A global history of changing knowledge

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ocean in his modeling; those firsts strongly influence the spatial pattern of the surface temperature response to carbon dioxide changes.

The middle chapters focus on climate sensitivity, which climate scientists define as the equilibrium increase in globally averaged surface temperature due to a doubling of carbon dioxide. Chapter 6 is a general discussion of the various factors that affect climate sensitivity. Manabe was one of the first scientists to show that how clouds were parameterized had a large effect on a model's climate sensitivity. That remains true in all current state-of-the-art climate models. Chapter 7 covers Manabe and Broccoli's work in the mid 1980s, when they determined that the GFDL model had a climate sensitivity of 3.2 °C. In *Beyond Global Warming*, the authors speculate that that number is close to the actual sensitivity of Earth's climate.

The final three chapters highlight the role of the ocean in climate change. Chapter 8 discusses Manabe's work with coupled models using the ocean general circulation model Kirk Bryan developed at GFDL during the 1970s. Manabe and his colleagues suggested early on that the strength of the robust meridional overturning circulation in the North Atlantic Ocean would weaken as the carbon dioxide level increased. That conclusion remains a feature of all future projections made by climate models. Chapter 9 speculates about changes to deep water formation in the ocean when the climate is cold, as at the Last Glacial Maximum. Finally, chapter 10 discusses how the water cycle between the atmosphere and ocean accelerates with global warming as evaporation increases due to higher ocean surface temperatures. As more evaporation leads to increased rainfall, Manabe and Broccoli suggest that wet regions will get wetter and dry regions will get drier.

I have only one point of disagreement with the book, which centers on the discussion of flux adjustments in chapter 8. Flux adjustments are arbitrary changes to the fluxes of heat and fresh water between the atmospheric and oceanic components of a climate model. In early models the adjustments were necessary for a model to maintain a modern climate state as it was integrated forward in time. However, improved climate models, including several developed at GFDL, have been able to run without them for over 20 years now. The need for them indicates inadequacies in the model, which include low spatial resolution, poor parameterizations of important processes, and missing processes. In my opinion, it is preferable to run climate models without using arbitrary flux adjustments, but Manabe and Broccoli endorse their continued use.

This book was a pleasure to read. It is also unlike any other book on climate that I have read because Manabe is unique among climate model developers, and because no other climate book documents a single career. *Beyond Global Warming* will be essential reading for graduate students and postdocs wanting to learn about climate modeling. It will also be an interesting read for any physicist interested in the climate and how future projections are made. It is a fitting tribute to Manabe's career, and I recommend it very highly.

Peter R. Gent
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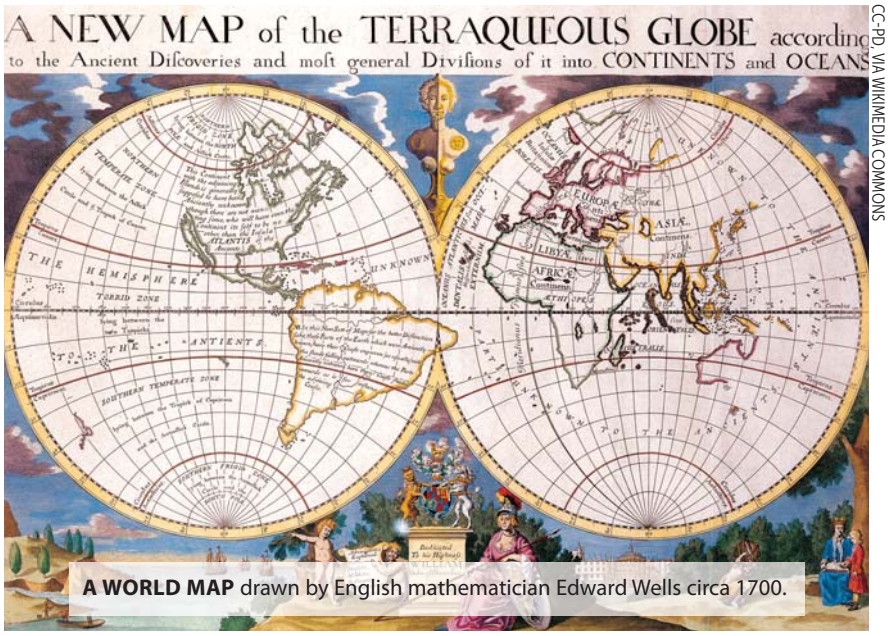

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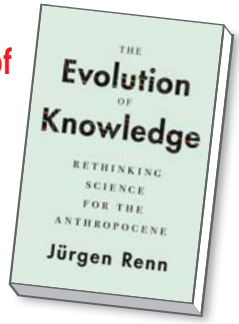
A WORLD MAP drawn by English mathematician Edward Wells circa 1700.

