aftercontraction induced by sotalol from 75.8 ± 14.9 mg (mean ± standard error to 264.5 ± 32.8 mg. According to Niedergerke (*5*) frog ventricular strips, depolarized with high concentrations of external potassium, contract more strongly the higher the concentration of extracellular calcium, and calcium exchange is directly related to contracture tension. Similarly, in the presence of sotalol the striking increase in tension of the aftercontractions caused by doubling external calcium supports the hypothesis that during a prolonged depolarization an influx of calcium may contribute to the production of active tension.

The tension of the sotalol-induced aftercontraction is only a small fraction of the main twitch tension (5 to 18 percent at 4.5 meq of calcium per liter). Kavaler, who succeeded in extending the duration of the contraction of ventricular strips by holding the plateau of the action potential at a positive potential (+ 15 mv) with an applied current, observed long-lasting contractures which developed about 80 percent of the active tension of the main twitch (*6*). The reason for this discrepancy may be that the electrically sustained plateau potential is positive, whereas the plateau produced by sotalol is slightly negative.

The change in the time course of myocardial electrical activity produced by sotalol may have a bearing on the antiarrhythmic properties of this drug (*2*). Sotalol prevents the ventricular fibrillation produced by coronary ligation or poisoning with ouabain (*2*). Other antiarrhythmic agents such as the β-adrenergic blocking agents pronethalol and propranolol do not prolong the cardiac action potential. These drugs have local anesthetic activity, and probably act by reducing depolarizing (Na^+) current (*7*). Sotalol, on the other hand, is not a local anesthetic agent (*8*). The QT interval is increased about 50 percent in animals when sotalol is present in concentrations sufficient to exert antifibrillatory activity (*2*). The concentration of sotalol for antifibrillatory action is estimated to be of the same order as the concentration that prolongs the action potential in vitro. Our studies indicate that in concentrations from 6×10^{-6} to 6×10^{-4} mole/liter, this drug does not decrease the rate of depolarization and hence does not interfere with the inward depolarizing current. Consequently, it appears that the antifibrillatory activity of sotalol, unlike that of other presently known antiarrhythmic agents, is attributable to the marked prolongation of the ventricular action potential.

ALBERTO J. KAUMANN*
CAMILLE B. OLSON
Department of Pharmacology,
Harvard Medical School,
Boston, Massachusetts 02115

References and Notes

1. J. R. Blinks, *Ann. N.Y. Acad. Sci.* **139**, 673 (1967); A. J. Kaumann and J. R. Blinks, *Fed. Proc.* **26**, 401 (1967).
2. A. J. Kaumann and P. Aramendía, *Acta Physiol. Latinoamer.* **26**, 206 (1966); P. Aramendía and A. J. Kaumann, *ibid.*, p. 307; A. J. Kaumann and P. Aramendía, *J. Pharmacol. Exp. Therap.*, in press.
3. A. J. Kaumann and J. R. Blinks, *Pharmacologist* **9**, 248 (1967).
4. J. R. Blinks, *Arch. Exp. Pathol. Pharmakol.* **248**, 73 (1964).
5. R. Niedergerke, *J. Physiol. London* **134**, 584 (1956); *ibid.* **167**, 515 (1963).
6. F. Kavaler, *Amer. J. Physiol.* **197**, 968 (1959).
7. A. Morales-Aguilerá and E. M. Vaughan Williams, *Brit. J. Pharmacol.* **24**, 332 (1965); E. W. Gill and E. M. Vaughan Williams, *Nature* **201**, 199 (1964).
8. P. M. Lish, J. H. Weikel, K. W. Dungan, *J. Pharmacol. Exp. Therap.* **149**, 161 (1965); J. R. Schmid and C. Hanna, *ibid.* **156**, 331 (1967).
9. Supported by grants HE 03788 and GM 95 from the U.S. Public Health Service. Sotalol was kindly supplied by Dr. P. M. Lish, Mead Johnson Research Center. A.J.K. is a fellow of the Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina.
* Permanent address: Segunda Cátedra de Fisiología, Escuela de Medicina, Universidad de Buenos Aires, Argentina.

