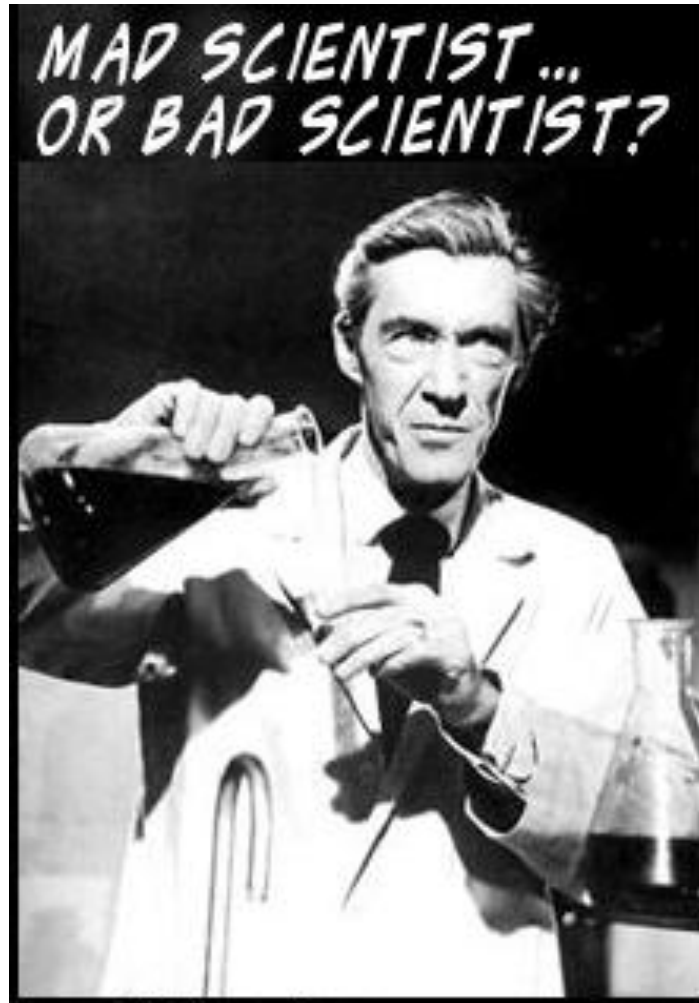


**TODAY:**



# Topic #2: ON SCIENCE & BEING A SCIENTIST

**“Science is simply  
common sense at its best!**

*~ Thomas Huxley*

**Do not become a mere recorder of facts,  
but try to penetrate the mystery of their origin.**

*~ Ivan Petrovich Pavlov*

# 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 from satellites is one important tool
  - How to observe changing Earth over time? – paleoclimatic indicators, “natural archives” (ice cores, tree rings, etc.) are one way;
  - Combined with computer models of past environments
- **ALSO: the Standard “tools” of science:**  
Hypotheses, prediction, testing,  
theories, and “laws of nature” all enter in.

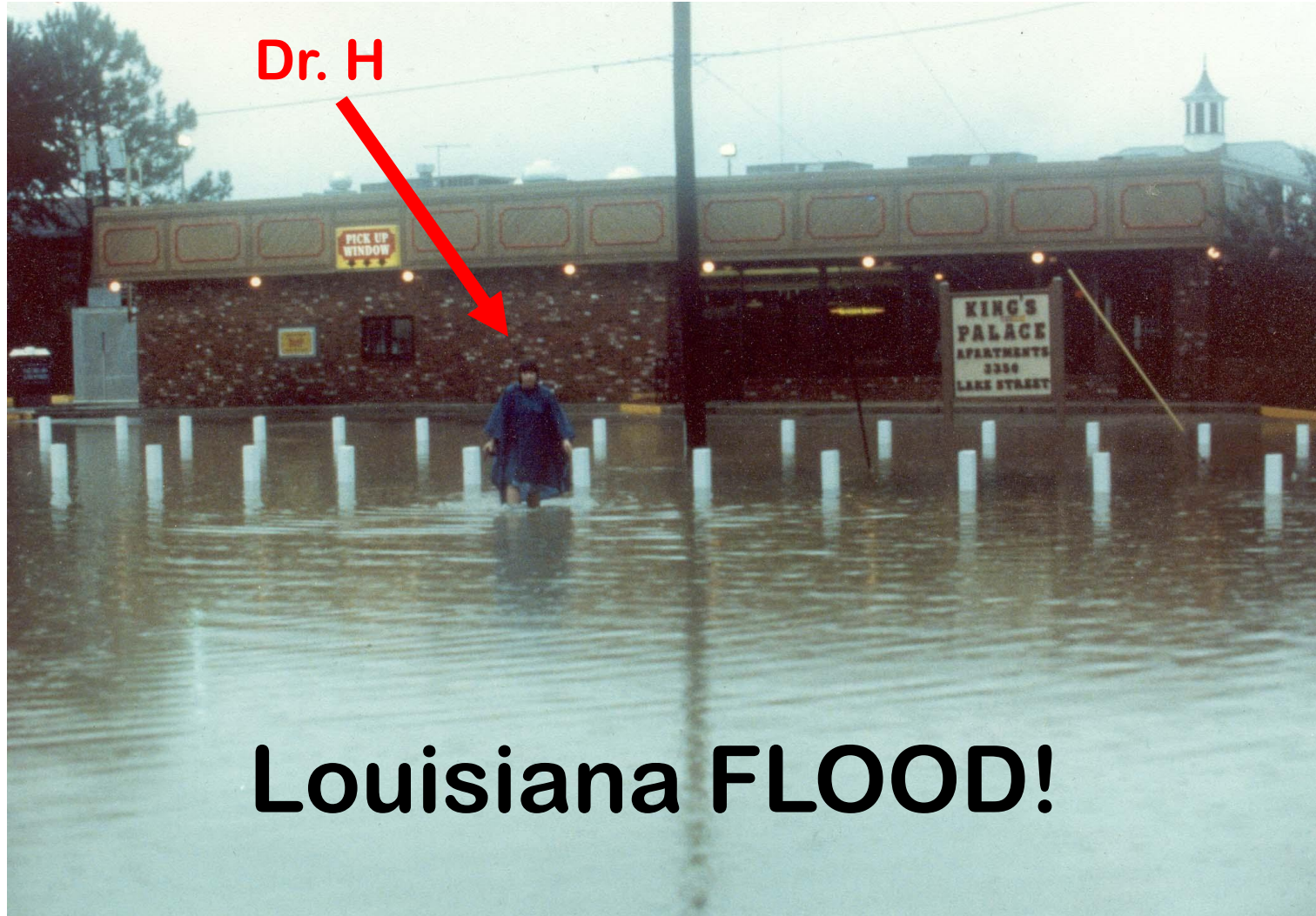
# THE PERSONAL SIDE OF BEING A SCIENTIST . . .

