the rage for cladistics in all fields of comparative biology, no one seems to have applied this approach to the features of eggshells by trying to identify nested sets (no pun intended) of characters shared by different types of eggshell. Weishampel and Horner, however, in a fine contribution, use what sparse evidence there is of embryonic and neonatal dinosaurs (only 3.5 percent of known dinosaur species are so represented) to chart phylogenetically the evolution of life-history strategies in dinosaurs, establishing minimal hypotheses of evolutionary change in nesting, parental behavior, and growth regimes. And, as Gregory Paul shows, the difference between dinosaurs and living warm-blooded animals—or for that matter, any animals—is enormous not only in terms of size: an elephant may produce about a dozen young in 40 fertile years, but a sauropod might have laid 500 to 4000 eggs. Consider that a baby elephant may weigh 400 pounds and grow to 10,000 (a 25-fold increase), but a sauropod laid a volleyball-sized egg of maybe 8 pounds that grew to 80,000. It is clear that, once again, we simply cannot assess dinosaurian biology solely by the yardsticks and limits of the arbitrary slice of life that exists on our planet today. This thoughtful, stimulating, and informative volume is required reading for a perspective on these and many other paleobiological issues; the field of dinosaurian development is hotter than ever.

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Vignettes: Non-Skepticism

At least two circularities are involved in the search for knowledge. One is the hermeneutic circle: we have to believe in order to understand and we have to understand in order to believe. That is why scepticism is so unfruitful a strategy. Why do I believe in quarks when no fractionally charged particle has ever unequivocally been observed in an experiment? Set your doubts aside for a while and see how belief in confined quarks enables us to understand a variety of phenomena . . . which otherwise would have no underlying intelligibility.

—*John Polkinghorne*, in *The Faith of a Physicist: Reflections of a Bottom-Up Thinker* (Princeton University Press)

The skepticism of science is famous, but not so widely known is its optimism. One might even suggest that creative work spans a wider spectrum than most activities between the hopeful and the critical, between proliferation and selection.

John Archibald Wheeler, in *At Home in the Universe* (AIP Press)

The Idea of Chemistry

From Chemical Philosophy to Theoretical Chemistry. Dynamics of Matter and Dynamics of Disciplines, 1800–1950. MARY JO NYE. University of California Press, Berkeley, 1994. xviii, 328 pp., illus. $48 or £37.50.

Is there a uniquely "chemical" way of seeing and describing the natural world? And if so, how does it compare with the "physical" way? When can we speak of the emergence of "theoretical" chemistry, and who were its practitioners? These and other important questions are the focus of Mary Jo Nye's highly original historical analysis of the *idea* of chemistry—the notion of a theoretical chemistry distinct both as a discipline and as a method of investigating nature. From the outset, Nye employs a novel approach: she centers on the problem of the dynamics of matter, rather than the traditional topic of the structure of matter. Chemical affinity and reactivity are thus ideal topics for understanding the interface between chemistry and physics, the crystallization of a specific discipline of modern theoretical chemistry in the 1920s and '30s. For, though it is generally considered that chemistry became an established profession, with its own identity, methods, and goals, well before physics, this empirical, laboratory culture did not attain the philosophical high status of physics because it was seen as lacking axiomatic and mathematical foundations. Kant had declared categorically that chemistry could never become "true knowledge."

Despite the attempts by the generation of Lavoisier's *chimistes* and *physiciens* to pursue problems of common interest, the 19th century saw an increasing demarcation of chemistry and physics as distinct disciplines. Nye argues that the chemists' urge to provide useful knowledge hampered the development of a theoretical chemistry and often produced incomprehension of closely related domains. But toward the end of the 19th century, chemical thermodynamics and electrochemistry led to the formation of a theoretical chemistry that sought to bridge, or even reduce, chemistry to physics. A group of Continental physical chemists that included W. Ostwald, S. Arrhenius, J. H. van't Hoff, W. Nernst, P. Duhem, and J. Perrin provided a mathematical mechanics of matter, centered on the relations between energy and the properties of macroscopic systems. Planck's quantum radiation hypothesis of 1900, the theories of the electron, and structural chemistry provided the impetus for the growth of specific research schools, molded by different national traditions, and laid the foundation for the new subdiscipline of physical organic chemistry in the early decades of the 20th century. Here Nye provides a fine-grained exploration of the Paris school of theoretical chemistry led by Robert Lespieau at the Ecole Normale; of the London-Manchester schools of A. Lapworth and T. Lowry; and of Christopher Ingold's 30-year effort at University College, London, to produce a general theory for a new physical organic chemistry.

Nye's is not a traditional narrative of ideas, experiments, and confirmatory achievements. Rather, it traces the varying ways in which chemists defined their identity, both conceptually and methodologically, within research schools. Nye makes a powerful argument for the thesis that by 1873 chemists had essentially recognized, before most physicists, "the conventional character of the basic definitions and premises of scientific explanation systems" and that "multiple explanations are superior to a simple but wrong explanation" (p. 72). Considerably later, Ingold's synthesis of physical chemistry and organic chemistry explored both molecular forces and structure, evolving into a genuine chemical theory of electrical, polar, and stereochemical effects compatible yet distinct from the then-emerging quantum chemistry.