15 April 1968

Visual Evoked Response Correlates of Unconscious Mental Processes

Abstract. *Average evoked responses and accompanying free associations elicited by subthreshold visual stimuli were studied to determine if a differential discrimination between two stimuli would be reflected in either or both of these responses. The results indicate that the effects of subliminal perception are encoded in the average evoked response and also influence the content of free associations.*

Bevan (*1*), in reviewing a number of studies which sought to investigate the influence of subliminal stimuli upon cognitive processes, concluded in favor of subliminal perception. Shevrin and colleagues (*2*) have shown that subliminal visual stimuli influence associations and imagery and also elicit verbal behavior which depends upon clanglike rather than conceptual relationships; this is in parallel with thinking as noted in clinical psychopathology (*2*).

Modifications in electrical activity of the brain—average evoked potentials—have been reported to be associated with complex psychological processes such as attention (*3*). Libet *et al.* (*4*) found electrocortical responses to somatosensory stimuli below the level of conscious awareness even when attention was directed to the stimuli. Schwartz and Shagass (*5*), by contrast, reported that electrocortical response and consciousness are coordinate and suggested that subliminal effects can be explained as attentional phenomena not reflected in the average evoked response. Pribram *et al.* (*6*), recording average evoked responses from the striate cortex of the monkey, found that these responses discriminate between a circle and vertical stripes flashed at 0.001 second.

Here we ask the following. (i) Will these responses discriminate between two subliminal stimuli matched essentially for size, color, general configuration, and brightness, but differing in specific content and complexity of internal contours (Fig. 1)? (ii) Will verbal free associations to subliminal stimuli which produce average evoked response discrimination suggest a complex symbolic process rather than a primitive sensing of difference?

Stimuli were presented in a two-field, Dodge-type tachistoscope. Luminance of blank and stimulus fields was 3.0 mlam. The room luminance was 0.9 mlam. Average evoked responses were recorded by Grass model III-D 8 channel electroencephalograph, Sanborn model 2007 channel tape recorder, Enhancetron model 1024, and Mosely model 7000 X-Y plotter. Bipolar recordings were made between frontal, vertex, and left occipital (2 cm above inion) placements; the left ear was grounded. Thirteen male college students of ages 20 to 22 served as subjects. Electroencephalogram (EEG) and free-association data were obtained in one 3-hour session.

Pilot investigations established that subjects did not perceive the stimuli presented at durations of 0.001 second

Table 1. Mean amplitudes of average evoked response components for frontal-occipital recordings.

Stimulus exposure time (sec)	B-C (μv)		C-D (μv)		D-E (μv)	
	R	D	R	D	R	D
0.001 (first series)	7.87	5.20	8.98	8.07	10.56	8.88
0.030	24.26	19.71	7.34	8.37	10.55	17.54
0.001 (second series)	7.05	4.77	5.32	6.57	8.41	10.79
Mean for three conditions	13.06	9.89	7.21	7.67	9.84	12.40

but could consciously discriminate differences in the stimuli presented at durations of 0.030 second. In the experiment, three series of 60 stimulations (30 for each stimulus) were presented at 0.001 second, 0.030 second, and again at 0.001 second, thus providing a basis for comparing data on free association and average evoked responses above and below the threshold for conscious discrimination. Each series of 60 stimuli was divided into six blocks of ten each, five of each stimulus presented in a modified random order. Subjects fixated a black dot in the center of the field and were asked not to blink until notified to do so, not less than 2 seconds after each stimulation. After each block of ten stimuli, the subject was told to relax, close his eyes, and describe as fully as possible what he had seen; after this there was a 2-minute period of free association restricted to single words (*7*). Five-minute rest periods were allowed between series. Two minutes of practice in free association preceded the experiment.

Free associations were scored for the incidence of words associated to the meaningful stimulus, the picture of the pen and knee (Fig. 1; the pen-knee stimulus will be referred to as R and the abstract form as D). On the basis of previous work (*2*), it was anticipated that three levels of verbal response would be elicited by the pen-knee stimulus: (i) associations to pen and knee, such as ink and leg (conceptual level); (ii) clang associations to pen and knee, such as *pen*nant and a*ny* (clang level); (iii) associations based on the clang combination, or rebus word penny, such as coin, Lincoln, dollar (rebus level). For scoring the conceptual and rebus levels, normative data on word associations are available based on associations obtained from 400 college undergraduates, a sample comparable to the one from which our subjects were drawn. Association scoring is highly reliable and subject to a scoring error of less than 3 percent (*8*).

For the analysis of the data on average evoked response, two subjects were discarded, one, because the electrocortical data were not fully recorded and another because the responses for both 0.001-second conditions took the form of a continuous alpha rhythm, so that it was impossible to determine the stimulus-evoked brain activity. Inspection of Fig. 2, illustrating the average evoked responses for two subjects, shows substantial similarity in the response configurations for both stimuli within each condition, and so it is highly unlikely that the coincidental action of random factors could account for these stable response patterns to two different stimuli.

