



PREFACE

## Integrative organismal biology: Papers in honor of Professor Marvalee H. Wake

Kurt Schwenk<sup>a,\*</sup>, Wyatt Korff<sup>b</sup>, J. Matthias Starck<sup>c</sup>

<sup>a</sup>*Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT 06269-3043, USA*

<sup>b</sup>*Department of Integrative Biology, University of California, Berkeley, CA 94720-3140, USA*

<sup>c</sup>*Department of Biology II, University of Munich (LMU), Großhaderner Straße 2, D-82152 Planegg-Martinsried, Germany*

### Introduction

With this special issue of *Zoology* we honor the extraordinary career of Professor Marvalee Hendricks Wake upon the occasion of her retirement from the University of California, Berkeley. However, make no mistake – Marvalee Wake is a work in progress! As a Professor Emeritus, retirement, for her, has only meant more time to devote to her favorite activities – research, teaching, mentoring, and service to the field. Indeed, not one to remain idle while others work, Marvalee's presence extends even to the pages of this Festschrift volume, in which she appears as co-author of one of its contributions (Summers and Wake).

Marvalee took her formal education all at the University of Southern California, completing her Ph.D. there in 1968 under the supervision of well known herpetologist and tropical biologist, Jay Savage. While at USC, Marvalee first evinced her lifelong interest in gymnophione amphibians (caecilians), publishing the first of nearly a hundred papers on the group before completing her degree. It is also at USC that Marvalee met her husband, David Wake, and gave birth to their son, Thomas Wake. It is notable that Marvalee completed her Ph.D. while caring for her infant son, an experience that shaped her later thoughts about the unique challenges faced by many women in the course of an academic career. Another of these challenges was how to cope as a two-career couple (Wake, 1993). Marvalee and David both found employment in

Chicago in the 1960s, with Marvalee becoming an Assistant Professor at the University of Illinois, Chicago Circle campus. However, when David was offered the Directorship of the Museum of Vertebrate Zoology at the University of California, Berkeley, Marvalee also moved to Berkeley where she was rapidly promoted, eventually becoming chair of the Department of Zoology.

Marvalee is widely regarded by Berkeley colleagues as one of the most successful chairs the department ever had – so much so that she was asked to reprise the role twice more during her career. Importantly, her second stint as chair occurred during the reorganization of the life sciences at Berkeley, a process in which Marvalee's influence was substantial. It was under her careful stewardship that the Department of Zoology, along with faculty from other units, was subsumed within the Department of Integrative Biology (1987–1989). As one might imagine, overseeing the organization of a large, new academic unit composed of faculty from several disparate departments, some of whom felt disenfranchised, was a task that required energy, tenacity, altruism, loyalty, commitment, sensitivity, administrative skill and political savvy – all attributes with which Marvalee is well endowed. Indeed, Marvalee's skills as an effective leader have been widely recognized by the international academic community. She has served (or will soon serve) as president of five major scientific societies: the American Institute of Biological Sciences, the American Society of Ichthyologists and Herpetologists, the International Society of Vertebrate Morphology, the International Union of Biological Sciences and the Society of Integrative and Comparative Biology.

\*Corresponding author.

E-mail address: [kurt.schwenk@uconn.edu](mailto:kurt.schwenk@uconn.edu) (K. Schwenk).

Space limitations do not allow us to enumerate the many national and international committees, panels, advisory boards, granting agencies, task forces, commissions, councils, etc., that Marvalee has served on, often as chair. However, her contribution in this regard is nothing short of astonishing – far beyond that of most scientists of her repute.

The brief recitation of some of Marvalee's administrative and advisory posts above hints at one of Marvalee's most remarkable qualities – her exceptional commitment to service. Perhaps more than anyone we know, Marvalee has personified the academic ideal of service at every level from the local institution to the global community. Throughout her career she has striven to help scientists at all stages to have the resources they need to do their work and to help the public to understand how that work contributes to society. She has further used these positions as opportunities to promote an understanding of organisms and evolution as foci of biological inquiry and to make the case for biodiversity. In every venue Marvalee has been unusually effective, perhaps because, as she has said, she is unwilling to take on a role unless she feels there is something she can directly contribute. Regardless, the international scientific community owes Marvalee a great debt for her leadership and service, which continues to this time despite her 'retirement'.

Another of Marvalee's legacies that cannot be underestimated is her contribution to teaching, graduate training and mentorship. We see Marvalee's signal contribution to the education of a new generation of vertebrate morphologists as especially noteworthy. Her former doctoral students and postdocs carry on the tradition of comparative anatomy and evolutionary morphology in institutions across North America and Europe. This is all the more notable because many of these students emerged from Berkeley at a time when molecular biology was first sweeping the land and organismal biologists, in general, and vertebrate morphologists, in particular, were hard pressed even to find positions to apply for! They, in turn, are now educating the next generation of integrative, organismal biologists. Marvalee would say that her success as an advisor rests on her ability to select good students, but her skills extend far beyond this. First and foremost, Marvalee teaches by example, modeling for her students the qualities of integrity, thoroughness and most of all, a commitment to scholarship – a belief that one's job is not done until one has explored completely the history of ideas surrounding one's topic. Second, Marvalee has always been remarkably effective in seeing to the material needs of her students. She is an extraordinary provider, fierce defender and shameless promoter of her brood. A "facilitator" in the truest sense of the word, Marvalee makes sure her students have the resources they need to do their work, whether it is a piece of

equipment or a stipend to get them through another year. Most unusually, perhaps, she is especially attentive to the psychological needs of her students and the many others who flock to her for advice and a sympathetic ear, and is known fondly as "mother Wake" by all those who have benefited from her ministrations.

