order of an entire phalanx—whereas RA cells had smaller receptive fields—on the order of half a phalanx in size. Field centers for SA cells on the proximal and middle phalanges were centrally located on the digit, whereas those for RA cells favored the radial and ulnar aspects of the digit. Receptive fields for RA cells, however, overlapped the central portion of the digit. Within the distal phalanx and digit tip representation, in contrast, the receptive fields for SA cells were smaller than receptive fields for RA cells. An inverse relation between receptive field area and cortical area of reprsentation, which held generally over larger regions of the area 3b representation (*8*), also seemed to hold within the finer organization of the area 3b map.

We regard these observations as an important step in the understanding of the modular organization of the somatosensory cortex. In a sense, the four architectonic strips 3a, 3b, 1, and 2 constitute the initial functional subdivisions of the somatosensory cortex, each receiving different submodal inputs systematically from the entire body surface. This study suggests that area 3b receives predominantly cutaneous input (*9*) and is further divided into alternating bands of neurons related principally to the SA and RA cutaneous receptor types. The skin surface is represented separately by the neurons in each functional class. We have shown previously that the cortical area that would represent a point on the skin within the area 3b representation in owl monkeys is 500 to 600 μm in diameter (*8*). The dimensions of SA and RA bands obtained in this study are consistent with the hypothesis of a point's being subserved by both afferent types. Alternately, the cortical area that would represent a region of skin the size of a receptive field is 1 to 1.2 mm in diameter. Such an area would contain approximately one set of adjoining SA and RA bands. This concept of cortical organization for area 3b of primates is directly analogous to the concept of ocular dominance columns being combined in "hypercolumns" in area 17 of monkeys (*2*) and does not preclude the existence of other segregated features of cortical organization in area 3b such as the orientation columns in area 17.

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References and Notes

1. V. B. Mountcastle, *J. Neurophysiol.* **20**, 408 (1957).
2. D. H. Hubel and T. N. Wiesel, *Proc. R. Soc. London Ser. B* **198**, 1 (1977).
3. The spatial distribution of neurons with excitatory-excitatory or excitatory-inhibitory binaural response properties within primary auditory cortex of cats has been studied [T. J. Imig and H. O. Adrian, *Brain Res.* **138**, 241 (1977); J. C. Middlebrooks, R. W. Dykes, M. M. Merzenich, *ibid.* **181**, 31 (1980); T. J. Imig and J. F. Brugge, *J. Comp. Neurol.* **182**, 637 (1968)].
4. M. M. Merzenich, J. H. Kaas, M. Sur, C. S. Lin, *J. Comp. Neurol.* **181**, 41 (1978).
5. J. H. Kaas, R. J. Nelson, M. Sur, C. S. Lin, M. M. Merzenich, *Science* **204**, 521 (1979).
6. P. R. Burgess and E. R. Perl, in *Handbook of Sensory Physiology*, A. Iggo, Ed. (Springer-Verlag, New York, 1973), vol. 2, pp. 29–78. We have not attempted to distinguish the influence of two types of SA receptors on cortical neurons; the rapidly adapting Pacinian receptors relay information to area 1 but not to area 3b of the somatosensory cortex (*4*).
7. Methods of preparation and recording were similar to those described by Merzenich *et al.* (*4*). For construction of peristimulus time histograms, 25 or 50 1-second step indentations were delivered by an electromechanical stimulator with a tip diameter of 1 mm.
8. M. Sur, M. M. Merzenich, J. H. Kaas, *J. Neurophysiol.* **44**, 295 (1980).
9. We have been unable to find any clear evidence of columns or bands within area 3b that are responsive to input from noncutaneous receptors.

