

ECONOMICS Lecture 2

The Scientific Methodology

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Topics

- What is Science?
- The Nature of Science
- Principles and Steps in Science
- Components of Scientific Theory
- Postulate of Economics: Rationality

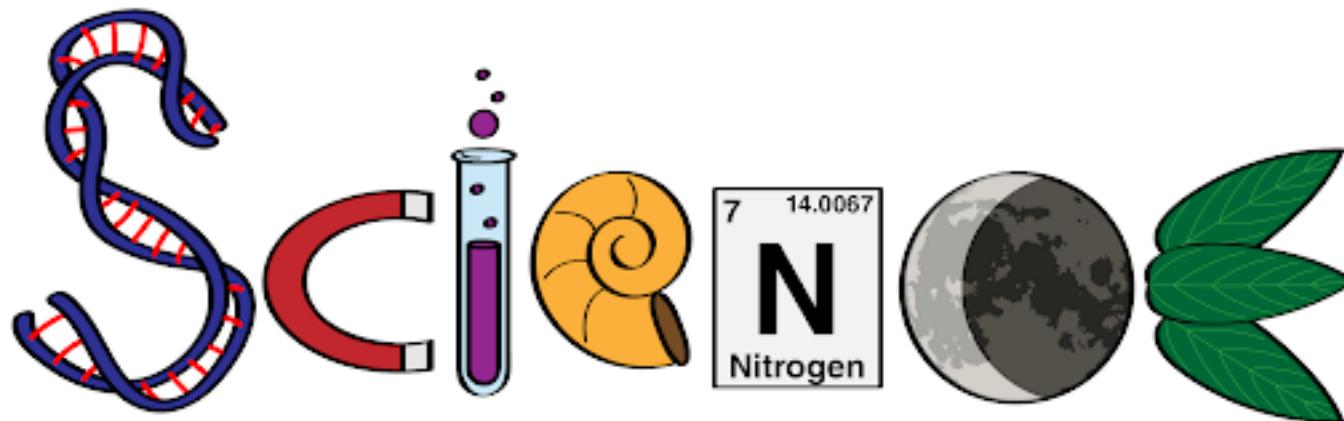


The lecture introduces the nature and development of science, explores the elements of Economics a social science, and provides the scientific foundation for economic study, analysis, and research.

What is Science?

Science (from Latin *scientia*, meaning "knowledge") is a systematic enterprise that builds and organizes knowledge in the form of **testable explanations and predictions about the universe**. In an older and closely related meaning, "science" also refers to a body of knowledge itself, of the type that can be rationally explained and reliably applied. A practitioner of science is known as a scientist.

Wikipedia



Classical Example - Newton's Apple

- According to legend, Isaac Newton was struck in the head by an apple while lying under a tree in an orchard in England.
- Whether it is a myth or a reality, the fact is certain that it was Newton who found the law of universal gravitation.
- Newton's law of universal gravitation is a widely accepted theory. It guides the efforts of scientists in their study of planetary orbits.
- Newton's First Law of Motion: Law of Inertia
- Newton's Second Law of Motion: Force = Mass • Acceleration
- Newton's Third Law of Motion: Law of Action and Reaction

Newton's Apple – Develop a Theory



Galileo's Experiment – Reject a Theory

According to the story, Galileo discovered through this experiment that the objects fell with the same acceleration, proving his prediction true, while at the same time disproving Aristotle's theory of gravity (which states that objects fall at speed proportional to their mass). Most historians consider it to have been a thought experiment rather than a physical test as there is little evidence that it actually took place, when he was a scientist.



