L32. Mon 11/14: Climate change science

I. The process of scientific inquiry
   A. Scientific terminology
   B. Scientific method
   C. Deductive vs inductive reasoning
   D. How it fits in with the class material

II. Making an argument
   A. Deductive vs. inductive arguments
   B. 2 great fallacies in non-critical thinking
   C. Other logical fallacies
   D. Science is typically inductive

III. An introduction to climate change

I. Scientific inquiry vs other questions

Some scientific questions for climate change:

1. Has the earth's atmosphere warmed in the last 50 yrs?
2. Is current global warming due to human-induced (anthropogenic) activities or natural variability?
3. How will Antarctic ice cover respond to warming?
4. What is the projected temperature rise due to a doubling of atmospheric CO_2?

Non-scientific questions (but with relevance to the science)

1. Should the U.S. response to climate change be based on the overall effect on our economy?
2. Is it unfair that the U.S. has caused a disproportionate amount of the global greenhouse burden?
3. Is environmental degradation immoral?
4. Is technology transfer to developing countries more effective than emission reductions in developed ones?

Scientific terminology vs colloquial use

Scientific terms are more rigorous than the way the terms are used colloquially (day-to-day expressions).

hypotheses- a formal generalization of a principle: nuclear-winter hypothesis, faint young sun hypothesis. Verification of the hypothesis after exhaustive testing may lead to its elevation to status of **theory**.

theories - theory of relativity, theory of evolution, atomic theory, Big Bang theory, plate tectonics theory. Represent truly broad general principles- unifying concepts that tie together the laws that govern nature.

Scientific terminology vs colloquial use

Isn't evolution only a theory, so it is not a fact or scientific law?

First you need to need to understand what 'evolution' means. Second, this question confuses the scientific vs. colloquial usage of the term 'theory'. No pre-determined amount of validation changes a theory into a law, which is a descriptive generalization about nature. When scientists talk about a theory, they have no reservations about its truth. Evolution by natural selection has survived so much testing that it is now deemed to be a fact, or law, by much of the scientific community.

Is 'global warming' a hypothesis or theory?

First, you need to be specific about what you are talking about when you say 'global warming'. Typically, 'global warming' describes an observed increase in the average temperature of the Earth's atmosphere and oceans. The terms 'global warming' or 'anthropogenic global warming' are also used to describe the theory that increasing temperatures are the result of a strengthening greenhouse effect caused primarily by man-made increases in carbon dioxide and other greenhouse gases.

