

## Morphometrics In Evolutionary Biology The Geometry Of Size And Shape Change With Examples From Fishes The Academy Of Natural Sciences Of Philadelphia Special Publication No 15

*Morphometrics has undergone a revolutionary transformation in the past two decades as new methods have been developed to address shortcomings in the traditional multivariate analysis of linear distances, angles, and indices. While there is much active research in the field, the new approaches to shape analysis are already making significant and ever-increasing contributions to biological research, including physical anthropology. Modern Morphometrics in Physical Anthropology highlights the basic machinery of the most important methods, while introducing novel extensions to these methods and illustrating how they provide enhanced results compared to more traditional approaches. Modern Morphometrics in Physical Anthropology provides a comprehensive sampling of the applications of modern, sophisticated methods of shape analysis in anthropology, and serves as a starting point for the exploration of these practices by students and researchers who might otherwise lack the local expertise or training to get started. This text is an important resource for the general morphometric community that includes ecologists, evolutionary biologists, systematists, and medical researchers. Rapid recent developments in DNA sequencing and genetic marker technologies call for the establishment of cost-effective, automated phenotyping assays for evolutionary biology and systematics, so that the effects of DNA polymorphisms and epigenetic changes on the phenotype can be evaluated. We discuss the use of digital image-based morphometrics in evolutionary biology and systematics with special emphasis on studies of taxa with porous genomes, i.e., taxa that do not conform to the traditional view of whole-genome isolation between species. We outline the phenomenon of the 'phenotypic mosaic' in taxa with porous genomes using well-documented examples from the literature and describe three important challenges arising for taxonomists: (1) character conflict in phylogenetic studies, (2) biased sampling of traits in morphological studies, and (3) cryptic ecological speciation. We demonstrate the use of geometric morphometrics using a combined molecular and morphometric dataset from an interspecific hybrid zone between two divergent Eurasian species of Populus, P. alba (white poplar) and P. tremula (European aspen). Elliptic Fourier analysis (EFA)-based morphometric data were collected for 527 leaf specimens from 84 trees with known genomic composition as determined by a set of 30 nuclear DNA microsatellites. In addition, to demonstrate the ease of scoring functionally relevant phenotypes via digital image analysis, quantitative differences in leaf reflectance were examined and their structural basis determined using scanning electron microscopy (SEM). The EFA results indicate a heritable inter-individual component for symmetric aspects and an important intra-individual component for asymmetric aspects of variation in leaf outlines. Symmetric traits displayed a striking variety of phenotypes in hybrids compared to their parental species, consistent with the notion of the phenotypic mosaic. Linear discriminant analysis of these morphometric traits revealed (1) clear dif.*

*Evolutionary Biology, of which this is the eighteenth volume, continues to offer its readers a wide range of original articles, reviews, and commentaries on evolution, in the broadest sense of that term. The topics of the reviews range from anthropology and behavior to molecular biology and systematics. In recent volumes, a broad spectrum of articles have appeared on such subjects as natural selection among replicating molecules in vitro, mate recognition and the reproductive behavior of Drosophila, molecular systematics of Crocodylia, evolution of the monocotyledons, and the communication network made possible among even distantly related genera of bacteria by plasmids and other transposable elements. Articles such as these, often too long for standard journals, are the stuff of Evolutionary Biology. The editors continue to solicit manuscripts on an international scale in an effort to see that everyone of the many facets of biological evolution is covered. Manuscripts should be sent to anyone of the following: Max K. Hecht, Department of Biology, Queens College of the City University of New York, Flushing, New York 11367; Bruce Wallace, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061; Ghillian T. Prance, New York Botanical Garden, Bronx, New York 10458.*

*Morphological Plant Modeling: Unleashing Geometric and Topological Potential within the Plant Sciences  
Geometry and Statistics for Studies of Organismal Form*

*All Apes Great and Small*

*Morphometrics*

*Applications from Paleozoic Bryozoa*

*Volume 18*

**Many of the papers in this volume were first presented at the Third International Great Apes of the World Conference, held July 3-6, 1998 in Kuching, Sarawak, Malaysia. The editors of this volume, the first in a two-volume series, are world renowned, having dedicated most of their lives to the study of great apes. The world's premiere primatologists, ethologists, and anthropologists present the most recent research on both captive and free-ranging African great apes. These scientists, through deep personal commitment and sacrifice, have expanded their knowledge of chimpanzees, bonobos, and gorillas. With forests disappearing, many of these studies will never be duplicated. This volume, and all in the Developments in Primatology book series, aim to broaden and deepen the understanding of this valuable cause.**

