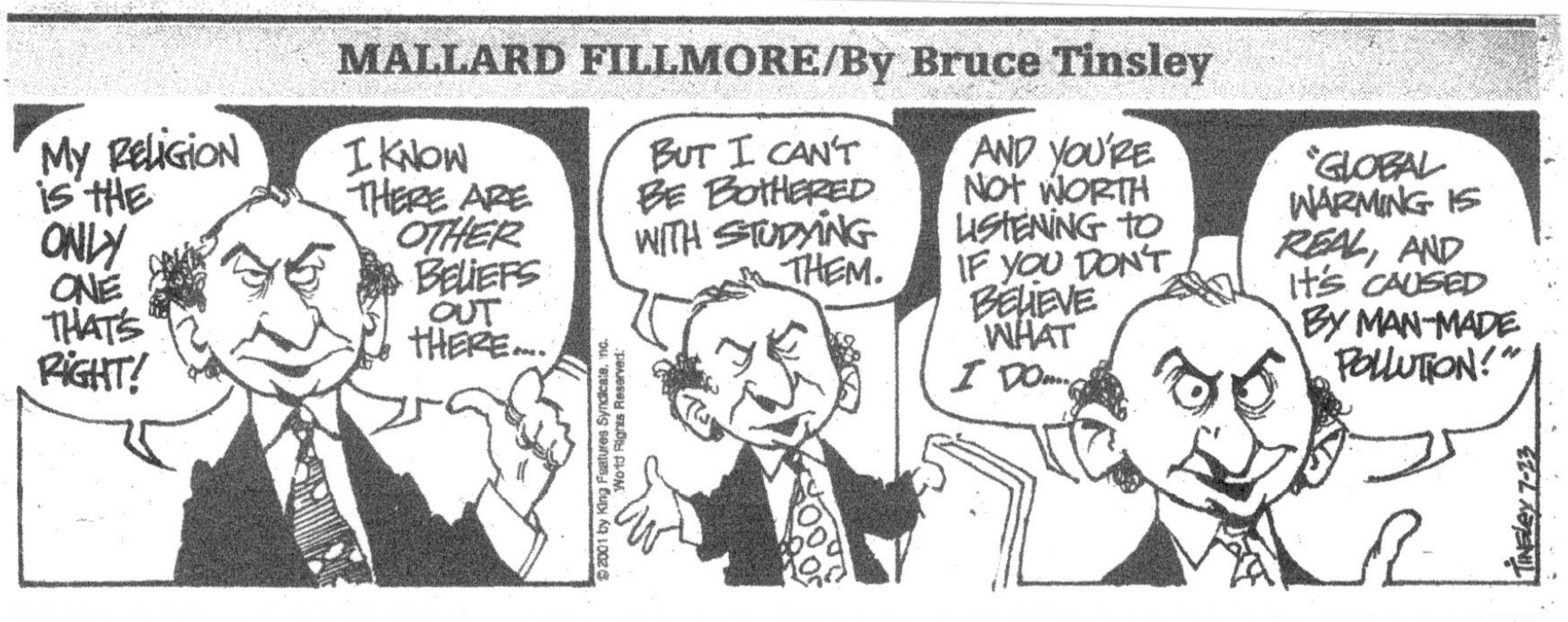
- **Inductive method cannot establish "certain" knowledge because the NEXT observation might change things!**

- **Deductive method might lead to FACTS and OBSERVATIONS becoming "Theory-laden":**

(We may observe *what we want to observe,* based on personally held beliefs in certain theories . . .

. . .Or there may be certain deeply held values underlying motivation for research)

A critique of GLOBAL CHANGE SCIENTISTS by a conservative cartoonist:



Do scientists merely "believe" in their results or are their views based on more compelling reasons (e.g., consistent observations, converging evidence, etc.)

More things to be aware of about the scientific process:

- **Observations might be ignored because they don't conform with theory!**
- **Risk of self-deception**
- **Methodologies have their limits**
- **Theories can never be positively proven to be true, but some can be <u>disproved</u> by "falsifying" them** **(Karl Popper, philosopher of science)**

Being able to FALSIFY some theories is an important step in the advancement of scientific knowledge!

