Details and Differences: On the Growth of Knowledge in the Physical Sciences

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In his 2014 paper "Closing the Loop", George Smith presents a novel view about the growth of knowledge in celestial mechanics in the 200 years succeeding Newton. On the Newtonian theory, one could take details of the solar system—e.g. the orbital elements of the known planets, their relative positions, their mass distributions, the positions and masses of their moons and other massive bodies—and calculate what differences they would make to the orbits of the planets. Discrepancies between the observed motions of the planets and predictions based on the application of Newtonian theory to known details of the solar system, could be taken to indicate the existence of previously unknown details of the solar system that are making an observable difference. Numerous times in the history of celestial mechanics, the investigation of such discrepancies led to the discovery of such previously unknown details, the most famous such discovery being that of the planet Uranus. According to Smith, the great epistemic achievement of Newtonian celestial mechanics was the identification of thousands of details that make a difference in the solar system, and the differences they make. He further makes the point that, although Newtonian gravity theory was radically overthrown in the transition to general relativity, the details that make a difference, and the differences they make, all remained intact across this transition, thus presenting a powerful response to Kuhn—much less knowledge is lost across a paradigm shift on this view.

I will call this view about the growth of knowledge in celestial mechanics the "details and differences view" (D&D view). It is not clear how much this view generalizes to other areas of the physical sciences. I will thus examine how it might apply to two other fields of the physical sciences: (1) global seismology and (2) the measurement of the fundamental constants of nature. I argue that the D&D view applies particularly well to global seismology because there is an existing theory, the theory of elastic waves, that plays the role that Newtonian theory does for celestial mechanics, and the Earth, much like the solar system, is an extremely complex system for which the natural way to proceed is to look for details that make a difference. I show that the D&D view is also applicable to the measurement of the fundamental constants of nature, but it includes another element—the active creation of phenomena—that is not seen in the other two examples. I examine the

implications for the growth of scientific knowledge through the measurement of the fundamental constants of nature.