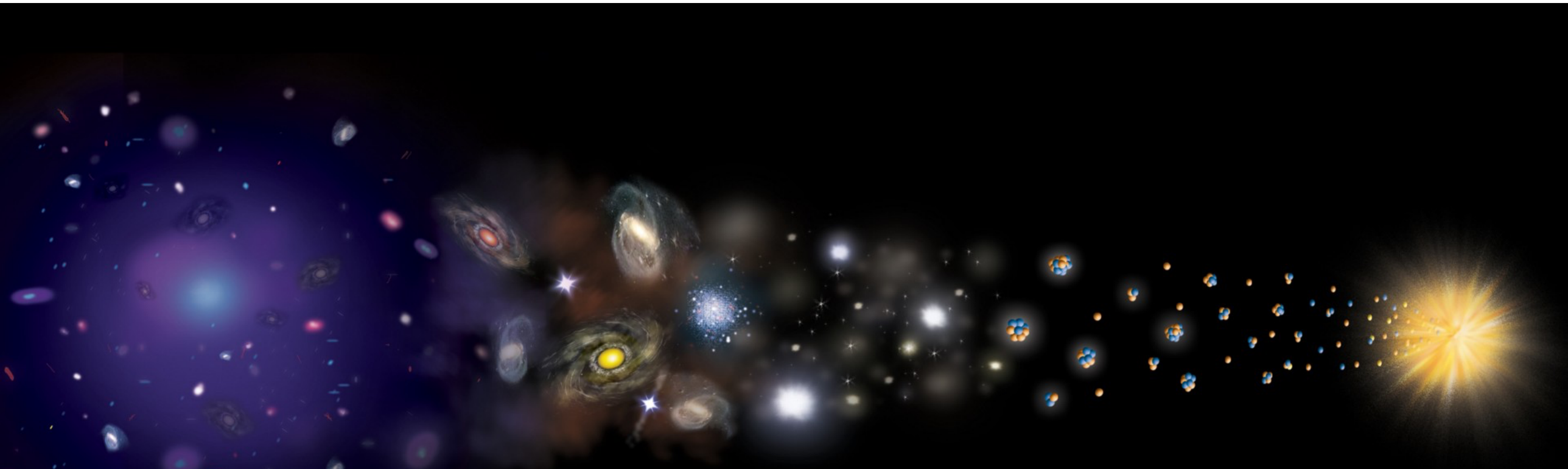
How did Statistics enter Physics?

Laplace, Maxwell, Boltzmann and the arrow of time

Anabel del Val

3rd Pinguino Lecture Series

VKI, 8 December 2018



FEB
MAR
APR
MAY
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AUG
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OCT
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DEC
#cosmos

DEC

#cosmos

DEC
Last day of the year
#cosmos

DEC
Evolution of humans
Last day of the year
#cosmos

Science is a profoundly human endeavor

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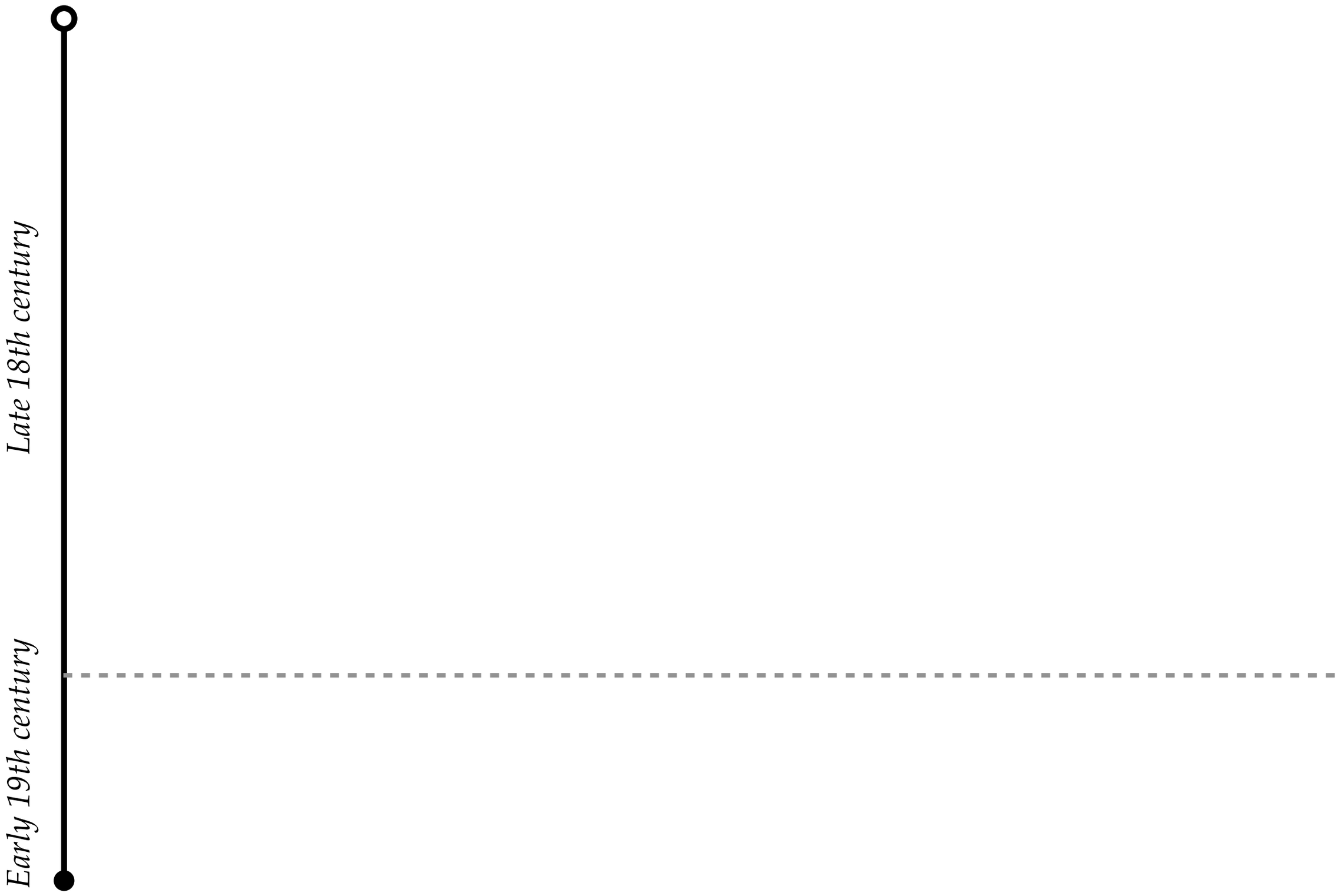
$$\frac{d(Science)}{dt} \neq 0$$

The state of Science in the late 18th century



The state of Science in the late 18th century

Newton's *Principia* was out

Classical Mechanics was blooming

Late 18th century

Early 19th century

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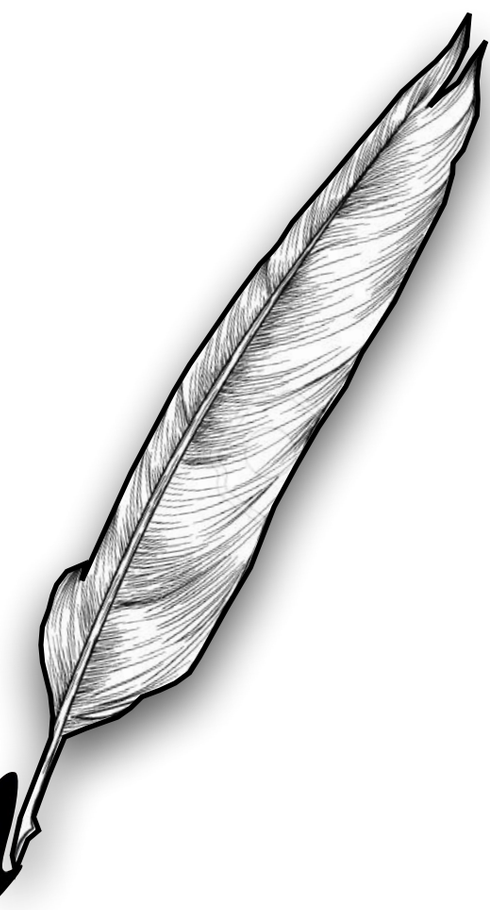
The theory of probabilities is the most happy supplement to ignorance and to the weakness of the human mind

Laplace



Determinism

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Determinism

Philosophical Essay on Probabilities 1814

By giving rights of citizenship to probabilities…

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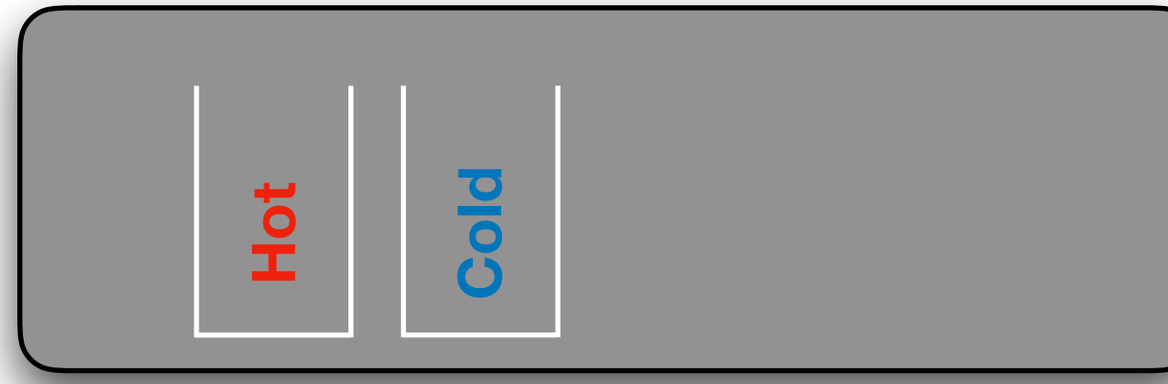

