subjects in the dominant LVF, but eight were inferior to all right-handed males, and only one was in the range of the right-handed males. It is possible that lowered lateralization, with possible dual representation of a function in both hemispheres, can lead to unusually good or poor performance, depending on the function measured.

The two traditional measures, handedness and sex, supplemented by our new measure of hand position, allow very simple, rapid, and reliable prediction of hemispheric specialization and lateralization. These observations allow us to meaningfully subcategorize left-handed writers and the method should be useful in lateralization research and in clinical medicine. Additional research is needed to determine how a dominant hand is controlled by an ipsilateral hemisphere, the sources of variability among individuals in the relationship between the brain and the hand, why manual control by an ipsilateral hemisphere leads to hand inversion and weak lateralization, the nature of the mechanisms underlying the association between performance measures and hand posture, and the possible cognitive correlates of handedness and hand position in writing.

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10. An analysis of variance was carried out, excluding subject RI, with three between-subject factors: (i) sex, (ii) group, (iii) task order, and two within-subject factors: (i) lateral field and (ii) task. Task order made no significant contribution to the variance, either as a main effect or in any of its interactions. The main effects of group [$F(2, 60) = 5.95$, $P < .005$] and sex [$F(1, 60) = 18.24$, $P < .001$] were significant; groups RN and LN had higher scores than group LI, and males were superior to females. The group by lateral field by task interaction was significant [$F(4, 120) = 80.35$, $P < .001$]; groups RN and LI had higher right visual field (RVF) scores on the syllable test and higher left visual field (LVF) scores on the dot location test, and group LN had the reverse. The four-way interaction among group, sex, lateral field, and task was also significant [$F(4, 120) = 10.38$, $P < .001$], which shows that females made a smaller contribution than males to the three-way interaction.
11. In a second analysis of variance for each task, superior/inferior field (SVF/IVF) was entered as a within-subjects factor instead of right/left field. The purpose was to compare the groups for degree instead of direction of lateralization. As a result of the definition of the field factor in this analysis, there must necessarily be a main effect of field. In both the syllable test and the dot location test, there was a significant group by field interaction [$F(2, 60) = 7.17$, $P < .005$, and $F(2, 60) = 9.16$, $P < .005$, respectively]. In both tasks, the interaction resulted from a larger difference between groups in the SVF than in the IVF: group LI was inferior to both groups RN and LN in the SVF but only marginally inferior in the IVF on the syllable test and not inferior on the dot location test. Thus, on both tests, the magnitude of the field difference was smaller for group LI than for groups RN and LN. Similarly, there was a significant sex by field interaction in both tests, with the field differences for females being smaller than that for males. Males surpassed females in both the SVF ($P < .001$) and in the IVF ($P < .05$).
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13. We thank D. Kemler, P. Rozin, and J. Wishner for helpful comments and criticisms. We are also grateful to our 73 subjects who volunteered their time.

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The Biochemical High-Risk Paradigm: Behavioral and Familial Correlates of Low Platelet Monoamine Oxidase Activity

Abstract. *A population of individuals potentially at risk for psychiatric disorders was identified by screening 375 college student volunteers for low platelet monoamine oxidase (MAO) activity levels. The lower and upper 10 percent in MAO activity were interviewed and family history data were obtained. Low-MAO probands reported more frequent psychiatric or psychological counseling and problems with the law. Families of low-MAO probands had an eightfold increase in the incidence of suicide or suicide attempts over those of high-MAO probands. This suggests that reduced MAO levels, reported previously in patients with affective disorders and chronic schizophrenia, may predict a vulnerability to psychiatric disorder.*

The "high-risk" approach to the study of psychiatric disorders attempts to transcend the dilemma of whether the biological and psychosocial abnormalities observed in psychiatric patients are of etiological significance or result from the disorders. To do this, high-risk studies focus on individuals believed vulnerable to psychiatric disorders before the disorder appears. To select a pool of vulnerable individuals, nearly all high-risk studies have relied on familial models and have examined the offspring or relatives of a clearly defined patient sample. Biochemical studies of psychiatric disorders, on the other hand, have usually begun with patients in "known" diagnostic groups and searched for abnormalities. The present study integrates the usual biochemical paradigm with the high-risk one to produce a new biochemically-at-risk strategy. Here, the "proband" is established by a biological measure, not a clinical one. The use of this strategy reduces the heterogeneity of the sample; eliminates the hospitalization, labeling, and treatment factors that confound other biochemical studies; and rigorously tests the power of the biological factor under investigation.

