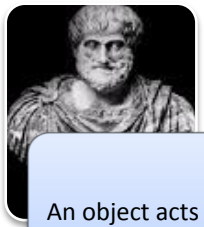
Causation

It’s not just for common folk!

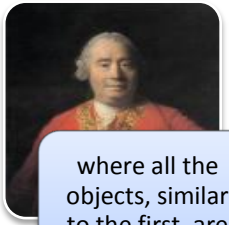
Science relies upon causal notions

"Inquiry in science is the pursuit of coherent, mechanistic accounts of natural phenomena" (Hammer, Russ, Mikeska, & Scherr, 2005)

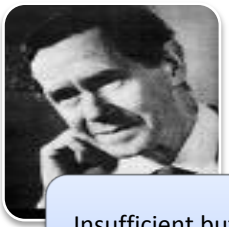
Causation has proved hard to define



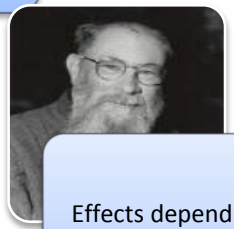
An object acts in accordance with its properties



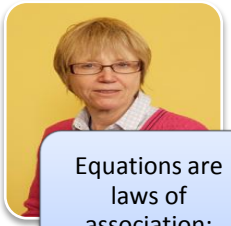
where all the objects, similar to the first, are followed by objects similar to the second



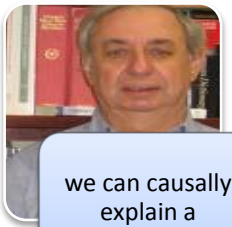
Insufficient but necessary part of unnecessary but sufficient conditions



Effects depend counterfactually on their causes



Equations are laws of association; causal laws are effective strategies



we can causally explain a situation when we can manipulate it

Causal Eliminitivists have challenged the role of causation in science

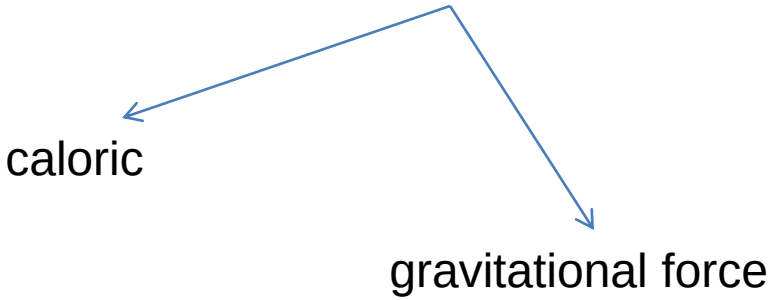
"The Law of Causation, the recognition of which is the main pillar of science, is but the familiar truth that invariability of succession is found by observation to obtain between every fact in nature and that which precedes it" (Mill, 1872)

"…the reason why physics has ceased to look for causes is that, in fact, there are no such things. The law of causality…is a relic of a bygone age, surviving, like the monarchy, only because it is erroneously supposed to do no harm." (Russell, 1913)

A fair compromise?

John Norton, (2003). Causation as Folk Science:

At a fundamental level, there are no causes and effects in science and no overarching principle of causality. However, in appropriately restricted domains our science tells us that the world behaves just as if it conformed to some sort of folk theory of causation….