In the last part of the book, Nye moves to the United States, where quantum chemistry was vigorously pursued by L. Pauling, J. Slater, and R. Mulliken among others. European physicists, including N. Bohr, M. Born, F. Hund, W. Heitler, and A. F. London, who initially made significant contributions to the emergence of quantum chemistry, relinquished the field primarily to American chemists. It was in the United States, too, that the elusive split between quantum chemists and chemical physicists occurred in 1933 with the founding of the *Journal of Chemical Physics* by Harold Urey. The increasing mathematization of quantum mechanical theories of electronic structure of molecules and crystals, the problems of chemical binding, and the statistical mechanical treatments of systems seemed to convey confidence in a deeper, more abstract understanding of chemistry, which, paradoxically, would lead to an almost visual perception of chemical entities, such as the chemical bond. Yet, as C. Coulson aptly warned: "That will never be, for a bond does not really exist at all: it is a most convenient fiction . . . both to experimental and theoretical chemists" (p. 261).

Nye's splendid account of scientists braving the often tortuous path between chemistry and physics is a story about how individuals have sorted out their views, even feelings and "aesthetic preferences" about the natural world, in building ever-changing disciplinary and professional identities.

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Categorization

Classification and Cognition. W. K. ESTES. Oxford University Press, New York, 1994. xii, 282 pp., illus. $49.95. Oxford Psychology Series, no. 22.

A full model of concept learning and categorization remains one of the most sought-after prizes in cognitive psychology. It is not hard to adopt a perspective whereby almost all cognition boils down to learning how to partition objects into useful groups. Concepts allow us to treat different objects equivalently, communicate, draw inferences, reason, and explain our world. To recognize a handwritten character as a *B* is to categorize it into the class of *B* letters. To remember reading an article is to categorize the article as belonging to the class of familiar things. To make a clinical diagnosis is to place a patient into a disease category. Although special-purpose routines will be needed to subserve these quite different categorizations, there is also guarded optimism that a unified model of categorization will be able to provide at least a partial explanatory account across many domains. The excitement and promise of this approach stem from its astoundingly wide sphere of application.

Categorization research has undergone several transformations. Before the 1970s, much of the work on concept learning began with the assumption that concepts are determined by necessary and sufficient defining features. In the 1970s, the prototype theory developed out of discontent with this rule-like, clear-cut approach. It assumed that concepts are organized around a best example that summarizes the most common or typical features of a concept's instances. The work summarized by Estes's book adopts a third, more recent, theory, which differs from the preceding theories in that concepts are not represented by summary or abstract descriptions. Rather, they are represented by their individual instances (called exemplars). In deciding whether an item belongs to a concept, the item is compared with the concept's exemplars. If the item is more similar to the concept's exemplars than it is to other concepts' exemplars, then it will be placed in the concept.

One of the primary attractions of exemplar models is that, even though they do not explicitly create abstract category representations, they can produce behavior that mimics behavior from models that force abstractions to occur. In the same way in which a prototypical man's face will spontaneously emerge when 50 photographs of different men's faces are superimposed, exemplar models can predict that category prototypes will emerge when many exemplars are combined. Even though only category instances are stored, previously unfamiliar prototypes may be categorized quite accurately (sometimes even more accurately than the exemplars themselves) because they are highly similar to many exemplars.

Estes's basic approach is to apply a relatively simple, mathematically formalized exemplar model to a wide variety of empirical results that have been obtained in human research laboratories including his own. He assumes that events are represented in terms of independent features (for example, *dog* might be represented by *four-legged, barks, furry,* and *tail*). When an event occurs and is effectively stored in memory, a trace of its features, including its category label, is laid down. Estes also presents a neural network implementation of his theory in which the influence of instance traces is altered with learning. Although Estes is one of the foremost researchers in mathematical psychology and his exemplar model is mathematically formalized, the equations that govern categorization behavior require only knowledge of simple algebra and are intuitively easy to grasp.

Estes applies his simple model to an extraordinarily wide array of results. He first applies it to standard empirical findings in human categorization. He provides formal accounts of how instances within a category vary in their typicality and categorization accuracy; how categories that are defined by different rules are learned with different degrees of efficiency; how concepts are combined; and how categorization is influenced by variables such as category size, presentation order, frequency, and featural similarity. However, Estes is not content merely to apply his model to traditional categorization results. True to his thesis that categorization is a core cognitive process, he subsequently applies it to work in memory, induction (for example, Given that an object has certain properties, what other properties is it likely to have?), pattern completion, and causal reasoning (for example, Is X, Y, or Z the cause of A?).

Not all readers will care about the fine details of Estes's accounts. Still, the research presented here is important for three reasons. First, it sets a standard for rigor, parsimony, and theoretical elegance in cognitive modeling. Second, in the study of human behavior, where truly general laws are rarities, it offers a coherent and predictive system for tackling both specific and general issues. Third, it provides formal tools for quantitative modeling of complex systems that researchers in many fields could effectively borrow. Although there must be more to cognition than remembering instances and generalizing from them, Estes makes a compelling claim for the broad and effective application of this process.

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