interconnected network. Those neurons fire with significant and precisely timed synchrony;[1] we cannot measure how such synchrony in input affects a single cell. On the one hand, such synchrony creates problems for cells that average out presumably uncorrelated inputs;[2] in a pulse code, on the other hand, single-spike synchrony might be the *signal* (not correlated noise),[3] performing a subtle computation like figure–ground computation.

This is just one of the indirect indications that cortical neurons may compute with single spikes rather than with temporal averages of them. Let me highlight two others:

▷ *All neurons are not created equal.* The behavior of a canonical "neuron" (as shown in Hopfield's figure 4) bears little relation to that of neurons in visual cortex. The canonical neuron—typically a motor or sensory neuron—behaves like a "relaxation oscillator" (as Hopfield reminded me during my thesis exam): Its voltage ramps steadily upward until it reaches a "threshold," at which it fires and resets to a low voltage. But when a *cortical* neuron is visually stimulated, the voltage inside it has strong and apparently random fluctuations, without ramping, and returns to *near* the threshold (rather than far below it) right after a spike is fired, as shown in many published records.[4]

The fact that intricately branched cortical neurons bear little resemblance to the "compact" canonical ones may help explain this difference. The presence of positive-feedback properties in these electrically remote branches[5] makes them capable in principle of performing very fast temporal discriminations,[6] which may appear as strong fluctuations in the cell's voltage. This idea remains speculative, because the most numerous of the branches are so much thinner than a recording electrode that no one has yet directly recorded their fastest electrical behavior.

▷ *The source and function of firing irregularity are not understood.* While a canonical neuron fires fairly regularly at all but its slowest rates, cortical neurons seem to fire very irregularly—almost randomly—at *all* rates. It is very difficult to reconcile this irregular output with a neuron model that performs significant temporal averaging.[7] In fact, despite order-of-magnitude disagreements about many key parameters, no published realistic model has yet produced realistic, fast firing patterns. In general, any neuron model that *can* produce strong firing irregularity (without resorting to *ad hoc* random numbers) is also capable of discriminating at single-spike time scales.

This irregularity is usually viewed as noise that contaminates an average-rate code. It might equally well be viewed as high-bandwidth *information* in a binary pulse code, if cells have the temporal precision to make use of it. A simple estimate[8] indicates that such a pulse code can carry at least a hundredfold more information than a purely analog rate code using the same irregular spikes. Could Nature be making use of the extra bandwidth of irregular spiking, in accordance with Hopfield's dictum that "if some quirky detail of neurobiology is useful in an important but special computation, that detail can be selected for and improved by evolution"?

At the moment, our knowledge of single neurons in cortex is much like the knowledge one gets of a computer's disk drive by watching the flickering light on its front: We observe the time-averaged activity and try to infer what caused it. But in cortex we do not yet know the detailed mechanisms producing that activity or their temporal precision. Without that knowledge it may be premature to accept the simplification that cortical neurons use a slow average-rate code while ignoring their strong, unexplained high-frequency signals as "inconvenient details."

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Polymers' Progress as Efficient Diffractors

Anthony Garito, Rui Fang Shi and Marvin Wu (May 1994, page 51), discussing the photorefractive effect in organic polymers, state, "These devices have shown response times and diffraction grating efficiencies . . . close to those of inorganic devices." The paper cited in this context is the first demonstration of the photorefractive effect in a polymer, performed in 1991. The diffraction efficiencies observed in that work were very small (on the order of 10^{-5}) and should not be compared to the performance of inorganic photorefractive materials. Since then, rapid progress in the field of organic polymer photorefractive materials has led to diffraction efficiencies as high as 35%, which do rival or in some cases exceed the performance of inorganic photorefractive materials.[1] Work in progress shows diffraction efficiencies approaching 100%. These results make organic photorefractive materials an exciting new prospect for nonlinear optical devices.

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North Dakota Firing Was Faculty Fueled

As members of the physics department at North Dakota State University, we feel it necessary to respond to the letter (October, page 90) protesting the dismissal of Manuel de Llano, a tenured professor in our department. Since none of the authors of that letter contacted any of us, we presume that they based it on information provided them by de Llano. Whoever controls your information can easily persuade you.

The letter strongly implies that de Llano's dismissal is a punishment for his public criticism of the NDSU administration. However, the process actually began with a *unanimous* request from the physics department faculty for his dismissal. We presented that request to the administration over three months before the state legislative audit committee hearing at which de Llano gave the testimony that the letter's authors suggest was one of the causes of his dismissal. The major cause, however, is his conduct within the department, which has been consistently disruptive and has interfered not only with his own functioning as a faculty