each other and form nonpolarized groups, and (ii) individuals position themselves in characteristic polarized groups (such as with bodies parallel). In mormyrid fish the electric organ discharges provide an additional type of biosocial stimulation for achieving schooling behavior. The fish usually form nonpolarized groups and occasionally show polarization as in parallel lineup and single file swimming; thus they are "facultative schoolers" in Breder's terminology (*9*). The electric signals and the electrosensory system in mormyrid fish appear to function as part of another schooling mechanism that is adapted to aid group cohesion in the turbid water and during migration at night.

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6. This operation does not interfere with the locomotion of the fish since the muscles controlling movement of the peduncle are located and innervated anterior to the lesion [V. Bruns, *Z. Zellforsch.* **122**, 538 (1971)]; M. V. L. Bennett, in *Fish Physiology*, W. S. Hoar and D. J. Randall, Eds. (Academic Press, New York, 1971), vol. 5, p. 347–491]. However, there probably was a loss of sensory input from cutaneous receptors in the skin surrounding the electric organ and the tail fin.
7. Behavior frequencies were compared by using the McNemar test for related samples. Correlation coefficients (Pearson product moment) were calculated to compare frequency distributions and to estimate frequency increases or decreases associated with the number of fish present in the observation tank. If not stated otherwise, the level of significance is $P < .005$.
8. The fish of group C had the longest time to adapt to the communal holding tank before being added to the observation tank. Part of the activity decrease could be accounted for by habituation; however, single file swimming and an increase in locomotor activity can be restored in an electrically silent group of fish by adding intact fish (L. Gordon, K. Johnson and P. Moller, in preparation).
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Orientation Anisotropy: Incidence and Magnitude in Caucasian and Chinese Subjects

Abstract. *Cutoff spatial frequencies for sine-wave gratings were measured at four orientations for 100 Caucasian and 24 Chinese subjects, all of whom were raised in carpentered environments. For the Caucasian subjects, average acuity for horizontal and vertical gratings was superior to that for obliques by about one-quarter of an octave. However, about 10 percent of subjects failed to show the effect. The Chinese subjects showed an anisotropy of about one-eighth of an octave. The carpentered environment explanation of orientation anisotropy cannot, in its present form, account for the wide variety of response patterns obtained, nor the differences between Chinese and Caucasian subjects.*

Performance on a variety of visual tasks is better for stimuli oriented horizontally or vertically than for those oriented obliquely (*1*, *2*). Possibly, superior resolution for horizontal and vertical contours is the result of being raised in a "carpentered world" (*3*); that is, one in which such contours predominate. In support of an environmental hypothesis, Annis and Frost (*4*) report that a group of Cree Indians, raised in a relatively noncarpentered environment, failed to show a statistically significant anisotropy, while a group of Euro-Canadians, raised in typical North American homes, did show one. In the study described here, we provide evidence that the carpentered environment hypothesis of orientation anisotropy is inadequate in its present form.

We determined acuity for sine-wave gratings at four orientations: horizontal (0°), vertical (90°), oblique right (45°), and oblique left (135°) in 100 Caucasian and 24 Chinese subjects, all of whom had spent their early years in carpentered environments. Most of the Caucasian group had been raised in typical North American homes, and the majority of the Chinese sample had lived in apartments in Hong Kong during their early years.

Each subject was tested in a session lasting about 45 minutes. An extensive visual history was taken, followed by testing on a T-O vision tester (*5*) to obtain a measure of the individuals' current visual status. In those cases where it was appropriate, attempts were made to bring a subject's acuity into a normal range with lenses (*6*).

After the preliminary screening, subjects were seated with their heads positioned in a head rest. The distance from their eyes to the face of an oscilloscope was 344 cm. A circular target field, subtending a visual angle of 1.2°, was surrounded by a rectangular white mask, subtending 11° by 9°. The grating, generated on the screen by conventional methods, had a mean luminance of 48 cd/m^2 and a Michelson contrast of 0.50 (*7*). The surrounding field had a luminance of 10 cd/m^2.

Subjects turned a small knob controlling a ten-turn potentiometer to adjust the spatial frequency of the grating. They were required to begin at a point well below their ability to resolve the stripes and then to increase the width until they could just detect the orientation of the stripes. A number of practice trials were given, during which subjects were encouraged to refine their settings to achieve a threshold measurement. All testing was monocular. Trials were given in pairs, one for each eye, and the orientation of the grating was changed after every second trial. A total of 48 trials was given, six at each target orientation. The order of orientations was randomized, with the restriction that all four orientations were represented in every four pairs of trials, and the order of eyes was counterbalanced so that each eye received a given orientation first an an equal number of times.

