A New Hypothesis on the Evolutionary Advantage of Sexual Reproduction

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Abstract

This paper asserts a new hypothesis on the evolutionary advantage of sexual reproduction: a species has a better chance of survival if it evolves and works together as a group and sexual reproduction is the species' cohesive measure that ensures a species' evolution as a group. This paper also proposes the use of computer simulation that emulates evolution as a stepping stone for further testing of the hypothesis.

Keywords: Evolution, Sexual Reproduction, Computer Simulation

Introduction

Why sexual reproduction? It is a question that has baffled evolutionists since the development of the theory of evolution. Despite several drawbacks to sexual reproduction, the majority of life reproduces sexually; there must be a clear and very profound answer to why that is. In this paper, we propose a new hypothesis to answer this question and computer simulations to test the hypothesis.

First, let us define sexual reproduction and asexual reproduction. Sexual reproduction is reproduction in which different individuals combine genetic material to produce offspring so that the offspring are not genetically identical to the parents, and not all of a parent's genes get passed on to an offspring. Asexual reproduction, on the other hand, is a form of reproduction in which a parent individual will directly pass on all their traits to the offspring. The offspring is exactly identical to the parent, a clone if you will.

In many ways, asexual reproduction is a better evolutionary strategy: only one parent is required, and all of the parent's genes are passed on to its progeny. In sexual reproduction, only half of each parent's genes are passed to the next generation. The passing of only half of each parent's genes is known as the two-fold cost of sexual reproduction. Each reproducing individual passes on just one of the two alleles it has for each trait; whereas when asexual reproduction occurs, each reproducing individual passes on both alleles it has for each trait. Since sexual individuals have the alleles that code for sexual reproduction and asexual individuals have the alleles that code for asexual reproduction, the allele for sex gets passed from generation to generation at half the rate of the allele for asexual reproduction. This essentially means that for sexual reproduction, half the population will be male (have the male allele) and the other half will be female (have the female allele).

Asexual individuals on the other hand, pass on both asexual alleles. For every one allele for sexual reproduction that a sexual individual passes on, two alleles for asexual reproduction will be passed on by the asexual counterpart. This means that species which employ sexual reproduction will produce only half as many offspring as opposed to asexual reproduction.

Not only do sexually reproducing species reproduce at half the rate of asexual reproducing species, they must also go through obstacles that do not hinder asexual reproducers. To name a few examples: sexual reproducing species must spend a great deal of time and energy to find and attract mates. The peacock is a good example, it must grow a very large and intricate tail to attract mates; not only is producing the tail very energy-consuming, the peacock must carry around its tail at all times, leaving it very vulnerable to predators. Sexual reproducing species must also consume time and energy to take part in "sex"; this also leaves both mates very vulnerable to predators.

Despite these very obvious drawbacks to sexual reproduction: a two-fold cost to sexual reproduction, time and energy spent in finding a mate, and vulnerability while partaking in "sex", it is still a very prevalent form of reproduction in all types of living life. If there is one thing certain about this world, it is that Nature is never random; if it's there, then there's a reason. This brings us to the central question, "Why sexual reproduction?"

Background

Right now, there are four generally accepted, possible explanations for why sexual reproduction is so prevalent among the many various walks of life. The four possible hypotheses are as follows: (1) Faster evolution. Sexually reproducing populations will evolve faster than a set of asexual clones, provided that the rate of favorable mutation is high enough. (2) Lower extinction rates. The taxonomic distribution of asexual reproduction suggests that asexual forms have a higher extinction rate than sexual forms. Thus sex may be maintained by group selection. (3) Deleterious mutations. The large numbers of deleterious mutations are more efficiently removed by sexual rather than asexual reproduction. (4) Host-parasite arms race. The co-evolutionary arms race of parasites and hosts produces rapid environmental change, making sexual reproduction advantageous.

The hypothesis behind faster evolution depends on the rate of mutation. If favorable mutations are rare, then in the case of an asexual population, each favorable mutation will have been fixed in the population before the next one arises. New favorable mutations will always arise in individuals that already carry the previous favorable mutation. Sexually reproducing individuals on the other hand vary from each other, a single population could have an individual possessing a favorable mutation and several other individuals that don't. Over time, the population as a whole will absorb the new favorable mutation. If the rate of a favorable mutation is rare, then the asexually reproducing population will evolve just as fast as a sexually reproducing population. However, if favorable mutations arise more frequently, the hypothesis works: the sexual population evolves faster. Each new favorable mutation will usually arise in an individual that does not already possess other favorable mutations; the greater speed with which the different favorable mutations combine together causes the sexual population to evolve faster. The higher the rate at which favorable mutations arises, the greater the evolutionary rate of a sexually reproducing population as compared to an asexual one.

