plementing a field-effect gate-induced Josephson junction (*1*). In this device, the electrodes are field-effect–doped such that the system becomes superconducting below a critical temperature determined by the gate voltage. By lithographically profiling the gate (see the figure), Schön *et al.* were able to induce a planar junction with an interface region with lower charge carrier density. In this structure, the electrodes become superconducting, whereas the area between them remains normal, creating an SNS-type junction within a single material. The SNS junction produced by Schön *et al.* (*1*) shows appreciable current at low applied voltage, indicating a strong proximity effect. A highly important result is the large I_cR_N product of critical current I_c and normal resistance R_N, which indicates that the same conducting modes contribute to both normal and superconducting transport.

An advantage of the present technology is that the SNS structure consists of a single material, thus avoiding problems with interface barriers and disorder. Furthermore, the technology of the Bell Labs group opens up the possibility of fabricating flexible proximity circuits in which several parameters of the normal and the superconducting regions can be tuned, such as the critical temperature and the geometry. By extending their approach in an obvious way through splitting and adding gates, it should be possible to design superconducting switching networks with interesting properties. Such devices could be used to develop tunable ballistic proximity dots and constrictions in which a small number of discrete quantum electronic modes are selected by split gates and Andreev reflections. Localized Andreev states in such structures may serve as qubits and logic gates for quantum computation.

References

1. J. H. Schön, C. Kloc, H. Y. Hwang, B. Batlogg, *Science* **292**, 252 (2001).
2. B. D. Josephson, *Phys. Lett.* **1**, 251 (1962).
3. A. F. Andreev, *Sov. Phys. JETP* **19**, 1228 (1964).
4. E. Scheer *et al.*, *Nature* **394**, 154 (2000).
5. V. T. Petrashov *et al.*, *Phys. Rev. Lett.* **74**, 5268 (1995).
6. J. J. A. Baselmans *et al.*, *Nature* **397**, 43 (1999).
7. H. Takayanagi *et al.*, *Phys. Rev. Lett.* **54**, 2449 (1985).
8. H. Schön *et al.*, *Nature* **406**, 702 (2000).
9. H. Schön *et al.*, *Nature* **408**, 549 (2000).

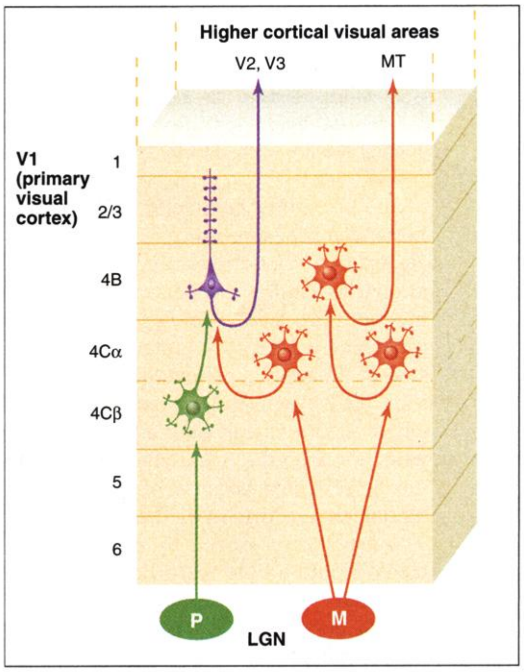
PERSPECTIVES: NEUROBIOLOGY

Function Following Form

Jonathan B. Levitt

Does the morphology of a neuron and its many processes (axons and dendrites) tell us what it does for a living? If so, anatomical information could serve to classify neurons into distinct functional classes. This issue has been of interest to neurobiologists ever since Cajal used a silver stain to demonstrate the dazzling complexity and diversity of neuronal forms throughout the central nervous system. In certain neurons, such as retinal ganglion cells, there is a strong correlation between the structure of their dendrites (slender extensions emanating from the neuronal cell body), the pattern of incoming electrical signals (inputs) they receive from other neurons, and their function. But elsewhere in the brain, for example in the cerebral cortex, we have only hints as to these relationships (*1*, *2*). On page 297 of this issue, Yabuta *et al.* (*3*) report a striking correlation in the primary visual cortex (area V1) of the monkey. They show that two different morphological classes of V1 neurons, spiny stellate cells and pyramidal cells, receive different signals from two major streams of visual information from the retina and then direct this information to higher cortical visual areas.

