Logical empiricism

Christian Wüthrich

http://www.wuthrich.net/

Introduction to the history and philosophy of science
Faculté des sciences, Université de Genève

Plan

1. History of logical positivism and logical empiricism

2. Characterisation of the position
   - Verificationist theory of meaning
   - Inter-theoretic reduction and the unity of science

What is logical empiricism?

Logical positivism (precursors: Auguste Comte and Ernst Mach, see lecture on the history of philosophy of science) or logical empiricism?

Characterisation (Logical empiricism)

Logical empiricism is a moderate version of the logical positivism of the Vienna Circle. It aims to reform philosophy by freeing it from doctrines that are not based on experience or logical analysis.

Exemplary works:

Carl G. Hempel (1965), ***Aspects of Scientific Explanation and Other Essays in the Philosophy of Science***. New York: The Free Press.

Carl G. Hempel (1966), ***Philosophy of Natural Science***. Englewood Cliffs: Prentice-Hall [français: ***Éléments d'épistémologie***, 2e édition, Paris: Armand Colin 1996].

Ernest Nagel (1961), ***The Structure of Science***. London: Routledge.

The Vienna Circle (the 'Ernst Mach Society')

- Hans Hahn, Otto Neurath and Philipp Frank regularly met in the cafés of Vienna to discuss philosophy of science (1907-1912).

Philipp Frank (cited in Thomas Uebel (2003, 151))

About 1910 there began in Vienna a movement which regarded Mach's positivist philosophy of science as having great importance for general intellectual life [...] An attempt was made by a group of young men to retain the most essential points of Mach's positivism, especially his stand against the misuse of metaphysics in science. [...] To this group belonged the mathematician H. Hahn, the political economist Otto Neurath, and the author of this book [i.e. Frank], at the time an instructor in theoretical physics in Vienna. [...] We tried to supplement Mach's ideas by those of the French philosophy of science of Henri Poincaré and Pierre Duhem [...]

Thomas Uebel (2003). Philipp Frank's history of the Vienna Circle. In G L Hardcastle and A W Richardson (eds.), *Logical Empiricism in North America*, University of Minnesota Press, 149-169.

- These meetings revived in 1922 with the participation of Moritz Schlick (chair of the philosophy of the inductive science at the University of Vienna).
- from 1926: Rudolf Carnap
- 1928: Ernst Mach Society officially established
- 1929: publication of the manifest of the Vienna Circle, *Wissenschaftliche Weltauffassung. Der Wiener Kreis*
- from 1933: dispersion of the Circle, most members emigrate to the USA
- 1936: Schlick is killed by a deranged student
- other prominent members included: Herbert Feigl, Kurt Gödel, Victor Kraft
- associated: Hans Reichenbach, Carl Gustav Hempel, Ludwig Wittgenstein.

Main representatives of logical positivism/empiricism

Moritz Schlick
(1882-1936)

Rudolf Carnap
(1891-1970)

Hans Reichenbach
(1891-1953)

The manifest of the Vienna Circle (1929)

The scientific conception of the world: the Vienna Circle

The scientific conception of the world of the Vienna Circle is characterised

> *essentially by two features. First it is empiricist and positivist: there is knowledge only from experience, which rests on what is immediately given [...] Second, the scientific world-conception is marked by application of a certain method, namely logical analysis. The aim of scientific effort is to reach the goal, unified science, by applying logical analysis to the empirical material [...] (309)*

Hans Hahn, Otto Neurath, Rudolf Carnap (1973). The scientific conception of the world: The Vienna Circle. In M. Neurath and R. Cohen (eds.), ***Empiricism and Sociology*** (pp. 298-318). Dordrecht: Reidel.

Logical empiricism

Empiricism:

- impossibility of *a priori* knowledge, except in mathematics; impossibility of metaphysical knowledge
- acceptance, in principle, of Hume's scepticism regarding causality (no knowledge of a 'secret connection' between cause and effect, only constant regularities)
- Experience determines the choice of scientific theories.
- The scientific method is hypothetico-deductive.

Logique:

- modern logic (Frege, Russell-Whitehead, Quine) as tool for the analysis of meta-scientific concepts: theory, explanation, law of nature, confirmation, inter-theory reduction

Verificationist theory of meaning

Thesis (The verification criterion of meaning)

The (cognitive) meaning of a proposition consists in its method of verification (or refutation), and a proposition which cannot be verified (or refuted) is (cognitively) meaningless.