**The book on "General Ichthyology" deals with air-breathing fishes which have evolved on several occasions. Evolution of the first bony fishes during the late Silurian and Devonian period produced two new features, lobe fins and the lung fishes. Animals inhabiting the water/air interface show many morphological and physiological adaptations designed with different types of function in that unique environments. In the present age there are new challenges. These include climatic change and contamination of the environment by anthropogenic activities. The subject matter has been delineated in 13 (Thirteen) chapters: Evolutionary Biology, Origin of**

**Fishes, Evolution of Air-breathing Habit in Vertebrates, Morphometrics of the respiratory organs, Evolutionary Transformations of the Respiratory Islets of Air-breathing Organs in Teleostean Fishes, Chloride cells in the Gills of Fresh water teleosts, Respiratory Surface Area Metabolism relationship in Air-breathing Fishes of India, Water/Air Transition in Biology, Structure of the heart of Amphipnous cuchia and their vasculature of the head and respiratory organs. Histochemistry and Functional Organisation, Fine Structure of the Respiratory Organs, Cytology of Macrophages in normal and mercury treated air-breathing fish, Oxygen Uptake and Phylogeny. The book will interest students and research workers in the field of General Ichthyology.**

**An increasing population faces the growing demand for agricultural products and accurate global climate models that account for individual plant morphologies to predict favorable human habitat. Both demands are rooted in an improved understanding of the mechanistic origins of plant development. Such understanding requires geometric and topological descriptors to characterize the phenotype of plants and its link to genotypes. However, the current plant phenotyping framework relies on simple length and diameter measurements, which fail to capture the exquisite architecture of plants. The Research Topic "Morphological Plant Modeling: Unleashing Geometric and Topological Potential within the Plant Sciences" is the result of a workshop held at National Institute for Mathematical and Biological Synthesis (NIMBioS) in Knoxville, Tennessee. From 2.-4. September 2015 over 40 scientists from mathematics, computer science, engineering, physics and biology came together to set new frontiers in combining plant phenotyping with recent results from shape theory at the interface of geometry and topology. In doing so, the Research Topic synthesizes the views from multiple disciplines to reveal the potential of new mathematical concepts to analyze and quantify the relationship between morphological plant features. As such, the Research Topic bundles examples of new mathematical techniques including persistent homology, graph-theory, and shape statistics to tackle questions in crop breeding, developmental biology, and vegetation modeling. The challenge to model plant morphology under field conditions is a central theme of the included papers to address the problems of climate change and food security, that require the integration of plant biology and mathematics from geometry and topology research applied to imaging and simulation techniques. The introductory white paper written by the workshop participants identifies future directions in research, education and policy making to integrate biological and mathematical approaches and to strengthen research at the interface of both disciplines.**

**A Morphometric Study of Crocodylian Ecomorphology Through Ontogeny and Phylogeny**

**Modern Morphometrics in Physical Anthropology**

**Form, Function, and Behavior**

**Craniofacial Development**

**Volume 1: African Apes**

**Evolutionary Biology of Orthopteroid Insects**

The idea of form is one of the most fundamental concepts underlying all of the sciences. Our visual system is so well developed that we are able to effortlessly classify and compare visual images. What is not so well developed has been our ability to measure this visual information. This book examines a number of recent approaches currently in use to numerically characterize the biological form. It presents a unique overview of these methods, starting with a review of measurement set in a historical framework. The book will be of interest to graduate students in addition to a wide range of researchers, including those in the specialized fields of human biology, growth and development, orthodontics, botany, biology, ecology, zoology, as well as dentistry and medicine.

