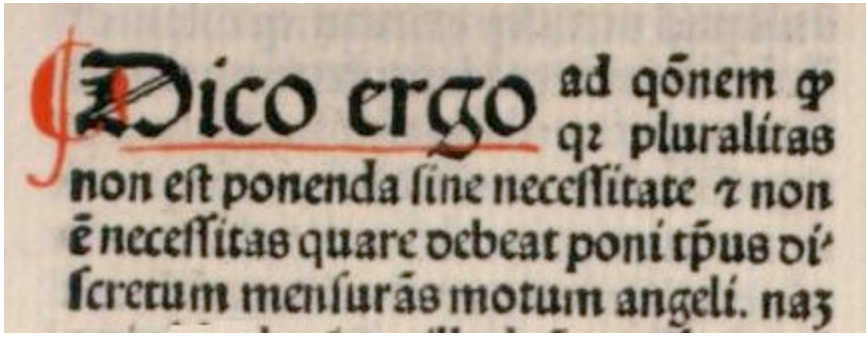
What is Science?

modes of logic: inference to the best explanation

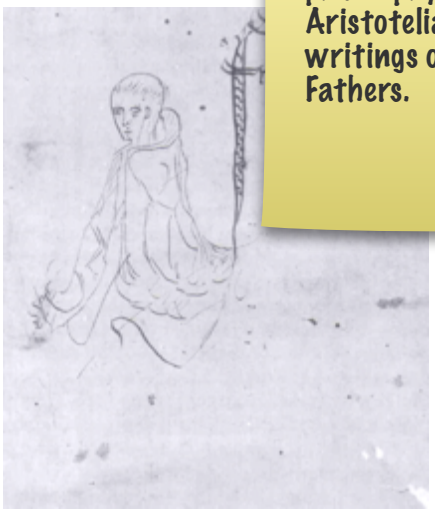
Before we get into this, let's look at what "best" means.

Occam's razor:

scholasticism: medieval european theology and philosophy based on Aristotelianism and writings of the Catholic Fathers.


Dico ergo ad qōnem q
qz pluralitas
non eſt ponenda ſine neceſſitate ⁊ non
ē neceſſitas quare debeat poni tp̄us di
ſcretum menſurās motum angeli. naz

Part of a page from Duns Scotus' book *Ordinatio*: "*Pluralitas non est ponenda sine necessitate*", i.e., "Plurality is not to be posited without necessity"



William of Ockham (1287 - 1347) was an English Franciscan friar, scholastic philosopher, and theologian.

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Problems with Occam's razor:

- who decides what is simple?
- how do you decide what data to compare to?

Notice that the hypothesis implies a prediction: islands get older as you go west.

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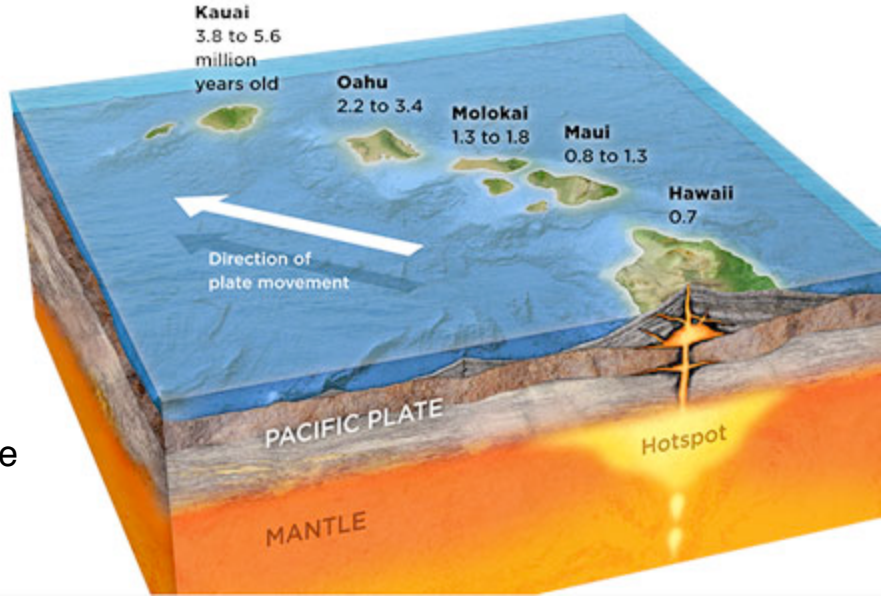
Ex: Early models of the Earth's structure that postulated tectonic motion were rejected because moving continents seemed overly complex and implausible. But this position was reversed as more evidence in favour of the hypothesis was discovered.

