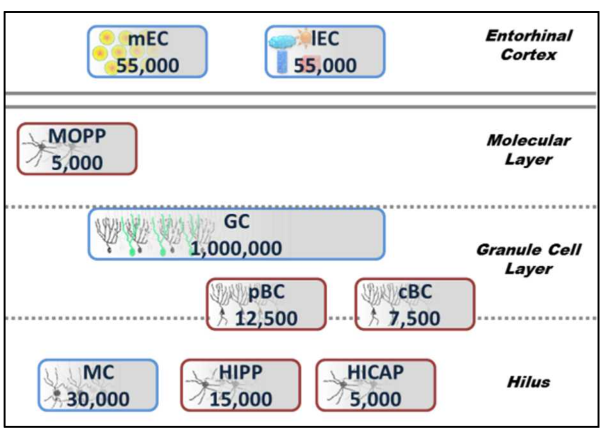
LDRD Highlight: Using High Performance Computing to Examine the Processes of Neurogenesi SAND2015-1443R **Separation/Completion of Episodic Information -** Sandia researchers developed novel methods and metrics for studying the computational function of neurogenesis, thus generating substantial impact to the neuroscience and neural computing communities. This work could benefit applications in machine learning and other analysis activities.

Background: Understanding how the brain distinguishes between patterns of related events that are separated in time could have far-ranging impacts with regard to Sandia's ambition to establish next-generation memory processing and pattern recognition systems. The purpose of this project was to computationally model the impact of neural population dynamics within the neurobiological memory system in order to examine how subareas in the brain enable pattern separation and completion of information in memory across time as associated experiences. Studies suggest a neural region responsible for memory encoding, the dentate gyrus, DG, is aided by lifelong neurogenesis, which is the generation of new neurons that enter into the local network. Neurogenesis may serve to support the process of discriminating (separating) patterns by reducing similarity between new and older event information. It may also support pattern completion by increasing associations between temporally similar events, which are then transmitted to the CA3 area of the hippocampus as sparse inputs. ***LDRD Accomplishments*:** This project examined the computational function of neurogenesis from a number of different perspectives. The researchers achieved human scale neuron number in simulations of the neurogenic DG region, which is among the first times this has been done in biologically realistic, hypothesis driven computational neuroscience research. As shown in Figures 1 and 2, these *scaling studies showed a marked interaction of scale with neurogenesis function, demonstrating that the presence of new neurons is more important in larger brains and thus perhaps uniquely important for human cognition.* A procedure for assessing the sensitivity and validity of large-scale neural models was developed; *this application of uncertainty quantification techniques to neuroscience is among the first demonstration of these methods to neuroscience* Finally, the team developed novel metrics for assessing the information content of the neurons in their simulations. These ensemble based information methods are based on compression theoretic approaches in computer science. ***LDRD Impact*:** *This work is among first human-scale neural circuit models that address a meaningful biological question, specifically the function of adult neurogenesis which has been implicated in a number of cognitive tasks.* The UQ approach and novel metrics have broad potential relevance to neuroscience community, both as potential tools in understanding neural function and potentially informing government programs. This work helped inspire a number of machine learning techniques that have potential impact in extending algorithmic pattern recognition capabilities. Identified potential application of neurogenesis based algorithms in compressive sensing are tightly aligned with the Beyond Moore's Law Research Challenge (as well as Detection at Limits and Data Sciences RCs). Additionally, the neurogenesis-inspired algorithmic adaptation approaches will contribute to Hardware Acceleration of Adaptive Neural Algorithms (HAANA) Grand Challenge.



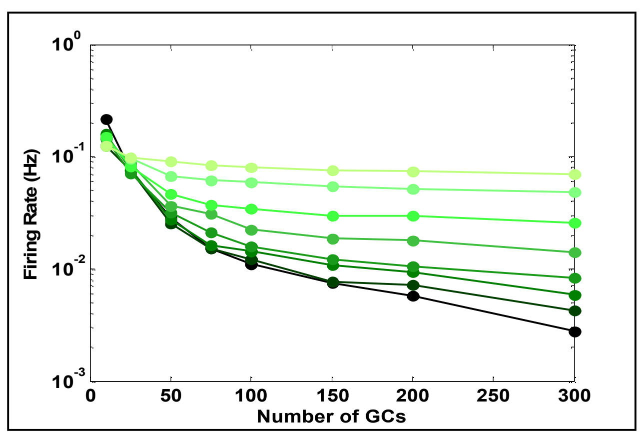


FIGURE 1 *(left)* Network diagram of simulated dentate gyrus circuit with realistic neuron numbers in rats. Human dentate gyrus region has ~10x levels, which was simulated on RedSky. ***Figure 2*** *(right)* Simulation scaled up to biologically realistic scales (x-axis is 1000s of neurons; lighter green lines are progressively higher neurogenesis levels), depicting the significant impact of scaling on function. Mouse: 300,000 GCs (principle neurons); Rat: 1,000,000 GCs; Human: 10,000,000 GCs; Synapses limiting – human ~10^{11} synapses; Human scale simulations (for a few seconds of activity) required 1200 cores for ~15 Red Sky hours.

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LDRD Highlight: Atomistic *Background:* . *LDRD Approach:* . *LDRD Accomplishments:* . *LDRD Impact:*

Upcoming LDRD Events

- March 2 – April 9: LDRD Idea Reviews
- April 14 – May 21: New and Continuation Standard and Grand Challenge proposals submission

LDRD Projected Budget and Status

- FY15 Q2 - $146M, 359 projects funded at $135.6M

Awards and Recognition for LDRD Participants:

- Somuri Prasad was awarded the Asian American Engineer of the Year award, by the Chinese Institute of Engineers-USA to honor outstanding Asian American professionals in STEM. (See the June 2014 LDRD Monthly report feature article, **Synthesis of Wear-Resistant Electrical Contact Materials by Physical Vapor Deposition leads to development of E-Beam Hard Gold**)
- Patrick Feng was also recognized by the Chinese Institute of Engineers, in the Most Promising Engineer of the Year award category. (See the September 2014 LDRD Monthly report feature article, **Triplet-Harvesting Plastic Scintillators**.)