Mendeleev's Table – Predictions

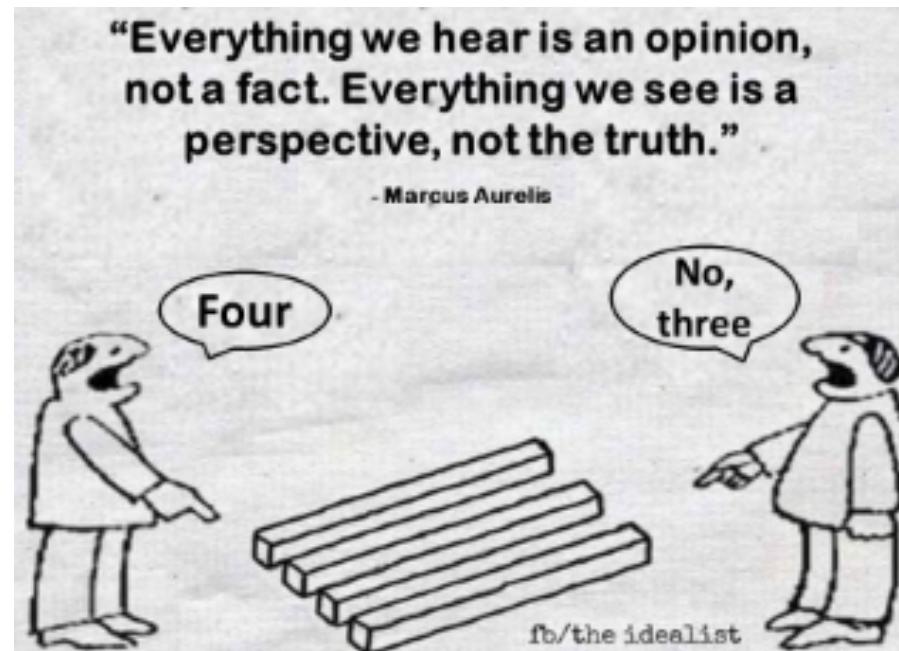
PubChem

1 H Hydrogen Nonmetal	2 He Helium Noble Gas
3 Li Lithium Alkali Metal	4 Be Beryllium Alkaline Earth Metal
11 Na Sodium Alkali Metal	12 Mg Magnesium Alkaline Earth Metal
19 K Potassium Alkali Metal	20 Ca Calcium Alkaline Earth Metal
37 Rb Rubidium Alkali Metal	38 Sr Strontium Alkaline Earth Metal
55 Cs Cesium Alkali Metal	56 Ba Barium Alkaline Earth Metal
87 Fr Francium Alkali Metal	88 Ra Radium Alkaline Earth Metal
1 H Hydrogen Nonmetal	Atomic Number Symbol Name Chemical Group Block
5 B Boron Metalloid	6 C Carbon Nonmetal
13 Al Aluminum Post-Transition Metal	14 Si Silicon Metalloid
15 P Phosphorus Nonmetal	16 S Sulfur Nonmetal
17 Cl Chlorine Nonmetal	18 Ar Argon Noble Gas
31 Ga Gallium Post-Transition Metal	32 Ge Germanium Metalloid
33 As Arsenic Nonmetal	34 Se Selenium Nonmetal
35 Br Bromine Nonmetal	36 Kr Krypton Noble Gas
49 In Indium Post-Transition Metal	50 Sn Tin Post-Transition Metal
51 Sb Antimony Metalloid	52 Te Tellurium Metalloid
53 I Iodine Nonmetal	54 Xe Xenon Noble Gas
81 Tl Thallium Post-Transition Metal	82 Pb Lead Post-Transition Metal
83 Bi Bismuth Post-Transition Metal	84 Po Polonium Metalloid
85 At Astatine Nonmetal	86 Rn Radon Noble Gas
104 Rf Rutherfordium Transition Metal	105 Db Dubnium Transition Metal
106 Sg Seaborgium Transition Metal	107 Bh Bohrium Transition Metal
108 Hs Hassium Transition Metal	109 Mt Meitnerium Transition Metal
110 Ds Darmstadtium Transition Metal	111 Rg Roentgenium Transition Metal
112 Cn Copernicium Transition Metal	113 Nh Nihonium Post-Transition Metal
114 Fl Florium Post-Transition Metal	115 Mc Moscovium Post-Transition Metal
116 Lv Livermorium Post-Transition Metal	117 Ts Tennessine Post-Transition Metal
118 Og Oganesson Noble Gas	
57 La Lanthanum Luminescent	58 Ce Cerium Luminescent
59 Pr Praseodymium Luminescent	60 Nd Neodymium Luminescent
61 Pm Promethium Luminescent	62 Sm Samarium Luminescent
63 Eu Europium Luminescent	64 Gd Gadolinium Luminescent
65 Tb Terbium Luminescent	66 Dy Dysprosium Luminescent
67 Ho Holmium Luminescent	68 Er Erbium Luminescent
69 Tm Thulium Luminescent	70 Yb Ytterbium Luminescent
71 Lu Lutetium Luminescent	
89 Ac Actinium Actinide	90 Th Thorium Actinide
91 Pa Protactinium Actinide	92 U Uranium Actinide
93 Np Neptunium Actinide	94 Pu Plutonium Actinide
95 Am Americium Actinide	96 Cm Curium Actinide
97 Bk Berkelium Actinide	98 Cf Californium Actinide
99 Es Einsteinium Actinide	100 Fm Fermium Actinide
101 Md Mendelevium Actinide	102 No Nobelium Actinide
103 Lr Lawrencium Actinide	

<https://pubchem.ncbi.nlm.nih.gov/periodic-table/>

Question: Science = Truth?

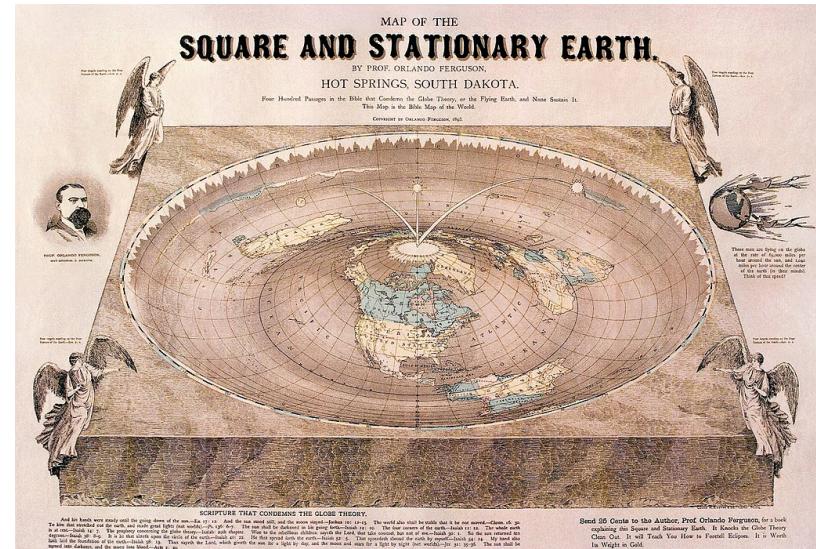
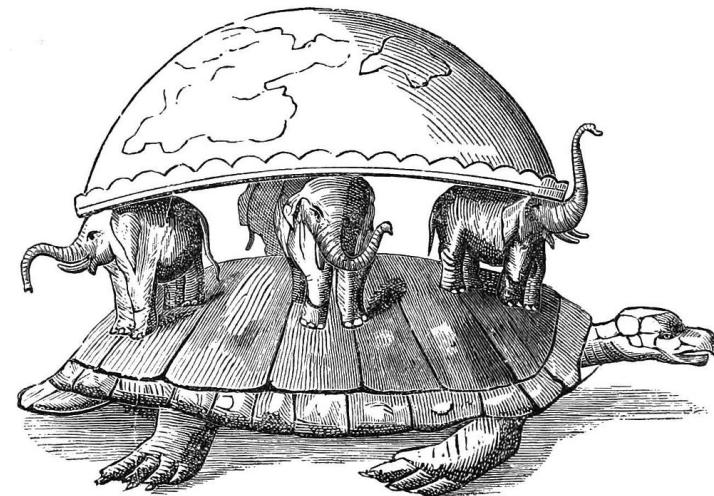
- Is science equivalent to truth? In what sense?
- What is truth and how can we find the truth?
- Is the statement “one plus one equals two” true?



<https://thecriticalthinkingandexaminedlifeblog.wordpress.com/2016/02/17/truth-or-not/>

Question: Science = Truth ?

The Flat Earth model is an archaic conception of Earth's shape as a plane or disk. Many ancient cultures subscribed to a Flat Earth cosmography, including Greece until the classical period, the Bronze Age and Iron Age civilizations of the Near East until the Hellenistic period, India until the Gupta period (early centuries AD), and China until the 17th century.



https://en.wikipedia.org/wiki/Flat_Earth

From Copernicus to Newton

- In 1543 Nicolaus Copernicus suggested that the Sun, rather than Earth, might be at the center of the universe. Newton's laws first appeared in his masterpiece, *Philosophiae Naturalis Principia Mathematica* (1687), commonly known as the Principia.
- In the intervening years Galileo, Johannes Kepler, and Descartes laid the foundations of a new science that would both replace the Aristotelian worldview, inherited from the ancient Greeks, and explain the workings of a heliocentric universe.
- In the Principia Newton created that new science. He developed his three laws in order to explain why the orbits of the planets are ellipses rather than circles, at which he succeeded, but it turned out that he explained much more. The series of events from Copernicus to Newton is known collectively as the **Scientific Revolution**.

Question: Science = Truth ?

Consider the history of people's inquiry into the center of the universe.

- Geocentrism
- Heliocentrism
- Galactic center
- Singularity
- Big bang



Where is the center of the universe? Can science provide the answer? Are we getting closer to the truth? Or further away?