The biochemical indicator chosen in our study to identify a population potentially at risk for psychiatric disorders is platelet monoamine oxidase (MAO) activity. We felt MAO activity to be especially promising for four reasons: (i) it has been reported in five out of seven studies to be lower in patients with chronic schizophrenia (*1, 2*) and bipolar (manic-depressive) affective disorders (*3*); (ii) it is consistent with two leading conceptualizations of biochemical abnormalities in the major psychoses—the transmethylation and dopamine hypotheses (*2, 4*); (iii) it is under genetic control (*2, 5*); and (iv) it is associated with some personality test differences in normal males (*6*) and with stable behavioral profiles in rhesus monkeys (*7*).

As is true of all promising biochemical leads, the significance of the finding of reduced MAO activities in psychopathologic groups is diminished in two respects. Low MAO activities are found in many but not all patients. More disturbing, there is a small percentage of "normal controls" whose MAO levels are well below the means of the patient groups.

Indeed, it was this group of presum-

Table 1. Occurrence of psychosocial problems in male subjects and in their families. Subjects were questioned about sibs, parents, parents' sibs, and grandparents; information on a total of 203 relatives of low-MAO probands and 214 relatives of high-MAO probands was obtained. The table reports the number of probands with one or more family members exhibiting psychosocial problems; actual rates of occurrence in the family populations were higher. Two low-MAO individuals were adopted and therefore excluded as probands in tabulations of family problems. Probabilities for the Fisher exact probability test are given when $P < .05$, one-tailed. Abbreviation: N.S., not significant.

Psychosocial problems	Low-MAO probands	High-MAO probands	Probability
In self	(N = 19)	(N = 17)	
Psychiatric contact	7	2	N.S.
Psychiatric hospitalization	2	0	N.S.
Convicted of offenses	7	0	.006
In jail	7	3	N.S.
Suicide attempts	2	0	N.S.
Any of above	12	5	.045
Psychiatric hospitalization, suicide attempt, conviction, or jail (*13*)	10	3	.032
In family	(N = 17)	(N = 17)	
Psychiatric contact	7	9	N.S.
Psychiatric hospitalization	6	2	N.S.
Problems with the law	3	1	N.S.
Suicide or suicide attempts	6	1	.043
Any of above	11	10	N.S.
Psychiatric hospitalization, suicides or attempts, problems with the law (*14*)	10	3	.016

ably normal individuals that provoked our curiosity and provided the impetus for this study. Are low-MAO normals simply individuals who have evaded the labeling and the institutionalization process but, nonetheless, exhibit psychiatric disorders or psychological indicators of impending breakdown? Or are they "invulnerables" who possess some ameliorative characteristics in their neurophysiology or environment that are protective? Do they lack additional detrimental factors which summate with low MAO, increasing the risk for psychological problems? Is it possible that some of their relatives, who might share the genetically controlled low MAO characteristic but lack a protective element, would show heightened rates of psychological disturbance?

To evaluate possible psychological concomitants of reduced MAO activity, 375 college students and university employees (203 men and 172 women, ages 18 to 38) were recruited from local sources and paid $5 each for giving an initial blood sample. Volunteers were told that we were interested in behavioral and neurophysiological correlates of various central neurotransmitters and that we would call back a subsample of individuals for further tests.