(WHY? can eliminate incorrect theories & get closer to truth)

THE SCIENTIFIC PROCESS IN ACTION

HOW DOES SCIENCE OPERATE & PROGRESS?

- **Driven by curiosity**
- **Dedicated & persistent research sparked by moments of intuition & exciting discovery**
- **Communal review of scientific results (I.e. PEER REVIEW)**
- **Scientists build on previous results; it is a cumulative process or enterprise**

- **Open but skeptical mind; theories may be falsified but never verified**

- **Human error, plagiarism, and fraud will get weeded out over time**

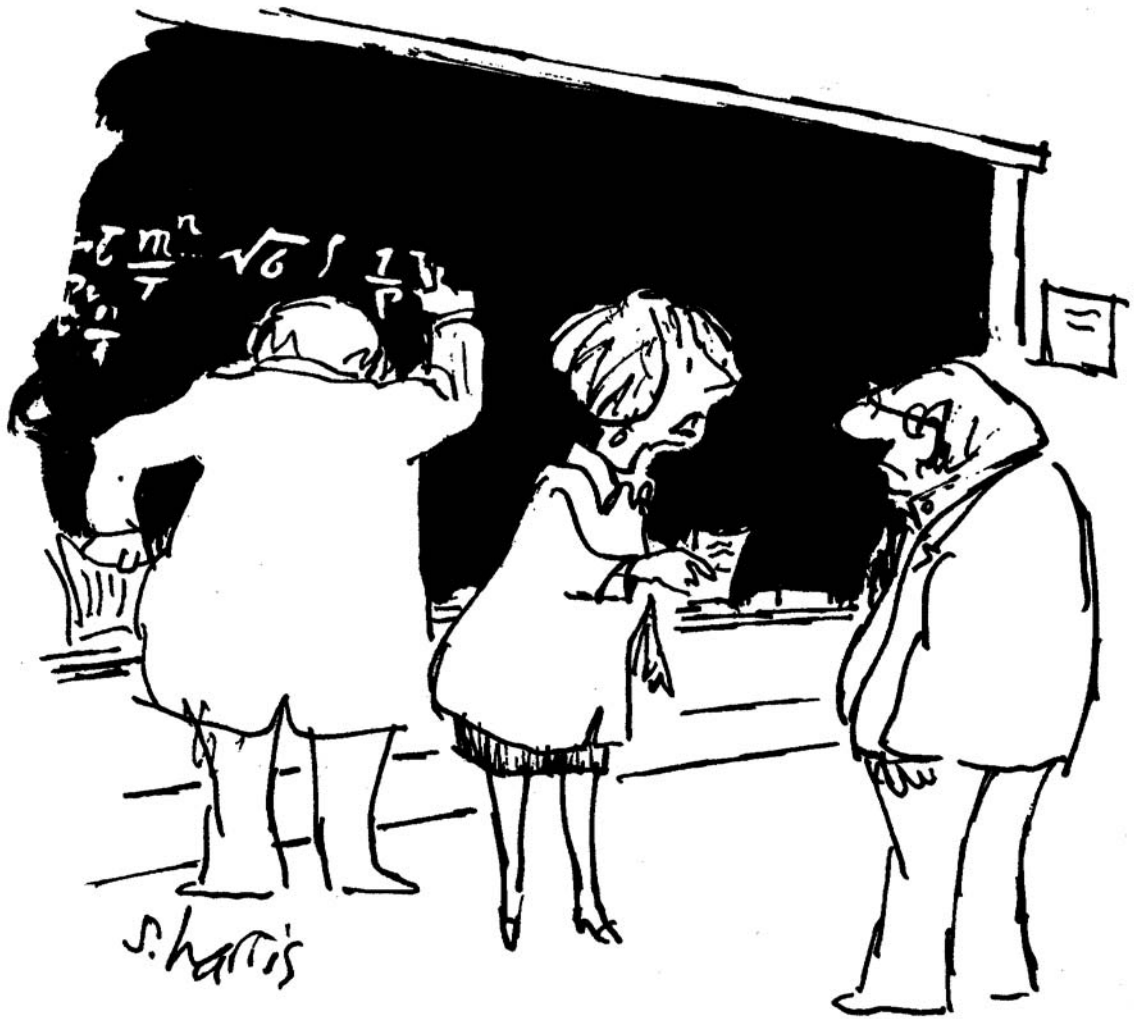
- **Conflicts of interest, (e.g. who's funding the research?), ethics, & human values play an important role in "objective" science (self-awareness needed!)**