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Human Homing: An Elusive Phenomenon

Abstract. *Recent experiments suggest an ability of blindfolded humans transported from home to indicate the direction of displacement. Attempts to replicate these results have been unsuccessful.*

Baker has recently reported experiments that indicate an ability in humans to navigate without instruments or celestial cues (*1*). Baker transported blindfolded high school and college students in buses and vans over indirect routes to "release" sites 6 to 52 km away and asked them, while they were still blindfolded, either before or after they left the van, to name or write down their estimate of either the compass direction of home or of the site *from* home. The students were moderately accurate in their estimates, displaying a mean error of only 47° (compared to 90° to be expected on the basis of chance alone), with mean vector lengths (a measure of the degree of consistency of estimates between subjects) in the range of 0.38 to 0.75 (where 0.0 indicates complete randomness and 1.0 represents perfect agreement). The possibility of such distributions arising by chance is less than 1 percent. Curiously enough, the ability of his subjects actually to point in the homeward direction or write down the direction of travel on any individual leg of the journey was only marginal; and on journeys with multiple stops, individuals who were poorly oriented at, for example, 10 km were as likely to be correct at 15 and 20 km as that subset which had been well oriented earlier (*2*). Baker also found that the accuracy of naming or writing the homeward bearing was reduced if his subjects wore magnets rather than equivalent weights on their blindfolds.

In view of the exciting nature of these results, we have tried on eight separate occasions to repeat Baker's experiments (*3*). In the first attempt, 40 Princeton undergraduates (essentially all of whom had lived in Princeton for at least 2 years) wearing double-layered velour blindfolds and black felt hoods were transported in a school bus and two vans, whose windows were covered with aluminum foil to reduce solar cues, over a circuitous path (route I in Fig. 1) to a location 20 km from Princeton (site 1 in Fig. 1). Half of the students wore alnico magnets attached to their blindfolds approximately between their eyes—very near the site proposed by Baker for a human magnetic sense organ (*2*)—while the others wore equivalent weights. The magnets produced fields at least as strong as those used by Baker, and, as in Baker's experiments, both magnetic polarities were used. The two groups were kept segregated to avoid any effects the magnets might have on the control subjects, and no one knew whether they wore magnets or weights. The students wrote down their estimate of the compass direction of home. The mean vector of the control group was 98° left of home, and the orientation was not statistically significant (Fig. 1). The mean vector of the magnet wearers (data not shown) was *more* accurately directed—12° to the right of the homeward bearing—although the mean vector length of 0.27 was again not statistically significant. Pointing was also random: a mean vector of 0.14 at 78° left for controls and 0.10 at 42° left for those with magnets. There was no effect of being transported in a van compared to the bus, nor was there any effect of seating position in either type of vehicle. These results provide no support for the hypothesis that humans can determine the direction of displacement or sense the earth's magnetic field.

The second test involved 15 graduate

students and staff members who were blindfolded (without magnets), hooded, and transported along route II in a van with covered windows. We adopted Baker's procedure of obtaining estimates at several stops (*3*). At a series of locations 8 to 18 km away (sites 2 to 7 in Fig. 1), each subject wrote down his estimate of the homeward direction. At site 3 the mean bearing was nonrandomly oriented 175° left of home at the 5 percent level; while at the other five sites the orientation was random (Fig. 1). In the third and fourth tests, 19 students and staff members were again blindfolded (without magnets) but left unhooded and transported in a van with its windows uncovered along route III to sites 8 to 13 ranging from 8 to 15 km distant and asked to estimate the direction of the site from home at each stop (Fig. 1); (as in Baker's data, the estimates have been reversed at these sites so as to indicate judgments of homeward direction). Eight subjects were transported on one trip, while 11 were tested on the second. At site 9 the subjects displayed a nonrandom orientation 98° right of home, at the 5 percent level. Orientation at the other five sites was random (Fig. 1).

Table 1. Summary of tests for direction finding. Distances are those from the departure site.