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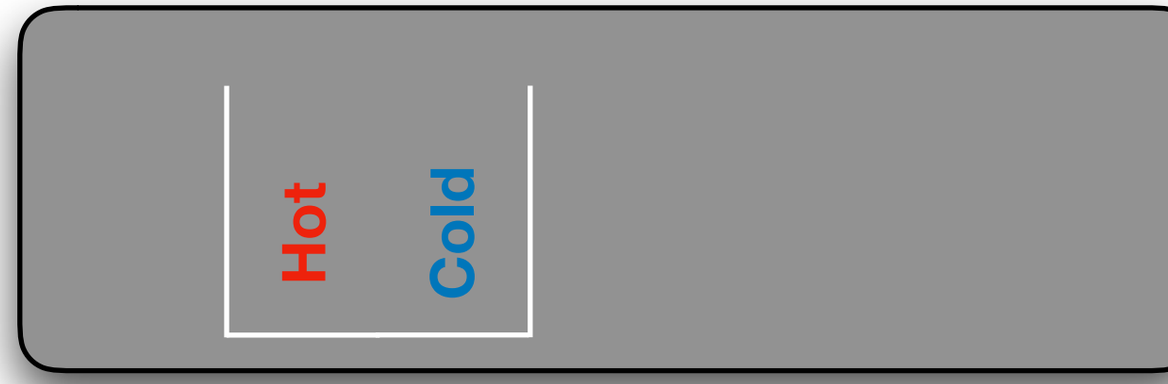

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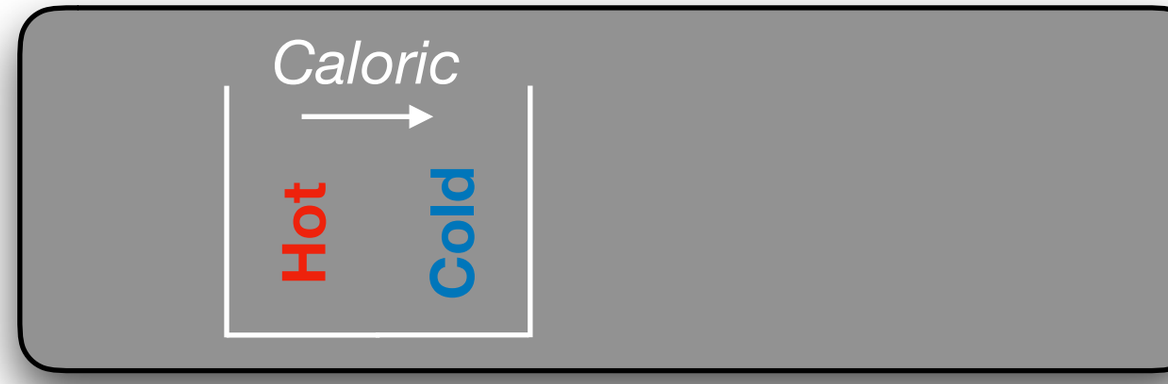

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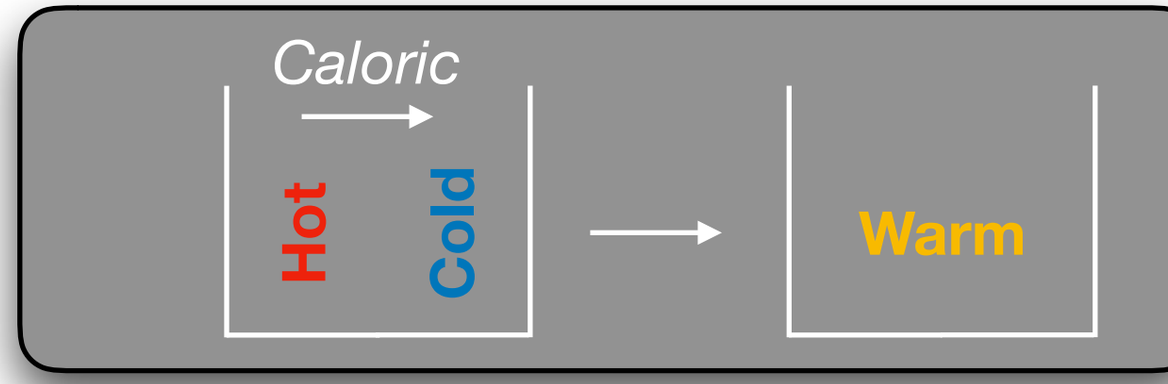

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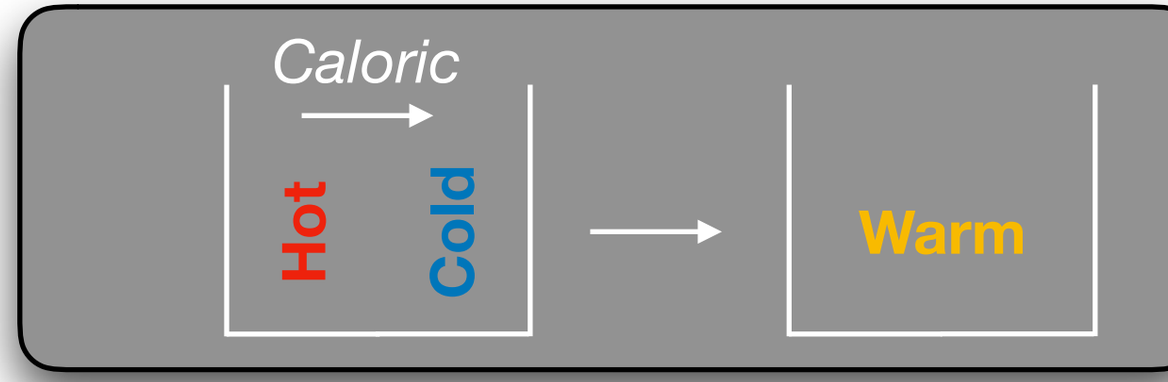

British Association for the Advancement of Science

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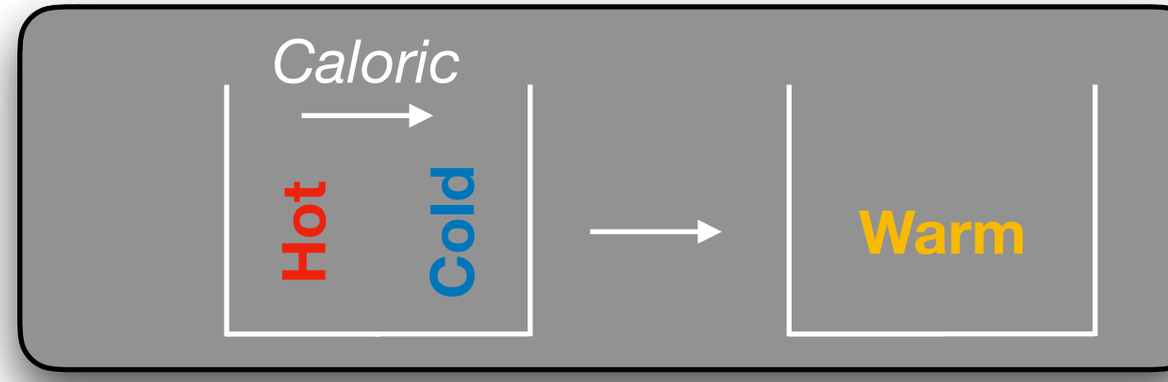

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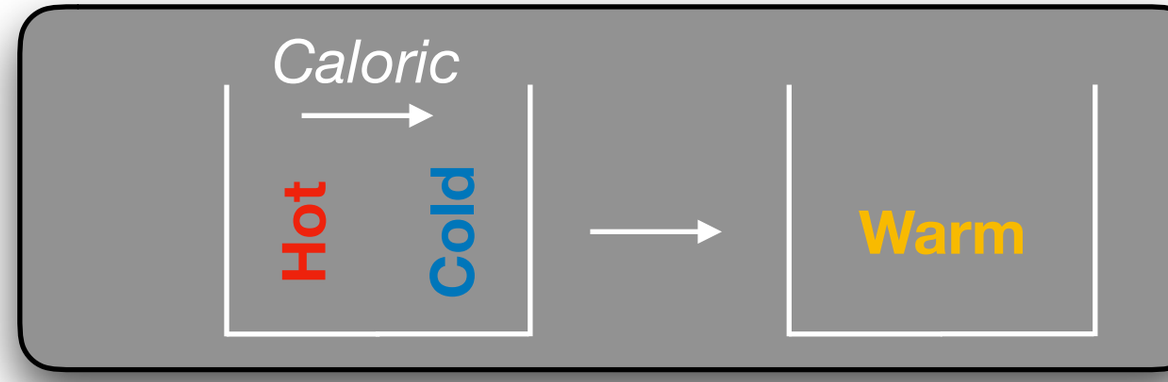

