

1807–2007: A Great Anniversary Celebration

AN INVITATION

John Wiley and Sons Inc. will celebrate its 200th anniversary in 2007. Would you write an article addressing your almost 30-year relationship with Wiley, the state of the field of morphology, and future trends in morphology?

*Swan Padhye, Executive Editor
John Wiley & Sons, Inc.*

A PERSPECTIVE

It is appropriate to place 1807, the year of John Wiley and Sons founding, into perspective.

In January of 1807, there was considerable excitement in Washington. President Thomas Jefferson planned a great January testimonial dinner to honor the heroes Lewis and Clark who had recently returned from their adventure of exploration of the recently purchased Louisiana Territory.

Meanwhile, Europe was engaged in the tumult of the Napoleonic wars. And, in fact, Napoleon Bonaparte was on his way to a fateful February 6 attack on Russia. Russia suffered a crushing defeat at Friedland, but there would be more of Bonaparte, Russia, and “General Winter” in the coming years.

During the next month in England, the Slave Trade Act became law, abolishing the slave trade in the British Empire. In the United States an Act of Congress abolished the importation of slaves beginning January 1, 1808.

In May of 1807, former Vice President of the United States Aaron Burr was indicted for treason and charged with an attempt to dismember the Union. He was acquitted.

Japan continued as an elaborate feudal state while developing art, literature, and the study of ancient history. Foreigners were excluded and the people of Japan remained inside the walls of the islands. In China, diplomatic interaction remained difficult as the Emperor, the Son of Heaven, was without equal. All “barbarians” who approached him did so as vassals. Western envoys did not understand this point of view and attempts to establish permanent relationships with China often resulted in Western humiliation.

England ruled the seas and continued the policy of impressment of American seamen. In June of 1807, the British frigate *Leopard* met the American frigate *Chesapeake* and demanded four of the *Chesapeake's* men. Upon refusal from the *Chesapeake's* crew and captain, the *Leopard* fired on the

American frigate, with the *Chesapeake* striking her flag. Amid great excitement and resentment, British ships were barred from American ports. In December, the Embargo Act prohibited American vessels from leaving for foreign ports and foreign vessels from entering American ports. This Act almost destroyed the commerce of the United States and was violently opposed by the Federalists who represented shipping interests in the northeast and New York.

In the midst of all this activity, Charles Wiley, then 25-years-old, laid the foundations for what Wiley is today by opening a small printing shop in the lower Manhattan area of New York City in 1807. During the next 4 years, he worked with other printers, primarily Isaac Riley, printing and publishing law books. In 1812, “C. Wiley, Printer” appeared for the first time on the title pages of several legal works.

For Wiley, the next 150 years were a time of significant expansion and change as it acquired several smaller publishing businesses and established subsidiaries worldwide. In 1989, Wiley significantly expanded its scientific, technical, and medical publishing program with the acquisition of Alan R. Liss, Inc., a leading publisher of journals and books in the life sciences.

A LONG AND PLEASANT RELATIONSHIP

I came to know Ann Epner and Eric Swanson, two representatives of the publisher Alan R. Liss, Inc., in the late 1970s. We were young and enthusiastic and over the course of many enjoyable evenings at various meetings, we became friends. This close relationship led me and my colleague, Ronald R. Cowden, to publish two books, *Developmental Biology of Freshwater Invertebrates* and *Advances in Microscopy*, through Alan R. Liss, Inc.

In the early 1980s I sat in a meeting of the Executive Committee of the American Microscopical Society where, after completion of regular business, discussion evolved to the idea that “there really needed to be a text on invertebrate histology.” But it was concluded that “the subject was so massive that it would take a lifetime to accomplish and only a fool or idiot would attempt it.” I realized that a couple of years before I had discussed the need for such a book with Ronald R. Cowden.

Feeling that I certainly met a few of the stated criteria, I left the meeting, went downstairs in the hotel, and sought out Eric Swanson.