Ex: The atomic paradigm was thought to be complex because it implied the existence of particles that had not been observed. Again, the weight of observations, and especially the parsimonious explanation of Brownian motion in terms of atomic interactions by Einstein, turned the tide.



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Problems with Occam's razor:

- who decides what is simple?
- how do you decide what data to compare to?
- Paul Dirac proposed a more extreme version of Occam's razor: theories should be mathematically beautiful

$$\left[i\gamma^{\mu}(\frac{\partial}{\partial x^{\mu}} + ieA_{\mu}) - m\right]\psi = 0$$ Dirac

$$i\hbar\frac{\partial}{\partial t}\psi = \left[\frac{1}{2m}\left(-i\hbar\nabla - \frac{e}{c}\vec{A}\right)^2 + e\phi - \frac{e\hbar}{2mc}\sigma\cdot B\right]\psi$$ Schroedinger

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Problems with Occam's razor:

- who decides what is beautiful?

In a tragic twist Dirac's equation was ultimately shown to be incomplete. Dirac though that the corrections were not `elegant' and hence regarded his life as a failure.

Paul Adrian Maurice Dirac (1902 - 1984) was a British theoretical physicist who made fundamental contributions to quantum mechanics and quantum field theory.

What is Science?

Let's get back to *modelling*. A model is part of a triplet of important concepts in science:

(scientific) law:

A law is a compact description of empirical properties of nature. It differs from a theory (see below) in that it does not explain the observations, it merely summarises them.

(scientific) theory:

Theories attempt to explain laws and fit them in a predictive framework.

Notice that this is not the common colloquial meaning of theory, which is something more like 'hypothesis'.

(scientific) model:

Models are logical frameworks intended to represent reality. Thus theories are special cases of models and many of the theories mentioned in the previous section are termed "models". However, the word is also used for simplified or idealised representations of nature.

What is Science?

Examples.

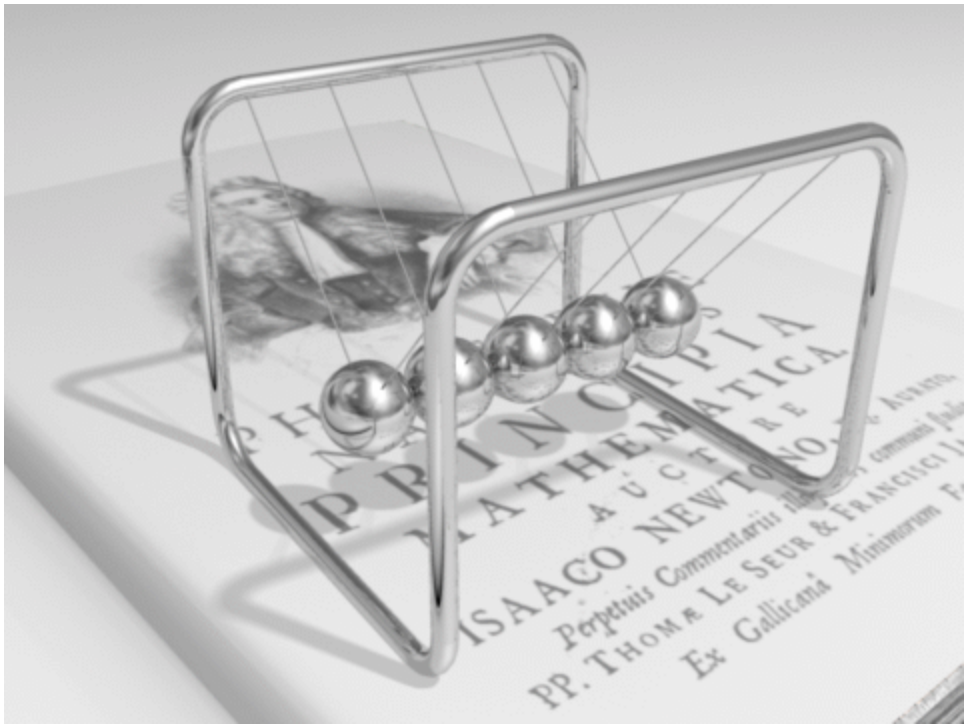
(scientific) laws:

Conservation of momentum.