British Association for the Advancement of Science

Molecules in 1873

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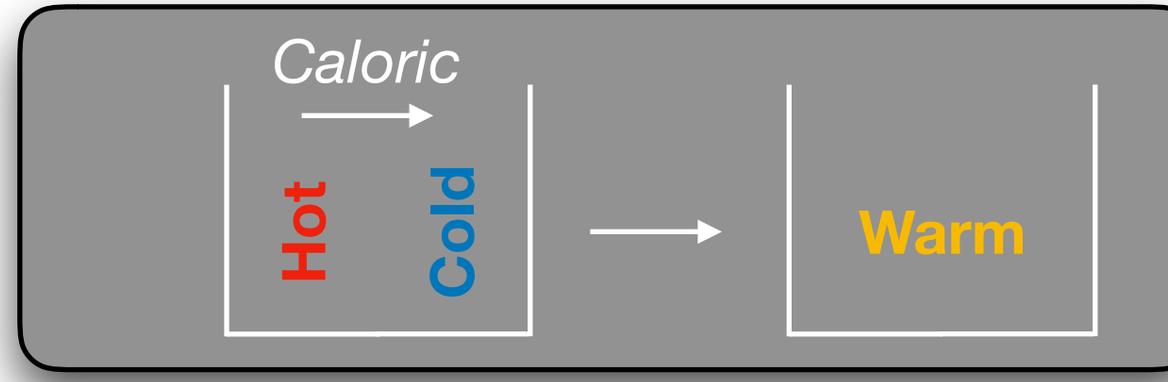
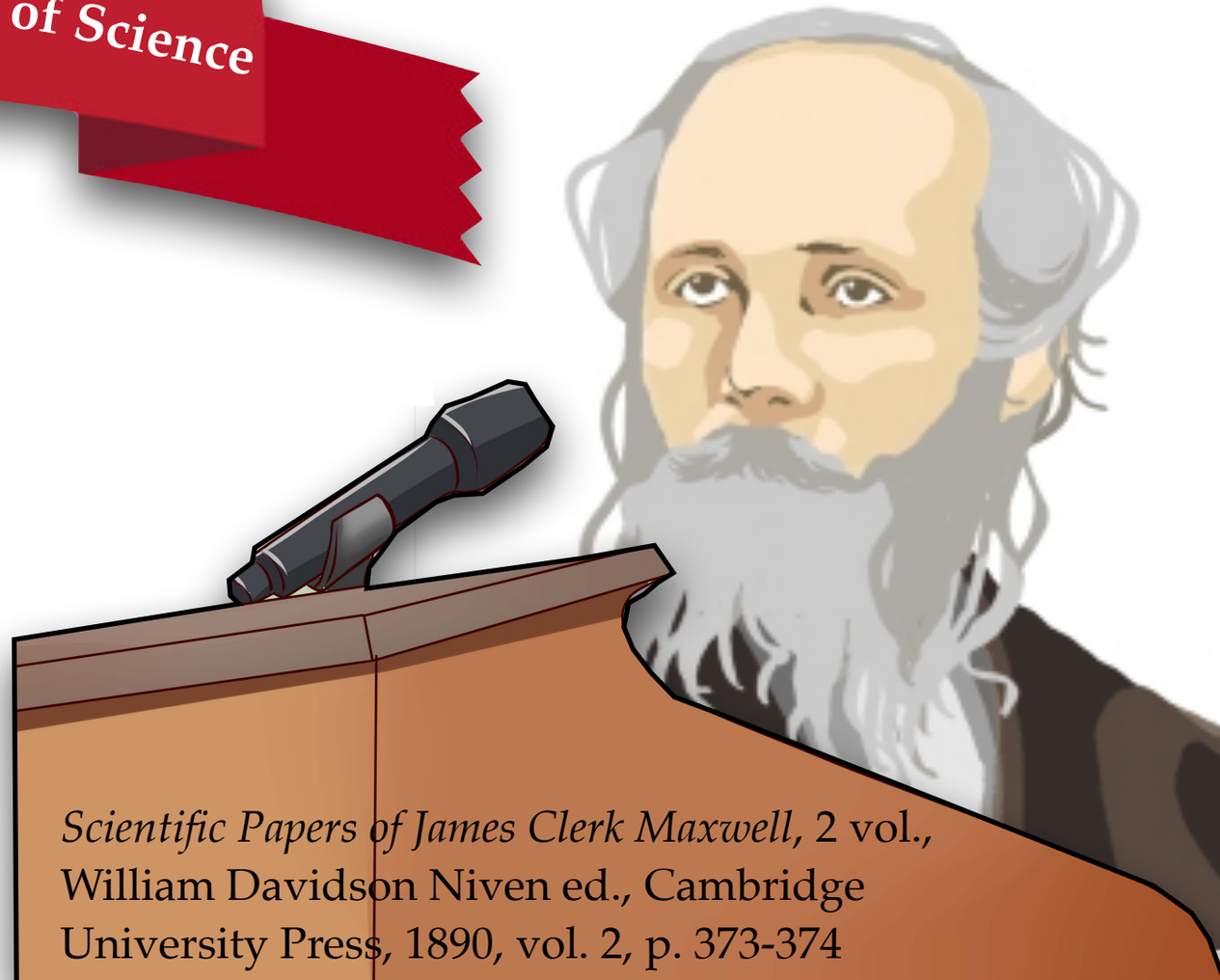


British Association for the Advancement of Science

***Molecules* in 1873**

The equations of dynamics completely express the laws of the historical method as applied to matter, but the application of these equations implies a perfect knowledge of all the data. […] we are obliged to abandon the strict historical method, and to adopt the statistical method of dealing with large groups of molecules

J. Clerk Maxwell



Scientific Papers of James Clerk Maxwell, 2 vol., William Davidson Niven ed., Cambridge University Press, 1890, vol. 2, p. 373-374

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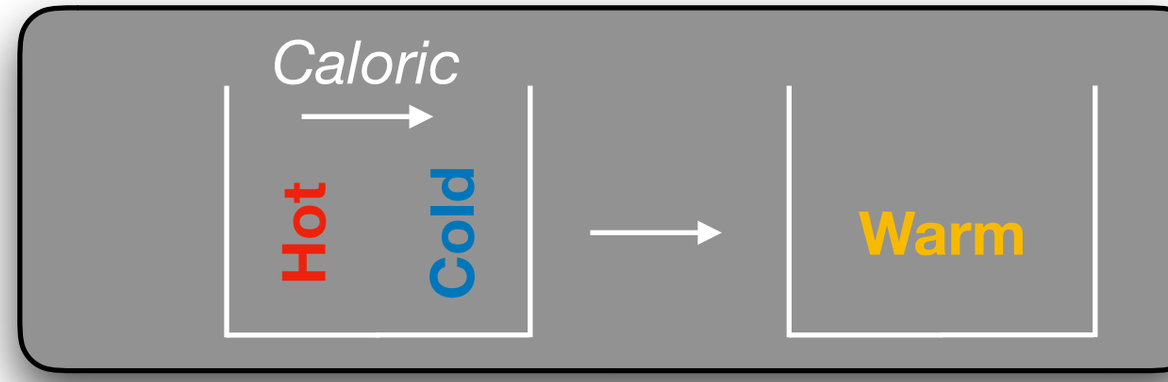

The true logic of this world is in the calculus of probabilities

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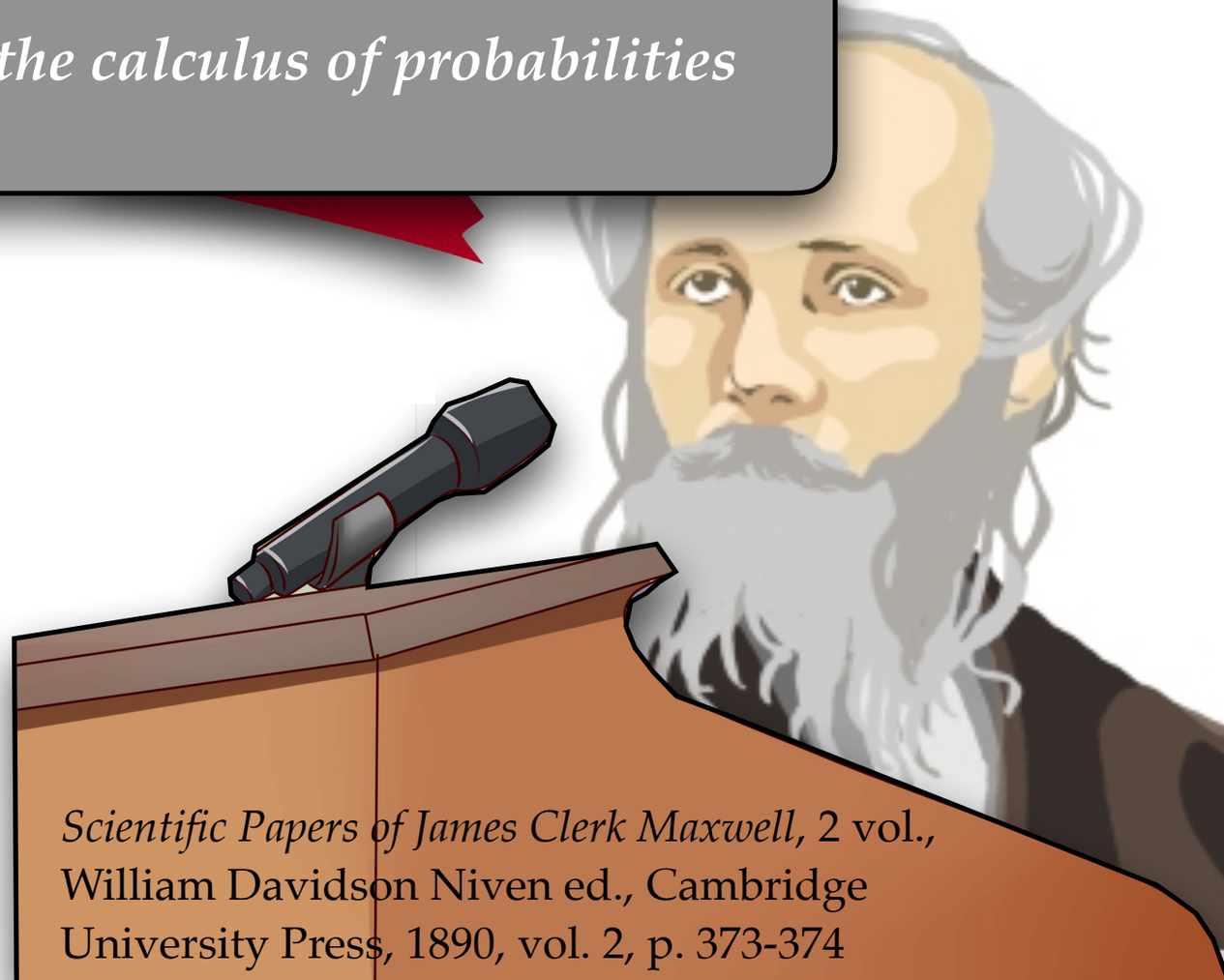

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The elementary grammar of things…

[…]
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and in time's womb
begins all ending.