- verifiability is in principle, not in practice
- 'weak' verifiability is sufficient, i.e., it is possible for experience to render it more or less probable
- propositions don't need to be conclusively falsifiable in order to be meaningful (holism!)
- statement can have emotive meaning even if it's cognitively meaningless

- *a priori* statements excluded from criterion because they are not genuine propositions, but only tautologies (= propositions that 'says nothing', is true no matter what)

$\Rightarrow$ Tautologies and empirical hypotheses form the entire class of significant propositions.

- general definition of metaphysical sentence: "sentence which purports to express a genuine proposition, but does, in fact, express neither a tautology nor an empirical hypothesis." (Ayer 1952, 41)
- In other words, they are synthetic *a priori* propositions.
- Synthetic *a priori* statements are (cognitively) meaningless, only analytic *a priori* and synthetic *a posteriori* statements are meaningful.

A J Ayer (1952). *Language, Truth and Logic*. New York: Dover.

Examples of meaningless propositions

- "The Nothing nihilates." (Martin Heidegger)
- "The Good is the class of the determinate conceived as a unity." (Plato)
- "There is an omnipotent God."
- "The State is the image of the divine on Earth." (Hegel)
- assertion that the world of sense-experience is altogether unreal (and only apparent)
- metaphysical debate between realists and idealists
- dispute between monism and dualism
- metaphysics and theology quite in general, because they consists of synthetic *a priori* propositions

Justification of observation statements

The singular propositions at the foundation of scientific knowledge are observation statements in a certain language, so-called protocol statements.

Characterisation (Protocol statements)

Protocol statements are special scientific statements that are directly justified by sense experience (observation) and make it possible to justify the theoretical statements of a science in turn.

Barberousse, Kistler, Ludwig. La philosophie des sciences au XXème siècle. Champs, 2000, pp. 10–31.

$\Rightarrow$ What is the justification for the protocol statements exactly?

Two epistemologies of protocol statements

- Schlick's psychologism in the tradition of Mach: protocol statements derive their truth from mental states. It is the private experiences of individuals producing observational statements that provide the infallible and subjective justification for scientific knowledge.
- The physicalism of Carnap and Neurath: protocol statements derive their truth from physical states in the world. Possibility of finding intersubjective invariants that transcend the private nature of each individual's experiences. Objects localised in space and time. Fallible justification and objective.

Example: liquid that changes from blue to red in a test tube

- psychologism: 'now here blue', then 'now here red'.
- physicalism: 'the liquid in the test tube on the table is blue', then 'the liquid in the test tube on the table is red'.

Two physicalisms: foundationalism and coherentism

- Carnap's foundationalism: protocol statements need no external justification, and are self-justifying. Infallible and objective justification
- Neurath's objection: risk of dogmatism. It must be possible to discriminate between good and bad observation statements.
- Neurath's coherentism: protocol statements can be true or false, and in order to judge this, they are evaluated against all scientific statements: the criterion of coherence.
- advantage: reflects the fact that a protocol statement can be good or bad
- cost: protocol statements become fallible; objective scientific knowledge, but fallible

Context of discovery vs. context of justification

Hans Reichenbach (1938). *Experience and Prediction*. University of Chicago Press.

Reichenbach (1938): distinction between the context of the discovery of scientific knowledge and the context of its justification.:

Characterisation (Context of the discovery)

The context of discovery concerns the discovery and development of scientific ideas, hypotheses and theories, and does not follow a 'logic' or method that is to be analysed by philosophy. It is not accessible through logical analysis. The sometimes irrational psychological processes of scientists, and the creativity associated with them, constitute the proper object of psychology (which can provide a causal explanation of these processes and this creativity).