- **Collaborative efforts (Team work!) essential as body of knowledge gets more complex**

“Because science is done by human beings, it involves occasional bursts of intuition, sudden leaps, a joyful breaking of the rules, and all the other characteristics we associate with other human activities.” Trefil & Hazen 1995

- **Wonder, awe, joy & mystery are at the source of scientists' love for their work**

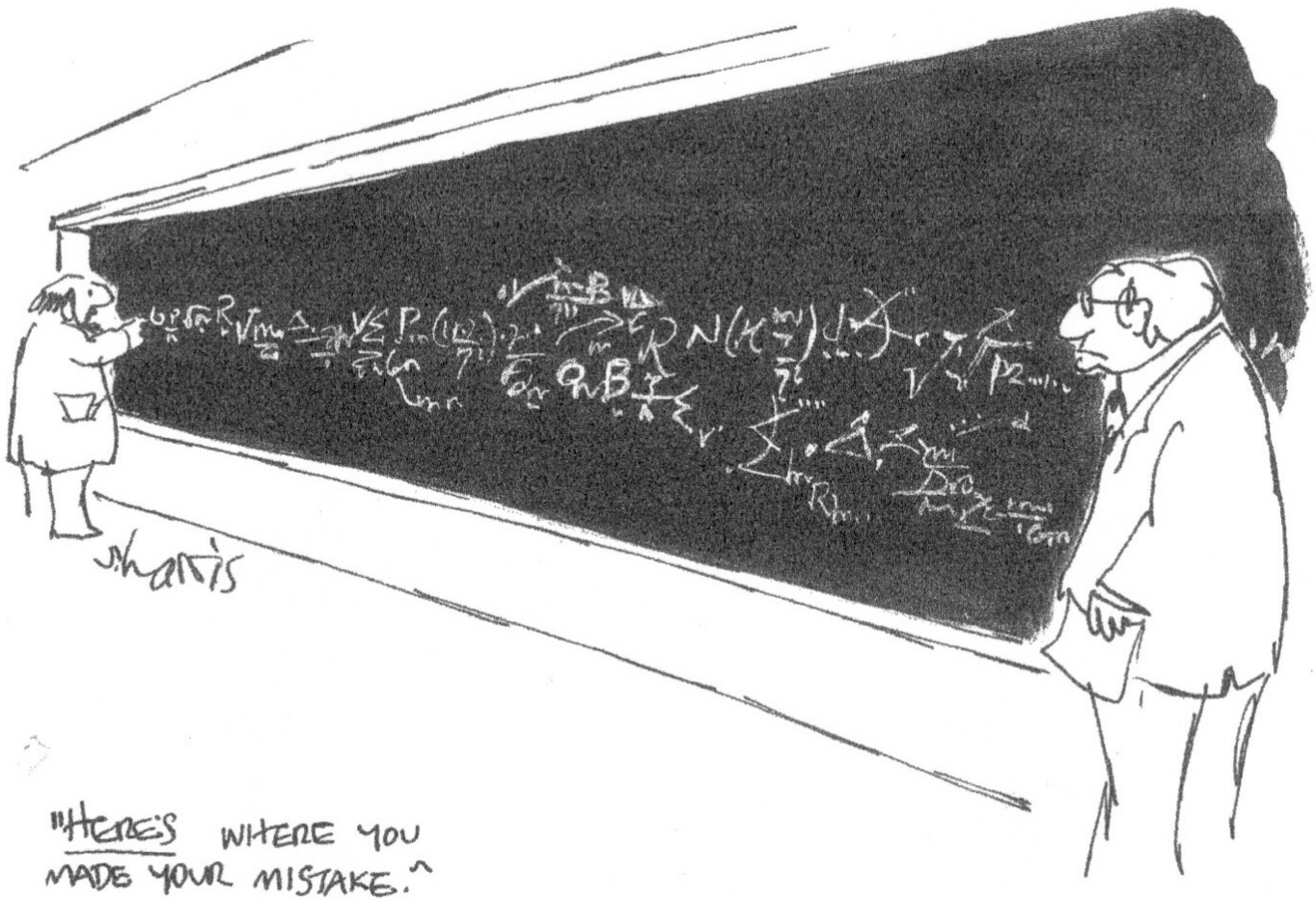
What aspect of science just discussed is depicted humorously by this cartoon?



