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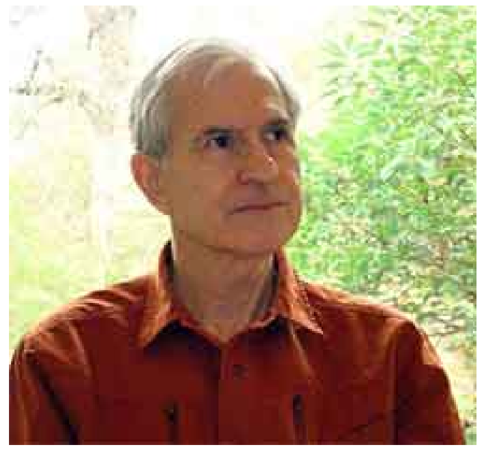
# The Mechanism of Short-Term Memory

## SDSC's Trestles supercomputer used to calculate the top-down activities of the brain

*"The Holy Grail of neuroscience has been to understand how and where information is encoded in the brain."*
-Thomas R. Insel, Director of the National Institutes of Mental Health, November 2012



*Lester Ingber, UC San Diego Ph.D. '66.*

Insel's quote appeared in a National Institutes of Health (NIH) press release that described a newly published study of monkeys in the journal Science, where researchers for the first time found that in-sync large-scale brain waves affecting various regions of the brain hold memories of objects just viewed. "This study provides more evidence that large-scale electrical oscillations across distant brain regions may carry information for visual memories," added Insel.

For Lester Ingber, a researcher based in Ashford, Oregon who received a Ph.D. in physics from UC San Diego in 1966, those types of studies by other established researchers that have begun to emerge only in recent years highlight a concept he's been investigating for more than 30 years: the relationship between large-scale, or "top-down" activities in the brain and short-term memory and consciousness.

One of Ingber's research interests is focused on what are known as multi-scale neocortical (of the brain's neocortex) interactions, including calculations of short-term memory and electroencephalogram (EEG) processes, which involve measuring electric currents in the brain.

As a user of the advanced digital resources within the National Science Foundation's eXtreme Science and Engineering Discovery Environment, or XSEDE, Ingber received an allocation on the *Trestles* supercomputer at the San Diego Supercomputer Center (SDSC) at the University of California, San Diego, which is a member of XSEDE.

Ingber used the flash memory-based cluster to facilitate research for his latest paper, published November in the *Journal of Theoretical Biology* and called "Electroencephalographic Field Influence on Calcium Momentum Waves." In that paper, the latest in a series, Ingber again connected the mechanism involved in conscious attention to short-term memories with the influence of synchronous EEG-measurable brain waves at the molecular scale.

"Such research discoveries, including the demonstration that large-scale brain activity as measured by scalp EEG does, in fact, process memory, present a compelling argument for continuing to study what occurs on the large scale in the brain," said Ingber.

In his paper, Ingber develops a model built from electrically excitable neurons and star-shaped multifunctional astrocytes, the most-abundant type of cell in the human brain. The neurons transmit electrical and chemical signals via synapses and waves of Ca2+ (calcium ions), flowing from astrocytes to neuron–neuron synapses, affect other electrical and neuromodulator (neuron-altering substance) processes. He explains the flow of influence as going from highly synchronized neuronal firings to Ca2+ waves, to astrocyte–neuron interactions, which in turn are likely, but not experimentally confirmed, to affect background 'spontaneous' synaptic activity that has been observed for many years to shape short-term memory.

"This work has provided a new test-bed to process models of Ca2+ waves influencing neuron-astrocyte interactions, which themselves are influenced by highly synchronized neuronal firings," said Ingber.

In using SDSC's *Trestles* cluster, Ingber was able to complete a month's worth of processing in only six hours. "Some similar work I did years ago actually took a few months of constant calculations on a then-powerful Convex machine," he noted.

"Dr. Ingber's work was ideally suited for *Trestles* in that he had developed an innovative model on lab-scale computational resources, but the computational demands of his research outgrew what was possible on his local resources," said Glenn K. Lockwood, a user services consultant with SDSC. "We worked with him to connect his single-node, multithreaded code to an MPI-based framework that fully exploited the data parallelism inherent in his project, allowing his entire dataset to be fitted using the most sensible and efficient forms of concurrency."

Ultimately, Lockwood wanted to ensure that Ingber's research was not slowed by the transition from computing on lab-scale resources to using national-scale resources. "*Trestles* was designed to serve users and communities that are new to larger-scale high-performance computing, and to also provide researchers with quick turnaround times," he said. "Plus, we want to make sure that researchers make the most productive use of their time by focusing on their own research instead of having to overcome any technological challenges on the computing end."

“I’m truly indebted to the XSEDE organization in general, and to Glenn Lockwood in particular, for enabling me to concentrate on the physics/neuroscience/coding of this project without having to take out time to fully learn yet another parallel language – which of course is important and still on my agenda,” said Ingber.

*(This release is based on an earlier article by Scott Gibson, XSEDE External Relations and the National Institute for Computational Sciences, University of Tennessee.)*

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