$\Rightarrow$ the impossibility of a 'logic of discovery', the study of the context of discovery is the proper object of the history of science and psychology

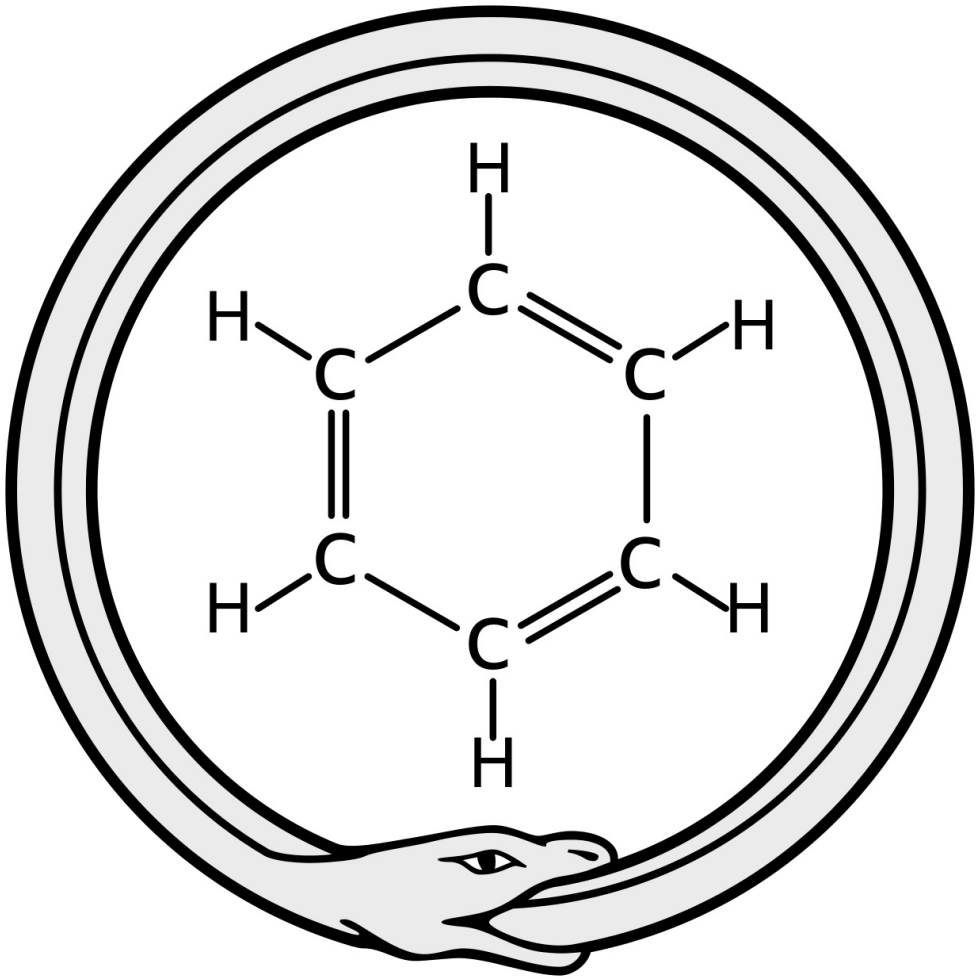
Context of discovery vs. context of justification

Example: discovery of the circular structure of benzene by Friedrich August Kekulé

> *"I turned my chair towards the fire and fell into a half-sleep. Again the atoms stirred before my eyes [...] Long chains, often more tightly linked, were all in motion, intertwining and writhing like snakes. But what was this? One of the snakes had grabbed its own tail, and this form was twirling mockingly before my eyes. I woke up in a flash [...]."*

D'Archimède à Einstein, les faces cachées de l'invention scientifique, chap. Du rêve à la science, de Pierre Thuillier, Fayard, 1988.

From the snake to the structure of benzene



Context of discovery vs. context of justification

Characterisation (Context of justification)

The context of justification, in contrast, is that of the defence and epistemic justification of scientific hypotheses and theories, and therefore constitutes the central themes of philosophy of science.

- The aim of scientific methodology is to establish the conditions under which hypotheses or theories are justified, confirmed or acceptable.
- Epistemic norms concern only the context of justification (according to logical empiricism).
- Epistemic norms: consistency, prohibition of invalid inferences, regulation of beliefs by empirical observations and experiments, etc.

Example

- The justification of the circular structure of benzene, or the defence that its structure is circular.

The ancient vision of the unity of science

René Descartes, *Principles of Philosophy* (1644)

> *Thus the whole of philosophy is like a tree. The roots are metaphysics, the trunk is physics, and the branches emerging from the trunk are all the other sciences, which may be reduced to three principal ones, namely medicine, mechanics and morals. By 'morals' I understand the highest and most perfect moral system, which presupposes a complete knowledge of the other sciences and is the ultimate level of wisdom. (186)*

René Descartes, *The Philosophical Writings of Descartes*, volume I. Translated by John Cottingham, Robert Stoothoff, Dugald Murdoch. Cambridge University Press (1985).