I presented the idea to Eric and he suggested that we adjourn for an evening of dining and discussion. By the end of the evening, our discussion had led us to the realization of the requirement of a multivolume treatise, tentatively entitled *Microscopic Anatomy of Invertebrates*. As I remember, along with the “goodbyes” and “good nights,” Eric said, “Send me a prospectus.”

The next few months were eventful. I sent a prospectus for a 15-volume treatise to Eric Swanson, now of John Wiley & Sons, Inc. John Wiley & Sons had acquired Alan R. Liss, Inc. and Eric Swanson had joined Wiley. Thus, my *formal* relationship with John Wiley & Sons began. After 9 months of anticipation, I received a letter of acceptance from Wiley. The only recommendation was the excellent advice that I invite an individual who was a recognized authority on the group(s) covered in each volume to serve as volume co-editor. And so I began the “impossible task, suited only for a fool or an idiot,” that would alter my career and, in fact, my life.

Intense years of organizing followed, but I was gratified by the willingness of colleagues to commit months of chapter writing to the project and to offer encouragement. The ebullient John Corliss agreed to co-edit the crucial Volume 1, *Protozoa*, and immediately secured all the chapter authors. And in the midst of an almost overwhelming and difficult period, Volker Storch arrived from Heidelberg to boost my spirits and to speak of the “books for 100 years.”

Wiley is populated with a considerable number of understanding and patient people. The first volume appeared a long 8 years after my evening discussion with Eric Swanson, a gestation time that was surely trying for a publisher. And I do remember the unlamented editor who rather acidly informed me that...“I received the manuscripts for one book in July and for another in August, but what about the book manuscripts that you promised for September?” But publication and editing moved rapidly, especially after I resigned my department headship, shut down my research laboratory, and negotiated a reduced teaching load at Western Carolina University. And on a wonderful occasion, the Wiley-Liss Division of John Wiley & Sons, Inc. was presented the award from the Professional and Scholarly Publishing Division of the Association of American Publishers: Best Books Published in 1991, Volumes 1–3 of *Microscopic Anatomy of Invertebrates*.

The treatise grew. Wiley editors changed. But Eric Swanson and, now, Joe Ingram continued to give complete support. At last, the final volume of a much-enlarged 20-book treatise was published in 1999.

Some time in the early 1990s, Eric Swanson asked me, “What do you want to do when you finally finish the treatise?” I immediately replied, “I would like to be Editor of the *Journal of Morphology*.” I felt that this might be unlikely and, for certain, would be a long time in coming. After all, the renowned Carl Gans had been Editor of the *Journal of Morphology* for decades and I knew that the microscopic anatomy treatise would not be completed for years. What I didn’t know was that Carl Gans had begun discussions with Eric Swanson about a pending Gans retirement and that Professor Gans had placed my name on a “short list” of his possible successors. And that is why, in response to my statement, Eric Swanson looked at me and said, “All right.”

To understand my feelings about the *Journal of Morphology*, allow me to return to 1966, when I occupied my first academic appointment at the small liberal arts institution, Presbyterian College, in Clinton, South Carolina. Marion, my wife of 1 year, asked me, “What do you want to accomplish in your career?” I replied, “*One day I want to publish a paper in the Journal of Morphology*.” And so it was a brimful day for me at the Fourth Congress of Vertebrate Morphology in Chicago when Carl Gans named me his successor as Editor of the *Journal of Morphology*.

The years following that day have been exciting and rewarding as I have worked with all at John Wiley & Sons to change the face of the journal while maintaining the traditions of Carl Gans and the line of distinguished editors holding the post since the journal’s founding by Professor C. O. Whitman in 1887.

MORPHOLOGY TODAY AND WHERE MIGHT WE GO FROM HERE?

In the late 18th century and throughout the 19th century Jena University, now Friedrich-Schiller Universität, possessed a brilliant faculty, including not only Zeiss, Abbe, and Schiller but also the great evolutionary morphologists, Carl Gegenbauer and Ernst Haeckel. And in Jena, the center of the first Golden Age of Morphology, their faculty colleague, Goethe, actually coined the term “Morphologie.”