B. The scientific method

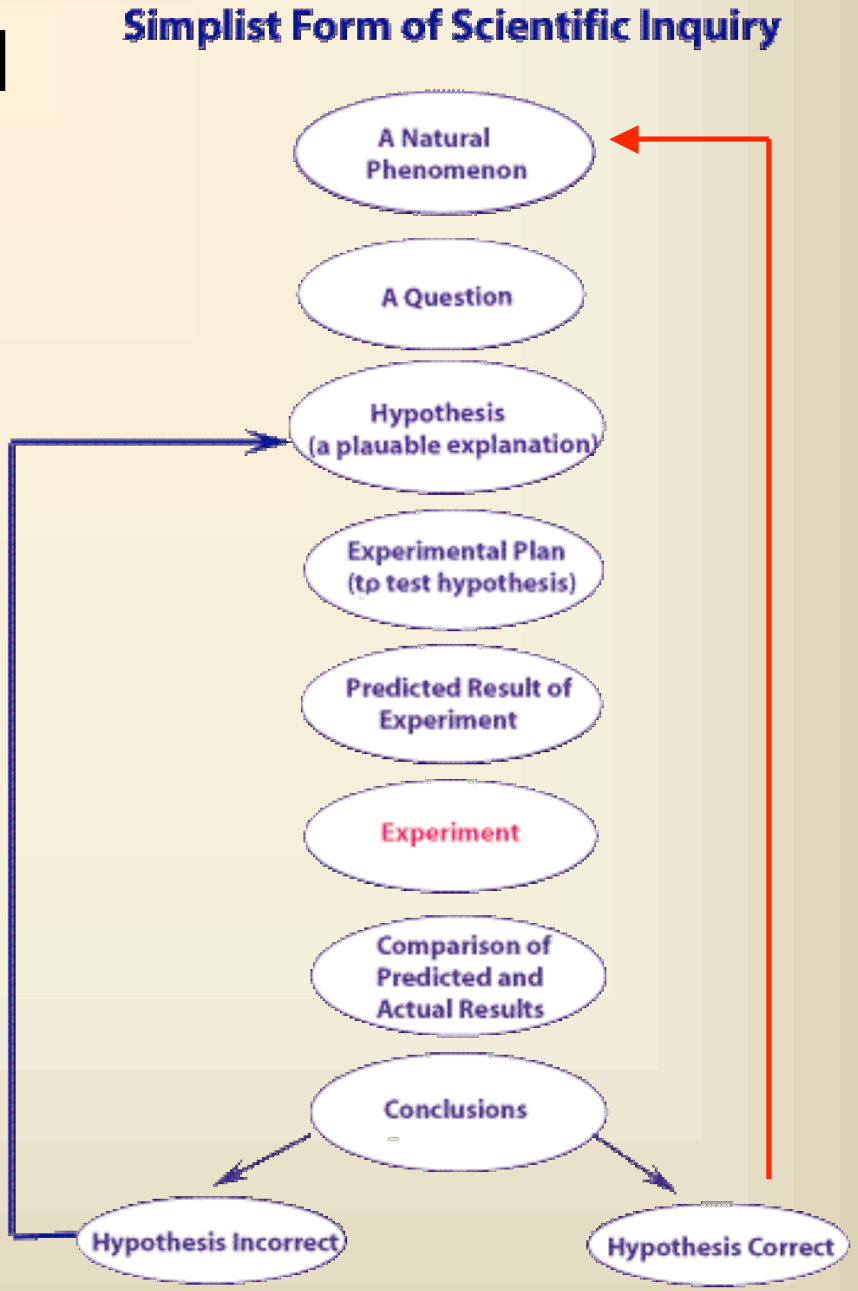
The scientific method is an open-ended inquiry. It begins with our perception of the real world and a determination of what we know and what we want to know.