Conservation of energy.

The second law of thermodynamics.

Boyle's Law.



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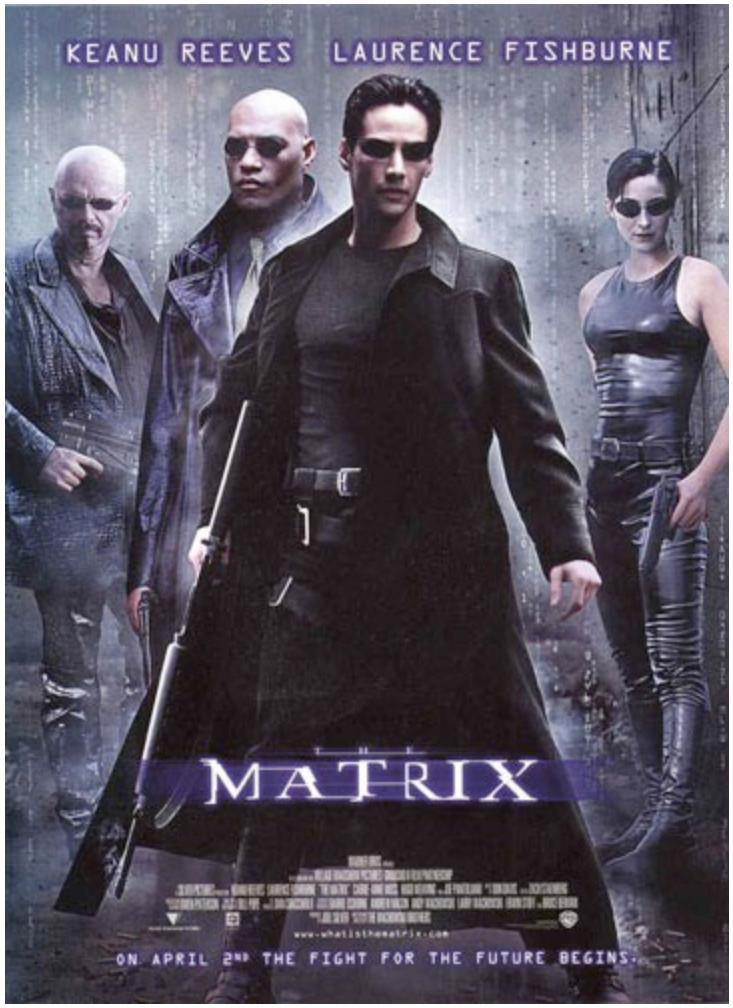

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Every collection of objects has a quantity called entropy associated with it. The entropy of the universe is always increasing. A number of colloquial versions of this exist:

- You can't win and you can't break even
- Disorder always increases in the universe
- Heat can not flow from a lower temperature to a higher temperature
- Perpetual motion machines are impossible