	Location	Treatment*	*N*	Mean vector		Statistical significance‡	
				Error†	Length	*z* test	*V* test
A	Millstone (20 km NNE)	C	20	−78°	0.24	n.s.	n.s.
B	Hillsborough (18 km N)	C	20	12°	0.30	n.s.	0.5
C	Reaville (20 km NW)	C	20	−145°	0.18	n.s.	n.s.
D	Linvale (23 km WNW)	C	20	−176°	0.05	n.s.	n.s.
E	Kingston (4 km NE)	C	19	3°	0.26	n.s.	n.s.
F	Pennington (18 km W)	C	19	−34°	0.16	n.s.	n.s.
G	Ringoes (25 km WNW)	C	19	54°	0.29	n.s.	n.s.
H	Flemington (26 km NW)	C	19	149°	0.14	n.s.	n.s.
I	Croton (33 km WNW)	C	9	−147°	0.16	n.s.	n.s.
J	Rosedale (5 km N)	C	12	−166°	0.12	n.s.	n.s.
		M	14	−140°	0.08	n.s.	n.s.
K	Rocky Hill (16 km NNE)	C	12	40°	0.31	n.s.	n.s.
		M	14	−144°	0.30	n.s.	n.s.
L	Belle Mead (22 km NNE)	C	12	22°	0.23	n.s.	n.s.
		M	14	128°	0.35	n.s.	n.s.
M	Woods Tavern (27 km NNE)	C	12	−49°	0.27	n.s.	n.s.
		M	14	56°	0.19	n.s.	n.s.

*C, control; M, magnet. †Relative to expected direction: home in the case of controls, and 180° from home for subjects wearing magnets. ‡*z* is the Rayleigh test with an 0.05 criterion; *V* is the modified Rayleigh test with 5 percent criterion; n.s., not significant.

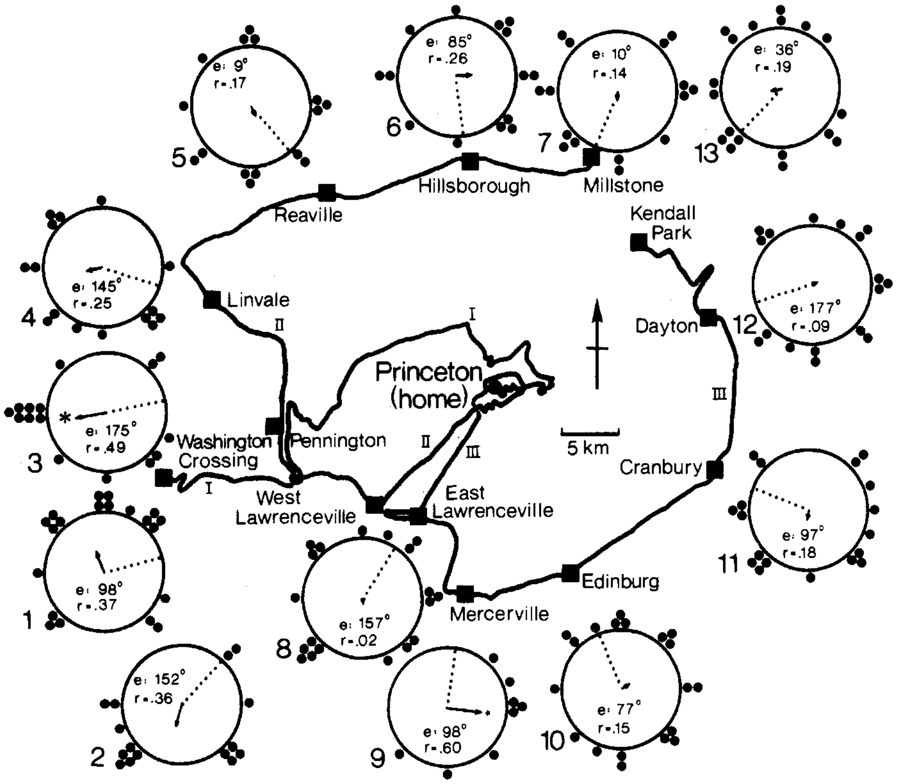

Fig. 1. The 209 individual estimates of homeward direction in the first four Princeton experiments are indicated by dots on the periphery of the 13 circles, each circle representing one "release" site. The routes to the sites are also shown. The dotted line in each circle is the homeward bearing, while the arrow is the mean vector of the estimates; *e* is the angular difference (that is, error) between the mean vector and the homeward direction; *r* is the length of the vector; and the asterisk indicates statistical significance at the 5 percent level. All statistics are Rayleigh tests as described by Batschelet (*4*). By the modified Rayleigh *V* test—a statistical procedure which takes into account the expected direction—no site was significant at the 5 percent level.