With the advent of a wide range of diagnostic tools and recently undreamed of research avenues now available to morphologists, we are experiencing a worldwide explosion of interest and activity in the field of morphological science. As we interact with other areas of biology, we also will bridge the gap that exists between the areas of vertebrate morphology and invertebrate morphology, to create a truly comparative and integrative morphology. I firmly believe that, once again, we have entered into a Golden Age of Morphology.

Where will this all lead? I have invited several colleagues to offer their thoughts on future trends in morphology. I feel that the following paragraphs predict an interesting, demanding, but exciting future for our discipline.

Stanislav Gorb

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Purely descriptive morphology without a super-goal already had become passé at the beginning of the twentieth century. Morphology is fun only in connection to other disciplines. We almost always look on structures actually to know more about something different: function, developmental processes, relationship between taxa, evolution, relationship between an organism, and environment, etc.

The role of morphology and organismal biology in general unfortunately has decreased in the course of the several last decades. However, now people from other disciplines, such as molecular biology, genetics, and even engineering and materials science suddenly rediscovered morphology and realized that they are not able to move forward within their own disciplines without having a solid basic knowledge about biological structure at various levels of organization. Classical histology, light and electron microscopy with a widest range of preparation methods, and morphometry are requested from different colleagues now as never before. I am absolutely convinced that the presence of a good solid journal like the *Journal of Morphology*, with a long tradition, excellent editorial service, very good printing quality, and wide circulation has contributed to the “survival” of morphology in the scientific community.

I personally see a few streams in modern morphology. Improvement of old and development of new methods may provide new information about already well-known structures. Computer-aided tomography and reconstructions definitely will be a kind of standard very soon. Morphology also needs the development of theoretical (mathematical) background for explanation and analysis of morphological data. There are several novel non-invasive or at least less invasive techniques for structure visualization (Cryo-SEM, Cryo-TEM, Scanning Probe Microscopy, Atomic Force Microscopy). In the future, using these methods, we will have numerous new, fascinating discoveries on “well-known” structures.

Morphological studies will become more complex. It would be really challenging to conduct projects on functional morphology of the relationship of several organ systems or to discover multifunctionality of structures (trade offs between different functions).

To be able to do this, morphology needs input from other disciplines, such as biomechanics, biochemistry, materials science, surface science, physics... On the other hand, *morphology will feed these disciplines with ideas and new challenging tasks*. For me personally, structure in combination with evaluation of various properties (viscosity, elasticity, viscoelasticity, hardness, friction, adhesion, reflectance...) of biological materials is an absolutely fascinating topic for the future. Furthermore, this combination of disciplines can provide interesting ideas for mimicking materials (biomimetics) by taking ideas from knowledge about the structure of biological materials. Without knowledge of morphology at different levels of organization, there is no way for mimicking features and no chance to obtain the right properties.

Designing of such mimicry systems in collaboration with other scientists can help biologists to conduct experiments, which would otherwise be impossible with living systems. Here I must think about experiments by Adam Summers who is evaluating mechanical properties of “bones” obtained with the use of 3D data and rapid prototyping technique. These kinds of data will help us to prove our concepts about the function of structures.

The explorative role of morphology is probably the most important one for biology itself. In my lab, we do not start any experiment without an explorative stage including a lot of morphological approaches. New organisms, new structures, new phenomena is what at the end makes science so fascinating and endless. Long live morphology!

Linda Trueb

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On the occasion of the 25th anniversary in 1984 of the American Society of Zoologists (now the Society of Integrative and Comparative Biology), Dr. Carl Gans presented a plenary lecture entitled “*Vertebrate morphology: Tale of a phoenix*.” He described a renaissance in morphological studies associated with the developing field of phylogenetic methodology, the burgeoning discipline of evolutionary developmental biology, and early ecomorphological studies. Indeed the phoenix, had arisen and taken flight, and it probably reached its zenith a decade later at the 4th International Congress of Vertebrate Morphology with a symposium entitled “*Vertebrate Morphology Today: The Many Guises of the Phoenix*” that honored Dr. Gans’ many and varied contributions to vertebrate morphology.