For the 0.030-second condition the average evoked responses were comparable in configuration to those reported in the literature (*9*). Two major diphasic waves can be observed within the first 500 msec. Of the five points of inflection, A could not be identified reliably and does not enter into the data analysis. Thus, C is defined as the first positive peak. Our values for latencies of these peaks (B, C, D, E; Fig. 2) and those reported by Haider, Spong, and Lindsley (*3*) are, respectively (our figures first): 175 msec and 160 msec; 252 msec and 210 msec; 283 msec and 255 msec; 348 msec and 300 msec. All amplitudes were lower for the two 0.001-second conditions than for the 0.030-second condition. Only one subject in each of the 0.001-second conditions had a peak latency for C which was greater in the briefer exposures than in the longer exposure. These findings are in agreement with Libet *et al.* (*4*) whose published curves show that amplitudes as well as latencies for subliminal average evoked responses were less than for the supraliminal ones.

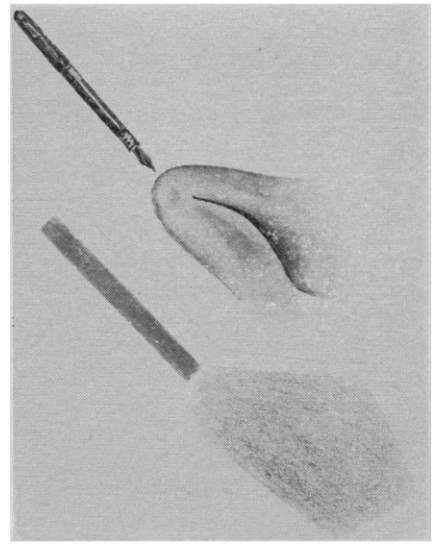

Fig. 1. Experimental stimuli. The pen-knee is the rebus (R) stimulus. Lower stimulus is abstract (D) stimulus.

Analyses of variance were computed for the B-C and D-E components based on the F-O average evoked responses which provided the most consistently measurable data (*10*). For the B-C positive-going wave the average amplitude for the three conditions was signficantly greater for stimulus R than for stimulus D ($F = 11.58$, 1/10 d.f., $P < .01$) (Table 1). Without a significant interaction between stimulus and exposure conditions, this main stimulus effect may be interpreted as showing that, regardless of exposure conditions (subliminal or supraliminal), the difference between the stimuli was at the same level of significance (*11*). For the D-E component, however, there was a significant interaction between stimulus and exposure condition ($F = 4.14$, 2/20 d.f., $P < .05$). An analysis of simple effects indicated that at the 0.030-second condition the D-E amplitude was significantly greater for stimulus D than for stimulus R ($t = 3.34$, Cochran approximation, $P < .01$).

The analysis of the free associations indicated that there were significantly more penny and knee associations during the first 0.001-second series than during the 0.030-second series (Friedman test, Wilcoxon modification, $P < .05$ for penny associates, $P < .01$ for knee associates). These findings were in accord with results from other experiments in which it was found that subliminal association effects decreased as the stimulus approached the recognition threshold or was clearly above it (*12*). The incidence of conceptual associates was positively correlated with both the B-C amplitudes of R and D for the first 0.001-second condition. (All correlations to be reported are Spearman rank order correlations.) The most stable estimate of these correlations was provided by the com-

bined R and D amplitude scores: (i) pen associates, 0.66 ($P < .05$); (ii) knee associates, 0.56 ($P < .10$); (iii) combined pen and knee associates, 0.70 ($P < .05$). The correlations for the clang and rebus effects were nonsignificant.

Special note should be taken of the significant penny associate effect, because this is based on the clang combination level of verbal response, a form of thinking resembling the transitions in thought found in dreams, symptom formation, and wit. The correlation between conceptual associations and the B-C amplitude for the first 0.001-second condition further suggests that there is a close relation between the degree of electrocortical response and the ensuing verbal effects.

Rhythmic after-activity in the alpha frequency range was noted in the average evoked responses. These waves were scored on the basis of the following criteria: (i) successive peak amplitudes in the range of 80 to 120 msec, (ii) minimum amplitudes of 3.3 μv. (iii) a minimum of three successive waves, (iv) the first 500-msec poststimulus was not scored because of stimulus-linked activity. Two judges independently counted the incidence of alpha in the average evoked responses. The reliability between the two judges was estimated by a rank order correlation which was 0.94.