Hymn to Time
Ursula K. Le Guin, 1929-2018

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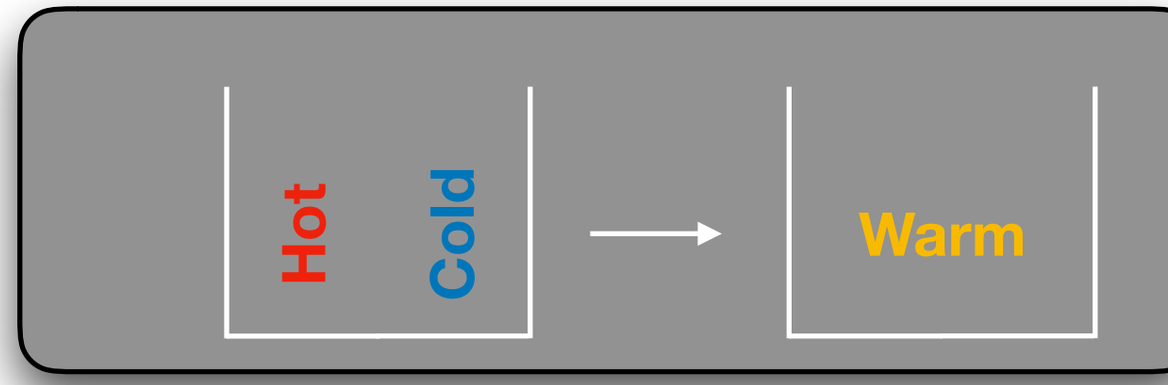

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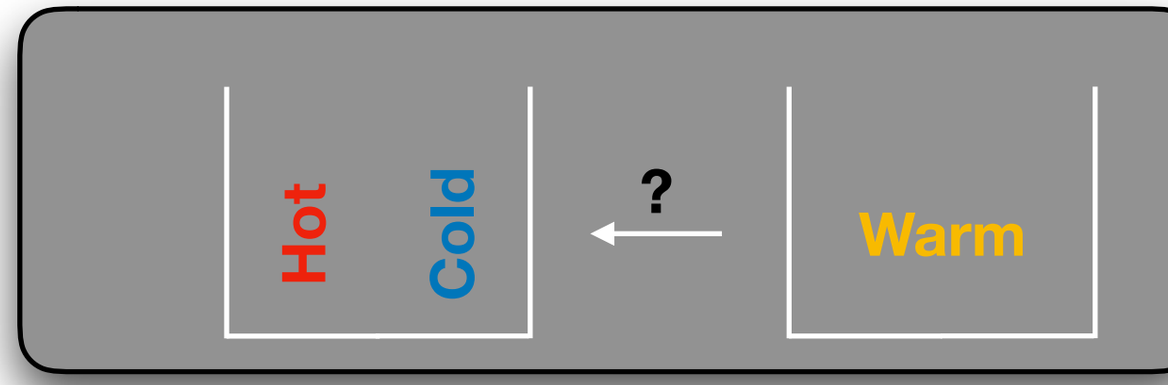

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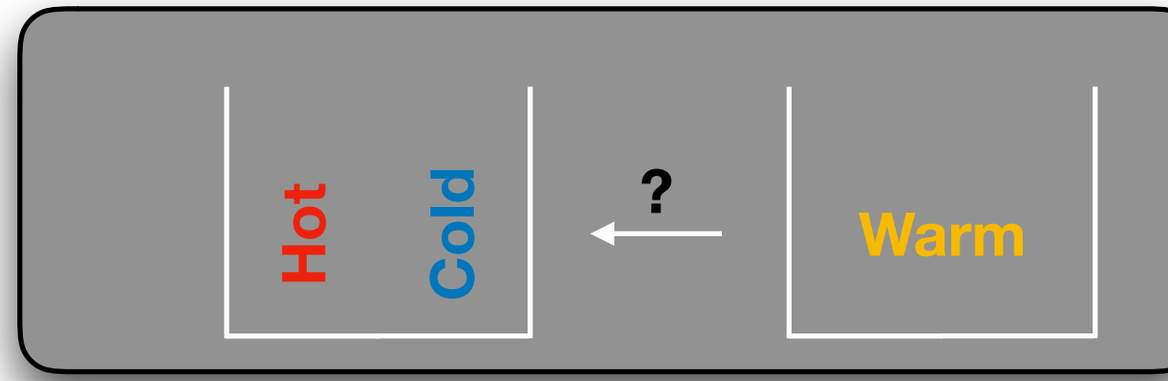

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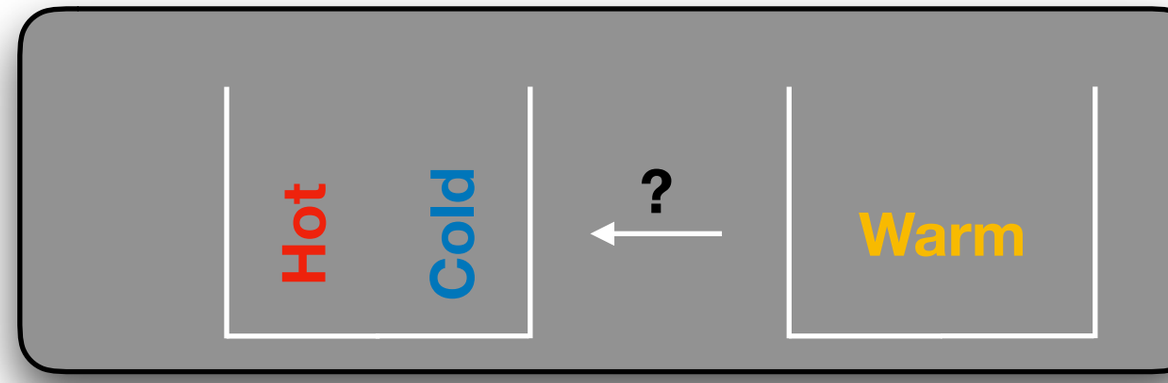

