Taxonomy must engage with new technologies and evolve to face future challenges

To the Editor — Despite taxonomy being fundamental to biology for discovering, describing and identifying the units of analysis across disciplines[1], it is generally agreed that the perceived importance of taxonomy is diminishing[2]. In the face of this paradoxical decline, we argue that fulfilment of a long-promised 'taxonomic renaissance'[3] must be strategic because few permanent taxonomic positions exist, little funding is available, and challenges are manifold.

We need to start with digitization and online accessioning of type specimens, prioritizing those taken from their countries of origin[4], as well as capacity building to enable taxonomists in developing countries to perform the best work possible and to collaborate globally[5]. Via high-resolution imaging technology, virtual taxonomy laboratory (VTL) approaches can accelerate taxonomic collaboration and productivity online. As these setups may be expensive, federal governments should prioritize establishing at least one such centre nationally to collaboratively write diagnoses, descriptions and manuscripts. Through mutually beneficial partnerships involving training and specimen exchanges, integrative approaches that incorporate many lines of evidence could become feasible worldwide.

Integrating this evidence efficiently will require a singular, centralized data storage system (rather than separately in GenBank, Barcode of Life Data (BOLD) System, Global Biodiversity Information Facility (GBIF) and so on), including a unified species list[6] as well as taxonomic history, relevant literature, original and updated morphological descriptions, high-quality images, life history data, molecular and morphometric resources for coalescent or other analyses (for example, barcodes[7]), and even ecological linkages and economic valuations. Ideally, this will be accomplished through an internationally funded institute or alliance for biodiversity and integrative taxonomy, but this will necessitate policy support. Such an institute would encourage increased hiring and advocate better recognition for primary data generation and their use, as well as encouraging metrics that value magnitude of contribution to papers rather than authorship order.

Once species data become accessible worldwide, the potential for collaboration between data providers and other researchers will be boundless. Unlimited multi-faceted data could be assembled and assessed in a truly integrative taxonomic framework. This will support incorporation of artificial intelligence methods to guide species delimitation analyses, as people are actively attempting for identification[8,9]. These algorithms could be trained with examples of well-resolved groups and then optimized weighting schemes could be used for other groups.

Deep-learning can also identify both new instances of the same species and new species via comparison with known species[9,10]. For each known species, a morphological, ecological, distributional and genomic variation 'space' would be defined, and specimens exceeding the limits of these spaces would be flagged for examination by experts, expediting sorting immensely while also preventing erroneous records. These integrative species definitions could be continuously updated and improved by experts, and once suitable they could even be applied to citizen-science data to gather an immense number of new records while also encouraging public participation in and appreciation of science. Conservation will also benefit, as accumulated distributional information, once verified, will enable the development of continually updated, accurate biodiversity hotspot maps, with approaches helping to compensate for under-sampling and under-description in species-rich areas such as the tropics, where taxonomic work is most needed.

These suggestions may seem a dramatic departure from current approaches, dismissing the human element of taxonomy, but this could not be more false. Taxonomists must modernize along with the field, while maintaining traditional practices and the invaluable knowledge they provide, which means embracing new technologies for species discovery, delimitation and identification, just as we have with molecular methods and new imaging technologies. Technological advances allow for unprecedented taxonomic approaches, but existing methods must be better integrated into a broader vision encompassing species discovery, rendering accessible rich data about known species, and scaling up analytical pipelines to meet urgent societal needs pertaining to biodiversity conservation and ecosystem conservation and management. ❐

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Published online: 10 November 2020
https://doi.org/10.1038/s41559-020-01360-5

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Acknowledgements

M.C.O., R.R.F. and C.-D.Z. were mainly supported by grants from the National Science Foundation,

China (31625024, 41761144068 and 31772495), and the Key Laboratory of Zoological Systematics and Evolution, Chinese Academy of Sciences (Y229YX5105). Other supports include the Research Fund for International Young Scientists NSFC 31850410464 and the CAS PIFI (2018PB0003 and 2020PB0142 to M.C.O.; 2020PB0130 to R.R.F.; and 2018PB0007 to A.R.); NSFC 31961143002 (to M.B.); and NRF2017NRF-NSFC001-015 (to J.S.A.).

Author contributions

C.-D.Z. and M.C.O. conceived the paper. M.C.O. led the writing with primary inputs from R.R.F., A.C.H. and C.-D.Z. M.C.O., R.R.F., A.C.H., J.C., J.S.A., Y.-H.Y., P.H.W., X.Z., M.B., A.R., F.Z., K.-P.M. and C.-D.Z. contributed to multiple drafts and provided substantial inputs overall.

Competing interests

The authors declare no competing interests.