

# 《科学哲学》读书会分享

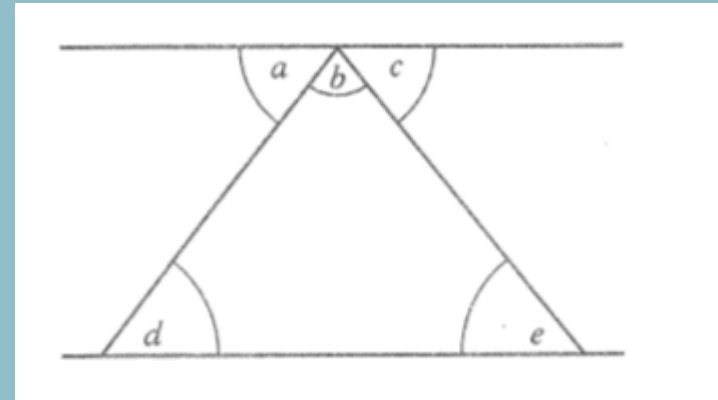
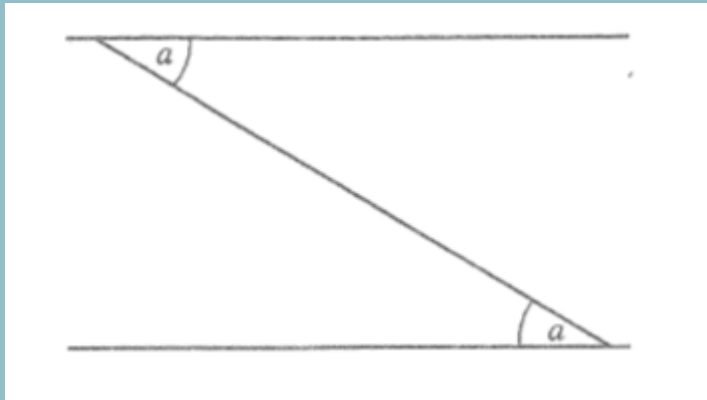
Chapter 7 The Structure of Scientific Theories

# 1. Overview

- Among scientists, [...] the term (**theory**) is often used to describe an established subdiscipline, [...] a whole area of inquiry; also means a body of **explanatory hypotheses** for which there is **strong empirical support**.
- Deductively organized systems
- Scientific theories are sets of hypotheses, which are tested by logically deriving observable consequences from them
- “**Hypothetico-Deductivism**”

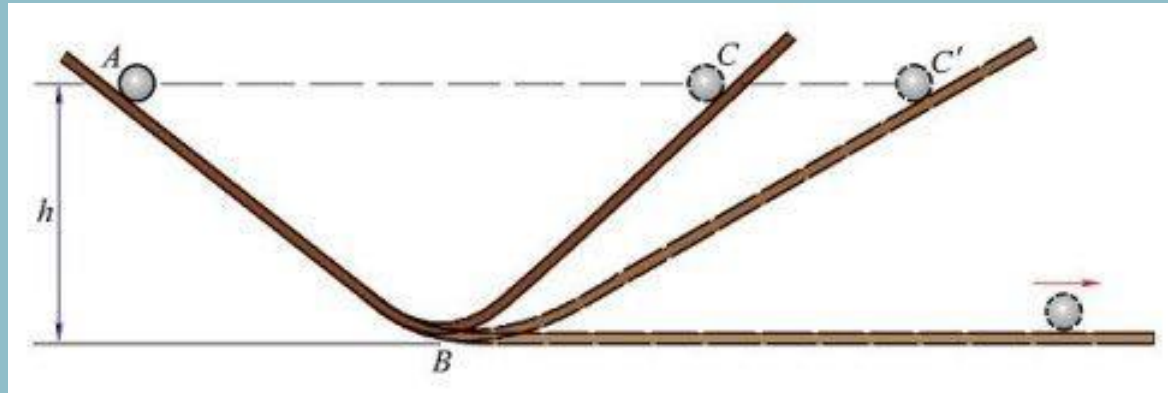
## 2. How Do Theories Work? E.g. Newtonian Mechanics

- Unify, identify underlying processes: makes an explanation scientific
- How?
- Axiomatic system



## 2. How Do Theories Work? E.g. Newtonian Mechanics

- Newton's first law:
- *An object moving at constant speed in a straight line continues to do so (forever) unless a force is applied to it.*
- Common-sense? Aristotle?



