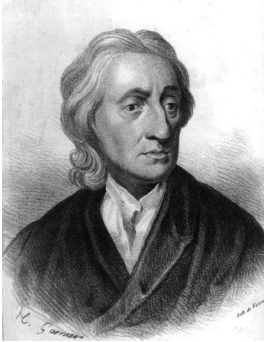
Causality and directed acyclic graphs

Get to know and have some intuition about

- Causality in philosophy (of science)
- Conditional independence relations
- Causal discovery algorithms
- Confounds and back doors



David Hume (1711-1776)

Explanations

Aristotle (384 – 322 BC)

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- Evolution: we have eyes to find and hunt for food

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Aristotle (384 – 322 BC)

Form follows from the goal of the object

- Example: a person has eyes to see
- Evolution: we have eyes to find and hunt for food
- But: how do you know the goal and what is its purpose

Explanations

René Descartes

(1596 – 1650)

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Naturalism:
Explanation of phenomena in terms of physical objects

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- Divide mechanism into parts

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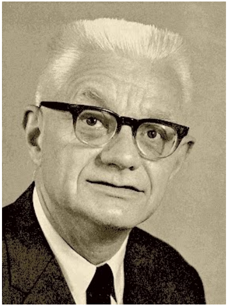
Naturalism:
Explanation of phenomena in terms of physical objects

- Example: the dials of a clock rotate by cogwheels and springs
- Divide mechanism into parts
- Not of mental processes like memory

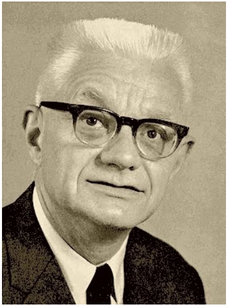
Explanations



Carl Hempel (1905 – 1977)

Logical positivists

Explanations



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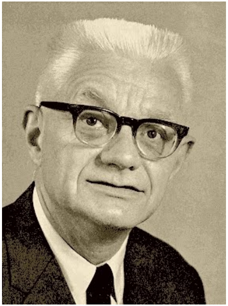
Deductive-nomological model

Explanations



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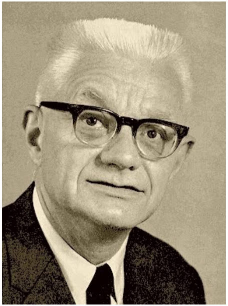
Deductive-nomological model

- $C_1, \ldots, C_k$ (circumstances)
- $L_1, \ldots, L_n$ (laws)

$\vdash E$ (explanandum)

Explanations



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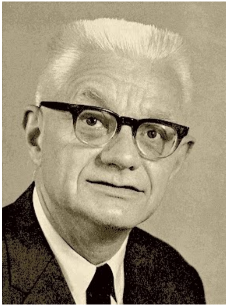

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$\vdash E$ (explanandum)

- Necessarily true if C and L are true.
- *The* basis for all sciences are laws and logical deductions.

Explanations

Isaac Newton (1643 – 1727)

Explanations

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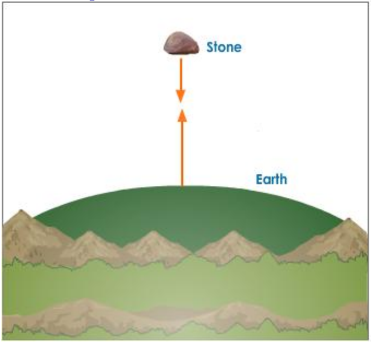
You can fall back on the laws of Newton

Example



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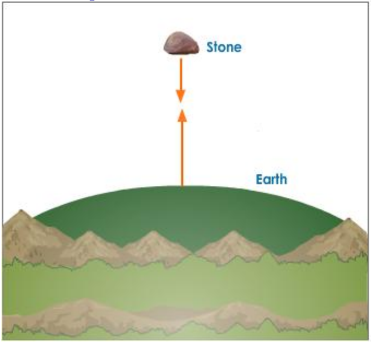
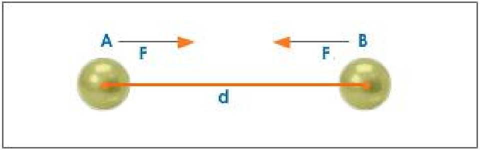
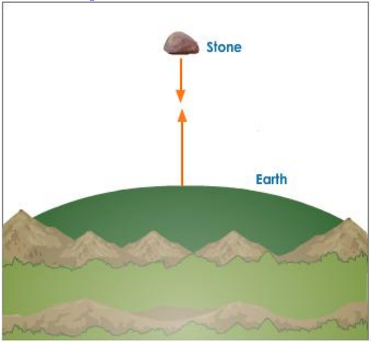
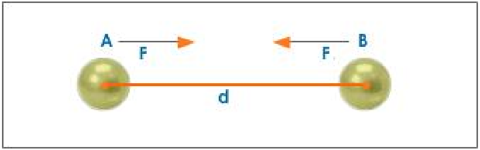




