Moreover, the future users of the data might include members of a wide range of biological research communities. Data on the plant *Arabidopsis* might be used by researchers studying maize, yeast, or even humans. Curators therefore endeavor to produce metadata that will facilitate "data journeys" across many intellectual and social boundaries. The objective is to enable future researchers to evaluate the applicability of a dataset to a diversity of organisms, problems, and biological systems—a challenging task requiring tradeoffs and negotiation among researchers who conceptualize phenomena in diverse and sometimes incompatible ways.

Of particular importance to preparing data for travel is the task of creating bio-ontologies for classifying data. Leonelli describes how the Gene Ontology, an early and widely adopted tool, structures biological knowledge as a hierarchical network of terms. This ontology links "child" terms to "parent" terms via relationships such as "part of," "is a," or "regulates" (e.g., the membrane is *part of* the cell). Creating such ontologies, Leonelli argues, should not be conceptualized as mere technical work but should be understood as a valuable contribution to scientific knowledge. Going further, she insists that creating ontologies is a particular kind of scientific theorizing. Her argument is not just that classifications are theory laden. Because the work of building bio-ontologies entails establishing criteria for what count as "good" terms, definitions, and relationships, she contends that these ontologies express criteria for evaluating and interpreting the scientific significance of the entities that they classify. In this way, bio-ontologies draw together and formalize knowledge and epistemological criteria that normally are widely dispersed across diverse research communities and publications. Like theories in other domains, these "classificatory theories" play an important role in guiding research, shaping both the questions and the methods of data-centric biology.

Leonelli's account nicely portrays not only the strengths but also the weaknesses of data-centric biological research, and she offers some well-considered criticisms. For example, she worries that the availability of data may unduly influence research agendas. She also notes that unequal access to digital tools may perpetuate inequalities in science, especially globally. She is concerned that data curators, whose work is often devalued as a "service" activity, are not accorded the scientific recognition that they deserve. And she wonders about the sustainability of the infrastructure needed to perform this kind of work.

Overall, *Data-Centric Biology* is a rich and carefully argued book that nicely integrates social and philosophical perspectives. Leonelli's writing is precise and engaging, although the book is occasionally a bit repetitive. Also, because she focuses on actors who seek to produce scientific openness, her account arguably gives short shrift to regimes and practices that restrict access to knowledge or constitute actors with knowledge monopolies. But these are minor criticisms. Leonelli has made a pathbreaking contribution to the historical, social, and philosophical study of the life sciences.

Stephen Hilgartner

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Harry Collins. *Gravity's Kiss: The Detection of Gravitational Waves*. vi + 408 pp., figs., tables, apps., bibl., index. Cambridge, Mass./London: MIT Press, 2017. $29.95 (cloth). ISBN 9780262036184.

"Ladies and gentlemen, we have detected gravitational waves. We did it." On 11 February 2016, the Executive Director of the Laser Interferometer Gravitational-Wave Observatory (LIGO), Dave Reitze, made this long-awaited announcement to the world. This happened one century after the first general relativistic derivation of gravitational waves by Albert Einstein, almost sixty years after Joseph Weber started his pioneering and isolated attempts to detect these extremely tiny effects with resonant bar detectors, and more

than forty years after Harry Collins first came into contact with this scientific field, a relationship that would lead to his pathbreaking contributions to controversy studies and the sociology of scientific knowledge.

From the scientific perspective, this Nobel-worthy achievement has the double function of serving as the conclusive step in the discovery phase as well as the starting point in the observatory phase of gravitational wave astronomy, when gravitational waves are routinely being used as signals for exploring the cosmos. From the point of view of the sociology of science, *Gravity's Kiss* probably represents the last act in the longest participatory involvement of a sociologist in the dynamics of a scientific field—an epic "fifty-year adventure," as the author proudly reminds us (p. 224).

The bulk of the book (Chs. 1–2 and 4–11) chronicles and analyzes in real time the discussions (occurring mostly via email) within the gravitational-wave community of the LIGO-Virgo Collaboration, from the announcement of a "very interesting event" during the engineering run on 14 September 2015 up to the February 2016 press conference, which coincided with the publication of the peer-reviewed "discovery paper" (p. 131). The discussions raise a number of intriguing questions concerning the process through which scientists came to believe that they had detected gravitational waves, as well as the process of building arguments to convince the scientific community at large of the reality of the effect. The themes addressed in real time are further elaborated in Chapters 12–14, in which Collins assumes the more distanced worldview of the analyst to draw the philosophical consequences of this study for the sociology of scientific knowledge.

The question of when the gravitational waves were first detected emerges in a very lively and articulated manner as the book unfolds. Was it when the "very interesting event" occurred and was recorded? Or was it when it appeared clear that a blind injection could not have occurred before the observation run officially started? Or did the experts become convinced when the statistical analysis powerfully showed the statistical significance of the observed event? Or did it happen when a second, and then a third, gravitational wave signal was detected? Or was it the completion of the "Procedure for Making a First Discovery" (Appendix 1) and the submission of the paper that should be considered the discovery moment?