## 2. How Do Theories Work? E.g. Newtonian Mechanics

- Newton's second law:
- *The force acting on a body is equal to the product of its mass and its acceleration.*
- $F = ma$ .
- Remark: Newton could say no more about it(mass) than that it was a “quantity of matter” and proportional to force.
- Corpuscularian metaphysics: rejected “at a distance” effect

## 2. How Do Theories Work? E.g. Newtonian Mechanics

- Newton's third law:
- *For every action, every application of force, there is always an opposed equal and opposite reaction, a force applied in the opposite direction.*
- Remark: this law make Newton's fourth law problematic

## 2. How Do Theories Work? E.g. Newtonian Mechanics

- Newton's fourth law:
- *The force between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.  $F = Gm_1m_2/d^2$*
- Uncomfortable: very “spooky” force that travels at **infinite speed** through complete **vacuums** and from which **no shielding is possible**

## 2. How Do Theories Work? E.g. Newtonian Mechanics

◦题外话:

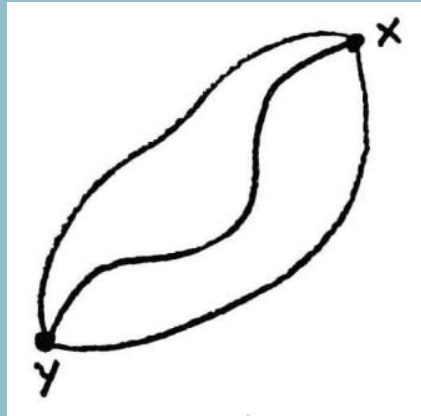
超距作用力 ×

$$F = G \frac{mm'}{r^2}$$

定域场 ?

Potential at centre = Av. pot. on ball  $-\frac{G}{2a}$  (mass inside)

最小作用量 ?





## 2. How Do Theories Work? E.g. Newtonian Mechanics

- The laws of Newtonian physics “work together” not only because they are about the same things, but because thinking about each of them helps us, and perhaps helped Newton, **formulate the others**.
- 1<sup>st</sup> law: “vacuously” true?
- Kepler, Galileo, stars, hydraulics, aerodynamics, thermodynamics...
- All of this explanatory power was revealed by mathematical **deduction** of the vast range of regularities from the **underived four axioms** of Newtonian theory

### 3. Theory as Explainers: H-D Model

- There has to be something more to being a theory than **merely having an axiomatic structure** from which theorems can be derived
- $A \text{ and } B \rightarrow A \text{ or } B$

The ideal gas law:  $PV = nRT$ , where  $P$  = pressure,  $T$  = temperature and  $V$  = volume, and  $r$  is the universal gas constant.

The quantity theory of money:  $MV = PT$ , where  $M$  is the quantity of money in an economy,  $V$  = the velocity of money—the number of times it changes hands,  $P$  is the average price of goods, and  $T$  is the total volume of trade.

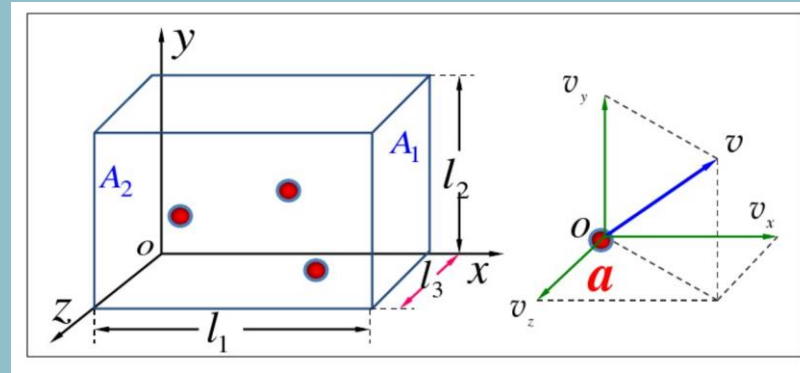
- “Working together” cannot be captured by the notion of logical derivation alone: philosophical challenge

