Different recombination rates keep highly selfish genes in check

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Mom, dad, or both? Hamlet fish are simultaneous hermaphrodites: they can be both the father and mother of their offspring. Their genes are more recombinant in the formation of egg cells than in the formation of sperm. Credit: O. Puebla

The hamlet fish can be both the father and mother of its offspring – a characteristic that is helping researchers to understand why genes often undergo recombination more readily in one sex.

Whether in a plant or animal - during the transition from one generation to the next, the genes are reshuffled before being passed to the egg and sperm cells, a process referred to as recombination. However, the genes in the germ cells of the parent having different sex chromosomes, in most cases the male, usually recombine to a lesser extent or not at all. Researchers at the Max Planck Institute for Evolutionary Biology in Plön, the Helmholtz Centre for Ocean Research in Kiel, the University of Kiel and the Smithsonian Tropical Institute in Panama have identified a possible cause for this remarkable phenomenon. To this effect, they analyzed the recombination rates of an unusual model organism: the black hamlet fish, Hypoplectrus nigricans, which is native to the Caribbean.

During the formation of sperm and egg cells, chromosomes are snipped apart and reassembled. This allows new genetic variants to be created – an important driving force of evolution. However, the extent to which the genetic blueprint of the germ cells is mixed depends on the sex. Usually, the germ cells of the parent having the same sex chromosomes (XX) are recombined more strongly than those of the parent having dissimilar sex chromosomes (XY) – a phenomenon known as the Haldane-Huxley rule, which is widely observed in both plants and animals.

Scientists have been searching for the cause of this phenomenon for a long time. The black hamlet with its unusual simultaneous hermaphroditic mating system has now shed some light on this mystery. Unlike many other fish species, Hypoplectrus nigricans is not disturbed by observers during its daily mating displays off the coast of Panama. This has enabled divers to observe its curious form of reproduction: not

only can the hermaphroditic fish lay eggs, it can also inseminate the eggs of others. Together with a partner fish, it can therefore be, alternatingly, the father or the mother of its offspring.

Egg cells are more strongly recombined than sperm cells

The scientists have now examined the offspring of a hamlet pair in detail, including an analysis of the DNA of the fish larvae. Because they also knew the genetic makeup of the adult fish, the researchers were able to identify which parts of the genome each parent contributed and which DNA segments were recombined. "Our analysis has shown that although the fish, as hermaphrodites, produce both sperm and egg cells, their genes are more recombinant in the formation of egg cells than in the formation of sperm," explains Loukas Theodosiou of the Max Planck Institute for Evolutionary Biology in Evolutionary Biology in Plön.

The female meiotic drive theory

By carrying out a detailed DNA analysis, the researchers identified a pattern that is consistent with a specific theory that explains the Haldane-Huxley rule. "As a hamlet produces both egg and sperm cells, we can now rule out other causes for the observed differences in recombination rates," says Theodosiou. According to the female meiotic drive theory, the different recombination rates are the result of differences in the formation of male and female germ cells.

In mammals, for example, the genetic material is distributed from male precursor germ cells to four germ cells. In females, however, three of those cells subsequently perish, leaving only one egg cell carrying genetic code. Thus, during the formation of germ cells the genes of the female organism already compete to be represented in the surviving egg cell.

Some genes or chromosome segments are particularly adept at securing a place in the egg cell with sometimes serious consequences: Chromosomal competition can cause errors in segregation resulting in chromosome loss and gamete sterility. In addition, deleterious alleles can accumulate in the driving regions of chromosomes which tend to be areas of unusual low recombination.

The frequent cutting, exchanging and reinsertion of gene segments during the formation of egg cells may therefore have arisen to prevent gene regions or chromosomes from gaining an advantage. In this case, a specific recombination pattern on the chromosomes would be expected. "And we discovered precisely such a pattern in the black hamlet. Our findings are therefore consistent with the hypothesis that female meiotic drive could account for gender-specific differences in recombination rates," says Theodosiou.

The scientists now want to study the role of recombination during the cross-breeding of different species. During their dives off the coast of Panama, the researchers found many variants of the colourful tropical fish. "Hamlets are in the middle of a speciation process, and new variants are presently being formed. By analyzing the DNA of these variants and their crossed offspring we can therefore observe evolution in progress."

More information: L. Theodosiou et al. Recombination in the eggs and sperm in a simultaneously hermaphroditic vertebrate, *Proceedings of the Royal Society B: Biological Sciences* (2016). DOI: 10.1098/rspb.2016.1821

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