As an undergraduate instructor, Marvalee's central focus was vertebrate evolutionary morphology. In the late 1970s Marvalee undertook the teaching of a then moribund course in comparative vertebrate anatomy, transforming it into a modern endeavor that was far ahead of its time. Through its incorporation of function and, especially, development as core elements, Marvalee's course was cutting edge from its inception and remained so until it was last taught in 2000. The transformation of the course was aided by the publication of her ground-breaking edited text, *Hyman's Comparative Vertebrate Anatomy* in 1979 (Wake, 1979). Throughout her teaching in this and related areas, Marvalee always emphasized the dynamic nature of form, showing how organisms are built as integrative systems, rather than presenting them as static entities that must be atomized to be understood.

As a scholar, Marvalee Wake's contributions have been numerous and significant (Appendix A). Marvalee is first and foremost an organismal biologist and empiricist. Early in her career she established herself as the world's leading authority on caecilian amphibian biology, and the depth and breadth of this knowledge has provided her a platform from which to address many issues of general biological interest (see also Hall, this volume). Although her focus was originally on reproductive morphology (an interest that continues to this day), there is virtually no aspect of caecilian biology that has escaped Marvalee's scrutiny. Indeed, Marvalee's work on caecilians can be credited, we believe, with eliciting renewed world-wide interest in the group which, historically, received scant attention. Her empirical work, in turn, has led Marvalee to make significant contributions in the general areas of phylogenetic character analysis, evolutionary constraint, stasis, historical contingency, regressive evolution, adaptive opportunism, hierarchical integration, heterochrony and miniaturization. As Hall (this volume) argues, her early work on development and regressive evolution foreshadows much of the later interest in the developmental basis of form apparent in the evolutionary developmental biology (evo-devo) movement.

Perhaps the most important theme to emerge from Marvalee's work as a scientist is her emphasis on the practice and theory of "integrative biology." Marvalee was a practicing integrative biologist long before this term was formally recognized or gained prominence, and it is exactly this approach to organismal biology that has inspired so many of her students and colleagues. In the last 15 years or so, Marvalee has

attempted to formalize the notion of integration through publication and her work with professional societies (Wake, 1990, 1995, 1998, 2000a, b, 2001, 2003, 2004; Barbault et al., 2003). She sees integrative biology as “both an approach to and an attitude about the practice of science” (Wake, 2003, p. 240) that is concerned, specifically, with complex questions dealing with the interactions of ecology (environment), development and evolution in organismal biology. Such broad questions, lying as they do within the interstices of traditionally recognized disciplines, require a multidisciplinary, multihierarchical approach. As such, integrative biology, in Marvalee’s view, seeks nothing less than broadly synthetic answers to the fundamental questions of biological diversity. In a kind of manifesto, Marvalee has outlined several principles and goals of integrative biology (Wake, 2003, 2004): (1) *the delineation of complex questions*; (2) *the organization of expertise to tease apart the questions hierarchically*; (3) *the extension of expertise into non-traditional arenas*; and (4) *the development of new educational/training modes*.

Importantly, Marvalee’s conception of integrative biology is inclusive. She does not exclude, for example, the many reductionist approaches that have flourished in recent years owing to rapid progress in molecular techniques and technology. Rather, she seeks to create a pluralistic context in which the results of such studies will have the greatest possible significance and meaning. By integrating horizontally across disciplines and vertically across hierarchies of biological organization, she argues, we are most likely to reveal unifying principles of interest to us all.

Marvalee is the first to point out that, in the context of the 21st century, truly synthetic integrative biology is most likely to be undertaken by teams of scientists working toward a common goal. Nonetheless, by learning about all aspects of their study systems/organisms, by tackling broad questions, by employing multidisciplinary and multihierarchical approaches in answering them, and by applying inductive, as well as hypothetico-deductive methods, individual scientists can, themselves, be practitioners of integrative biology. Throughout her long career, Marvalee Wake has epitomized these ideals – she practices what she preaches.

In this modest volume, some of her students and colleagues honor her with their own integrative contributions. The diversity of the topics represented here, ranging from broad theory to detailed anatomy, from function to phylogeny, from development to evolution, and from fish to dinosaurs, is a microcosm of Marvalee’s own wide interests and a measure of her influence. Finally, we note that the papers published here represent only a small sample of work from the many individuals who wished to contribute, but owing

to limitations of space and time, could not be accommodated here.

