



Introduction to the proceedings of the Rome 2002 Geometric Morphometrics workshop. Homage to Leslie F. Marcus

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During summer 1990, four of us, F.J.R., D.S., A.L., M.C., met at Stony Brook (NY) for the second morphometrics workshop, funded by the U.S. National Science Foundation. The objective of the workshop was to introduce new morphometric techniques, associated with the field now called "Geometric Morphometrics," to a wide range of evolutionary ecologists. F.J.R. organized this workshop, A.L. and M.C. were participants, and D.S. generously helped participants extract their data and results from a multitude of now ancient digitizing, computing and printing devices. The workshop was quite successful, and since that time geometric morphometric methods have spread throughout the scientific community and the field has now reached a mature phase based on a solid mathematical and algebraic foundation (Adams *et al.*, this volume). The success of these techniques is also due, in part, to the efforts of a strong international Geometric Morphometrics community, that has met frequently for collaborative work and has hosted numerous workshops held in many countries throughout the world (see the Morphometric web site at Stony Brook). Present at most of these workshops, including the 1990 S.U.N.Y. Stony Brook workshop, was Leslie F. Marcus, who served as both a lecturer and a participant. Les was a Research Associate in Palaeontology at the American Museum of Natural History and Professor of Biology Emeritus at Queens College and the Graduate School of the City University of New York. He was scheduled to be an instructor for the Geometric Morphometrics Workshop in Rome in January of 2002, however, his failing health prevented him from joining us and D. A. was asked to join the team to cover some of his lectures. Les died on Friday February 22, 2002.

Leslie F. Marcus was an atypical participant at the morphometrics workshops. He was an instructor, lecturing on multivariate statistical methods for morphometric analyses. However, Les was also a student, who was able to understand (more quickly than most) the importance of the new and novel Geometric Morphometric methods being presented. He was one of the first to understand the significance of the new geometric approach to morphometrics. He also understood the importance of making the new methods available to the broader scientific community, an area where he devoted much of his efforts. For instance, his 1993 paper with James Rohlf, "A revolution in morphometrics" (Rohlf & Marcus, 1993) reviewed the basics of this new approach and presented it to a wide audience. In 1991 Les also organized the international morphometrics computer bulletin board and listserv MORPHMET, an active and interesting forum dedicated to discussing the use and application of morphometrics in biology, anthropology, and other disciplines. Until his death Les was also the moderator of the listserv, which is now moderated by Dennis Slice.

Les' participation in nearly every morphometrics workshop demonstrates the importance he placed on small-group, intensive learning. It was at these work-

shops where much of the foundation of the modern geometric morphometrics was laid and where scores of new practitioners learned their trade. Equally important in the dissemination of these methods were the published volumes that resulted from the workshops. These usually included chapters on new methodological advances authored by the instructors and exemplar application papers by the students. During the 1990s Les co-organized and co-edited three workshop/symposium volumes (Marcus *et al.*, 1993, 1996; Corti *et al.*, 2000). He was also the director of the important N.A.T.O. A.S.I. workshop held in Italy in 1993, resulting in the seminal volume, "Advances in Morphometrics" (Marcus *et al.*, 1996). His energy, enthusiasm, organization, and contributions at future workshops, and their resulting publications, will be sorely missed.

Les' main interests were in quantitative biology, and the application of statistical methods in testing hypotheses of biological shape and evolution. However, we also would like to remember Leslie Marcus for his tireless efforts and zeal in helping colleagues and young students understand and apply statistical techniques. He was fascinated with problem-solving and finding ways in which he could inspire new colleagues and introduce them to multivariate statistical methods, computer-assisted data collection and Geometric Morphometrics. Many scientists from around the world came to him for aid, became scientific colleagues, and then friends. His generosity, openness and desire to improve the work of his colleagues remain legendary.