READ THROUGH THE QUOTES ON THE PINK SHEET AND DECIDE:

Which quote do you like best? = # \_\_\_\_

Which quote surprises you the most  
(as coming from a scientist)? = # \_\_\_\_

# Passionate Interest & Curiosity



**Louisiana FLOOD!**

# Dedicated Work Effort

e.g. Field Work!

**JACQUIE**  
in her field  
area in  
Churchill,  
Manitoba  
concentrating  
on coring  
that tree!



**Dedicated  
Work Effort**

**...more  
Field Work!**

**ELIZABETH**  
really getting  
“into” her  
work by  
standing in a  
muddy creek  
bed!



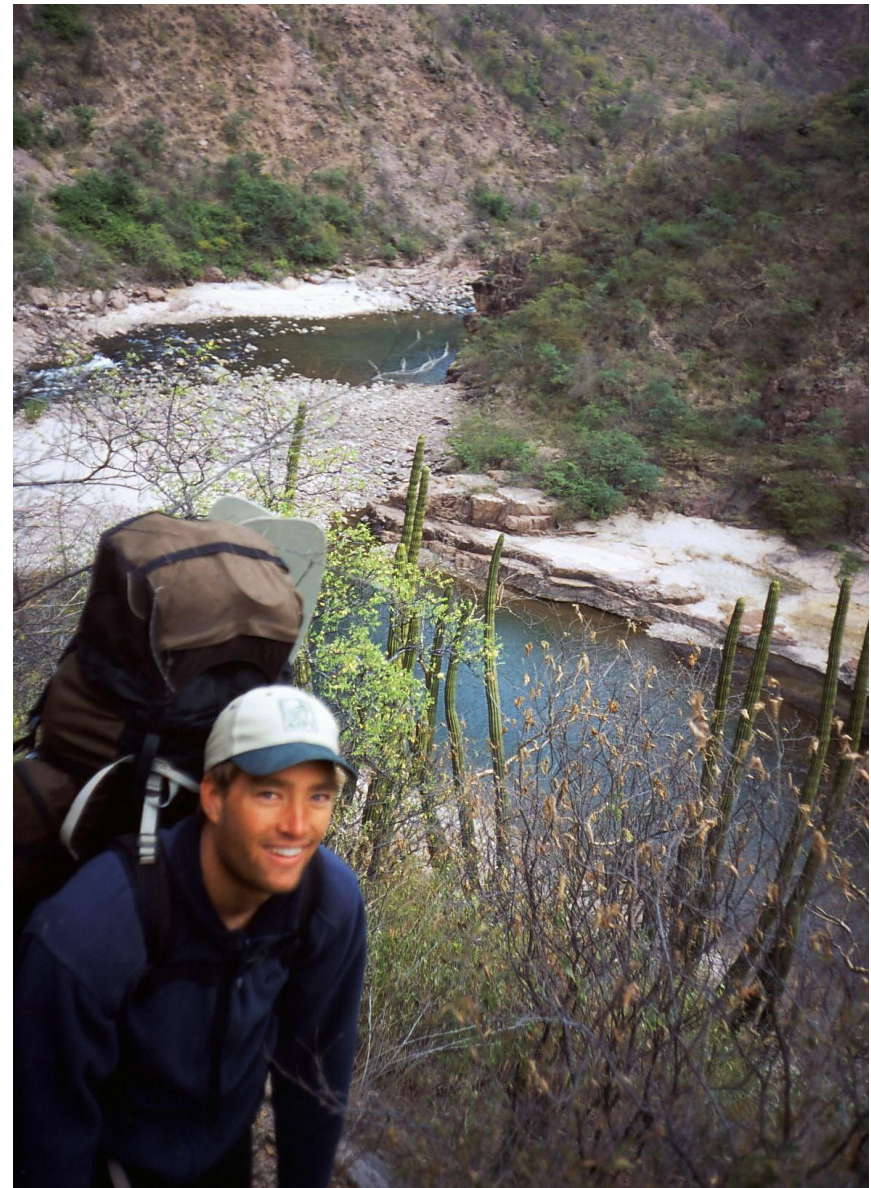
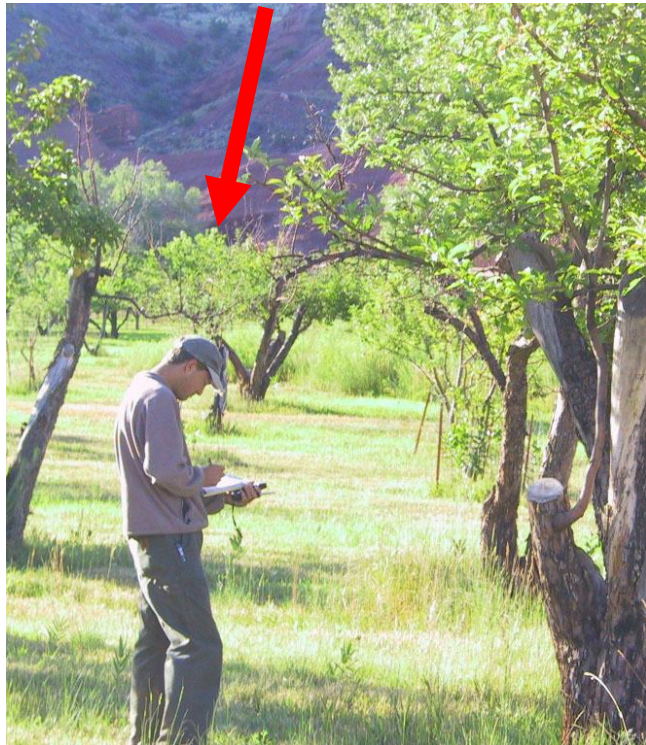


# Dedicated Work Effort

...more Field Work!