The proportion of alpha present in the EEG records accompanying each of the 2-minute free association periods was judged on an 11-point scale (0 to 10). The reliability coefficient between two judges was 0.98. In the few instances in which the two judges disagreed, resolution was arrived at and a final ranking of scores on the 11-point scale agreed upon. Ratings of average evoked response alpha and free association alpha correlated 0.63 ($P < .05$).

There were a number of significant correlations between the incidence of average evoked response alpha and subliminal effects for the first 0.001-second condition when alpha for both R and D evoked responses were combined. The correlation between the average evoked response alpha and the incidence of penny associates was 0.75 ($P < .01$). The correlation between average evoked response alpha and clangs was 0.73 ($P < .02$). The correlations between the response alpha and the conceptual level effects (pen and knee associates) were not significant.

The B-C amplitude which discriminated between R and D has been reported by Haider, Spong, and Lindsley (*3*) to be associated with attention to a supraliminal stimulus. The pen-knee stimulus is the more interesting of the two stimuli and more likely to attract attention. It is thus possible that an unconscious attentional mechanism may be involved. However, Spehlman (*13*) has reported that the more internal contours a visual stimulus contains the greater the amplitude and latency of the same first positive-going component. In Pribram's study (*6*), the vertical stripes, a more complex stimulus than the circle, were associated with an enhanced positive-going amplitude. The pen-knee stimulus is more complex in its contours than the abstract stimulus. At 0.030 second, subjects often identified the difference between the two stimuli by referring to the internal contour demarcating the leg which is absent in the D stimulus (Fig. 1). Spehlman's findings may also be explained as due to an attentional factor, insofar