Despite recent advances in genetics, development, anatomy, systematics, and morphometrics, the synthesis of ideas and research agenda put forth in the classic Morphological Integration remains remarkably fresh, timely, and relevant. Pioneers in reexamining morphology, Everett Olson and Robert Miller were among the first to explore the concept of the integrated organism in both living and extinct populations. In a new foreword and afterword, biologists Barry Chernoff and Paul Magwene summarize the landmark achievements made by Olson and Miller and bring matters discussed in the book up to date, suggest new methods, and accentuate the importance of continued research in morphological integration. Everett C. Olson was a professor at the University of Chicago and at the University of California, Los Angeles. He was a former president of the Society of Vertebrate Paleontology. Robert L. Miller was associate professor of geology at the University of Chicago, associate scientist in marine geology at the Woods Hole Oceanographic Institution, and a member of the board of editors of the Journal of Geology.

This volume is based on the NATO Advanced Study Institute, "Advances in Morphometrics" held in 11 Ciocco, Tuscany, Italy from July 18-30, 1993, and directed by Leslie F. Marcus. The "Advances in Morphometrics" ASI was advertised in Nature and a number of professional journals. Announcements were sent to relevant institutions and departments throughout the world. Because NATO required that the majority of attendees be from NATO countries, the 71 persons attending represented nine NATO countries, four eastern European countries, now recognized as equal partners for ASIs, and a few participants from non-NATO countries. Participants were all active scholars in different disciplines within biology, as well as computer science, statistics, geology and paleontology. Their experience ranged from that of graduate students to senior faculty, as well as one emeritus scholar. A complete list of the those attending and their addresses, phone and FAX numbers and, where available, e-mail addresses is given in the participants list. All the local arrangements were made by Marco Corti and Anna Loy of the University of Rome "la Sapienza." They made the initial contact with the 11 Ciocco conference center and then arranged for computer and Xerox rentals, design of logos, organization of posters, and publication of poster abstracts.

Applications in Biology and Paleontology

A Primer

Bones and Cartilage

Morphodynamics

The Guenons: Diversity and Adaptation in African Monkeys

Ontogeny and Phylogeny

It has been twelve years since a work relating to the long-tailed African monkeys known as the guenons has been published and fifteen years have passed since the last major scientific symposium was held that was solely dedicated to current research on members of this monkey group living in the wild. Since that time, new guenon species and subspecies have been discovered, previously unstudied guenon species have become the subject of long-term research projects, and knowledge of the more well-known guenon species has greatly increased. This volume presents novel information and keen insight on research previously studied and newly discovered. A wide range of topics related to guenon biology is presented, including evolution, taxonomy, biogeography, reproductive physiology, social and positional behavior, ecology, and conservation. Composed of 26 chapters compiled by 47 authors, many of whom are young investigators in their field, *The Guenons: Diversity and Adaptation in African Monkeys* provides a valuable resource for researchers and scientists in the fields of anthropology, primatology, zoology, and conservation biology.

*Bones and Cartilage* provides the most in-depth review and synthesis assembled on the topic, across all vertebrates. It examines the function, development and evolution of bone and cartilage as tissues, organs and skeletal systems. It describes how bone and cartilage develop in embryos and are maintained in adults, how bone is repaired when we break a leg, or regenerates when a newt grows a new limb, or a lizard a new tail. The second edition of *Bones and Cartilage* includes the most recent knowledge of molecular, cellular, developmental and evolutionary processes, which are integrated to outline a unified discipline of developmental and evolutionary skeletal biology. Additionally, coverage includes how the molecular and cellular aspects of bones and cartilage differ in different skeletal systems and across species, along with the latest studies and hypotheses of relationships between skeletal cells and the most recent information on coupling between osteocytes and osteoclasts. All chapters have been revised and updated to include the latest research. Offers complete coverage of every aspect of bone and cartilage, with updated references and extensive illustrations. Integrates development and evolution of the skeleton, as well a synthesis of differentiation, growth and patterning. Treats all levels from molecular to clinical, embryos to evolution, and covers all vertebrates as well as invertebrate cartilages. Includes new chapters on evolutionary skeletal biology that highlight normal variation and variability, and variation outside the norm (neomorphs, atavisms). Updates hypotheses on the origination of cartilage using new phylogenetic, cellular and genetic data. Covers stem cells in embryos and adults, including mesenchymal stem cells and their use in genetic engineering of cartilage, and the concept of the stem cell niche. *Morphometrics in Evolutionary Biology: The Geometry of Size and Shape Change, with Examples from Fishes*. Geometric Morphometrics for Biologists. A Primer. Academic Press.

