KECK GRADUATE INSTITUTE
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Allen Foundation Awards Grant to KGI Professor to Study Brain Complexity

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Christoph Adami

To understand how an information-processing network functions, an engineer must appreciate its elements and their interconnections. But when it comes to the brain, with its extraordinary capacity to integrate information and adapt to novel and complex environments, the architecture remains largely a mystery.

Recently, the Allen Foundation awarded a $608,000 grant to a team that includes KGI Professor Christoph Adami (http://www.kgi.edu/Faculty-and-Research/Christoph-Adami.html) , PhD, along with researchers from the California Institute of Technology and the University of Wisconsin-Madison, to better understand how brains are wired. The two-year project is the first step in mapping the connection matrix, or "connectome," of an artificial, evolved brain and the simple brain of a flatworm to learn more about their functional organization.

The application of these techniques to the human brain, however, is still decades away, said Adami, who is on sabbatical this academic year at Michigan State University's BEACON Center for the Study of Evolution in Action (http://beacon-center.org/) .

"Ultimately, we are interested in evolving artificial intelligence with the goal of creating machines that are comparable to higher-functioning animals," he said. "This has been attempted over the last 30 years but nobody was able to design a brain with any complexity."

"The beauty of the process of evolution," he continued, "is that you don't have to understand how something works to evolve its functionality."

Adami, in cooperation with Jifeng Qian, KGI doctoral student in computational and systems biology, and Research Assistant Professor Arend Hintze (http://www.kgi.edu/Faculty-and-Research/Arend-Hintze.html) , PhD, recently published a paper in *PLos ONE* examining the computational tools used in the brain of a flatworm. "Colored Motifs Reveal Computational Building Blocs in the C. Elegans Brain (http://www.plosone.org/article/info:doi/10.1371/journal.pone.0017013) " discusses how to deconstruct the worm brain into its functional parts through color-coded networks.

Adami is involved in a separate paper, now under review by *PLoS Computational Biology*, which explores a new theory of brain complexity based on the concept of information integration. The researchers evolved brains in the computer with increasing performance. At the same time, they observed that their theoretical complexity measure increased as performance increased, thereby validating the measure. In the future, researchers will be able to predict how well a brain performs just by calculating how well it integrates information, allowing more robust comparisons among brains of different species.

These evolving brains are considered more "lifelike" because they rely on sensory information as well as rudimentary memory of past events to make decisions, Adami said.

"As far as we know, we are the first researchers who have been able to evolve true memory in robot brains," he added.

Whirlwind Sabbatical

Adami has spent much of his sabbatical publishing research conceived during his first six years at KGI. He is also determined to finish his book, *Evolution of Biological Information and Complexity*, which he

started in 2002. It explores how biological evolution increases the amount of information stored in an organism's genes, leading to increased complexity throughout evolutionary history.

As a theorist, he is collaborating with practitioners at Michigan State University to apply information theory to solve real-world problems, such as HIV drug resistance. He is joined by four other KGI colleagues at the BEACON Center, including Hintze, who is on leave from KGI to work as a research scientist at the center. Bjorn Ostman (PhD '10) is completing his postdoctoral research at the center. PhD student Nicolas Chaumont is on leave from KGI this academic year, supported by BEACON funds, and PhD student Jory Schossau will go on leave to work with the center starting in June.

Adami was instrumental in developing the "Avida Artificial Life" system, which creates an environment within any standard computer in which populations of computer programs can live, evolve and adapt. That system is central to the BEACON's approach to digital evolution systems that can fuel a technologically brighter world.

By Margie Fishman

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