Plant polymerases IV and V are special forms of Polymerase II

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A biologist has found that two kinds of RNA polymerase found in plants such as this Arabidopsis are actually derivatives of a much-studied Polymerase II found in eukaryotes. The find has implications for undersanding gene silencing.

(PhysOrg.com) -- It's a little like finding out that Superman is actually Clark Kent. A team of biologists at Washington University in St. Louis has discovered that two vital cellular components, nuclear RNA Polymerases IV and V (Pol IV and V), found only in plants, are actually specialized forms of RNA Polymerase II, an essential enzyme of all eukaryotic organisms, including humans.

"We've caught evolution in the act," said Craig Pikaard, Ph.D., WUSTL professor of biology in Arts & Sciences. "We've known for decades that RNA Polymerases I, II and III are found in all eukaryotes, but it's only over the past several years that we've been aware that plants have two more nuclear polymerases, Pol IV and Pol V. Now it is clear that these enzymes evolved from Pol II over the past several hundred-million years. This is a new snapshot into the evolution of RNA polymerases, which are the enzymes responsible for decoding the information stored in the chromosomes."

Analyzing purified Pol IV and Pol V by a sophisticated technique known as tandem mass spectrometry, the Pikaard lab and a team of collaborators at Pacific Northwest National Laboratory, led by Ljiljana Paa-Toli, discovered 12 subunits in both Pol IV and Pol V that correspond one-for-one to the 12 subunits of Pol II. Some of the Pol IV and Pol V subunits are encoded by the same genes as the corresponding Pol II subunits, but others come from duplicated Pol II subunit genes that have changed over time. Overall, four subunits of Pol IV are distinct from their Pol II counterparts, six subunits of Pol IV are different from their Pol II counterparts, and four subunits differ between Pol IV and Pol V. Yet, all of the Pol IV and Pol V subunits are "apples that haven't fallen far from the Pol II tree."

The finding is important because it reveals more about the roles played by RNA in complex organisms. RNA polymerases are the enzymes responsible for making RNA from DNA templates. They are key players in determining which genes get switched on and which get turned off. RNA Polymerase II, for instance, is vital in the production of messenger RNAs that specify the amino acid sequences of each of the proteins in the cell. Despite having evolved from Pol II, Pol IV and V do not appear to be involved in protein synthesis, or to be absolutely essential for life. Instead, they have taken on specialized roles in gene silencing in plants.

This is important to prevent the expression of potentially harmful genes, such as virus-derived "jumping genes" known as retrotransposons, and invading nucleic acids, such as the genomes of replicating viruses. The Pikaard lab has shown that Pol IV is required for the production of small interfering RNAs (abbreviated as siRNAs) that specify the silencing of matching DNA sequences, whereas Pol V makes longer RNAs that are thought to pair with the siRNAs at the affected chromosomal sites.

Pikaard and his colleagues' work may have implications for applied medical research. For instance, gene therapy procedures sometimes use retroviral vectors as a way of introducing a foreign gene to replace a function impaired by disease. Often this foreign gene, called a transgene, restores the missing function for a while and then unexpectedly goes silent. The silencing process may have parallels to the pathway in plants that makes use of Pol IV and Pol V. Pikaard hypothesizes that Pol II accomplishes the functions of Pol IV and Pol V in other non-plant eukaryotes.

The research revealing the subunit compositions of RNA Polymerases II, IV and V in the plant genus Arabidopsis was published online Dec. 23, 2008 in Molecular Cell. The work was supported by the National Institutes of Health and the U.S. Department of Energy.

Pikaard's laboratory has been investigating the functions of Pol IV and Pol V since playing a leading role in their discovery in 2005. The Dec. 23 Molecular Cell paper is one of three related papers published by the Pikaard lab in rapid succession. In a paper published Nov. 14, 2008 in Cell, Pikaard and his colleagues explain how Pol IV and Pol V work together to use the non-coding region of DNA to prevent destructive, virus-derived genes from being activated. Then in a paper published Dec. 4 in Molecular Cell, the Pikaard lab announced a breakthrough in understanding the phenomenon of nucleolar dominance, the silencing of an entire parental set of ribosomal RNA genes in a hybrid plant or animal. That study is one of the first to demonstrate how siRNAs can

play a role in controlling the dosage of vital genes, and not just harmful genes, and implicates the pathway in which Pol IV and Pol V function.
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