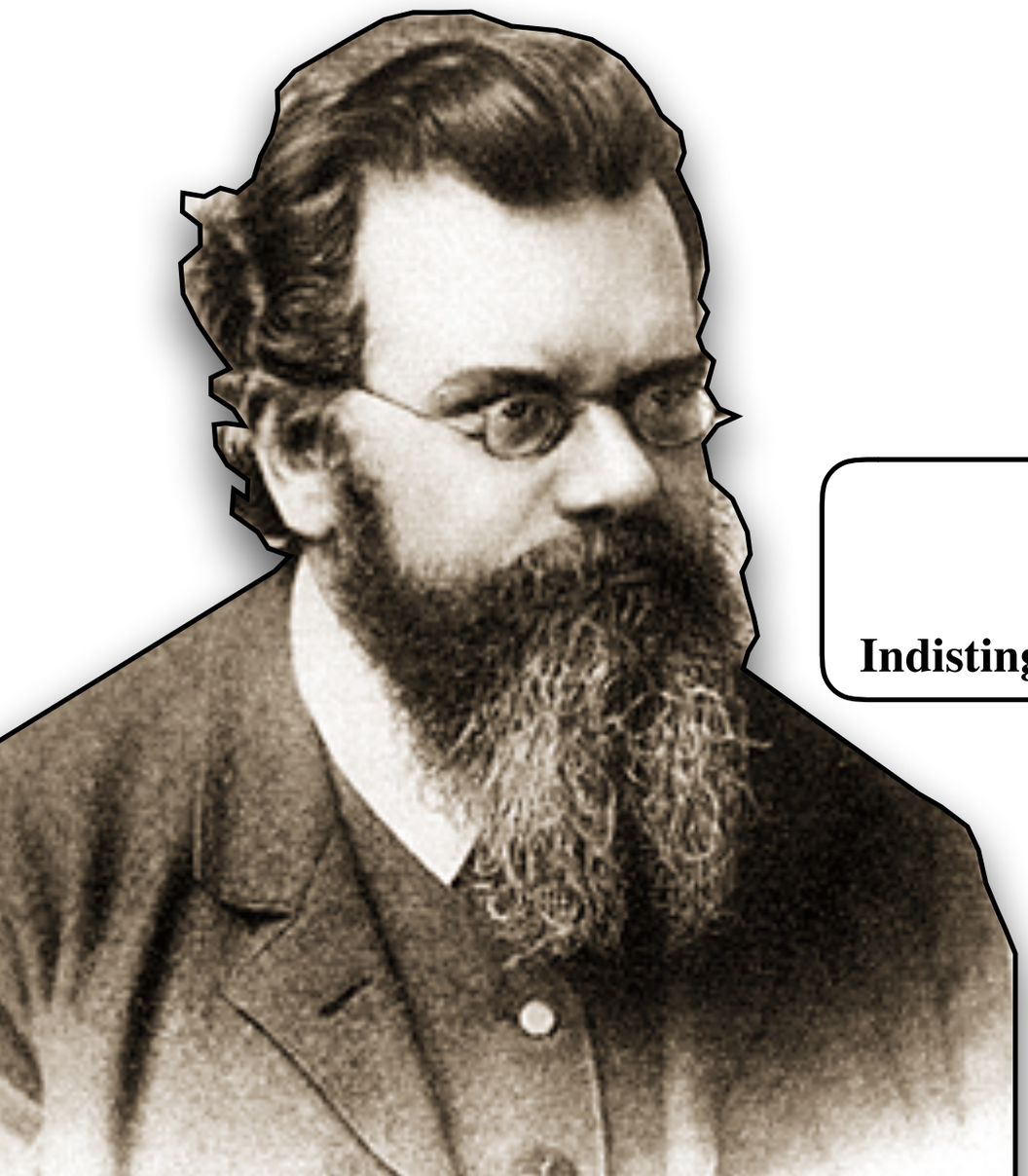

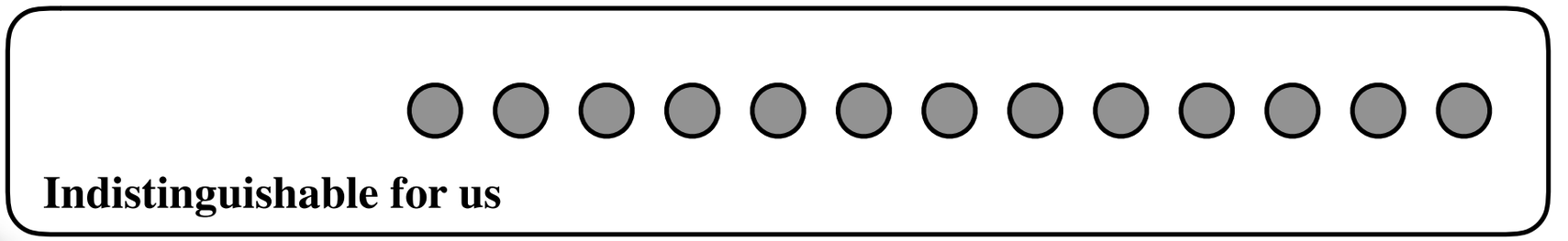

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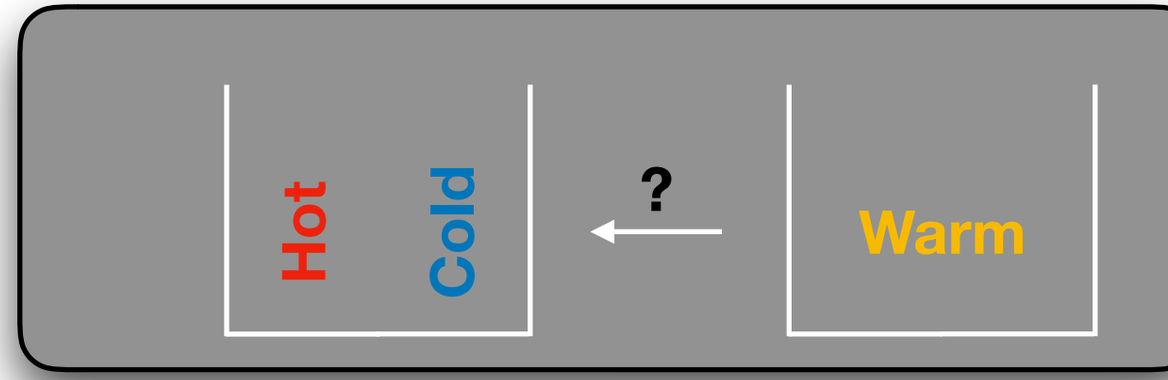
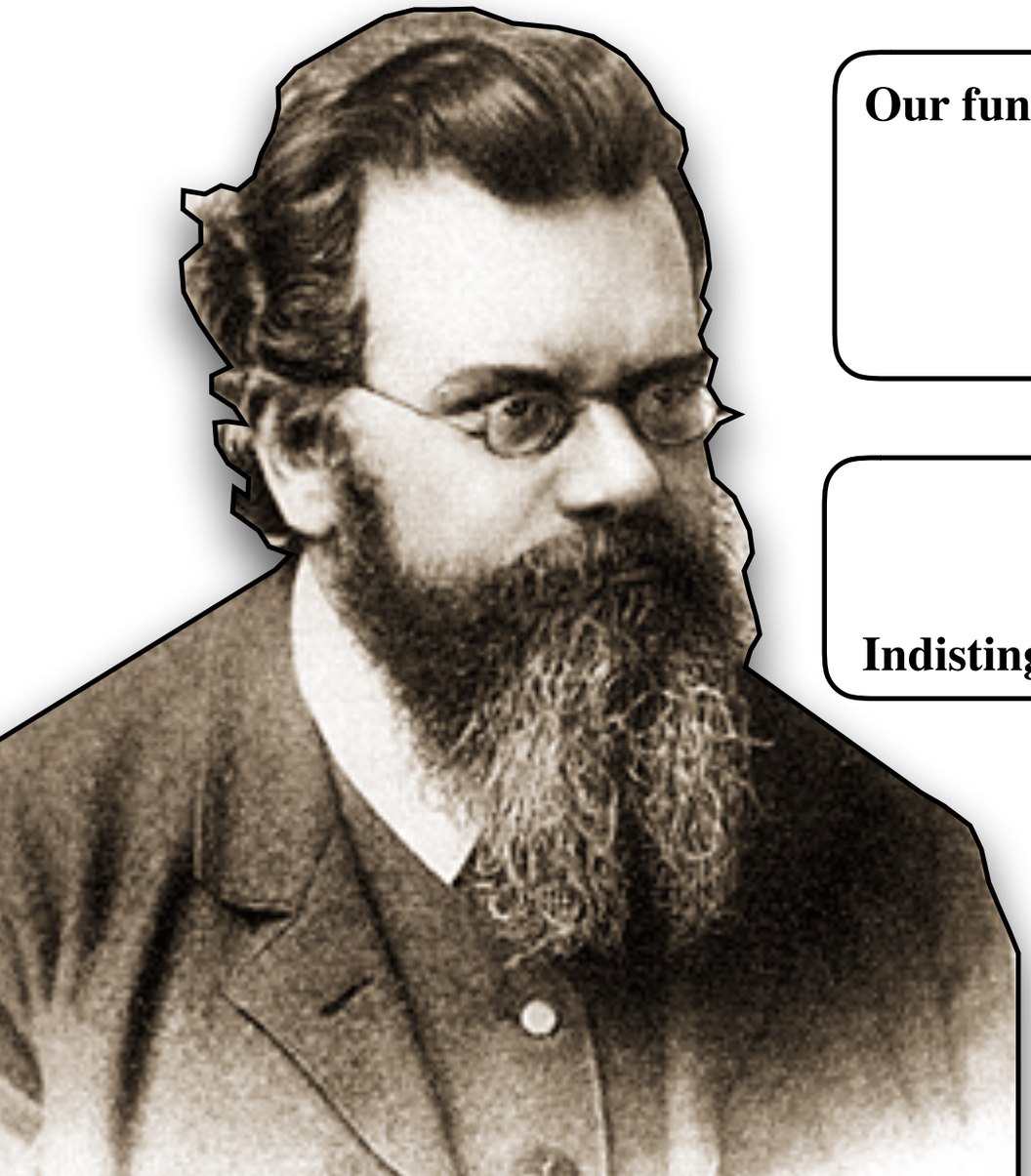
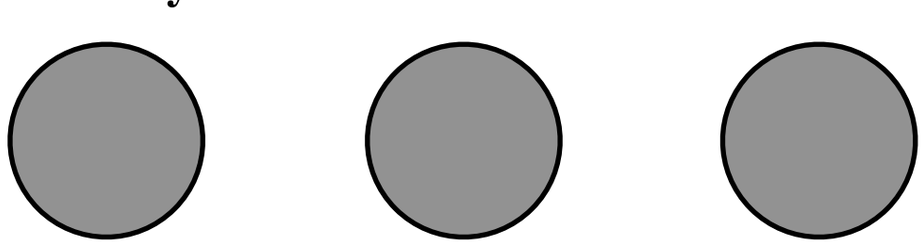




Our fundamental interactions lay here



Indistinguishable for us

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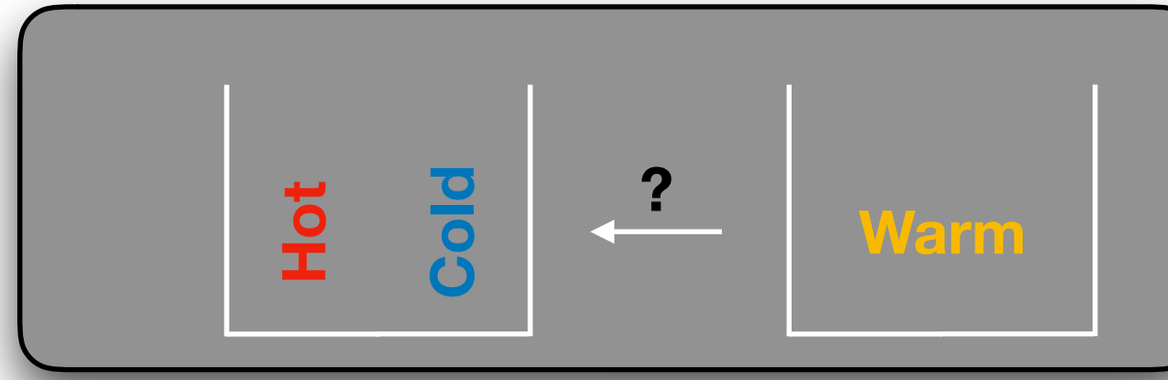

