Nearly 100 years ago, D’Arcy W. Thompson published one of the first studies visualizing two-dimensional evolutionary morphology, comparing (among other examples) the shapes of crania in humans and apes and graphing the “distortions” that would permit one to transform into another. In the past 20 years, collaborations among mathematical biologists, morphologists, paleontologists and computer scientists have led to the rise of geometric morphometrics, which allows the sophisticated statistical analysis of shape in the biological world and the visualization of evolutionary shape change. Anthropologists have been at the forefront of such work, studying the cranium, dentition and postcranial elements of living and fossil humans and other primates in ways that would never have been imagined even 30 years ago.

This lecture will survey the methods and techniques of 3D GM (three-dimensional geometric morphometrics) and review some of the major results of analyses conducted to date by numerous researchers, especially my colleagues in the NYCEP Morphometrics Group (http://www.nycep.org/nmg). 3D GM requires the recording of landmarks on bony surfaces and may involve semi-landmarks placed between fixed landmarks. With new technology, data collection has evolved from the use of simple devices such as 3D digitizers to high-resolution surface scanners and CT scanners. Analytical methods have also become more complex, combining multivariate statistics, least-squares superimposition of datasets, splines and advanced visualization programs.

Among the many projects undertaken by numerous colleagues, not all of which can be discussed here, a few can be noted: 1) comparison of cranial shape variation in Neanderthals vs. modern humans, revealing that Neanderthals are more different from Homo sapiens than species of chimpanzees or macaques are from each other, thus supporting Homo neanderthalensis as a distinct species of hominin (Harvati et al., 2004); 2) study of cranial shape variation in modern baboons, documenting a continuity of form with only slight “steps” at the boundaries of recognized varieties, suggesting that there is only one extant species of Papio with numerous subspecies, rather than multiple species (Frost et al., 2003); 3) analysis of growth patterns in various primate species, revealing that the patterns are relatively consistent across closely related species and most cranial shape is fixed from a quite young age, so that juvenile individuals can be “grown up” along their ontogenetic trajectories to allow comparison of their inferred adult shape—this has been accomplished for individuals of such species as the fossil human Australopithecus africanus (Fig. 1) and the rare and newly recognized African monkey Rungwecebus kipunji, which have then been compared to adults of closely related species (McNulty et al., 2006; Singleton et al., 2010); 4) reconstruction of damaged individuals of such fossil hominins as Sahelanthropus tchadensis, Homo neanderthalensis and others using a “puzzle-piece” approach with CT scans and a computer visualization approach for other fossil species (Ponce de Leon and Zollikofer, 2001; Zollikofer and Ponce de Leon, 2005; Zollikofer et al., 2005; Fig. 2, Delson et al., in prep.); 5) analysis of shape variation in crania of Homo erectus and related fossil humans leading to the recognition that such variation is within the expected range for a single species and that additional species such as H. ergaster, H. georgicus and H. soloensis can be accommodated within H. erectus (Baab, 2008); 6) a comparison of

Figure 1. Wireframe views of a) Sts 5, b) Taung simulated as an adult, c) SK 48 (from McNulty et al., 2006).
scanned articulating tibial and talar surfaces using semi-landmark grids with the aim of distinguishing species and individuals (Harcourt-Smith et al., 2008); and 7) an ongoing study of Old World monkey cranial shape change through time, combining a baseline molecular phylogeny with laser scans of extant and fossil species’ crania, reconstruction of damaged fossils, inference of cranial shape at any point on the tree, and placement of fossils close to the most similar inferred shape (Delson et al., in prep.).

Research underway by members of the NYCEP Morphometrics Group is aimed at reconstructing and visualizing the pattern and history of cranial shape variation in Old World monkeys and hominins, combining the above approaches with new ones to be discussed in this talk.


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