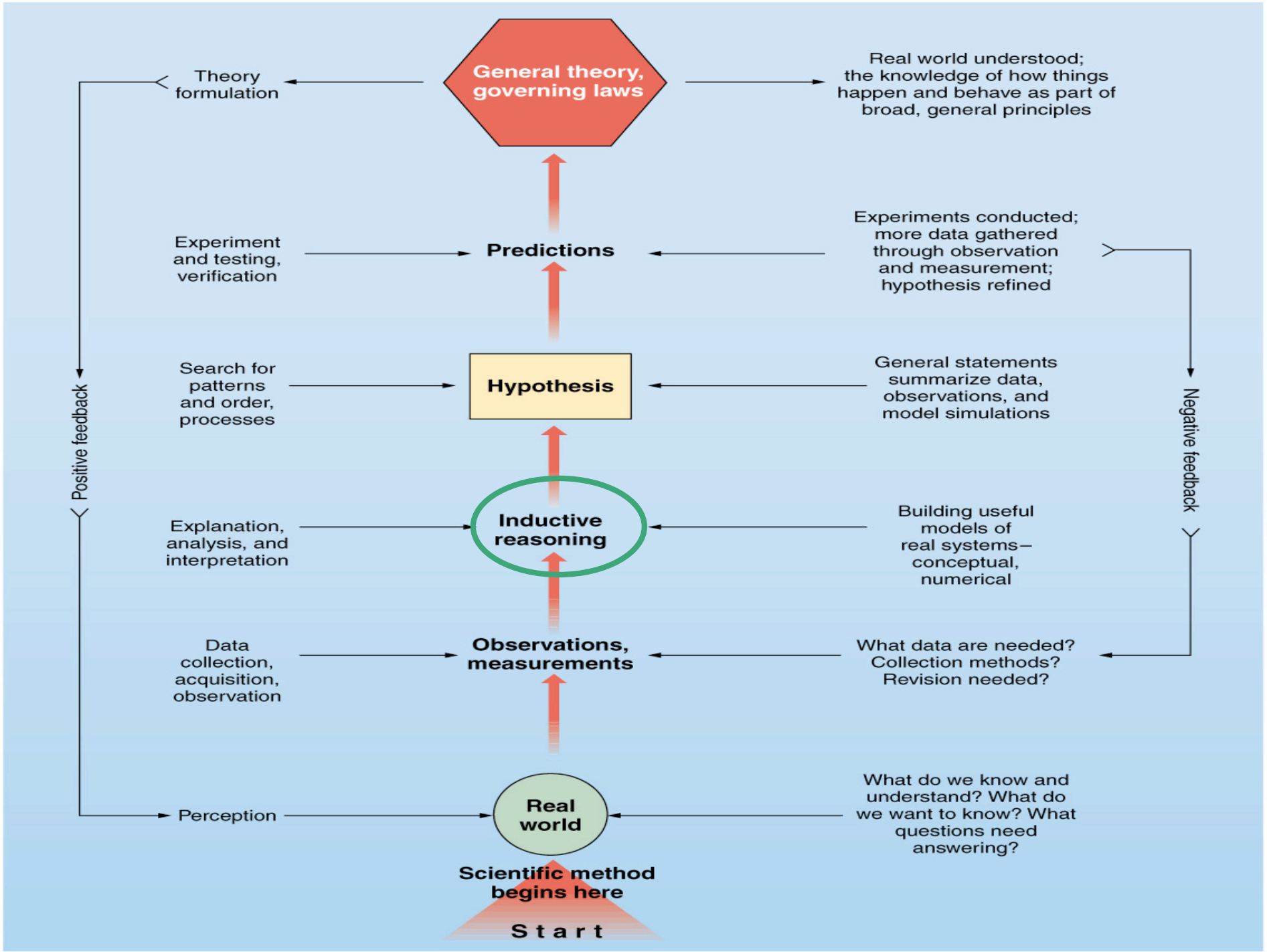
Observations: What data are needed? How do we collect those data?

Analysis and inductive reasoning: identify consistent patterns that may be present, draw generalizations from specific facts.