And this?

(Note: young Edison didn't really do this!)

How about this one?



And lastly, what about this one?

"COMRADE — THE COMMISSAR OF MATHEMATICS WANTS IT TO EQUAL 29.86."

IN-CLASS ACTIVITY

"Think-Pair-Share" Exercise on:

CARTOONS & QUOTES
ABOUT & BY SCIENTISTS

DIRECTIONS FOR THIS CLASS ACTIVITY:

1. **THINK:** First, on your own, match the cartoons and quotes with the one phrase that best expresses an aspect of science that the cartoon is "spoofing" or the quote is illustrating.
2. **PAIR:** Pair up with another student (or get in a group of 3) and introduce yourselves to each other.
3. **SHARE:** Share your answers with each other and discuss your reasoning.
4. The correct answers will then be revealed in a Class Discussion about each phrase.

CARTOON A

CARTOON B

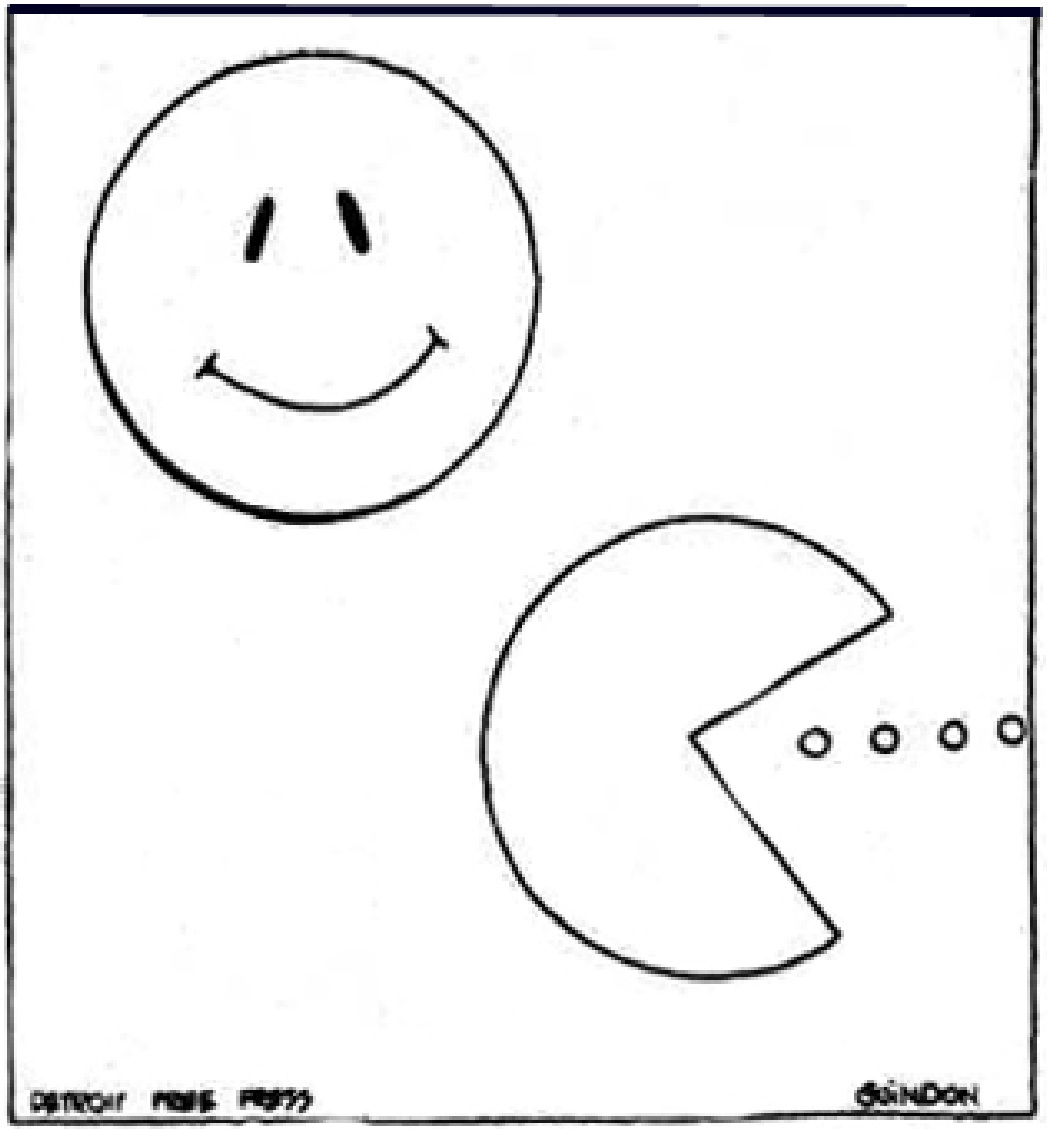

THINK TANK
"IT'S OUR NEW ASSEMBLY LINE. WHEN THE PERSON AT THE END OF THE LINE HAS AN IDEA, HE PUTS IT ON THE CONVEYOR BELT, AND AS IT PASSES EACH OF US, WE MULL IT OVER AND TRY TO ADD TO IT."

CARTOON C


Ah, ha – just as I expected.
Ah, ha – just as I expected.
Ah, ha – just as I...
S. Harris

CARTOON D

CARTOON E



In the year 2074, A.D., a curator at the Museum of Modern Art in New York will conclude that the happy face and Pac-Man were done by the same artist.

CARTOON F

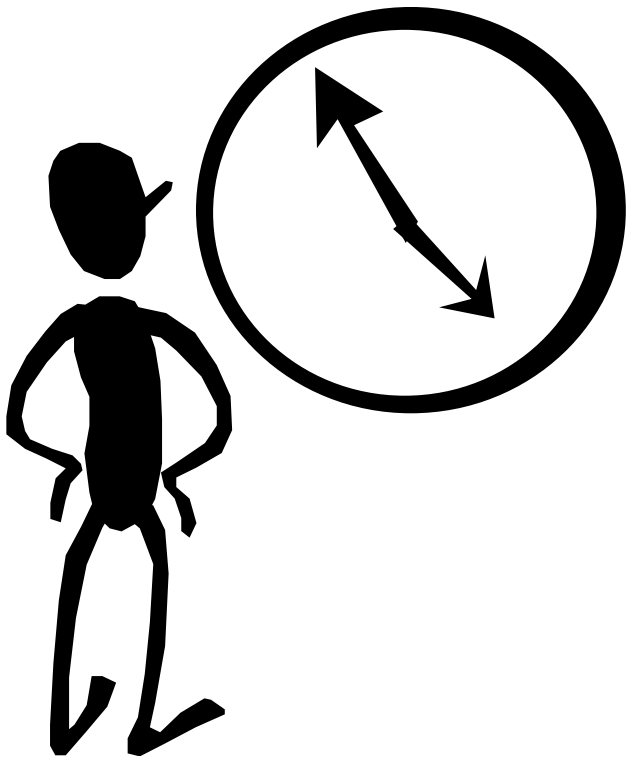

I'VE DONE IT— I'VE FOUND THE MOST BASIC PARTICLE!
I'VE FOUND THE PARTICLE THAT MAKES UP THAT BASIC PARTICLE!
I'VE FOUND THE PARTICLES THAT MAKE UP THE PARTICLES...

CARTOON G

"IT STARTED WITH A SIMPLE CASE OF PEER-REVIEW."

