readily detectable on both day and night sides of the planet. The high intensities measured at 1480 and 1657 Å, approximately 5.5×10^{10} and 3.0×10^{10} rayleighs, respectively, suggest that the emission may occur primarily at the longer wavelengths, and indeed this conclusion is apparently forced by a consideration of the available energy sources. The long-wavelength emission is one of the major surprises revealed by Mariner 10 and poses a considerable challenge in the continuing effort to unravel and interpret the ultraviolet results.

A. L. BROADFOOT
S. KUMAR, M. J. S. BELTON
Kitt Peak National Observatory, Tucson, Arizona 85717
M. B. MCELROY
Center for Earth and Planetary Physics, Harvard University, Cambridge, Massachusetts 02138

References and Notes

1. A. L. Broadfoot, in preparation. This paper will give details on the instrument design, construction, and calibration. Absolute preflight calibration was carried out by using a high-intensity duoplasmatron source and a Weya-Namioka monochromator.
2. The look direction is specified by the clock and cone angles. The cone, or polar, angle is measured with respect to the spacecraft-sun axis, with zero cone angle defining the solar direction. The clock, or azimuthal, angle is measured in a plane perpendicular to the spacecraft-sun axis, with its zero value defined by the projection of Canopus on this plane.
3. C. A. Barth, J. B. Pearce, K. K. Kelly, L. Wallace, W. G. Fastie, *Science* **158**, 1675 (1967).
4. C. A. Barth, private communication.
5. J. L. Bertaux and J. E. Blamont, *Astron. Astrophys.* **11**, 200 (1971).
6. G. E. Thomas and R. F. Krassa, *ibid.*, p. 218.
7. One rayleigh corresponds to a column excitation rate of 10^6 photons per square centimeter per second.
8. C. A. Barth, *J. Atmos. Sci.* **25**, 564 (1968); *Int. Astron. Union Symp. 40* (1971), p. 17; T. M. Donahue, *J. Geophys. Res.* **74**, 1128 (1969); S. Kumar and D. M. Hunten, *ibid.*, in press; M. B. McElroy and D. M. Hunten, *ibid.* **74**, 1720 (1969); L. Wallace, *ibid.*, p. 115; ———, F. E. Stuart, R. H. Nagel, M. D. Larsen, *Astrophys. J.* **168**, L29 (1971).
9. J. W. Chamberlain, *Planet. Space Sci.* **11**, 901 (1963).
10. T. M. Donahue, *Ann. Geophys.* **22**, 175 (1966).
11. D. E. Anderson and C. W. Hord, *J. Geophys. Res.* **76**, 6666 (1971).
12. D. I. Strickland, A. I. Stewart, C. A. Barth, C. W. Hord, A. L. Lane, *ibid.* **78**, 4547 (1973).
13. H. W. Moos and G. J. Rottman, *Astrophys. J.* **169**, L127 (1971).
14. M. B. McElroy and J. C. McConnell, *J. Geophys. Res.* **76**, 6674 (1971).
15. G. J. Rottman and H. W. Moos, *ibid.* **78**, 8033 (1973).
16. We would like to express our appreciation for the assistance of Frank E. Stuart and the Electronics Laboratory at Kitt Peak National Observatory in construction of the instrument. We are especially grateful for the exceptional effort put forth by Sam S. Clapp, senior engineer at Kitt Peak. Special thanks are due to Jet Propulsion Laboratory personnel, particularly Clayne Yeates and Jim Dunne for providing the science support. This research was sponsored by the National Aeronautics and Space Administration. Kitt Peak National Observatory is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

6 March 1974

Search by Mariner 10 for Electrons and Protons Accelerated in Association with Venus

