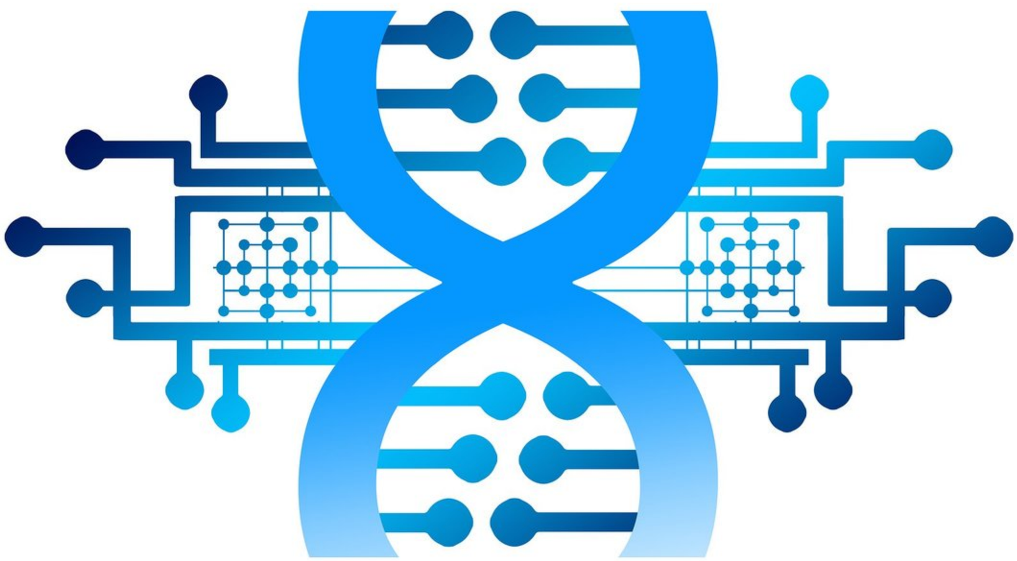
Model of multicellular evolution overturns classic theory

November 3 2020



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Cells can evolve specialized functions under a much broader range of conditions than previously thought, according to a study published today in *eLife*.

The findings, originally posted on bioRxiv, provide new insight about natural selection, and help us understand how and why common multicellular life has evolved so many times on Earth.

Life on Earth has been transformed by the evolution of multicellular life forms. Multicellularity allowed organisms to develop specialized cells to carry out certain functions, such as being nerve cells, skin cells or muscle cells. It has long been assumed that this specialization of cells will only occur when there are benefits. For example, if by specializing, cells can invest in two products A and B, then evolution will only favor specialization if the total output of both A and B is greater than that produced by a generalist cell. However, to date, there is little evidence to support this concept.

"Rather than each cell producing what it needs, specialized cells need to be able to trade with each other. Previous work suggests that this only happens as long as the overall group's productivity keeps increasing," explains lead author David Yanni, Ph.D. student at Georgia Institute of Technology, Atlanta, US. "Understanding the evolution of cell-to-cell trade requires us to know the extent of social interactions between cells, and this is dictated by the structure of the networks between them."

To study this further, the team used network theory to develop a mathematical model that allowed them to explore how different cell network characteristics affect the evolution of specialization. They separated out two key measurements of cell group fitness—viability (the cells' ability to survive) and fecundity (the cells' ability to reproduce). This is similar to how multicellular organisms divide labor in real life—germ cells carry out reproduction and somatic cells work to ensure the organism survives.

In the model, cells can share some of the outputs of their investment in viability with other cells, but they cannot share outputs of efforts in reproduction. So, within a multicellular group, each cell's viability is the return on its own investment and that of others in the group, and gives an indication of the group's fitness.

By studying how the different network structures affected the group fitness, the team came to a surprising conclusion: they found that cell specialization can be favored even if this reduces the group's total productivity. In order to specialize, cells in the network must be sparsely connected, and they cannot share all the products of their labor equally. These match the conditions that are common in the early evolution of multicellular organisms—where cells naturally share viability and reproduction tasks differently, often to the detriment of other cells in the group.

"Our results suggest that the evolution of complex multicellularity, indicated by the evolution of specialized cells, is simpler than previously thought, but only if a few certain criteria are met," concludes senior author Peter Yunker, Assistant Professor at Georgia Institute of Technology, Atlanta, US. "This contrasts directly to the prevailing view that increasing returns are required for natural selection to favor increased specialization."

More information: David Yanni et al, Topological constraints in early multicellularity favor reproductive division of labor, *eLife* (2020). DOI: 10.7554/eLife.54348

Provided by eLife