Geometry and Biology

Origination of Organismal Form

A Course in Morphometrics for Biologists

Morphological Integration

Allometry, Morphological Integration, and Phylogenetic Implications

The Geometry of Size and Shape Change, with Examples from Fishes

***This book offers a thorough and up-to-date treatment of the use of morphometric procedures in a wide variety of contexts. As one of the most dynamic and popular fields on the contemporary biological scene, morphometrics is gaining notice among researchers and students as a necessary complement to molecular studies in the understanding and maintenance of biodiversity. This is the first reference to meet that growing need.***

***Morphological convergence is observed throughout the tree of life. Convergent morphologies have been attributed to a variety of mechanisms including ecomorphological adaptation, and ontogenetic plasticity among others. Parallelism has been considered a specialized subset of convergence where common descent has contributed toward the independent evolution of similar morphologies. However, morphological convergence can mislead phylogenetic reconstruction when assumptions of character independence are violated by a misunderstanding of morphological variation making it difficult to distinguish processes of convergence from parallelism. Rigorous study of morphological variation and ontogeny provide a means to resolve evolutionary pattern and process in organismal groups that are complicated by the evolution of recurrent or convergent morphologies.***

***Phylogenetic analysis and morphometrics have been developed by biologists into rigorous analytic tools for testing hypotheses about the relationships between groups of species. This book applies these tools to paleontological data. The fossil record is our one true chronicle of the history of life, preserving a set of macroevolutionary patterns; thus various hypotheses about evolutionary processes can be tested in the fossil record using phylogenetic analysis and morphometrics. The first book of its type, *Fossils, Phylogeny, and Form* will be useful in evolutionary biology, paleontology, systematics, evolutionary development, theoretical biology, biogeography, and zoology. It will also provide a practical, researcher-friendly gateway into computer-based phylogenetics and morphometrics.***

***Morphometrics with R***

***Geometric Morphometrics for Biologists***

***Morphometrics for Nonmorphometricians***

***The Use of Digital Image-based Morphometrics to Study the Phenotypic Mosaic in Taxa with Porous Genomes***

***Morphometric Analysis of Skull Shape in Recent and Fossil Canids (Mammalia: Carnivora)***

***Shaping Primate Evolution***

This book frames and demonstrates the best of modern morphometric methods, bridging the gap between biostatistics and organismal biology.

Morphodynamics is defined as the unique interaction among environment, functional morphology, developmental constraints, phylogeny, and time—all of which shape the evolution of life. These fabricational patterns and similarities owe their regularity not to a detailed genetic program, but to extrinsic factors, which may be mechanical, chemical, or biological in nature. These self-organizing mechanisms are the focus of Morphodynamics. Illustrated by numerous examples from across the biological spectrum,

this book embodies the foundation of noted paleontologist Adolf Seilacher's thinking on the study of morphodynamics. It represents his unique approach of presenting paleontology from an ecological and constructional perspective, rather than a purely taxonomic one. The hallmark of Seilacher's storied career has been a constructional and functional focus. He begins by discussing the basic principles—form, pattern formation, ecology and evolution, as well as the factors that override those processes. Next, he examines how morphodynamic principles are implemented in various invertebrates including single-celled protists, Ediacarans, sponges, coelenterates, shelled organisms, worms, arthropods, and echinoderms. The final chapter explores how morphogenetic principles may apply to clonal colonial organisms. Summarizing seventy years of research into the interactions of form, function, and evolution, the book is copiously illustrated with the author's own distinctive drawings and an abundance of photos. It provides a framework for readers to pose their own questions and sharpen their interpretive skills on this fascinating topic. The first edition of Geometric Morphometrics for Biologists has been the primary resource for teaching modern geometric methods of shape analysis to biologists who have a stronger background in biology than in multivariate statistics and matrix algebra. These geometric methods are appealing to biologists who approach the study of shape from a variety of perspectives, from clinical to evolutionary, because they incorporate the geometry of organisms throughout the data analysis. The second edition of this book retains the emphasis on accessible explanations, and the copious illustrations and examples of the first, updating the treatment of both theory and practice. The second edition represents the current state-of-the-art and adds new examples and summarizes recent literature, as well as provides an overview of new software and step-by-step guidance through details of carrying out the analyses. Contains updated coverage of methods, especially for sampling complex curves and 3D forms and a new chapter on applications of geometric morphometrics to forensics Offers a reorganization of chapters to streamline learning basic concepts Presents detailed instructions for conducting analyses with freely available, easy to use software Provides numerous illustrations, including graphical presentations of important theoretical concepts and demonstrations of alternative approaches to presenting results Fossils, Phylogeny, and Form

