

Philosophy of Space and Time: Week 9

A-Series and B-Series, Reprise

Recall McTaggart's distinction between the A-series and B-series:

A-series: We can order events according to whether they are past, present, or future. This morning's breakfast happened in the past; this seminar is happening now, in the present; your afternoon is in the future.

B-series: We can also order events according to their temporal relations to one another—*earlier/later than*, etc.

Question: Can B-series facts be grounded in something else?

- McTaggart claims that B-series facts can be grounded in A- and C-series facts.
- But do there exist alternative ways of grounding B-series facts?
 - B-series facts grounded in certain metaphysical facts? (E.g. causal facts?)
 - B-series facts grounded in certain physical facts? (E.g. entropy?)

Of course, even if one is a B-theorist, one always has the fallback option of saying that B-series facts are fundamental and irreducible.

Time-Reversal Invariance

We say that a theory is *invariant* under some transformation just in case the dynamics of the theory remains the same under the transformation. (E.g., recall that the dynamical laws of special relativity are *Lorentz invariant*; and the dynamical laws of Newtonian mechanics are *Galilean invariant*.) A theory is *time-reversal invariant*, i.e. *time symmetric*, just in case, if a given history is a solution of the laws of that theory, then so is the time-reversed history.

Thermodynamics

- Thermodynamics is the study of relationships between variables like temperature, pressure, and volume.
- It appeals to concepts like work and heat to explain the properties of macroscopic systems, e.g.
 - (a) Heat engines
 - (b) Ice melting
 - (c) Gases expanding

Recall: Thermodynamics is a principle theory! Its four principles (the analogues of the relativity principle and light postulate in the case of special relativity) are the *laws of thermodynamics*.¹

- **Zeroth law of thermodynamics:** If two systems are in thermal equilibrium with a third system, they are in thermal equilibrium with each other.
- **First law of thermodynamics:** When energy passes, as work, as heat, or with matter, into or out from a system, the system's internal energy changes in accord with the law of conservation of energy.
- **Second law of thermodynamics:** In a natural thermodynamic process, the sum of the entropies of the interacting thermodynamic systems increases.
- **Third law of thermodynamics:** The entropy of a system approaches a constant value as the temperature approaches absolute zero.

The second law of thermodynamics is *manifestly not time reversal invariant*. Therefore, thermodynamics *tout court* is not time reversal invariant.²

¹The details for us aren't important, but see e.g. the textbook by Blundell and Blundell for more information.

²There is some debate regarding the *source* of the time asymmetry in thermodynamics—see the paper by Brown and Uffink on the further reading for discussion.

Statistical mechanics

- Statistical mechanics is our theory for describing the behaviour of large numbers of bodies—e.g. atoms.
- Statistical mechanics is regarded as providing the *constructive underpinning* of thermodynamics (recall again the principle/constructive distinction from the weeks on special relativity).³

Consider a movie of some particle bouncing around in a box. The time-reversed movie is also a solution of statistical mechanics. Therefore, statistical mechanics is *time reversal invariant*.

Puzzle: How do the time-asymmetric laws of thermodynamics emerge from the (more fundamental) time-symmetric laws of statistical mechanics? (This is a very hot topic in the philosophy of statistical mechanics.)

Back to Temporal Asymmetries

So: How might we ground B-series facts?

- Physical candidate: The thermodynamic arrow of time. (Roughly, *entropy increases*; cf. the second law above).
 - Weird result: Consider ‘big crunch’ universes. (“Gold universes”—Dainton pg. 53.)
- Metaphysical candidate: The causal arrow of time. (Namely: *causes precede their effects*).
 - Thought: Event *a* is earlier than event *b* if *a* is the cause of *b*.
 - Endorsed by the arch B-theorist, Mellor. (*Real Time II*).
 - But: This would rule out backwards causation and causal loops (and hence certain time travel scenarios—cf. last week) by fiat. A problem?

³Indeed, much work has been done on demonstrating that one can obtain the laws of thermodynamics from those of statistical mechanics in certain *limits*.