Why Sex Is Good

by
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Birds do it. Bees do it.
Even educated fleas do it.
Let's do it. Let's fall in love.
—Cole Porter

Part I—"It"

Why do so many organisms go through sexual reproduction? It seems like every organism we think about does it: clams, jellyfish, trees, and elephants. And while we're thinking about it: why only two sexes? It doesn't have to be that way. Some fungi have dozens of sexes, enough to keep a romance novelist and a scriptwriter of soap operas ecstatic for years.

Sex really isn't necessary for reproduction. Bacteria and many one-celled organisms like amoebae reproduce quite nicely by simply dividing in half (binary fission). They produce identical copies of themselves, quite an efficient way of sending one's genes on to the next generation. They do it alone. For them, it doesn't take two to tango.

Complex organisms can do it too. Some lizard species have only one sex—females. They reproduce parthenogenetically—that is, females produce eggs that spontaneously start development without sperm being involved at all. They are completely asexual.

Some species have it both ways: they reproduce both sexually and asexually. Queen bees when they produce females (workers) release sperm out of a storage sac and fertilize the egg in the normal way, but when they want to produce males (drones) they hold the sperm back and the eggs develop by parthenogenesis.

Water flea *(Daphnia)* populations seem to switch from asexual to sexual depending on environmental conditions. And some species of fish actually switch from being one sex to the other depending on which gender is in short supply. Science fiction writers should love these gender benders.

So, this brings us to a fundamental question that biologists have not solved: *If organisms can survive well without sex—in fact, may do better without it—why has sexual reproduction evolved?*

Questions

1. Propose three hypotheses to explain why sexual reproduction has evolved. (At least 20 have been suggested!)
2. Can you propose any way to test your favorite hypothesis?

Part II—Is It Always Good?

In a world without sex there would be no males and females. No flowers, no insects specialized in pollinating them, no extravagant colour and form like the peacock's tail; and much animal behaviour would not exist. —Rolf Hoekstra

All of that is true, but so what? Who needs this stuff that Hoekstra is talking about for survival?

The great German biologist August Weismann proposed an answer to the question of "Why sex?" He asserted that sex increases genetic variation. When two different individuals mate by joining their gametes together, they produce a brand new genetic mixture and this promotes evolutionary adaptation.

This idea held sway for a hundred years until a couple of authors, George Williams and Maynard Smith, said, "Hold on. There are a couple of problems with this scenario." Sex is not always good.

1. Mixing of the genes tends to break up favorable combinations. Why break up a good thing?
2. Asexual reproduction is twice as efficient as sexual reproduction at sending one's genes into the next generation. Every time a sexual mother produces a child, that child only has one-half of the mother's genes; the other half is from dad. An asexual mother reproducing parthenogenetically would give her child the complete set. In fact, it is better to have every individual in a population capable of reproduction (i.e., be a female) than to have individuals who are not (i.e., be a male). Such populations should rapidly out-reproduce a sexual population. This has been called the "two-fold cost of sex."

On both of the above counts, it seems clearly disadvantageous for individuals to reproduce sexually! Yet sex has evolved and seems here to stay.

Many scientists have tried to puzzle their way out of this dilemma by testing some of the assumptions inherent in the argument.

Questions

1. Can you design a way to test the hypothesis that asexual reproduction leads to a higher evolutionary fitness (i.e., leads to more progeny) than sexual reproduction?

Part III—Sex and Stress

There is a snail that lives in New Zealand lakes that has both asexual and sexual individuals. Curtis Lively (currently at Indiana University) and his colleagues decided that the snails could be used to test the hypothesis that a changing or stressful environment would favor sexual reproduction—the logic being that if the environment changes, then variation (sexual reproduction) is a good thing; some of your offspring might have the right genetic constitution to survive.

Here's the situation the biologists found. The snails live in freshwater habitats and there are over a dozen worm parasites that attack them. The scientists reasoned that there might be a difference in the fitness of the asexual and sexual individuals in ponds where there were different degrees of parasitism.

This is what they found: in ponds where there was a high degree of parasitism there was a much higher percentage (2.5 times more) of sexually reproducing individuals.

