ISSN 0376-5156
Geophytology 48(2): 157-160
November 2018

# The changing scenario of morpho-taxonomic research and an accelerated demand of morphotaxonomists in bio-systematics

**Arindam Chakraborty* and Subhankar Pramanik**

Birbal Sahni Institute of Palaeosciences,
53 University Road, Lucknow-226007, India
*Corresponding author's e-mail: arindam@bsip.res.in

*Manuscript received:* 3 October 2018
*Accepted for publication:* 8 November 2018

## ABSTRACT

Comparative morphology and systematics has been an essential tool for research in biological science and evolutionary biology, but with rapid integration of molecular techniques into systematics and phylogenetics, the role of morphological attributes in evolutionary biology and taxonomy has become debatable. Scientists have gradually become more inclined towards molecular driven techniques rather than morphological features for taxonomical analysis. But it is also true that molecular data alone cannot determine accurate phylogenetic relationships of organisms. In palaeontology, morphological data provide the only means to understand an extinct taxon's evolutionary history. Phylogenetic accuracy in phylogenetics requires data generated from both morphological analysis and molecular driven techniques. Morphological data is comparatively easier to obtain and morphological characters have innumerable variants that help in delimitation and identification. The evolution of modern techniques of microscopy, morphometrics and MorphoEvoDevo has revived the essence of morphological taxonomy and thus accelerated the demand of morphotaxonomists.

**Key words:** Morpho-taxonomy, Bio-systematics, Evolution.

## INTRODUCTION

The world of living organisms exhibits an immense variation and the variation can be a result of ontogenic differences, genetic differences or differences induced by the environment. These living organisms are classified on the basis of 'characters'. Character is a combination of features of a 'biological taxon' that differentiates it from other taxa and is not absolute. Traditionally, taxonomy has been mainly dependent upon comparative external morphological (shape, size, structure) and anatomical characters. The time and effort needed to generate data from other sources such as biochemistry and molecular biology ensure that morphology in general will continue to reign the taxonomic study for years to come (Ogura 1964, Cronquist 1981). Morphological characters have several advantages owing to the fact that they are easily observed and need not require elaborate laboratory facilities. A hand lens or dissecting microscope or possibly a light microscope are often enough to meet the necessities. Morphological attributes have been in use for several centuries which has led to the development of a well knit elaborate terminology to describe these variations and serves equivalent to any large information database. The current trend in morpho-taxonomic research is to exploit characters that have been neglected in past, most of which are environment induced characters or ecological characters discussed later in this article. There are several secrets of evolution unraveled and when we talk about evolution, we try to establish relationship between the past and the present which includes all aspects from variation to speciation. Fossils even exhibit a high degree of morphologic variations due to the dimension of time through which life has evolved. The preservation potential of the organism, susceptibility to adverse environmental conditions, post-mortem transport, time averaging of assemblages and compaction of sediments are additional factors that introduces morphologic diversity into fossil populations. It is not easy to predict the amount of variation in a population, but a biologist or a palaeontologist specializing in a group of individuals gets acquainted with variations typical to that population and hence can isolate the unusual variations. Hence, the biologist or the palaeontologist has to be an expert in morphological taxonomy too. Moreover, phylogenic accuracy is directly proportional to the number of characters in an analysis (Hillis 1996). It implies that incorporation of data generated through molecular and biochemical analysis doesn't reduce the importance of data generated from morphological study. The morpho-taxonomic research at present is just not restricted to delimitation of taxonomic units through visible morphological attributes, but also includes a deeper aspect of comparative morphogenesis. The comparative studies of morphogenesis have resulted in an unexpected renaissance of evolutionary developmental morphology termed as 'MorphoEvoDevo' (Wanninger 2015), which has increased scope for morphotaxonomists. There are several reasons why this field of morpho-taxonomy requires more scientists.