The Causal Fundamentalist's Dilemma

First horn

EITHER causation places restrictions on factual content of science…

We must find some factual restriction that can be applied across all sciences…

Second horn

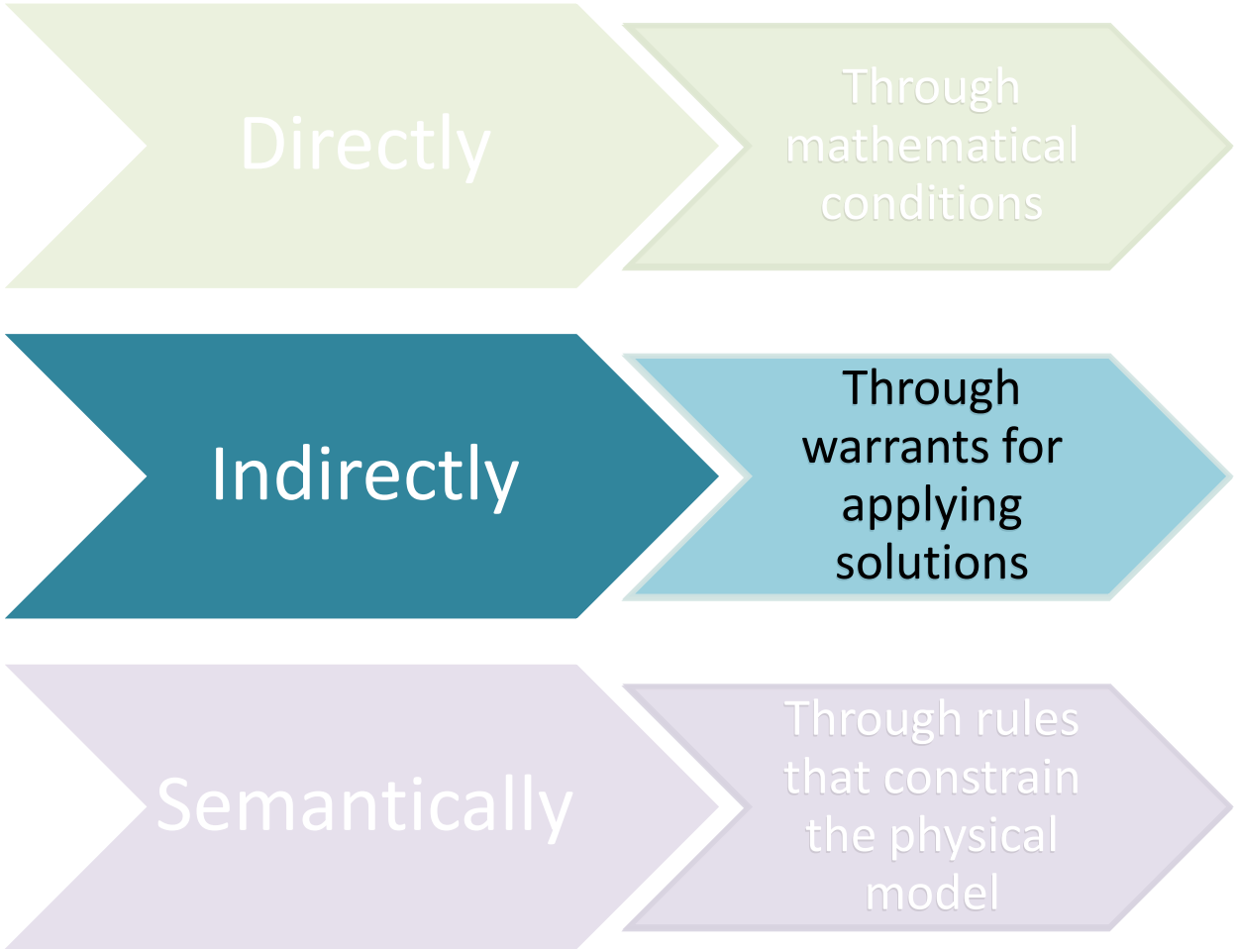
OR it does not

or causation is an empty honorific

Either way, there are serious problems for the notion that causation is fundamental to science

Let’s turn this bull around!

First Horn: Causation *does* put factual restrictions on our physical theories



Norton’s ‘Mass on the Dome’ problem has acausal solutions…

IS CLASSICAL PHYSICS ACAUSAL?

Norton: even *classical* physics is acausal

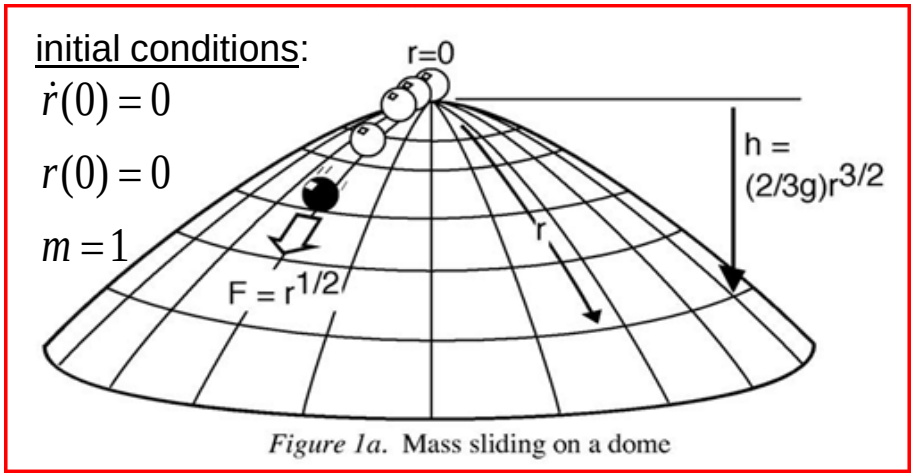


Figure 1a. Mass sliding on a dome

$$F = m\frac{d^2r}{dt^2}$$

$$r^{1/2} = \frac{d^2r}{dt^2}$$

A ball of unit mass sits at rest on top of a dome. What happens?