Abstract. *The University of Chicago instruments on board the Mariner 10 spacecraft bound for Mercury have measured energy spectra and fluxes of electrons from 0.18 to 30 million electron volts and protons from 0.5 to 68 million electron volts along the plasma wake and in the bow shock regions associated with Venus. Unusually quiet solar conditions and improved instrumentation made it possible to search for much lower fluxes of protons and electrons in similar energy regions as compared to earlier Mariner missions to Venus—that is, lower by a factor of 10^2 for protons and 10^3 for electrons. We found no evidence for electrons or protons either in the form of increases of intensity or energy spectral changes in the vicinity of the planet, nor any evidence of bursts of radiation in or near the observed bow shock where bursts of electrons might have been expected in analogy with the bow shock at the earth. The importance of these null results for determining the necessary and sufficient conditions for particle acceleration is discussed with respect to magnetometer evidence that Venus does not have a magnetosphere.*

The primary objectives for the University of Chicago charged-particle experiments on board the Mariner 10 spacecraft are to study the interactions of charged particle and magnetic field to distances within ~ 0.4 A.U. from the sun and to search for populations of charged particles that might be associated with the planet Mercury. However, since the trajectory for the

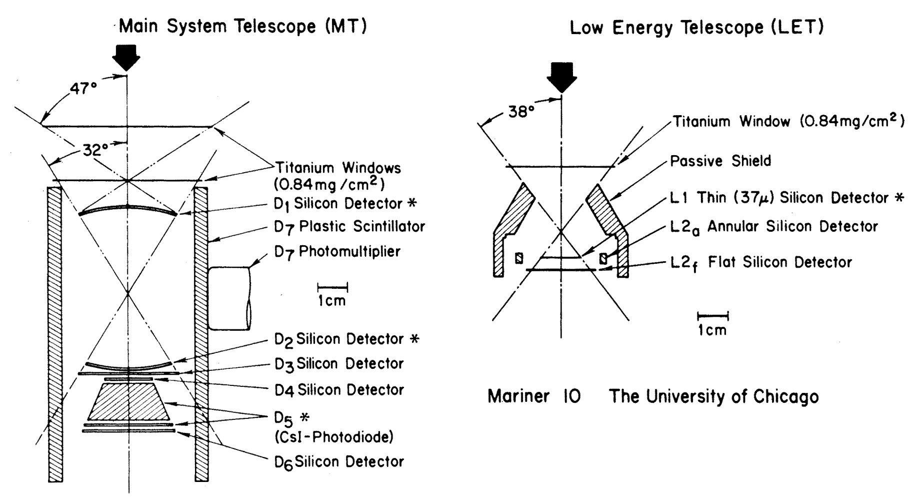

Fig. 1. Cross-section views of the sensing elements in the main telescope (MT) and the low energy telescope (LET) on Mariner 10 spacecraft. The main axis for the cones of particle acceptance for the MT and LET are 45° and 50°, respectively, with respect to the sun-spacecraft line, and ~ 15° out of the ecliptic plane. All detectors shown with asterisks have pulse-height analyzers. These telescopes and their electronics are almost identical with the Pioneer 10 MT (*9*) and LET (*9*).

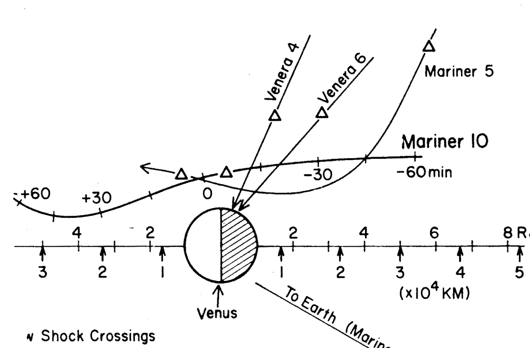

Fig. 2. Trajectories of spacecrafts are projected onto a polar coordinate plot. The trajectory for Mariner 2 in 1962 would lie outside the scale of this diagram. All bow shocks were identified by magnetometer observations as given in Table 1. The choice of trajectory for Mariner 10 was made to optimize the mission to Mercury (*13*).

