The telltale heart of chordate evolution: Study shows model organism making do with less

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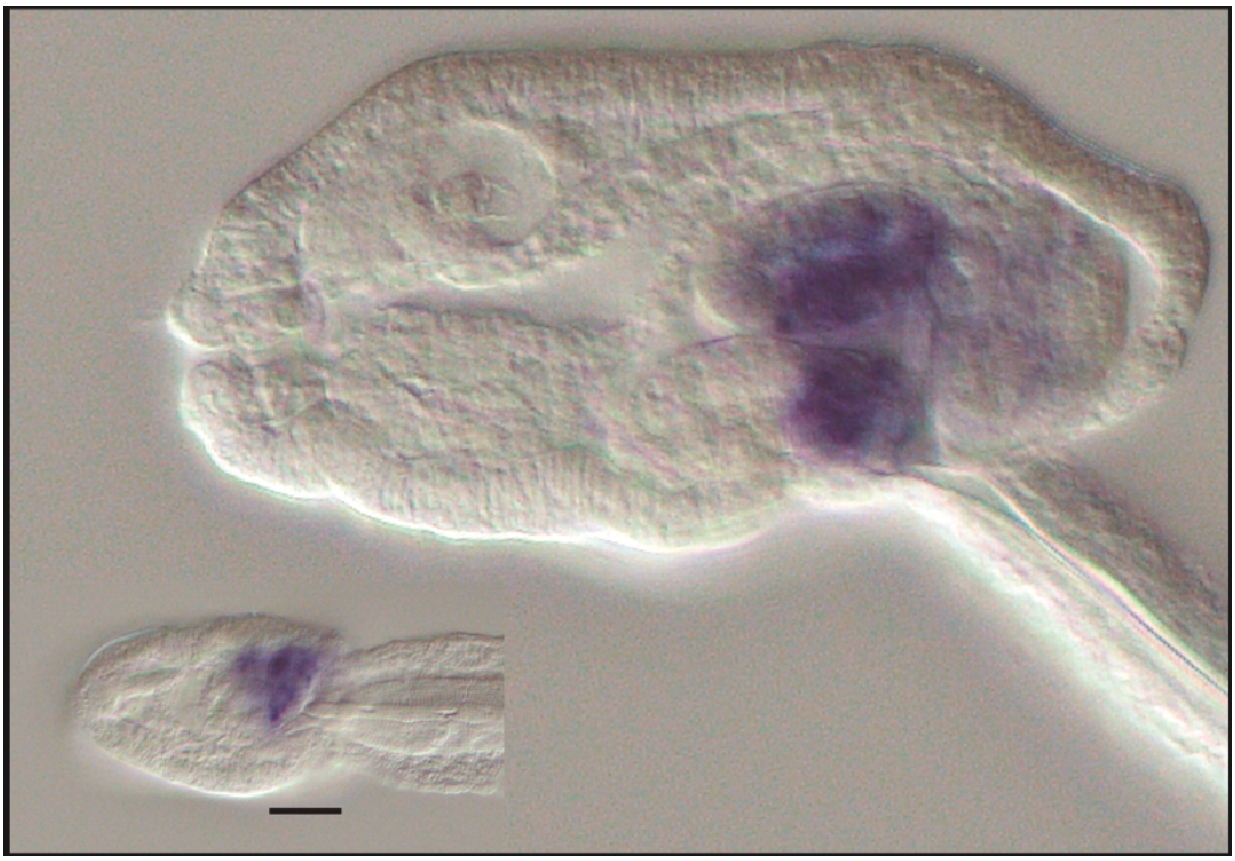


The chordate *Oikopleura dioica*, despite losing lots of genes, maintains a typical body plan with organs and structures (heart, brain, thyroids, etc.) which can be considered to be homologues to the vertebrates. Credit: Universitat de Barcelona

A new study led by researchers of the University of Barcelona and the Biodiversity Research Institute (IRBio), published in the journal *Molecular Biology and Evolution*, proves once more that evolution does not always imply more complexity or more genes in living beings.

