New mathematical model reveals how major groups arise in evolution

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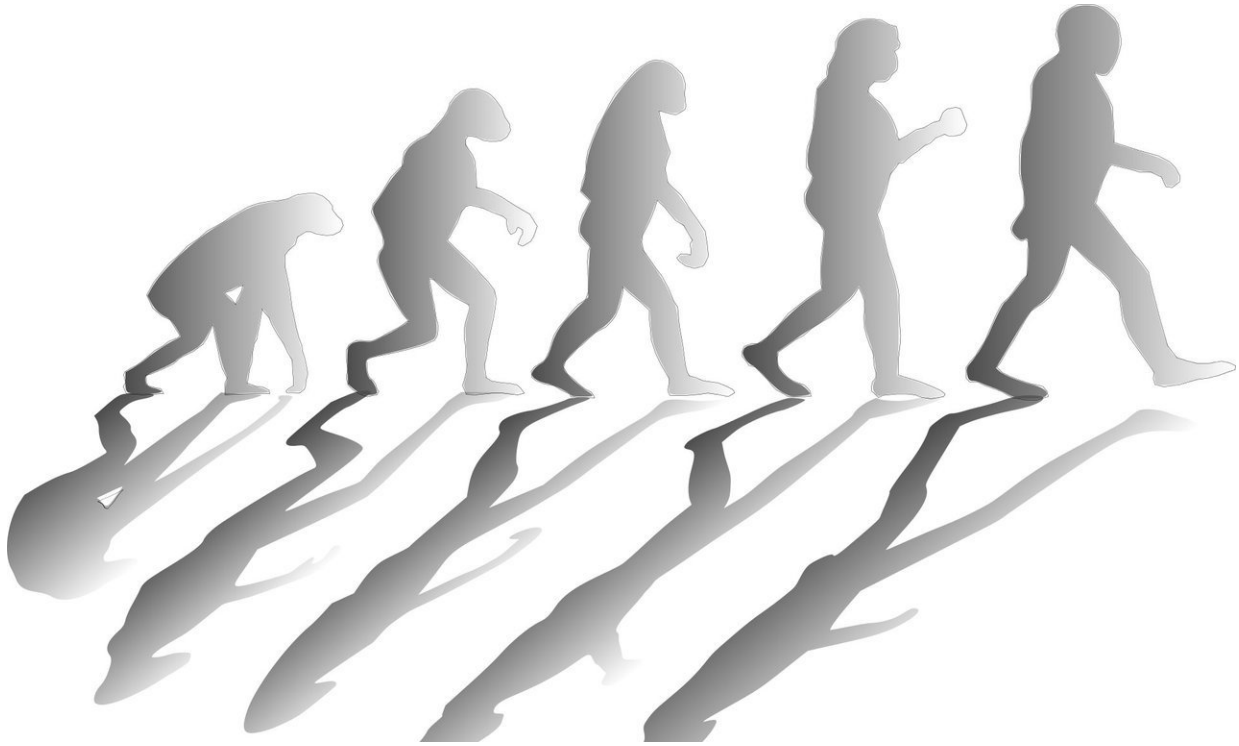

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Researchers at Uppsala University and the University of Leeds presents a new mathematical model of patterns of diversity in the fossil record, which offers a solution to Darwin's "abominable mystery" and strengthens our understanding of how modern groups originate. The research is published in the journal *Science Advances*.

The origins of many major groups of organisms in the fossil record seem to lie shrouded in obscurity. Indeed, one of the most famous examples, the flowering plants, was called "an abominable mystery" by Darwin. Many modern groups appear abruptly, and their predecessors—if there are any—tend to be few in number and vanish quickly from the fossil record shortly afterwards. Conversely, once groups are established, they tend to be dominant for long periods of time until interrupted by the so-called "mass extinctions" such as the one at the end of the Cretaceous period some 66 million years ago.

Such patterns appear surprising, and often seem to be contradicted by the results from "molecular clocks"—using calibrated rates of change of molecules found in living organisms to estimate when they started to diverge from each other. How can this conflict be resolved, and what can we learn from it?

In a paper, Graham Budd, Uppsala University, and Richard Mann, University of Leeds, present a novel mathematical model for how the origin of modern groups based on a so-called "birth-death" process of speciation and extinction. Birth-death models show how random extinction and speciation events give rise to large-scale patterns of diversity through time. Budd and Mann show that the ancestral forms of modern groups are typically rather few in number, and once they give rise to the modern group, they can be expected to quickly go extinct. The modern group, conversely, tends to diversify very quickly and thus swamp out the ancestral forms. Thus, rather surprisingly, living organisms capture a great percentage of all the diversity there has ever been.

The only exceptions to these patterns are caused by the "mass extinctions," of which there have been at least five throughout history, which can massively delay the origin of the modern group, and thus extend the longevity and the diversity of the ancestral forms, called

"stem groups." A good example of this is the enormous diversity of the dinosaurs, which properly considered are stem-group birds. The meteorite impact at the end of the Cretaceous some 66 million years ago killed off nearly all of them, apart from a tiny group that survived and flourished to give rise to the more than 10,000 species of living birds.

The new model explains many puzzling features about the fossil record and suggests that it often records a relatively accurate picture of the origin of major groups. This in turn suggests that increased scrutiny should be paid to molecular clock models when they significantly disagree with what the fossil record might be telling us.

More information: Graham Budd and Richard Mann. The dynamics of stem and crown groups. *Science Advances* (2020). DOI: 10.1126/sciadv.aaz1626 , advances.sciencemag.org/content/6/8/eaaz1626

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