mission to Mercury requires a close pass near Venus (for a gravity assist) we have taken this opportunity to carry out a further search for electrons and protons that might be the result of acceleration occurring from the interaction of the solar wind and interplanetary field with the Venusian ionosphere. Two earlier searches on Mariner 2 (*1*) and Mariner 5 (*2*) gave negative results at the level of sensitivity reported for their instrumentation. We have not found any evidence for Venus-associated particle fluxes with instrumentation capable of measuring flux variations approximately 1000 times smaller than those of the Mariner 5 detectors for charged particles. Furthermore, the Mariner 10 measurements were made in the presence of an interplanetary particle flux that was extremely stable and characteristic of minimum solar activity. The results of the magnetometer and plasma experiments on board spacecraft from both the United States [Mariner 2 (*1*), Mariner 5 (*3*), and Mariner 10 (*4, 5*)] and the U.S.S.R. [Venera 4 (*6, 7*) and Venera 6 (*7*)], revealing the existence of a bow shock without a detectible planetary magnetic field, have raised interesting questions concerning the necessary and sufficient conditions for electron and proton acceleration in the vicinity of a planetary bow shock.

The experimental results are preliminary only in the sense that the analysis is based on data sent to our laboratory over high speed data lines from the tracking station and not from station-recorded magnetic tapes, which will be available at a later time.

Two charged-particle telescopes provide measurements of the energy loss, total energy, and range of charged particles that enter the cones of acceptance of the telescopes whose elements are shown in Fig. 1. They identify electrons, protons, and heavier nuclei, and measure their energy spectra. For our report here on the search at Venus we have concentrated on measurements of electrons with energies of 0.18 to 30 Mev and protons with energies of ~ 0.5 to 2 Mev.

The trajectory of Mariner 10 with respect to Venus is shown in Fig. 2, displayed in a plane defined by the positions of the sun, Venus, and the spacecraft. The trajectories of all other missions are also shown (the Mariner 2 trajectory would lie outside the scale of Fig. 2). There are two interesting features of the Mariner 10 trajectory for charged-particle, magnetic field, and plasma observations. First, the trajectory lies inside or near the boundary of a possible plasma wake for several days; and, second, the trajectory after passing the bow shock near closest approach continues near the sun-Venus line for $\sim 5\ R_V$ (R_V, radius of Venus = 6052 km). Thus (i) any accelerated particles which might be "sloughed off" from the region of interaction between the magnetized solar wind and the atmosphere of Venus likely would have been detected "downstream" and (ii) particles accelerated within or associated with the bow shock could have been detected "upstream" from the bow shock even if they appeared as bursts of intensity increases like those discovered in and near the bow shock of the earth (*8*) and Jupiter (*9*).

Both the fluxes measured on Mariner 10 and the University of Chicago experiment on the interplanetary monitoring platform, IMP-8, at the earth showed that the interplanetary fluxes were typical of quiet times under conditions of near minimum solar activity for at least 2 days before and 2 days after the closest approach (Fig. 3).

Figure 3A shows the counting rate for electrons > 0.18 Mev and protons > 0.60 Mev measured in 3-minute in-