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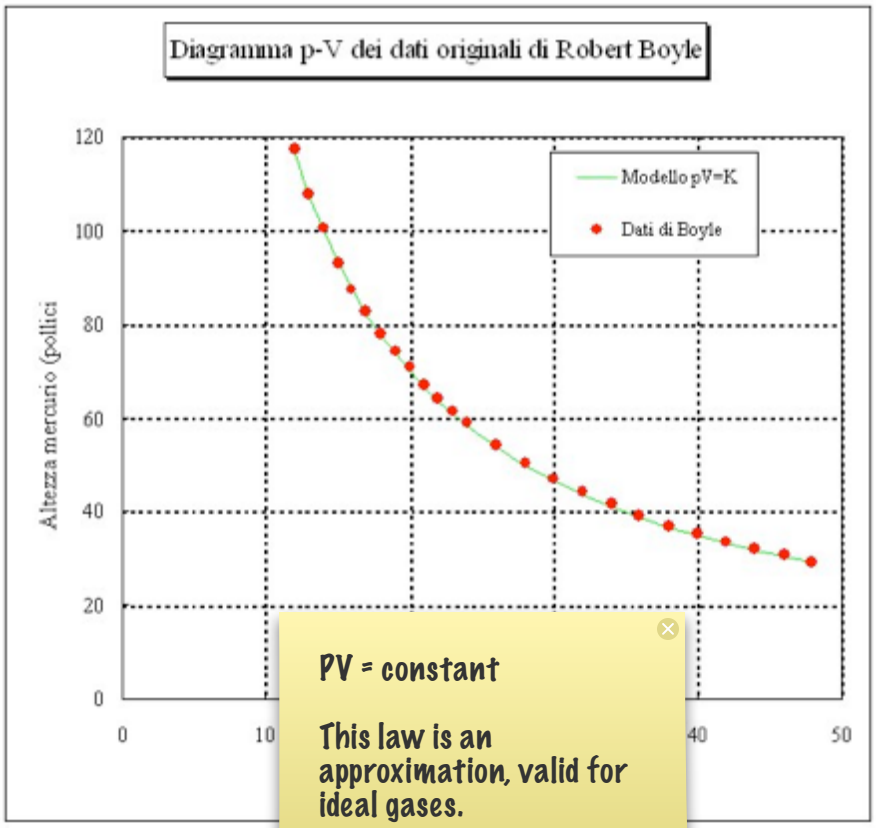

PV = constant

This law is an approximation, valid for ideal gases.

Ohm's law is a similar approximate law

What is Science?

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(scientific) laws:

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Conservation of energy.

exact

The second law of thermodynamics.

Boyle's Law.

approximate

What is Science?

Examples.

(scientific) theories:

Theory of Relativity

Newton's Theory of Gravity

Einstein's Theory of Gravity

The Concordance Model of Cosmology

The Standard Model

Theory of Evolution

Theory of Plate Tectonics

We will discuss these later.

will also discuss that theories can never be 'wrong' only more or less useful, or superseded.

notice that there are two theories of gravity!
This is not a problem, both are valid theories.

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Examples.

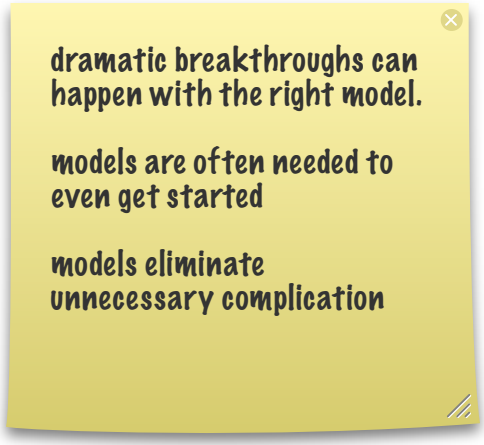
(scientific) models:

inclined plane

Earth

Solar System

rain model



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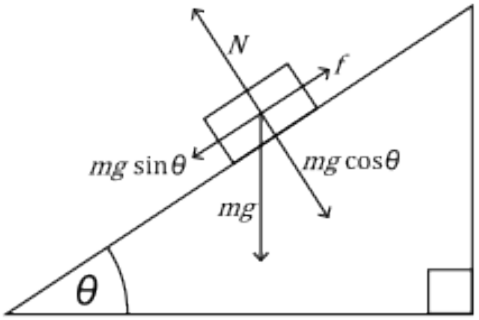

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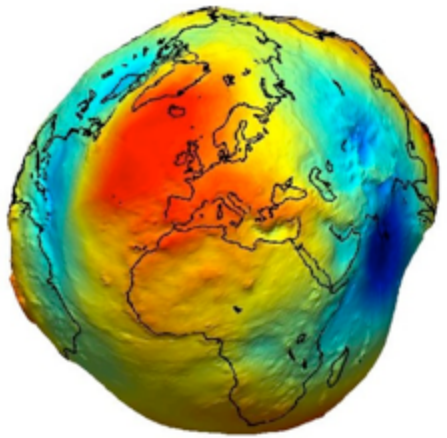

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