The hypothesis of a lower extinction rate for sexually reproducing species relies on a peculiar but old observation. First, let us define the universal system of nomenclature that biologists use. All living things are divided into the five kingdoms; an example would be the animal or plant kingdom. Every kingdom is subdivided into phyla; every phyla is subdivided into classes; every class is subdivided into orders; every order into families; every family into genus; every genus into a species. Since 1886, evolutionists have known that asexual reproduction has a peculiar taxonomic distribution. It is usually confined to an odd species, or perhaps a whole genus, within a larger taxonomic group that mainly reproduces sexually; only very rarely is it found throughout a larger taxonomic group than a genus. The often isolated taxonomic distribution of asexual reproduction suggests that asexual lineages have a higher extinction rate than sexual lineages—that asexual lineages usually do not last long enough to diversify into a genus or higher taxonomic level.

The deleterious mutation hypothesis follows with the following idea. A sexually reproducing population should be able to enable a population to generate some viable individuals from ones that have bad mutations. Recombination of DNA may concentrate deleterious mutations into certain individuals, leaving others free from mutation. However, for this hypothesis to be viable, two requirements must be met: (1) the mutation rate must be high enough; and the female gains the advantage whatever the deleterious mutation rate, but the advantage gained increases with mutation rate. (2) An individual with two mutations must be significantly worse off than an individual with only one. In other words, bad mutations will have a synergistically deleterious effect on an organism's fitness. To give a better visual, imagine two computers: one has a lousy, out-of-date CPU; the other has a lousy, out-of-date stick of ram. You swap the good CPU from the computer with bad ram and trade it for the out-of-date CPU from the computer with good ram. You'll end up with one good computer and one computer worse off than before. This means that a population can generate some viable individuals from ones that have deleterious mutations, at the cost of generating individuals with high loads of deleterious mutations; by the laws of natural selection, these individuals would be the first to die off, there by ridding deleterious mutations quicker.

The host-parasite theory revolves around the fact that sex is more likely to be advantageous if environments change rapidly. This would make sex advantageous every few hundred years, but why every generation? The answer lies in co-evolution: the relationship between hosts and parasites may generate a fast enough environmental change to make sex advantageous in the short term. In the case of the parasite the "environment" is the host's resistance mechanism and for the host, the "environment" is the parasite's method of penetrating its defenses. A sexually reproducing population would have greater genetic diversity as compared to an asexual population. Such a large genetic diversity makes it difficult for parasites to adapt to its hosts' defenses. For example, a parasite-prone individual from a sexually reproducing population might mate with a non-parasite-prone individual. The resulting offspring might be more resilient to parasites than its parasite-prone parent. As a result, because of the great genetic diversity, parasites have a more difficult time finding a suitable host. In the case of a parasite-prone individual from an asexual population, its resulting offspring will be exactly identical to its parasite-prone parent, there by making it much easier for the parasite to find a suitable host, and much more difficult for an asexual population to ward off parasites.

New Hypothesis

The exact reason why so many living things reproduce sexually could be any one of these hypotheses; it could even be all these hypotheses combined. However, we believe that there is another possible hypothesis behind this golden question. Our hypothesis states that one reason living things reproduce sexually is that the population of descendents of sexually reproducing individuals will formulate into big "clusters" of similar sexually reproducing individuals as opposed to the progeny of an asexual population, which we believe, will formulate into many smaller groups of similar asexual individuals.

In order to explain our hypothesis in better detail, we will explain in more detail the difference between sexual reproduction and asexual reproduction. In sexual reproduction, two individuals must mate with each other. The individuals must be very similar in nature, i.e. in the same species or, in some cases, the same genus for them to be able to reproduce valid offspring. For example, a horse can mate with another horse, but not an elephant. In some rare cases, the same genus is similar enough to reproduce fertile offspring; one example being a tiger mating a lion; the pairing can often produce fertile offspring. Asexual individuals on the other hand, simply reproduce clones of themselves; the offspring is exactly identical to the parent (except in the case of mutation).