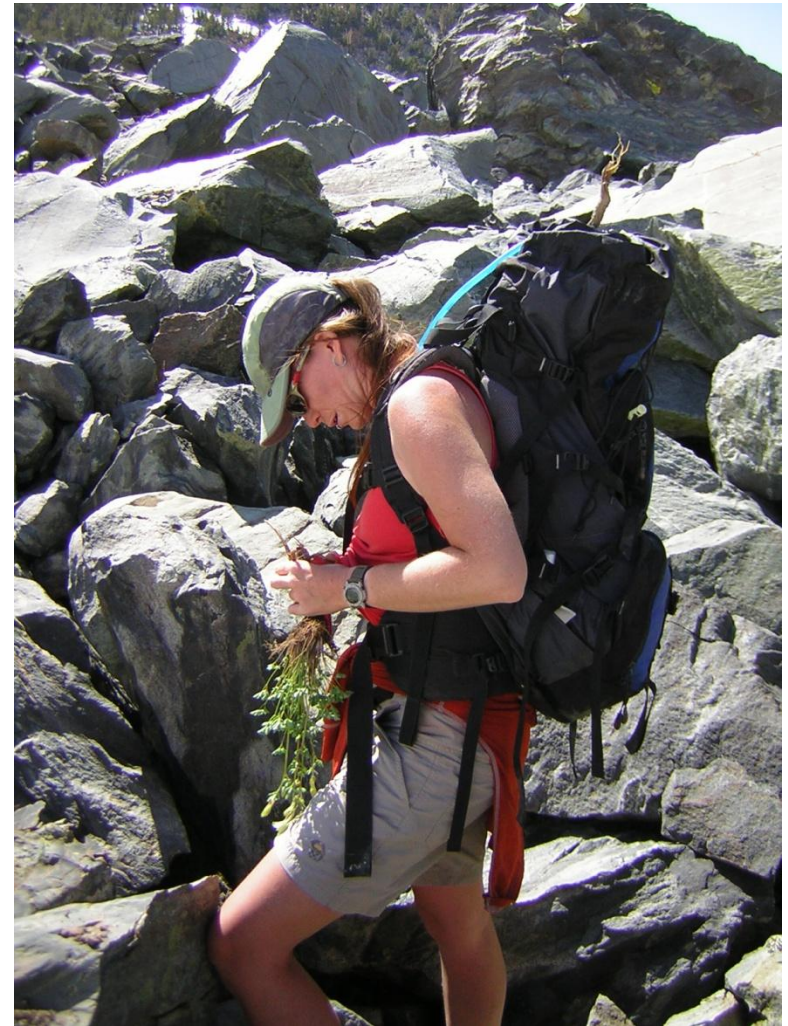
**KANIN**

in a field of  
apple trees!



# Dedicated Work Effort!

**REBECCA**  
collecting field data



**...even more Field Work!**

**Dedicated  
Work Effort!**

**...and  
(sometimes  
tedious)**

**LAB 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



# 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.

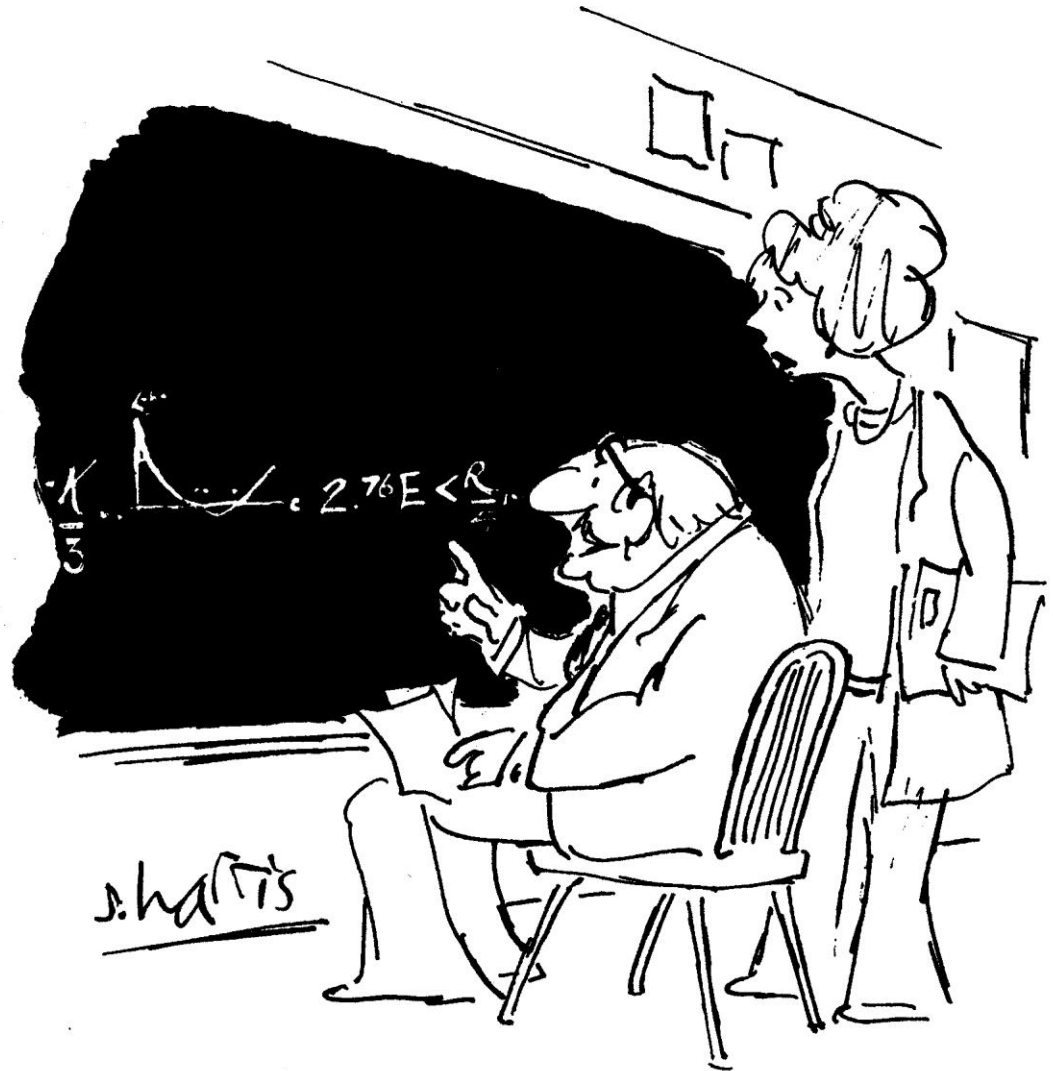
# HYPOTHESIS

## Form a **HYPOTHESIS**

- a “tentative guess” about how the world works
- must be able to be evaluated with available data
- 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."

# 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 or established theory)  
..... and predict a specific observation.