## References

- Barbault, R., Guégan, J.-F., Hoshi, M., Mounolou, J.-C., van Baalen, M., Wake, M.H., Younés, T., 2003. Integrative biology and complexity in natural systems: keys to addressing emerging challenges. *Biol. Int.* 44, 6–12.
- Wake, M.H., 1979. *Hyman’s Comparative Vertebrate Anatomy*, 3rd ed. University of Chicago Press, Chicago.
- Wake, M.H., 1990. The evolution of integration of biological systems: an evolutionary perspective through studies of cells, tissues, and organs. *Amer. Zool.* 30, 897–906.
- Wake, M.H., 1993. Two-career couples – attitudes and opportunities. *BioScience* 43, 238–240.
- Wake, M.H., 1995. An integrated approach to the biology of biodiversity. *Biol. Int.* 31, 1–6.
- Wake, M.H., 1998. Integrative biology in biodiversity: an approach to questions, answers, and training. In: Chou, C.-H., Shao, K.-T. (Eds.), *Frontiers in Biology: The Challenges of Biodiversity, Biotechnology and Sustainable Agriculture*. Academia Sinica, Taipei, Taiwan, pp. 35–40.
- Wake, M.H., 2000a. Integrative biology as a framework for education and training. *Biol. Int.* 39, 14–18.
- Wake, M.H., 2000b. Towards an integrative biology: a symposium for the American Association for the Advancement of Science. *Biol. Int.* 38, 11.
- Wake, M.H., 2001. Integrative biology: its promise and its perils. *Biol. Int.* 41, 71–74.
- Wake, M.H., 2003. What is “integrative biology”? *Integrated Comput. Biol.* 43, 239–241.
- Wake, M.H., 2004. Integrative biology: the nexus of development, ecology and evolution. *Biol. Int.* 46, 1–18 (Electronic publication: <http://www.iubs.org/test/bioint/46/bi46.htm>, accessed 12 September 2005).

## Further reading

### *Appendix A. Publications of Marvalee H. Wake (excluding published abstracts and book reviews)*

1967. Wake, M.H. Gill structure in the caecilian genus *Gymnopsis*. *Bull. Soc. Calif. Acad. Sci.* 66, 109–116.
1968. Wake, M.H. Evolutionary morphology of the caecilian urogenital system. Part I. The gonads and fat bodies. *J. Morphol.* 126, 291–332.
1969. Wake, M.H. Gill ontogeny in *Gymnopsis*. *Copeia* 1969, 183–184.
1970. Wake, M.H. Evolutionary morphology of the caecilian urogenital system. Part II. The kidneys and the urogenital ducts. *Acta Anat.* 75, 321–358.
1970. Wake, M.H. Evolutionary morphology of the caecilian urogenital system. Part III. The bladder. *Herpetologica* 26, 120–128.
1972. Wake, M.H. Evolutionary morphology of the caecilian urogenital system. Part IV. The cloaca. *J. Morphol.* 136, 353–366.