Questions

1. Before carrying out the experiment, why did the scientists expect there would be a difference in fitness between sexual and asexual snails in ponds with different degrees of parasitism?
2. Are the data they obtained consistent with Weismann's hypothesis? Explain your thinking.

Part IV—An Experiment

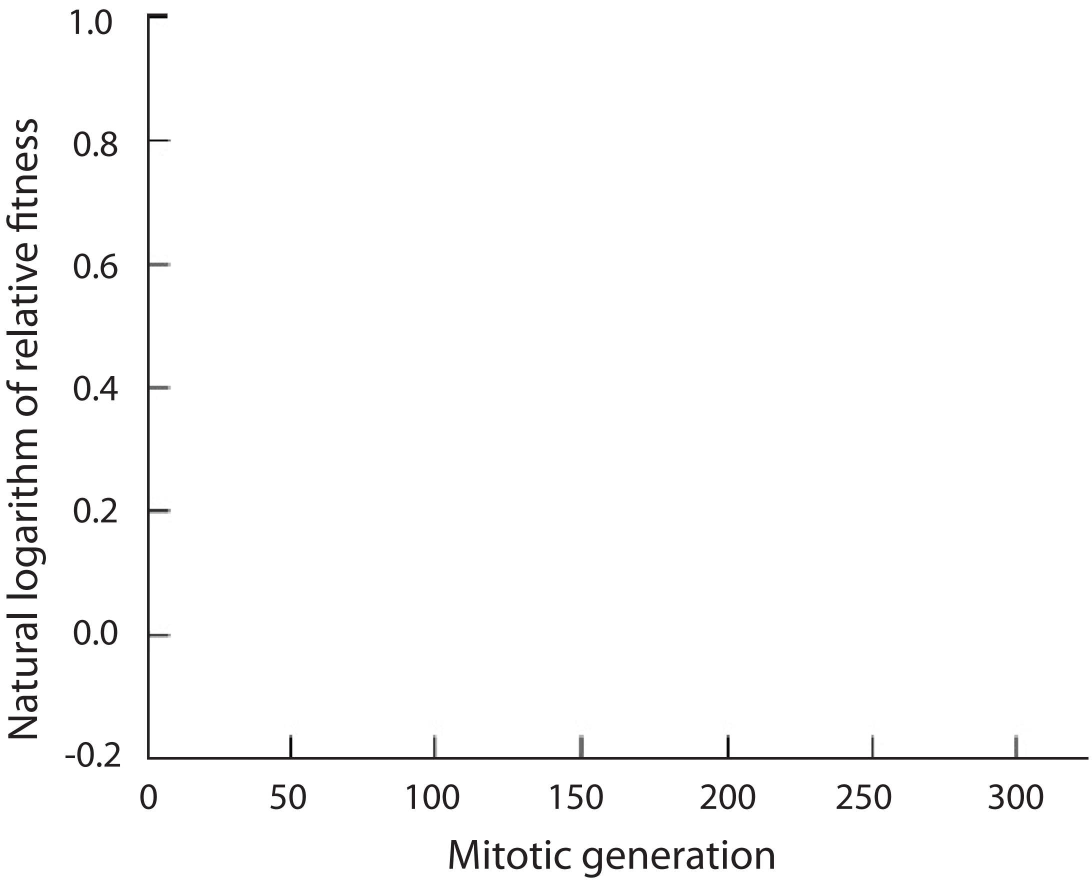
A team of scientists at the Imperial College London tackled the problem and published their results in *Nature* magazine (March 25, 2005). They decided to use yeasts, which are single-celled fungi, because they can reproduce both sexually and asexually, are easy to keep in the lab, and reproduce very rapidly.

Yeasts normally reproduce asexually, but when they are stressed (starved, high temperatures, etc.) they will reproduce sexually. The scientists did not want this switching to occur. So they genetically manipulated one asexual strain. They deleted the two genes (SPO11 and SPO13) required for normal meiosis, so that sexual reproduction was impossible. Now they had two pure strains—asexual and sexual.