# **INDUCTION:**

**IN**dividual observations →

General conclusion

# **DEDUCTION:**

**DE** (“the”) big picture (theory) →

conclusion / prediction about a  
specific observation

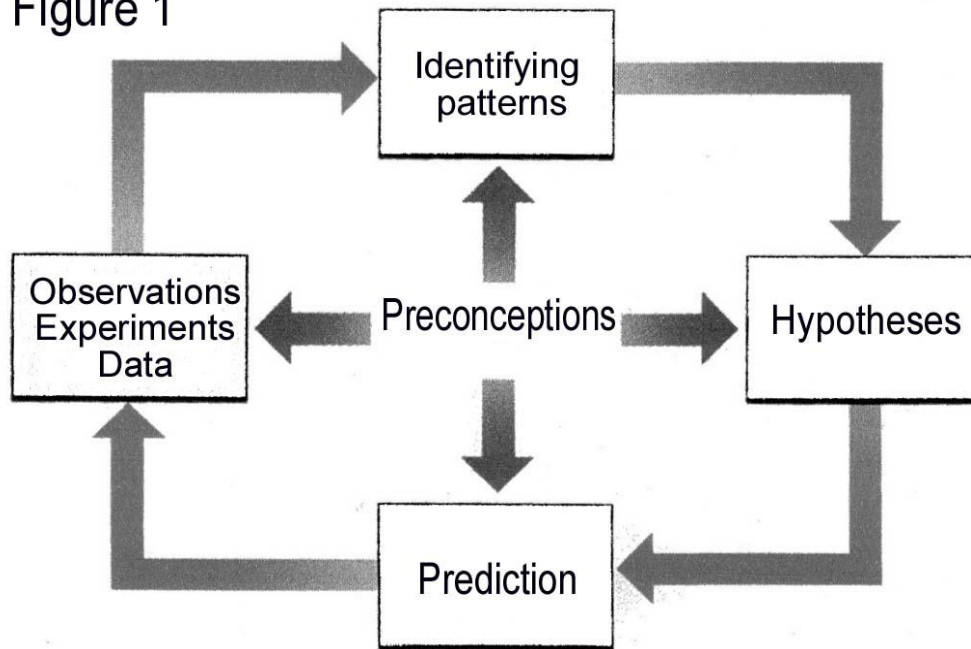
**Pirsig suggests:**

**“ . . . 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” . . .

Figure 1



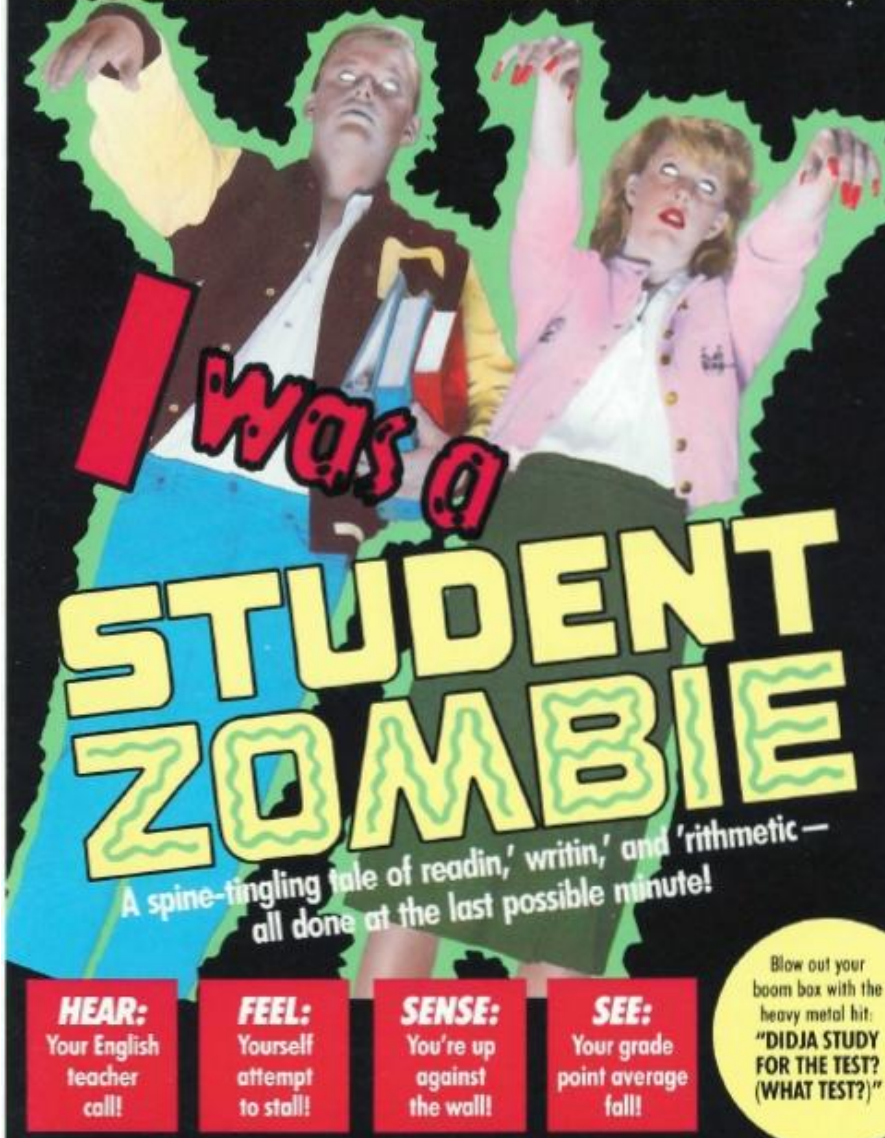
- No “right” place to enter cycle
- Usually a specific hypothesis is under consideration
- **KEY POINT:** Scientists must “believe” (accept) the results of their experiments and observations whether or not they fit the hypothesis or preconceived notion.

- **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 +/- predicting the behavior of processes and phenomena in the world

**Review  
this  
later in  
Class  
Notes**

It's happening right now...in YOUR town...  
in YOUR school...in YOUR class...in YOUR BRAIN!



**ZOMBIE  
BREAK !**

Starring THE TEACHER'S PET · THE PUZZLED ATHLETE · THE CRAFTY CHEATER  
and A CAST OF DOZENS OF DAZED, DEMORALIZED DUNCES JUST LIKE YOU