Creation, Bible, and the Truth

The Creation account in Genesis describes all the land as existing "in one place" while all waters are gathered likewise. Geometrically, this can only happen on a sphere, and therefore Genesis implies a round earth.

Genesis 1: 9-10 And God said, “Let the water under the sky be gathered to one place, and let dry ground appear.” And it was so. God called the dry ground “land,” and the gathered waters he called “seas.”

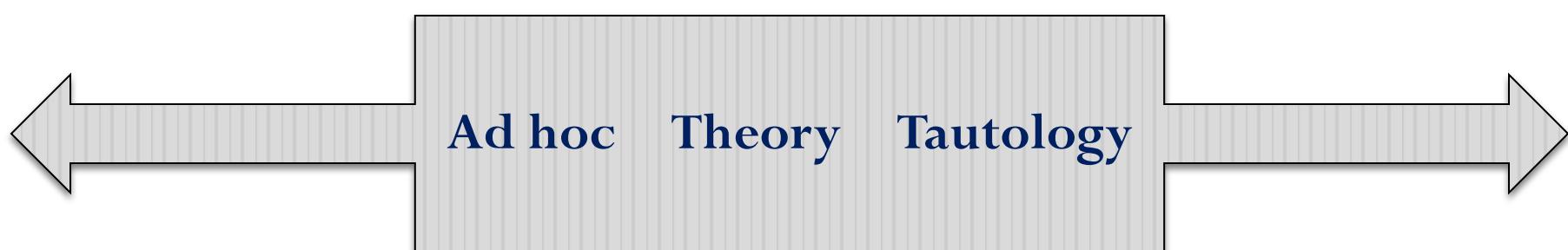
*Isaiah 40:22 It is he who sits above **the circle of the earth**, and its inhabitants are like grasshoppers; who stretches out the heavens like a curtain, and spreads them like a tent to dwell in;*

*Job 26:7 He stretches out the north over the void and hangs **the earth on nothing**.*

*John 14:6 Jesus said, “I am the way and **the Truth** and the Life....”*

Science: General Principles

- Science distinguishes a law or theory from facts.
- The universe has its own objective laws. (not random)
- Data/facts cannot be self-explanatory. (not ad hoc)
- It requires abstract theory to explain. (not tautology)



Natural Laws Described in the Bible

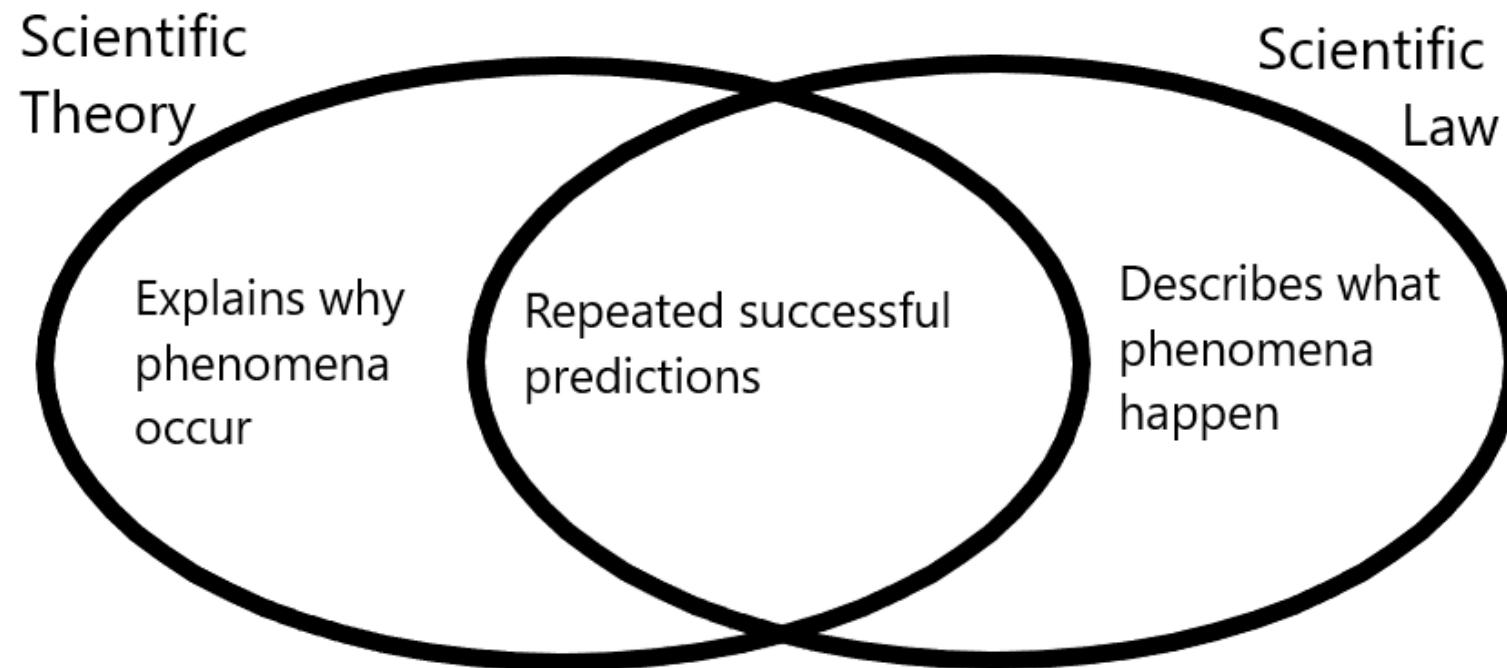
Genesis 8:22 While the earth remains, seedtime and harvest, cold and heat, summer and winter, day and night, shall not cease.

Matthew 13:6 But when the sun rose they were scorched. And since they had no root, they withered away.

Mark 13:28 Now learn this lesson from the fig tree: As soon as its twigs get tender and its leaves come out, you know that summer is near.

Isaiah 24:5-6 The earth lies defiled under its inhabitants; for they have transgressed the laws, violated the statutes, broken the everlasting covenant. Therefore a curse devours the earth, and its inhabitants suffer for their guilt; therefore the inhabitants of the earth are scorched, and few men are left.

Scientific Theory & Scientific Law



Scientific theories explain why something happens, whereas scientific law describes what happens. Laws differ from hypotheses and postulates, which are proposed during the scientific process before and during validation by experiment and observation. Hypotheses and postulates are not laws, since they have not been verified to the same degree, although they may lead to the formulation of laws.