Blood samples were analyzed for platelet counts and for platelet MAO activities, with [^{14}C]benzylamine as the substrate (*2*), and are reported in units of nanomoles per 10^8 platelets per hour. The top and bottom 10 percent of the sample were then contacted for further study; complete data, as described below, were obtained from 87 percent. The final groups of high-MAO and low-MAO individuals were selected on the basis of their mean platelet MAO activity from both the initial screen and repeat visit values; the high and low groups were separated by four MAO units. All subjects had been asked not to take any drugs at the time of the second blood sample. Inhibitors of MAO were not being used by any of the sample, and none of the drugs that had been previously used by the individuals (for example, marijuana) are known to be MAO inhibitors in concentrations used in man. Since males had lower mean values than females (10.1 versus 13.2, $t = 7.36$, $P < .001$) the limits for the low and high groups were chosen separately: males 2.40 to 8.39 (N = 19) and 12.35 to 22.54 (N = 17), and females 5.80 to 10.98 (N = 18) and 14.92 to 28.10 (N = 17). Eighty-four percent of the low-MAO males but only 17 percent of the low-MAO females fell below the mean of a group of chronic schizophrenics studied previously (*2*).

Subjects participated in a structured interview on personal and family history, and were studied with perceptual and cognitive tasks, average evoked response measures, and personality assessment tests. The interview questions related to four general areas thought to be relevant: (i) psychiatric treatment contact, hospitalization and suicide attempts, and involvement with the law; (ii) family stress and childhood problems; (iii) psychiatric history of relatives; and (iv) other medical illnesses. The interviewers, test givers, and subjects were not aware of the laboratory results, and all of the information was kept separate until the final data analysis.

As predicted from the studies of psychiatric patients, low-MAO subjects reported a twofold higher incidence of psychiatric contact; 15 of 37 low-MAO subjects versus only 7 of 34 high-MAO subjects (P = .049, Fisher exact test, one-tailed) reported seeing a psychiatrist or psychologist for "personal rather than vocational problems." No overall difference in incidence of childhood adjustment problems, family stress, or medical or neurological illness was found. Three past psychiatric hospitalizations were reported in the low-MAO group and none in the high group (two in low-MAO males and one in a low-MAO female; P = .13, Fisher exact test). The two males were hospitalized after suicide attempts, and the female was hospitalized during a 2-month depressive episode.

The finding that male subjects had more extremely low MAO levels suggested that our results might be stronger in males considered alone. As indicated in Table 1, the most notable findings were the increased incidence of reported psychosocial problems in low-MAO males and the increased incidence rate of suicide or suicide attempts in their relatives. Relatives of low-MAO males had a rate of 3.93 percent, eight times that of the 0.47 percent rate in high-MAO males.

The finding of increased rates of suicide and suicide atttempts in the families of low-MAO probands is of note in view of a recent report of low MAO levels in postmortem examination of brains of suicides (*8*), although another study did not find a similar difference (*9*). While suicide may be twice as common in affective disorder patients as in schizophrenics (*10*), it is at least 10 to 15 times more common in both groups than in normal populations. Examining relatives of bipolar affective disorder probands, Perris and d'Elia (*11*) found suicide as a cause of death in 6.8 percent, far above general population figures. Kety *et al.* (*12*) found five suicides among 63 parents of 33 schizophrenic probands adopted at an early age, with none in the control parents. In comparison, only one diagnosis of schizophrenia and one of uncertain schizophrenia were made in these 63 parents.

Our results offer further evidence that reduced MAO levels are associated with some predisposition to psychiatric vulnerability. While the features of this vulnerability may be partially inferred from

our analysis of personality traits, cognitive performance, and electrophysiological measures to be reported subsequently, the clinical significance of low MAO activity in this young population can only be assessed after longitudinal follow-up.

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14. Items were aggregated on the basis of their being both objectively verifiable and serious; the same aggregation is used both for individual and for family data.
15. We thank D. Gastfreund, C. King, A. Nichols, M. Sihvonen, and M. Wigglesworth for technical assistance.

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Fluorescent Nectar

Thorp *et al.* (*1*) hypothesize that fluorescence of exposed floral nectars acts as an attractant of zoophilous flowers for anthophiles—absorbing ultraviolet light and emitting light of other colors. A critical examination of this hypothesis is needed. Several points suggest that it is unlikely that ultraviolet fluorescence from exposed nectars would contribute to the attractiveness of the flowers, or even be seen by insects. An examination of the spectral sensitivity of insect eyes, their color vision, and the spectral composition of daylight will illuminate the arguments.

