Genes in place: New research shows location matters for evolution

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(PhysOrg.com) -- A new paper by researchers at the New England Complex Systems Institute reveals the limitations of evolutionary studies that ignore geography. They show that how individuals are arranged in space, and the patterns formed by living populations themselves, play a crucial role in evolution.

Most mathematical models of evolution consider only the population's overall genetic composition, essentially assuming that both the genes and the organisms could be anywhere and that every individual interacts equally with every other--that the population is well-mixed. It turns out that the difference between such random mixing and actual spatial distribution is important.

When scientists assume that populations are well-mixed, they miss what happens when offspring live in the spaces left by their parents. For instance, if predators consume all the prey in a given area too quickly, they or their descendants may end up starving later--even though there may be more prey outside their hunting area. Likewise, a disease that is too virulent may destroy its hosts before getting a chance to spread. In other words, behaviors that appear effective in the short term may lead to their own demise in the long term. When space is ignored, voracious predators and virulent diseases escape from the local effects of their behavior. Those are very different outcomes.

"The same issues arise for all kinds of exploitation. Overexploiting locally impacts your offspring if they live where you did, but not if they

can go anywhere they want," NECSI President Yaneer Bar-Yam said. "If you imagine what types of organisms would populate the world if the mixing models were accurate, and what types would exist with spatial distributions, they are completely different."

Even models that allow for space but don't consider all the possibilities it implies, including so called "patch" models, miss the point. "Organisms are 'ecosystem engineers,'" says Blake Stacey, the lead author. "Their actions can change their environment, so models of selection need to include the consequences of an organism's actions on their environment and its effect on later generations," which often matter in the real world.

NECSI researchers have developed an ingenious and intuitive test to determine just how much the spatial arrangement really matters. In the test, organism locations are periodically swapped in a controlled fashion as the evolutionary simulation is run. If the traditional treatments were valid, the swapping wouldn't change the outcomes. But when space is modeled realistically, the swapping dramatically affects evolutionary behavior. What's more, the test can pinpoint where older attempts to include space in the evolutionary equations don't measure up.

These results have implications for how we understand invasive species and emergent pandemics. Human travel often brings species to new areas, sometimes unintentionally, endangering the native organisms. Travel not only transmits diseases but also makes killer epidemics more likely. Furthermore, a spatial understanding of evolution is important for studying the emergence of social behaviors like cooperation and altruism.

The stakes of getting spatial models right extend beyond evolutionary biology. "These concerns are very general," Bar-Yam said. "The same issues arise in social systems, when people exploit their environment. There is a real difference if they suffer the consequences or not. Imagine

what would happen if people's homes were swapped around from one house to another every so often. How many people would put time and effort into taking good care of their homes?" With global mobility and connectivity these issues are central to how we take care of our world for ourselves and our children.

More information: To download the manuscript, visit: arxiv.org/abs/1110.3845

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