The mythical phoenix seems to have been ill-equipped to compete with an upstart in the 1980s-molecular technology. In a matter of 20 years, a single human generation, isozyme

electrophoresis, restriction site analysis, and DNA/RNA sequencing became ever and ever less expensive, automated, and increasingly, the common tools of choice to apply to problems in evolutionary biology. As equipment has become more sophisticated and molecular laboratories more common, cohorts of students have mastered laboratory techniques applied to fragments of organisms. The tissues are processed and the genetic sequences aligned, while the students debate the merits of analytical methodologies to apply to their results. They produce genealogical trees representing organisms that, in many cases, they have never seen in the lab, let alone observed in nature.

Darwinian selection had its way with the phoenix, which in most cases wasn't clever enough, or equipped, to learn how to follow the money as well as its molecular competitors. Vertebrate morphologists retired. Vertebrate natural history and vertebrate comparative anatomy became passé, even arcane academic pursuits, with the result that most contemporary students of vertebrate biology have only a rudimentary knowledge of morphology and how it is studied. One can but wonder how these students will describe organisms and their characters. How will they describe biodiversity? How will they inform and engage the public? Genomics may be the coin of modern scientists, but the appearance—the morphology—of the organism is the lingua franca of the rest of the world.

Lest I be thought a naysayer, let me emphasize that the phoenix persists. He can be found among the botanists, the paleontologists, and the invertebrate zoologist—practitioners in disciplines that have yet to discard morphology for molecules. With luck, the phoenix will survive and future generations of vertebrate biologists, recognizing their loss, will seek renaissance training—training that equips them with the skills to appreciate, to see, and to describe the organisms that are the terminal taxa on their trees. We can only hope that the ability to see form and contemplate function will foster in these students the imagination to address the spectacular patterns of morphological change that are revealed through time and across phylogenies.

Volker Storch

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In the future, morphology will gain access to more and more modern techniques in cytochemistry, histochemistry, biochemistry, in combination with imaging procedures (presumably offered in imaging centers). Altogether, this will produce a deeper understanding of the architecture of animals, allowing eventual application in material sci-

ence and bionics. Another important question is how are all these structures maintained, i.e., turnover rate, differential aging, change of structures in time? Why do structures degenerate? What is senescence, and eventually death? A third problem is how do structures develop individually and how is this development influenced by time and by various external factors?

At the end, some decades from now there will be a fusion of various fields and we will understand how to copy living systems. We haven't understood what biodiversity really means. Why are there so incredibly many forms of metabolic pathways in prokaryotes and of structures in eukaryotes? What holds all this together? Is the biosphere a self-repairing system or could it collapse?

B.G.M Jamieson

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Although one cannot predict novel techniques that may emerge in the study of morphology, future trends are well sign-posted by Wiley publications and especially by the *Journal of Morphology*, which is the flagship in these studies. Future work must continue to employ a variety of techniques, most of which are exemplified in this journal. There will be a continued use of line-drawing by hand augmented, or where appropriate, supplanted by computer graphics. In addition to the use of light microscopy, with a variety of staining procedures and optical means including interference microscopy, the depiction of external morphology will continue to rely considerably on scanning electron microscopy but additional techniques, for instance three-dimensional (3D) laser modeling, may be expected to be increasingly used. Transmission electron microscopy will remain central to analysis of internal structure and increasingly high resolution of digital images will be obtained and will be augmented by magnetic resonance and X-ray procedures. An array of techniques for assaying chemical composition will be refined. Morphological studies should continue to be stimulated by curiosity and by individual interests but it is to be hoped that, in parallel, studies may be organized, and funded, within a framework resembling the Tree of Life program in molecular biology, so that in-depth studies of the morphology of all systems may be undertaken, using a wide array of techniques, on representative species of all major groups of the animal and other kingdoms. Morphological studies should increasingly be linked to epigenesis and other aspects of embryogenesis and should go hand in hand with phylogenetic and functional studies.