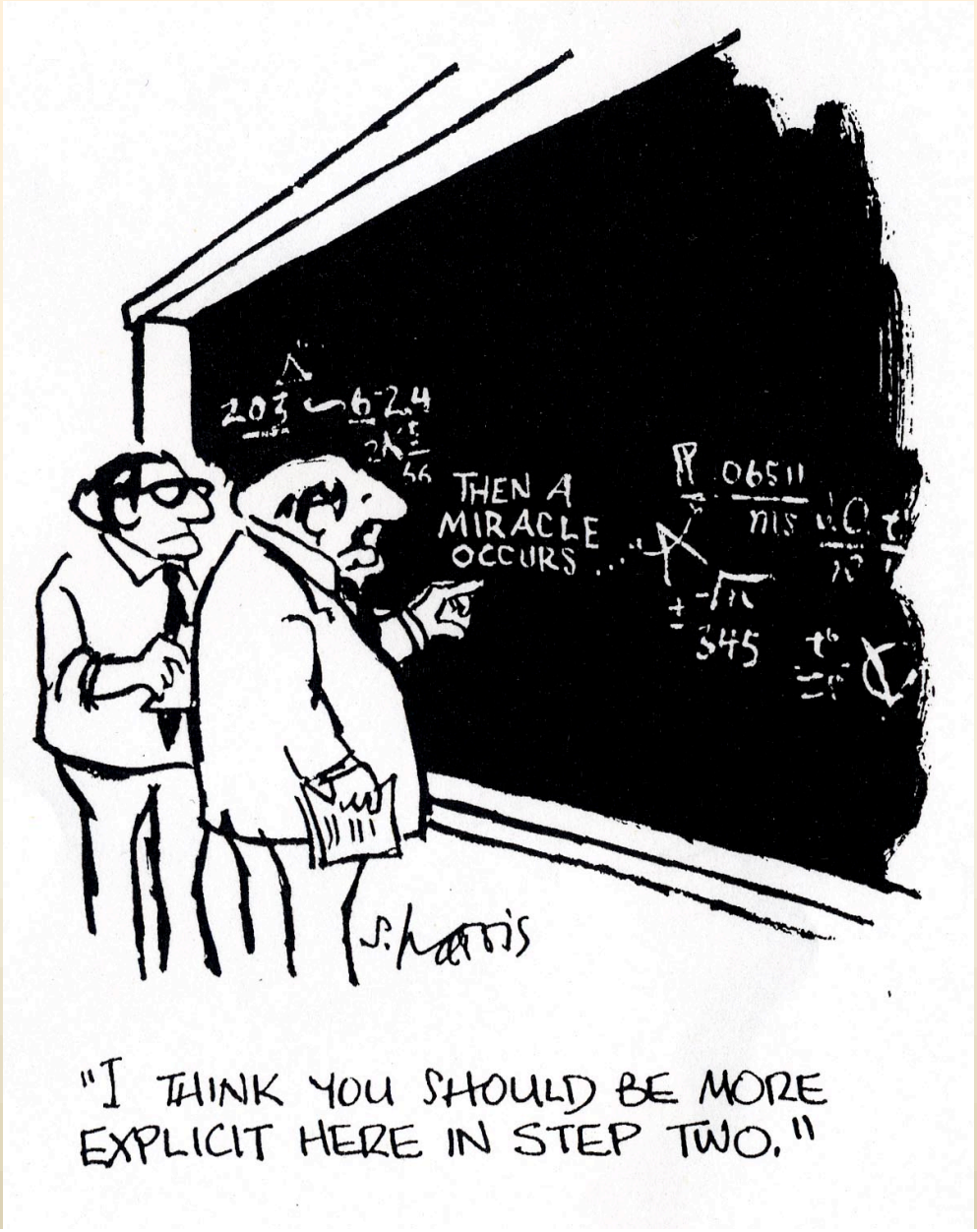
Generate hypothesis. A good hypothesis is testable and provides predictions of results for future tests.

Further observations and testing allow for revision of understanding previous observations or revision of hypotheses.




General theory, governing laws
Theory formulation
Real world understood; the knowledge of how things happen and behave as part of broad, general principles
Predictions
Experiment and testing, verification
Experiments conducted; more data gathered through observation and measurement; hypothesis refined
Hypothesis
Search for patterns and order, processes
General statements summarize data, observations, and model simulations
Inductive reasoning
Explanation, analysis, and interpretation
Building useful models of real systems—conceptual, numerical
Observations, measurements
Data collection, acquisition, observation
What data are needed? Collection methods? Revision needed?
Real world
Perception
What do we know and understand? What do we want to know? What questions need answering?
Positive feedback
Negative feedback
Scientific method begins here
Start

