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## The deciduous confusion: it is time to get the contrast right

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A survey of published literature reveals a common yet inaccurate distinction between two broad terminologies used to describe forest trees and shrubs and their attributes: “*deciduous*” versus “*conifer(ous)*”, according to their leaves (broad-leaved vs. needle-like or scale-like leaves) or leaf retention (deciduous vs. evergreen). In a broad sense, a deciduous tree (or stand) refers to any tree species (or group of trees in the context of a deciduous stand) that sheds its foliage at the end of the growing season. A conifer(ous) tree refers to any of the members of the cone-bearing seed plants of the division Pinophyta (subset of gymnosperms) that keep their foliage throughout the year (i.e., evergreen – their foliage persists and remain green through the growing year). But there is a fundamental confusion in the way and manner that deciduousness (i.e., the ability of a tree to shed its foliage at the end of the growing season) has been inferred as the main distinguishing characteristic for these categories. The opposite of a deciduous tree is not coniferous but rather an evergreen tree, but because nearly all coniferous tree species keep their foliage throughout the year (i.e., evergreen), the term *conifer(ous)* has almost exclusively become synonymous with evergreen and very commonly used to contrast between deciduous trees. This notion, however, is inaccurate given the fact that some prominent species or genera of conifers (including *Larix* spp., *Metasequoia glyptostroboides* H.H. Hu & W.C. Cheng, some species of *Taxodium* [e.g., *Taxodium distichum* (L.) Rich.], and *Pinus* [e.g., *Pinus roxburghii* Sarg.], among others) are well and truly deciduous by nature and exhibit same characteristics (shedding their foliage at the end of the growing season) as non-conifers. Hence, the term *deciduous* is expansive and applicable to both deciduous and coniferous tree categories.

By similar argument, casual reference to those trees or shrubs with wide leaves (broad-leaved, as opposed to the needle-like leaves of *conifers*) as *deciduous* is inadequate, given the fact that many broad-leaved tree species (especially in temperate and tropical climates) are truly evergreen or can retain their foliage when conditions are favourable (examples include some species of *Magnolia* [e.g., *Magnolia grandiflora* L.], *Ilex* [e.g., *Ilex aquifolium* L.], *Eucalyptus* spp., *Arbutus* [e.g., *Arbutus menziesii* Pursh], among others). Therefore, the *deciduous* versus *conifers* terminology, in comparative terms, is a mismatch and not mutually exclusive. Their generalization and continued use in the scientific literature present a challenge to both experienced and beginning researchers, in what I refer to as the ‘deciduous confusion’.

To demonstrate the pervasive nature of this problem, I conducted a limited search in Web of Science (on June 29, 2021) for published articles (restricted to journal articles only) from 1980 to 2020 that have both terms “deciduous” and “conifer(ous)” mentioned in the title (abstracts, keywords, and full text were not considered). The search yielded some 202 eligible articles from 80 journals, out of which 166, representing 80.6 percent frequency or every 4 out of 5 retrieved articles, had instances of this misuse. The breakdown indicated an 80.9 and 79.2 percent frequency of misuse between 1980–1990 ( $n = 21$ ) and 2010–2020 ( $n = 96$ ), respectively, suggesting an unabating trend. Although this exercise was limited to only the titles and therefore not intended to yield an exhaustive list, these numbers provide an indication of the frequency with which one might expect to encounter the terms used, perhaps incorrectly, in published literature. To a limited extent, these terms occurred more frequently in studies from Europe and North American as compared to those from East Asia that used other synonyms or modifiers (such as broadleaf or deciduous broadleaf/conifers) which provide more clarity.

The main point from this search summary, particularly for beginner researchers, is that one should be aware of the ambiguity surrounding the use of deciduous and coniferous (as commonly used for forests, stands, trees, shrubs, foliage, etc.) when probing the literature. While there is no need to restrict the use of these terms, it is imperative that the disparity between them is brought to bear for authors to come to a consensus on a universally acceptable terminology. From a botanical standpoint, a more accurate contrast for a coniferous tree (or stand) is a broadleaf tree, where the distinction is established according to leaf type (broad-leafed vs. needle-like or scale leaves). Given that both broadleaf and coniferous trees and shrubs can exhibit deciduousness, authors should consider using “evergreen” and “deciduous” as qualifiers – e.g., “deciduous broadleaf”, “evergreen conifer”, and “deciduous conifer” – especially when comparing between broadleaf and conifer trees (forests or stands) to avoid ambiguity. In this modern era of scientific publishing, it is imperative for us to strive to improve clarity in our communication. To this end I recommend that the deciduous versus conifer mismatch should at best be avoided and that authors fashion their working definitions to include the appropriate qualifiers, especially when the implications of their studies transcend the geographic area of interest.

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