Jens T. Hoeg

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I believe the future of morphology (*zoomorphology*) lies in its becoming a center point that can, in teaching and research, integrate other disciplines. I am worried that many colleagues now seem to believe that the primary task of morphology is to provide characters for input in *phylogenetic* analyses. If morphological research is to survive and thrive, it must continue to see itself as a zoological discipline in its own right, not merely as a “technical aid” to phylogenetic analyses. This means that morphologists must interface very actively with other, experimentally oriented fields such as ecology, physiology and evolutionary biology to gain the synergy that comes from working across disciplines. Here, our immense strength is knowledge and expertise about the integrated animal in a comparative frame.

William M. Kier

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Recent advances in imaging technology are dramatically altering the ways that we investigate the morphology of organisms. For instance, although we still often use serial sections of fixed and embedded tissue to explore the 3D arrangement of the components of a tissue or structure, new technologies such as Laser Scanning Confocal Microscopy and Magnetic Resonance Imaging provide exciting glimpses of the future potential of investigating the 3D morphology of intact and perhaps living cells, tissues, and organisms. An important aspect of these advances is the potential elimination of many of the artifacts of the processing of tissues for morphological investigations. Perhaps of greater potential interest, however, is the possibility that we may observe and analyze morphology in a dynamic, living state. This is of particular importance as it will help us to associate structure and function much more directly than is now possible and is likely to alter profoundly our understanding of morphology.

Claus Nielsen

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Zoomorphology has been invigorated over the last decades by the introduction of new microscopic methods and through inspiration from results from molecular methods and the new me-

thods for phylogenetic analyses. This trend will probably grow during the coming years. Morphological investigations of many both developmental and adult stages are still needed, and it should be emphasized that there are very many phylogenetically important groups which have remained very poorly studied. It can be expected that studies of these groups will throw important light on the phylogenetic analyses, and combination of morphological and molecular methods is certain to give the most interesting and well-supported results. Morphologists should seek close collaboration with the molecular biologists to ensure that morphological information is incorporated in the phylogenetic analyses. The inspiration should go both ways.

Steven F. Perry

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I will mainly address my speciality, respiratory morphology to suggest future trends in morphology. In the last third of the 20th century respiratory morphology experienced two powerful technological/methodological impulses: electron microscopy and stereology. The former demonstrated once and for all the presence in all vertebrates of a pulmonary epithelium, and of two parenchymal epithelial cell types in amniotes. Stereology, on the other hand, made possible reliable and reproducible estimations of diffusing capacity, which then could be compared directly with physiologically determined values. Diffusing capacity became a Rosetta stone that allowed translation between structure and function of respiratory organs in all animals.

These advances together with others such as immunohistochemistry, computer-aided modeling and muscle fiber typing have served to remove the barrier between respiratory morphology and physiology. On this foundation a Society of Respiratory Biology is now being created. The first International Congress of Respiratory Biology, which took place in August, 2006, demonstrated clearly that morphology is almost always hyphenated (i.e., combined with something else), and acts as a bridge between traditional disciplines.

One example of how this works is seen in surfactant studies. With the discovery of type 2 cells as the source of surfactant a Pandora's box was opened: what is the ontogeny and phylogeny of these cells, do they recycle surfactant, how can we determine the exact composition of surfactant as it leaves the cells, is it present on all wet surfaces, how do insects prevent their tracheal systems from filling with intercellular fluid, how do tiny fish larvae fill their swim bladders? Attempts to answer each of these questions begin with morphology and loop back to it, revolving about the central question of conservation of structural integrity at an air-fluid interface.

On the basis of this random example we see that the role of respiratory morphology today lies in its function as a focal point in integrative studies. Allegorically, morphology gave birth to comparative anatomy, systematics, developmental biology, bionics, functional morphology, paleontology and many other disciplines and is now gathering back the grown children together with their families. Given that bridging function is crucial in our age of communication, it is ironical that general morphology positions at the university level are being sacrificed for more specialized ones that have less integrative but more commercial potential. This was the message at the last International Congress of Vertebrate Morphology in 2004. Our experience 2 years later at the ICRB, however, showed that morphology continues to play a central role in modern integrative biology.

