

traditional scientific speciality' and is certainly not a Kuhnian 'scientific revolution' (pp. 198, 200). 'Green chemistry' instead acts as an umbrella term which hosts many different scientists working on many different problems. Linthorst does recognize that STS scholars have argued that green chemistry is a form of 'greenwashing' (pp. 27–8). The promise of green chemistry has undeniably acted as a get-out-of-jail-free card for the chemical industry and national governments, enabling them to portray the future of commercial chemistry in a positive light without regulating it in the present. In the Anthropocene, when unregulated corporations threaten the very ecosystems on which the survival of our species (and of all others on Earth) depends, a more critical take on industry-funded sciences like green chemistry would not be untimely (p. 67). Yet Linthorst resists the label of greenwashing, insisting at one point that some green chemists are 'good-willing' and 'have been producing valuable chemical knowledge to tackle environmental problems' (p. 201). This may well be true, but does not exonerate chemists from the charge of greenwashing. As the old saying goes, the road to hell is paved with good intentions.

doi:10.1017/S0007087423000511

Marco Tamborini, *The Architecture of Evolution: The Science of Form in Twentieth-Century Evolutionary Biology*

Pittsburgh: University of Pittsburgh Press, 2022. Pp. 283. ISBN: 978-0-8229-4735-6. \$455.00 (hardcover).

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Alternative approaches to evolutionary theory do exist, often with long pedigrees in largely continental traditions: evolution is not co-extensive with adaptationist preferences in explanation ... D'Arcy Thompson kept the structuralist vision alive, with an explicitly anti-Darwinian evolutionary version, in the finest work of prose in English natural history.

Stephen Gould, 'On growth and form', in *Evolution* (1998), pp. 23–4.

Marco Tamborini's *The Architecture of Evolution* explores, and attempts to identify, the contrasting recent historical developments in Continental and anglophone approaches to animal morphology – the science of form – particularly from a modern German perspective. Tamborini's goal is to stress 'the deep intersections between philosophical theories, morphological practices, and architectural design' (p. 205) in order to argue that 'what biologists eventually accepted and firmly defended was no longer Goethe's idea of grounding morphology as an independent science. Rather, *morphology was reimagined as a transdisciplinary methodology at the boundary between biology, engineering, and literature*' (p. 208, emphasis added).

If there is one central concept it is 'constraint', although a number of others are invoked in the book – such as evolvability, modularity, burden and heterochrony. Such quasi-mechanistic terms took over from non-vitalistic concepts such as *Bauplan*, *Gestalt*, holism and organicism as explanatory factors in the evolution of the complexity of anatomical forms. Tamborini writes, 'The debate about the number and kind of mechanisms

that limit phenotype variation and evolution would deeply shape the development of late twentieth-century evolutionary biology' (p. 204).

Chapter 1 outlines D'Arcy Thompson's (1860–1948) influential rebuttal of vitalism through mechanical and mathematical principles common to organic and inorganic structures. Chapters 2–3 illustrate the application of this approach (especially under the influence of the mechanical engineer Franz Reuleaux) among German anatomists (Hans Petersen, Hermann Braus) and Italian (Giuseppe Colosi) and Russian (Michael Nowikoff) zoologists in the 1920s. There was a focus on analogy, convergence and parallelism in evolution (p. 46). 'International networks would eventually merge with their German-speaking colleagues and greatly influence post-Second World War German morphology' (p. 46); they 'criticized an excessively oversimplified explanation of morphogenesis according to which random mutations were responsible for both form and evolutionary change' (p. 50).

In Germany (Chapter 4) the palaeontologist Otto Schindewolf (1896–1971) argued for the saltationist emergence of new morphological types through macromutations (as in Goldschmidt's 'hopeful monsters'). His organismic stance (p. 88) was attacked by Gerhard Heberer, causing frictions that 'were accentuated to the point of severing the bridges between the [anglophone] neo-Darwinists and the German-speaking supporters of morphology' (p. 67). These frictions featured at the Tübingen meeting of palaeontologists in 1929, Rudolph Wedekind defending genetics (p. 69) against the Lamarckian Franz Wiedenreich (p. 74).

Chapters 5–7 introduce the new, optimistic atmosphere following the Second World War, embodied in a number of exhibitions (for example The New Landscape at MIT designed by the artist Gyorgy Kepes). The one at the Festival of Britain of 1951 (Growth and Form, opened by Le Corbusier) was devoted to D'Arcy Thompson's impact on art and design, later spelled out in the interdisciplinary symposium Aspects of Form, edited by Lancelot Law Whyte and introduced by Herbert Read. Chapter 6 surveys the involvement of the likes of Herbert Simon, Paul Weiss, Joseph Needham, Arthur Koestler, Conrad Waddington and Ludwig von Bertalanffy in the 1960s, in the end 'failed efforts to synthesize different disciplines to understand the dynamics of form changes' (p. 123). But they 'set the direction for further evolutionary investigations' (p. 124). Importantly, Carl Pantin's functional and 'engineering approach' (p. 132) to 'Organic Design' steered a new generation of palaeontologists (Martin Rudwick, Stephen Gould, David Raup, John Sepkoski) towards notions of 'morphospace' and the use of computer modelling, the 'paleontological revolution of the 1960s' (p. 136).