The spectral sensitivity of insects ranges from ultraviolet (~ 300 nm) to yellow-orange (~ 650 nm) (*2, 3*). Ultraviolet (~ 300 to 400 nm) in daylight is relatively impoverished, representing about 12 percent of the energy in the insect visual spectrum (*4*). To compensate, insects are more sensitive to ultraviolet than to light in other wave bands (*2, 3*), and the ultraviolet receptors of insects' eyes are narrower in their sensitivity range (*2*). This explains their greater ability to discriminate colors which contain ultraviolet (*3*).

It is well known that most fluorescers are poor in terms of quantum efficiency (*5*); a quantum efficiency of 25 percent produces bright fluorescence. Two nectar constituents, tyrosine and tryptophan, fluoresce brightly in neutral water solution, at quantum efficiencies of 21 and 20 percent, respectively (*6, 7*). The spectrum of fluoresced light is generally as broad or broader than that of the exciting light (*5, 7, 8*) and the energy efficiency of fluorescence always less than the quantum efficiency, as the photon fluoresced at the longer wavelength has less energy than the photon absorbed.

So, fluorescence of nectar by ultraviolet light takes energy from an impoverished part of the insect visual spectrum to which insects are highly sensitive and transforms it to an already rich part of that spectrum (to which insects are less sensitive) with considerable inefficiency. The contribution of fluoresced light to longer wavelengths reflected from floral parts would probably be obscured by overall diffuse reflection and further minimized by place-to-place variation in diffuse reflectance within the flower, by shading, and by specular reflections (see below).

The nectaries of flowers with exposed nectar are frequently on the hypanthium, which is often greenish to yellowish-green and probably always has a greater spectral reflectance than foliage (*9*). Such floral parts reflect fairly evenly in all parts of the insect visual spectrum—absorbing red—and so appear as bee-white to bee-grey with bee-yellowish tints (*3, 9*). Calculations (using a reflectance of 25 percent from the hypanthium and a quantum efficiency of .20, that is, an energy efficiency of 15 percent, with fluorescence in the wave band 400 to 500 nm) show that equivalent reflectance is only 30 percent (*10*), or an augmentation of the hypanthium color of only 5 percent in one of the three wave bands in the trichromatic color vision system of bees or other insects (*3, 9, 11*). Thorp *et al.* (*1*) also consider depletion of ultraviolet in fluorescent nectar, implying that this could contribute to contrastive insect-color patterns. However, the ultraviolet absorption would have to be very high through the thin film or small droplet to render any color change. Color changes due to a nectar drop would be probably imperceptible to insects. If the color change due to fluorescence were significant, it should impart color to the human eye.

Nectar reflecting ultraviolet alone would be far more effective for two reasons: (i) it would be reflecting, potentially more efficient than fluorescence, in a wave band to which insects are highly sensitive, and (ii) the color, ultraviolet, would contrast with the colors of adjacent floral parts (*3, 9*). Ultraviolet as an insect color is apparently rare and thus distinctive, being approached most closely by some red flowers (*3*).

Nectar is often seen as sparkling droplets in flowers, due to specular (mirror-like) reflections from the surface tension film. These would obscure any color imparted through either fluorescence or diffuse reflection, yet would be highly visible to insects. Insects, hovering in front of flowers before foraging or leaving, could be examining for specular reflections or other close-in attractants (such as scent) as clues to the amount of nectar present.

The observation of Thorp *et al.* (*1*) that there are more plant species with open flowers and easily visible fluorescing nectar than with nonfluorescing hidden nectar bears consideration. The fluorescence is imparted by some constituent or constituents not identified by Thorp *et al.* Mono- and disaccharides are not fluorescers [see also (*1*)] but other constituents (aromatic amino acids, vitamins, phenolic compounds, and glycerides) are, and may have phylogenetic (*12*) or anthecological significance (*6, 13*), but I doubt that fluorescence of nectar per se is important as an attractant for pollinating insects.

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