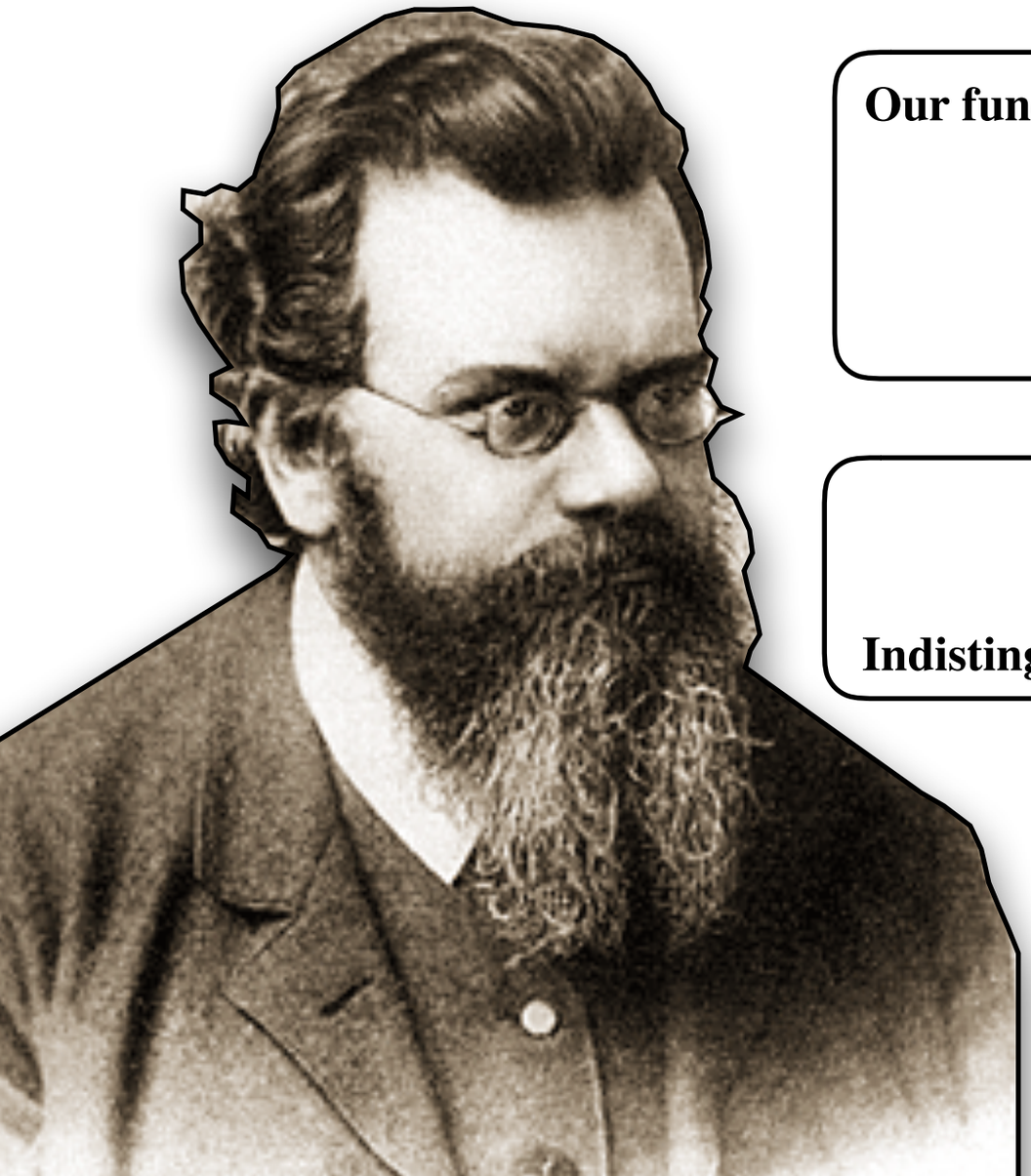

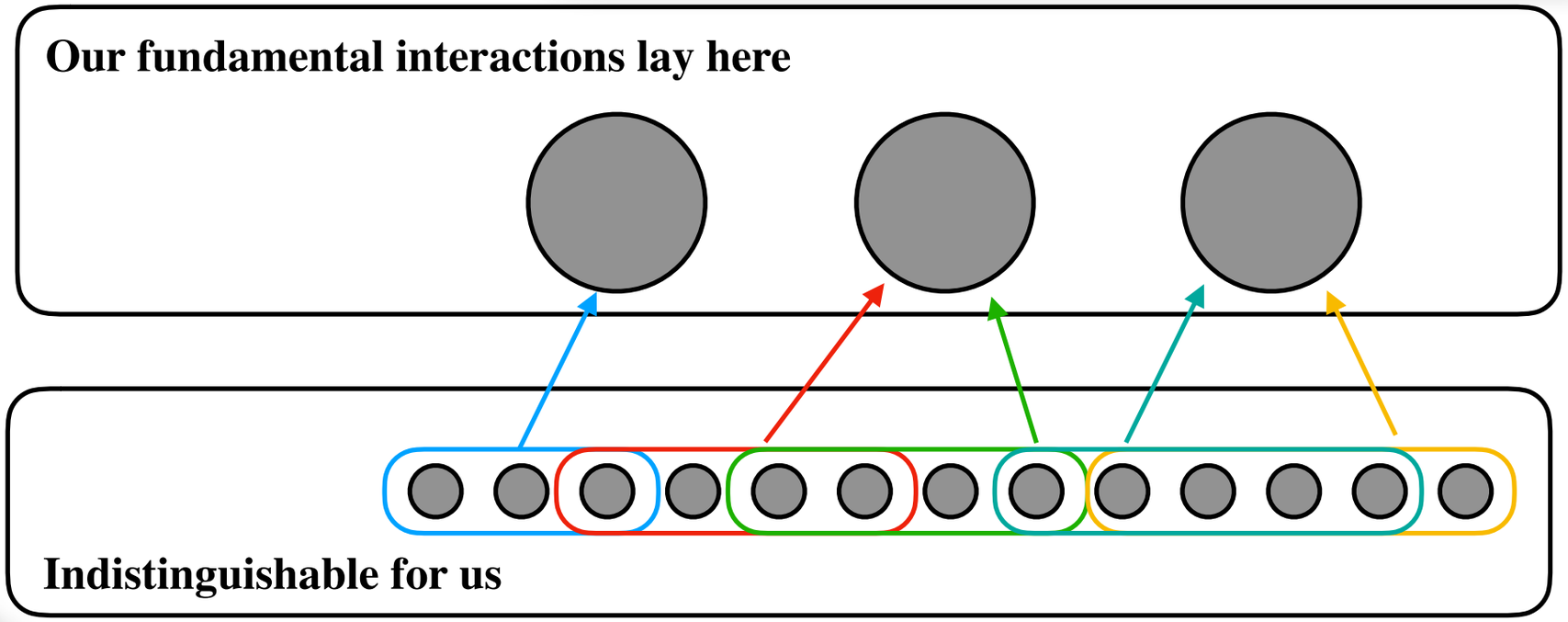

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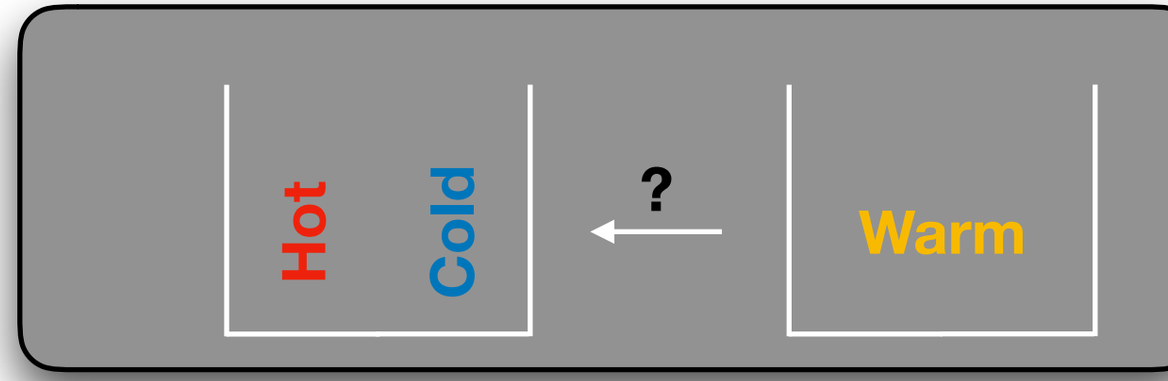
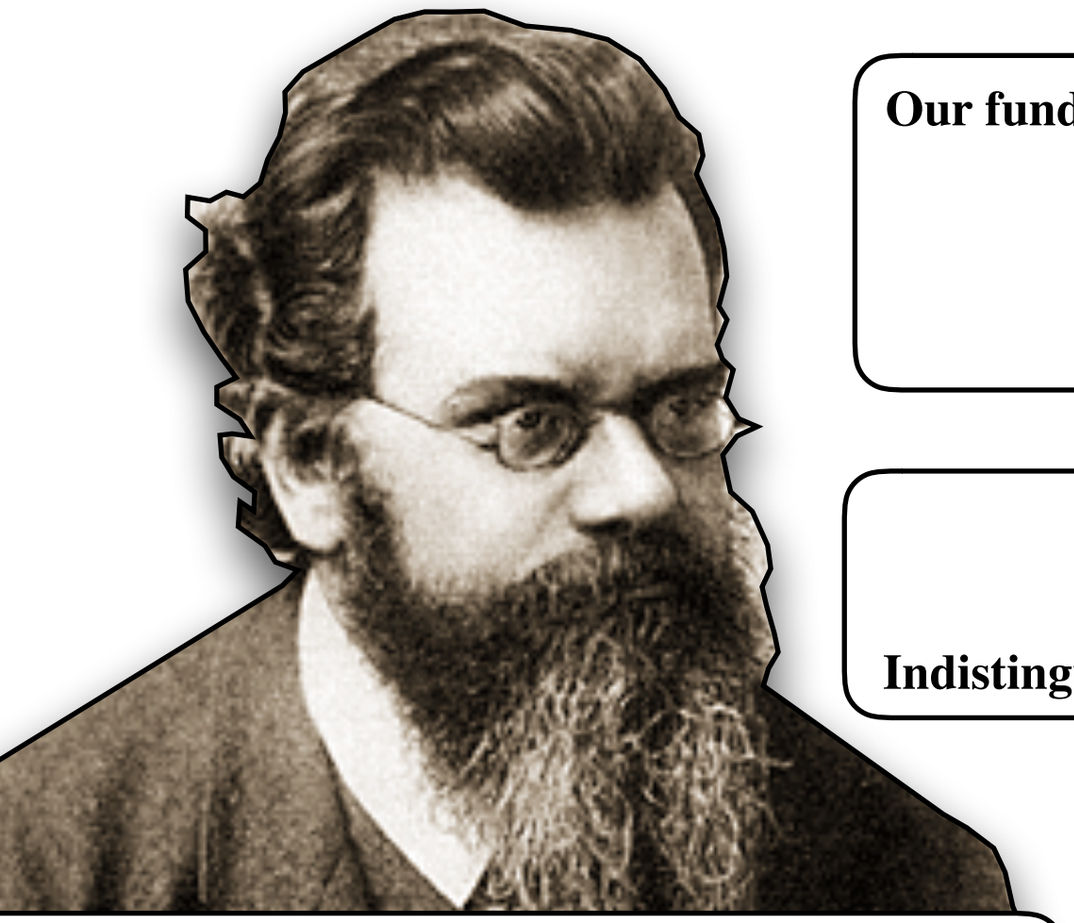
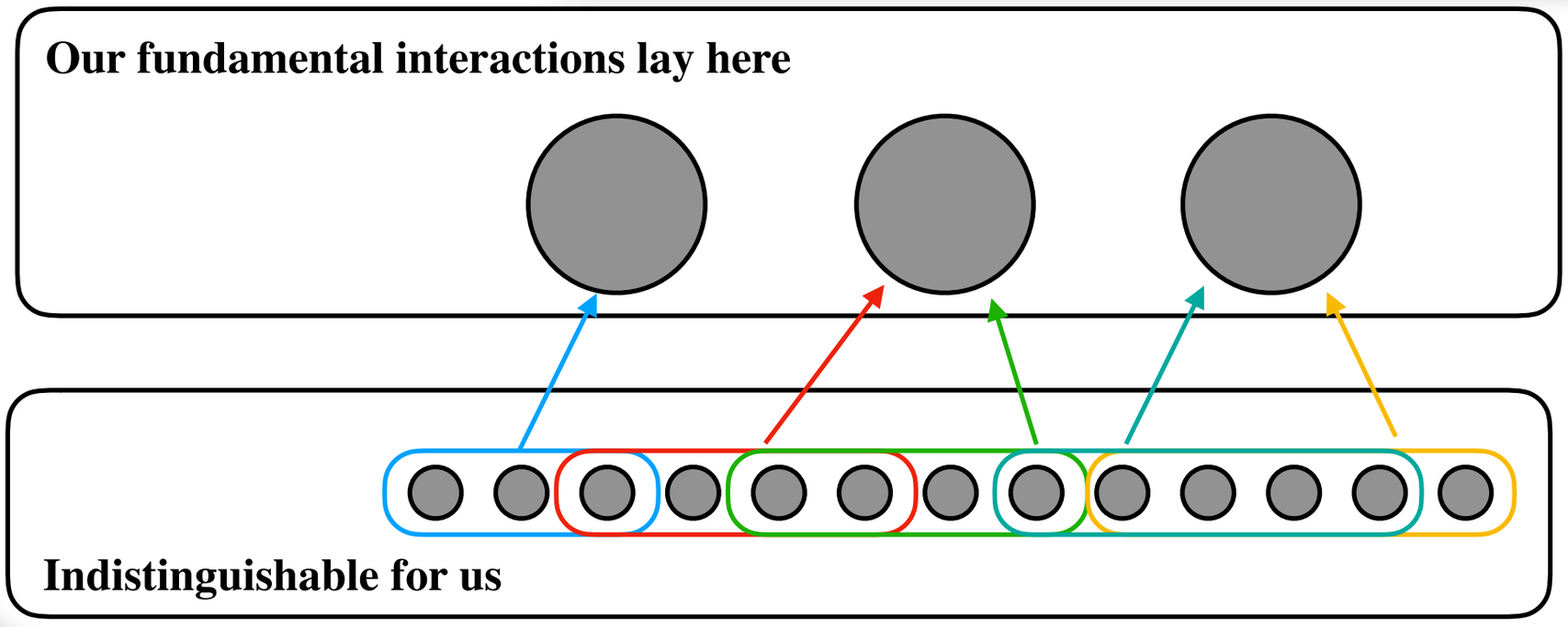