**The Measurement of Biological Shape and Shape Change**

**Mus Musculus Helgolandicus: Insights Into Their Origin. A Study Based on Genetic and Morphometrics Analysis**

**Morphometrics for the Life Sciences**

**The Neocortex**

**General Ichthyology**

*Evolutionary Biology, of which this is the twenty-second volume, continues to offer its readers a wide range of original articles, reviews, and commentaries on evolution, in the broadest sense of that term. The topics of the reviews range from anthropology, molecular evolution, and paleobiology to principles of systematics. In recent volumes, a broad spectrum of articles have appeared on such subjects as asymmetric sexual isolation, biochemical systematics in plants, species selection, DNA hybridization and phylogenetics, modes of evolution in Pleistocene rodents, and development and evolution of the vertebrate limb. We have also attempted to provide a forum for conflicting ideas. Articles such as these, often too long for standard journals, are the material for Evolutionary Biology. The editors continue to solicit manuscripts on an international scale in an effort to see that everyone of the many facets of biological evolution is covered. Manuscripts should be sent to anyone of the following: Max K. Hecht, Department of Biology, Queens College of the City University of New York, Flushing, New York 11367; Bruce Wallace, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061; Ghilleen T. Prance, New York Botanical Garden, Bronx, New York 10458. The Editors vii Contents 1. Phylogeny of Early Vertebrate Skeletal Induction and Ossification Patterns ... 1 John G. Maisey Introduction: The Fossil Record... .. 1.*

*Now With A New Full Color Design And Art Program, The Fifth Edition Of Strickberger's Evolution Is Updated With The Latest Data And Updates From The Field. The Authors Took Care To Carefully Modify The Chapter Order In An Effort To Provide A More Clear And Student-Friendly Presentation Of Course Material. The Original Scope And Theme Of This Popular Text Remains, As It Continues To Present An Overview Of Prevailing Evidence And Theories About Evolution By Discussing How The World And Its Organisms Arose And Changed Over Time. New Boxed Features Concentrating On Modern And Exciting Research In The Field Are Included Throughout The Text. New And Key Features Of The Fifth Edition - New Full Color Design And Art Program - Maintains The Student-Friendly Engaging Writing-Style For Which It Is Known - A Reorganized Chapter Order Provides A More Clear And Accessible Presentation Of Course Material. - Chapters On The Evolution Of Biodiversity Are Now Found On The Text's Website. - Access To The Companion Website Is Included With Every New Copy Of The Text. - New Boxed Features Highlight New And Exciting Research In The Field. This first systematic survey of the subject combines multivariate statistical analysis, geometry, and biomathematics. Contributions to Morphometrics*