The fifth test was performed near Albany. Two groups, one of ten subjects and the other of nine, were transported from the SUNY campus while wearing blindfolds and paper bags as hoods, each to a different site. In order to further minimize the possible effect of solar cues, the tests were begun after dark. At the test site 16 km southwest of campus, the mean vector of the written estimates was 0.14 directed 77° to the right; while at the second site 17 km southeast of campus, the mean vector was 0.17 and 79° to the right. The orientation at both sites was therefore random. The written estimates with respect to the subjects' homes were also random, as were their attempts to point.

Despite the apparent simplicity of Baker's various methods and the consistency of his results, we could not repeat the phenomenon either at Albany or Princeton: at most sites orientation was random, and even in the two cases showing some statistical tendency, there was no systematic preference for the homeward direction. Even when all the data are combined, nothing emerges: the mean vector length for the 209 Princeton controls is 0.08 directed 123° right of home. Nor was there any tendency for some people to do consistently well. We concluded that the students in Baker's studies either had cues available to them which were absent in the Princeton and Albany experiments, or are dramatically better than Americans in using whatever cues may be involved in judging displacement.

In an effort to reconcile our conflicting results, Baker later joined us in three further attempts to repeat the human homing experiments in Princeton. We were aided by a group of outside observers including Donald R. Griffin, James Randi, Charles Walcott, Geoffrey Watson, and Janet and Timothy Williams. On the first day we transported 20 blindfolded, hooded subjects in two vans with foil-covered windows to each of four locations (A through D in Table 1) using a mutually agreeable protocol essentially identical to the one described above. None of the sites yielded statistically significant orientation by the *z* test, although site B is significant by the *V* test (Table 1). On the second day Baker and his colleague J. G. Mather ran the experiments, incorporating a trip to the roof of Eno Hall to allow the subjects a view of the surrounding topography. They selected a more nearly linear route to the west-northwest. Although five stops were planned (E through I in Table 1), only one van (carrying nine subjects) went to the fifth site. Orientation was statistically random at all locations (Table 1).

The experiment on the third day was again run by Baker and Mather. The 26 subjects were transported in three vans along a generally northern route from the Lawrenceville School to four sites (J through M in Table 1). Of these, 14 subjects wore magnets at the back of the head, and the polarity of the magnet was arranged so that a compass held in front of the head always indicated that north was behind the head. These individuals would be expected to indicate that they were being taken south, while the 12 controls wearing lead weights ought to indicate north as the direction of displacement. Neither group was oriented at any site, nor was there any consistent difference between the directions of their mean vectors (Table 1). The one instance of orientation at the 5 percent level out of the 34 statistical tests in Table 1 is about what ought to turn up by chance.

We believe that our consistent failures indicate that the phenomenon is neither as simple nor as robust as we had been inclined to hope. We urge others to attempt to repeat this intriguing yet technically undemanding experiment.

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References and Notes

1. R. R. Baker, *Science* **210**, 555 (1980).
2. ———, *Human Navigation and the Sixth Sense* (Hodder and Stoughton, London, 1981).

3. While many of Baker's methods invite criticism, the very fact that they worked so well for him and, more importantly, that magnets seemed to reduce the accuracy of orientation (without, we suppose, affecting the subjects' ability to sense such visual, auditory, topographic, olfactory, or verbal cues as we might be inclined to wonder about) serve to make his results compelling. We have been careful to incorporate them in our tests. The distances chosen are among those that gave the best results in Baker's experiments (*2*). Although we adhered to Baker's 2-year residence criterion in our first six tests, Baker subsequently reported finding no effect of residence time. Hence, we relaxed this criterion in the last two experiments. Baker's route-based navigation hypothesis (*2*) makes residence time irrelevant.

4. E. Batschelet, in *Animal Orientation and Navigation*, S. R. Galler, K. Schmidt-Koenig, G. J. Jacobs, R. E. Belleville, Eds. (Government Printing Office, Washington, D.C., 1972), pp. 61–92.