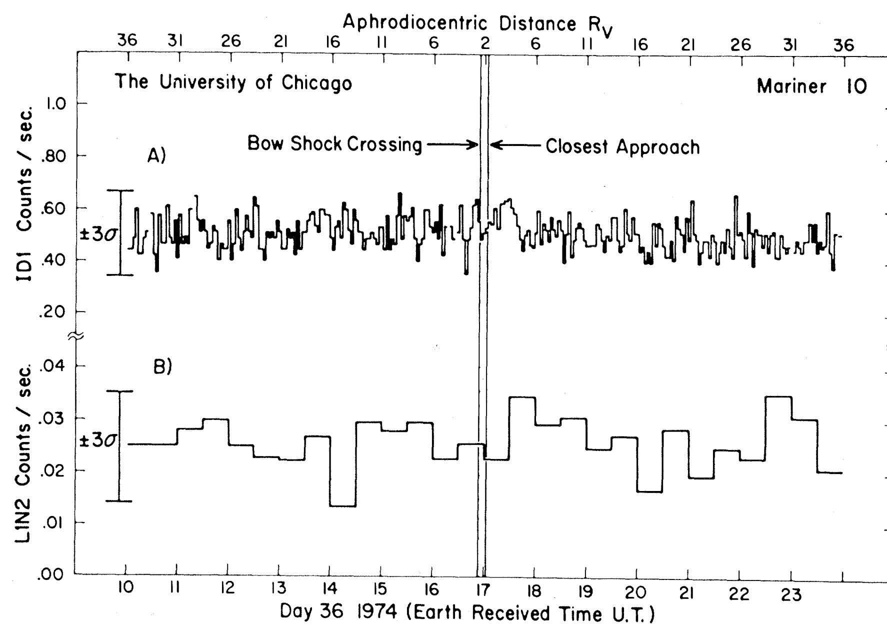

Fig. 3. (A) The counting rate from detector D1 (ID1) for electrons ~ 0.18 to 1.2 Mev and protons 0.6 to 10 Mev with a 3-minute averaging interval. (B) The counting rate from detector L1 (L1N2) for protons 0.52 to 1.8 Mev with a 30-minute averaging interval. L1 has no response for electrons.

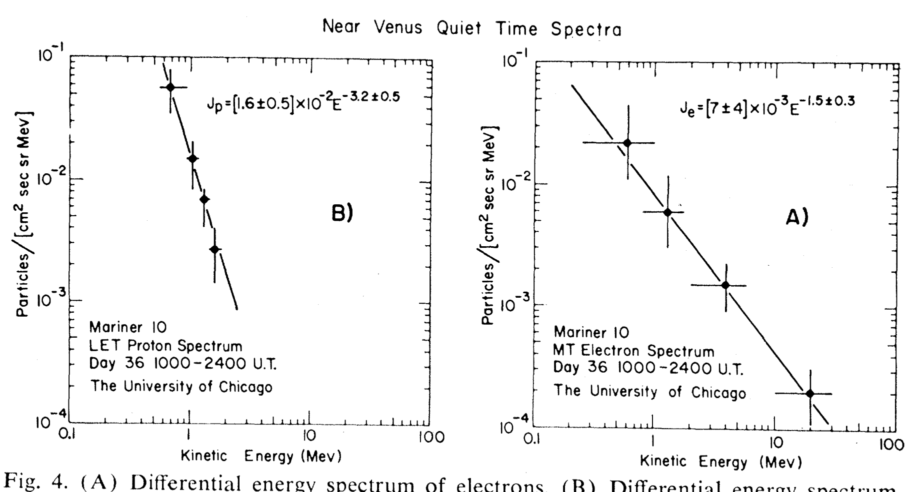

Fig. 4. (A) Differential energy spectrum of electrons. (B) Differential energy spectrum of protons. These spectra are identical with solar quiet time interplanetary spectra for this period.

Table 1. A comparison of charged-particle and magnetic field experiments during Venus encounter.

Mission (year of encounter)	Phase of solar cycle activity	Bow shock*	Search for Venus-associated charged particles: Electrons: Minimum energy (kev)	Electrons: Minimum flux†	Protons: Minimum energy (kev)	Protons: Minimum flux†	M_V/M_E: Scaling of particle observations	M_V/M_E: Magnetometer
Mariner 2 (1962)	Solar active	No (*1*)	70 (*1*)	< 5 (*1*)	500 (*1*)	< 5 (*1*)	$< 9 \times 10^{-2}$ (*2*)	$< 5 \times 10^{-2}$ (*1*)
Mariner 5 (1967)	Near solar maximum	Yes (*3*)	45 (*2*)	< 3 (*2*)	320 (*2*)	< 1 (*2*)	$< (1 \times 10^{-3}$ to $1 \times 10^{-2})$ (*2*)	$< 2 \times 10^{-3}$ (*3*)
Venera 4 (1967)	Near solar maximum	Yes (*6, 7*)						$< 3 \times 10^{-4}$ (*6*)
Venera 6 (1970)	Near solar maximum	Yes (*7*)						
Mariner 10 (1974)	Near solar minimum	Yes (*4, 5*)	180	$< 5 \times 10^{-3}$	520	$< 1.4 \times 10^{-2}$	$< 1 \times 10^{-3}$	$< 5 \times 10^{-4}$ (*4*)

* Magnetic field plus plasma. † Equal to 30 fluctuations in the count rate (particles cm^{-2} sec^{-1} sr^{-1}).

