

Why does sexual reproduction persist?

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Producing offspring does not always require a partner. Some lineages reproduce without fertilization, while others alternate among reproductive modes. Sexual reproduction nonetheless remains widespread. Its persistence becomes a scientific puzzle when we count its costs rather than assuming that any familiar biological process must be the best possible arrangement.

The question is not whether sex creates variation. It is when the consequences of genetic mixing can outweigh its costs, for the lineages and conditions being compared. A benefit in one setting need not explain every species, and an explanation for continued maintenance need not also explain the first origin of sex.

1. Name the comparison

Sexual reproduction involves meiosis and the joining of genetic contributions through fertilization. Outcrossing joins contributions from different individuals; self-fertilization also involves sex but changes the genetic comparison. Treating all selfing as asexual reproduction would erase a distinction that matters in experiments.

Costs can include finding partners and the allocation of reproductive effort. In a particular idealized comparison, a lineage producing only reproductive daughters can increase faster than an otherwise equivalent lineage allocating half its offspring to sons. That familiar twofold argument requires its assumptions: equal total offspring production, equal survival and no compensating contribution or ecological difference. It is a model of one cost, not a universal numerical tax on every sexual organism.

Otto's review emphasizes that changing selection, finite populations and differences in reproductive behavior alter the conditions under which sex can be maintained. [1] Explaining a pattern therefore requires stating the comparison, not merely naming a possible advantage.

2. Mixing changes associations

Recombination rearranges inherited variants. It can place favorable variants together, separate a favorable variant from an unfavorable neighbor, or break apart a combination that was already successful. None of these consequences guarantees an improvement in every offspring. A process that increases the range of combinations can generate both better and worse matches to the present conditions.

A hypothetical example makes the logic concrete. Two lineages carry favorable variants at different positions. Without an exchange process, those variants may compete in separate backgrounds until one lineage acquires the other's change independently. With appropriate genetic mixing, a descendant can receive both. This example identifies a possible benefit; it does not quantify how often the required parental combinations occur or whether their combination really improves fitness.

The opposite case is equally possible in a model. If a particular combination works especially well, breaking it apart can reduce average performance. The empirical question concerns the distribution of such effects and the rate at which environments and genetic backgrounds change.

3. A changing opponent supplies a test

Host-parasite coevolution provides one experimentally tractable hypothesis. Parasites can become especially effective against common host variants, changing which host combinations are favored. Under suitable conditions, generating less common combinations through outcrossing can help host populations respond. This is a conditional mechanism, not a claim that rarity always protects an organism.

Morran and colleagues compared nematode populations exposed to no pathogen, a fixed pathogen strain, or a coevolving bacterial pathogen. In their *Caenorhabditis elegans* system, coevolution with *Serratia marcescens* maintained more outcrossing in populations able to vary their mating behavior. Obligately selfing populations became extinct in the coevolution treatment, while outcrossing populations persisted. [2]

The controls matter as much as the dramatic outcome. A fixed infectious challenge and an evolving opponent are different environments. If both were called simply “parasites present,” the experiment's test of continuing change would be obscured. The result supports a mechanism in that experimental system; it does not demonstrate that parasites explain all sexual reproduction.

4. Why the experiment is not the whole answer

The study compares particular nematode mating systems, genetic backgrounds and experimental conditions. A self-fertilizing worm is not a universal stand-in for every asexual organism. Nor does persistence during the experiment establish that an observed advantage would remain identical across all environments and timescales.

This limitation does not make the experiment weak. It makes the inference identifiable. Researchers changed a proposed driver and measured a response while distinguishing relevant alternatives. Extending the explanation requires comparisons in other systems, not simply repeating the conclusion at a larger scale.

Other models emphasize the fate of harmful mutations or the ability to combine advantageous changes. These proposals are not automatically mutually exclusive. Their importance can depend on population size, genetic associations and environmental variation. The existence of several plausible mechanisms is a reason to seek discriminating measurements rather than declare that variation, by itself, has solved the problem. [1]

5. An advantage needs the right timescale

A reproductive mode can have a short-term numerical benefit while creating different longer-term possibilities. Conversely, a process that sometimes helps populations adapt need not spread simply because it would help a future population. An evolutionary explanation must connect its consequences to the actual transmission of variants affecting that process.

Consider two hypothetical populations starting with 100 reproductive individuals. If one doubles each interval and the other increases by a factor of 1.5, after five intervals their sizes would be 3,200 and about 759, ignoring all density effects. A later advantage would have to be assessed against this already accumulated difference. The arithmetic does not describe real sexual and asexual growth rates; it shows why a vague promise of future adaptability cannot replace an explicit comparison.

The same care applies when examining surviving lineages. The organisms available to study are descendants of populations that persisted. Inferring universal superiority from their mere existence risks ignoring extinct alternatives and the environments that filtered them.

6. What remains unresolved

We have mechanisms capable of making genetic mixing advantageous and experiments supporting some of them under specified conditions. We do not have one established benefit that applies equally to every lineage. The relative importance of costs, parasites, mutation, recombination and ecological circumstances remains a question for particular systems.

Sex persists because its consequences can be favored despite its costs, not because every sexual offspring is improved or because organisms collectively plan for future change. The deeper lesson is that producing variation and explaining why a variation-producing process is maintained are different scientific tasks.

Related reading

Article 027, “Why can resistance persist after we stop using an antibiotic?”, examines another case in which genetic background and transmission prevent a simple prediction from selection alone. The link is optional and reciprocal.

References

- [1] S. P. Otto. The evolutionary enigma of sex. *The American Naturalist* 174, Supplement 1, S1-S14 (2009). <https://doi.org/10.1086/599084>
- [2] L. T. Morran, O. G. Schmidt, I. A. Gelarden, R. C. Parrish II and C. M. Lively. Running with the Red Queen: Host-parasite coevolution selects for biparental sex. *Science* 333, 216-218 (2011). <https://doi.org/10.1126/science.1206360>