Instead of sexual reproduction, rotifers scavenge new genes from other pond life

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The tiny rotifer has thrived for millions of years without sex. Credit: Flickr/Specious Reasons, CC BY-NC

Sexual reproduction is thought to be essential for mixing up genes and holding your own in the race for survival. A major embarrassment to this theory are microscopic animals called rotifers, one class of which has reproduced without sex for millions of years.

Theory says they should be extinct, but clearly they aren't. So how have they done it?

DNA sequencing now shows that they make up for their lack of sex by incorporating genes from other rotifers of the same or different species, or even from fungi and bacteria.

You'll find rotifers in ponds or puddles. Under the microscope they're incredibly cute little (smaller than 1mm) multicelled invertebrates, motoring around like tiny paddle-steamers.

This is an illusion from the circle of whirling cilia around their heads that drives them forward and wafts tasty algae and decaying scum through their tough little jaws.

When their puddle dries up, rotifers shrink into dehydrated specks that look like crinkly barrels. They can stay that way for years and blow around to new pools. They rehydrate in just a few hours, and can efficiently patch up their DNA, broken in many places during desiccation.

This insignificant little creature poses a big problem for understanding one of biology's oldest mysteries: why do animals have sex?

Why sex?

Sex is spectacularly inefficient. Animals waste a lot of time and energy courting and keeping a mate. Worse, half the population have no offspring.

The "why sex?" question was first asked by Charles Darwin 150 years ago. Ever since, evolutionary geneticists have wondered why sex seems always to win the evolutionary race over asexual reproduction.

Many theories have been put forward and debated over decades. The most accepted is that sex is useful for shuffling new gene combinations by recombining parent genomes.

This enables animals to adapt to changed environments and colonise new ecological niches. Importantly, all these new combinations of genes help animals to keep pathogens at bay by giving them a "moving target".

Sex in animals

In mammals, sexual reproduction is obligatory – we can't do virgin birth. A few reptile and frog species reproduce by parthenogenesis, in which the female makes diploid eggs from combinations of her own genes. But offspring developed from unfertilised eggs are less fit than their sexual sisters. So asexual species don't last long.

Many invertebrates can reproduce both sexually and asexually, and some (such as aphids) indulge in sex only sporadically, in response to environmental cues. But there are none that never have sex – except for bdelloid rotifers.

In the hundreds of years since the Dutch scientist Antonie van Leeuwenhoek first saw bdelloid rotifers under his newly invented microscope, no-one has ever spotted a male.

Females lay eggs but there is no meiosis (the reduction division that produces sperm or eggs), so her eggs all contain genomes identical to hers.

Genomes of bdelloid rotifers are weird. There are two copies of each gene as you expect of a diploid, but they are very different. This suggests that they originated as a hybrid between two species whose genes and genomes diverged 60 million years ago.

Their homologous chromosomes have been differently rearranged so they can't pair at meiosis. The conclusion is that bdelloid rotifers have eschewed sex for 60 million years.

New DNA for rotifers

Sequencing a bdelloid rotifer genome produced a big surprise, as about 8% of the genes looked foreign. Some genes were typical of fungi or bacteria, and endowed the rotifer with handy new properties such as breaking down toxins or using new foodstuffs. This "horizontal transfer" between rotifers and other organisms is ancient and ongoing.

Foreign DNA is spread all over the rotifer genome. So how did it get there? It seems that dehydration makes holes in cell membranes that can suck up DNA. The rotifers' efficient mechanism for repairing double stranded DNA breaks in dehydrated animals is perfect for incorporating foreign DNA into the genome.

More extraordinary still is what happens to DNA from other rotifer individuals or species. It isn't incorporated just anywhere in the genome, but lines up with the appropriate DNA sequence and recombines. This means that a new version of a particular gene may replace the old. Just like sex.

Bacteria can do it

This ability to take up and use DNA from the environment isn't unique to rotifers.

Bacteria reproduce by fission to make clones of genetically identical cells. But they can take up DNA from another bacterial strain, swap it for the resident gene, and express a variant protein in the wild. This

"DNA transformation" provided the first evidence that genes are made from DNA.

DNA transformation is only one of several tricks that bacteria use to scavenge variant and novel genes. Bacteria can also receive little packages of foreign bacterial genes by way of a virus.

Some bacteria can exchange long DNA molecules – even the whole genome – through tube-like structures. This conjugation looks most like what we would consider sex.

In throwing up a great variety of genotypes, sexual reproduction still seems to be the best bet in the long run – for vertebrates and invertebrates.

In its absence, organisms such as the tiny rotifers have had to find other ways to boost their gene pool.

Far from falsifying the theory that genetic variation is essential for evolutionary success, rotifers brilliantly confirm it.

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