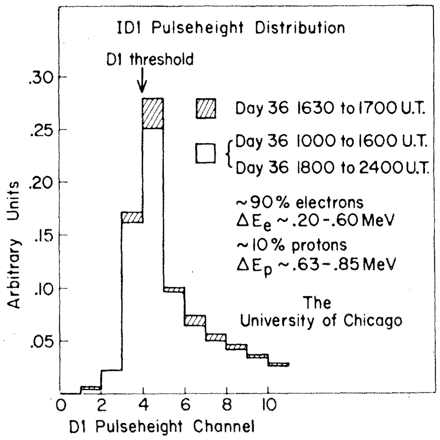

Fig. 5. Normalized ID1 pulse height distributions for two time intervals. The excess number of events during bow shock passage is shown in shaded areas.

tervals. Figure 3B is the counting rate for protons > 0.52 Mev in 30-minute intervals. In both cases these counting rates correspond to interplanetary quiet time fluxes with fluctuations < 3 standard deviations (σ). The electron spectrum (Fig. 4A) throughout the time interval 1000 to 2400 hours U.T. [all times are expressed in ERT (Earth Received Time) with the spacecraft event time being approximately 2½ minutes earlier] is $J_e = (7 \pm 4) \times 10^{-3}$ $E^{-1.5 \pm 0.3}$ electron cm^{-2} sec^{-1} sr^{-1} Mev^{-1}, where E is the kinetic energy of the particle. We have taken into account the response function of the main telescope for electrons. This is in close agreement with the interplanetary observations of Hurford *et al.* (*10*). The corresponding proton spectrum in Fig. 4B is $J_p = (1.6 \pm 0.5) \times 10^{-2} \times E^{-3.2 \pm 0.5}$ proton cm^{-2} sec^{-1} sr^{-1} Mev^{-1}, which is in good agreement with recent measurements by IMP-8 at the earth.

A further search for a change in the electron spectral index near the bow shock was undertaken (Fig. 5) by dividing the pulse height distributions at low energy from the D1 detector pulse height analyzer into intervals (i) during the bow shock crossing (1630 to 1700 U.T.), (ii) before (1000 to 1600 U.T.) the bow shock crossing, and (iii) after (1800 to 2400 U.T.) the bow shock crossing. The intervals were normalized by means of the total number of charged particles stopping in detector D1 during each analysis period. The individual pulse height channels for both distributions were all within 0.5σ of each other. The small excess flux during bow shock passage is not statistically significant. Also, by investigating time intervals as short as 1 second, it was found that there were no very short bursts of particle fluxes from 1000 to 2400 U.T.

In Table 1 we have compared our null results with all previous charged-particle, magnetometer, and plasma measurements near Venus. All the particle and magnetic field experiments are consistent with a very complex magnetogasdynamic shocklike structure close to the planet, a very weak intrinsic magnetic field, and no magnetosphere. We would also conclude from our data that there is no evidence for electron bursts comparable to the bursts observed in and behind the earth's bow shock (*8*) even though the shock magnetic field strengths at Venus and the earth are comparable. Other than the fact that the physical dimensions of the bow shock at Venus are approximately an order of magnitude smaller than those for the earth, the magnetic structure in the bow shock found by Mariner 5 and now by Mariner 10 suggests that the bow shock differences alone will not account for the different behavior in particle acceleration at the earth and Venus. Whether particle acceleration is occurring at much lower energies than can be detected in our experiment is an open question in view of the enhanced fluxes of < 1-kev electrons observed both in the bow shock and as discrete bursts upstream from the shock by the plasma detector on Mariner 10 (*5*).