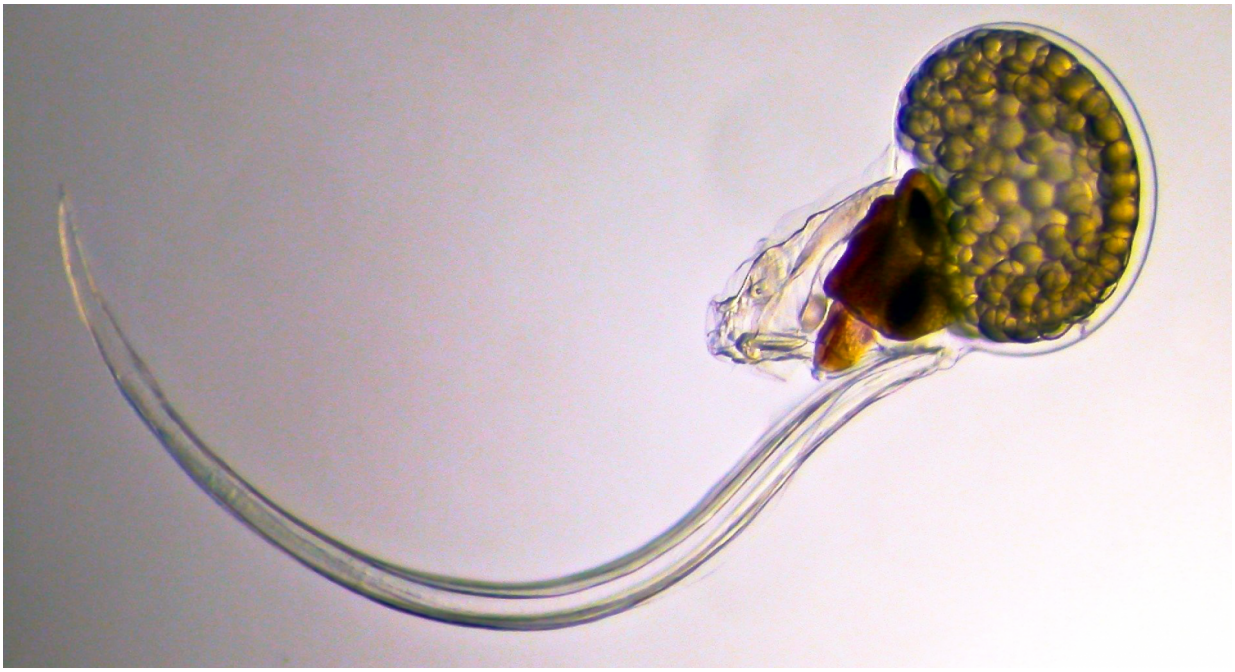
The planktonic organism *Oikopleura dioica*, an animal model in the study of evolution and embryonic development in vertebrates (the taxonomic phylum known as chordates), has lost most of the genes related to retinoic acid metabolism—-a molecule thought to be vital to vertebrate physiology and embryonic development.

According to authors Ricard Albalat and Cristian Cañestro, the "results show that gene loss can follow non-random patterns, like the co-elimination of all genes related to a function no longer useful during the evolution of a certain species, such as the case of retinoic acid in *O. dioica*"

Retinoic acid (RA) is a molecule derived from vitamin A (retinol), which is fundamental in the physiology and embryonic development of chordates, including humans. Retinoic acid (RA) is an essential factor in chordates to regulate the expression of genes involved in processes of cell proliferation and differentiation, like those occurring during the embryonic development of organs and systems, or during body patterning. Moreover, some genetic diseases that cause alterations in RA action can alter cell proliferation and lead to cancer development such as acute promyelocytic leukaemia.

The chordate *O. dioica* is an organism evolutionary close to vertebrates. They both share a similar body plan and some organs or homologue structures like heart, brain or skeleton musculature, which have a RA-dependent development. A big challenge of this study has been to prove that these organs develop in *O. dioica* without RA due to the massive loss of genes involved in its synthesis and to demonstrate the absence of

alternative pathways.



Oikopleura dioica mature female with eggs. Credit: Universitat de Barcelona

Gene loss would have enabled *O. dioica* to develop without vitamin A, which would be a new example of how gene loss can be an evolutionary strategy that allows the adaption of species to biological situations in a beneficial way.

"Our results are compatible with the loss of genes related to RA in *Oikopleura dioica* happened in an scenario of regressive evolution, in which the lost functions were not essential for the organism," said professor Ricard Albalat.

"In humans, as in the rest of the chordate species, there are multiple

enzymes that regulate the synthesis and degradation of RA. Understanding how these enzymes are regulated is important for our health. Everything points to the RA metabolic machinery as a genetically robust system, forming a pathway which is hard to modify in which several enzymes encoded by multiple genes can do the same function in a redundant way. Moreover, to discover that RA was also important for non-vertebrate animals means that RA metabolic machinery could be ancient, early originated during animal evolution."

Biological innovation is not necessarily linked to an increase of functional complexity or number of genes, according to the authors. Genomic rearrangements, changes in epigenetics mechanisms, loss of light-receptor organs, decrease of body complexity and size, or increase of the speed of embryonic development and life cycle of *O. dioica* are some situations that might have allowed the evolution of new ways to create a heart without the requirement of RA.

According to co-author Cristian Cañestro, "these results show an example of what has been called the 'reverse paradox' of evolutionary and developmental biology (evo-devo), in which morphologically similar structures differ in the genes responsible for their development."

"The heart is another paradigmatic example we try to understand: how is it possible that *O. dioica* generates a heart without RA, whereas RA is essential to create this organ in all other chordates? We soon hope to find some answers and assess the impact that RA loss caused in the cardiogenic gene function," said Cañestro.

Provided by Oxford University Press

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