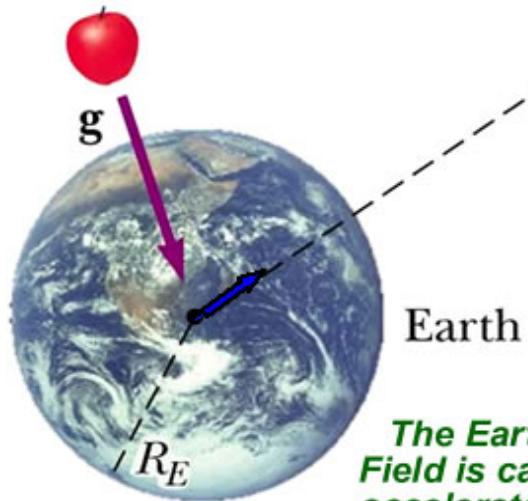
Where a Good Theory Stands?

- First of all, science requires that we cannot use facts to explain facts. Otherwise, it becomes ad hoc. Ad hoc is a special theory that only explains one particular type of phenomena. Example: classification of gravity.
- Second, we cannot make tautological statements to explain something. Tautology means repeating or describing something in a different way. Examples: Money is currency. Gobi is a desert. Biped has two feet.
- Both do not make a lot of sense in developing an elegant theory. A robust scientific theory stands in between.
- Science can be a state of the art. (e.g., $F=ma$ or $E=MC^2$)

Example: Where a Good Theory Stands?

**Newton's Universal Law
of Gravitation**

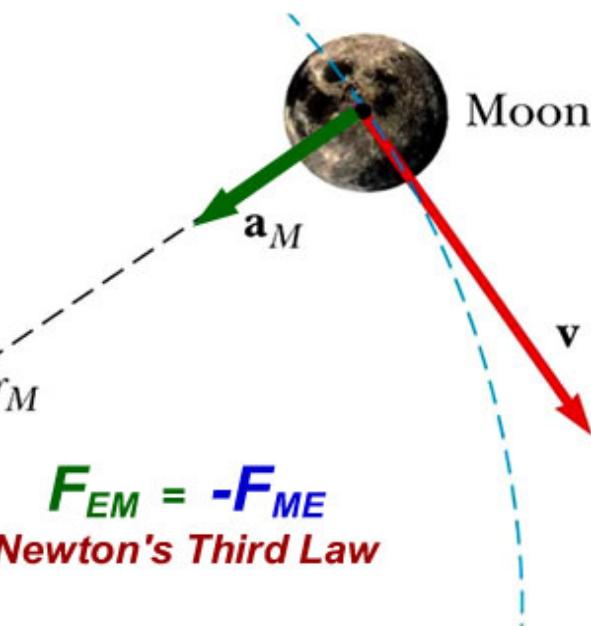
$$F_G = \frac{Gm_E m_M}{r_{EM}^2}$$



The Moon's Gravitational Field is causing the Earth to accelerate toward the Moon.

$F_{EM} = -F_{ME}$
Newton's Third Law

The Earth's Gravitational Field is causing the Moon to accelerate toward the Earth.



Components of a Scientific Theory

- **Postulate:** a statement assumed to be true without proof. They serve to explain undefined terms, and to serve as a starting point for proving other statements. Postulates are not facts.
- **Assumption:** a statement that is assumed to be true and from which a conclusion can be drawn. Scientists often make simplified and unrealistic assumptions for constructing a model.
- **Model:** a schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics.
- **Test:** Theory is abstract and unrealistic. To test a theory, scientists must derive and formulate observable implications.

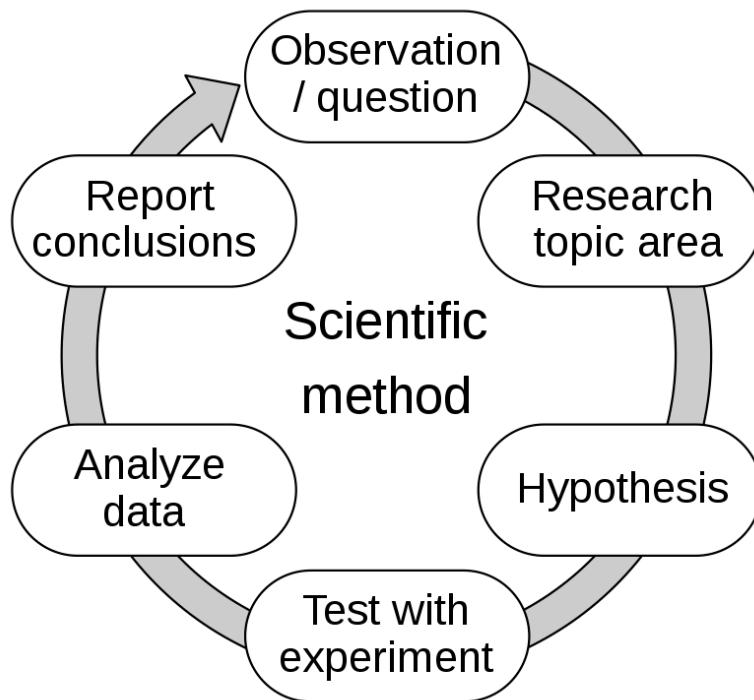
Example: Postulates in Geometry

Euclidean geometry is an axiomatic system, in which all theorems are derived from a small number of axioms. Near the beginning of the first book of the Elements, Euclid gives five postulates for plane geometry, stated in terms of constructions. **Postulates do not have to be facts and can be unrealistic.**

"Let the following be postulated":

1. To draw a straight line from any point to any point.
2. To produce a finite straight line continuously in a straight line.
3. To describe a circle with any center and distance.
4. That all right angles are equal to one another.
5. The parallel postulate.

Scientific Method: Procedures



The scientific method involves careful observation, applying rigorous skepticism about what is observed, given that cognitive assumptions can distort how one interprets the observation. It involves formulating hypotheses, via induction, based on such observations; experimental and measurement-based testing of deductions drawn from the hypotheses; and refinement (or elimination) of the hypotheses based on the experimental findings.

Scientific Method: Hypothesis Testing

- The process in the scientific inquiry involves making conjectures (hypotheses), deriving predictions from them as logical consequences, and then carrying out experiments or empirical observations based on those predictions.
- A hypothesis is a conjecture, based on knowledge obtained while seeking answers to the question. The hypothesis might be very specific, or it might be broad. **Most important, scientists must be able to test hypotheses by conducting experiments or studies.**
- A scientific hypothesis must be falsifiable, implying that it is possible to identify a possible outcome of an experiment or observation that conflicts with predictions deduced from the hypothesis; otherwise, the hypothesis cannot be meaningfully tested.