## INCREASING REQUIREMENT FOR MORPHOLOGICAL DATA: PAVING PATHWAY FOR MORPHOTAXONOMISTS

Homoplasy and genetic saturation are major drawbacks of molecular analyses based phylogenetics. Rokas et al. (2003) illustrated the same and emphasized that molecular analyses is problematic for taxa characterized by deep divergences and rapid radiations. The most compelling logic behind collections of more and more morphological data long into the future is to resolve the phylogenetic relationships of fossil taxa and their relationships to the living taxa (Maddison 1996, Jenner 2004). The reconstructed Tree of Life must include fossil taxa. Considering all the species that have ever evolved, most are now extinct and many of the extinct groups were diverse, ecologically important and very distinct from their nearest living relatives. Fossil taxa can preserve critical combinations of synapomorphy and plesiomorphy and most of these combinations are in the form of morphological attributes. Moreover, the understanding of the rate and timing of macroevolutionary processes in both living and fossil taxa also requires phylogenetic information from fossils. Besides molecular driven techniques that help in determination of divergence dates for living taxa, external calibration is also essential. This calibration usually comes from fossil evidence, which requires correct assignment of fossils to groups of living taxa. Since, older fossils are rarely identical with living species, we cannot simply assign fossils to living groups based on overall similarity. An estimation of phylogeny for the fossil and living taxa is needed. Therefore, this can only be done using the morphological data.

When it comes to extant species, there are several superficial attributes that are induced ecologically and are found to be taxonomically significant. Pubescence is one such morphological attribute in plants that is often environmentally controlled. It is characterized by for example, development of hairs on the surface of plant body in response to the environment with a motive of self protection. Variation in the hairs on the twigs of *Picea* (one of the conifers belonging to Pinopsida) is used in the identification of different *Picea* species (Fernald 1950). Similarly, the trichomes in the Family Cucurbitaceae vary from unicellular to multicellular, conical to elongated, smooth to ridges, with or without flattened disk at base and cyctolithic appendages, thin to thick walled, curved at apices to blunt. Trichome micromorphology in the Family Cucurbitaceae was found taxonomically significant (Ali 2011). In taxonomy of flowering plants, reproductive characters are often given priority than vegetative attributes. As the sexual reproductive characters are only produced for a brief period, they are of less evolutionary significance. The reproductive characters on the other hand are liable to strong selection pressures originating from various aspects of reproductive biology, e.g., the pollinator relationship (Clifford & Lavarack 1974). Therefore, the current trend is to treat both the attributes equally (Tomlinson 1984). Around 86% of the species on earth is yet to discovered, described, identified and catalogued (Mora et al. 2011) and as a matter of fact morpho-taxonomic research is never-ending and the same applies to the role of morphotaxonomists in bio-systematic studies.

## INTEGRATING MODERN TECHNIQUES TO ENHANCE MORPHO-TAXONOMIC RESEARCH: DIVERSIFYING THE ROLE OF MORPHOTAXONOMISTS

Morpho-taxonomy has evolved over years and is not just restricted to qualitative techniques. Integration of quantitative methods has diversified this field of research. Morphometrics or morphometry has given a new dimension to morphological analysis with an additional objective of studying the factors that affect the shape and size. In broad sense morphometrics is a field of multivariate statistical analysis concerned with the quantification of shape, the description of shape variability, the assessment of group differences in shape and the covariation of shape with other variables. The two major types of morphometrics that are currently employed are geometric morphometrics and outline analysis. Geometric morphometrics (Slice 1996) deals with specific points on a biological specimen or its image or outline that can be located according to a rule and hence can be homologous across a sample of the same kind of structure. On the other hand, outline analysis uses mathematical coefficients fitted to points sampled along the outline of the specimen which is an interesting technique to quantify the shape of a group of individuals with similar structure, but not exactly identical structure. This in turn helps morpho-taxonomists in their higher level of research in establishing inter-relationships between organisms. The quantitative analysis of morphological attributes has been superseded by two main modern approaches viz., Eigen shape analysis and Elliptical Fourier analysis. Generation of morphological data has become easier with the development of computer programs like MorphoSys. MorphSys is a morphometry specialized computer program that works with the help of a video system comprising camera, frame grabber, a video monitor and a personal computer. In addition to capturing morphometric data from plant specimens such as leaves, this system has also been used in the studies of variation in xylem element diameter, floral apex shape (Evans & Dickinson 1996) and gastropod shell morphology (Stone 1998).