In the future, we morphologists can pursue our integrative goals under a new label (neurobiology, respiratory biology, cell biology, etc.) and continue to work morphologically. It will become increasingly the role of morphological/anatomical journals and societies to foster interaction among these so-called “hyphenated” morphologists.

This could take place on an even broader scale than presently. Just as the ICRB included botanists, medical practitioners, entrepreneurs and animal physiologists to name a few groups, a morphologists’ meeting could include a wide variety of persons focusing on morphological issues. Such a meeting would not exclude a broad bionic interface with industry and applied sciences. My recent attempts to revitalize the Morphology Study Group within the German Zoological Society along these lines by regrouping under the name of Integrative Structural Biology was premature but resulted in lively discussion and in reassurance of the critical role of morphology in the future.

Adam P. Summers

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We are in the early years of a new Golden Age of Morphology that springs from the synergistic effects of new techniques for visualization and new uses for well-described morphology. Our ability to visualize morphology has leapt forward on two fronts. The specificity of differential stains has progressed to the point where the particular gene products can be localized. This provides unprecedented access to the underlying mechanisms determining morphology and an ability to at once see global distributions of cell types and tissues as well as the most fine scale arrangement. On a parallel, and equally exciting, track has been the development of computer aided visualization techniques that give true 3D representations of data usually

seen in only two dimensions such as serial sections. There are also new and emerging techniques that are fundamentally 3D that reveal a startling array of anatomical detail including immunohistochemistry as revealed by confocal microscopy, hard tissues visualized with radiographic computed tomography scanning, and soft tissues via magnetic resonance imaging (MRI) and sonography. These 3D techniques reveal morphology in good detail, though conventional histology and electron microscopy inevitably do better. The exciting aspect of these techniques is not in the resolution of detail as much as it is in the ability to provide context by showing the true arrangement of anatomical detail in life. In concert with new techniques has been a delightful realization on the part of reductionist biologists that the shape of organism is of fundamental importance. The burgeoning field of evolutionary developmental biology is founded on an ability to compare structure across phylogeny. This requires an understanding of morphology across a wide range of taxa. Model systems, the target of hugely productive and important molecular work, have started to garner attention from morphologists and most excitingly from molecular biologists crossing over into this discipline as its importance is realized. In short, history may well show us that there was no better time to be a morphologist, especially a comparative, broadly trained morphologist, than at the dawn of the 21st century.

James Hanken

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Cambridge, Massachusetts*

Morphology is among the oldest of scientific disciplines. The fact that it remains viable today attests to its fundamental importance in biological study and to its ability to adapt and change in response to new questions, approaches, technology, and intellectual discoveries. Morphology thrives today because it readily incorporates relevant methods and data from disparate fields, ranging from genomics to hydrodynamics, and from phylogenetics to ecology. Unlike at many times in the past, contemporary morphology is not content to produce only static descriptions of organismal anatomy for a small number of model species. Instead, accounts and explanations regarding ontogeny, function and evolution across a broad and diverse range of organisms and from microscopic to macroscopic scales, are paramount and will remain so far into the future. Far from diverting the science of morphology into wayward directions with no compelling goal, these and other trends will continue to help realize the ultimate promise of morphology to provide a detailed and comprehensive understanding of biological structure and form, in all its dynamic manifestations.

George V. Lauder

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Cambridge, Massachusetts*

The future of morphology is bright as it is one of the most integrative of disciplines, spanning both multiple levels of biological organization and a diversity of technical approaches. The outlook for the coming decades promises an even wider integration of morphological concepts and approaches into a diversity of allied research areas. Three areas of morphological research over the past 10 years have demonstrated the beginnings of trends that are likely to be key elements of future work. First, new approaches to visualizing morphological structures will revolutionize our ability to understand both the relationships among structures, and how structures move. New microscopic techniques allow visualization of biological tissues from nearly the atomic level through whole cellular components to macroscopic anatomy. Atomic force microscopy, two-photon fluorescence microscopy, and micro-computed tomography (uCT) all allow organismal structure to be studied in a level of detail never before imagined, and greatly facilitate 3D reconstruction of anatomy. In addition, the latest generation of digital video systems has both high-resolution and high-speed, often achieving megapixel resolution at speeds of 1000s of frames per second. Such video images, when used to image rapidly moving morphological features in both light and under X-ray, provide a new view of how morphological structures function.