Average threshold spatial frequencies were computed for each subject. These data, averaged for both eyes of all subjects within each group, are shown in

Fig. 1. The averaged data show the typical anisotropy pattern found by others (*1, 2, 4*), with approximately equal resolution for horizontal and vertical gratings and a depressed sensitivity for obliques. An analysis of variance showed these differences to be significant ($F_{3,\,297} = 110.8$, $P < .00001$). There was no significant difference between eyes and no eye-orientation interaction. The Chinese group performed differently from the Caucasians in two respects. First, overall acuity was lower for the Chinese subjects. Second, the magnitude of the orientation anisotropy was much less than for the Caucasian group, although it was statistically significant ($F_{3,\,69} = 9.1$, $P < .001$).

A quantitative estimate of orientation differences in acuity was obtained by computing an anisotropy index (*8*). This index gives the difference in acuity between the pooled values for horizontal and vertical and the pooled values for the obliques, expressed in octaves of difference from horizontal and vertical, an octave representing a change by a factor of 2. The mean anisotropy index, averaging values for both eyes for all Caucasian subjects, was 0.26, indicating that performance for obliques was about one-quarter of an octave poorer than that for horizontals and verticals. A relative frequency histogram of the anisotropy index is shown in Fig. 2a. Because many subjects exhibited a different pattern in each eye, the index for each eye was entered separately to present a more accurate picture of the range encountered. The distribution is negatively skewed, with 15 percent of the cases having an index of less than 0.10. The range of the index is quite large, varying between −0.29, indicating a superiority for obliques, and +0.73, a pronounced anisotropy. A similar histogram is shown for the Chinese subjects in Fig. 2b. The average anisotropy index for this group was 0.13, with 46 percent of values less than 0.10. The difference between the mean anisotropy indices for both groups was significant ($t = 3.7$, d.f. = 122, $P < .001$).

Approximately 10 percent of the subjects showed different patterns in each eye. The most extreme instance was an individual who performed better for the main axes in one eye and for obliques in the other, although in general the pattern was an anisotropy in one eye and no orientation differences in the other. Some of these subjects were given more extensive testing; in almost every case, the same acuity patterns were obtained. In addition, when binocular testing was employed the anisotropic pattern usually prevailed.

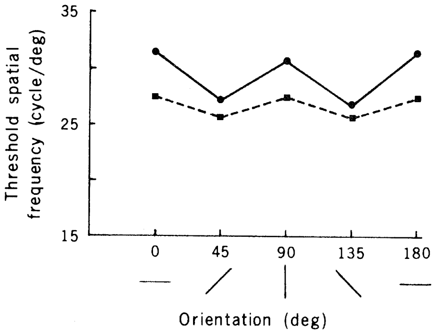

Fig. 1. Threshold spatial frequencies plotted as a function of grating orientation for Caucasian (solid line) and Chinese (dashed line) subjects. The points were derived by averaging data for both eyes for all subjects. Both groups showed a statistically significant anisotropy; the magnitude of the effect was smaller, but statistically significant, for the Chinese subjects.

Because the anisotropy index is a relative measure designed to reflect differences between orientations and not absolute acuity levels, it might be argued that a small anisotropy is simply a product of lowered visual acuity. This could account for the differences between Chinese and Caucasian scores. However, correlations between anisotropy index and mean acuity for each group separately, and for both groups combined, were small and nonsignificant ($r_{\text{Cauc.}} = -0.11$; $r_{\text{Chin.}} = -0.06$; $r_{\text{comb.}} = -0.01$). Thus, we conclude that lowered acuity is not responsible for the anisotropy differences between the two groups.

The data reported here lead us to question the extent to which early visual experience influences orientation anisotropy. Even though all of the subjects in the Caucasian group were raised in broadly similar environments containing a preponderance of horizontal and vertical contours, a number of these subjects failed to show an anisotropy in either one or both eyes. Within the Chinese group also, there was presumably a great deal of similarity between the subjects' early visual environments. While the overall level of anisotropy was reduced for the Chinese, there was a fairly large range of acuity patterns among individuals. The difference between the Chinese and Caucasian groups, in terms of the magnitude of anisotropy, is similar to that found by Annis and Frost (*4*) in their comparison of acuity patterns of Euro-Canadians and Cree Indians (*9*). Undoubtedly, there were differences between the early visual environments of our Caucasian and Chinese subjects. Nevertheless, these environments were probably more similar than those of the Euro-Canadians and Crees, which suggests that the overall level of "carpentry" in one's early visual world is not the major contributing factor to orientation anisotropy.