The visual system relays different types of visual information in parallel through the magnocellular (M) and parvocellular (P) pathways of the retina. The M and P pathways transmit this information to separate divisions of the visual thalamus and themselves terminate in separate layers of V1 (layers 4Cα and 4Cβ, respectively). Layer 4C neurons project to other layers of the visual cortex, which provide outputs to higher cortical areas (V2, V3, MT) that are thought to mediate distinct visual abilities, such as seeing color or motion (see the figure). The different activities of these areas might reflect differential contributions from the P and M pathways. Layer 4B, one of the targets of relays from layer 4C, contains many direction-selective neurons that respond better to stimulus motion in one direction than in the opposite direction. Layer 4B neurons receive a prominent M input, and provide a substantial output to visual cortical areas such as area MT (V5) known to be important in motion perception. Convergence of M and P signals onto single cells in layer 4B has previously been demonstrated (*4*), but Yabuta *et al.* now show that this convergence occurs only on certain cells in this layer. Using an elegant combination of anatomical and electrophysiological techniques in monkey brain slices from cortical area V1, Yabuta *et al.* determined the locations of neurons providing excitatory inputs to neurons in layer 4B. They then labeled the cells whose activity they had recorded. Their results show that different morphological classes of cells within layer 4B receive distinct patterns of input from layer 4C. Spiny stellate neurons receive strong input from layer 4Cα but none from 4Cβ, whereas pyramidal neurons receive strong input from both layers 4Cα and 4Cβ (see the figure).



Information relays in the visual cortex. Distinct types of visual signals (M and P) are relayed from the retina through separate divisions of the lateral geniculate nucleus of the thalamus (LGN) to different portions of primary input layer 4C of the primary visual cortex (V1). A further relay conveys these signals to layer 4B, which provides a major output from V1 to higher visual areas (V2, V3, MT). Spiny stellate cells in layer 4B (orange), which project to area MT (V5), receive a strong M input but no P input. Pyramidal cells (purple), which project to areas V2 and V3, receive both M and P inputs.

These results are important beyond simply classifying cells on the basis of morphology. Because stellate and pyramidal cells of lay-

---

The author is in the Department of Biology, City College of New York, New York, NY 10031, USA. E-mail: jbl@sci.ccny.cuny.edu

er 4B appear to project to separate higher visual areas (*5, 6*), knowing which visual signals they carry may help to distinguish the different streams of information transmitted through visual areas of mammalian cerebral cortex (particularly those areas that mediate motion perception) (*7, 8*). For example, the pathway emanating from layer 4B is thought to be dominated by the M system and therefore is essentially insensitive to color information. Can P signals be detected emanating from layer 4B in experiments in vivo? If so, what perceptual relevance might they have? Also, not all cells in layer 4B are directionally selective; are these cells primarily stellate or pyramidal in morphology? What are the visual response properties of these cells? Do they too project to visual motion areas such as MT? Yabuta *et al.*'s data make an important contribution to our understanding of how differences among the various parallel pathways emanating from V1 might acquire their unique functional characteristics.

Why might the cerebral cortex segregate relays of visual information in this way? Perhaps there is a need to isolate particular projection pathways leaving V1 from the influence of feedback inputs (from higher cortical areas back to V1). Pyramidal cells can be distinguished from stellate cells because they have access through their apical dendrites to feedback projections from higher cortical areas, which terminate in the upper cortical layers. It may be that some visual computations use feedback from downstream cortical areas, whereas others do not. Cells in layer 4B retain some of the characteristics of their inputs, but they are more selective for the spatial frequency, direction of motion, and orientation of the stimulus. This clearly indicates that they perform further computations on incoming information. The Yabuta *et al.* findings suggest that some aspects of visual motion are analyzed solely in a feedforward ("bottom-up") manner, whereas others make use of feedback ("top-down") signals. Different motion perception pathways could consist of a color-blind motion channel versus one multiplexed with chromatic information, or of channels concerned with motion at different spatial scales or speeds. The suggestion of selective access to feedback is complicated by the fact that certain feedback pathways to V1 (from areas V3 and MT) terminate broadly within layer 4B itself, but these pathways might specifically target different groups of neurons.