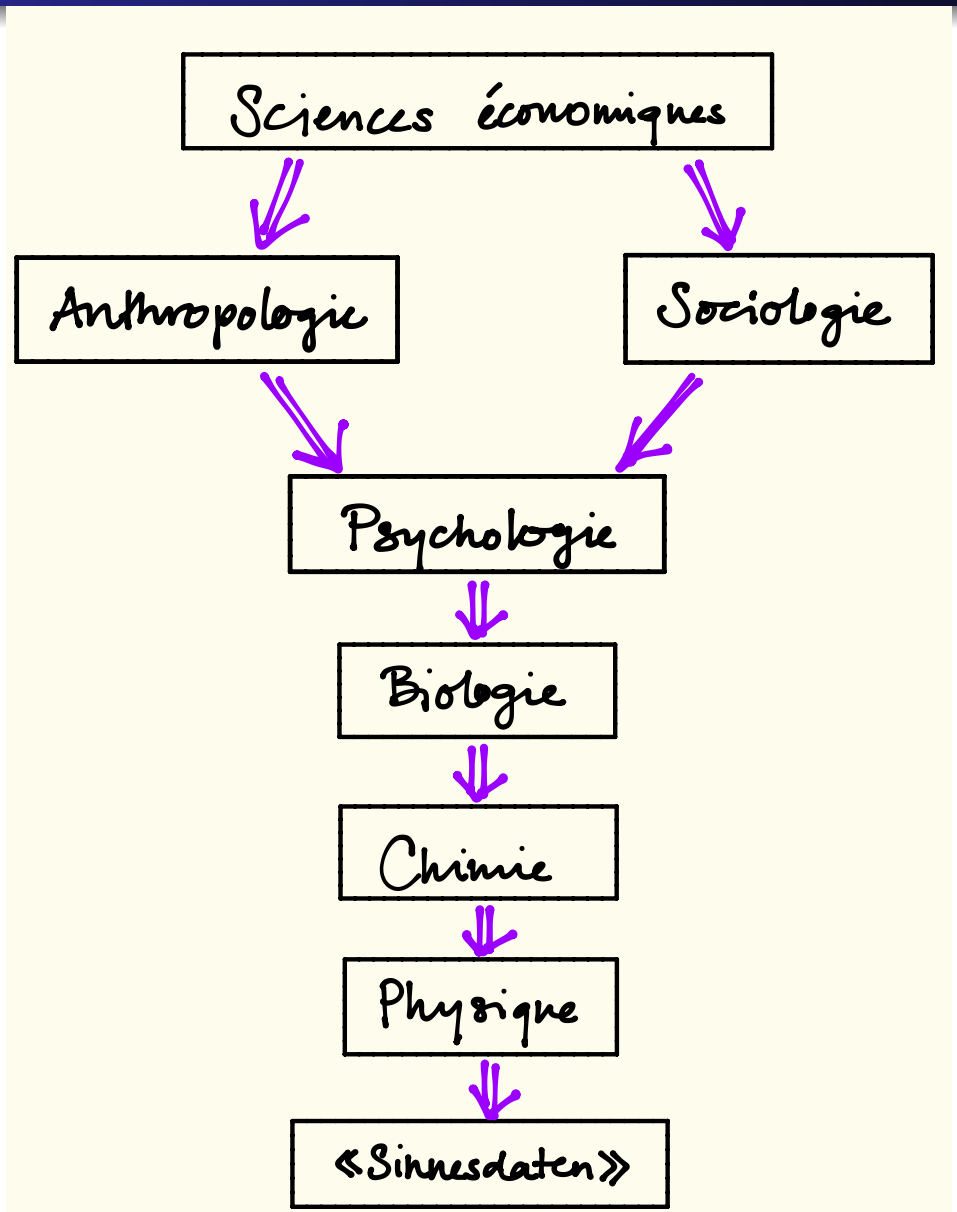
Inter-theoretic reduction and the unity of science

- The 'scientific conception of the world' of the Vienna Circle contained the thesis of the unity of science. The positivists believed that this unity consisted in the reducibility of all language to the terms of observation that correspond to sensory data (German *Sinnesdaten*).