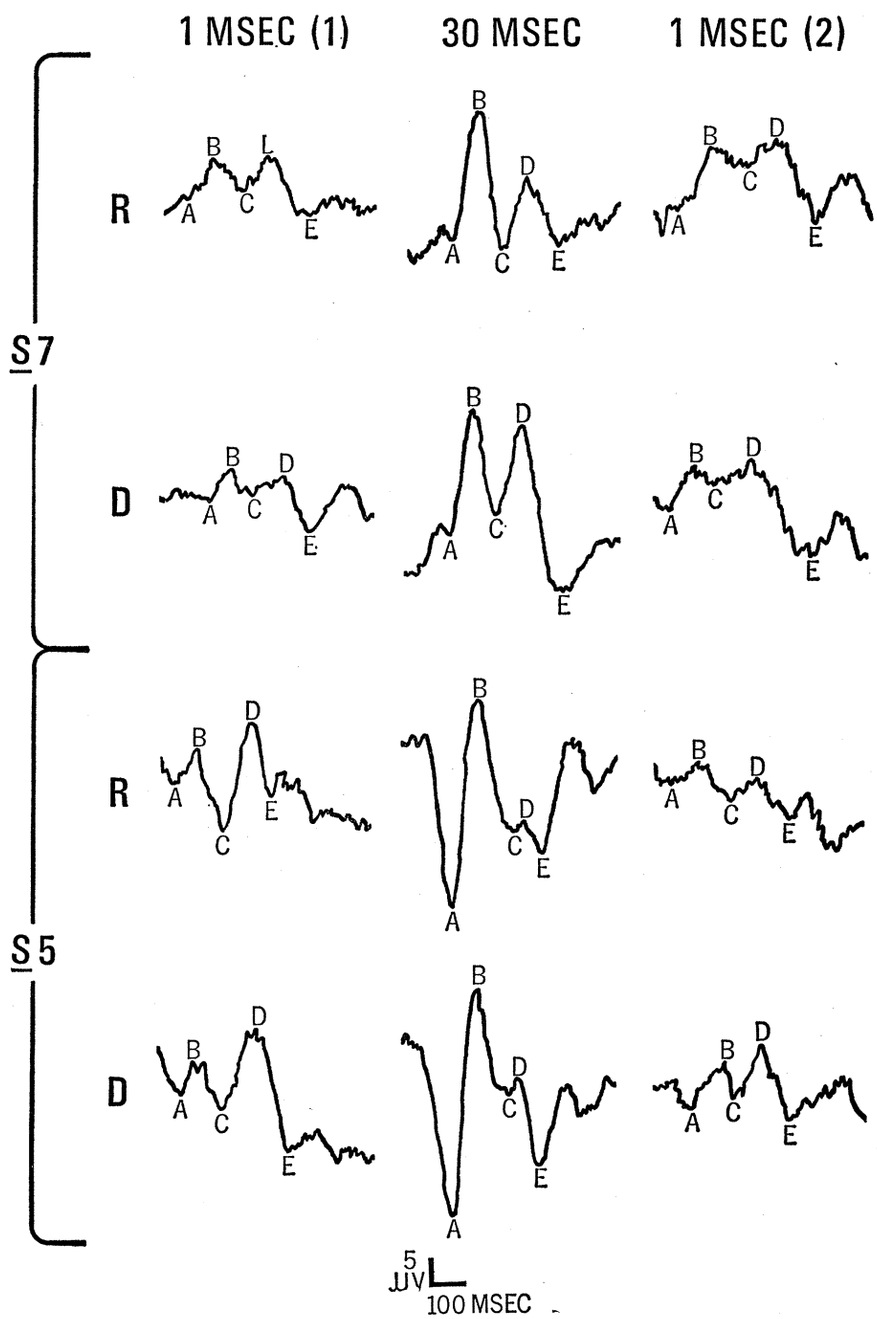

Fig. 2. Average evoked responses (from subjects 7 and 5) as recorded from frontal-occipital electrodes for each exposure condition and for each stimulus, R and D. Average evoked responses are based on approximately 30 sweeps for each curve. Positive polarity downward.

as the more complex stimulus is likely to attract more attention. In any case, the average evoked response is apparently able to reflect differences in stimuli at subliminal speeds of exposure as a result of either attentional factors or specific content differences.

If attention or complexity of stimulus determines the amplitude difference in favor of R, what would account for the later reversal in favor of D for the 0.030-second condition? Attentional processes may oscillate, first being directed at the more immediately interesting stimulus and then shifting to the less interesting one. If so, this shift toward the less interesting stimulus was strongest during the supraliminal condition, which may suggest that unconscious levels of cognition may be more closely linked to the intrinsically interesting stimulus. These are hypotheses which need further investigation.

The significant correlations between the alpha average evoked response activity and the verbal subliminal effects suggests that the subject's state at the time of stimulation already predisposes toward at least one type of subliminal effect. Shevrin and Rennick (*3*) found that average evoked response alpha was more likely to occur while subjects were free associating during somatosensory stimulation than while they were attending to the stimulus or performing arithmetic calculations. Lindsley (*14*) hypothesized that alpha waves would characterize brain activity during free associating. A high incidence of alpha may be coordinate with a state of consciousness which favors fantasy, loose thought connections, and, in general, thinking of an illogical rather than a logical type. It is interesting that average evoked response alpha correlated with the rebus and clang level subliminal effects, both of which are based on illogical phonic rather than conceptual relations, while the B-C amplitures correlated with conceptual level effects. Heightened attention to subliminal stimuli as reflected in increased B-C components may be related to realistic associations, while the shift in state of consciousness concomitant with alpha may be related to unrealistic associations. With both alpha and the B-C amplitudes, the most stable estimates of the correlation with verbal subliminal effects occurred when both R and D average evoked responses were combined, which suggest that some general factors are at work to produce the optimum level of attention and state of consciousness to enhance the later emergence of verbal subliminal effects.

The subliminal verbal effects appeared only in the first 0.001-second condition, suggesting that, beyond a certain point, multiple exposures of stimuli work against subliminal influences. Furthermore, the average evoked response effects tended to diminish in the second subliminal condition. The second subliminal series followed the supraliminal condition which might have changed the manner in which the stimulus input was processed.

Our results indicate that, in the absence of a conscious discrimination, there may nevertheless be present an electrocortical discrimination related to differences in stimulus content which are also revealed in verbal associations. The average evoked response may contain a complex coding for both conscious and unconscious psychological processes of a symbolic nature beyond those heretofore suspected.