On a personal level, A.L. and M.C. benefited greatly from his enthusiasm and scientific knowledge during 15 years of frequent visits in Italy, United States, and at worldwide meetings. A solid friendship was established and, immediately, his interests in life, philosophy, art, and food exploration became as important to them as science. D.A. is grateful for Les' patience as a colleague, advice as a mentor, and encouragement as a friend. As a colleague and mentor, Les would patiently describe a complex statistical concept over and over again, until it finally made sense. Most importantly though, as a friend Les was always positive and encouraging about one's dreams, desires, and goals, both professional and personal. In addition to invaluable professional interactions, D.S. will be forever grateful to Les for his friendship and culinary adventurism. No workshop at a new place is now without the question, where would Les eat? F.J.R. is grateful for knowing Les for so long (since the early 1960s). Collaborations were productive and always a pleasure because he was a real gentle man.

For his friendship, his tireless efforts in assisting the morphometrics community, and for many other reasons, we dedicate the Proceedings of the Rome 2002 Workshop to the memory of Leslie F. Marcus.

These proceedings are part of a tradition of nearly fifteen years of morphometric workshops at which Les has participated (e.g., Rohlf & Bookstein, 1990; Marcus *et al.*, 1993, 1996; Klingenberg & Bookstein, 1998; Corti

et al., 2000). Italian scientists have been involved in Geometric Morphometrics since its inception, and the International Geometric Morphometric Workshop held in Rome at the Museo Civico di Zoologia in January of 2002 was the fourth workshop to be hosted in Italy. This volume represents the proceedings of that workshop. The 30 participants were from Italy, Argentina, Japan, Spain, Belgium, the U.K., Chile, Germany, and the U.S. Lecturers were the editors of this volume and also contributed to the proceedings.

The volume is introduced by an essay by Adams, Rohlf and Slice, which summarizes the progress of Geometric Morphometrics ten years after the similar summary by Rohlf and Marcus (1993). This essay presents a logical and coordinated introduction to geometric morphometrics, in which the recent advances in the field are discussed. Both outline and landmark methods are presented, and a set of procedures for analysing shape changes is proposed after ten years of theoretical advancement and experimental application. The article documents the growing use of Geometric Morphometrics during the 90's and explains future directions, focusing on new approaches, such as sliding semilandmarks, and the new extensions of geometric morphometric data to basic biological methods, such as studies of symmetry, motion analysis, and quantitative genetics that could soon find their way into mainstream research.

The paper by Cardini and Slice investigates the morphological relationships among the living marmots through the analysis of landmarks and outlines of the mandible. Analyses include both Elliptic Fourier Analysis and alternative landmark-based outline standardization methods, such as Generalized Procrustes Analysis and the baseline superimposition. The different approaches are then evaluated for their efficiency in reflecting phylogenetic relationships among taxa.

Loy, Spinosi and Carlini use landmark-based geometric morphometrics to investigate size and shape features involved in sexual dimorphism and interspecific differentiation in the mustelids *Martes foina* and *M. martes*, which are sexually dimorphic in size. Shape differences in the skull of males and females of the two species are interpreted in terms of specific feeding adaptation and specialization.

Beolchini and Corti use the same two-dimensional landmark-based approach to investigate the taxonomy and systematics of the African fossorial rodent *Tachyoryctes*. Skull size and shape are analysed after Procrustes analysis. They conclude that variation in size and shape does not support the actual proliferation of names, but rather reflects relationships with current ecology. This is shown using two-block partial least squares, where variation in shape was related to predominant ecological parameters, such as rainfall, temperature and elevation.

Raia investigates the morphological correlates of feeding habits in large land mammals through two-dimensional landmark-based morphometrics. Mandibles of

both extant and extinct land carnivores allow the ordination and classification of different species from the major groups, and the author finds that biomechanical requirements related to the quality of food explain much of the observed variation.

