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Transposable Elements May Have Had A Major Role In The Evolution Of Higher Organisms

ATHENS, Ga. -- Genes are the on-off switches in plants and animals, directing everything from growth to fighting disease. Until a mere 50 years ago, scientists thought all genes worked from a stable position along a chromosome. Then, a brilliant researcher named Barbara McClintock (who was to win the Nobel Prize) showed that some genes actually move around.

These genes, which scientists now call transposable elements or transposons, have been found in vast numbers in virtually every organism researchers have studied. And yet their role has been the subject of considerable discussion and even controversy. The question remains: Are transposable elements merely self-replicating "junk" DNA as some researchers suspect, or do they contribute to the function and evolution of the organisms in which they reside?

Now, a molecular biologist at the University of Georgia has proposed that transposons may play a crucial and central role in evolution and could be the "missing link" in our understanding of how multicellular and vertebrate organisms arose.

"The whole idea of transposons as purely selfish DNA is beginning to crumble," said John McDonald, a professor in the department of genetics at UGA, "It now appears that at least some transposable elements may be essential to the organisms in which they reside. Even more interesting is the growing likelihood that transposable elements have played an essential role in the evolution of higher organisms, including humans."

McDonald has studied and published papers on transposons for more than 10 years. His new theory was published in the March issue of the journal Trends in Ecology and Evolution, which will be released this week.

For years, researchers believed that transposable elements were simply pieces of rogue DNA, barnstorming through the cellular world like petulant children, causing the misexpression of other genes and, in general, looking out for number one. That early picture, however, began to change dramatically in the 1970s, when it became clear that transposons are pervasive. It simply made no sense that such elements would be conserved over thousands of millennia if they had no real function. So, a number of scientists, including McDonald, began to look at the bigger picture, sensing that transposons may be crucially important to the functioning of all plants and animals.

The evidence is only now becoming clear. Two major events in the history of life were the origin of eukaryotes (multicellular organisms with well-defined cell nuclei) and vertebrates. The evolution of these "higher" forms of life obviously meant a quantum increase in the number of genes needed to direct cellular functions. A scientist at the University of Edinburgh in Scotland, Adrian Bird, has argued that in order to keep the genes working in an orderly manner, higher organisms developed two global gene-silencing mechanisms, one that aided the transition from bacteria and viruses to more complex organisms like yeast and invertebrates, and another which smoothed the transition from invertebrates to vertebrates.

"While Bird's hypothesis is compelling, it did not explain the evolutionary driving force behind the establishment of global silencing mechanisms in the first place," said McDonald. "In recent years, a body of evidence has been accumulating which suggests that these global repression mechanisms initially arose as a defensive response to the selfish drive of transposable elements."

The lines of evidence McDonald uses in developing his theory focus on the two gene-silencing mechanisms that organisms have developed. One of these mechanisms involves the formation of a tangled complex of DNA and protein called chromatin within a eukaryotic nucleus. McDonald argues that chromatin formation likely originated as an adaptive response to the action of transposons.

In fact, studies have found that transposons make up a large part of constitutive heterochromatin, regions on chromosomes that are permanently condensed and, for the most part, genetically inactive in every cell.

The second major gene-silencing mechanism in higher organisms is called methylation. McDonald points out that the vast majority of methylated gene sequences in humans and other vertebrates are contained in transposable elements. Thus, McDonald argues, it is likely that methylation and other related silencing mechanisms also originally evolved as a defense against transposable elements.

"By silencing transposable elements, host genes are able to protect themselves from mutations that actively jumping elements can cause," said McDonald.

The key lies in understanding that these global-silencing mechanisms, which evolved in response to "selfish DNA," have been subsequently co-opted by the host plant or animal cell to serve a regulatory function.

McDonald said it is increasingly clear that organisms need transposons and that their apparent continual back-door assaults on normal genes may, in truth, be more like a vast, sophisticated chess game on an enormously complex board. The new structures and functions that emerge from their battle serve to drive the evolution of the host genomes in which transposable elements reside.

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