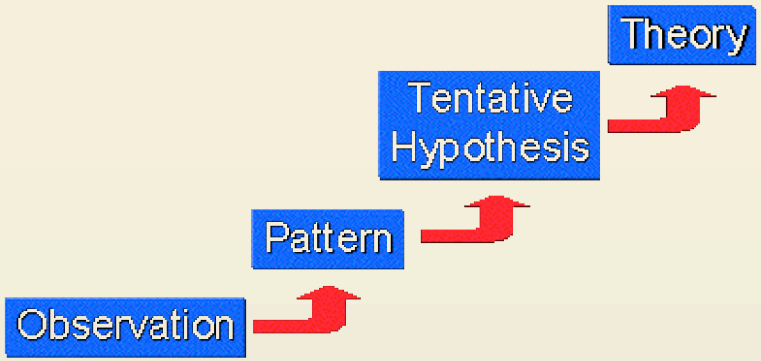
The scientific method



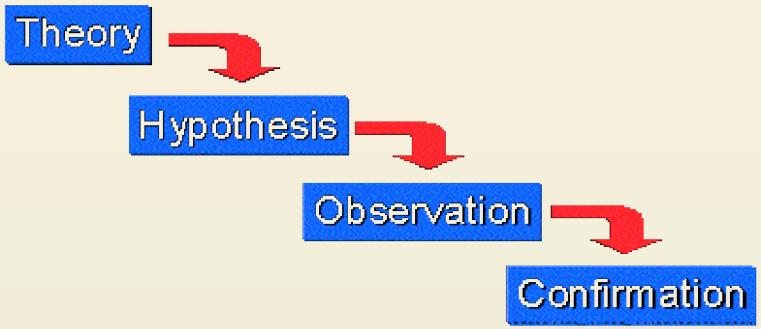
C. Deductive and inductive reasoning

http://trochim.human.cornell.edu/kb/dedind.htm

inductive reasoning:
"bottom up" approach
more open ended and
exploratory.
Specific to the general



deductive reasoning:
"top-down" approach
more narrow and concerned with
testing or confirming hypotheses.
General to the specific.



continuous cycle of research

Think about the range of the scientific processes that we have covered in this class

Part I: The fundamentals: Laws, facts, concepts, methods, observations…

1. Tragedy of the Commons
2. Feedback effects
3. $E = h\nu$
4. $\lambda_{max} = 2898/T$
5. $F = T^4$
6. troposphere, stratosphere, mesosphere, thermosphere
7. CO_2 is a greenhouse gas
8. Conservation of angular momentum
9. ITCZ, westerlies, easterlies, etc.
10. reservoirs and lifetimes
11. California coastal upwelling
12. earth interior structure
13. sea floor spreading
14. plate tectonics
15. Simpson's index of biodiversity

Part II: Paleoclimate: Observations/ evidence, methods, patterns, hypotheses, theories…

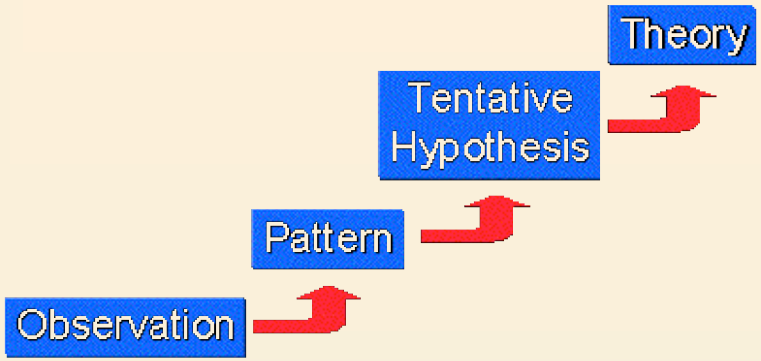
1. Origin of moon
2. Fossilized stromatolites
3. BIFs and redbeds 2 bya.
4. Cambrian explosion
5. Carboniferous coal deposits
6. Meteorite cause of K-T extinction?
7. Evolution of animals
8. oxygen isotopes in sea floor as paleoclimate proxies
9. Evidence of past glaciations
10. Solar + vegetation feedbacks caused the mid-Holocene climatic optimum?

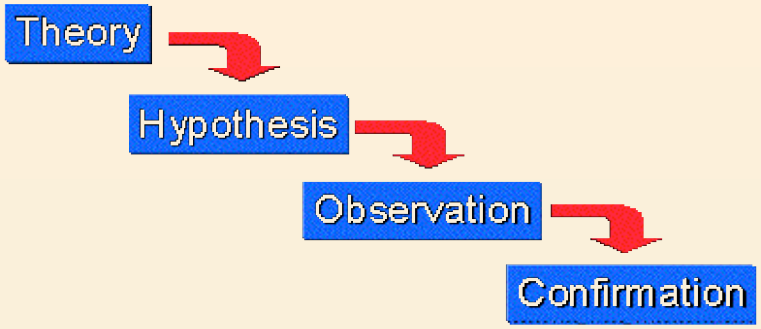
II. Making an argument

An **argument** is a series of statements used to persuade someone of something. That "something" is called the **conclusion** or **main claim**. The first job in analyzing any argument is to identify its conclusion. One way to identify conclusions, or other parts of an argument, is to look for their indicators .