5. We thank K. Schenck for organizing the Princeton experiments, B. Presley and T. Spalding for arranging the Lawrenceville School test, and F. Dyer, C. G. Gould, H. Wildman, J. L. Kirschvink, and W. Towne for help and comments on the manuscript. We also thank W. Gergits for help in the tests at Albany. Supported by grants BNS 78-24754 (to J.L.G.) and BNS 79-23711 (to K.P.A.) from the National Science Foundation.

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Myelinated Central Vertebrate Axon Lacks Voltage-Sensitive Potassium Conductance

Abstract. *Intracellular recordings were obtained from the goldfish Mauthner cell soma and axon before and after intracellular iontophoresis of drugs that block voltage-sensitive potassium conductance. Analysis of the action potentials generated by the axon hillock–initial segment and by the axon suggest that axonal impulses lack this potassium conductance. Thus, impulse repolarization in the Mauthner axon, and perhaps in other vertebrate central axons, may not involve an active potassium current.*

The mechanism of action potential electrogenesis at anuran nodes of Ranvier resembles that of squid giant axon. In both, depolarization results from an increase in voltage-sensitive sodium conductance and repolarization from a combination of sodium inactivation and an increase in voltage-sensitive potassium conductance ($g_{\rm K}$) (*1*). Despite an early report that voltage-sensitive $g_{\rm K}$ could not be detected at rat sciatic nodes (*2*), it has been generally assumed (*3*) that the mechanism of action potential electrogenesis at vertebrate nodes resembles that of squid and anurans. However, recent voltage clamp analyses of nodes from rabbit and rat sciatic nerve indicate that the predominant factors in repolarization are rapid sodium inactivation and a large leakage current, with voltage-sensitive $g_{\rm K}$ playing no significant role (*4*). Pharmacological analysis of axons in the rat dorsal column also suggests that the central projections of peripheral sensory neurons repolarize without any significant contribution by voltage-sensitive $g_{\rm K}$ (*5*). These findings raise serious questions about the general applicability of the classical model of action potential electrogenesis to myelinated axons. Such issues include (i) the contribution, if any, of voltage-sensitive $g_{\rm K}$ to impulse repolarization in axons of neurons contained entirely within the central nervous system and (ii) the question of whether the classical model is appropriate for all nonmammalian vertebrates other than anurans. We present evidence indicating that, in the axon of a teleost central neuron, a voltage-sensitive change in $g_{\rm K}$ plays no significant role in action potential electrogenesis.

Experiments were performed on goldfish Mauthner cells (M cells). The M cell is a large medullary interneuron having a myelinated axon extending posteriorly along the contralateral side of the spinal cord. Although nodes of Ranvier have not been found along the M axon, active electrogenic zones have been identified electrophysiologically, spaced at intervals of about 2 mm (*6*). Procedures for the restraint and artificial respiration of curarized fish and for exposure of the medulla have been described previously, as has electrophysiological identification of the M cell, the axon cap surrounding the axon hillock–initial segment, and the axon (*7, 8*). We used intracellular iontophoresis to introduce drugs known to block voltage-sensitive $g_{\rm K}$ in a number of excitable cells and monitored subsequent changes in the time course of the action potentials generated in the axon or in the axon hillock–initial segment. Microelectrodes were filled with a mixture of KCl and tetraethylammonium (TEA), KCl and 4-aminopyridine (4AP), or KCl and both drugs (*9*). The same electrode was used to record intracellularly, to introduce the drugs, and to block propagating action potentials with hyperpolarizing currents. For iontophoresis, a continuous depolarizing current of as much as 20 nA was most effective. Soma-dendritic penetrations were made 100 μm lateral to the axon cap. Axonal penetrations were made either 1.0 mm or 2 to 2.3 mm posterior to the axon cap—that is, on either side of the first active zone (*6*). Antidromic action potentials were evoked by stimulating the spinal cord and orthodromic action potentials by stimulating the ipsilateral posterior eighth nerve.

Iontophoresis of TEA or 4AP into the

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