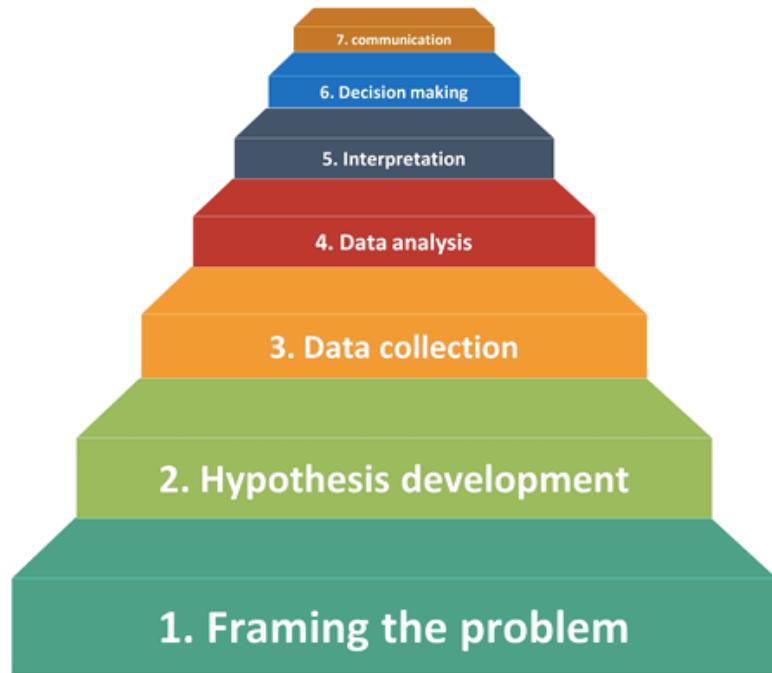
Summary: Steps in Scientific Inquiry

- Start from the real life observation and data, trying to explain
- State the postulate, make assumptions, and develop a theory
- Derive testable or refutable implications from the model
- Collect and process data, design experiment to test the theory
- Reject or accept; improve and apply the theory in practice

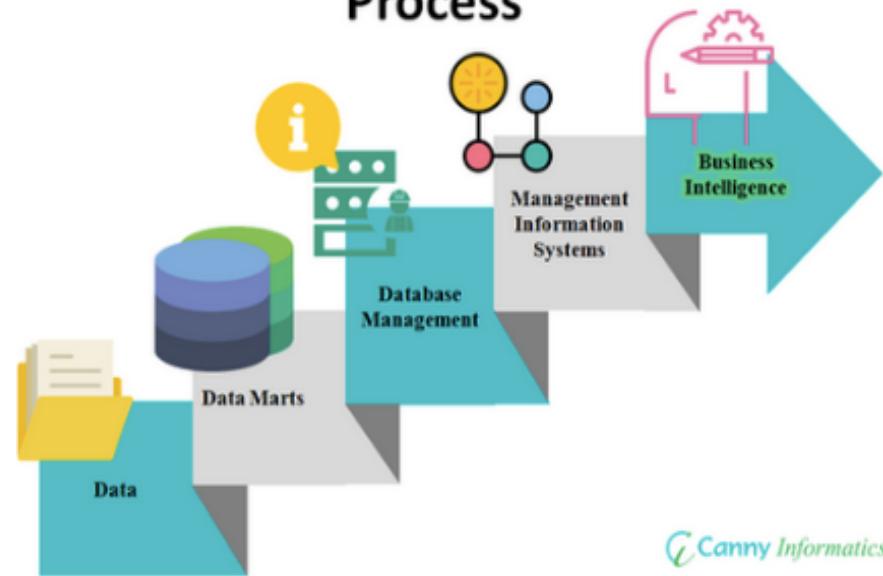
Remember: There is no perfect theory.

All models are wrong but can be useful.