### 3. Theory as Explainers: H-D Model

- The fundamental, underived general laws of a theory work together by revealing the *causal structure* of underlying processes
- What's wrong with the theory composed of the ideal gas laws and the quantity theory of money is that there is **no single underlying structure common to both the behavior of gases and money** for there to be a theory about
- **BUT:** The notion of an underlying mechanism may seem disturbing given the empiricist argument that there is **nothing to causation beyond regular sequence**; there is no glue, no mechanism, no secret power or necessity in nature to link events together in ways that make the course of things **inevitable** or **intelligible**.

### 3. Theory as Explainers: H-D Model

- However, We must do so because so many theories manifestly work like this
- Euler's law
- Kinetic theory of gases
- $\frac{3}{2}kT = \frac{1}{2}mv^2 \Rightarrow PV = nRT$ , under assumptions:
  - (a) gases are made of molecules moving on straight- line paths until they collide with each other or the container,
  - (b) the motion of the molecules—like that of observable objects—is governed by Newton's laws of motion,
  - except that (c) molecules are perfectly elastic, **take up no space**, and, except when they collide, exert **no gravitational or other forces** on one another



### 3. Theory as Explainers: H-D Model

- Boyle's law, Charles's law, Gay-Lussac's law, Graham's law, Dalton's law, Brownian movement...
- The kinetic theory of gases consists of:
  - 1) Newton's laws of motion, 2) gases are composed of perfectly elastic point- masses (molecules) which obey Newton's laws, 3)  $\frac{3}{2}kT = \frac{1}{2}mv^2$ , 4) some other laws like this one about pressure and volume of the gas
- The kinetic theory provides an example of one way that the components of a theory **work together** to explain observations and experiments——making a set of claims about **invisible, unobservable, undetectable** components of the gas and their equally **unobservable** properties, then we can explain observable phenomena P, V, T...

### 3. Theory as Explainers: H-D Model

- Axiomatic or **syntactic approach to scientific theories:**
- “hypothetico- deductivism”
- Most theories in science they are typically about processes that we **cannot directly observe**, rather the scientist **deduces testable consequences** from these **hypotheses**.
- It is from these two ideas, that the foundations of a theory are *hypotheses* supported by the consequences *deduced* from them, that the name hypothetico-deductive model derives.