Vorlesungen über Gastheorie (1896-8), 2 vol., Leipzig, Johann Ambrosius Barth, vol. 2, § 88, p. 254 (English translation by Stephen G. Brush, *Lectures on Gas Theory*, Berkeley, University of California Press, 1964, p. 444)



Not until after a time enormously long compared to 10 power 10 power 10 years will there be any noticeable unmixing of the gases. One may recognize that this is practically equivalent to never

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Joseph's Fourier analytical treatment of the flow of heat

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Hermann von Helmholtz puts forward the idea of *heat death of the Universe*

What this means for us today

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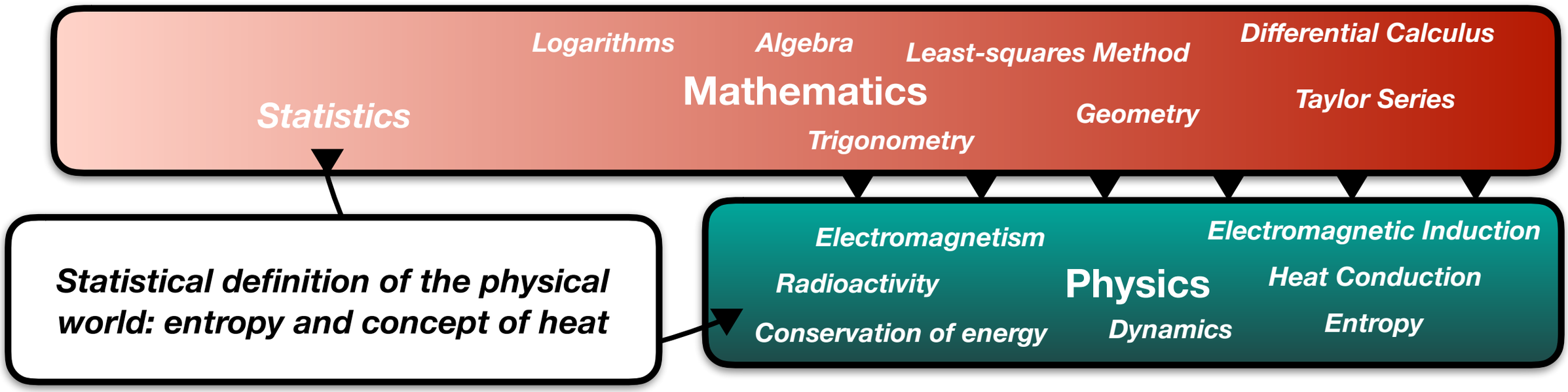

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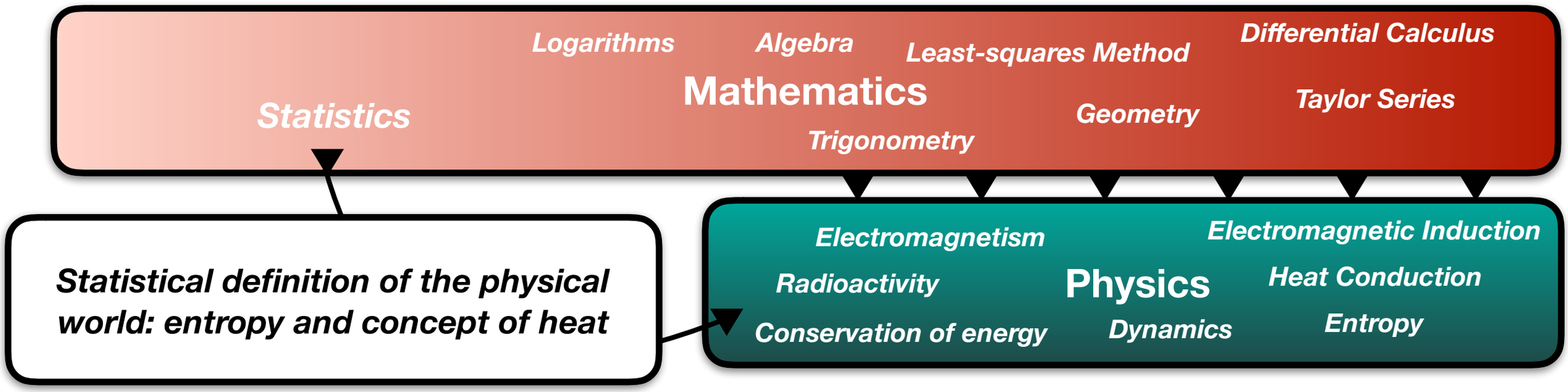

Phase change processes

Improved fluid dynamics models

Rarified gas dynamics

Electric propulsion

Atmospheric entry

Plasma thrusters

We never know…

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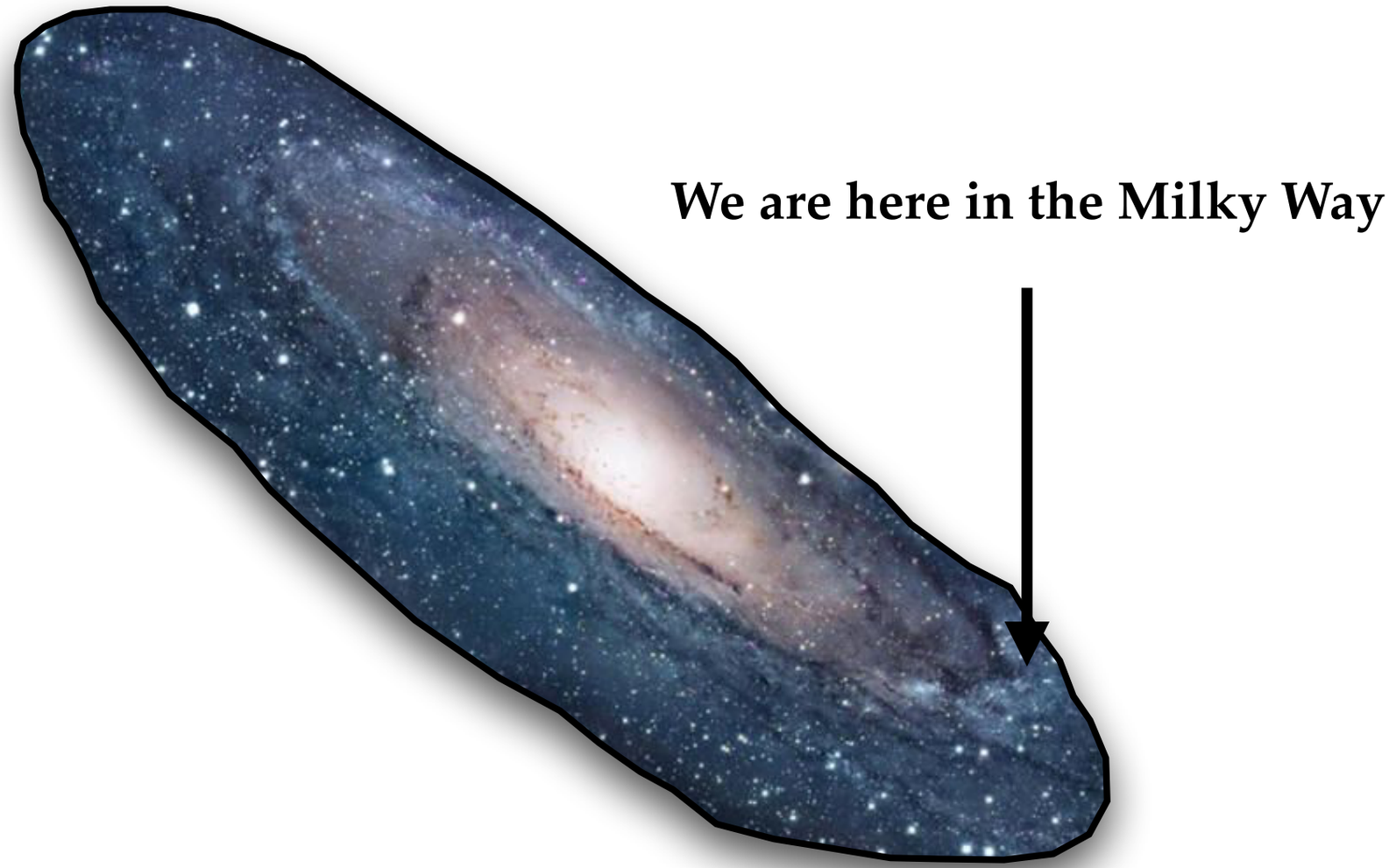

