Changing environment organizes genetic structure

November 13 2007

What is the fundamental creative force behind life on Earth? It's a question that has vexed mankind for millennia, and thanks to theory and almost a year's worth of number-crunching on a supercomputer, Rice University physicist and bioengineer Michael Deem thinks he has the answer: A changing environment may organize the structure of genetic information itself.

Deem's research is available online and slated to appear next month in *Physical Review Letters*.

"Our results suggest that the beautiful, intricate and interrelated structures observed in nature may be the generic result of evolution in a changing environment," Deem said. "The existence of such structure need not necessarily rest on intelligent design or the anthropic principle."

The information that allows all living things to survive and reproduce is encoded in genes. Deem's theory probed the structure of this genetic information, looking for patterns that were created over time.

The study by Deem and postdoctoral fellow Jun Sun found the structure of genetic information becomes increasingly modular when two conditions are taken as givens: horizontal gene transfer (HGT) and a changing environment. Like modular furniture that can be rearranged in different functional patterns, modular genes are standardized components that lend themselves to flexible rearrangement, and this genetic modularity arises spontaneously because of the selective pressure

of a changing environment and the existence of horizontal gene transfer.

Genes are typically transferred vertically. People, plants and animals pass genes vertically, from generation to generation, through sexual reproduction. Bacteria transfer genes vertically via conjugation. HGT allows genes, pieces of genes and collections of genes to move between species, even in cases where vertical transfer is physically impossible.

Though scientists have known about HGT for years, it was thought to be rare and infrequent until sophisticated tools opened the genetic history of many species in the 1990s. Today, HGT is widely accepted as the primary reason for antibiotic drug resistance, and Deem said HGT played a significant role in human development as well. "Our acquired immune system is a product of horizontal gene transfer and is organized in a modular fashion," he said.

Deem's study found that an organism's fitness -- the likelihood that it and its descendants will survive in a rapidly changing environment -- increases as the modularity of its genetic code increases. Another finding was that the faster the environment changes, the more modular genetic information becomes.

Because modularity begets complexity, the more modular genetic information becomes, the more complex the web of life becomes. For example, human beings are far more complex than singled-celled yeast, yet they have only about four times as many genes. The complex nature of multicellular plants and animals derives not only from the genes themselves, but also from the complex regulatory networks that control the production and interaction of the products of genes -- proteins -- to fulfill multiple roles. This regulatory network is another example of modular organization.

"Modularity and hierarchy are prevalent in biology, from the way atoms

are arranged in molecules, molecules into amino acids and amino acids into secondary structures, domains and proteins," Deem said. "This hierarchy continues with multiprotein complexes, protein regulation pathways, cells, organs, individuals, species and ecosystems. Our research suggests that modularity and hierarchy are prevalent because genetic information self-organizes into increasingly more modular forms. A changing environment and the biochemistry of horizontal gene transfer appear to be part of the source for this fundamental creativity of life."

Source: Rice University