

19th Century Science

By the end of the 19th century, science had been very successful in improving the human standard of living. Understanding of chemistry, biology and physics (particularly Newtonian physics) had been so spectacular, and the benefits so great, that science was generally regarded as invincible.

James Gleick in *Chaos, Making a New Science* suggests that the 20th century will be remembered by just three things: relativity, quantum mechanics, and chaos.

I would add Kurt Gödel's theorems challenging logic. My perceptions are below in chronological order,

Relativity

Einstein dramatically revised world views of physics, particularly space and time. His view seems to challenge Newton, but it is really a refinement of Newtonian mechanics. Many credit that to Newton's massive intelligence, I'm not sure that we can really make that assertion. Still, for most it is mind-bending.

Quantum Mechanics

Multiple researchers in the early 20th century postulated a discreteness in physics and physical uncertainty, largely using solutions of mathematical equations describing physical models. Quantum predictions were intuitively outrageous, and difficult to test. Over several decades experiments were devised to test the predictions. Unfortunately, all of the predictions tested agreed with the predictions (God plays dice despite Einstein's objections). Fortunately, many practical results from the theory have been implemented to human advantage.

Gödel's results

Alfred North Whitehead and Bertrand Russell in the first decade of the 20th century made a major effort to provide a complete and compelling basis for logic. After documenting their work in three volumes (the second Principia Mathematica) they acknowledged that they had not succeed (but expected others to succeed). Within 20 years, Kurt Gödel showed that their quest was indeed impossible. But, if you can't trust logic, how can you trust Gödel's theorems?

Chaos

In the 1960's Edward Lorenz developed a simple model to simulate climate and ran it on one of the early computers (which used vacuum tubes). A mistake in initializing a run showed different results than expected. From this mistake, the concept of chaos developed: non-linear systems of equations are sensitive to the smallest differences of input parameters (the Butterfly effect).

So the 20th century ended destroying the confidence with which it started. Chaos is, perhaps, the most troublesome. It was discovered empirically, not theoretically in the 19th century tradition. This is very discomfiting. Essentially all important scientific processes are non linear, and chaos severely limits the confidence in predictions. And essentially the only way to check the validity is empirical, not possible for long term predictions.

So, we have gone from understanding everything, to not being certain about anything.