1972. Estes, R., Wake, M.H. Caecilian amphibians: their first fossil record. *Nature* 239, 228–231.
1972. Savage, J.M., Wake, M.H. Geographic variation and systematics of Middle American caecilians, genera *Dermophis* and *Gymnopsis*. *Copeia* 1972, 680–694.
1973. Wake, M.H. Diversity of marine life. In: Ingmanson, D.E., Wallace, W.J. (Eds.), *Oceanology, An Introduction*. Wadsworth Publ. Co., Belmont, CA, pp. 169–213.
1974. Bennett, A.F., Wake, M.H. Metabolic correlates of activity in the caecilian *Geotrypetes seraphini*. *Copeia* 1974, 764–769.
1974. Tarr, K.J., Aebersold, P.M., Wake, M.H. A Selected Bibliography of Current Research in Higher Education in the Biological Sciences. University of California (statewide internal publication). 46pp.
1975. Wake, M.H. Another scaled caecilian. *Herpetologica* 31, 134–136.
1975. Wake, M.H., Case, S.M. The chromosomes of caecilians. *Copeia* 1975, 510–516.
1975. Case, S.M., Wake, M.H. Electrophoretic patterns of certain proteins in caecilians (Amphibia: Gymnophiona). *Comp. Biochem. Physiol.* 528, 473–476.
1976. Wake, M.H. The development and replacement of teeth in viviparous caecilians. *J. Morphol.* 148, 33–64.
1977. Wake, M.H. Fetal maintenance and its evolutionary significance in the Amphibia: Gymnophiona. *J. Herpet.* 11, 379–386.
1977. Case, S.M., Wake, M.H. Immunological comparisons of caecilian albumins (Amphibia: Gymnophiona). *Herpetologica* 33, 93–97.
1977. Thexton, A.J., Wake, D.B., Wake, M.H. Control of tongue function in the salamander *Bolitoglossa occidentalis*. *Arch. Oral Biol.* 22, 361–366.
1977. Wake, M.H. The reproductive biology of caecilians: an evolutionary perspective. In: Guttman, S., Taylor, D. (Eds.), *Reproductive Biology of the Amphibia*. Plenum Press Publ., New York, pp. 73–102.
1978. Wake, M.H. An ovoviviparous Eleutherodactylus, with comments on the evolution of live-bearing systems. *J. Herpet.* 12, 121–133.
1978. Wake, M.H. Ontogeny of *Typhlonectes obesus*, with emphasis on dentition and feeding. *Papeis Avulsos, Zool.* 12, 1–13.
1979. Wake, M.H., Wurst, G.Z. Tooth crown morphology in caecilians (Amphibia: Gymnophiona). *J. Morphol.* 159, 331–342.
1979. Hetherington, T.E., Wake, M.H. The lateral line system in larval *Ichthyophis* (Amphibia: Gymnophiona). *Zoomorphologie* 93, 209–225.
1979. Wake, M.H., Hafner, J.C., Hafner, M.S., Klosterman, L.L., Patton, J.L. The karyotype of *Typhlonectes compressicauda* (Amphibia: Gymnophiona), with comments on chromosome evolution in caecilians. *Experientia* 36, 171–172.
1979. Jensen, W.A., Heinrich, B., Wake, D.B., Wake, M.H. *Biology*. Wadsworth Publ. Co., 646pp.
1979. Wake, M.H. (Ed.). *Hyman's Comparative Vertebrate Anatomy*, 3rd ed. University of Chicago Press, Chicago.
1979. Wake, M.H. Preface and General considerations on animal form. In: Wake, M.H. (Ed.), *Hyman's Comparative Vertebrate Anatomy*, 3rd ed. University of Chicago Press, Chicago, pp. ix–xi; 1–6.
1979. Wake, M.H. General features of chordate development. In: Wake, M.H. (Ed.), *Hyman's Comparative Vertebrate Anatomy*, 3rd ed. University of Chicago Press, Chicago, pp. 7–111.
1979. Wake, M.H. The comparative anatomy of the urogenital system. In: Wake, M.H. (Ed.), *Hyman's Comparative Vertebrate Anatomy*, 3rd ed. University of Chicago Press, Chicago, pp. 555–614.
1980. Wake, M.H. The reproductive biology of *Nectophrynoides malcolmi* (Amphibia: Bufonidae), with comments on the evolution of reproductive modes in the genus *Nectophrynoides*. *Copeia* 1980, 193–209.
1980. Wake, M.H. Reproduction, growth and population structure of *Dermophis mexicanus* (Amphibia: Gymnophiona). *Herpetologica* 36, 244–256.
1980. Wake, M.H. Morphometrics of the skeleton *Dermophis mexicanus* (Amphibia: Gymnophiona). Part I. The vertebrae, with comparisons to other species. *J. Morphol.* 165, 117–130.
1980. Wake, M.H. Fetal tooth development and adult replacement in *Dermophis mexicanus* (Amphibia: Gymnophiona): fields versus clones. *J. Morphol.* 166, 203–216.
1980. Wake, M.H. Amphibians; Axolotl; Frog; Salamander and Newt; Toad. In: *Academic American Encyclopedia*. Arete Publ., New York, pp. 377–380; 378; 336–337; 29–30, respectively.
1981. Wake, M.H. Structure and function of the male Mullerian gland in caecilians (Amphibia: Gymnophiona), with comments on its evolutionary significance. *J. Herpet.* 15, 17–22.
1982. Wake, M.H., Hanken, J. The development of the skull of *Dermophis mexicanus* (Amphibia: Gymnophiona), with comments on skull kinesis and amphibian relationships. *J. Morphol.* 171, 203–223.
1982. Wake, M.H. Diversity within a framework of constraints: reproductive modes in the Amphibia. In: Mossakowski, D., Roth, G. (Eds.), *Environmental Adaptation and Evolution, A Theoretical and Empirical Approach*. Gustav Fischer Verlag, Stuttgart, pp. 87–106.
1983. Bemis, W.E., Schwenk, K., Wake, M.H. Morphology and function of the feeding apparatus of *Dermophis mexicanus* (Amphibia: Gymnophiona). *Zool. J. Linn. Soc.* 77, 75–96.
1983. Wake, T.A., Wake, D.B., Wake, M.H. The ossification sequence of *Aneides lugubris*, with comments on heterochrony. *J. Herpet.* 17, 10–22.
1983. Wake, D.H., Roth, G., Wake, M.H. On the problem of stasis in organismal evolution. *J. Theor. Biol.* 101, 211–224.
1983. Wake, M.H. *Gymnopsis multiplicata* Peters, *Dermophis mexicanus* (Dumeril and Bibron), and *Dermophis parviceps* (Dunn) (Caecilians). In: Janzen, D.H. (Ed.), *Costa Rican Natural History*. University of Chicago Press, Chicago, pp. 400–401.
1983. Wake, M.H., Campbell, J. A new genus and species of caecilian from the Sierra de las Minas of Guatemala. *Copeia* 1983, 857–863.

