

Afterword: Laplace's Demon

Dr Rob Appleby

LAPLACE'S DEMON TURNS 200 years old this year (2014) having been first published by Pierre-Simon Laplace in 1814. The actual word 'demon' never appeared in the original work; instead Laplace talked of an 'intellect':

"We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes."

– Pierre Simon Laplace, *A Philosophical Essay on Probabilities*.

His demon is concerned with the role of determinism, reversibility and free will in a universe obeying the classical laws of mechanics and the demon has, as discovered by Frank and Ted in 'The Tiniest Atom', some startling implications.

To understand the demon, let's go back to the laws of classical mechanics. These laws of nature, as formulated by luminaries like Newton, Lagrange and Hamilton, are a set of ideas and equations that let us calculate and predict the motion of physical bodies. The simplest formulation is Newton's, in which the push or pull of one body on another is described using the idea of a force. For example, we can apply a force to a bike to push it up a hill, or to a string with a conker attached to the other end, to keep the conker from flying off. Once we figure out the forces on a particular body, by a combination of experience and insight, Newton's equations let us figure out the motion in the future if we know where and how fast it is going at the present time. If there is no force then the theory simply tells us the position and speed in the future by applying the equations. This is extremely powerful. For example, when combined with the theory of gravity by the same Mr Newton, we can put satellites into orbit and even send men to the moon.

The laws of classical mechanics have two very important features built into their structure. The first is reversibility, meaning time can run either forwards or backwards to show how the motion evolves. In some sense the equations do not care about the direction of time and work either way. The second feature is related to the first and is called determinism. Essentially this means that knowing the position and speed of a body at some time is all we need to know to figure out exactly and uniquely its past and future motion. So if I know the position and speed applied to a rocket now then I know its position and speed precisely for all time simply by applying the equations.

This apparently innocuous feature has a startling consequence. Imagine our universe is made of tiny particles that obey these laws of classical mechanics and that the current state of the universe in its entirety is made up by their positions, and speeds at a given time. In other words the state of the universe is essentially a snapshot of all of these particles at some time. If they obey the classical laws of mechanics then it's possible, knowing the current state, to calculate the state slightly in the future and slightly in the past. Hence it's possible to figure out the positions and speeds at any time. Both in the past and in the future. They can be calculated in an entirely deterministic way. This is the essence of Laplace's demon, which is an entity that can somehow know all of these positions and speeds and hence know (albeit through a fairly complicated calculation) the state of the universe at any time in the future. Pretty disturbing stuff, as where does this leave freedom of choice for the people living in this universe and made up of these little particles? This is sometimes called the clockwork universe, comparing the universe to a mechanical clock. But where does it leave free will?

These startling conclusions on determinism and free will are the essence of Laplace's demon. But they only apply in a universe that obeys these classical laws. The standard way out is to appeal to quantum mechanics, where inherent indeterminacy means it is impossible to know

precisely the position and speed of a particle at a given instant of time. This uncertainty is built into the theory, which our universe seems to obey, and so it is simply impossible to know the current state of the universe. More recent arguments against this demon have come in the form of information theory and the ultimate computational power of the universe, which hinge on the amount of information it has been theoretically possible to compute given the current age of the universe. Whatever the possible resolution, there are certainly enough counter-arguments to hang onto free will for the inhabitants of this universe for at least a little while longer.

© Comma Press

From the forthcoming anthology, *Thought X: Fixing Science with Fiction* (Comma Press), edited by Ra Page. All rights reserved.

Supported by the Institute of Physics and Arts Council England.