then tests them to see if any have some of the properties that he is looking for, selection for adaptive properties in the darwinian sense; he then mutates it and repeats the process. He goes through 600–800 iterations. In each case, he is simply selecting the circuit that is getting closer and closer to what he wants. At the end, he has a circuit that works. He then looks at the circuit and he has not the foggiest notion about how it works and it takes him three–four months to find out. In some case, the computer has actually invented a clock. The point that I am making is that, when we come to look at some of the pathways involved in pattern formation, they are often not as we would have designed it. Evolution is not like that. All that matters is that it works.

But there are problems in the evolution of biological structures as Darwin fully realized, and that is the adaptive nature of the intermediate forms; until flight is possible, what is the advantage of wings? There are answers, but it is often difficult to find them, particularly in relation to changes early in development, for example at gastrulation, in which the layers that form the gut and major organs move inside the embryo. And Ruse quotes, with apparent approval, the claim that, at the single cell level, even the evolution of the flagellum, which is based on a rotary motor driving an external filament, could not have evolved gradually. But then the evolution of the cell is itself much more complex.

Convergence, contrary to Morris, is hardly surprising given that there are a limited number of ways of dealing with the external world. Complex tool-making, and the necessary belief in physical cause and effect which makes us human, had its origin with our primate-like ancestors. Convergence in embryonic development, such as gastrulation, is not convergence but divergence from a fundamental developmental process in setting up the germ layers of the embryo. But, for Morris, life, and its complex varieties, is just too surprising, relying as it does on just simple building blocks. Invoking a deity is hardly helpful and he only just avoids doing so specifically.

Evolutionary theory is the true theoretical biology. There are still problems to be solved, not least the intermediate stages and their adaptive advantage as complex organs develop and evolve. Ruse's book helps little, but anyone interested in such problems should read Conway Morris.

doi:10.1016/j.tree.2004.01.010

Mutatis mutandis

Mutants: On Genetic Varieties and the Human Body by Armand Marie Leroi. HarperCollins, 2004. £7.99 (320 pages)
ISBN 0006532152

Brian K. Hall

Department of Biology, Dalhousie University, Halifax, NS, Canada, B3H 4J1

We study rare events to understand common occurrences; the storm of the century to understand how weather works; a world war to understand normal human behaviour. It is within such traditions that we study mutants to understand normal growth and development.

Mutants – deviations from the norm – are the subject of this engagingly written book, which itself is a mutant: combining developmental biology and molecular genetics with analysis of real life (albeit mostly dead) mutants from human history who deviate from the norm. *Mutants* is avowedly human oriented, Leroi's aim being nothing less than to understand how individual normal humans develop.

The subtitle *'On genetic variety…'* is a slight misnomer in that only one class of genetic variety is discussed. Leroi's self-imposed remit is to examine variety that is based on a genetic mutation. He does not discuss the enormous variety (variation) encompassed by normal human development, much of which is genetic, but based on genetic traits that are continuous and result from the concerted action of many genes: continuous variation in height and size; the variety in facial features or DNA sequences that enable every one of the six billion humans to be distinguished physically or genetically from every other [1]. Variation also results from diet, nutrition, environmental insults, disease or parasites. Leroi is fascinated by the deviant phenotype rather than the 95th percentile. And that fascination is well placed and admirably translated into text, but more importantly, into prose, for this is an engaging read.

Leroi weaves examination of mutant individuals from past and contemporary historical records with perhaps the most accessible treatment of the developmental and molecular changes that produce such mutants. Buffon, Geoffroy (father and son), James Merrick (the 'elephant man') among others make an appearance. We learn that Cleopatra ordered the dissection of pregnant slave girls so that their embryos could be studied. The origins of this legend are obscure. It might be apocryphal, or result from confusing Cleopatra the Ptolemaic Queen with Cleopatra

Corresponding author: Brian K. Hall (bkh@is.dal.ca).
Available online 11 March 2004

the obstetrician contemporary of Galen's (130–220 AD) who wrote about obstetrics [2,3].

Identification of a mutant gene is not enough. To produce a mutant phenotype, a mutated gene must have substantial effects on other genes and developmental processes. A mutation with such an obvious effect on a chicken as 'preventing feathers from forming' is almost certainly a mutation in an important signalling, regulatory or switch gene. Indeed, we cannot speak of 'a mutation…preventing feathers from forming', as this implies that the gene mutation is sufficient in and of itself. It is not. Leroi's approach is to describe the example from the past and then plug our current understanding of how human mutants with two heads or a tail or claws instead of fingers, come into being by taking us from the mutated gene to alterations in downstream molecular, cellular and development events.