1983. Wake, D.B., Roth, G., Wake, M.H. Tongue evolution in lungless salamanders, Family Plethodontidae. III. Patterns of peripheral innervation. *J. Morphol.* 178, 207–224.
1984. Roth, G., Wake, D.B., Rettig, G., Wake, M.H. Distribution of accessory and hypoglossal nerves in the hindbrain and spinal cord of lungless salamanders, Family Plethodontidae. *Neurosci. Lett.* 44, 53–57.
1984. Wake, M.H. Science as a way of knowing—Evolution: the biology of whole organisms. *Amer. Zool.* 24, 443–450.
1984. Wake, M.H. A new caecilian from Peru. *Bonn. Zool. Beitr.* 35, 213–219.
1984. Wake, M.H., Exbrayat, J.-M., Delsol, M. The development of the chondrocranium of *Typhlonectes compressicaudus* (Gymnophiona), with comparison to other species. *J. Herpetol.* 19, 68–77.
1984. Wake, M.H. A new species of *Caecilia* (Amphibia: Gymnophiona) from Bolivia. *Amphibia-Reptilia* 5, 215–220.
1984. Fritzsich, B., Wake, M.H. Electroreception in amphibians. *Amer. Sci.* 72, 228.
1985. Wake, M.H. Oviduct structure and function in non-mammalian vertebrates. In: Duncker, H.R., Fleischer, G. (Eds.), *Functional Morphology of Vertebrates*. Gustav Fischer Verlag, Stuttgart. *Fortschritte der Zoologie* 30, 427–435.
1985. Wake, M.H. The comparative morphology and evolution of the eyes of caecilians (Amphibia: Gymnophiona). *Zoomorphology* 105, 277–295.
1985. Wake, M.H. Comment on the proposals to remove the homonymy between Caeciliidae in Amphibia and Insecta. *A.N. (S.) 2333. Bull. Zool. Nomencl.* 42, 220–221.
1985. Wake, M.H. Gymnophiona. In: Frost, D.R. (Ed.), *Amphibian Species of the World*. Assn. of Systematics Collections, Lawrence, KS.
1986. Fritzsich, B., Wake, M.H. The distribution of ampullary organs in Gymnophiona. *J. Herpetol.* 20, 90–93.
1986. Wake, M.H. A perspective on the systematics and morphology of the Gymnophiona (Amphibia). *Mem. Soc. Zool. France* 43, 21–38.
1986. Wake, D.B., Wake, M.H. On the development of vertebrae in gymnophione amphibians. *Mem. Soc. Zool. France* 43, 67–70.
1986. Wake, M.H., Schwenk, K. A preliminary report on the morphology and distribution of taste buds in gymnophiones, with comparison to other amphibians. *J. Herpetol.* 20, 254–256.
1986. Wake, M.H. The morphology of *Idiocranium russelli* (Amphibia: Gymnophiona), with comments on miniaturization through heterochrony. *J. Morphol.* 189, 1–16.
1986. Wake, M.H. The urogenital morphology of dipnoans, with comparison to other fishes and to amphibians. *J. Morphol. Suppl.* 1, 199–216.
1986. Wake, M.H. Caecilians. In: Halliday, T., Adler, K. (Eds.), *The Encyclopedia of Reptiles and Amphibians*. Facts on File, Inc., New York, pp. 16–17.
1987. Wake, M.H. A new genus of African caecilian (Amphibia: Gymnophiona). *J. Herpetol.* 21, 6–15.
1987. Billo, R., Wake, M.H. Tentacle development in *Dermophis mexicanus* (Amphibia: Gymnophiona: Caeciliidae). *J. Morphol.* 192, 101–111.
1987. Wake, M.H., Nygren, K.M. Variation in scales in *Dermophis mexicanus*: are gymnophione scales of systematic utility? *Fieldiana, N.S.* 36, 1–8.
