

DEVELOPMENT

Learning from Errors

Manfred D. Laubichler

A pathological condition is created at will, the intensity of which can be regulated by the duration of the experiment. And, master of all variables, one can dispose of the problem in such a way as to provide the greatest opportunity for a rigorous solution.

—Isidore Geoffroy Saint-Hilaire (1)

Scientists and lay people alike have been drawn to monsters, because they do not fit into existing paradigms, violate common held assumptions (as well as social norms), and thus have the allure of the illicit, the impossible, and the forbidden. Monsters have, for instance, played important parts in undermining arguments in favor of the fixity of species, a perforationist view of development, and a strictly gradualist conception of evolutionary change. Mark S. Blumberg (a developmental psychobiologist at the University of Iowa) has capitalized on this fascination with the forbidden to communicate his views on development and evolution to a wider audience. The result, *Freaks of Nature*, is a highly readable, entertaining, and informative introduction to the science and culture connected with freaks and monsters.

Blumberg presents the reader with a Wunderkammer of animal curiosities that includes conjoined twins, cyclops, two-headed snakes, two-legged dogs, and goats walking upright as well as the whole menagerie of P. T. Barnum from the Bearded Lady and the Elephant Man to armless wonders and the man “from whose belly another man issued.” For each of these “freaks,” Blumberg offers a highly informative account of the developmental basis of their condition, thus highlighting the central role of development in explaining phenotypic variation. In this sense, his book is a passionate argument for a renewed interest in teratology and teratogeny as a way to understand phenotypic evolution.

But, like most previous students of monsters, Blumberg has an additional agenda. He wants to draw attention to what he considers a continuing neglect of a developmental systems perspective by the current establishment in evolutionary and developmental biology.

The reviewer is at the School of Life Sciences, Arizona State University, Tempe, AZ 85287–4501, USA. E-mail: manfred.laubichler@asu.edu

This central claim of the book places Blumberg in the middle of ongoing debates about the genetics underlying evolutionary change and the role of development in explaining phenotypic evolution. *Science*'s readers are familiar with what is at stake in these debates (2): Is phenotypic evolution primarily the result of gradual genetic change of protein coding genes (3)? Or is it rather a consequence of changes in the cis-regulatory regions of the genome that control gene expression (4, 5)? A subsequent question, and one closer to Blumberg's examples, deals with the role of developmental processes in enabling and constraining phenotypic evolution. This problem was the main focus of attention of the late Pere Alberch, whose work has inspired most of Blumberg's substantive arguments about such processes' importance (6).

Research into the developmental basis of these freaks holds the promise of making substantial contributions to these debates. Simple logic dictates that all phenotypic variation (the foundation of natural selection) is the product



Adapting during development. Born without functioning legs, Johnny Eck “grew naturally into a hand-walker, exhibiting graceful movements with no sign of handicap or exertion.”

Freaks of Nature

What Anomalies Tell Us About Development and Evolution / And What They Tell Us About Development and Evolution

by Mark S. Blumberg

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of development. Thus all explanations of phenotypic evolution must include an understanding of the mechanisms of development and differentiation and of the roles that inherited factors (e.g., genomes and maternal effects) play in these mechanisms. Mechanistic and comparative studies have already revealed much about the complex regulatory networks that govern the development of phenotypes, so we are in a position to productively apply

these insights to study the kinds of examples Blumberg discusses. Monsters, which demonstrate the kinds of phenotypic changes that are possible due to small changes in the regulatory logic of development, represent ideal natural experiments for exploring the complexities of the genotype-phenotype map and developmental regulation.

Besides raising and contributing examples to these substantive questions about a mechanistic theory of phenotypic evolution, Blumberg has a third agenda. Both his choice of examples (monsters and freaks as outcasts in nature and culture) and his constant evocation of “heretic” or “renegade” scientists reflect his desire to transform biology into “an evolutionary framework that is as exquisitely integrated as the animals that we seek to

explain.” As his frequent references to the philosophical perspective of “developmental systems theory” make clear, Blumberg wants to overcome the reductionism he thinks is at the center of gene-based and population-based evolutionary biology. By reducing phenotypic evolution to the abstract dynamics of genes in populations, he argues, we miss what Alberch attempted to accomplish, a “theory of form ... where ‘the properties of interactions ...’ take precedence over any ‘specific genetic constitution.’”

However, current work toward a mechanistic theory of phenotypic evolution has moved far away from simple genetic reductionism. There are many detailed comparative and experimental studies on gene regulatory networks and their role in explaining the mechanisms of differentiation in development and the logic of phenotypic transformations (5). Studies on phenotypic plasticity demonstrate how environmental cues interact with the developmental system by provid-

ing crucial input into the developmental cascades (including underlying gene regulatory networks) and thereby cause dramatic phenotypic transformations—for example, between queen and worker in social insects (7). Such work amply demonstrates that current studies in developmental evolution have moved far beyond the ideological posturing of some early versions of evo-devo.