3D reconstruction of morphology is a critical step toward the second major avenue of future morphological research: finite element analysis and computational models of structural and environmental interactions. As computational tools become increasingly more sophisticated, morphologists will be able to build 3D models of organismal structures, and deform these features with applied forces. Coupled models of both solid-solid and fluid-structure interactions permit predictions of loading patterns on anatomical structures, and calculation of the effect of moving structures on the environment.

The third area in which future studies of organismal morphology will increasingly play a dominant role is the emerging area of biorobotics. Organisms move easily on land, in the water, and in air, and engineers are increasingly turning to biology for inspiration in designing robots that can move equally well in each of these disparate media. The future development of biomimetic robots that use principles of organismal function will increasingly rely on understanding the structural design of organisms.

James Stewart

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Morphology is the study of form and, although there is much to appreciate in the intricacies of complex structures as individual entities, interpretation of the function and evolution of these structures requires a context that includes an understanding of the nature of phenotypic variation as well as the mechanisms that produce it. One classic question that remains relevant, and benefits from recent methodological advances asks, "How do complex phenotypes develop?" Phenotypes are integrated systems that are expressed through specific genetic and developmental sequences and comprehending these complex structures requires an understanding of the developmental hierarchy that generates them. Fortunately, there are numerous natural experiments that provide models for understanding phenotypic variation. Homoplasy (independently derived similarity), has been a prominent evolutionary outcome in a variety of biological systems. This phenomenon is ideally suited for study of the relationship between phenotypic expression and developmental mechanisms. Understanding how independently derived structures become similar requires knowledge of developmental pathways, i.e., is similar or different developmental mechanisms involved, and ultimately the relationship between genotypic variation and phenotypic variation. These studies require an appropriate phylogenetic context to recognize homoplasy and an integrative analysis to understand how selection may influence functional units during development. One outcome of this approach will be to understand how functional units interact during development and how this interaction influences phenotypic expression.

Seth Tyler

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Orono, Maine*

Molecular phylogenetics is providing a welcome impetus to evaluate concepts of relationships of organisms. Some bold new hypotheses of relationships emerging from sequence analysis of genes are at surprising odds with many long-standing hypotheses based on morphological similarities, and the challenge now is to see how readily probable scenarios of evolutionary change in morphology can be fitted to the molecular hypotheses. Because molecular data sets are independent of morphology they can be especially valuable in deciphering the evolution of morphological characters. Particularly intriguing are questions about the earliest forms of life and the ancestral states of major clades of

organisms. As molecular phylogenies identify basal taxa in given clades, we should learn what the ancestors that gave rise to those clades looked like—what morphology allowed the establishment and diversification of the clade? At the same time, morphology provides tests of molecular trees. Because morphological characters are far more complex than molecular ones, their information content must be weighed strongly in evaluating hypotheses of relationships.

Gerhard Haszprunar

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Recent developments in phylogenetic analysis have strongly encouraged molecular characters as a meaningful data-basis from the alpha-taxonomic up to the kingdom level of evolution. Nevertheless, morphology (i.e., all kinds of visualization of any characters including fine-structure, immunoreactions, or even 3D-molecule images) remains not only as a valuable, but even a crucial element in phylogeny.

First, to see things means to believe in things. In particular, modern methodological progress such as electron microscopy (TEM and SEM) or immunoreactive reactions combined with fluorescent dyes and Confocal Laser Scanning Microscopy have added a wealth of new and highly significant data concerning phylogeny. We also are on the way to apply real-time and non-invasive methods (e.g., magnetic resonance tomography) to small subjects and await another rush in our understanding of characters. The more details we can add to any “character” the better we can infer whether observed similarities may be interpreted as homologies rather than as homoplasies.

