How tree frogs keep their Y chromosomes healthy

Sex chromosomes are the pair of chromosomes that fate whether we become male or female. Females carry two X chromosomes, while males carry one X and one Y chromosome. These chromosomes are quite special among the genome: unlike other pairs of chromosomes, the human X and the Y are completely different. The X is large and gene-rich, whereas the Y is much smaller and has retained less than 50 functional genes.

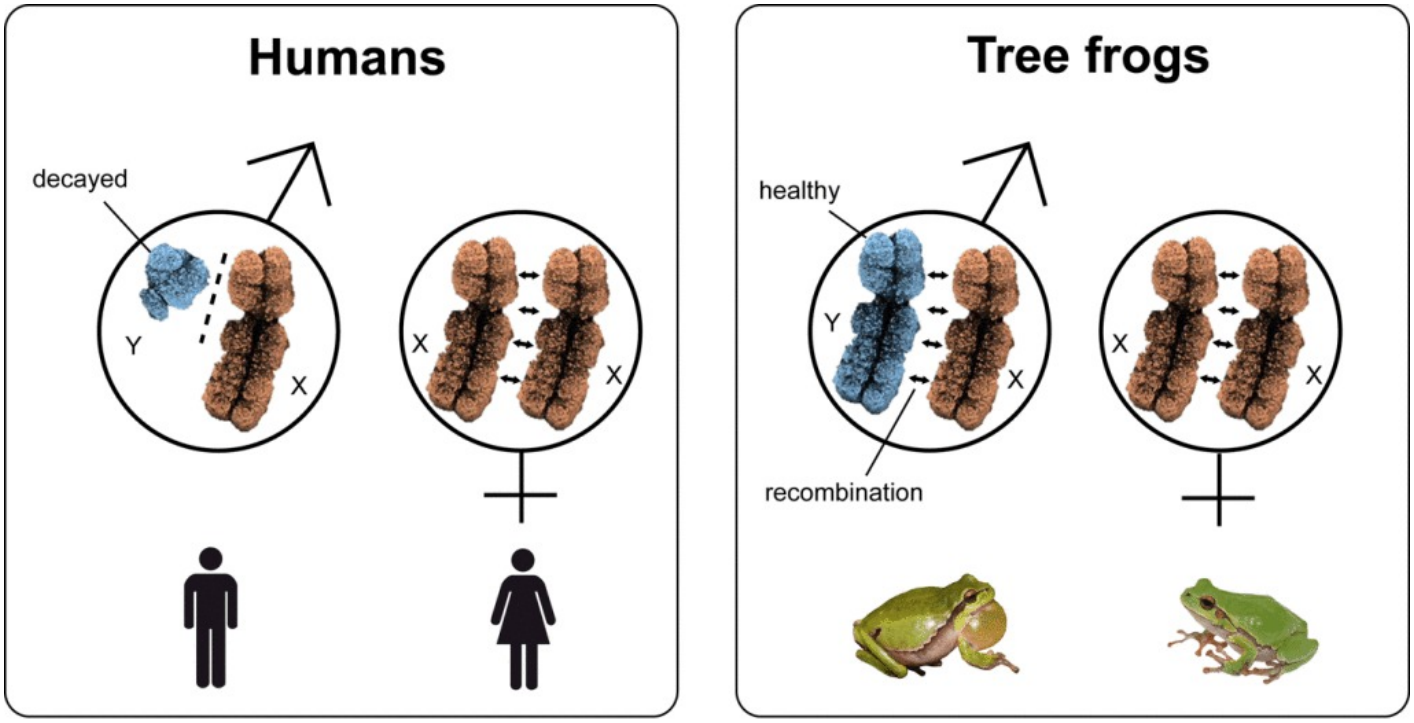

Fig. 1. Recombination between sex chromosomes in humans and tree frogs.
In humans, recombination occurs in women (their two X chromosomes exchange genetic material, resulting in new combinations in the X of ovules) but is suppressed in men (the Y does not exchange with the X, resulting in its clonal transmission to spermatozoids, and ultimately, to its genetic decay). In tree frogs, both males and females recombine their sex chromosomes, preventing the Y from decaying.