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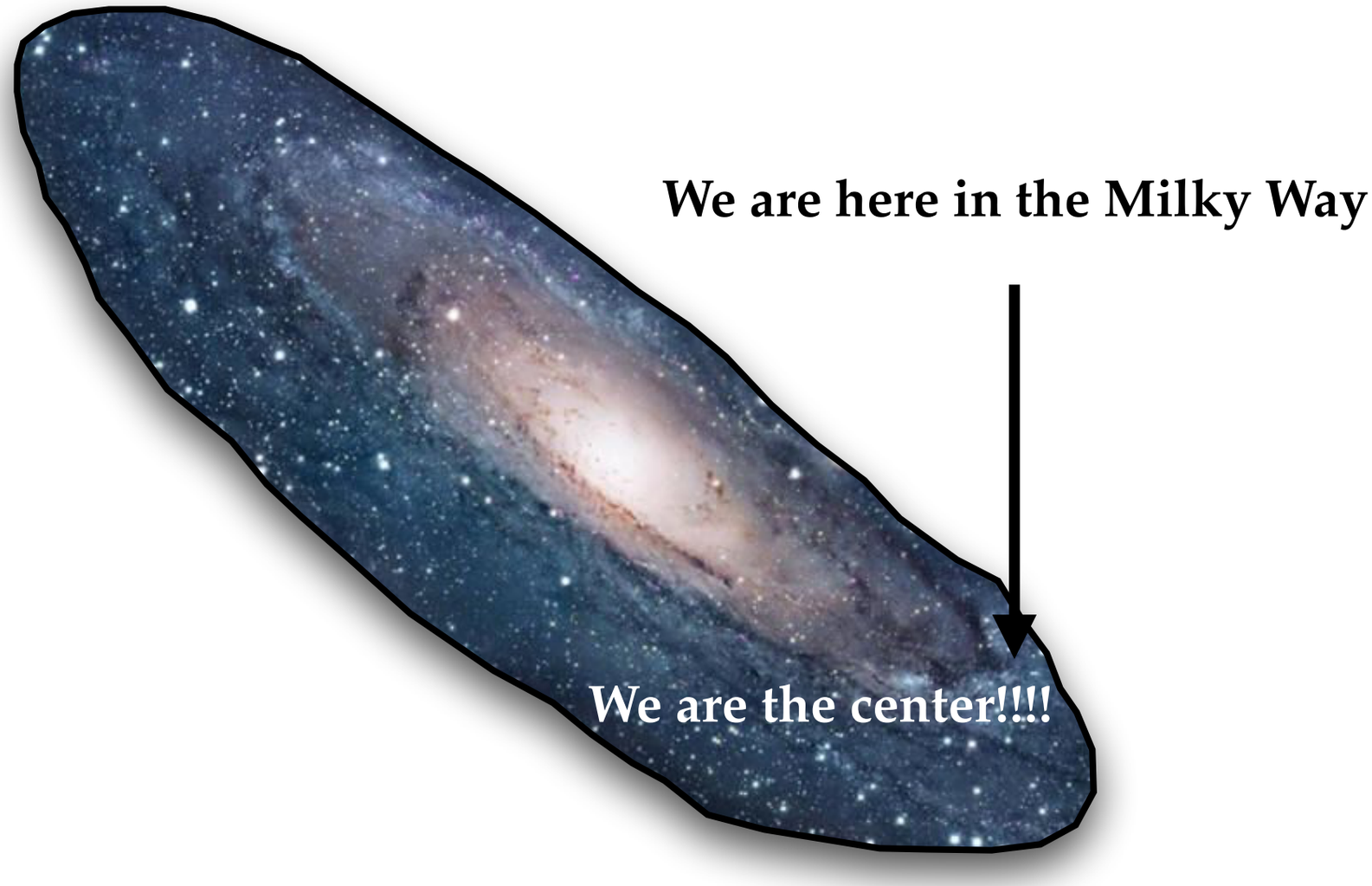

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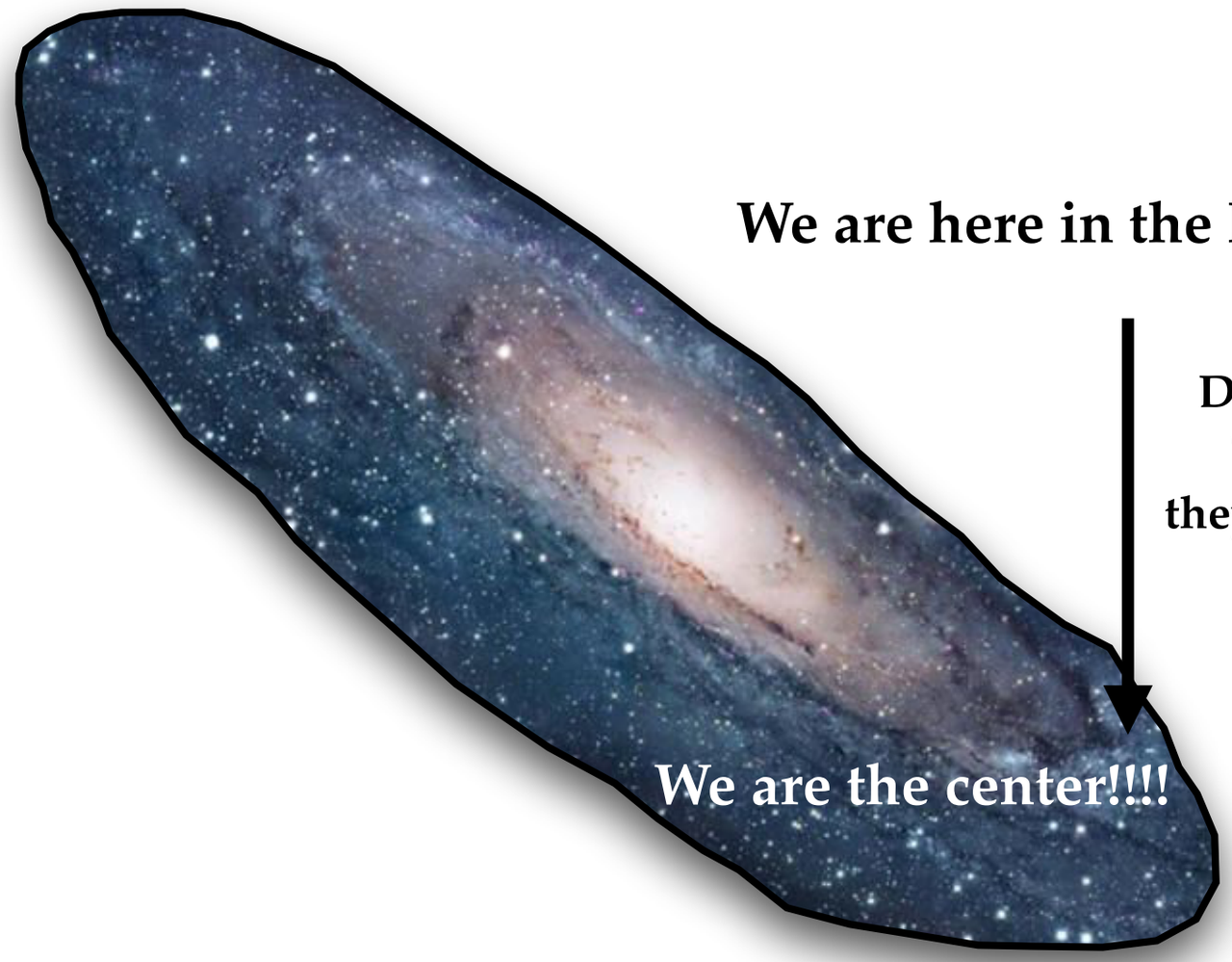
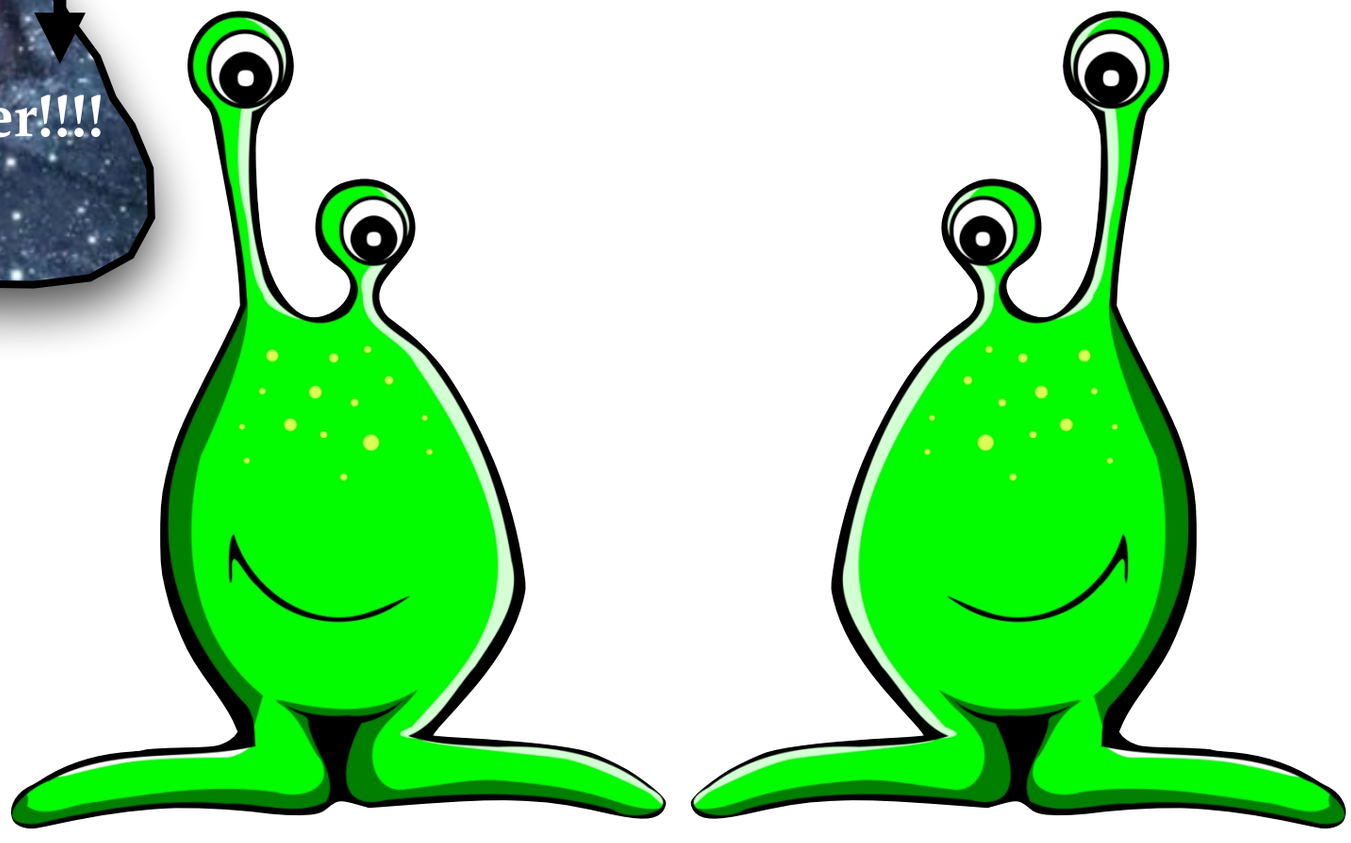


Dude I'm telling you, they are not intelligent species. They presume to be the center of the Universe but they revolve around an average star of an average galaxy in a far away corner…LOL!



Lost Lecture by Carl Sagan, 1994

We never know…

Lost Lecture by Carl Sagan, 1994

How did Statistics enter Physics?

Laplace, Maxwell, Boltzmann and the arrow of time

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3rd Pinguino Lecture Series

VKI, 8 December 2018