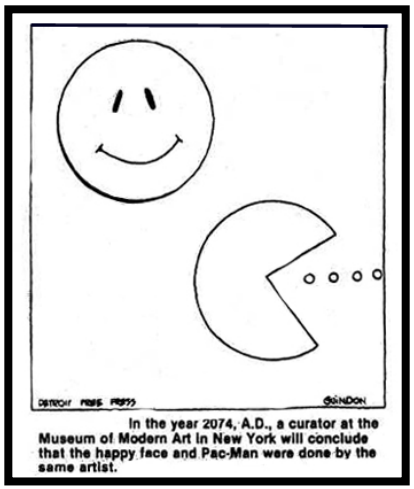
PART B:

SOME QUOTES BY SCIENTISTS



IT’S TIME TO END YOUR DISCUSSION . . .

PLEASE WRAP IT UP AND QUIET DOWN.



E INDUCTIVE REASONING

Inductive reasoning reasons from the "INdividual to the general" -- in other words, a general statement or conclusion is made based on one or more individual observations.

In this cartoon, the curator is making an unfounded conclusion (or generalization) that the same artist created both the happy face and Pac-Man.

The cartoon illustrates one of the dangers of inductive reasoning (making unfounded conclusions from too little evidence) in a humorous way.

D DEDUCTIVE REASONING

Deductive reasoning reasons from **"DE"** (the) whole thing (the general) to an individual situation"

-- in other words, a general theory, law, or statement is assumed and then conclusions are drawn about individual things based on the general theory.

Deductive reasoning also has dangers, as illustrated in the cartoon where the dog erroneously deduces he is a cat based on the correct theory that all cats have four legs.

F EVER-CHANGING NATURE OF SCIENTIFIC KNOWLEDGE

Cartoon F is the best answer for this phrase.

It illustrates that no discovery should be considered "final" in science -- something new may always turn up to change what we know.

(Cartoon B is another possible choice, but B is better described by one of the other phrases)

C PREDICTION & TESTING

Cartoon C illustrates (in a humorous way) how prediction and testing go hand in hand.

Sometimes the most important scientific discoveries take place in experiments when we do NOT get the results that are predicted.

A CONFLICT OF INTEREST

Cartoon A best illustrates the concept of "conflict of interest," which arises when a scientist may have funding from a specific source, or have a strong personal interest in a specific scientific outcome, that may influence his or her objectivity in conducting research or drawing conclusions.

"Conflict of interest" usually is an internal conflict within a scientist or scientific research group -- not an external "battle" among scientists (as depicted in Cartoon G).

G REVIEW OF SCIENTIFIC RESULTS BY COLLEAGUES

Cartoon G depicts the process of **PEER REVIEW** in a humorous and unflattering way. Peer review is a careful evaluation of one's results, publications, etc. by one's colleagues.

The review is designed to determine if the research is valid and a significant contribution to science.

Note that the peer review process is a normal and beneficial part of the scientific process.

It does not usually end up in a fist fight as depicted in the cartoon!

and the last cartoon . . . . .

B

_____ SCIENCE IS A CUMULATIVE ENTERPRISE (i.e. process)

Cartoon B best illustrates the idea that science is a cumulative process.

Science progresses by new pieces of information that are added to pre-existing knowledge.

Although Cartoon F also expresses the concept of new knowledge being progressively discovered by individuals, the "conveyor belt" image of several scientists adding to an idea one after the other in a cooperative venture is a slightly better representation of the "cumulative enterprise" concept.

PHRASES ABOUT SCIENCE FOR MATCHING:

__5___ Curiosity & self-discovery tend to motivate scientists
("Ask questions! . . " Paul Ehrenfest)

__4__ Dedicated & persistent research yields benefits
("No, it's a great life . . ." Steven Weinberg)

__2__ Scientists are attracted by the wonder, awe, & joy found in their research *("The joy of insight . . ." Victor Weisskopf)*

__1__ Inspiration emerges from a well-informed mind
("Newton's . . act of the prepared imagination" John Tyndall)

__7__ Theories cannot be verified, but they can be falsified
("No amount . . . can prove me right . . ." Albert Einstein)

__3__ Self-deception can color an observation
(" ...art to be learned -- not to see what is not." Maria Mitchell)

__6__ Knowledge is ever-changing
("law of change ...Nature never stands still ..." Laurence Gould)

WHAT'S NEXT?

