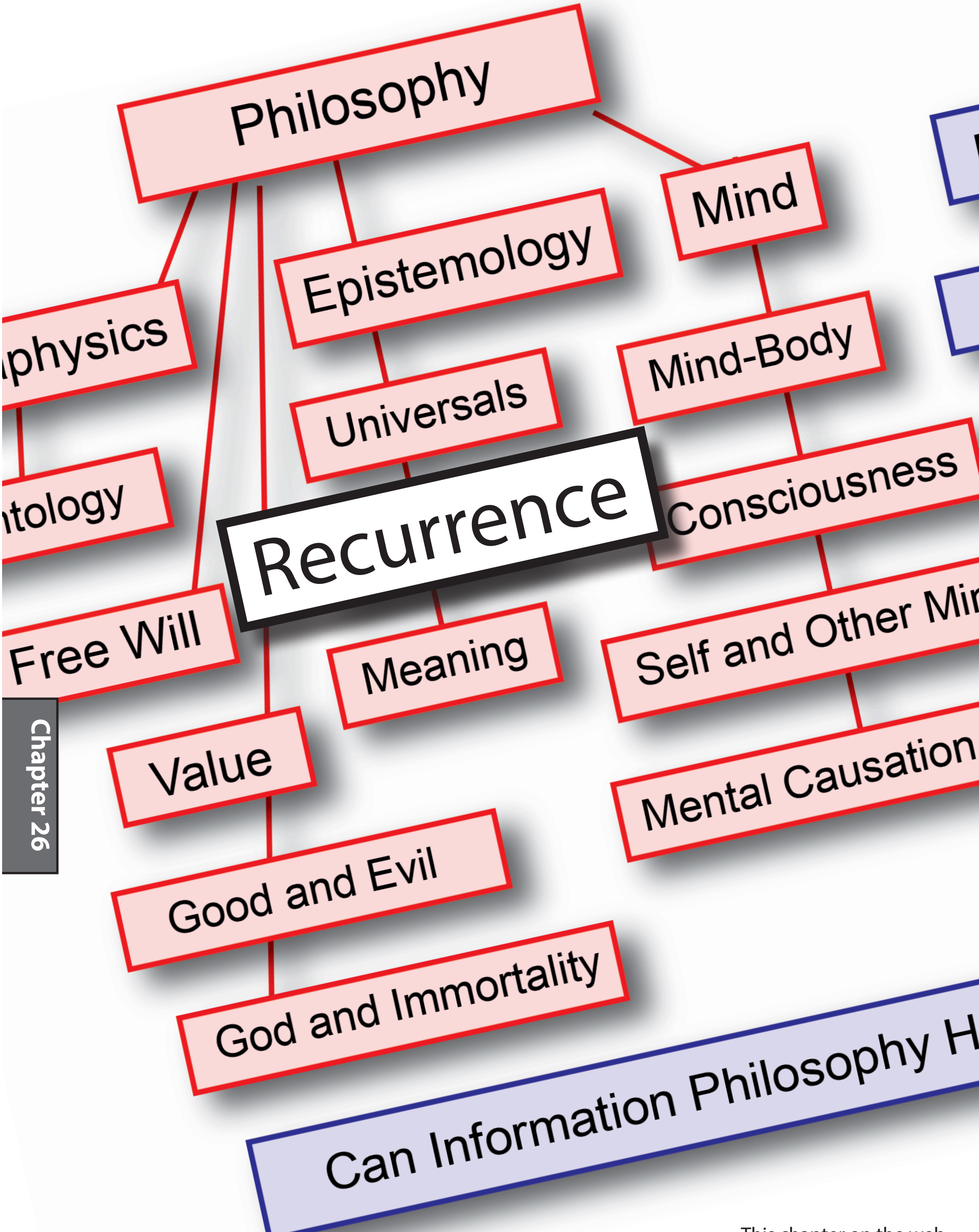

Chapter 26

This chapter on the web
informationphilosopher.com/problems/recurrence

The Recurrence Problem

The idea that the macroscopic conditions in the world will repeat after some interval of time is an ancient idea, but it plays a vital role in modern physics as well.