1988. Wake, M.H. The science educator looks at museums: perspective of a zoologist. In: Heltne, P.G., Marquardt, L.A. (Eds.), *Science Learning in the Informal Setting*. Chicago Acad. Sci., Chicago, pp. 305–314.
1988. Wake, M.H. *Gymnopsis multiplicata* Peters. *Cat. Amer. Amph. Rept.* 411.1–411.2.
1988. Wake, M.H. *Minascaecilia sartoria* Wake and Campbell. *Cat. Amer. Amph. Rept.* 412.1.
1988. Fritzsich, B., Wake, M.H. The inner ear of gymnophione amphibians and its nerve supply: a comparative study of regressive events in a complex sensory system (Amphibia: Gymnophiona). *Zoomorphology* 108, 201–217.
1989. Wake, M.H. Phylogenesis of direct development and viviparity. In: Wake, D.B., Roth, G. (Eds.), *Complex Organismal Functions: Integration and Evolution in Vertebrates*. John Wiley & Sons, Chichester, pp. 235–250.
1989. Packard, G.C., Elinson, R.P., Gavaud, J., Guillette, L.G., Lombardi, J., Schindler, J., Shine, R., Tyndale-Biscoe, H., Wake, M.H., Xavier, F.J., Yaron, Z. How are reproductive systems integrated and how has viviparity evolved? In: Wake, D.B., Roth, G. (Eds.), *Complex Organismal Functions: Integration and Evolution in Vertebrates*. John Wiley and Sons, Chichester, pp. 281–293.
1989. Wake, M.H. Hyobranchial metamorphosis in *Epicrionops* (Amphibia: Gymnophiona: Rhinatrematidae): replacement of bone by cartilage. *Ann. Sci. Nat. Paris* 10, 171–182.
1990. Schmidt, A., Wake, M.H. The olfactory and vomeronasal system of caecilians (Amphibia: Gymnophiona). *J. Morphol.* 205, 255–268.
1990. Zylberberg, L., Wake, M.H. Structure of the scales of *Dermophis* and *Microcaecilia* (Amphibia: Gymnophiona), and a comparison to dermal ossifications of other vertebrates. *J. Morphol.* 206, 25–43.
1990. Wake, M.H. The evolution of integration of biological systems: an evolutionary perspective through studies of cells, tissues, and organs. *Amer. Zool.* 30, 897–906.
1991. Hanken, J., Wake, M.H. Experimental approaches to the analysis of form and function. *Amer. Zool.* 31, 603–604.
1991. Wake, M.H. The impact of functional morphology and biomechanics on studies of evolutionary biology. In: Dudley, E.C. (Ed.), *The Unity of Evolutionary Biology*. Proc. 4th Int'l Cong. Syst. Evol. Biol., Dioscorides Press, Portland, OR, pp. 555–557.
1992. Wake, M.H. Patterns of peripheral innervation of the tongue and hyobranchial apparatus in caecilians (Amphibia: Gymnophiona). *J. Morphol.* 212, 37–53.
1992. Wake, M.H. Reproduction in caecilians. In: Hamlett, W.C. (Ed.), *Reproductive Biology of South American Vertebrates*. Springer-Verlag, New York, pp. 112–120.
1992. Wake, M.H. Biogeography of Mesoamerican caecilians (Amphibia: Gymnophiona). *Tulane Studies in Zoology and Botany. Suppl. Publ.* 1, 321–325.
1992. Wake, M.H. Evolutionary scenarios, homology and convergence of structural specializations for vertebrate viviparity. *Amer. Zool.* 32, 256–263.