*Morphometric Tools for Landmark Data*

*Morphometric Studies of Australopithecines*

*Developmental and Evolutionary Skeletal Biology*

Documentation of microevolution through geologic time is a significant paleontologic contribution to evolutionary biology. Paleomicroevolutionary studies require accurate stratigraphic resolution over a large geographic area, through changing environments, over a sustained period of time, with an abundant, complex, eurytopic fossil group. The combination of cryptostome bryozoans, revised taxonomic procedures, multivariate morphometric methods, and advances in microcomputer technology allows for research of this nature. Multivariate analysis of a large morphometric data set demonstrates that discrete fenestrate bryozoan morphs can be recognized objectively at three hierarchical levels: species, genera and families. Recent studies of hard-part versus electrophoretic species recognition in cheilostome bryozoans and scleractinian corals support the interpretation that fenestrate species represent true biological species rather than morphotaxa. Morphometric analysis demonstrates that some characters are taxonomically more important than others, but use of all available characters yields the most reliable results. *Worthenopora* is a Mississippian cryptostome bryozoan tentatively assigned to the order Cheilostomata (Jurassic and younger) but some early workers. This alignment raises the question of affinities between cryptostomes (class Stenolaemata) and cheilostomes (class Gymnolaemata). Based on wall structure, growth sequence, zooecial shape, and secondary structures such as stylets, *Worthenopora* is here shown to be a stenolaemate, assignable to the suborder Ptilodictyina with other bifoliate cryptostomes, with no special affinities with cheilostomes. Paleontologic data frequently do not satisfy assumptions of normality and homoscedasticity of many parametric statistical tests. Normal scores tests, which employ normal order deviates (rankits), provide an attractive alternative for treatment of such data. Computer programs Rankit and Mathematica provide a practical method of calculating rankits and converting raw data, making normal scores tests more accessible. Three-dimensional shapes of cryptostome bryozoan autozooecial chambers are important for systematics and paleoecologic interpretations, however, computer automation of three-dimensional reconstruction from serial sections is not yet practical. Based on morphometric analysis of the rhabdomesoid *Streblotrypa prisca*, ecophenotypic and geographic variation are significant factors for microevolutionary studies. Apparently non-astogenetic morphologic growth gradients are demonstrated with colonies of *S. prisca*. A morphologic cline distributed over a 300 km transect is demonstrated; control is unclear, but it may be associated with a depth gradient.

Morphology has traditionally been used as the primary criterion for species delimitation, and many modern studies still utilize this in practice. The influence of phenotypic plasticity can confound studies in evolutionary biology and ecology, and the limited resources for conservation projects may be applied inefficiently. Understanding of the contributing factors of morphological variation is needed. *Elimia proxima* a highly variable freshwater snail (Pleuroceridae), has been described as a separate species multiple times over the last century by different researchers because of the high degree of morphological variation. Robert T. Dillon performed a study of the ecological correlates of the morphological variation in *E. proxima* in 1980. In this study we re-examine the correlated variation of Dillon's original study using size independent Geometric Morphometric analysis. Samples of snail shells from 25 populations (n=1203) were photographed and digitized with 19 landmarks for use in Thin Plate Spline analysis. Multiple regressions, Partial mantel Tests and . . . (Partial Eta Squared) tests were performed and Wilk's Lambda values were calculated for the influence of size and the 14 environmental variables of Dillon's original study in the variation in shape. Results indicate a complex interaction of both genetics and environmental variables in the generation of shell phenotype, and we assess the relative contribution of each to the overall variation seen in *E. proxima*. -Author

The neotropical ecoregion consisting of South America, Central America, Southern Mexico, the Caribbean Islands, and Southern Florida, has long been considered an area rich in mammalian diversity and one that contains some of the world's iconic carnivores such as the Jaguar and Puma. These, and other carnivores represent the highest trophic levels within neotropical areas and as keystone species, can markedly alter omnivore and herbivore mammalian communities and indirectly, plant communities. Unfortunately, due to human population pressures, many neotropical areas and the mammals within them are increasingly at risk. This problem is compounded by the lack of current genetics, evolutionary biology and conservation data of these critical carnivores available to conservation biologists at the forefront of trying to preserve and protect these imperiled geographical areas. This book helps to meet these shortcomings by providing contributions from 60 of the world's leading scientists in the area of neotropical carnivores. The first section of the book covers molecular population genetics and phylogeography of diverse neotropical carnivores such as otters, coatis and other Mustelidae and Procyonidae, wild cats (jaguar, puma, ocelot, jaguarondi, Pampas cat, and Andean cat) and the Andean bear. Significant sections of the book are also devoted to the topics of reproduction, geometric morphometrics of wild canids and a complete paleontological view of the evolution of all neotropical carnivore groups. Furthermore, the book contains several chapters on the conservation details and varying cultural perspectives regarding the two larger and more mythical neotropical carnivores, the

*jaguar and the Andean bear, which together, are the paradigm for the conservation programs in Central and South America.*

*Morphometrics in Evolutionary Biology*

*Uniqueness and Diversity in Human Evolution*

*Strickberger's Evolution*

*Beyond the Gene in Developmental and Evolutionary Biology*

*Morphometric Approaches to Systematics and Microevolution*

*Geometric Morphometric Analysis of Shell Shape and Correlation with Physical and Chemical*

*Environmental Variables in *Elimia Proxima* (Gastropoda: Pleuroceridae) from the Eastern United States*