Answer 1: Nothing.

$$r(t) = 0, \text{ for all } T$$

Answer 2: It slides down the side after an arbitrary time T

$$r(t) = 0, \text{ for } t \leq T$$

$$r(t) = (1/144)(t-T)^4 \text{ for } t \geq T$$

Norton's acausal solution obeys Newton's Laws (in letter, if not in spirit)

Newton's Laws	**Norton's acausal solution**
1st Law: Objects at rest…	For every time there is no force, it is at rest. Only when there is a force does it accelerate!
2nd Law: F=ma	$r = (1/144)(t-T)^4$ $ma = (1/12)(t-T)^2 = r^{1/2} = F$
3rd Law: For every action…	$F = r^{1/2}$ –> *action/reaction force is just gravity!*

Norton's 'dome' is a great example of how causation *can* make a difference

Physicists throw out "physically unreasonable" solutions…

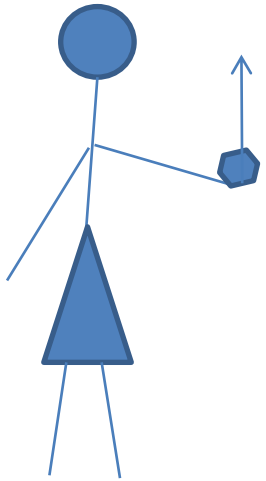
> *Excerpt from interview with physics grad student:*
> "So I would throw it out…you know, what we should really be arguing about is what's gonna happen in the real world….Cause the point of physics is to model the real world."

How do we choose solutions?

WARRANTS PLAY AN IMPORTANT META-MATHEMATICAL ROLE IN PHYSICS

There are always more solutions to equations than obtain in the real world

You throw a rock into the air at 10 m/s from 1 m above the ground. How long will it take to hit the ground?



$$F = m\frac{d^2y}{dt^2}$$

$$y = \frac{1}{2}gt^2 + v_0t + y_0$$

Answer 1:

2.1 seconds

Answer 2:

-.096 seconds

physically unreasonable!

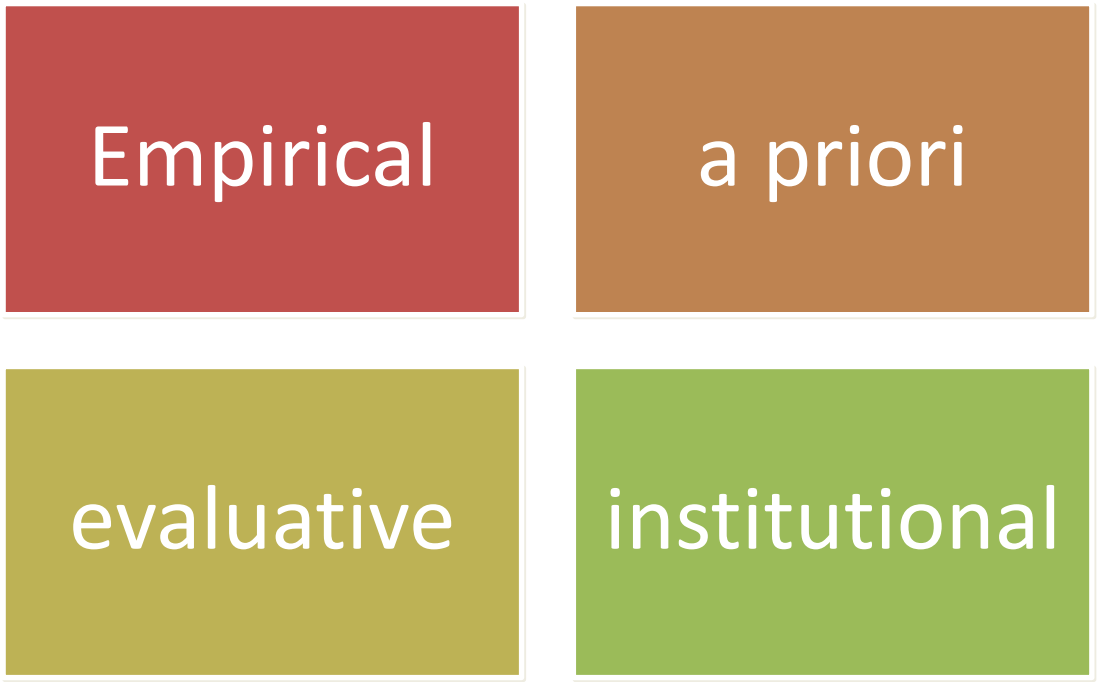
Physicists must rationally decide which solutions to keep

