

# Mathematics of the Brain—But What About Mathematics *in* the Brain?

By William Kolata

This issue of *SIAM News*, in conjunction with Mathematics Awareness Month (April 2007), is devoted to advances in mathematical and computational studies of the brain. This is a field with a long history. Almost from the very beginning of the era of digital computers, researchers have risen to the challenge of using computers to create and understand complex mathematical models of the brain.

K.S. Cole, H.A. Antosiewicz, and P. Rabinowitz, in a 1955 article in the *Journal of the Society for Industrial and Applied Mathematics* [1], described their attempt to model the Hodgkin–Huxley equations on the SEAC (the National Bureau of Standards Eastern Automatic Computer). A subsequent (1959) article in the journal by R. Fitzhugh and Antosiewicz [3] describes a coding error in the SEAC program that introduced “a spurious saddle point which had a strong effect on the solutions of the membrane action potential near threshold”; otherwise, the authors continue, the “error seems to have had little effect on the shapes” of the graphs.

This is perhaps an early example of the scientific paradigm used so successfully ever since to study the brain, as well as other phenomena:  
experiment → mathematical model → digital machine computation → experiment.

The application of mathematics to study the brain has resulted in remarkable progress, as the articles in this issue illustrate. But with the use of new experimental tools (functional MRI and direct recording of neural response), neuroscientists have begun recently to look at the flip side—namely, how the brain does mathematics.

This was brought home to me by a recent article in *Science* magazine with the somewhat obscure title “Temporal and Spatial Enumeration Processes in the Primate Parietal Cortex” [4]. The researchers made direct recordings from the brains of monkeys that had been trained on a temporal and spatial recognition task; specifically, they recorded activity of neurons in the intraparietal sulcus (a horizontal groove in the parietal lobe of the cortex, which sits behind the frontal lobe but forward of the rearmost (occipital) lobe). The researchers identified three sets of neurons: one for recognition of cardinality, another for recognition of ordinality, and a third for integration of this information into an abstract representation of quantity.

Readers might share my first reaction: Who would have expected the distinction between cardinal and ordinal numbers to be so important in the brain? Further thought led to what seems to be a plausible explanation, from evolution. Human primates evolved as hunter/gatherers in mixed environments, savannah and forest. The ability to estimate quantities of resources or competitors would have been advantageous—at a single glance over the open savannah and by enumeration in time in dense forest. Thus, cardinal and ordinal representations may have developed separately, perhaps at different times. Later in evolution, the estimation and processing of quantity may have become important enough to favor the integration of these processes.

Pursuing this topic a bit further, I found a nice 2004 review article, “Arithmetic and the Brain” [2]. The authors conclude by offering challenges for neuroscience, among which is to understand the local coding of these number-related areas and their global coordination. One day, I can imagine neuroscientists studying the brains of applied mathematicians who are studying the brain.

## References

- [1] K.S. Cole, H.A. Antosiewicz, and P. Rabinowitz, *Automatic computation of nerve excitation*, *J. Soc. Indust. Appl. Math.*, 3 (1955), 153–172.
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- [3] R. Fitzhugh and H.A. Antosiewicz, *Automatic computation of nerve excitation—detailed corrections and additions*, *J. Soc. Indust. Appl. Math.*, 7 (1959), 447–458.
- [4] A. Nieder, I. Diester, and O. Tudusciuc, *Temporal and spatial enumeration processes in the primate parietal cortex*, *Science*, 313:8 September (2006), 1431–1435.

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