Using your class notes packet & D2L

READING / SELF-TESTS / READINESS QUIZZES

Reading-ST-RQ you should complete asap:

1. Read & study the Syllabus and the Online FAQ (Frequently Asked Questions)
2. In D2L, try out the Practice Self Test A (ST-A) & Readiness Quiz A (RQ-A) on the Syllabus & FAQ

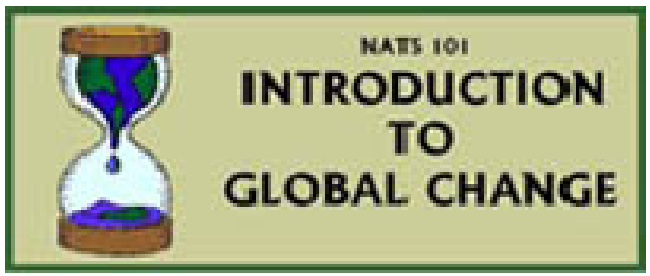
Reading-ST-RQ to prepare for next week:

1. Read IGC Chapter 1
2. In D2L, test your understanding of Chapter 1 by taking Practice Self Test B (ST-B) & Readiness Quiz B (RQ-B)

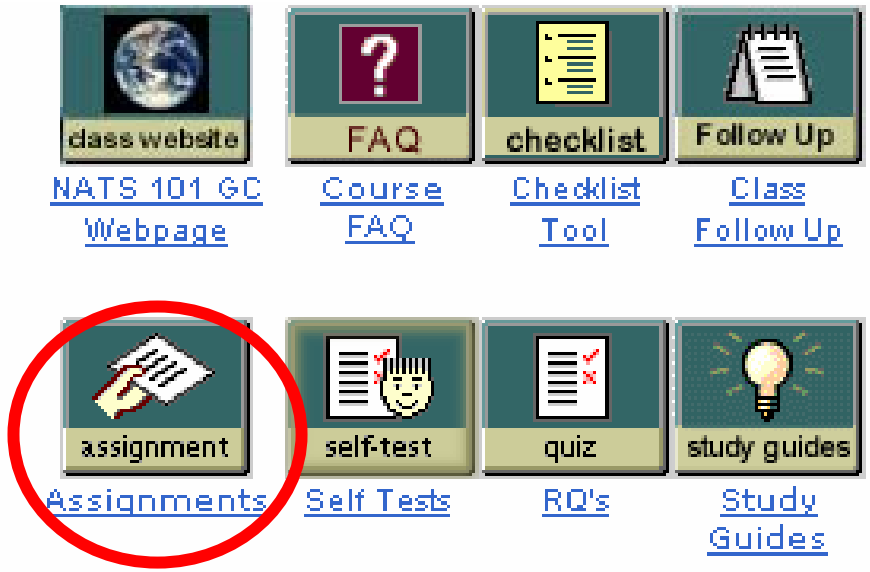
FIRST HOMEWORK ASSIGNMENT (15 pts)

DUE next Tuesday in class, Aug 29

I-1. Your Ecological Footprint



At right are the tools we'll be using most often this semester. Other D2L tools (Grades, D2L Email, etc.) are in the red & blue navigation bars above.



ASSIGNMENTS

Fall 2006 Semester

These are graded in-class and homework assignments.
For READING & ONLINE QUIZ assignments, CLICK HERE

[Links and details to be posted as each assignment takes place or is assigned.]

NOTE: If you have questions about a grade, see below to find out who graded the assignment and talk to or email that TA *directly* about your grade.