Stage 1: premise	statements that directly support the conclusion. evidence (or reasons) for accepting the argument and its conclusions. Often indicated by phrases “because” “since” “obviously” (beware of “obviously”)
Stage 2: inference	premises of argument used to obtain further propositions. Often denoted by phrases “implies that” or “therefore”.
Stage 3: conclusion	Final stage of inference affirmed on the basis of the original premises and the inference from them. Indicated by phrases “therefore”, “it follows that” “we conclude”.

Deductive and inductive arguments





inductive argument:
if the premises are true, it is improbable that the conclusion would be false.

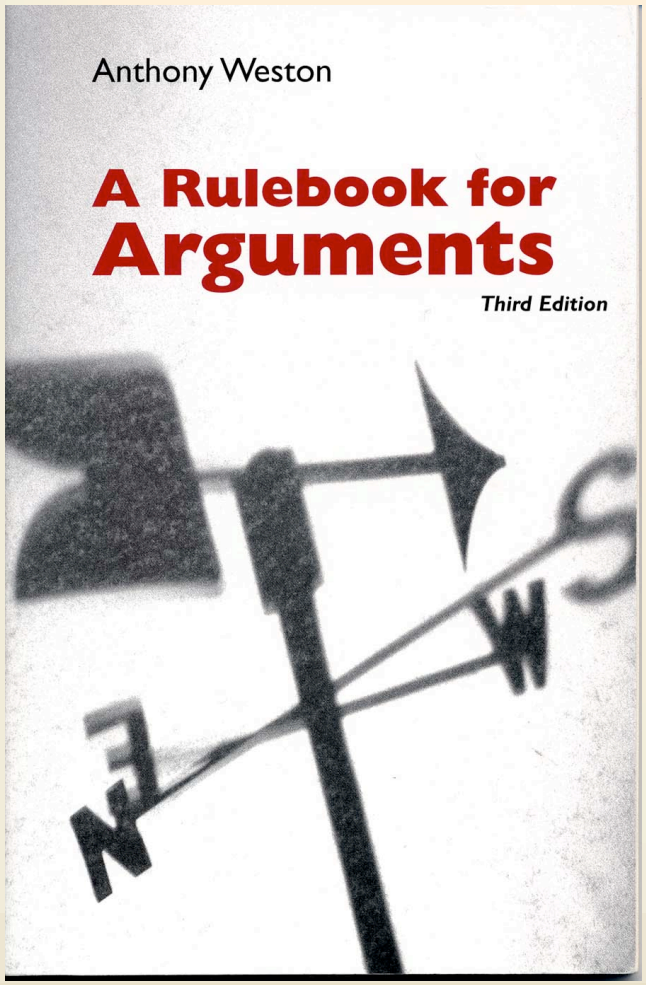
1. Socrates was Greek. (premise)
2. Most Greeks eat fish. (premise)
3. Socrates probably ate fish. (conclusion)

deductive argument:
conclusion follows necessarily from the premises and inferences.

1. All men are mortal. (premise)
2. Socrates was a man. (premise)
3. Socrates was mortal. (conclusion)

Any inductive argument can also be expressed deductively, and any deductive argument can also be expressed inductively.

Composing an argument



1. Distinguish premises and conclusion
2. Present your ideas in a natural order
3. Start from reliable premises
4. Be concrete and concise
5. Avoid loaded language
6. Use consistent terms
7. Stick to one meaning for each term

Arguments by example
Arguments by analogy
Arguments from authority
Arguments about causes

Deductive arguments

Critical thinking and Fallacies

critical thinking online:

http://www2.sjsu.edu/depts/itl/graphics/main.html

Fallacies are technically incorrect and misleading arguments. They are often logical arguments which appear to be correct but which can be seen to be incorrect when examined more closely.

