Sex: Why bother? Scientists probe evolutionary mysteries

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What advantage did sex offer when it first appeared and why does sex persist in modern organisms, stopping them from becoming asexual again? One University of Houston professor thinks he may have uncovered some new clues in answering these questions.

By studying one of the great mysteries of biology – the evolution of sexual reproduction – Ricardo Azevedo, an assistant professor in the department of biology and biochemistry at UH, has found in a study using a computational model that a leading theory may be more plausible than previously thought, His findings are described in a paper titled "Sexual Reproduction Selects for Robustness and Negative Epistasis in Artificial Gene Networks," appearing in the current issue of *Nature*.

Collaborating with Christina Burch from the University of North Carolina at Chapel Hill, Azevedo and his team created a very simple model of how genes interact with each other to produce an organism and simulated the evolution of this simple genetic system under different conditions. What they found was quite surprising – sexual reproduction itself can lead to the evolution of a special feature of the genetic architecture known as negative epistasis that, in turn, confers an evolutionary advantage to sexually reproducing organisms. In other words, sexual reproduction may be self-reinforcing. They also found that sexually reproducing populations evolved an increased robustness to mutations when compared to asexual ones.

These findings suggest a good news/bad news scenario when it comes to

the evolutionary implications of sex. Sexual populations adapt better to their environments and become more resistant to harmful mutations, but these advantages are more likely to benefit our natural enemies.

According to Azevedo, the issue is that there are many costs associated with sexual reproduction. First, sexually transmitted diseases are widespread in sexually reproducing populations, making sex risky. Second, there's the so-called "twofold cost of sex," such that if females carry most of the burden in mammalian sex, this appears to be true in evolutionary terms, as well. A mutant human female able to reproduce asexually and give birth to more females like her would give rise to a population with twice the reproductive rate per capita of the normal human population and would become dominant within a few centuries.

While a switch to asexual reproduction is extremely unlikely to happen in humans due to a genetic quirk of mammals called genomic imprinting, asexuality can and has re-evolved many times in animals such as reptiles, fish and insects. However, despite its many costs, sexual reproduction is widespread and asexual populations tend to be relatively short lived in an evolutionary time scale.

"Asexuality seems to be an evolutionary dead end," Azevedo said. "So sex must have its benefits."

Many benefits of sex have been proposed over the last century, but scientists have had a hard time figuring out which ones are decisive. One being examined here, known as the mutational deterministic hypothesis (MDH), postulates that sexual reproduction confers an advantage by helping natural selection remove harmful mutations from the population.

"According to MDH, in order for sexual populations to overcome the twofold cost of sex, two things must be true," he said. "The production rate of harmful mutations must be relatively high, such that each

individual acquires on average one or more harmful germline mutations not inherited from its parents. The second is that these harmful mutations must interact in a special way, called negative epistasis, such that adding more and more harmful mutations makes you progressively worse off."

For example, if a single harmful mutation lowers fitness by 5 percent on average, then successive mutations are expected to lead to a progressive decline in 5 percent steps if the mutations don't interact with each other. Negative epistasis, however, comes into play, for example, if the second mutation decreased fitness by 10 percent, the third by 15 percent and so forth.

While biologists have been trying to figure out just how prevalent negative epistasis is in nature to test MDH, relatively little attention has been paid to the question of what conditions could lead to the existence of negative epistasis in the first place. If those conditions were known, it would help scientists decide whether it's even worth looking for it or not. Azevedo's study suggests that it is. In many of their simulated worlds, sexual reproduction generated negative epistasis, thus creating the conditions required for its own maintenance. If this is true about the real world, this would constitute a spectacular example of evolution forging its own path.

Although the thought that sex may have evolved as a kind of "genetic waste disposal" mechanism would seem depressing, it gets worse. The evolutionary benefits of sex are likely reaped most effectively by organisms with fast generation times and large population sizes, such as disease-causing microorganisms. That sex also may confer an increased ability to fight back parasites, as proposed by another theory for the evolution of sex, probably serves as little consolation. But it's exactly why scientists, like most other human beings, find sex so intriguing.

Source: University of Houston