Data for Scientific Decision Making



Effective Decision Making Process



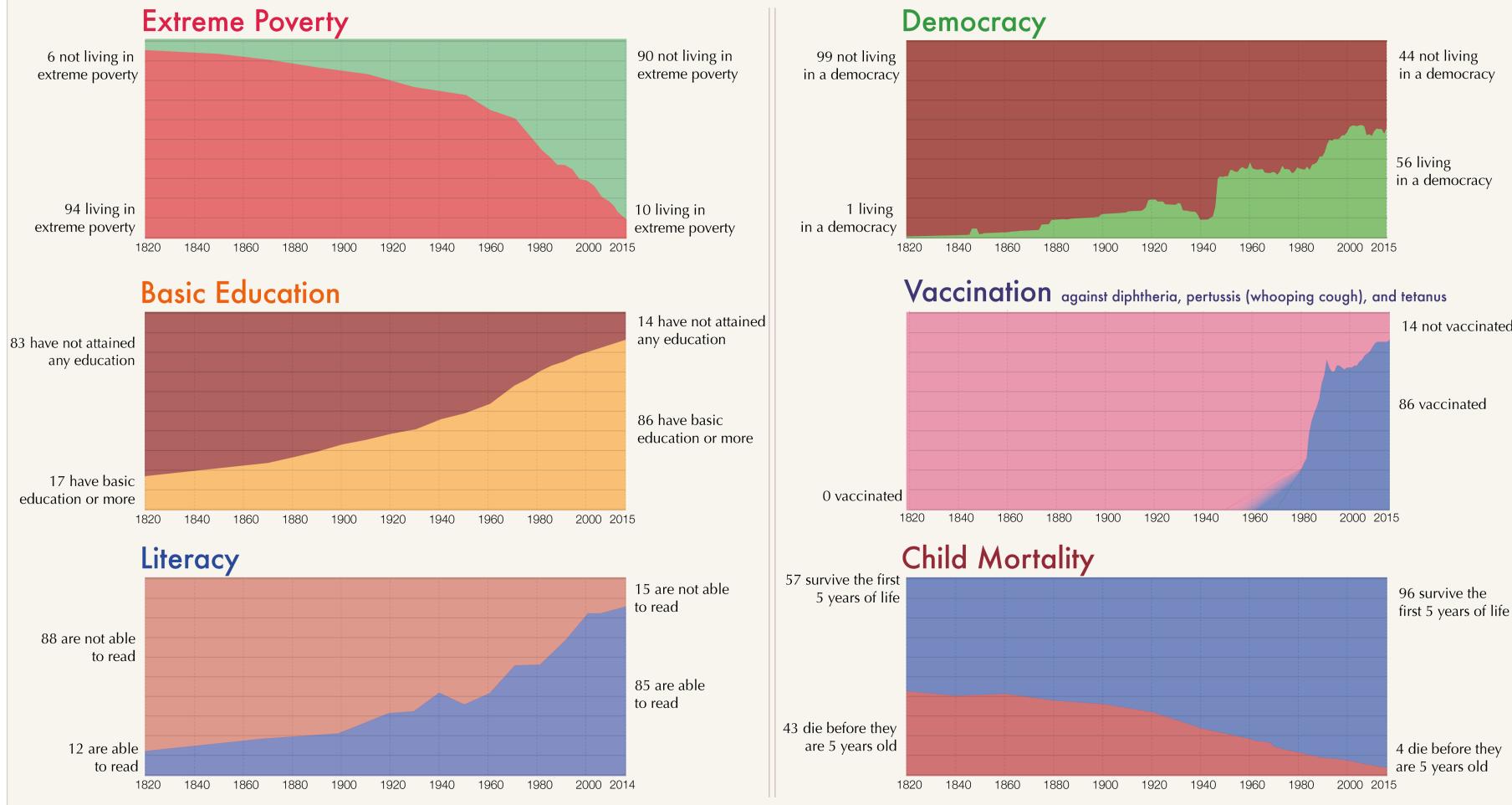
Canny Informatics

- Steps in Scientific Research
- Data System in Business

Economics as a Science

- Real life is our lab. Like other sciences, Economics consists of explanations (theories) that help us understand and make valid predictions about the real world, together with the empirical evidence (observations and data) for and against them.
- The scientific method requires scientists to use abstract theory based on certain assumptions to help explain how a complex, real world operates. More importantly, theory developed this way shall be subject to empirical test.
- Connecting the dots between theory and practice, scientists can test, evaluate, improve and apply the theory.
- For objective analysis, decision making and evaluation, economists emphasize the special role of data in an ever-changing world.

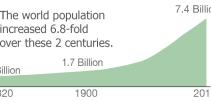
The World as 100 People over the last two centuries



Data sources:

Extreme Poverty: Bourguignon & Morrison (2002) up to 1970 – World Bank 1981 and later (2015 is a projection).
 Vaccination: WHO (Global data are available for 1980 to 2015 – the DPT3 vaccination was licensed in 1949)
 Education: OECD for the period 1820 to 1960, IIASA for the time thereafter.
 Literacy: OECD for the period 1820 to 1990, UNESCO for 2004 and later.

Colonialism: Wimmer and Min (own calculation of global population share)
 Continent: HYDE database
 Child mortality: up to 1960 own calculations based on Gapminder; World Bank thereafter



All these visualizations are from OurWorldInData.org an online publication that presents the empirical evidence on how the world is changing.

Licensed under CC-BY-SA by the author Max Roser.

The Postulate of Economics

The starting point of the economic science:

Rationality / Economic Man / Self-Interest

- What does it mean by rationality?
- Is it a realistic or true assumption?
- Does it mean people do not make mistakes?
- What is the implication of rationality in economics?

Adam Smith on Self-Interest

The natural effort of every individual to better his own condition...is so powerful, that it is alone, and without any assistance, not only capable of carrying on the society to wealth and prosperity, but of surmounting a hundred impertinent obstructions with which the folly of human laws too often encumbers its operations.

The Theory Of Moral Sentiments, Part I, Section I, Chapter I, p. 9, para. 1.

How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortune of others, and render their happiness necessary to him, though he derives nothing from it except the pleasure of seeing it.

Lecture in 1755, quoted in Dugald Stewart, Account Of The Life And Writings Of Adam Smith LLD, Section IV, 25.

Adam Smith on Invisible Hand

*Every individual... neither intends to promote the public interest, nor knows how much he is promoting it... he intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an **invisible hand** to promote an end which was no part of his intention.*

The Theory Of Moral Sentiments, Part IV, Chapter I, pp.184-5, para. 10.

On incentives and perverse incentives:

*It is **the interest of every man** to live as much at his ease as he can; and if his emoluments are to be precisely the same, whether he does, or does not perform some very laborious duty, it is certainly his interest...either to neglect it altogether, or...to perform it in [a] careless and slovenly a manner...*

The Wealth Of Nations, Book V, Chapter 1, Part II, p. 719, para. b20.

Adam Smith on Invisible Hand

*[The rich] consume little more than the poor, and in spite of their **natural selfishness** and rapacity...they divide with the poor the produce of all their improvements. They are led by an **invisible hand** to make nearly the same distribution of the necessaries of life, which would have been made, had the earth been divided into equal portions among all its inhabitants, and thus without intending it, without knowing it, advance the interest of the society, and afford means to the multiplication of the species.*

The Wealth Of Nations, Book IV, Chapter V, Digression on the Corn
Trade, p. 540, para. b 43.

Postulate of Economics: Highlights

- It is not a fact because we can't observe it.
- It doesn't necessarily have to be real and true. Why?
- We cannot use this postulate to explain facts. Why?
- We can derive a theory based on this postulate.
- The theory is subject to empirical test and evidence.

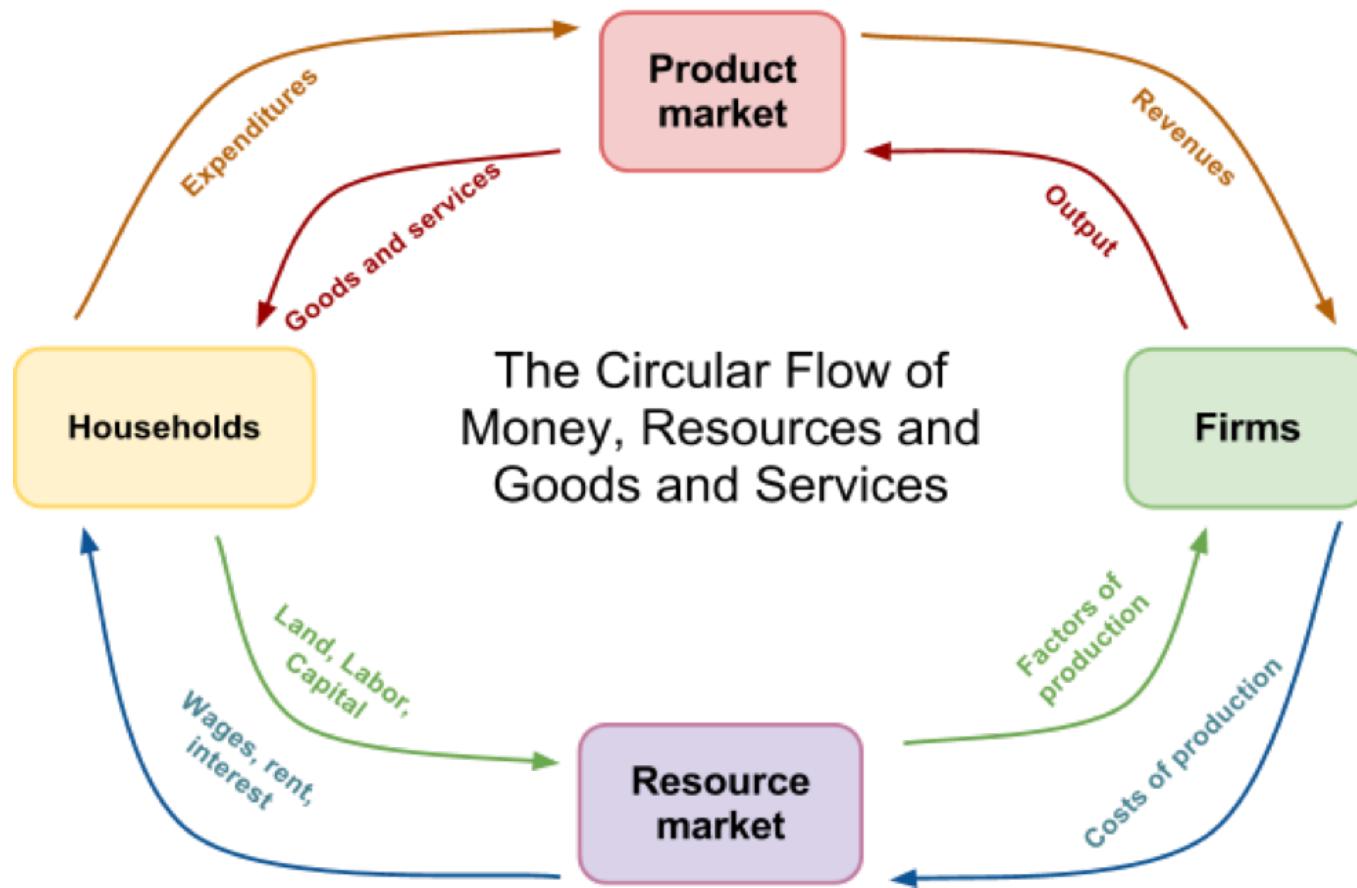
What distinguishes science from other forms of knowledge is whether the explanations/hypotheses/implications derived from the postulate and theory can be testable or verifiable.