Morphometrics is concerned with the study of variations and change in the form (size and shape) of organisms or objects adding a quantitative element to descriptions and thereby facilitating the comparison of different objects and organisms. This volume provides an introduction to morphometrics in a clear and simple way without recourse to complex mathematics and statistics. This introduction is followed by a series of case studies describing the variety of applications of morphometrics from paleontology and evolutionary ecology to archaeological artifacts analysis. This is followed by a presentation of future applications of morphometrics and state of the art software for analyzing and comparing shape. This introduction to morphometrics does not rely on complex mathematics and statistics. It includes application case studies in fields ranging from paleontology to evolutionary ecology, and it discusses software for analyzing and comparing shape.

This book aims to explain how to use R to perform morphometrics. Morphometric analysis is the study of shape and size variations and covariations and their covariations with other variables. Morphometrics is thus deeply rooted within statistical sciences. While most applications concern biology, morphometrics is becoming common tools used in archeological, palaeontological, geographical, or medicine disciplines. Since the recent formalizations of some of the ideas of predecessors, such as D'arcy Thompson, and thanks to the development of computer technologies and new ways for appraising shape changes and variation, morphometrics have undergone, and are still undergoing, a revolution. Most techniques dealing with statistical shape analysis have been developed in the last three decades, and the number of publications using morphometrics is increasing rapidly. However, the majority of these methods cannot be implemented in available software and therefore prospective students often need to acquire detailed knowledge in informatics and statistics before applying them to their data. With acceleration in the accumulation of methods accompanying the emerging science of statistical shape analysis, it is becoming important to use tools that allow some autonomy. R easily helps fulfill this need. R is a language and environment for statistical computing and graphics. Although there is an increasing number of computer applications that perform morphometrics, using R has several advantages that confer to users considerable power and possible new horizons in a world that requires rapid adaptability.

*Advances in Morphometrics*

A Thesis Submitted to the Faculty of the University of Louisiana at Monroe in Partial Fulfillment of the Requirements for the Degree of Master of Science in the Department of Biology

Molecular Population Genetics, Evolutionary Biology, and Biological Conservation of Neotropical Carnivores

PHYLOGENETIC ANALYSIS MORPH PB

An Analytical Approach

Evolutionary Biology

Shaping Primate Evolution is an edited collection of papers about how biological form is described in primate biology, and the consequences of form for function and behavior. The contributors are highly regarded internationally recognized scholars in the field of quantitative primate evolutionary morphology. Each chapter elaborates upon the analysis of the form-function-behavior triad in a unique and compelling way. This book is distinctive not only in the diversity of the topics discussed, but also in the range of biological organization that are addressed from cellular morphometrics to the evolution of primate ecology. The book is dedicated to Charles E. Oxnard, whose influential pioneering work on innovative metric and analytic techniques has gone hand-in-hand with meticulous comparative functional analyses of primate anatomy. Through the marriage of theory with analytical applications, this volume will be an important reference work for all those interested in primate functional morphology.

A more comprehensive version of evolutionary theory that focuses as much on the origin of biological form as on its diversification. The field of evolutionary biology arose from the desire to understand the origin and diversity of biological forms. In recent years, molecular evolutionary genetics, with its focus on the modification and inheritance of presumed genetic programs, has all but overwhelmed other aspects of evolutionary biology. This has led to the neglect of the study of the generative origins of biological form. Drawing from developmental biology, paleontology, developmental and population genetics, cancer research, physics, and theoretical biology, this book explores the multiple factors responsible for the origination of biological form. It examines the essential problems of morphological evolution—why, for example, the basic body plans of nearly all metazoans arose within a relatively short time span, why similar morphological design motifs appear in phylogenetically independent lineages, and how new structural elements are added to the body plan of a given phylogenetic lineage. It also examines discordances between genetic and phenotypic change, the physical determinants of morphogenesis, and the role of epigenetic processes in evolution. The book discusses these and other topics within the framework of evolutionary developmental biology, a new research agenda that concerns the interaction of development and evolution in the generation of biological form. By placing epigenetic processes, rather than gene sequence and gene expression changes, at the center of morphological origination, this book points the way to a more comprehensive theory of evolution.

Proceedings of a NATO ARW held in Alagna, Italy, August 26-31, 1989