Variability in facial morphology among modern North and East African human populations is analysed by Bruner and Manzi. Despite the apparent diversity in these modern populations, highly-correlated facial variability was not observed in a three-dimensional Procrustes analysis, with differences scattered along various principal component axes.

Costa, Pasqualetto, Ribaldi and Loy characterize shape changes during growth and shape differences between the Siberian sturgeon *Acipenser baerii* and the Adriatic sturgeon *A. naccarii*. Results are discussed in terms of the diagnostic power of characters and methodology, and are suggested as important in detecting possible human intervention and manipulation.

The remaining four papers are devoted to morphometric investigations of invertebrates. Fontaneto, Melone, and Cardini examine shape and size diversity of the ultramicroscopic “trophi”, the articulated hard jaws of bdelloid Rotifers, a lineage that has evolved complete asexuality. Landmarks recorded from S.E.M. pictures are used throughout various statistical and geometrical analyses in order to define phenetic relationships among the different taxa.

Roggero uses geometric morphometrics to compare variation in the size and shape of all 37 species of the Coleoptera genus *Phalops* with a phylogeny derived independently and based on morphological characters. Both landmark methods and Elliptic Fourier analysis are used on male and female genital structures, with the assumption that variation is not related to adaptation during evolution. Patterns of morphometric variation are found to be discordant with the assumed phylogeny for the group. This finding reiterates a common question that has received considerable attention over the past decade, namely, what is the best way to use Geometric Morphometric data in phylogeny estimation?

Rufino, Abelló and Yule investigate sexual dimorphism in the brachyuran *Liocarcinus depurator*. Based

on commercial trawling catch-rates along the Spanish Mediterranean coast, this is the most abundant crab. The authors are able to show a different shape in the female abdomen, which has not been detected previously and could have an important role during reproduction. This is also one of the very few papers that uses Resistant Fit superimposition to visualize results.

Finally, Giri and Collins analyse shape variation of the cephalothorax of *Aegla uruguayana* and *A. platensis*, two sympatric crustaceans species from the La Plata basin. A two-dimensional landmark based approach was used to evaluate and compare the interspecific and intraspecific shape differences between the two species. Differences found in the male and female cephalothorax are interpreted with respect to reproductive behaviour

In their introduction to the volume “Advances in morphometrics” Marcus and Corti (1996) wrote: “*applications are just beginning to become common in the literature, and as new generations are trained and take their place, we will really see what this revolution has brought*”. Ten years later we feel confident that the aim has been reached, the new approach spread and students now apply these techniques broadly and correctly to answer a variety of biological questions. This volume is a proof of these advances.

REFERENCES

- Corti M., Hingst-Zaher E., Marcus L. F., 2000 - Geometric morphometrics in mammalogy, *Hystrix Ital. J. Mammal.*, 11: 1-154.
- Klingenberg C. P., Bookstein F. L., 1998 - Morphometrics and evolution. *Acta Zool. Hung.*, 44: 1-194.
- Marcus L. F., Bello E., Garcia-Valdecasas A., 1993 - Contributions to morphometrics. *Monografias del Museo Nacional de Ciencias Naturales*, vol. 8, Madrid.
- Marcus L. F., Corti M., Loy A., Naylor G. J. P., Slice D. E., 1996 - *Advances in morphometrics*. Plenum Press, New York.
- Marcus L. F., Corti M., 1996 - Overview of the new, or Geometric Morphometrics. *In*: L. F. Marcus, M. Corti, A. Loy, G. J. P. Naylor & D. E. Slice (eds), *Advances in morphometrics. Overview of the new, or geometric morphometrics*. Plenum Press, New York, pp. 1-13.
- Rohlf F. J., Bookstein F. L., 1990 - Proceedings of the Michigan morphometric workshop. Univ. Michigan Museum, Ann Arbor.
- Rohlf F. J., Marcus L. F., 1993 - A revolution in morphometrics. *Trends Ecol. Evol.*, 8: 129-132.