Bing (2008) examined the warrants of physics majors working on HW problems to indicate their epistemic frames

Physical Mapping	Calculation
Math Consistency	Invoking Authority

Physicists must rationally decide which solutions to keep

Freeman (2008) identified warrants backed by 4 modes of intuition



Causation can be a factor in helping to decide which to keep

Causation can provide warrant for keeping/ditching solutions

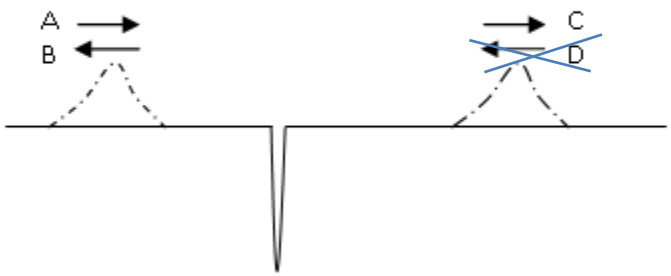
CAUSAL WARRANTS IN PHYSICS

Scattering

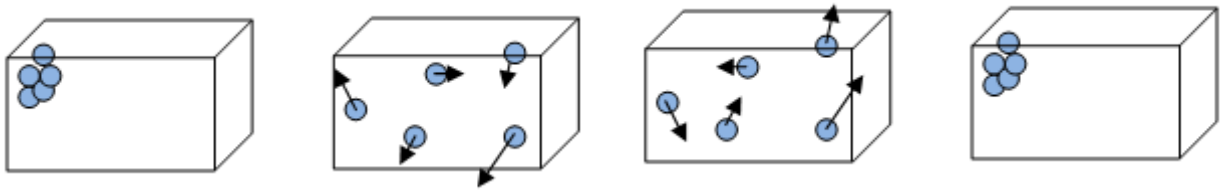
$$-\frac{\hbar}{2m}\nabla^2\Psi + V\Psi = E\Psi$$

$$\int \psi^* \psi \, d\tau = 1$$

$$\Psi(x) = Ae^{ikx} + Be^{-ikx} + Ce^{ikx} + \cancel{De^{-ikx}}$$



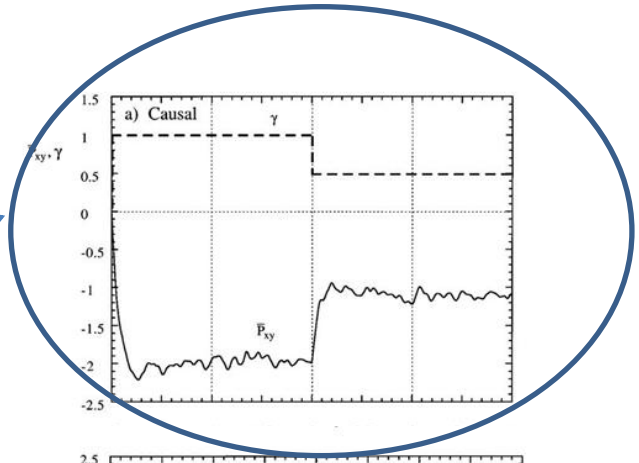
Loschmidt's Paradox & the Direction of Time



$$\delta B(t_1) = L(t_1 - t_2) F(t_2) \delta t_2$$

$$\delta B_C(t_1) = +L_C(t_1 - t_2) F(t_2) \delta t_2, \quad t_1 > t_2,$$

$$\delta B_A(t_1) = -L_A(t_1 - t_2) F(t_2) \delta t_2, \quad t_1 < t_2.$$



Evans & Searles (1996)

Can causal notions play more than a ceremonial role in science?

Causation implicitly constrains the facts of science

Causation can make a real difference in physical theories

Causal notions can be recovered by our sciences through observation

We now have a strong empirical basis for believing in causation