3rd law of Newton

Example





3rd law of Newton

- C : we are in the gravitational pull of the earth

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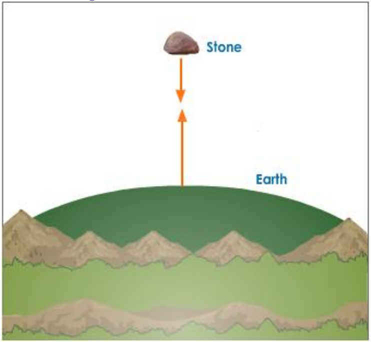

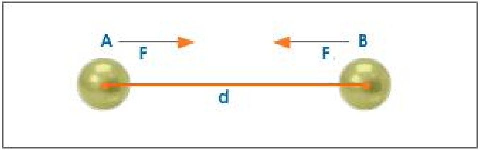

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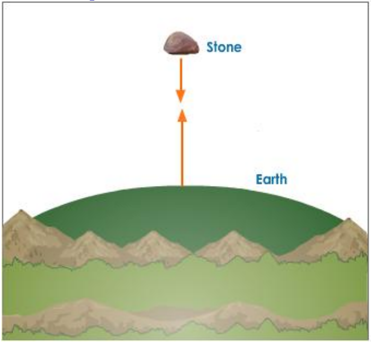

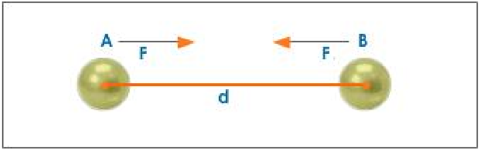

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$$F = ma \text{ and } F = \frac{gm_1m_2}{d^2}$$

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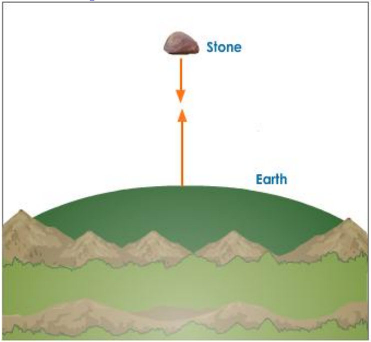

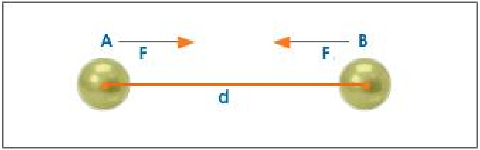

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$$F = ma \text{ and } F = \frac{gm_1m_2}{d^2}$$

$\vdash$ the rock falls to the earth

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- Does the effect really always follow the cause? No.
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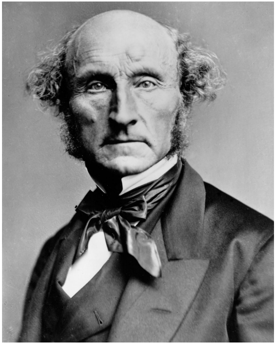
- But it is a causal relation? That could be, but what is causality....
- This is what we need to figure out. It is the key to providing an explanation.

Causal relation and laws

John Stuart Mill's conditions

- A always co-occurs with B
- A occurs before B
- There is no alternative explanation for the co-occurrence of A and B

But this was unsatisfactory because A does not always occur with B; no universality.



John Stuart Mill (1806-1973)

Probabilities enter the stage

- Probability is essential to replace 'universal laws'
  Example
  $$P(\text{catch fish} \mid \text{fishing rod}) \geq P(\text{catch fish} \mid \text{no fishing rod})$$

- Conditional independence relations are the key to causal relations
  Example
  $$P(\text{shark bite} \mid \text{ice cream}) \geq P(\text{shark bite} \mid \text{no ice cream})$$
  $$P(\text{shark bite} \mid \text{ice cream, hot weather}) = P(\text{shark bite} \mid \text{hot weather})$$

Hans Reichenbach (1891-1953)

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  Example

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- 'Screening off': search for nonredundent and sufficient 'variables' that define the relation (statistically relevant)

Wesley Salmon (1925-2001)

Probabilities enter the stage

- Spirtes and Glymour: Use screening off principle to identify unique relations from data
- Pearl: Semantics for difference between 'see' and 'do'
  Example

$$P(\text{catch fish} \mid \text{rod}) \neq P(\text{catch fish} \mid \text{do(rod)})$$

- Causality definition:

$$E(\text{catch fish}) \neq E(\text{catch fish} \mid \text{do(rod)})$$

Judea Pearl (1936-)

Peter Spirtes (1956-)

Clark Glymour (1942-)