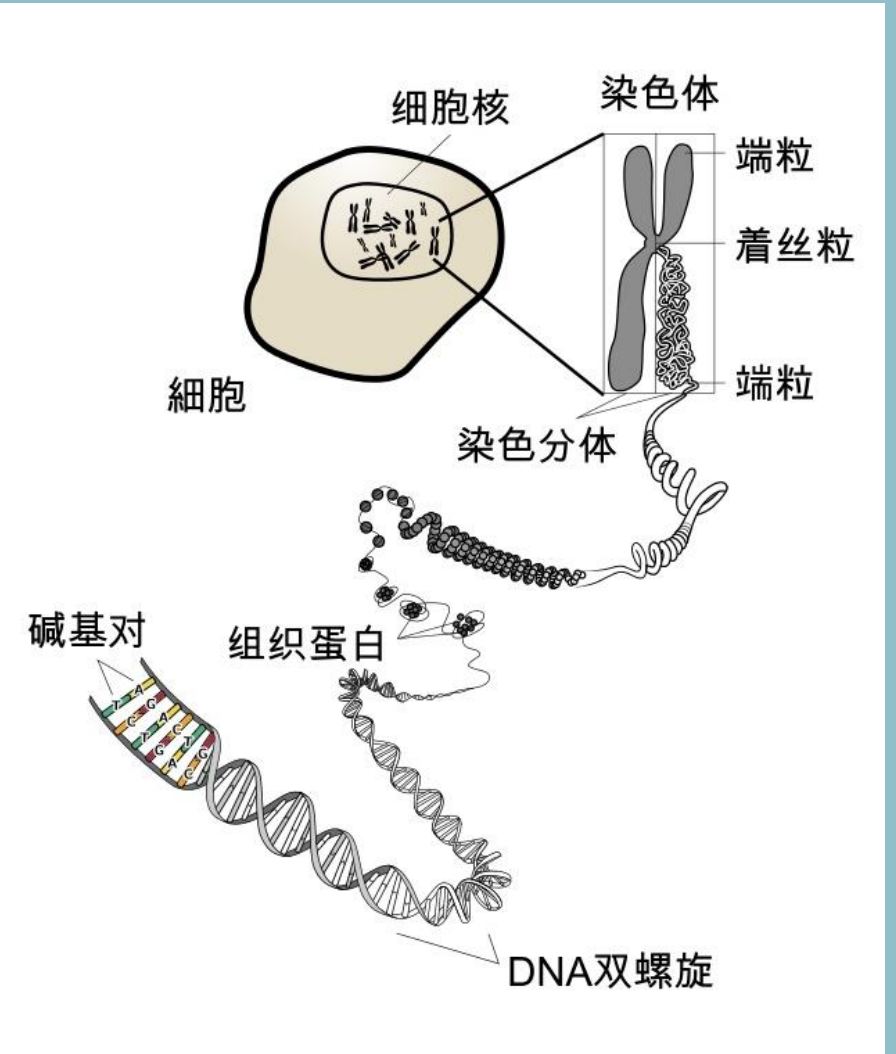
### 3. Theory as Explainers: H-D Model

	Explained theorem	Underived axioms
Chemical stoichiometry	$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$	electron- sharing/chemical bond
Atomic theory	electron- sharing/chemical bond	Behavior of electrons
Quantum theory	behavior of electrons	...

- No one suggests that scientists actually present theories as axiomatic systems (though Newton did so), still less that they explicitly seek the derivations of less fundamental laws from more fundamental ones
- the axiomatic account of theories is a “**rational reconstruction**” of scientific practice designed to reveal its underlying logic

### 3. Theory as Explainers: H-D Model

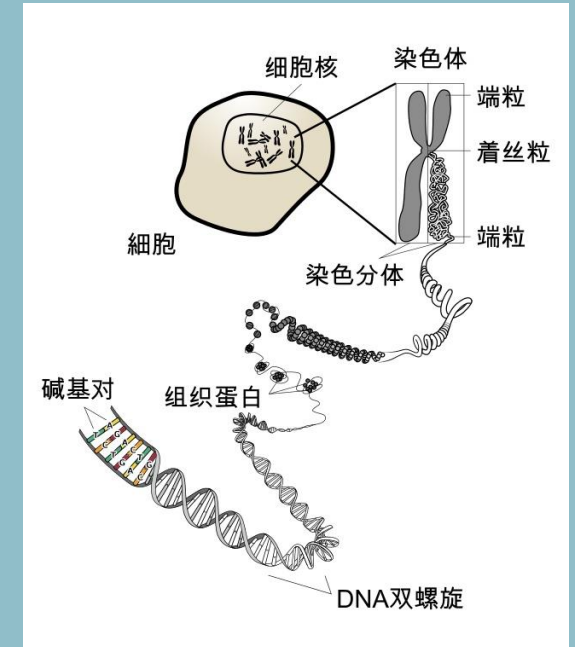
- DNA and Mendelian genetics





### 3. Theory as Explainers: H-D Model

- DNA and Mendelian genetics
- So, if Mendel discovered laws about genes, it stands to reason that they obtain in virtue of the operation of laws about DNA molecules. And if this is so, then how more clearly to explain Mendel's laws than **by showing that they obtain in virtue of another set of laws**, and how more clearly to show this than to **logically derive the former from laws of molecular biology**



## 4. The Philosophical Significance of Newtonian Mechanics and Theories

- Deterministic vs. free will
- The heavens differ from the Earth in their perfection and changelessness. And everything under the Sun had a purpose ordained by the designing deity.
- Common-sense/teleology
- Newton's four laws became the paradigm case of what a scientific law should be: universal in form, apparently unencumbered by *ceteris paribus* clauses (until electrostatic forces were discovered), and continually applicable to wider and wider ranges of phenomena.



感谢聆听！