Theory evaluation is equally necessary as theory construction.

Economic Theory and Models

- Economic theory is a systematic collection of the ideas and principles that aim to describe how economies work. Economists use models to simplify reality in order to improve our understanding of the world and help us make predictions/decisions.
- Models can be displayed in various forms, mostly in mathematical equations or geometric graphs. In microeconomics, production possibilities frontier (PPF) and the demand and supply model (D-S), for instances, are two of the most fundamental tools.
- To help us visualize the complex economic system, the first model in our lecture is the **circular-flow model**. It includes two economic agents and two different markets in exchange for goods and services (output/product market) and for land, labor, capital (resource/factor market). To facilitate all these transactions, money is the medium of exchange and unit of account.

The Circular-Flow Diagram



Economic Theory and Prediction

- Example 1: According to the RAND Health Insurance Experiment conducted in 1974-1982, generous health insurance can increase health-care usage and costs without generating better physical health outcomes (Aron-Dine et al, 2013).
- Example 2: The law of demand predicts that regions engaging in international trade tend to export high quality products abroad and keep regular products for domestic consumption. (e.g., Washington apples, California nuts, Florida oranges)
- Example 3: Gravity model in explaining international trade: The trade volume between two nations is proportional to their economic sizes but inversely related to the square distance between the two countries (Anderson, 2011).

Ronald Coase on Economic Research

"As I see it, progress in understanding the working of the economic system will come from an interplay between theory and empirical work. The theory suggests what empirical work might be fruitful, the subsequent empirical work suggests what modification in the theory or rethinking is needed, which in turn leads to new empirical work. If rightly done, scientific research is a never-ending process, but one that leads to greater understanding at each stage."