Drawing increasingly on archival sources, Chapters 8–9 focus on the new post-war "German" approach to science of form' (p. 148) in which biologist Heberer alongside architects Frei Otto and Buckminster Fuller (pp. 160–4) triggered a 'major contribution to twentieth-century study of form' (p. 149). Tamborini identifies an invitation from fellow palaeontologist Adolf Seilacher to Gould and Raup to a 1971 meeting in Tübingen as crucial (p. 147), building on *Konstruktionsmorphologie*, deriving from Hermann Weber's old-style holist and *alt-Nazi* thinking (p. 151), and elaborated by Otto, biologist Wolfgang Gutmann and Johann-Gerhart Helmcke (a biologist/anthropologist famous for his exploitation of electron microscopy). In interdisciplinary institutes in Stuttgart and Tübingen during the 1970s, tensions emerged (p. 186), especially in Otto's interactions with the maverick and ultimately ostracized Gutmann – with his 1972 *hydroskeletal theorie*, influenced by Pantin (p. 179). Meanwhile taxonomists/phylogeneticists Willi Hennig and Adolf Remane returned homology to centre stage.

In Chapters 10–11 Tamborini identifies the Dahlem conference in 1981 as the 'grounding meeting of evolutionary developmental biology as an autonomous evolutionary discipline' (p. 190), arguing (in Chapter 10) that Otto and Helmcke's biotechnical approach to form facilitated the final reconciliation of German and anglophone accounts of evolutionary change. An important influence was the recently published work of Viennese theoretical

biologist Rupert Riedl, famous for the concepts of ‘burden’ and ‘diagrammatic morphotype’ illustrating the interconnectedness of characters. Tamborini sees the Raup/Seilacher ‘non-adaptive morphogenetic programs ... using computers’ (p. 158) as an anticipation of Gould and Lewontin’s seminal manifesto ‘The spandrels of San Marco’ of 1979.

Although architecture as such (through Otto, Le Corbusier, Nervi and Buckminster Fuller) played a part in the overall story, the title of this book refers to a broadly structuralist approach to morphology and to the influence of engineering and mechanics, especially prominent in Germany. But palaeontologists provided the morphological data calling for explanation, data primarily of static, adult forms evolved over eons. Tamborini often refers to ‘morphogenesis’ but does not define it, and like most post-Haeckelian evolutionists ignores the easily observable dramatic, dynamic formative processes of embryogenesis which actually account for each and every morphology, despite passing reference to Wilhelm Roux and Hans Driesch in Chapter 1. The discoverer of the organizer, Hans Spemann, was probably the most famous German biologist in the 1920s and 1930s: neither are mentioned. As Gould and Lewontin point out in their 1979 manifesto, ‘*Developmental* constraints, a subcategory of phyletic restrictions, may hold the most powerful rein of all over possible evolutionary pathways’ (p. 160).

doi:10.1017/S0007087423000754

Hannah Wills, Sadie Harrison, Erika Jones, Rebecca Martin and Farrah Lawrence-Mackey (eds.), *Women in the History of Science: A Sourcebook*

London: UCL Press, 2023. Pp. xxviii + 446. ISBN 978-1-8000-8415-5. £50.00 (hardback); £30.00 (paperback); £0.00 (open-access PDF).

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Five editors coordinated with nearly fifty other scholars to produce an ambitious sourcebook reflecting the diverse histories of women who pursued and produced natural knowledge from 1200 BCE to CE 2015. The range of entries is significant, not only chronologically but also geographically, with about a third reaching beyond Britain and Europe. The results offer an impressive, perhaps necessarily eclectic, set of brief primary-source readings, some translated into English. The editors’ intention is to interrupt what they note as linear and narrow views of science, opting to focus on a wide range of knowledge production in generally overlooked spaces. In particular, they emphasize the multiple ways in which women have contributed to science, both in areas common to scientific studies and in other areas of activity not readily identified as such. International scholars bring broad expertise to their individual entries and the general editors provide introductions to each of the twelve sections.

The individual entries are relatively short, with a few exceptions, but collectively they offer compelling and evocative examples for readers unlikely to be familiar with the myriad of subjects, chronologies and geographies. Each of the selections is a primary source with a brief introduction and documentation, typically with several footnotes. Because