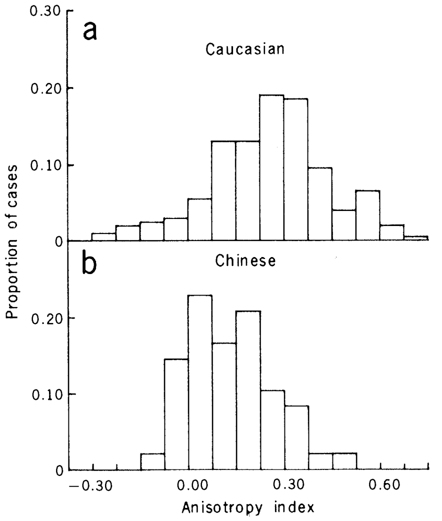

Fig. 2. Relative frequency histograms showing anisotropy classified according to an anisotropy index, which was computed by the formula in (*8*).

It is generally assumed that orientation anisotropy is of neural origin and not simply a product of optical aberrations (*10*). Although others have argued in favor of an experiential basis for anisotropy (*4, 11*), the possible contribution of a genetic component should be given further consideration. The wide range of acuity patterns we obtained is consistent with the existence of a genetic factor. Additional support for a genetic component may be found in a report that infants as young as 6 weeks show an anisotropy (*12*). Also, as Annis and Frost (*4*) pointed out, a genetic interpretation of their results cannot be ruled out, as they were unable to locate a sample of Cree Indians who were raised in a carpentered environment.

In summary, we have documented the existence of subjects who were raised in highly carpentered environments and who failed to show an anisotropy. Further, it appears that the average magnitude of the anisotropy differs across ethnic groups. These results emphasize the need to qualify any hypothesis concerning the role played by early visual input in determining adult perceptual capacities until the magnitude of the nonenvironmental contributions can be established.

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3. M. H. Segall, D. T. Campbell, M. J. Herskovits, *The Influence of Culture on Visual Perception* (Bobbs-Merrill, Indianapolis, Indiana, 1966).
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6. Subjects with prescribed corrective lenses were required to wear them during testing. If any subjects scored below normal values on the T-O vision tester or exhibited large differences in acuity for orthogonal gratings in the experimental situation, we attempted to improve their performance to normal with lenses. Those with obvious amblyopias were dropped from the sample. Since we did not refract our subjects to ensure a perfect optical correction, we were concerned that some cases of uncorrected astigmatism might have influenced our results. However, when we computed an astigmatism ratio by dividing the acuity for one axis by that for the orthogonal axis, the distribution for both Chinese and Caucasian samples approximated that reported for normal subjects by D. E. Mitchell *et al.* (*11*). Thus, we conclude that the differences between Chinese and Caucasian scores reported here were not produced by systematic differences in astigmatism.
7. Contrast is defined as
$$\frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}}$$
where L is luminance.
8. The anisotropy index (AI) was computed as follows:
$$AI = \frac{(V + H) - (OL + OR)}{(V + H)/2}$$
where V, H, OL, and OR are mean thresholds for vertical, horizontal, oblique left, and oblique right orientations, respectively. Subjects performing equally well on all orientations would have an index of 0.0, while those exhibiting a drop in acuity for obliques by a factor of 2 would have an index of 1.0.
9. Anisotropy indices were computed from Annis and Frost's published figure. For Euro-Canadians this was approximately 0.21 and for the Cree Indians it was 0.10. These values are somewhat smaller than we obtained, perhaps reflecting procedural differences, but the difference between the Euro-Canadians and Cree Indians is about the same as that between the present samples of Caucasians and Chinese.
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13. Authorship order was determined by a coin toss. We thank B. Frost and D. J. K. Mewhort for constructive criticism, D. J. K. Mewhort for assistance in the data analysis, and S. Wong and A. Wong for help in recruiting Chinese subjects. Supported by National Research Council of Canada grants A0044 to P. C. Dodwell and A0353 to B. Frost and Defense Research Board of Canada grant 9425-12 to P. C. Dodwell and J. Z. Jacobson.

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Skeletal Calcite in Living Scleractinian Corals: Microboring Fillings, Not Primary Skeletal Deposits

As far as is known, modern scleractinian corals construct their skeletons entirely of calcium carbonate in the form of aragonite. Houck, Buddemeier, and Chave (*1*) recently challenged this concept by reporting as much as 46 percent primary skeletal calcite in certain tropical reef corals. Further examination of their samples of *Porites lobata* (*2*) indicates that the calcite is not a primary deposit of the coral but is associated with microborings.