The Venera 4 (*6*) and Mariner 10 (*4*) magnetometer results establish that the upper limit of an intrinsic dipole magnetic moment for Venus (M_V) relative to that of the earth (M_E) is $M_V/M_E \leqq 3 \times 10^{-4}$. These magnetic field measurements would place a hypothetical magnetopause in the interior of the planet. Thus an earthlike magnetosphere is impossible at Venus. Our measurements, which indicate no energetic planet-associated fluxes yield an upper limit for the Venus magnetic dipole moment, $M_V/M_E < 10^{-3}$, consistent with no magnetosphere. We conclude, therefore, that the observed bow shock stands off from the electrically conducting ionosphere. These bow shock conditions are similar to the observations at Mars (*11*). Although qualitative models for the interaction of the magnetized solar wind with a conducting ionosphere have been considered recently (*12*), the preliminary results from Mariner 10 do not clearly distinguish among the different solar wind–ionospheric interactions.

We now have two planetary systems where electrons and protons appear to be accelerated in and near bow shocks, namely at the earth (*8*) and at Jupiter (*9*). It is interesting, therefore, that perhaps only bow shocks in front of planets with magnetospheres can lead to high energy particle acceleration. This in turn reopens the question, Where do the particles gain most of their energy—that is, in the shock, behind the shock, or before escaping outward through the magnetospheric boundary? In view of the astrophysical importance for understanding shock acceleration of charged particles it is essential to resolve these alternatives.

J. A. SIMPSON, J. H. ERAKER
J. E. LAMPORT, P. H. WALPOLE
Enrico Fermi Institute,
University of Chicago,
Chicago, Illinois 60637

References and Notes

1. L. A. Frank, J. A. Van Allen, H. K. Hills, *Science* **139**, 905 (1963); E. J. Smith, L. Davis, Jr., P. J. Coleman, Jr., C. P. Sonnett, *J. Geophys. Res.* **70**, 1571 (1965).
2. J. A. Van Allen, S. M. Krimigis, L. A. Frank, T. P. Armstrong, *Science* **153**, 1673 (1967); *J. Geophys. Res.* **73**, 421 (1968).
3. H. S. Bridge, A. J. Lazarus, C. W. Snyder, E. J. Smith, L. Davis, Jr., P. J. Coleman, Jr., D. E. Jones, *Science* **153**, 1669 (1967).

N. F. Ness, K. W. Behannon, R. P. Lepping, Y. C. Whang, K. H. Schatten, *ibid.* **183**, 1301 (1974).

H. S. Bridge, A. J. Lazarus, J. D. Scudder, K. W. Ogilvie, R. E. Hartle, J. R. Asbridge, S. J. Bame, W. C. Feldman, G. L. Siscoe, *ibid.*, p. 1293.

6. K. I. Gringauz, V. V. Bezrukikh, L. S. Musatov, T. K. Breus, *Cosmic Res.* **6** (3), 411 (1968); Sh. Dolginov, E. G. Iroshenkov, D. N. Zhuzgov, *ibid.* (4), p. 561.
7. K. I. Gringauz, V. V. Bezrukikh, G. I. Volkov, L. S. Musatov, T. K. Breus, *ibid.* **8** (3), 431 (1970).
8. C. Y. Fan, G. Gloeckler, J. A. Simpson, *Phys. Rev. Lett.* **13**, 149 (1964); L. A. Frank, *J. Geophys. Res.* **70**, 1593 (1965).
9. J. A. Simpson, D. Hamilton, G. Lentz, R. B. McKibben, A. Mogro-Campero, M. Perkins, K. R. Pyle, A. J. Tuzzolino, *Science* **183**, 306 (1974).
10. G. J. Hurford, R. A. Mewaldt, E. C. Stone, R. E. Vogt, Proceedings of the 13th International Conference on Cosmic Rays, Denver, (1973), vol. 1, p. 324.
11. J. J. O'Gallagher and J. A. Simpson, *Science* **149**, 1233 (19 E. J. Smith, A. J. Coleman, D. E. Jones, *ibid.*, p. 1241.
12. See F. C. Michel, *Comments Astrophys. Space Phys.* **111**, 27 (1971); P. K. Murherjee and S. P. Talwas, *Planet. Space Sci.* **21**, 507 (1973); E. W. Greenstadt, *Cosmic Electrodyn.* **1**, 380 (1970).
13. J. A. Dunne, *Science* **183**, 1289 (1974).
14. We thank the Mariner 10 project office, especially Dr. James Dunne, W. E. Giberson, D. H. Swenson, A. H. Matzke, and the staff of the Laboratory for Astrophysics and Space Research of the Enrico Fermi Institute, particularly F. Sopron, G. Lentz, J. Coates, and S. Christon. This work was supported in part by JPL contract 953091, NASA grant NGL14-001-006, and NSF grant GA-38913X.