As a consequence, Blumberg's account is itself a hybrid. By insisting that we take full advantage of these famed experiments of nature (which he describes so well), he provides an illustrative set of examples and research challenges. But by framing his natural history of freaks within an outdated and strangely ideological “holistic” outline of evo-devo, he places himself outside the kind of science that can actually explain these phenomena in a mechanistic fashion.

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ENTOMOLOGY

Social Selection

Nigel R. Franks

The *Lives of Ants* has an unusual ontogeny. The first author, Laurent Keller, is an exceptionally talented evolutionary biologist (at the University of Lausanne); the second, Élisabeth Gordon, is a French journalist, and the product of their union has been translated from français to anglais by a third party. Unfortunately, this ménage à trois has produced a book uncertain of its target. That is a pity, as it seems such a sound idea: to team a pioneering scientist with a professional wordsmith to the benefit of all. Indeed, writing has been described as the painful physiological process of “turning blood into ink.” So, employ a surrogate to take

The reviewer is at the School of Biological Sciences, Woodland Road, University of Bristol, Bristol BS8 1UG, UK. E-mail: NigelFranks@bristol.ac.uk



Food sharing. Trophallaxis between two *Oecophylla smaragdina* workers (Queensland, Australia).

the strain. But beware: This book, arguably as a result, does not work perfectly either as popular science or as a biology text.

Several aspects of the book limit its value to hands-on biologists. Many of the examples are not attributed to the scientists who made the discoveries or had the insights. The recommended reading list does not compensate for the absence of a full bibliography and formal citations. The inclusion of a glossary and a comprehensive index would have made the book more useful for all its readers.

Sadly, the book also falls a little short in serving the general reader. The authors aim for a popular audience by, for example, occasionally referring to larvae as “baby ants.” This is cloyingly, nay nauseatingly, cute and seems to deny metamorphosis. The text sometimes seems to ignore the difference between scent and smell. Given that much of ant society is regulated by chemical signals, it is worth distinguishing between scents and sensibility. Producing a scent and sensing it are two separate processes. As the great lexicographer Samuel Johnson once put it to a lady who had complained that he smelled, “No, madam, I stink! You smell.” There are also inconsistencies: At the beginning of the book, the authors proclaim that “unlike bees, [ants] never go in for dancing.” Later, we find a section headed “Dancing and squeaking” in which we are told that ants may even gesture to one another in “little dances.” But readers who wish to explore the matter further will find no specific references.

Quirkily, the humor found in the book appears to be accidental. For example, the text notes that wood ant mounds get wonderfully warm and then describes them as only “the tip of the iceberg.” It refers to Pierre-André Latreille being imprisoned during the French revolution despite his description of the societies of ants as a “republic” and follows up with his friends referring to him as a “prince of entomologists.” Dangerous talk: Off with

his head? Perhaps this book had Mrs. Malaprop as a ghost editor?

Despite its eccentricities, the book offers readers a fascinating account of the biology of ants. The authors, for example, describe Keller's discovery, with others, of the extraordinary reproductive biology of the native fire ant *Wasmannia auropunctata* in French Guiana. Colonies have many queens and such societies bud-off from one another. (These are ants as fungi.) Remarkably, all the queens were genetically identical, and all the workers had inherited the same paternal genes. Surely, one male could not have mated with every queen? No, males clone themselves: “At fertilization, their spermatozoa, which are kept in the queen's spermatheca, penetrate the eggs and reach their nuclei. . . some of them apparently eliminate the maternal genome and take its place.” The authors note, “This mode of reproduction is absolutely without parallel anywhere in the animal kingdom.” This represents Keller at his best—direct, enthusiastic, and modestly declaring that the discovery of this bizarre biology was one of his “greatest . . . flukes.”

On balance, the book will reward its readers. Its strengths greatly exceed its shortcomings—but it could have been so much better.

The writer Clive James simultaneously stated and demonstrated his talent to “turn a phrase until it catches the light.” But James's writing is also vivid because he captures his own experiences. More broadly, consider a telling story (possibly apocryphal) about Roosevelt and Churchill. After the two met for important discussions, Churchill had flown home and FDR was deciding how to report their progress to the American people. Someone switched on the wireless, and Churchill's unmistakable voice filled the

room. Churchill had got the scoop by writing his own bulletin. A White House aide commented: “He rolls his own, Mr. President.” There is more to this than simply being swift by cutting out the intermediary. Writing directly from personal experience is surely a better way to show leadership and for scientists to capture the delights of discovery and their passion for progress. Inadvertently, *The Lives of Ants* offers a very strong argument for scientists to find their own voices. There is a need for a popular book based on Keller's wonderful discoveries (especially in social genetics), and there must be a way to cite the literature for specialists that does not dilute the narrative. So, my hope is that next time Laurent Keller will roll his own.

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The Lives of Ants

by Laurent Keller and
Élisabeth Gordon

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