3D simulation shows how form of complex organs evolves by natural selection

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Researchers at the Institute of Biotechnology at the Helsinki University and the Universitat Autònoma de Barcelona (UAB) have developed the first three-dimensional simulation of the evolution of morphology by integrating the mechanisms of genetic regulation that take place during embryo development. The study, published in *Nature*, highlights the real complexity of the genetic interactions that lead to adult organisms' phenotypes (physical forms), helps to explain how natural selection influences body form and leads towards much more realistic virtual experiments on evolution.

"Right now we have a lot of information on what changes in what genes cause what changes in form. But all this is merely descriptive. The issue is to understand the biological logic that determines which changes in form come from which changes in genes and how this can change the body", explains Isaac Salazar, a researcher at the University of Helsinki and in the Department of Genetics and Microbiology of the UAB, and lead author of the article. In nature this is determined by embryo development, during the life of each organism, and by evolution through natural selection, for each population and species.

But in the field of evolution of organisms it is practically impossible to set up experiments, given the long timescale these phenomena operate on. This means that there are still open debates, with hypotheses that are hard to prove experimentally. This difficulty is compensated for by the use of theoretical models to integrate in detail the existing experimental data, thus creating a virtual simulation of evolution.

The researchers used a theoretical model based on experiments on embryo development, on a previous study by the same authors, also published in *Nature* (Salazar-Ciudad and Jernvall, 2010), and on three different mathematical models of virtual evolution by natural selection of form. Evolution takes place virtually on the computer in populations of individuals in which each individual can mutate its genes, just as this works in nature. Through the development model, these produce new morphologies and natural selection decides which ones pass on to the next generation. By repeating the process in each generation, we can see evolution in action on the computer.

This simulation enables a comparison of the different hypotheses in the field of evolution regarding which aspects of morphology evolve most easily. The first vision is that all metric aspects of form contribute to adaptation and that, consequently, all are fine-tuned by evolution over time. The second vision is that some aspects of form have greater adaptive value and that the remainder evolve collaterally from changes in these. The third is that no aspect of form is intrinsically more important, but what is important adaptively is a complex measurement of the form's roughness.

"What we have found is that the first hypothesis is not possible and that the second is possible in some cases. Even if ecology favoured this type of selection (the first vision), embryo development and the relationship between genetic and morphological variation imposed by this is too complex for every aspect of morphology to have been fine-tuned. In one way, what we are seeing is that natural selection is constantly modelling body forms, but these are still a long way from perfection in many ways", points out Salazar.

More information: www.nature.com/nature/journal/ … ull/nature12142.html