$\Rightarrow$ empiricist foundation

- Logical empiricism finally abandoned the Vienna Circle's original aspiration for this semantic reductionism (it simply proved impossible to define all scientific terms by terms that describe immediate observations).
- But logical empiricism took a weaker position on the unity of science. According to this view, all theories concerning phenomena at a certain level are reducible, in principle, to theories at a more fundamental level. According to this view, chemistry is reducible to physics, biology to chemistry, and so on.

Inter-theoretic reduction and the unity of science



What is reduction?

Ernest Nagel: reduction as derivation

1. Homogeneous reduction: reduction of laws to other laws without the latter laws containing terms that do not appear in the reduced laws. Example: derivation of Galileo's law of the fall of bodies from Newton's laws.
2. Heterogeneous reduction: the reduced laws contain terms which do not appear in the reducing theory. Examples: derivation of the laws of optics from Maxwell's theory of electromagnetism (the latter does not contain the term 'light'); derivation of certain thermodynamic laws from statistical mechanics; psychology and physics.

Ernest Nagel (1961). *The Structure of Science*. London: Routledge.

Homogeneous reduction: Galileo and Newton

- Galileo's law of free fall states that the acceleration (change in velocity over time) of any falling object is constant, regardless of its mass.
- Newton formulated his second law, a fundamental principle of dynamics: $F = m \cdot a$, i.e., the net force F on a body is equal to the body's mass m times the acceleration a.
- In the particular case of gravity (for fall distances small compared to the Earth's radius): $m \cdot g = m \cdot a$ or $a = g$, g being a constant relative to the Earth's surface.
- Newton's law of universal gravity states that the gravitational force F_G between two bodies with masses m_1 and m_2 whose centres of mass are at a distance r is $F_G = G\frac{m_1 m_2}{r^2}$, where G is Newton's fundamental constant of gravity.
- Velocity varies constantly, independently of mass, as Galileo's law of free fall states. Newton's theory allows us to calculate this constant: $g = (G \cdot M_E)/(R_E)^2 = 9.81 m/s^2$, where M_E is Earth's mass and R_E is Earth's radius.

Homogeneous reduction: Galileo and Newton

- Galileo's law can easily be subsumed under Newton's law of gravitation, which is more general (it can also be used to derive Kepler's laws describing the motion of the planets).
- Same concepts of velocity, acceleration and mass in both theories: homogeneous reduction.

Apollo 15 (1971), Astronaut David Scott's feather and hammer experiment on the moon, in homage to Galileo:

`https://www.youtube.com/watch?v=5C5_dOEyAfk`

Heterogeneous reduction: thermodynamics and statistical mechanics

- Classical thermodynamics (Sadi Carnot): theoretical concepts of 'temperature' and 'entropy'
- Statistical mechanics (Ludwig Boltzmann): conception of large sets of molecules characterised by statistical parameters such as average kinetic energy
- Some laws that contain the term 'temperature' are derivable, in a strictly deductive way, from laws that contain only mechanical terms.

Example: ideal gas law (law of Boyle-Mariotte)

$$pV = nRT$$

p: pressure, V: volume, n: number of molecules (in mol), R: gas constant, T: temperature

Reduction of classical thermodynamics

- This derivation employs an equation which relates temperature to the molecules' average kinetic energy:

$$\langle E_{kin} \rangle = 3kT/2$$

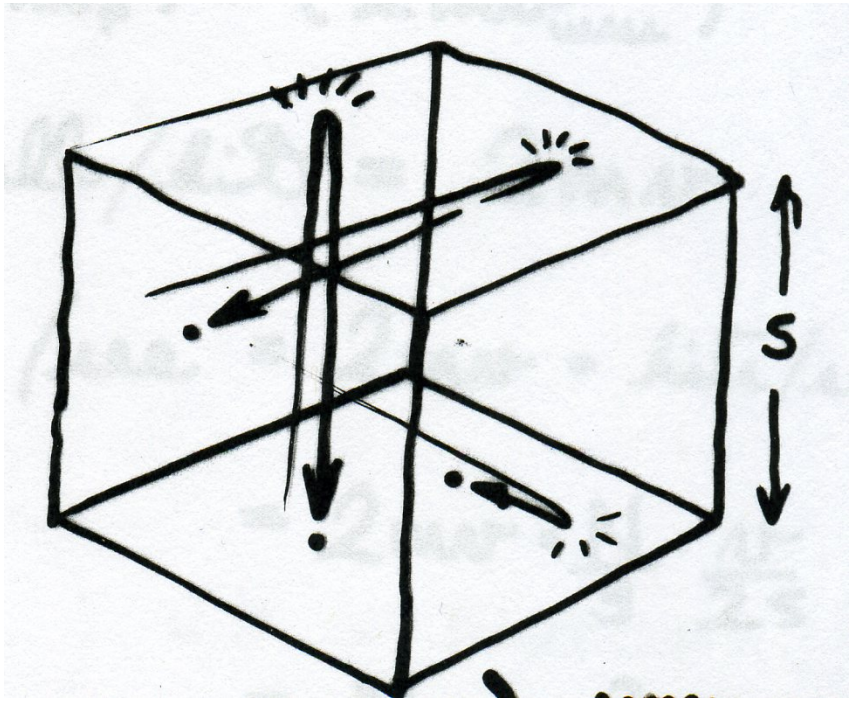
  k: Boltzmann's constant
- Nagel: a 'bridge principle' relates the terms of the reduced theory and those of the reductive theory in heterogeneous reductions.
- Here, the temperature is associated with the average kinetic energy—different concepts!

*In more detail: simple derivation of ideal gas law

Assumptions:

1. Newtonian dynamics, i.e.
   (a) total mv is conserved (conservation of momentum)
   (b) F = rate of change of mv
2. gas is dilute, i.e. gas particles are point particles or very nearly so, i.e. their cross-section small compared to the density, i.e. no collisions between particles
3. collisions between particles and walls orthogonal and fully elastic
4. auxiliary assumptions about the set up

*In more detail: the set up (auxiliary assumptions)



- box size: $s \times s \times s$
- N particles of mass m
- $v =$ (average) velocity of particles
- particles evenly divided among three groups moving orthogonally

*In more detail: derivation

For a given wall and particle:

- t from one hit to next $= 2s/v$
- number of hits/second $= 1/t = v/2s$

$\Rightarrow$ total hits by all particles on wall/sec $= N/3 \cdot v/2s$

- momentum of particle before hit $= +mv$
- momentum of particle after hit $= -mv$

$$\begin{aligned} \text{total momentum before} &= \text{total momentum after} \\ (+mv)_p &= (-mv)_p + (2mv)_{wall} \end{aligned}$$

- momentum acquired by wall/hit $= 2mv$
- total momentum acquired by wall/sec $= 2mv \cdot$ hits/sec $= 2mv \cdot N/3 \cdot v/2s = Nmv^2/3s$

*In more detail:

- $F =$ rate of change of mv

$\therefore$ $F = \frac{Nmv^2}{3s}$ (force on wall)

- pressure = force/unit area, i.e. $p = \frac{F}{s^2}$

$\therefore$ $ps^2 = \frac{Nmv^2}{3s}$

- but $s^3 = V$ (volume)

$\therefore$ $pV = N \cdot \frac{2}{3} \cdot \frac{mv^2}{2}$

- Compare this to the ideal gas law: $pV = nRT$
- n, N: measures of amount of gas

$\Rightarrow$ $T = \frac{mv^2}{2} \cdot \frac{2N}{3nR}$, i.e., kinetic energy times a constant

Heterogeneous reduction: psychology and physics

- If psychology were reducible to physics (as the logical empiricists thought), the reduction would be heterogeneous:
- Psychological theories contain terms such as 'belief', 'desire' or 'suffering', which are absent from physical theories.

$\Rightarrow$ Additional hypotheses must therefore be introduced to establish the relationship between these terms and those of the physical theories.

- These hypotheses are the bridge principles (or bridge laws).

Model of reduction according to Nagel

Laws of the reducing theory plus bridge principles

$\Downarrow$ [deduction (= inter-theoretic explanation)]

Laws of the reduced theory

1. There is much discussion about the nature of bridge principles: logical form (conditional? biconditional?), interpretation (empirical laws? definitions? identity relations?), possibility (chemistry? biology? psychology?).
2. Reductive derivations are rarely strictly deductive. In most cases it is necessary to make approximations and idealisations.