

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 branches⁵ 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 estimate⁸ 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

member but also with ours. The censure mentioned in the letter was not for his public statements but rather for his taking complaints outside the department *before* attempting to resolve them within the department. The letter fails to mention that before that censure de Llano had been repeatedly censured by the department and reprimanded by the dean for yet more serious misconduct. That de Llano has also criticized the NDSU administration in public makes it easy to portray the matter as an issue of academic freedom or freedom of speech. It is not.

Some idea of the careful selection of information that appears to have been made available to the letter's authors can be had by examining their statement of de Llano's accomplishments at NDSU. Supposedly he "reformed and revitalized the department during his five-year term" as chair. De Llano was in fact hired as chair in 1985 for a three-year, not five-year, term, at the end of which an election for chair was to be held. That election, however, was canceled with the dean's consent and against the tenured faculty's recommendations. De Llano then continued as chair until the spring of 1990, when a strong and unanimous request initiated by the department faculty resulted in his removal from that position. This removal revitalized the department more than any action of de Llano's had. Indeed, research activity and grantsmanship have increased markedly since that time. De Llano's behavior, however, has grown progressively more disruptive, to the point where we felt compelled to request his dismissal.

As faculty members, we are keenly aware of the importance of tenure for the protection of academic freedom. Since dismissing a tenured professor is an extraordinary measure that must be taken only in extraordinary circumstances, any such action that appears to threaten academic freedom must be examined carefully. However, such examination requires access to *all* the facts, not just those selected by one party.

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Do Pensions Siphon Funds from Research?

Having recently left my position as a research specialist at Ohio State University, I have had the opportunity to learn about the pension plan. There is both an employee and an employer contribution; in my case the employer contribution was paid by Federal grants (NSF, DOE) in the amount of 13.5% of salary, which amounted to tens of thousands of dollars. Despite my having served long enough to qualify for pension vesting, the so-called benefits are so meager that it is financially favorable for me to request the return of the employee contribution (that is, my money), which has been held without interest for up to six years. I won't see a penny of the 13.5% ever.

In fact, it is practically impossible for a postdoc or similar employee of Ohio State University to gain anything from the pension plan. Yet this hefty charge limits available funds and hence salaries.

An additional "benefit" charged to the Federal government was 1.1% of my salary (thousands of dollars after several years), which went to pay for "early retirement." To the best of my knowledge, this money is charged to both faculty and staff members and paid entirely to faculty members. University overhead of 46% is charged on top of these "direct" costs.

Perhaps the general lack of research funds and the low salaries for scientists employed on a short- or not-so-short-term basis are due partly to systematic redirection of those funds to other purposes. I am interested in collecting similar stories (preferably with documentation) to help determine if a formal study is warranted.

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Support for Science: Rationales and Ratios

I very much agree with the main points of Roland W. Schmitt's article "Public Support of Science: Searching for Harmony" (January 1994, page 29). However, Schmitt overlooks one important benefit of science that seems to be missing from most discussions of the rationale for the support of science in the post-cold-war era. Science is important to society not just as a neutral tool to be applied toward meeting societal demands that originate entirely outside of science.

It is also important in helping to shape what those demands will be. Clearly a society whose members believe that the Earth is the center of a universe designed specifically as a stage for humankind to prove its worth will set very different goals for itself than a society that believes we occupy a tiny speck in a universe that evolved for billions of years before producing us.

Schmitt's discussion of societal concerns focuses on the need to recognize "what new things we must learn about nature or what pioneering concepts need to be invented to address these concerns." What is omitted is that the "new things we learn about nature" tell us something more about what our concerns should be. If the efforts of our society are to have real significance, we need to do the best we can to base our goals on a true understanding of how the universe is. This, it seems to me, is the most important benefit that science has to offer.

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Roland Schmitt helps perpetuate the myth that the Defense Department owns 60% of US Federal research and development expenditures (roughly \$40 billion of the \$75 billion annual total). Anyone as familiar with the DOD budget as Schmitt is must know that this is a red herring. Misleading ratios are not a satisfactory substitute for logical planning in deciding how much to cut defense R&D in the post-cold-war era.

The \$40 billion figure erroneously cited for the DOD is not just R&D but RDT&E (the T&E denotes "test and evaluation"). The true science and technology portion of the RDT&E total (budget lines 6.1, 6.2 and 6.3a, for the fiscally informed) amounts to about \$8 billion. The rest of the RDT&E budget goes to pay for things like F-22 aircraft development, missile defense deployment, operation of test ranges, military system upgrades and field engineering support.

Thus what a physicist would call R&D is really only about \$8 billion per year. A quick calculation shows this to be only about 18% of what the Feds put into *real* R&D. Included in this \$8 billion is over \$1 billion for basic research, distributed to hundreds of universities by the research organizations of the Army, Navy, Air Force, Advanced Research Projects Agency and Ballistic Missile Defense Organization. There's obviously no magic about attaining a 50:50 split