**R** REMEDIAL READING  
REQUIRED

# THE SECRET LIFE OF SCIENTISTS & ENGINEERS

*A web-exclusive  
series from NOVA*



<http://www.pbs.org/wgbh/nova/secretlife/>

**Meet Gavin Schmidt: Climate Scientist**

One of the founders of the

RealClimate Blog: <http://www.realclimate.org/>

# 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”:**

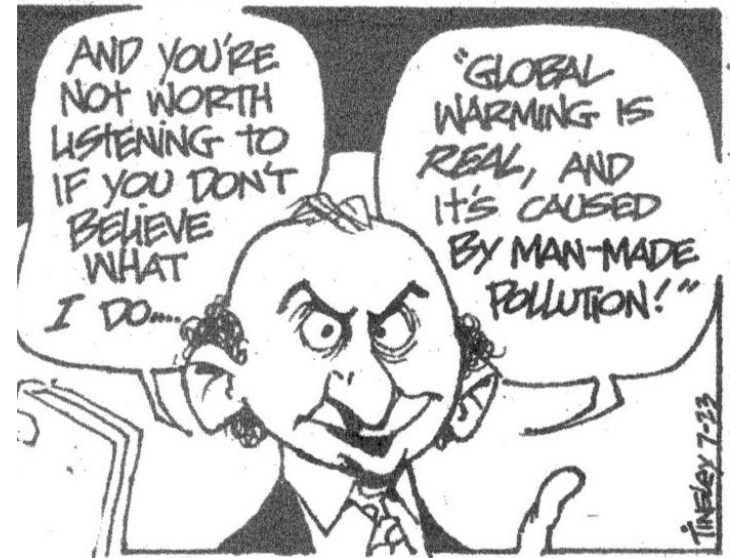
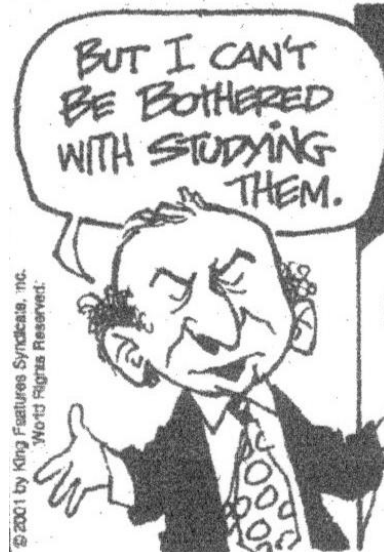
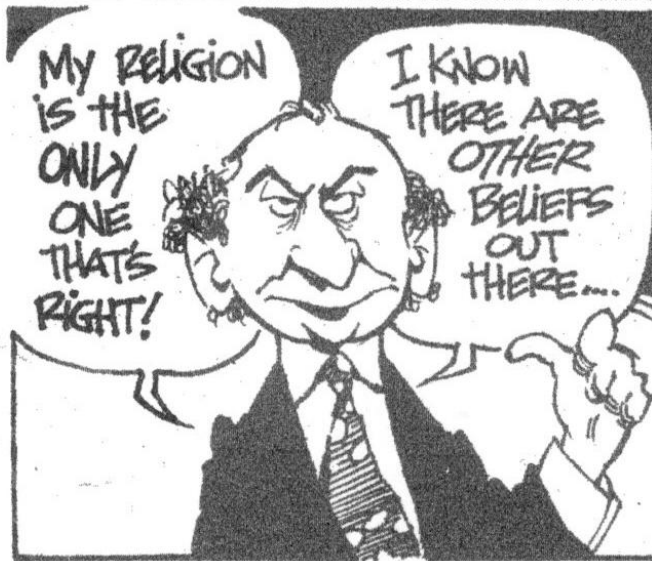
i.e., We may observe *what we want to observe*, based on personally held beliefs in certain theories . . .

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

Scientists often say: “I believe such and such is happening . . . .” But what do they really mean by that??

A critique of GLOBAL CHANGE SCIENTISTS  
in the “Mallard Fillmore” comic strip  
(which often critiques the political “left” from  
the political “right” perspective)

MALLARD FILLMORE/By Bruce Tinsley



Do scientists merely **“believe”** in their results or are their views based on more compelling scientific reasons ?

(e.g., consistent observations, converging evidence, etc.)

**“Science replaces  
‘private prejudice’  
with publicly  
verifiable evidence.”**

Richard Dawkins



## 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 disproved 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? We 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