Are projection pathways distinguished this way elsewhere in the cerebral cortex? Because a variety of systems in the brain consist of multiple parallel subsystems, the visual cortex is a valuable model, reminding us that anatomy and physiology do indeed have something to do with one another.

References

1. G. Einstein, D. Fitzpatrick, *J. Comp. Neurol.* **303**, 132 (1991).
2. J. A. Matsubara, R. Chase, M. Thejomayen, *J. Comp. Neurol.* **366**, 93 (1996).
3. N. H. Yabuta, A. Sawatari, E. M. Callaway, *Science* **292**, 297 (2001).
4. A. Sawatari, E. Callaway, *Nature* **380**, 442 (1996).
5. J. B. Levitt, T. Yoshioka, J. S. Lund, *J. Comp. Neurol.* **342**, 551 (1994).
6. S. Shipp, S. Zeki, *Eur. J. Neurosci.* **1**, 309 (1989).
7. K. R. Gegenfurtner, M. J. Hawken, *Trends Neurosci.* **19**, 394 (1996).
8. B. A. Wandell *et al.*, *Neuron* **24**, 901 (1999).

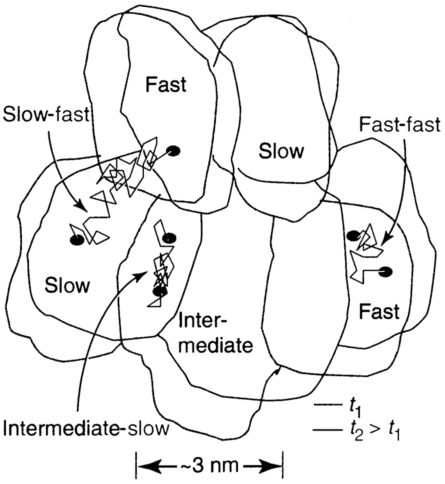
PERSPECTIVES: PHYSICAL CHEMISTRY

Single Molecules Rock and Roll Near the Glass Transition

M. D. Ediger and J. L. Skinner

The motion of molecules in liquids and solids is traditionally measured by spectroscopy and by the scattering of particles or radiation. Such experiments usually average over a very large number of molecules. Recently, researchers have developed techniques for measuring the dynamics of individual molecules in condensed systems (*1–3*). Single-molecule experiments can provide a wealth of new information in cases where different molecules exhibit different dynamics (*4, 5*). An impressive example is reported on page 255 of this issue by Deschenes and Vanden Bout (*6*), who have measured the rotation of individual dye molecules in a polymer film a few degrees above the glass transition temperature T_g (the temperature below which the polymer becomes an amorphous solid). They find that different molecules rotate with very different rates. This may have important implications for our understanding of the glass transition, which has been a notoriously difficult challenge.

Glasses are important as structural and optical materials and are also used for drug delivery applications and biological tissue preservation. If crystallization can be avoided while a liquid is cooled, the molecules in the liquid move more and more slowly. Eventually, motion is frozen (at least on the time scale of human perception) and an amorphous (noncrystalline) solid is formed. Although glasses have been used as practical materials for millennia, there is no agreement about what causes the slowdown of molecular motion responsible for the glass transition. One clue comes from contrasting the motion in a high-temperature liquid with that in a material near T_g. In the past 10 years, ensemble experiments (which involve large numbers of molecules) have been interpreted to indicate that dynamics near the glass transition are spatially heterogeneous (*7–9*): Dynamics in one region of the sample may be orders of magnitude faster than in another region only a few nanometers away, even though the material may contain only a single type of molecule and exist in a single thermodynamic phase. Regions of different dynamics do not remain fixed in space but rather evolve on very long time scales (perhaps as long as weeks or more). If this view is correct, then individual molecules will have different rates of motion at different places in the material, and the rate of mo-



Dynamics of individual molecules near T_g. Regions of different dynamics at two different times (t_1 and t_2) showing possible trajectories of individual molecules in such a heterogeneous environment. Each trajectory is labeled to indicate how the reorientation of this molecule would be observed to change with time. Spatial aspects of this figure are inferred from other measurements (*12*).

The authors are in the Department of Chemistry, University of Wisconsin–Madison, Madison, WI 53706, USA. E-mail: ediger@chem.wisc.edu, skinner@chem.wisc.edu