Studying mutants has enormously influenced our understanding of how genes mutate and how abnormal mRNA or protein directs the organism away from normality. But it has also done much more. Entire fields of research have been founded on the discovery of a chance mutation. Take the development of arms, wings, legs and fins of fishes, frogs, birds and mammals as an example.

The many research papers about limb development trace their origin to two independent studies carried out 56 years ago. John Saunders [4] saw that a specialized ridge ran along the limb buds of chick embryos. Henamed it the apical ectodermal ridge (AER). When removed, the resulting limb was shorter than normal and parts of the skeleton were missing. The late Ed. Zwilling [5] examined a spontaneous mutant in a chicken flock. The chicken had no wings but otherwise was entirely normal. Young *wingless (wl)* mutant embryos had limb buds with an AER that then deteriorated. The resulting Saunders–Zwilling model of limb development founded the field of developmental skeletal biology [6,7]. The discovery that the AER signals to cells that form the skeleton (and vice versa) set the course for studies of the epithelial–mesenchymal interactions that are at the basis of the development of most tissues and organs of human bodies. Mutants are important.

Mutations of arms and legs feature prominently in Leroi's book: dwarfs (achondroplasia), giants (acromegaly), missing arms or legs (the thalidomide syndrome), extra fingers or toes (polydactyly), and much more. But so do mutations that result in albinos, piebalds, hermaphrodites or individuals with hair all over the body (hypertrichosis). And we learn about the variant ('mutant') molecules that mutated genes encode: the receptor for fibroblast growth factor and dwarfism; bone morphogenetic proteins and soft-tissue ossification; growth hormone and gigantism; testosterone and hermaphroditism, and much more. If your interests are in historical records of diverse abnormalities, in how genes produce such abnormalities and in how to integrate the two, then *Mutants* is an ideal read.

References

1 Hallgrimsson, B., Hall, B.K. eds (2004) *Variation: A Hierarchical Examination of a Central Concept in Biology* Elsevier
2 Riddle, J.M. (1992) *Contraception and Abortion from the Ancient World to the Renaissance*, Harvard University Press
3 Needham, J. (1959) *A History of Embryology*, 2nd edn, Cambridge University Press
4 Saunders, J.W. Jr (1948) The proximo-distal sequence of origin of the parts of the chick wing and the role of the ectoderm. *J. Exp. Zool.* 108, 363–404
5 Zwilling, E. (1948) The role of epithelial components in the developmental origin of the 'wingless' syndrome of chick embryos. *J. Exp. Zool.* 111, 175–188
6 Hall, B.K. (1978) *Developmental and Cellular Skeletal Biology*, Academic Press
7 Hall, B.K. (2004) *Bones & Cartilage: Developmental Skeletal Biology*, Elsevier

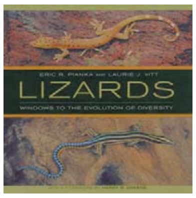
doi:10.1016/j.tree.2004.03.002

Leapin' non-ophidian squamates!

Lizards: Windows to the Evolution of Diversity by Eric R. Pianka and Laurie J. Vitt. University of California Press, Organisms and Environments Series, 2003. US$45.00/£29.95 hbk (xiii 1 333 pages) ISBN 0 520 23401 4

Kurt Schwenk

Department of Ecology & Evolutionary Biology, University of Connecticut, Storrs, CT 06269-3043, USA



For too long, snakes have held the limelight. Snake biologists (or 'snake-grabbers', as we lizard biologists prefer to call them) have cynically exploited the public's unhealthy fascination with death-dealing serpents to advance their own dark and duplicitous agenda. No matter that most snakes are harmless little things that eat the occasional mouse. No matter that snakes are really just tubes with teeth. And no matter that snakes are, in fact, just one of several groups of limbless lizards. The snake-grabbers aren't telling. But well known ecologists Eric Pianka and Laurie Vitt are fighting back. In their ambitious new book, they put forth the case for lizards, arguing that these beautiful and astonishingly diverse reptiles are deservedly a central focus of biological research. 'What we have learned about lizards is applicable to nearly every conceptual area in modern biology…entire fields of

Corresponding author: Kurt Schwenk (kurt.schwenk@uconn.edu).
Available online 11 March 2004