And yet, once upon a time some 200 million years ago, the Y was nearly identical to the X. What happened? As gametes (ovules and spermatozoids) are produced, the two chromosomes of each pair normally bind together and exchange their genetic material, a process called “recombination”. This permits the formation of new genetic combinations that we transmit to our offspring. We are thus perpetually generating new genetic diversity, which has allowed our species to adapt to changing environments, but also to replace genes that have become malfunctional. However,

recombination is turned off between the X and Y chromosomes in males, as it would otherwise mix male Y-genes with female X-genes and create intersex offspring. But this has had long-term detrimental consequences for the Y chromosome, which through time could no longer renew its malfunctional genes, and has progressively degenerated by losing most of them. In fact, it is widely accepted that the human Y chromosome is doomed to extinction, raising popular concern about the fate of the male gender itself…

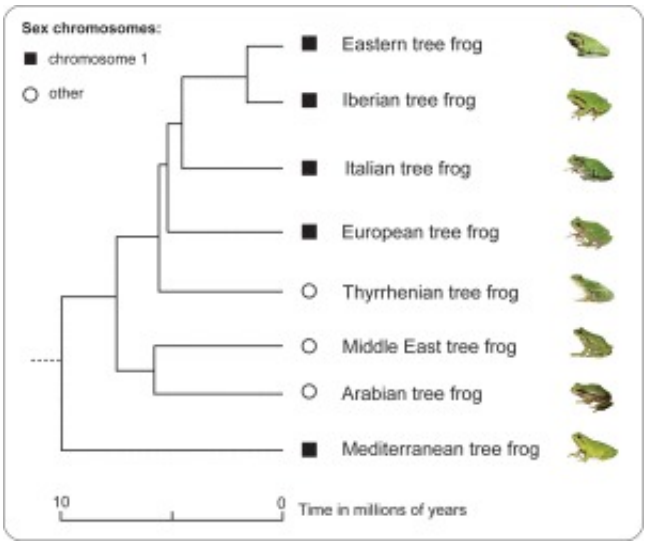

Fig. 2. Tree of sex in tree frogs from Europe and surroundings.
The tree shows relationships between species and the chromosome pair that determines sex (chromosome 1 or other). The sex chromosomes of tree frogs have changed at least twice within the last 10 million years of evolution. Thus, the Y chromosome is replaced before having time to degenerate.

Degenerated sex-chromosomes are not only specific to humans. They are also commonly found in all mammal and most bird species. Thus, this dramatic fate has long been assumed to be the only possible evolutionary outcome. Yet, some animals are exceptions: in fishes and amphibians, sex-chromosomes are often intact; they thus seem to have found a way to prevent their decay.

So how do they do it? A research team from the University of Lausanne led by Dr. Christophe Dufresnes and Prof. Nicolas Perrin have answered this question in European tree frogs, where the Y has stayed identical to the X, both morphologically and in gene content. By analyzing genetic markers in the eight different species inhabiting Europe and the surrounding regions, they showed that this lack of differentiation resulted from two processes acting in parallel.

First, unlike humans, the X and Y chromosomes of every species of tree frogs are still occasionally exchanging genetic material by recombination (Fig. 1). Although this process is very rare, it

appears sufficient to maintain the Y similar to the X, thus preventing its isolation and decay.

Second, the pair of chromosomes that acts as the sex chromosomes has changed several times throughout evolution (Fig. 2). In five tree frog species, the chromosome 1 pair determines sex, but not in the other three species. As these “turnovers” seem frequent (i.e. every couple of million years), no chromosome has remained the Y chromosome for a time sufficiently long to accumulate gene malfunctions and degenerate.

Thanks to these two mechanisms, the Y chromosomes of tree frogs have stayed healthy throughout hundreds of millions of years of evolution. And what about us? It is possible that our Y chromosome disappears, but this should not be an issue. If this were the case, like in tree frogs, it would be replaced by a new one. So men still have good days ahead of them.

By Dr. Christophe Dufresnes

Publication

Sex-Chromosome Homomorphy in Palearctic Tree Frogs Results from Both Turnovers and X-Y Recombination.
Dufresnes C, Borzée A, Horn A, Stöck M, Ostini M, Sermier R, Wassef J, Litvinchuck SN, Kosch TA, Waldman B, Jang Y, Brelsford A, Perrin N
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