1992. Wake, M.H. Morphology, the study of form and function, in modern evolutionary biology. In: Futuyma, D., Antonovics, J. (Eds.), *Oxford Surveys in Evolutionary Biology*. Oxford University Press, New York, pp. 289–346.
1992. Lessa, E.P., Wake, M.H. Morphometric analysis of the skull of *Dermophis mexicanus* (Amphibia: Gymnophiona). *Zool. J. Linn. Soc.* 106, 1–15.
1992. Wake, M.H. “Regressive” evolution of special sensory organs in caecilians (Amphibia: Gymnophiona): opportunity for morphological innovation. *Zool. Jb. Anat.* 122, 325–329.
1993. Wake, M.H. Two-career couples – attitudes and opportunities. *BioScience* 43, 238–240.
1993. Wake, M.H. The skull as a locomotor organ. In: Hanken, J., Hall, B.K. (Eds.), *The Vertebrate Skull*, Vol. 3. University of Chicago Press, Chicago, pp. 197–240.
1993. Wake, M.H. Non-traditional characters in the assessment of caecilian phylogenetic relationships. *Herp. Monogr.* 7, 42–55.
1993. Wake, M.H. The evolution of oviductal gestation in amphibians. *J. Exp. Zool.* 266, 394–413.
1993. Wake, M.H. Evolutionary diversification of cranial and spinal nerves and their targets in the gymnophione amphibians. *Acta Anat.* 148, 160–168.
1994. Wake, M.H. The use of unconventional morphological characters in the analysis of systematic patterns and evolutionary processes. In: Grande, L., Rieppel, O. (Eds.), *Interpreting the Hierarchy of Nature – From Systematic Patterns to Evolutionary Process Theories*. Academic Press, New York, pp. 173–200.
1994. Wake, M.H. The International Union of Biological Sciences and its United States National Committee. *BioScience* 44, 422–423.
1994. Wake, M.H. Comparative morphology of caecilian sperm (Amphibia: Gymnophiona) *J. Morphol.* 221, 261–276.
1994. Wake, M.H. Caecilians in captivity. In: Murphy, J.B., Adler, K.K., Collins, J.T. (Eds.), *Captive Management and Conservation of Amphibians and Reptiles. Contributions to Herpetology*, Vol. 11. Society for the Study of Amphibians and Reptiles, Ithaca, NY, pp. 223–228.
1994. Wake, M.H., Dubois, A., Frost, D., Moore, T.E., Nussbaum, R.A. Case #2936. Comments on Opinion 1462 (homonymy between CAECILIIDAE in Gymnophiona and in Psocoptera). *Bull. Zool. Nomencl.* 51, 237–239.
1994. Wake, M.H. Biosystematics: an essential component of biodiversity analysis. *IUBS/IMI Special Publication*, pp. 1–7.
1995. Wake, M.H. The spermatogenic cycle of *Dermophis mexicanus* (Amphibia: Gymnophiona). *J. Herpetol.* 29, 119–122.
1995. Wake, M.H. An integrated approach to the biology of biodiversity. *Biol. Int.* 31, 1–6 (Editorial).
1995. Wake, M.H. The current status of the *Diversitas* program and its implementation. *Biol. Int.* 31, 7–18.
1995. Wake, M.H. IUBS and International Systematics. *Assoc. Syst. Coll. Newsletter* 23, 62, 69.
1995. Carrier, D.R., Wake, M.H. The mechanics of lung ventilation in the caecilian *Dermophis mexicanus*. *J. Morphol.* 226, 289–295.
1996. Schmidt, A., Wake, D.B., D.B. Wake, D.B. Motor nuclei of nerves innervating the tongue and hypoglossal musculature in a caecilian (Amphibia: Gymnophiona), as revealed by HRP transport. *J. Comp. Neuro.* 370, 342–349.
1997. Schmidt, A., Wake, M.H. Cellular migration and morphological complexity in the caecilian brain. *J. Morphol.* 231, 11–27.
1997. Wake, M.H. Caecilians at Las Cruces Biological Station. *Amigos Newsletter*. 48, 10–11.
1997. Rocek, Z., Wake, M.H. Third World Congress of Herpetology. *Herpet. Rev.* 28, 178–180.
1998. Wake, M.H. Amphibian locomotion in evolutionary time. *Zool.* 100, 141–151.
1998. Schmidt, A., Wake, M.H. Development of the tectum in gymnophiones, with comparison to other amphibians. *J. Morphol.* 236, 233–246.
1998. Wake, M.H. Cartilage in the cloaca: phallosomal spicules in caecilians (Amphibia: Gymnophiona). *J. Morphol.* 237, 177–186.
1998. Wake, M.H. Integrative biology in biodiversity: an approach to questions, answers, and training. In: Chou, C.-H., Shao, K.-T. (Eds.), *Frontiers in Biology: The Challenges of Biodiversity, Biotechnology and Sustainable Agriculture*. Academia Sinica, Taipei, Taiwan, pp. 35–40.
1998. Wake, M.H. Amphibian reproduction, overview. In: Knobil, E., Neill, J.D. (Eds.), *Encyclopedia of Reproduction*, Vol. 1. Academic Press, New York and San Diego, pp. 161–166.
1998. Wake, M.H., Dickie, R. Oviduct structure and function, and reproductive modes in amphibians. *J. Exp. Zool.* 282, 477–506.
1998. Wake, M.H. *Dermophis oaxacae*. *Catalogue of American Amphibians and Reptiles*. SSAR 661, 1–2.
1999. Hall, B.K., Wake, M.H. (Eds.). *The Origin and Evolution of Larval Forms*. Academic Press, New York and San Diego.
1999. Hall, B.K., Wake, M.H. Introduction: larval development, evolution and ecology. In: Hall, B.K., Wake, M.H. (Eds.), *The Origin and Evolution of Larval Forms*. Academic Press, New York and San Diego, pp. 1–19.
1999. Wake, M.H., Hall, B.K. Epilogue: prospects for research on the origin and evolution of larval forms. In: Hall, B.K., Wake, M.H. (Eds.), *The Origin and Evolution of Larval Forms*. Academic Press, New York and San Diego, pp. 411–416.
1999. Wake, T.A., Wake, M.H., Lesure, R. A Mexican archaeological site includes the first Quaternary fossil of caecilians. *Quatern. Res.* 52, 138–140.
1999. Wake, M.H. Libbie Hyman and comparative vertebrate anatomy. *Amer. Mus. Novit.* 3277, 33–39.
2000. Dünker, N., Wake, M.H., Olson, W.M. Embryonic and larval development in the caecilian *Ichthyophis kohtaoensis* (Amphibia, Gymnophiona): a staging table. *J. Morphol.* 243, 3–34.
2000. Wake, M.H. TAIB symposium on alternative reproductive strategies. *Biol. Int.* 38, 3–6.
2000. Wake, M.H. Towards an integrative biology. A symposium for the American Association for the Advancement of Science. *Biol. Int.* 38, 11.