Petrographic thin sections revealed these samples of *P. lobata* to be extensively altered by a branching network of fine ($\simeq 3$ μm in diameter) calcite-filled tubules (Fig. 1A) extending to the living coral polyp layers. The tubules are probably fungal or algal in origin. Endolithic plant borings are a prominent characteristic of tropical reef corals (*3, 4*), but microborings or exposed filaments of these plants to date have been associated only with the precipitation of aragonite and magnesium calcite (*4, 5*). Although Houck *et al.* identified algal borings, they concluded that most of the calcite is "not associated with any evidence of boring" and, more importantly, suggested that the calcite is skeletal calcite "deposited by the coral as an alternate form of calcification."

Our study of the samples does not support these conclusions. Etching of the polished coral surfaces with ethylenediaminetetraacetic acid (EDTA) at *p*H 8 caused the calcite to stand out in relief from the finer, more soluble aragonite. Figure 1B shows the filamentous nature of the more resistant calcite which when completely dissolved leaves a branching, tubular organic network (Fig. 1C). We observed enough calcite-filled microborings in thin sections and scan-

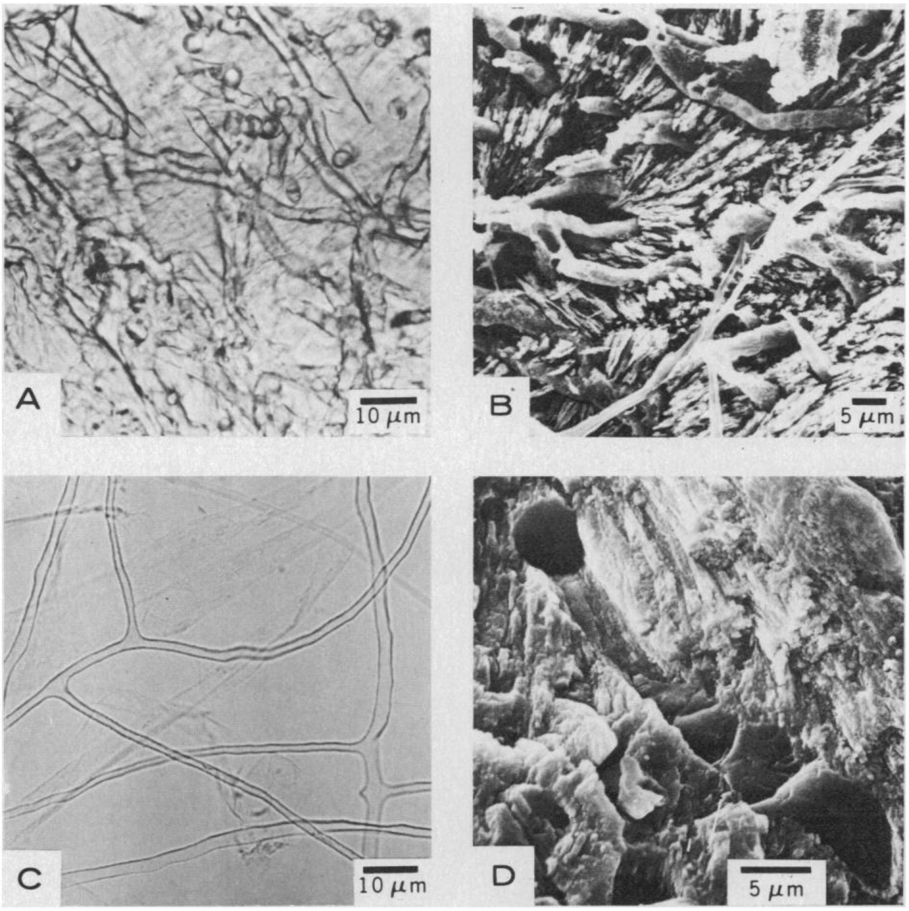

Fig. 1. (A) Photomicrograph of *Porites lobata* from Waikiki reef showing extensive alteration of skeletal aragonite by microborings. (B) Scanning electron micrograph of a polished surface from *P. lobata* etched with EDTA. Less soluble calcite in the microborings projects from the finer aragonite crystals of the coral skeleton. (C) Photomicrograph of organic sheaths from microborings which remain after the carbonate has been removed by EDTA. (D) Scanning electron micrograph of the fractured surface across a calcite-filled microboring.