HOWARD SHEVRIN
DEAN E. FRITZLER
Menninger Foundation, Topeka, Kansas

References and Notes

1. W. Bevan, *Psychol. Bull.* **61**, 81 (1964).
2. H. Shevrin and L. Luborsky, *J. Nerv. Mental Dis.* **133**, 479 (1961); H. Shevrin and C. Fisher, *J. Abnorm. Psychol.* **72**, 362 (1967); L. Stross and H. Shevrin, *Int. J. Clin. Exp. Hypnosis* **15**, 63 (1967); L. Stross and H. Shevrin, *J. Amer. Psychoanal. Ass.*, in press; L. Stross and H. Shevrin, *J. Nerv. Mental Dis.*, in press.
3. H. Shevrin and P. Rennick, *Psychophysiology* **3**, 381 (1967); R. M. Chapman and H. R. Bradgon, *Nature* **203**, 1155 (1964); H. Davis, *Science* **145**, 182 (1964); M. Haider, P. Spong, D. B. Lindsley, *Science* **180** (1964); J. H. Satterfield *Electroencephalogr. Clin. Neurophysiol.* **19**, 470 (1965).
4. B. Libet, W. W. Alberts, E. W. Wright, Jr., B. Feinstein, *Science* **158**, 1597 (1967).
5. M. Schwartz and C. Shagass, *ibid.* **133**, 1017. (1961).
6. K. H. Pribram, D. N. Spinelli, M. C. Kamback, *ibid.* **157**, 94 (1967).
7. The verbatim instruction for the free-association procedure was as follows. It will help you to relax if you close your eyes, so would you please close them now and let them remain closed until I tell you to open them. Fine, when I tell you to begin, I want you to say all of the different individual words that come into your mind in the space of several minutes and I'll tell you when to begin and when to stop. I want you to say all of the words—about anything at all—that come into your mind, no matter how related or unrelated, how nonsensical or even silly they may seem. It's very important that you say any and all of the different words that come to mind. You can do this best by making yourself comfortable and just letting the words come up by themselves. Are you ready? Okay, begin please.
8. H. Shevrin and L. Stross, PHS grant M-2257, Progress Report, Appendix A, Manual for Scoring (1964).
9. K. A. Kooi and B. K. Bagchi, *Ann. N.Y. Acad. Sci.* **112**, 254 (1964); L. B. Speck, B. Dim and M. Mercer, *Arch. Gen. Psychiat.* **15**, 59 (1966).
10. For the vertex-occipital recordings all measures were in the same direction as for the frontal-occipital recordings although there was much greater individual variability. The frontal-vertex recordings were highly variable, and no consistency of direction could be determined.
11. For a discussion of the relation between interactions and main effects, see A. L. Edwards, *Experimental Design in Psychological Research* (Holt, Rinehart and Winston, New York, rev. ed, 1962), p. 184.
12. H. Shevrin and L. Luborsky, *J. Abnorm. Soc. Psychol.* **56**, 285 (1958); *J. Nerv. Mental Dis.* **133**, 479 (1961); D. Spence. *J. Abnorm. Soc. Psychol.* **68**, 92 (1964); D. Spence and B. Holland, *ibid.* **64**, 163 (1962).
13. R. Spehlman, *Electroencephalogr. Clin. Neurophysiol.* **19**, 560 (1965).
14. D. B. Lindsley, in *Handbook of Physiology*, J. Field, H. W. Magoun, B. E. Hall, Eds. (American Physiological Society, Washington, D.C., 1960), p. 1553.
15. Supported by the Research Department of the Menninger Foundation. We thank Mrs. P. Walters, for the assistance in the administration of the experiment; W. Spencer, for assistance in maintaining the electronic equipment used in the research; Miss Lolafaye Coyne, for supervision of the data analysis; and Mrs. Simpson, for assistance in the scoring of the data; Dr. E. E. Green and Dr. J. Kovach, for careful reading of the manuscript; P. Rennick, Lafayette Clinic, Detroit, Michigan, and B. Naylor, Department of Mental Health, Montpelier, Vermont, who participated in some of the early thinking and pilot work.

25 March 1968; revised 27 May 1968

Terrestrial Volcanic Belts

The article by Sagan, Levinthal, and Lederberg on Martian contamination [*Science* **159**, 1191 (1968)] points up the difficulty of certainty that the planet will not be seriously affected by unmanned exploration. One statement, however, detracts from the argument because it is simply untrue. "Terrestrial volcanic belts tend to be connected by [underground] . . . river systems. . . ." I cannot think of any volcanic belts that can be said to be connected by underground river systems. Are Japan and the Aleutians so connected? Italy and the African Rift Valley? Hawaii and New Zealand? If Mars has much liquid water, it may well have underground water movement, and the groundwater could conceivably carry biological contaminants. Such groundwater movements might be related to hydrothermal water supply, which might be related to volcanic activity in some way; there is no necessary direct connection.

"Underground rivers" are special cases of groundwater movement, and are not particularly common. The authors' statement is unfortunate in an otherwise carefully reasoned article.

DAVID L. AMSBURY
National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas 77058

27 March 1968