Many exercises on this website

Two common fallacies in public discussions of climate

1. **drawing conclusions from too little evidence.**

e.g. This winter in Detroit was hot/cold. Therefore, global warming has already begun/does not exist.

2. **overlooking alternatives.**

e.g. Icebergs are melting. Sea level is rising. Therefore, melting icebergs are raising sea level. (what about thermal expansion, continental ice?)

e.g. The stratosphere is cooling. Therefore, global warming is not happening. (what about stratospheric ozone depletion?)

Argumentum ad hominem

Argumentum ad hominem: literally "argument against the person". Attacking the *person* of an authority rather than his or her qualifications.	"You can't listen to that scientist; she drives an SUV." "Don't vote for that energy initiative-- it was written by the auto industry."	"Of course you would think the earth is warming; you're from radical Berkeley." "You say now that climate is warming, but 20 years ago, you thought that climate was cooling."

Information or suspicions about vested interests, hidden agendas, predilections, or prejudices may make you more vigilant in your scrutiny of that argument--but they should not be allowed to influence its evaluation. However, in the case of **opinions**, expert and otherwise, where you must rely not on the argument or evidence being presented but on the judgment of someone else, personal or background information may be used to evaluate the ideas expressed.

9 common fallacies that I hear when people argue about global warming

Shifting burden of proof / ad ignoratiam (appeal to ignorance): arguing a claim is true just because it has not shown to be false	Argumentum ad nauseum-belief that an assertion is true the more often it is heard.	Sweeping generalizations: incl, drawing conclusions from too little evidence, overlooking alternatives.
Bifurcation/ false dilemma- "black and white" fallacy. One presents a situation as having only 2 alternatives, when in fact other alternatives exist	Appeal to common belief / ad populum: appealing to emotions of crowd. "Everyone's doing it." no reasons are offered to show that "everybody" is an informed or impartial source	Straw man- misrepresent someone else's position so that it can be attacked more easily, then to knock down that misrepresented position, then to claim that the the original position has been demolished
Plurium interrogationum-many questions; fallacy occurs when a questioner demands a simple answer to a complex question.	Slippery slope argument- states that should one event occur, so will other harmful events	Argumentum ad logicam- "fallacy fallacy" arguing a proposition is false merely on the grounds that it has been the conclusion of a fallacious argument.

Fallacious arguments on both sides

1.	CO_2 will harm all plants because it has been shown to harm corn	CO_2 benefits all plants because it has been shown to benefit cotton.
2.	Humans cannot live in a world with 400 ppm CO_2 because there is no evidence that we have ever been able to do it.	The current global temperature rise is natural because climate models are imperfect and therefore cannot prove otherwise.
3.	You object to the Kyoto protocol? You don't believe in treaties, but treaties have been shown to end wars, so your opposition to Kyoto has been proven throughout history to be misguided.	You think we need to limit greenhouse gases? Sure, you want us to go back and live in caves and live like savages. That isn't realistic, so limiting greenhouse gases is foolish.

Fallacious arguments on both sides

4.	The movie Waterworld shows that global warming will flood most continents on this planet.	Global warming is a myth. Michael Crichton's new fiction book says so. Senator Inhofe agrees.
5.	In a recent poll, most Americans believe that climate change is real, so you should too. (note the difference between this and 'most scientists believe that climate change is real)	In a recent poll, most Americans don't believe that climate change is real. (what gives them the authority to make such a science judgment?)

Fallacious arguments on both sides

6.	"Global warming will destroy the earth! The planet will be uninhabitable! You are destroying the earth!"	"Climate change is a myth. It's a hoax. It's pure fiction. It's a trick. It isn't real." "WMDs"
7.	"You either support this legislation or else you support the rapid death of the planet."	"You either drill for oil, or we go back to living like cavemen". "Either you are with us or you are with the terrorists."
8.	"Will you follow your conscience instead of your pocketbook and support our legislation?"	"You say you want to protect these owls, but is the sacrifice of human lives worth the life of this bird, or do you want to support our economy?