As Collins shows, there cannot be any definitive answer to these questions. A discovery in large collaborations of this kind cannot happen in a single moment. It is a "long Aha" (p. 255), which also happened in different ways for different people and in which social dynamics had a strong influence. Given the historical relevance of the event—of which the scientists and the author were fully conscious—the discovery also raised complex problems concerning communication with the world outside the LIGO-Virgo collaboration. Collins analyzes, and criticizes, the "obsession with secrecy" (p. 61), as well as other aspects of this story that seem to show a widespread culture of deceit in such large collaborations. In Collins's view, this attitude risks seriously affecting the integrity of the scientific community in its search for truth and weakening the leadership role he argues scientists should have in democratic societies. The most relevant case is how the community of scientists handled the discoveries of the second and third events. While they played an important role in strengthening scientists' belief that the first signal was truly a gravitational wave effect, these were not communicated to the outside world until much later (see Collins's "Postscript").

A brief chapter summarizing the history of gravitational wave detection research (Ch. 3) is added to fill in the story; there is also a discussion of the reception of the discovery within the larger community of scientists and the lay public, including a short analysis of the views of fringe scientists who opposed the discovery claim (pp. 227–253). The book is certainly very important and unique in many respects: as a firsthand contemporary history of a scientific discovery; as a socio-philosophical analysis of how such achievements are accomplished in large communities (in this case with more than a thousand scientists); and as self-reflection on the expertise and participatory commitments of the analyst who has been involved in this research for decades. The way the book was written makes it very entertaining and instructive. On

the other hand, that also constitutes its limits, as one may be distracted by the lack of a clear organizing structure and by the presence of some repetitions, as well as a few typos.

Roberto Lalli

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Ilana Löwy. *Imperfect Pregnancies: A History of Birth Defects and Prenatal Diagnosis.* xi + 277 pp., notes, index. Baltimore: Johns Hopkins University Press, 2017. $44.95 (cloth). ISBN 9781421423630.

It could be argued that prenatal diagnosis is one of most controversial biomedical interventions of the twentieth century. Broadly defined as the search for fetal anomalies *in utero*, prenatal diagnosis is made possible by a constellation of medical technologies such as amniocentesis, ultrasound, and, more recently, the use of noninvasive blood tests to analyze the fetal genome. The standard historical narrative places the origin of prenatal diagnosis in the early 1970s, when cytogeneticists uncovered the link between well-known birth defects such as Down syndrome (DS) and the presence of an abnormal number of chromosomes. Since that time, countless scholars, medical professionals, patients, and activists have debated the moral implications of this technology—namely, the use of selective abortion to prevent the birth of children with disabilities.

Ilana Löwy, in her book *Imperfect Pregnancies: A History of Birth Defects and Prenatal Diagnosis*, challenges this interpretation. Instead, she makes the provocative claim that prenatal diagnosis has actually remained remarkably uncontroversial in the decades since its introduction. The debate over the relationship between prenatal screening and eugenics, Löwy argues, has dominated the literature and obscured the ways in which the technology has already transformed the medical management of pregnancy. With a perspective informed by her previous work on cancer screening, Löwy asserts that prenatal diagnosis is, above all, a diagnostic technology. Drawing on medical literature, archival documents, and sociological and anthropological studies of reproduction, Löwy traces the history of what she calls the "prenatal diagnosis dispositif": the material, social, and economic conditions that allowed for the technology's gradual diffusion and widespread acceptance.

The book's first two chapters provide a prehistory of prenatal diagnosis. Löwy locates the roots of the practice not in the eugenics movement of the early twentieth century but, rather, in long-standing efforts to study and prevent "monstrous births." Beginning in the 1950s, tests to detect Rhesus factor incompatibility shifted the focus of prenatal care from mother to fetus, foreshadowing the development of genetic techniques in the following decade. Chapter 2 provides a new perspective on the familiar story of cytogenetics. The discovery that some birth defects could be linked to chromosomal anomalies was a boon for medical genetics, but interest in nongenetic methodologies and etiologies persisted.

The third chapter further decenters the role of genetics by linking the history of prenatal diagnosis with the discipline of teratology, later dysmorphology. Teratology, the study of abnormal embryonic development, was a marginal medical specialty until two high-profile incidents in the early 1960s—the thalidomide crisis and the outbreak of German measles—highlighted the environmental component of fetal malformation. As the resolution of ultrasound gradually improved, the study of human malformation extended to the living fetus. Löwy argues that the routinization of obstetric ultrasound is an essential but often overlooked component of prenatal diagnosis, enabling the visual identification of congenital abnormalities and dramatically increasing the number of fetuses diagnosed *in utero*. For Löwy, "the story of prenatal diagnosis is, to an important extent, the story of the convergence of studies of abnormal form and of abnormal hered-