Another modern technique that has opened up new vistas for morphotaxonomists is the use of Scanning Electron microscope (SEM) owing to its capacity of revealing new surface details of biological specimens (Heywood & Dakshini 1971). With the use of SEM, a new field of research in bio-systematics known as 'Ultrastructural Systematics' emerged. The seed surface patterns and ornamentations on the wall of spores and pollen grains are of useful attributes of palynology. The exine ornamentation patterns have been a great help for identification and delimitation of taxa at lower levels. Very little is known about the genetic control of exine patterns, but certain microscopic bodies associated with tapetum known as Ubisch bodies have gained attention of the scientists because their ornamentation and composition is identical to that of the exine. This suggests close relationship between the mechanisms that led to the formation of Ubisch bodies and the exine surface. SEM has also enhanced taxonomic research in the field of micropalaeontology. The morpho-taxonomic research on fossils is a vast field, since organisms which got fossilized mostly did not get cemented with their entire body at one place. So, unless and until an organic connection is established between the parts of the fossilized organism deposited in parts at different locations, they cannot be assigned a single name. Hence, the parts are named differently, just like a fossil leaf, a fossil stem and fossil spore might belong to a same genus, but they are assigned different scientific names in palaeontology due to the lack of evidences establishing the organic connection between them.

Descriptive and experimental functional morphology has found its way into applied sciences such as biomaterial engineering, bionics and nanosciences. The documentation of embryonic and larval development with the advancement of microscopy has paved the path for the golden age of Evolutionary Developmental Morphology (MorphoEvoDevo). Haeckel's biogenetic law or theory of recapitulation proposes that at least parts of the evolutionary history of a species are conserved in its ontogeny (Haeckel 1866). So, it is better to have an integrated approach rather than a conservative approach when we look forward for phylogenetic accuracy of organisms under study. The idea of appearance, transfer, transformation, loss or gain of a character or a set of characters in the evolutionary history of an organism can never be clear if the approach is conservative.

## CONCLUSIONS

Morphological data has its own importance in the science of classification and the role of morphotaxonomists in bio-systematics can never shrink because solving puzzles in evolutionary history of the organisms be it extinct or extant requires synergistic efforts. Morpho-taxonomic research also needs evolution; evolution here in the sense developing techniques to reach to a wider audience and to drive the younger generation to take interest in this field. This field needs to be more attractive and technology friendly. Recent initiatives have been taken to make morphological data accessible to a wider audience by online databases like MorphDBase (www.morphd base.de) or MorphoBank (www.morphobank.org). The continued generation of molecular data across the plant and animal kingdom also calls for morphological expertise for interpretation of the gene functions. High resolution micro-morphological research tools such as Stimulated Emission Depletion Microscopy (STED), Serial Transmission Electron Microscopy (STEM), Micro-Computed Tomography (Micro-CT), Synchotron X-Ray Tomography, Magnetic Resonance Tomography (MRT) and Light Sheet Microscopy will develop new vistas for morphotaxonomists and will shine further if combined with a powerful 3D software. In a developing country like India, many potential morpho-taxonomic experts can contribute to biosystematics if laboratory facilities improve and supply of modern equipments increase. Hence, steps should be taken that scientists throughout the country working in this field should have an enhanced access to SEM. This also calls for a revolution in the funding policies on scientific research by the central government.

## ACKNOWLEDGMENTS

We express our sincere gratitude to the Director, BSIP, Lucknow for providing necessary facilities to carry out this work. A.C is thankful to National Post Doctoral Fellowship (NPDF) of SERB, DST and S.P is thankful to the authorities of BSIP for Birbal Sahni Research Scholarship.

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