Second and equally important: Phylogeny has a two-fold aim. The first is to construct a tree to get a framework for interrelationships. However, we also want to infer “what happened in evolution?”—and this is the field of morphology in the broad sense (note that all physiological adaptations need a structural basis). It is this latter question that makes the link to evolutionary biology, which as a discipline focuses on the mechanisms of evolution. There is no question that it is the phenotype rather than the genotype, which is subject to selection.

Finally, and not the least: In these days where evolution as a basic scientific framework is (strangely enough) still under discussion, it is a primary aim to transport results of phylogenetic analysis to the broad public. And here the circle closes: to see things is to believe in things.

In summary, morphology will continue as a vital discipline in the future and never will become outdated or obsolete.

R. Glenn Northcutt

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It's always dangerous to pretend you have a crystal ball that will allow you to predict the future, particularly the future of any scientific field. Having said that, I believe that there will be at least three trends in morphology over the next years: 1) a continuing search for the molecular basis of the development of structure; 2) a new generation of functional studies, as monitors become even more miniaturized; 3) a renewed interest in morphological diversity, as we face an accelerating crisis in animal extinction. There is no question that the amazing progress that has been made in isolating developmental genes and in understanding their functions will continue and should provide critical information on how developmental changes produce morphological phylogenies. I believe we are also at the very beginnings of a new nanotechnology that promises to provide scientists with new devices and ways of measuring biological functions that have been beyond our technical capabilities. Finally, I hope that the looming loss of animal diversity will trigger a renaissance in descriptive and experimental morphological studies of animals that are not considered “animal models,” before all we have left are those models.

Marvalee H. Wake

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Science in the 21st century is changing dramatically, from individual to team-based research, from idiographic and reductionistic practices to nomothetic, synthetic approaches, and to a broader acquaintance with a more diverse literature, technical scope, and philosophy than currently enjoyed despite the explosion of new literature. The tools for communication and efficient and effective data capture make this possible. Biology in particular will utilize such approaches. With new emphasis on exploring the hierarchy of biological organization to understand complexity—that hierarchy centered by the organism—morphology will be recognized as a linchpin in the science of biology. It is the phenotype; colleagues investigating the genetic basis of development are realizing the need to understand organogenesis and morphology to interpret what they have manipulated. Similarly, community ecologists begin to recognize that a food web, for example, is not merely a collection of interacting species, but one predicated on feeding *mechanics* and their structural/functional bases. Morphology is more pervasive and essential than ever. New ideas, techniques, and approaches to

complex questions frequently require the integration of morphology to achieve real understanding. Morphology will be recognized as a strong and equal partner in 21st century science.

Sue Herring

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Two future trends in morphological research are already obvious, because they are driven (or at least fed) by developments external to the field.

The first is the burgeoning information about the genome and the “proteome.” One of the goals of modern biology is to explain the phenotype in molecular terms, and we are sure to see increasing efforts to tie genetic data to morphology and to understand morphological variation from a molecular point of view. The other obvious trend is the increasing power of desktop computation. Our ability to manipulate numbers has already resulted in vastly more sophisticated statistical treatment of morphological data and a generalized move to more quantitative analysis of structure. In addition, computational power has enabled modeling of complex phenomena such as vortex waves during animal locomotion and stress transmission through the mammalian skull. While it is still difficult to test the validity of such computational models, they have opened up totally new morphological areas of investigation.

Another trend I would like to see is a broadening of the taxonomic scope of functional morphol-

ogy. Although interesting morphological features in diverse taxa are still receiving good anatomical descriptions (in large part because of the *Journal of Morphology*), functional studies outside of a few model organisms seem to be getting rarer. In particular, much work remains to be done applying modern functional techniques to understand invertebrates.

SALUTATIONS

It has been an eventful and very productive 200 years for Wiley. We practitioners of the discipline of morphology recognize and appreciate the many contributions of John Wiley and Sons to our field of science. And so, we send a sincere and heartfelt HAPPY BIRTHDAY and our hopes for a wonderful coming 200 years.

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