Typical scientific arguments are inductive

All evidence presented, assessed, and conclusion drawn. (inductive scientific approach)

vs.

Conclusion drawn. Evidence drawn to support that conclusion, evidence cited to contradict contrary conclusion (deductive argument approach).

Scientific arguments typically entail attacking one or more premises on scientific grounds. To weed out documents that distort results, mix opinions with science, or present faulty logic, there is a process called **peer review** (a quality control certification filter) that gives us a body of acceptable representations of rigorous research.

III. Modern climate change: lines of evidence

Scientific reasoning based on the physics of the earth's energy balance

- The "greenhouse effect" is a reality that keeps our planet warmer than it would be without an atmosphere. (observations)
- CO_2, H_2O, CH_4, N_2O, and CFCs are important greenhouse gases.
- Atmospheric greenhouse gases are accumulating in the atmosphere.
- This rise in concentrations is due to human activities.
- These gases increase the radiative forcing on the planet. (deduction)
- Average global temperatures must rise to maintain radiative energy balance. (inference)

Scientific reasoning based on past climate on earth (observations)

•Greenhouse gas concentrations are intricately related to earth's climate.

•Warm times are associated with relatively high greenhouse gases and cold times are associated with low greenhouse gas concentrations.

•CO_2 concentrations are much higher now than any time in the last 420,000 years (the extent of our ice core record), probably > last million yrs.

•CH_4 and N_2O concentrations are also much higher now than any other time in our ice core record.

•The climate is sensitive enough that it will respond to the continued forcing of modern greenhouse gas increases. Temperatures will rise. (inference)

III. Modern climate change: testing the prediction

Predictions based on the scientific reasoning

- Earth is experiencing a forcing that will increase the energy input into the system.
- Greenhouse gas concentrations will continue to rise as long as fossil fuel combustion continues.
- Global atmospheric temperatures will rise.
- Global sea levels will rise
- Ecosystems and biota will respond to changing temperatures and climate.

Observations that confirmed the predictions

1. Global atmosphere AND ocean temperatures are indeed rising
2. Greenhouse gases are continuing to rise at unprecedented rates
3. Global average sea levels are rising
4. Ecosystems and biota are changing in response to climatic and other anthropogenic pressures.
5. An increasing body of observations gives a collective picture of a warming world and other changes in the climate system.

III. Modern climate change: defending the data

Objections to the data:

"Most land temperature measurements are taken in the city, which is subject to the **urban heat island** effect. Cities are warmer than their surroundings, thus biasing the temperature record, since many temperature records are near cities."

"Surface measurements indicate a 0.17 C/decade increase, but **satellite measurements** indicate only 0.04 C/decade. Satellites have much greater coverage so must be correct."

Latest results:

The urban heat island effect has been shown to have insignificant impact on the overall trends. Half of the rural stations showed greater effecs than the urban areas.

Much wrangling over the different records has occurred, but recent corrections to the satellite record largely resolve the inconsistencies. Global temperature increases since 1982 are estimated at 0.163 - 0.239° C /decade. Earth's average surface temperature has warmed by 0.6° C in the last century.

Modern climate change: detection to attribution

So global warming has been **detected**, but can we **attribute** the warming to humans?

In order to do this, we must separate the natural and anthropogenic causes of climate change. It is easier to separate natural vs. anthropogenic sources of greenhouse gases because of a range of chemical tools. For global climate, the primary tools are global climate models.
Radiative-convective models incorporate vertical energy exchanges
Energy-balance models include energy transfers between latitudes,
General Circulation Models incorporate the fields of motion in the atmosphere and/or oceans. (see TES, chapter 6)

Climate models: moving from **detection** to **attribution**.

Energy balance models can attribute past global temperature shifts to natural variabilities in solar input and albedo. In contrast, the modern temperature rise can only be explained if you include the forcing caused by human-produced greenhouse gases.