Ancient middle eastern civilizations called it the Great Year. They calculated it as the time after which the planets would realign themselves in identical positions in the sky.

The Great Year should not be confused with the time that the precession of the equinoxes takes to return the equinoxes to the same position along the Zodiac - although this time (about 26,000 years) is of the same order of magnitude as one famous number given by Babylonian astronomers for the Great Year (36,000 years).

Many societies have the concept of the Great Year, but none did calculations as carefully as the Babylonians. But since the planets orbital periods are not really commensurate, they kept increasing the time for the Great Year searching for a better recurrence time.

The Greek and Roman Stoics thought the Great Year was proof of law in nature and the God of reason that lies behind nature.

In modern philosophy, Friedrich Nietzsche described an eternal return in his *Also Sprach Zarathustra*.

Zermelo's Paradox

Ernst Zermelo' criticized Ludwig Boltzmann's *H*-Theorem, the attempt to derive the increasing entropy required by the second law of thermodynamics from basic statistical mechanics.

It was the second "paradox" attack on Boltzmann. The first was Josef Loschmidt's claim that entropy would be reduced if time were reversed. This is the problem of microscopic reversibility.[1]

Zermelo was an extraordinary mathematician. He was (in 1908) the founder of axiomatic set theory, which with the addition of the axiom of choice (also his work, in 1904) is the most common foundation of mathematics. The axiom of choice says that given any collection of sets, one can find a way to unambiguously select one object from each set, even if the number of sets is infinite.

1 See chapter 25 on irreversibility.

Before this amazing work, Zermelo was a young associate of Max Planck in Berlin, one of many German physicists who opposed the work of Boltzmann to establish the existence of atoms.

Zermelo's criticism was based on the work of Henri Poincaré, an expert in the three-body problem, which, unlike the two-body problem, has no exact analytic solution.

Poincaré had been able to establish limits or bounds on the possible configurations of the three bodies from conservation laws. Planck and Zermelo applied some of Poincaré's thinking to the n particles in a gas. They argued that given a long enough time, the particles would return to a distribution in "phase space" (a $6n$-dimensional space of possible velocities and positions) that would be indistinguishable from the original distribution.

Thus, they argued, Boltzmann's formula for the entropy would at some future time go back down, vitiating Boltzmann's claim to have proved that entropy always increases - as the second law of thermodynamics requires.

Boltzmann replied that his argument was statistical. He only claimed that entropy increase was overwhelmingly more probable than Zermelo's predicted decrease. Boltzmann calculated the probability of a decrease of a very small gas of only a few hundred particles and found the time needed to realize such a decrease is many orders of magnitude larger than the presumed age of the universe.

The idea that a macroscopic system can return to exactly the same physical conditions is closely related to the idea that an agent may face "exactly the same circumstances in making a decision. Determinists maintain that given the "fixed past" and the "laws of nature" that the agent would have to make exactly the same decision again.[2]

2 See chapter 5

The Extreme Improbability of Perfect Recurrence

In a classical deterministic universe, given enough time, the universe can return to the exact circumstance of any earlier instant of time, because it contains the same amount of matter, energy, and information.

But, in the real universe, information expands from a minimum at the origin, to ever larger amounts of information.

Arthur Stanley Eddington was probably the first to see that the expanding universe with increasing information provides a resolution to Zermelo's objection to Boltzmann.

> "By accepting the theory of the expanding universe we are relieved of one conclusion which we had felt to be intrinsically absurd. It was argued that every possible configuration of atoms must repeat itself at some distant date. But that was on the assumption that the atoms will have only the same choice of configurations in the future that they have now. In an expanding space any particular congruence becomes more and more improbable. The expansion of the universe creates new possibilities of distribution faster than the atoms can work through them, and there is no longer any likelihood of a particular distribution being repeated. If we continue shuffling a pack of cards we are bound sometime to bring them into their standard order — but not if the conditions are that every morning one more card is added to the pack."[3]

And note that it is the failure of recurrence that makes all the arrows of time of chapter 24 into one-way arrows.

3 *New Pathways in Science*, 1939, p.68