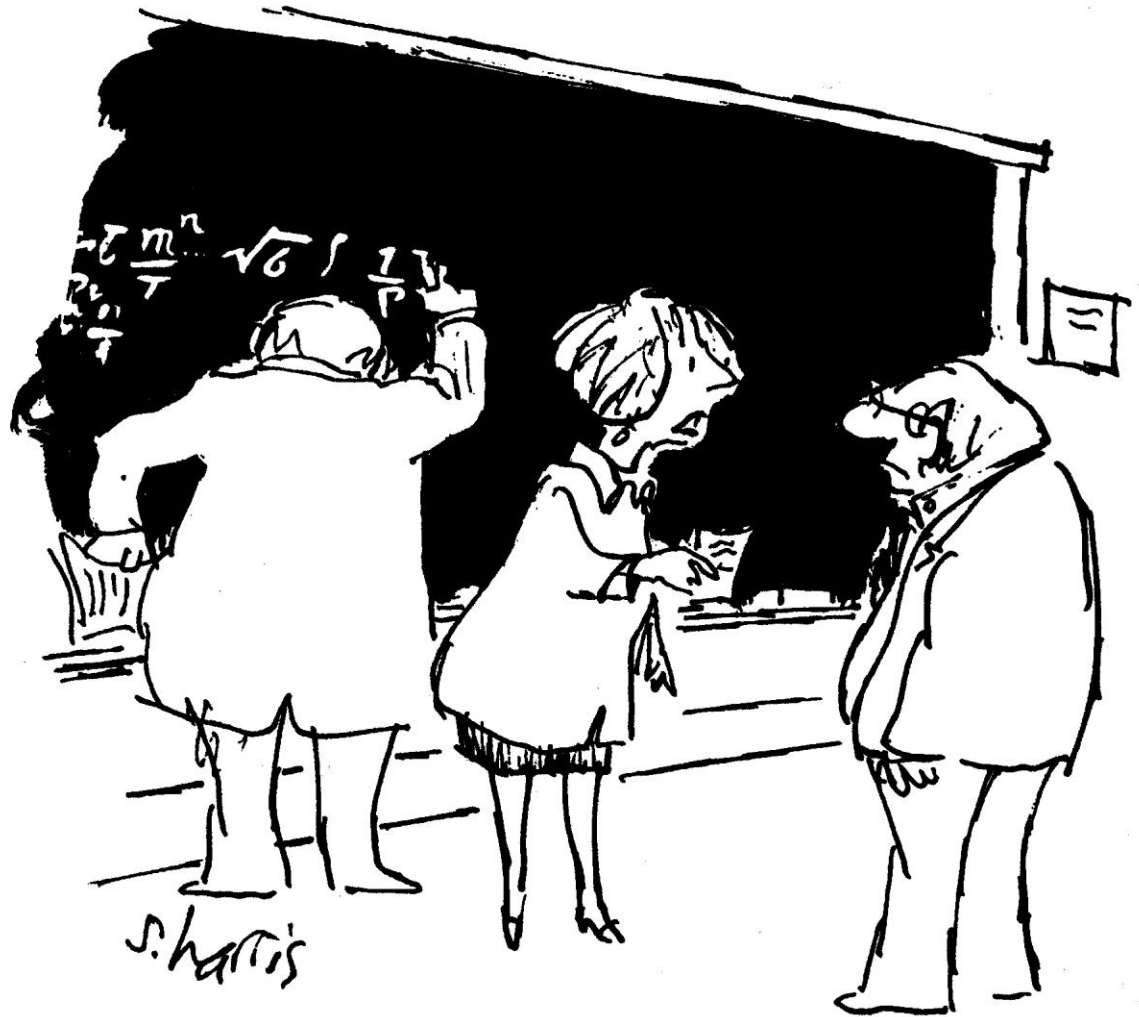




the  
symphony of science

<http://www.symphonyofscience.com/>

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

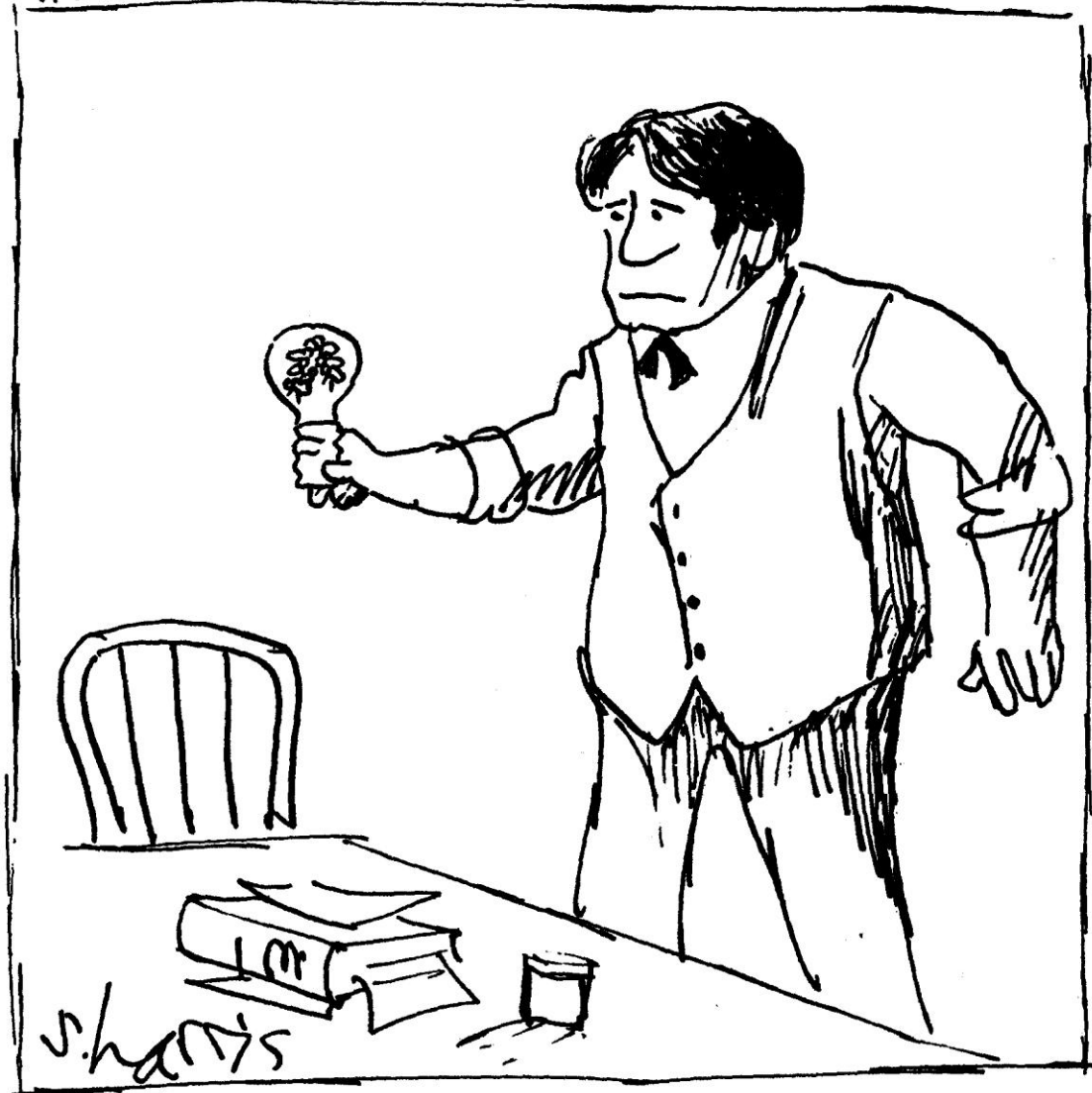


"WE COLLABORATE. I'M AN EXPERT, BUT NOT AN AUTHORITY, AND DR. GELPIS IS AN AUTHORITY, BUT NOT AN EXPERT."