We believe that a sexually reproducing individual must mate with another individual similar to itself. The resulting offspring will be similar to their parents, but not identical. If an offspring were to mutate, the mutation cannot be so profound that it is too dissimilar to the rest of its population. Otherwise, that offspring would be unable to produce offspring of its own. Therefore, because an individual must be similar to the rest of its population, the population as whole will evolve with large "clusters" of similar individuals. These "clusters", we believe, are the result of sexually reproducing organisms needing individuals similar to themselves in order to reproduce.

Whereas, we believe that an asexual reproducing individual will produce children identical to itself. When one of the offspring mutates, its children will be similar to their parent and slightly different than the rest of the population. Over time, this difference will become more pronounced. This, we believe, will result into a distribution of different progeny that is very diversified. We believe there will be very many small groups of individuals similar to themselves but different than other descendents.

The next part of the hypothesis relies on an assumption that is debatable between biologists. We believe that an individual will have a better chance of survival if there are many other individuals similar to itself; that if an individual is part of a group, then it will have a better chance of survival. Several examples would be predatory animals such as lions and wolves which rely on teamwork in order to survive. The same can be said for non-predatory animals such as gazelle which travel in herds in order to protect themselves and their offspring. As stated before, this is a key aspect to our hypothesis: species as a whole have a better chance of survival when they are in groups. Therefore, sexual reproduction is a species' mechanism to keep the species together as whole, as opposed to having hundreds of different species branch off on their own and losing the advantage of the "group."

In short, a species has a better chance of survival if it evolves as a group (this is open to debate). And sexual reproduction is a species' method of ensuring a species' evolution as a group, instead of disparate branches evolving off on their own.

The only way to test this hypothesis is to take two species; one that reproduces sexually, and one that reproduces asexually. Then analyze how the species evolves over a long period of time; i.e. millions and millions of years. If by sexual reproduction, there are few species with large populations as opposed to many disparate species with small populations, then half of our hypothesis would be correct. The other half, the idea that a species has a greater chance of survival if it evolves in groups, would have to be debated by biologists. For our purposes, we are only interested in proving that sexual reproduction creates a smaller number of species with large populations as opposed to asexual reproduction.

However, we don't have the luxury of so much time to analyze evolution in the real world. Therefore, the evolution has to be done artificially in order to test this hypothesis. What we propose is to create two computer programs to simulate the reproduction and evolution of an asexual population and that of a sexual population. This of course, is a controversial method: using computer simulations to simulate nature. Although questionable, this method is a stepping stone for our hypothesis. If the programs' results collaborate with our theory, then at least the hypothesis has backing support to work from. If not, then there is no need to take the hypothesis any further; it's a dead end.

Computer Simulation

We develop two computer programs, an asexual program and a sexual program to simulate asexual reproduction and sexual reproduction. The design and architecture of the programs are as follows. For the asexual program, we generate one string of integers between 0-3 to simulate a DNA strand that is composed of the 4 DNA bases. The program then takes the DNA and reproduces its offspring by copying the DNA. According to a percentage specified by the user, there is a chance that the duplicated DNA will have a mutation. The number of offspring produced at each time is random, but with an average specified by the user. This process is repeated as many generations as specified by the user.

On the other hand, the sexual program takes two DNA strings from the parents. If two strands are similar with differences within a limit specified by the user, then offspring are created by randomly copying one DNA base from the two parents and this is repeated until the DNA strand is completed. Again, the number of offspring is random with a user specified average.

To simulate different scenarios, we have made our programs very flexible. They allow the user to specify the rate of mutation, the average number of offspring, the number of generations, and how similar two parents shall be in order to reproduce a valid offspring.

Since the number of population in a simulation increases exponentially as the number of generations, it is very important to make the computer program memory efficient.

We perform several simulations under different assumptions. Due to space limitation, we cannot present the results in detail. However, our preliminary experiments show some promising results.

Conclusion

We have come up with a hypothesis to the golden question of evolutionary science: "Why sexual reproduction?" Our hypothesis is that sexual reproduction leads to big "clusters" which means the population as a whole has a better chance of survival. In order to verify out hypothesis, we are working on computer simulations to simulate evolution. Although not conclusive, our preliminary results are promising.

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