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Digital Morphology: modelling anatomy and evolution

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The morphology and anatomy of a biological structure can be seen as a structural and functional system, the final results of evolutionary pressures and stochastic processes related to the actual physical and physiological environment of its components. The current imaging techniques (digital anthropology) and the multivariate approaches to the study of geometric covariation (geometric morphometrics) provide a quantitative exploration of the extant and extinct human variability. Such tools allow the recognition of morphological relationships within anatomical systems, and their variation within phylogenetic processes. We apply these techniques and principles to the study of the cranial variability and integration, mostly within the framework of the evolution of the human genus. The craniofacial system is investigated in terms of modules and spatial relationships, along ontogenetic and phylogenetic trajectories. The reciprocal influences between the splanchnocranial, basicranial, and neurocranial components, as well as those between the hard (bones) and soft (brain, connectives, muscles) tissues are modelled using geometrical analyses and multivariate ordination methods, trying to localise adaptations and constraints. The main target is a dynamic and visualisation-based interpretation of the evolutionary changes, not grounded on the variation of single traits but on the covariation of the whole system.

For a long time paleoanthropology has been constrained by two main limitations: the physical restrictions of the fossil themselves, and the application of a linear and accepted reductionism in the interpretation of the phylogenetic process.

The first problem is maybe the major historical constraint in paleontology. This is the only scientific discipline in which every possible interest and investment (cultural or economical, personal or institutional) is centred onto a specific physical object. The importance of the object often far exceeds the importance of the scientific process, shaping the course and rate of the advances in this field.

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The physical availability of the fossil often has influenced the history of the paleontology more than the potential information associated with the fossil itself. Clearly, this can easily generate some not so wealthy results, when personal interests are too much linked with the uniqueness of the object to study. Apart from these problems of ethics and scientific politics, there are of course physical problems, related to the fragile and delicate nature of the fossil remains. The more complete the fossil, the more useful it is, thus the content of information secluded within its geological matrices. Reconstructions of fragmented fossils are invasive and based on changing perspectives (for example: Tattersall & Sawyer, 1996), handling and movements of the remains are expensive and risky, the available analyses are limited by the absolute principle of the integrity of the fossil. The digital tools, easily available since few years, supplied a complete solution to both of this kind of limitations (Zollikofer *et al.*, 1998; Weber *et al.*, 2001, Zollikofer & Ponce de León, 2005). Computed tomography allows a detailed reproduction of the anatomical elements, transformed in models which account for a couple of very relevant components: their density and their spatial organisation (Bruner, 2004). From one side, the physical presence of the fossil is no more strictly necessary to its analysis and study. This limits some bad effects of the "fossil geopolitics", which many times have affected a proper development of the discipline. On the other hand, the anatomy is completely available to morphological and densitometric surveys and transformations, its particles being transformed in pixels and bits. Of course, the same it is true for the studies involving living species (human and non-human primates), taking into account the application of biomedical imaging techniques such as magnetic resonance.

The second large innovation in the paradigms and tools of the evolutionary disciplines has been the introduction of shape analysis and multivariate approaches. For long time in anatomy and morphometrics the attention has been devoted to variation, and in particular to variation of single traits. Shape analysis shifted the attention to the spatial organisation of the whole structure, and multivariate techniques shifted the attention from variation of elements to co-variation between elements (Bookstein, 1991; Rohlf & Marcus, 1993; O'Higgins, 2000; Zelditch *et al.*, 2004). It was a methodological and conceptual change. Evolution is hence no more intended as change in the variation, but as change in the patterns of co-variation, and morphology is interpreted as the result of a dynamic process. Concepts like morphological integration and modularity have recently supported an interesting new stage of the evolutionary studies (Breuker *et al.*, 2006). Anthropology has made a step ahead along this cultural transition (Richtsmeier *et al.*, 1992; Slice, 2004). Because of its evolutionary role, morphogenetic complexity, and paleontological representation, the craniological studies have been particularly influenced by this mophometric revolution (Bastir & Rosas, 2005; Bastir *et al.*, 2006; Bruner, 2007), developing earlier pioneering promises accounting for a system-based approach to the cranial organisation (Moss & Young, 1960; Enlow, 1990).

It is also worth noting that the digital approaches offer also another interesting change: most of the tools available are freely shared on the web or definitely cheap in terms of costs, developed within worldwide communities, and based on common technologies (*www.nespos.org; http://www.virtual-anthropology.com/3d_data/3d-archive*). That is, at least within the economic levels of the industrial countries, research does not necessarily require high costs and expensive investments. A basic digital morphology laboratory can be easily arranged with a laptop and freeware resources available on the web.

This approach supported and required new and interesting expertises. Since the end of the 19th century a biologist should integrate the anatomical/physiological knowledge with proper chemical information in order to reproduce real properties within a test tube. This was the foundation of the *in vitro* experimental era. On the other hand, the *in silico* approach requires the integration of the biological competence with informatics and numerical modelling. The target is the same: the reproduction of specific relationships and processes within a simpler and controllable environment, to test hypotheses.

Bastir M. & Rosas A. 2005. Hierarchical nature of morphological integration and modularity in the human posterior face. *Am. J. Phys. Anthropol.,* 128: 26-34.

Bastir M., Rosas A. & O'Higgins P. 2006. Craniofacial levels and the morphological maturation of the human skull. *J. Anat.,* 209: 637-54.

Bookstein F.L. 1991. *Morphometric tools for landmark data.* Cambridge University Press, Cambridge.

Breuker C.J., Debat V. & Klingenberg C.P. 2006. Functional evo-devo. *Trends Ecol. Evol.,* 21: 488-92.

Bruner E. 2004. Models for Natural History. *Journal of Anthropological Sciences.* 82: 11-18.

Bruner E. 2007. Cranial shape and size variation in human evolution: structural and functional perspectives. *Child's Nerv. Sys.,* 23: 1357-1365

Enlow D.H. 1990. *Facial Growth.* WB Saunders Company, Philadelphia.

Moss M.L. & Young R.W. 1960. A functional approach to craniology. *Am. J. Phys. Anthropol.,* 18: 281-292.

O'Higgins P. 2000. The study of morphological variation in the hominid fossil record: biology, landmarks and geometry. *J. Anat.,* 197:103-120.

Richtsmeier J.T., Cheverud J.M. & Lele S. 1992. Advances in anthropological morphometrics. *Annu. Rev. Anthropol.,* 21: 283-305.

Rohlf F.J. & Marcus L.F. 1993. A revolution in morphometrics. *Trends Ecol. Evol.* 8: 129-132.

Slice D.E. 2004. *Modern morphometrics in physical anthropology.* Kluwer Academic – Plenum Publishers, New York.

Tattersall I, Sawyer GJ. 1996. The skull of "Sinanthropus" from Zhoukoudian, China: a new reconstruction. *J. Hum. Evol.,* 31:311-314.

Weber GW, Schäfer K, Prossinger H, Gunz P, Mitteröcker P, Seidler H. 2001. Virtual anthropology: The digital evolution in anthropological sciences. *J. Physiol. Anthropol. Appl. Hum. Sci.,* 20:69-80.

Zelditch M.L., Swidersky D.L., Sheets H.D. & Fink W.L. 2004. *Geometric morphometrics for biologists.* Elsevier, San Diego.

Zollikofer C.P.E. & Ponce de León M.S. 2005. *Virtual reconstruction: a primer in computer-assisted paleontology and biomedicine.* Wiley-Liss, New York.

Zollikofer C.P.E., Ponce de León M.S. & Martin R.D. 1998. Computer assisted paleoanthropology. *Evol. Anthropol.,* 6: 41-54.