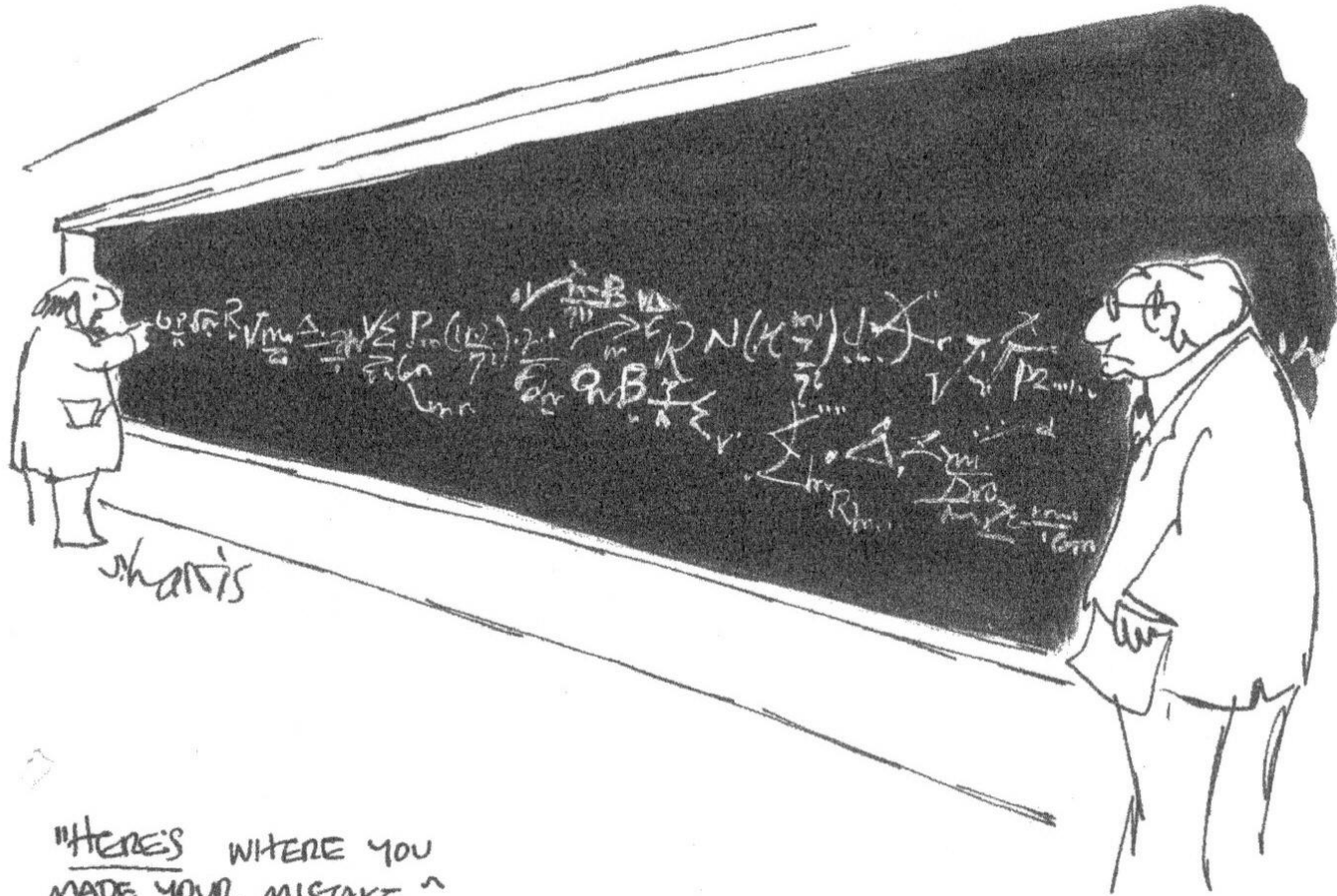


YOUNG THOMAS EDISON TRIED TO PASS OFF A  
CONTAINER FILLED WITH FIREFLIES AS AN  
INCANDESCENT BULB

And this?



How about this one?

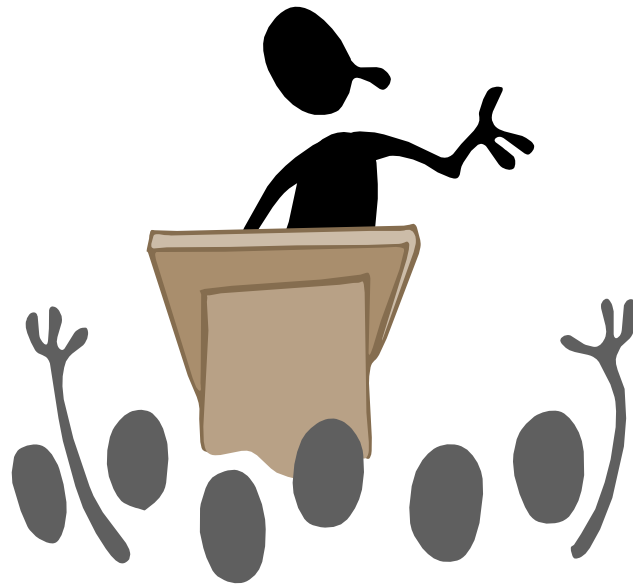


And lastly,  
what about  
this one?



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

# QUESTION BREAK!



**YOU CAN CONTINUE THE DISCUSSION ONLINE ON  
SCIENCE QUOTES ON THE D2L DISCUSSION BOARD**

# IN-CLASS ACTIVITY

**“Think-Pair-Share” Exercise on:**

**CARTOONS & QUOTES  
ABOUT & BY SCIENTISTS**

**INTRODUCE YOURSELF TO YOUR MINI-TEAM**  
while the stapled handout is being distributed . . . .  
(one for every 2- 3 people)

 **WE RE-USE & RECYCLE – PLEASE DO NOT WRITE  
ON THIS HANDOUT SO WE CAN COLLECT IT  
AND RE-USE IT AGAIN**

Following are the directions . . . . .

# DIRECTIONS FOR CLASS ACTIVITY:

- 1. THINK:** First, look over the cartoons and quotes and decide on 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 your Mini-Team.
- 3. SHARE:** Share & discuss your ideas & answers with each other and discuss your reasoning.
- 4. Come to a consensus and WRITE YOUR ANSWERS ON YOUR TEAM’S ATTENDANCE CHECK** (NOT the green handout!) The correct answers will be revealed in several minutes during a Class Discussion about each phrase.  
**See how well can you do !!!**

**CARTOON A**



## CARTOON B



"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."