The Imperial College team decided to compare the reproductive rate of the asexual vs. the sexual yeasts in two different environments: harsh and benign. That is, "fitness" would be measured by comparing the growth rate relative to the non-evolved ancestral strain. The benign environment had plenty of nutrients although glucose was limited so that growth was not uncontrolled. The harsh environment had the same glucose concentration but was at a higher temperature and had more demanding osmotic conditions.

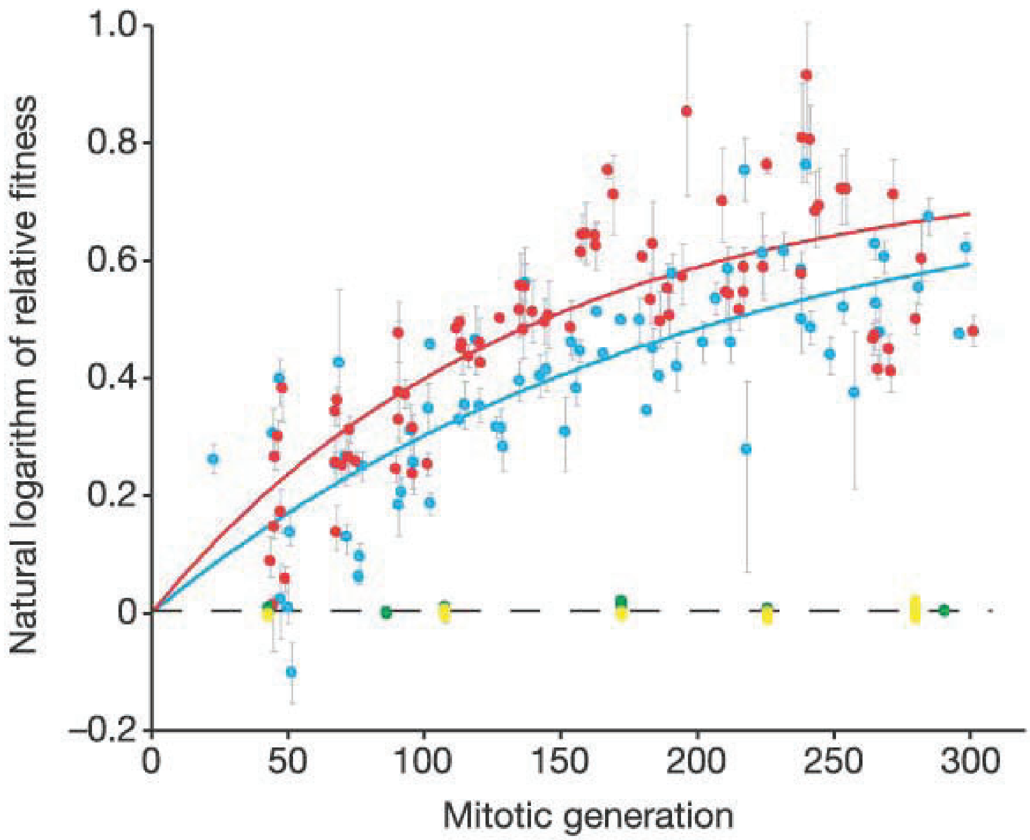
Question

1. On the graph below plot the results you would expect if Weismann's hypothesis were correct. Plot the changes in fitness values over time in the populations of sexual yeasts in benign conditions, asexual yeasts in benign conditions, asexual yeasts in harsh conditions, and sexual yeasts in harsh conditions.



Part V—The Results

Here are the results of the real experiment.



The change in natural logarithm of fitness of asexual and sexual populations of yeast in benign and harsh environments. Points show fitness measurements for individual populations with twice log-likelihood error bars (these approximate 95% confidence limits); the error bars for the benign treatment are plotted but are mostly too small to be discriminated. The fitted model for the harsh environment is plotted for asexual (blue) and sexual (red) treatments (parameters: a1 = 0.761, a2(asexual) = -5.287, a2(sexual) = -4.901). Yellow symbols, asexual strains in the benign environment; green, sexual in the benign environment; blue, asexual in the harsh environment; red, sexual in the harsh environment. (Reprinted by permission from Macmillan Publishers Ltd: *Nature* 434, 636-640, doi:10.1038/nature03405, copyright 2005.)

Question

1. What conclusions can you make based upon the data?