= Assignment has been completed or is past due

GROUP ASSIGNMENTS
(in-class activities)

G-1 Group Ecological Footprint

G-2

G- 3

G-4

G-5

G-6

INDIVIDUAL ASSIGNMENTS
(homework assignments)

I-1 My Ecological Footprint (15 pts)

I-2 Sun Safety & the Electromagnetic Spectrum (35 pts)

I-3 Tree-Ring Crossdating (25 pts)

I-4 The Bristlecone Tree-Ring Report (50 pts)

I-5 Linking-to-Life Slide (20 pts)

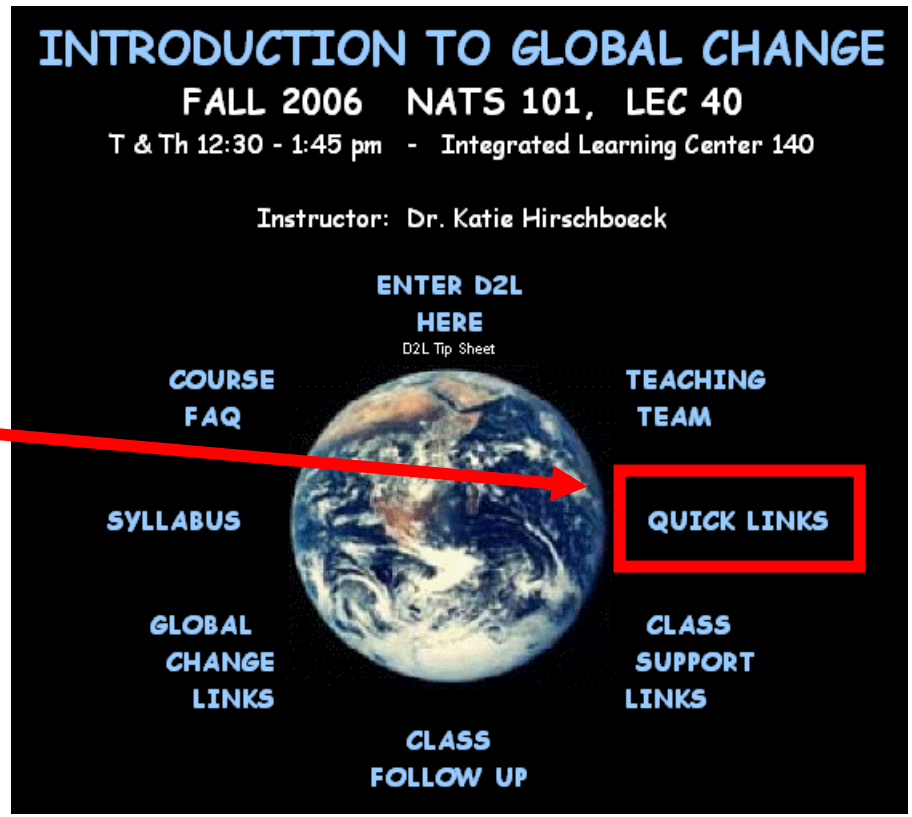
I-6 Global Warming Debate Preparation (25 pts)

FIRST HOMEWORK ASSIGNMENT (15 pts)

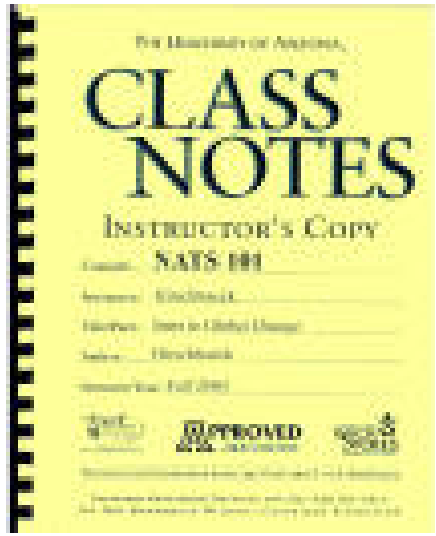
DUE next Tuesday in class, Aug 29

I-1. Your Ecological Footprint

NOTE: A link to the I-1 Assignment will also be posted under QUICK LINKS for those students not yet able to get into D2L



IMPORTANT:



For next Tuesday's GROUP ASSIGNMENT on Ecological Footprints,

PLEASE BRING YOUR CLASS NOTES PACKET WITH YOU TO THE NEXT CLASS!!

Before you leave today . . . .

- ✓ **Turn in your paper with your quote selections A & B**
- ✓ **Turn in any completed YELLOW BACKGROUND FORMS**
- ✓ **Return the GREEN HANDOUTS to one of the TA's**