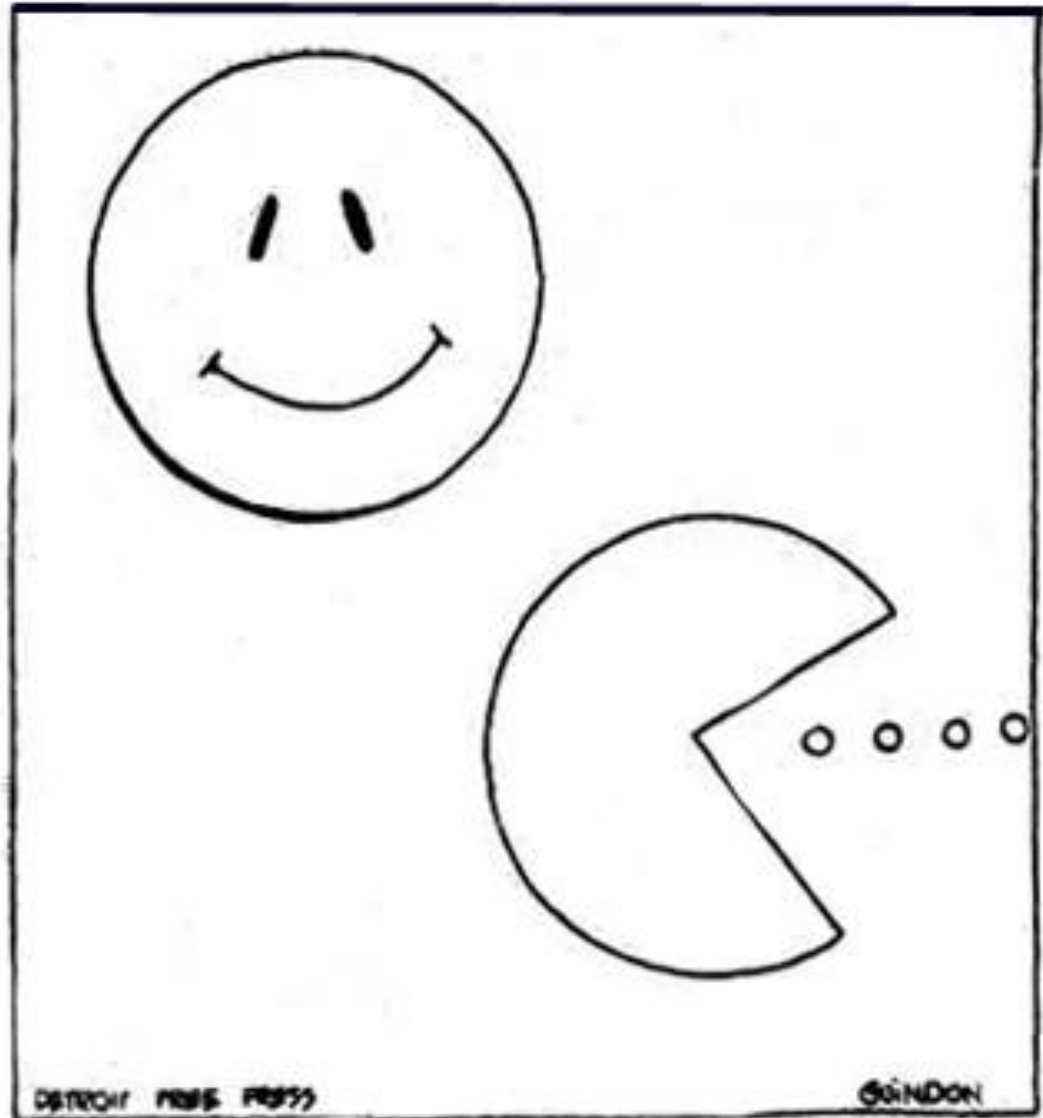
**CARTOON C**



**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**



# CARTOON G

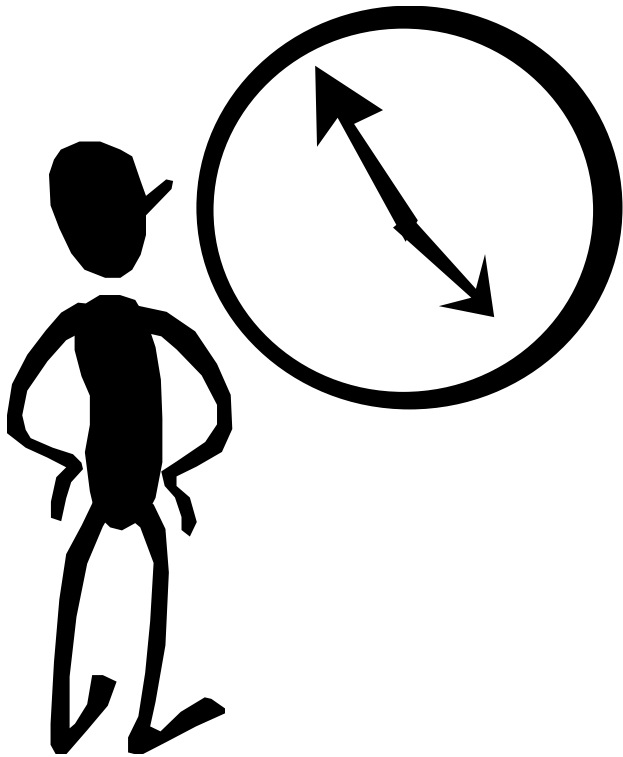


"IT STARTED WITH A SIMPLE CASE OF PEER-REVIEW."

**PART B:**  
**SOME QUOTES BY SCIENTISTS**

# DIRECTIONS FOR CLASS ACTIVITY:

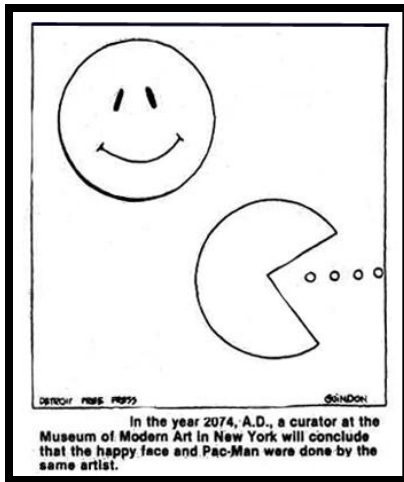
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- 4. Come to a consensus and WRITE YOUR ANSWERS ON YOUR TEAM’S ATTENDANCE CHECK** (NOT the green handout!) The correct answers will be revealed in several minutes during a Class Discussion about each phrase.  
**See how well can you do !!!**



**IT'S TIME TO END  
YOUR DISCUSSION . . .**

**PLEASE WRAP IT UP  
AND QUIET DOWN.**



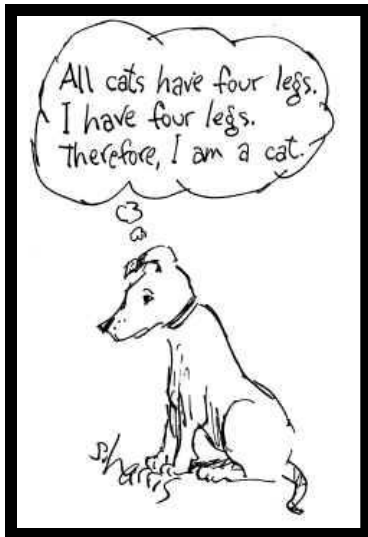


## **E** **INDUCTIVE REASONING**

Inductive reasoning reasons from the "I**N**dividual 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)*



# RE-CAP OF WHAT YOU SHOULD BE DOING:

## Reading-ST-RQ to prepare for next Tuesday:

1. Read **SGC – I Chapter 1 on GLOBAL CHANGE** -- In D2L, test your understanding of Chapter 1 by taking the corresponding **Practice Self Test & Readiness Quiz**
2. **COMING UP NEXT WEEK:** Your **first GRADED RQ (RQ-1) on SGC (the 2<sup>nd</sup> half of Text by Hobson ) Chapters 2 & 6. It will be posted this weekend and is **DUE** no later than **SEP 2** a week from today, 30 minutes before class beings!**
3. Your first **INDIVIDUAL ASSIGNMENT I-1** will be announced next week (It is **NOT** yet posted in D2L).

# CONSIDER BEING A PRECEPTOR!

[fp.arizona.edu/kkh/nats101gc/](http://fp.arizona.edu/kkh/nats101gc/)

**INTRODUCTION TO GLOBAL CHANGE**

Instructor: Dr. Katie Hirschboeck

**ENTER D2L  
HERE**  
D2L Tip Sheet

**COURSE  
FAQ**

**TEACHING  
TEAM**

**SYLLABUS**

**QUICK LINKS**

**GLOBAL  
CHANGE  
LINKS**

**CLASS  
SUPPORT  
LINKS**

**CLASS  
FOLLOW UP**

The image shows a navigation menu for the course 'INTRODUCTION TO GLOBAL CHANGE'. At the top, the title is in large blue letters. Below it, the instructor's name 'Dr. Katie Hirschboeck' is listed. The central focus is a photograph of the Earth from space. Surrounding the Earth are several menu items in white text: 'ENTER D2L HERE' with a 'D2L Tip Sheet' link below it, 'COURSE FAQ', 'SYLLABUS', 'GLOBAL CHANGE LINKS', 'CLASS FOLLOW UP', 'QUICK LINKS', and 'CLASS SUPPORT LINKS'. The 'TEACHING TEAM' link is highlighted with a red rectangular border, and a red arrow points to it from the right side of the image.

**Have a great WEEKEND!**