A new type of heredity described in Paramecia

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Considered as an obsolete theory for many years, the transmission of acquired traits has returned to the forefront of debate thanks to the development of epigenetic research. In this context, a team from the Institut de biologie at the Ecole normale supérieure (CNRS/ENS/INSERM)2 has described how in Paramecia, mating types are transmitted from generation to generation through an unexpected mechanism. These types are not determined by the genome sequence but by small RNA sequences transmitted via the maternal cytoplasm, which specifically inactivate certain genes during development. A Paramecium can thus acquire a new mating type that will be inherited by its progeny without any genetic modification being involved.

Published in *Nature* on May 7, 2014, this work highlights a novel mechanism that may be governed by natural selection, thus allowing the evolution of species.

Paramecia, single-cell eukaryote organisms, are hermaphrodite: during their sexual reproduction (or conjugation), the partners exchange their genetic material. Paramecia nevertheless have two "mating types," called E and O. Conjugation can only occur between different mating types. As early as the 1940s, scientists such as Tracy Sonneborn had noted that mating type was not transmitted to progeny in Mendelian fashion: a new type of trait transmission, not dependent on the chromosomes, had to be involved, but they did not succeed in elucidating it.

Today, the team led by Éric Meyer at the ENS Institut de biologie has described the mechanism underlying this alternative heredity. To achieve this, they first showed that the difference between the E and O mating types was due to a transmembrane protein called mtA. Although its encoding gene is present in both types, it is only expressed in E individuals. The scientists then revealed the mechanism by which this gene is inactivated in type O individuals.

Paramecia have two nuclei: a germinal micronucleus that is transmitted during sexual reproduction and a somatic macronucleus—resulting from the latter—where the cell's genes are expressed. The mechanism for the transmission of mating types is based on small RNA, called scnARN, which are produced during meiosis. The original function of these RNA is to eliminate from the macronucleus a whole series of genetic sequences called transposable elements, which, like introns, have been introduced into the genes during evolution. As a first step, the scnARN scan the maternal macronucleus in order to identify the sequences that were deleted in the previous generation, and then make the same rearrangements in the new macronucleus. However, unexpectedly, this genome "cleaning" mechanism also allows the cell to silence functional genes. In type O individuals of Paramecium tetraurelia, scnARN eliminate the mtA gene promoter, thus deleting its expression. Thus, it is through the scnARN inherited from the maternal cytoplasm, and not from a particular gene sequence, that the mating type of Paramecium is defined.

This silencing process could in principle affect any gene. Thus in theory, Paramecia could transmit to their sexual progeny infinitely variable versions of the macronuclear genome from the same germline. As with genetic heredity, this mechanism may cause errors that might occasionally endow progeny with a selective advantage. In other words, the somatic macronucleus genome of Paramecium may evolve continuously, and in certain cases allow a short-term adaptation to changes in environmental conditions. And this can occur without any genetic mutations being involved. This type of Lamarckian heredity may thus offer a hitherto unsuspected lever for natural selection.

More information: Deepankar Pratap Singh, Baptiste Saudemont, Gérard Guglielmi, Olivier Arnaiz, Jean-François Goût, Malgorzata Prajer, Alexey Potekhin, Ewa Przybòs, Anne Aubusson-Fleury, Simran Bhullar, Khaled Bouhouche, Maoussi Lhuillier-Akakpo, Véronique Tanty, Corinne Blugeon, Adriana Alberti, Karine Labadie, Jean-Marc Aury, Linda Sperling, Sandra Duharcourt, Eric Meyer. "Genome-defence small RNAs exapted for epigenetic mating-type inheritance." *Nature*, 2014; DOI: 10.1038/nature13318

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