2000. Wake, M.H. Letter re “Conservation in a human-dominated world”. *Issues in Sci. Tech.* 16, 14–16.
2000. Wake, M.H. Integrative biology as a framework for education and training. *Biol. Int.* 39, 14–18.
2000. Wake, M.H., Wake, D.B. Early developmental morphology of vertebrae in caecilians (Amphibia: Gymnophiona): resegmentation and phylogenesis. *Zool. Anal. Compl. Syst.* 103, 68–88.
2001. Savage, J.M., Wake, M.H. A re-evaluation of the status of taxa of Central American caecilians (Amphibia: Gymnophiona), with comments on their origin and evolution. *Copeia* 2001, 52–64.
2001. Summers, A.P., Wake, M.H. A clarification regarding the holotype of *Caecilia volcani* (Amphibia: Gymnophiona). *Copeia* 2001, 561–562.
2001. Wake, M.H. Integrative biology: its promise and its perils. *Biol. Int.* 41, 71–74.
2001. Wake, M.H. Bodies and body plans – how they came to be. In: Kress, W.J., Barrett, G. (Eds.), *A New Century of Biology*. Smithsonian Publ., Washington, DC, pp. 28–52.
2001. Wake, M.H. Scientific responsibility in a changing world. *Biol. Int.* 42, 1–2.
2002. Wake, M.H. Tetrapod limbless locomotion. In: *The Encyclopedia of Life Sciences*, Vol. 18. Nature Publ. Group, London, pp. 195–198, [www.els.net](http://www.els.net).
2002. Wake, M.H. Summary of conclusions. International Symposium on “New Perspectives for Zoology.” *Int. J. Zool. Sci.* 18 (Suppl.), 9.
2002. Wake, M.H. Placentation. In: Pagel, M. (Ed.), *Encyclopedia of Evolution*. Oxford Univ. Press, New York, pp. 905–990.
2002. Wake, M.H. Viviparity and oviparity. In: Pagel, M. (Ed.), *Encyclopedia of Evolution*, Oxford Univ. Press, New York, pp. 1141–1143.
2002. Wake, M.H. Caecilians. In: Halliday, T., Adler, K.K. (Eds.), *New Encyclopedia of Reptiles and Amphibians*. Andromeda Oxford Limited, Oxford, pp. 38–41.
2003. Wake, M.H. Life history evolution. In: Hall, B.K., Olson, W.M. (Eds.), *Key Concepts and Approaches in Evolutionary Developmental Biology*. Harvard Univ. Press, Cambridge, MA, pp. 234–242.
2003. Wake, M.H., Summers, A.P. Morphology. In: Hall, B.K., Olson, W.M. (Eds.), *Key Concepts and Approaches in Evolutionary Developmental Biology*. Harvard Univ. Press, Cambridge, MA, pp. 268–275.
2003. Barbault, R., Guégan, J.-F., Hoshi, M., Mounolou, J.-C., van Baalen, M., Wake, M.H., Younés, T. Integrative biology and complexity in natural systems: keys to addressing emerging challenges. *Biol. Int.* 44, 6–12.
2003. Wake, M.H. Gymnophiona (Caecilians). In: Hutchins, M., Duellman, W.E., Schlager, N. (Eds.), *Grzimek’s Animal Life Encyclopedia*, 2nd Edition, Vol. 6, Amphibians. Gale Group, Farmington Hills, MI, pp. 411–413.
2003. Wake, M.H. Tailless caecilians (Caeciliidae). In: Hutchins, M., Duellman, W.E., Schlager, N. (Eds.), *Grzimek’s Animal Life Encyclopedia*, 2nd Edition, Vol. 6, Amphibians. Gale Group, Farmington Hills, MI, pp. 435–441.
2003. Wake, M.H. What is “integrative biology”? *Integ. Comp. Biol.* 43, 239–241.
2003. Wake, M.H. The osteology of caecilians. In: Heatwole, H., Davies, M. (Eds.), *Amphibian Biology*, Vol. 5, Osteology. Surrey Beatty and Sons, Pty. Ltd., Chipping Norton, Australia, pp. 1811–1878.
2003. Wake, M.H. Embryonization and the evolution of viviparity. In: Hall, B.K., Pearson, R.D., Mueller, G. (Eds.), *Environment, Development, and Evolution: Toward a Synthesis*. MIT Press, Boston, MA, pp. 151–169.
2003. Wake, M.H. Reproductive modes, ontogenies, and the evolution of body form. *Anim. Biol.* 53, 209–223.
2004. Wake, M.H. Integrative biology: the nexus of development, ecology and evolution. *Biol. Int.* 46, 1–18 (Electronic publication: <http://www.iubs.org/test/bioint/46/bi46.htm>).
2004. Wake, M.H. The future of IUBS in the 21st Century. *Biol. Int.* 46 (Electronic publication: <http://www.iubs.org/test/bioint/46/bi46.htm>).
2004. Poe, S., Wake, M.H. Quantitative tests of general models for the evolution of development. *Am. Nat.* 164, 415–422.
2005. Wake, M.H. A busy, innovative year for AIBS. *BioScience* 55, 3 (Editorial).
2005. Donnelly, M.A., Crother, B.I., Guyer, C., Wake, M.H., White, M.E. (Eds.). *Ecology & Evolution in the Tropics. A Herpetological Perspective*. University of Chicago Press, Chicago.
2005. Wake, M.H., Parra Olea, G., Sheen, J. Biogeography and molecular phylogeny of certain New World caecilians. In: Donnelly, M.A., Crother, B.I., Guyer, C., Wake, M.H., White, M.E. (Eds.), *Ecology and Evolution in the Tropics: A Herpetological Perspective*. University of Chicago Press, Chicago, pp. 48–64.
2005. Summers, A.P., Wake, M.H. The retroarticular process, streptostyly and the caecilian jaw closing system. *Zoology* 108, 307–315.
- In press. Wake, M.H. A brief history of research on gymnophionan reproductive biology and development. In: Jamieson, B.M.G., Exbrayat, J.-M. (Eds.), *Reproductive Biology and Phylogeny of Gymnophionans*. Science Publishers, Inc., Enfield, NH.