A global history of changing knowledge



The Evolution of Knowledge
Rethinking Science for the Anthropocene
Jürgen Renn
Princeton U. Press, 2020. $35.00

Jürgen Renn's *The Evolution of Knowledge: Rethinking Science for the Anthropocene* is a book to read twice, or not at all. A global history of knowledge is a breathtakingly ambitious project, even more so when oriented toward our current global challenges. Renn argues that an expansive perspective is prerequisite for addressing those challenges. His sweeping account of knowledge throughout human history aims to show how the structure of knowledge today contributes to—and offers a platform for addressing—the potentially existential threats of the Anthropocene. Renn faces down the difficulties of crafting such an account with skill and resolve. The result is provocative and challenging and asks much of its readers.

The book's five sections are arranged according to scale, from individuals and communities to institutions to global networks of knowledge. In the book's synoptic first section, "What Is Science?

What Is Knowledge?," Renn argues that knowledge is created by mental, material, and social factors. Our minds determine the categories we can easily apprehend and incline us to certain patterns of abstract thinking. We use mental abstractions to generate representations of ideas, which facilitate both the ideas' manipulation and their dissemination. Human communities are then structured in ways guided by those representations. The interdependence of Renn's three dimensions of knowledge—the mental, the material, and the social—is critical for understanding the book's broader argument and vision.

In part 2, Renn turns to how knowledge changes at the scale of individuals and their local social environments, drawing on developmental psychology and biology. Key here is the insight that abstract reasoning is not a straightforward consequence of our mental architecture; it is shaped by the material and social resources available during cognitive development. That set of resources has distinctive "challenging objects"—phenomena that behave recalcitrantly with respect to contemporary knowledge systems. It also has "borderline problems"—questions that straddle knowledge systems and prompt their extension. Addressing challenging objects and borderline problems is the principal mechanism by which knowledge systems change. The history of knowledge is therefore, according to Renn, contingent, path dependent, and layered, but it proceeds via discernable patterns.

As should now be evident, the book's argument unfolds in a technical language that becomes tractable only with some effort. For example, the book's 18-page glossary (which is unhelpfully broken into thematic sections rather than presented as a single, alphabetized list) defines *scientific knowledge* as "knowledge resulting from the exploration of the potentials inherent in the material or symbolic culture of a society within a knowledge economy specifically dedicated to the generation of such knowledge, allowing for its corrigibility and involving appropriate control procedures." That definition begins to make sense somewhere in part 3, but the understanding is hard won.

Part 3 describes and exemplifies "knowledge economies." Those are the distributed, and sometimes global, networks arranged to preserve, distribute, and employ external representations of knowledge, examples of which range from tools and artifacts to rituals, music, and language. Institutions—which Renn understands broadly as social arrangements, like universities or scientific societies, that reproduce stable forms of behavior within them—are integral components of knowledge economies. They have assumptions and values built into them that both guide and constrain the evolution.

Although Renn's observations about how knowledge moves at institutional scales are edifying, his metaphor of the knowledge economy is problematic. As Renn himself observes, the cultural resources at our disposal shape how we craft the external representations of our abstract concepts. The cultural resources of our age are increasingly those of the market, and that places troublesome constraints on our thinking. Renn, in his conclusion, worries about "new ways of accessing scientific information [being] blocked by its transformation into a commodity." It would therefore be preferable to have a representation of institution-level knowledge processes that did not invite us to think of knowledge as a measurable economic resource to be exchanged and hoarded as capital.

Knowledge on the global scale is the subject of part 4. We are now accustomed to hearing about global processes, but Renn is careful not to miscast global knowledge as distinctive of our time. Our globalized knowledge practices are not a novel legacy of modernity, but part of the layered history of knowledge going back millennia. The point is critical because that history informs the features of our global knowledge system, including the constraints that produce some of our era's challenges.

Those challenges, and how to address them, are the subject of the book's part 5. Renn shows tremendous faith in the power of concepts to do useful work. He argues that there are problems with "the Anthropocene" as a concept, but defends its potential to help us "integrate knowledge from all the disciplines concerned" and address human disruption of the systems stabilizing the biosphere. Doing so, per Renn, requires unshackling ourselves from the constraints of legacy knowledge systems, such as disciplinary divisions, which inhibit the goal-oriented coordination of diverse bodies of knowledge. His proposed recategorization of knowledge into the areas of system, transformation, and orientation knowledge—roughly, the understandings of Earth's natural systems, of human processes and their interaction with those systems, and of human values—is presented with the goal of overcoming intellectual territorialism and fostering the coordinated mobilization of knowledge toward well-defined ends.

That's an abstract proposal, indicative of abstract exposition. Although *The Evolution of Knowledge* is littered with historical examples, the breadth of the subject matter means those examples are necessarily cursory. As a result, it is often challenging to envision how the processes Renn discusses manifest through human agency and, correspondingly, how the solutions proffered can translate into concrete policy. Nevertheless, this book presents a powerful system within which to reason not just about the history of knowledge but about its future. And that is reason enough to read it twice.

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