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Comment on “Gene Regulatory Networks and the Evolution of Animal Body Plans”

Jerry A. Coyne

Davidson and Erwin (Reviews, 10 February 2006, p. 796) argued that known microevolutionary processes cannot explain the evolution of large differences in development that characterize phyla. Instead, they proposed that phyla arise from novel evolutionary processes involving large mutations acting on conserved core pathways of development. I question some of their assumptions and show that natural selection adequately explains the origin of new phyla.

In their review of the evolution of animal body plans, Davidson and Erwin (*J*) proposed that the origin of higher level clades, such as phyla, involves mechanisms other than the normal microevolutionary processes thought to cause speciation. They claim that “classic evolutionary theory, based on selection of small incremental changes” cannot provide “an explanation of evolution in terms of mechanistic changes in the genetic regulatory program for development of the body plan.” However, in proposing this genetic and mechanistic disconnect between micro- and macroevolution, Davidson and Erwin make four assumptions that seem dubious.

First, Davidson and Erwin note that there has been little change in phylum- and superphylum-level body plans since the early Cambrian, but that great changes have occurred within phyla and classes—a pattern they contend demands new evolutionary processes (*J*). Their underlying assumption is that evolution during the Cambrian involved phylum-level changes in body plans, with all phyla emerging suddenly and no new phyla or body plans arising since then. This “top-down” view of evolution was discussed and critiqued by Dawkins (2). It seems more reasonable to assume that the speciation events that occurred during the Cambrian and thereafter did not produce new phyla but merely new species differing from each other and their ancestor in minor ways. Only over long periods of time, during which many species became extinct, did the ancestor of the distinct groups we call “phyla” acquire the traits that made them so distinct. It is hard to believe that a given speciation event could produce a taxon having a radically different group of traits—i.e., a new phylum arising in one step.

Department of Ecology and Evolution, University of Chicago, 1101 East 57th Street, Chicago, IL 60637, USA.
E-mail: j-coyne@uchicago.edu

Morphological evolution may indeed have been rapid during the early Cambrian, accounting for the rapid origin of many ancestral groups and morphological novelties. It is certain, however, that speciation, morphological diversification, and extinction have continued throughout evolutionary time, so that groups destined to be called “phyla” have probably arisen frequently and are still arising today, but simply haven’t yet diverged enough to merit this rank.

Second, Davidson and Erwin assume that the lack of new phyla reflects something fundamentally distinct about this taxonomic rank, signified by their use of the word “body plan.” They propose that this distinctness reflects the refractory nature of the genes underlying phyletic differences (*J*): “Conservation of phyletic body plans may have been due to the retention since pre-Cambrian time of GRN [genetic regulatory network] kernels, which underlie development of major body parts.” However, phyla are arbitrary divisions in the tree of life. They are simply reifications—the names we give to the descendants of very old lineages. The traits used to distinguish phyla differ only in degree and not in kind from those used to separate groups below the phylum level (e.g., subphyla and classes). Nor do phylum-level differences involve different “body plans” (drastically different types of bodily organization into which we can neatly fit each species). All one can say from observing modern phyla (3) is that they are diagnosable by different complexes of characters involving diverse traits. Phyletic differences involve body plans only because any difference in morphology involves the body plan. Phyla are not so distinct from one another that the higher classification system has remained constant. Tardigrades, for example, could be treated as their own phylum or lumped in with arthropods. Tongue worms (pentastomids) were designated as their own phylum, but are now known to be

phylogenetically nested within the Arthropoda. Indeed, because of the arbitrary nature of all categories above the species level, some systematists now prefer “rank free” classifications.

Third, Davidson and Erwin note that “different levels of change that have occurred in evolution are imperfectly reflected at different levels of Linnean classification,” and that “these inhomogeneous events have been caused by architectural alterations in different locations in the underlying GRNs” (*J*). The view that the Linnean hierarchy somehow reflects hierarchical types of genetic change is almost certainly wrong. It is extremely unlikely, for example, that differences between orders in all groups of organisms correspond to “alterations in deployment of plug-ins [flexible subcircuits of GRNs] and I/O [input/output] switches.” Systematists have treated different groups differently, and no one has seriously proposed that the orders of mammals, for example, reflect the same kind and degree of genetic distinctness as the orders of insects.

Finally, Davidson and Erwin claim that neither micro- nor macroevolutionary theory explains the evolution of “the genetic regulatory program for development of the body plan” (*J*). If one accepts the view that differences between phyla or between other higher level clades involve the accumulation of lesser differences between lower level clades over long periods, then microevolutionary theory (i.e., adaptive accumulation of micro-mutations through natural selection) does explain the evolution of different body plans. Indeed, there can hardly be another explanation. Although Erwin and Davidson imply that major changes in the conserved “kernels” of the genetic network are responsible for “critical morphological innovations,” it is unlikely that macromutations played an important role in major evolutionary change. This view, once an important part of the theory of punctuated equilibrium, was abandoned even by Gould and Eldredge, the architects of that theory (4). Thus, there appears to be no basis for Davidson and Erwin’s claim that the processes producing higher level clades differ from those creating lower level clades, or that different types of genetic change apply to different taxonomic levels.

References

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