- The Conduct of Economics: The Example
of Fisher Body and General Motors, 2006

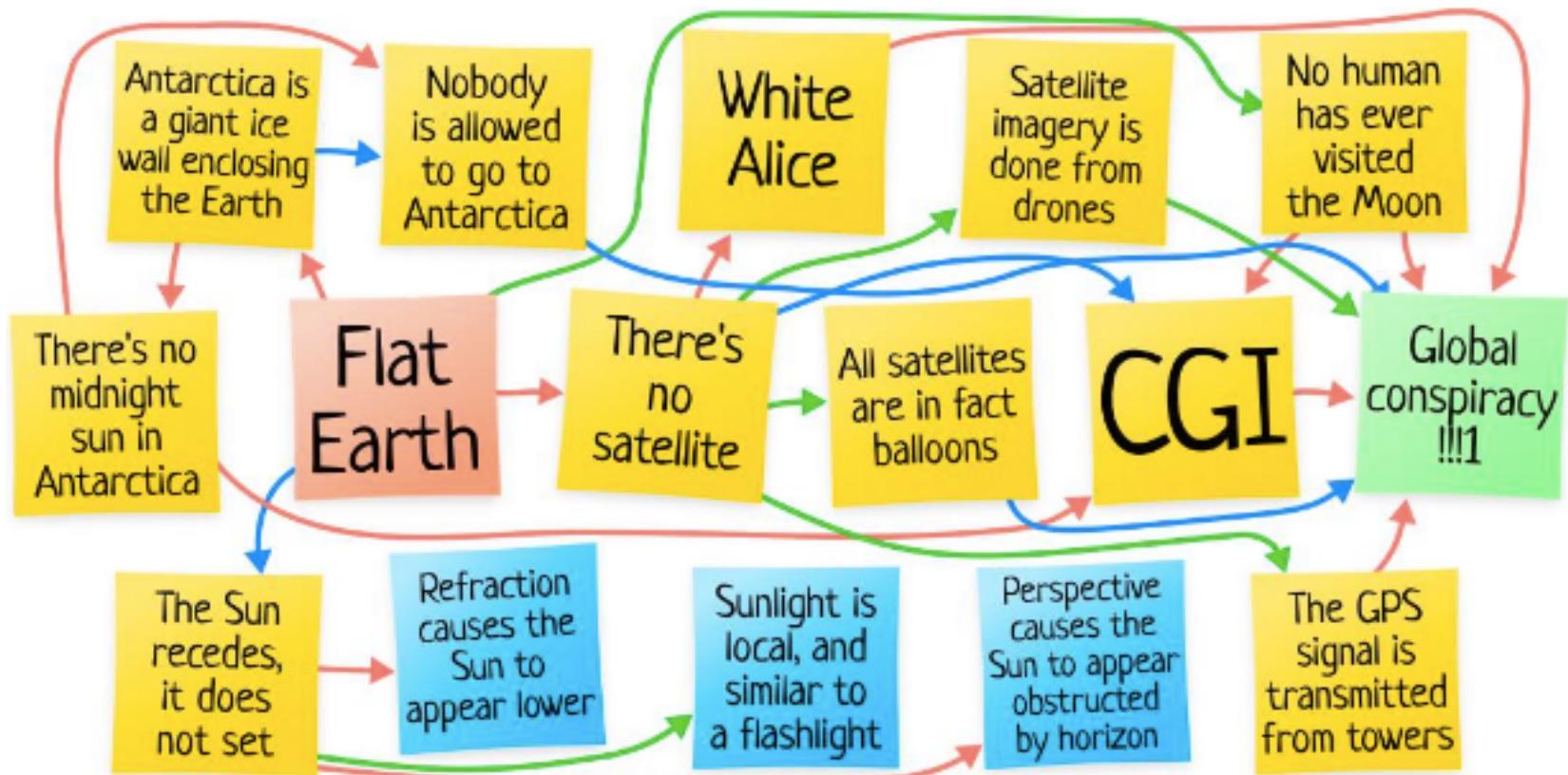
Reference and Appendix

- [1] <http://en.wikipedia.org/wiki/Science>
- [2] <http://undsci.berkeley.edu/index.php>
- [3] <http://en.wikipedia.org/wiki/Postulate>
- [4] <https://en.wikipedia.org/wiki/Theorem>
- [5] https://en.wikipedia.org/wiki/Scientific_law
- [6] <http://www.physicsclassroom.com/class/circles/U6L3c.cfm>
- [7] <http://library.thinkquest.org/2647/geometry/intro/p&t.htm>
- [8] http://en.wikipedia.org/wiki/History_of_the_Center_of_the_Universe
- [9] Ad hoc hypothesis <http://skepdic.com/adhoc.html>
- [10] From Abracadabra to Zombies <http://skepdic.com/contents.html>
- [11] Tautology quotes <https://www.azquotes.com/quotes/topics/tautology.html>
- [12] Leonard Mlodinow (2016) The upright thinkers. Vintage. ISBN 9780345804433

Ad Hoc Hypothesis & Explanation

- The Latin *ad hoc* means "for this (special purpose)." The term is normally used more narrowly to refer to some explanation which exists for no other reason but to save a favored hypothesis.
- It is thus not an explanation which is supposed to help us better understand a general class of events.
- Almost any explanation could be considered "ad hoc" if we define the concept broadly enough because every hypothesis is designed to account for some observed event.
- A key characteristic of ad hoc rationalizations is that the "explanation" offered is only expected to apply to the one instance in question.
- For whatever reason, it is not applied any other time or place where similar circumstances exist and is not offered as a general principle which might be applied more broadly.

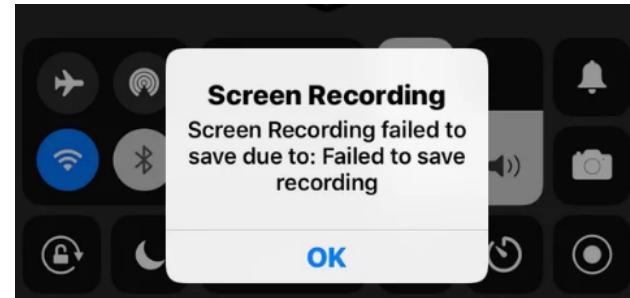
Ad Hoc Hypothesis: Example



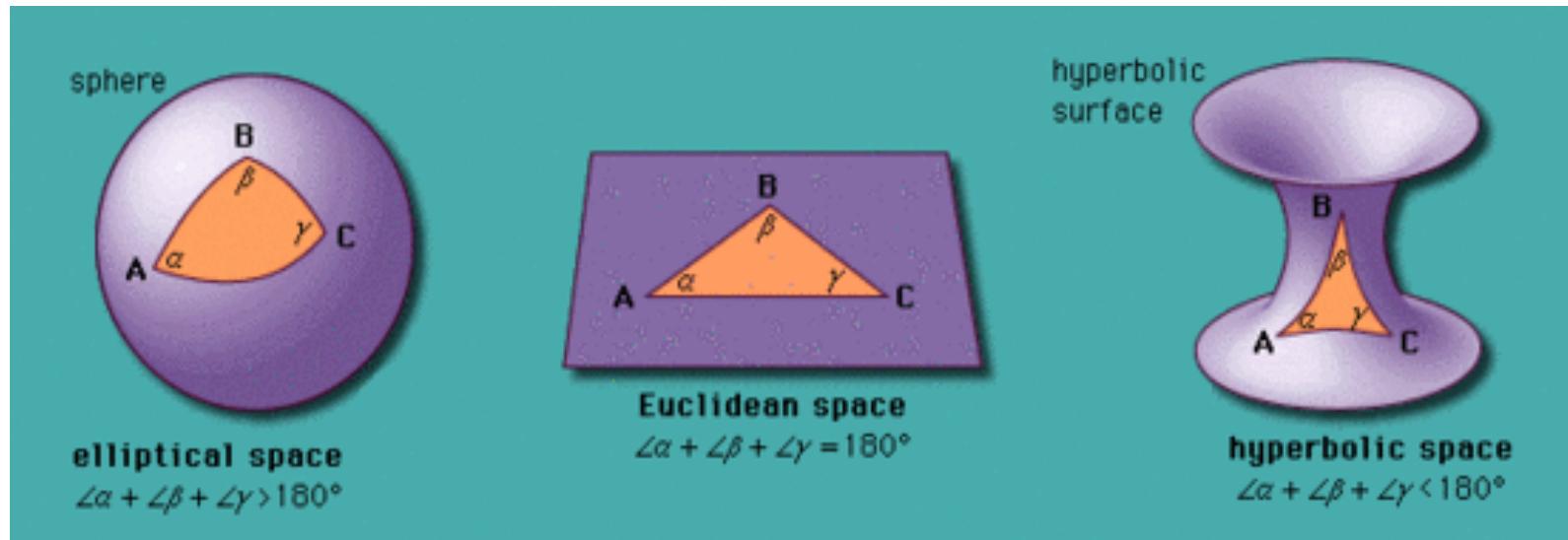
The flat-Earth model survives not because the Earth is flat, but because every time a problem is found, its proponents would quickly invent an ad-hoc hypothesis to explain the problem away. This would continue without any attempt to reject it. The long chains of ad-hoc hypotheses will eventually reach unfalsifiable hypothesis.

Tautology and Contradiction

- A tautology is a compound statement that is always true.
- A contradiction is a compound statement that is always false.
- An implication is a conditional statement that is a tautology.



Euclidean vs Non-Euclidean Geometry



For over two thousand years, the adjective "Euclidean" was unnecessary because no other sort of geometry had been conceived. Euclid's axioms seemed so intuitively obvious that any theorem proved from them was deemed true in an absolute, often metaphysical, sense. Today, however, many other self-consistent non-Euclidean geometries are known, the first ones having been discovered in the early 19th century.

Occam's Razor: Law of Parsimony

- The problem-solving principle that states “Entities should not be multiplied without necessity.”
- The razor's statement that "other things being equal, simpler explanations are generally better than more complex ones" is amenable to empirical testing.
- Occam's razor says that when presented with competing hypotheses that make the same predictions, one should select the solution with the fewest assumptions, and it is not meant to be a way of choosing between hypotheses that make different predictions.