6 March 1974

Seasonal Changes in Goldfish Learning?

Shashoua (*1*), using a "float training" technique, has recently confirmed reports by Agranoff and Davis (*2*), who used shuttle box avoidance procedures, that goldfish exhibit a cyclic annual change in ability to learn. A maximum was reported for the winter months, with a minimum occurring in the months of July and August. A possible cyclic change in hormonal levels was proposed as explanation for these findings (*1*).

For 4 years I have been training goldfish in shuttle boxes for use as "donors" in studies of the so-called chemical transfer of learning (*3*). Even though I used a schedule very similar to that employed by Agranoff's group (*2*), I did not observe any systematic seasonal change in learning ability. This was the case in work carried out both in the United States, where I obtained fish from the same supplier as Agranoff and Shashoua [Ozark Fisheries, Stoutland, Missouri (*4*)], and recently in Denmark, with fish supplied by Barilli and Biagi, Bologna, Italy. For example, the most recent groups of fish trained during the periods of Shashoua's maxima and minima, respectively, showed performances on the 10th and final day of training of 82.2 percent avoidance (mean of 18 fish trained in March) and 83.4 percent avoidance (mean of 12 fish trained in August).

It seems difficult to account for this discrepancy in results. An apparent difference in the way the fish are treated before training may be crucial, however. Both Agranoff and Shashoua use the fish 1 or 2 days after arrival, and do not report feeding the fish (*1, 2*). In all of my work the fish were allowed an adaptation period of at least a week in the home tanks, and were fed twice a day, before being used in an experiment. Shipment during the hot summer months, when minimal learning ability was reported to occur, is probably highly stressful, even more so because the metabolic rate of the fish, which are poikilotherms, will be greatly increased. The effects found by Agranoff and Shashoua may be due to greater stress and starvation preceding training in the summer months. Therefore it would appear premature to propose any endogenous mechanisms for the observed effects.

E. J. FJERDINGSTAD
Anatomy Department B, University of Aarhus, Aarhus, Denmark

References

1. V. E. Shashoua, *Science* **181**, 572 (1973).
2. B. W. Agranoff and R. E. Davis, in *The Central Nervous System and Fish Behavior*, D. Ingle, Ed. (Univ. of Chicago Press, Chicago, 1968), p. 196.
3. E. J. Fjerdingstad, *J. Biol. Psychol.* **11**, 20 (1970); in *Chemical Transfer of Learned Information*, E. J. Fjerdingstad, Ed. (North-Holland, Amsterdam, 1971), p. 199.
4. ———, in *Memory and Transfer of Information*, H. P. Zippel, Ed. (Plenum, New York, 1973), p. 440.

12 October 1973

Fjerdingstad proposes that metabolic stress during shipment or the feeding schedules used may be responsible for my observations (*1*) and those of Agranoff and Davis (*2*). As I reported (*1*), animals obtained from local hatcheries and those obtained from Ozark Fisheries showed the same cyclic patterns of activity and learning behavior, so that the stress in transport could not be a factor. Also, all our animals are kept at a constant temperature (21°C), and they are fed once a day, so that starvation cannot be a determining factor.

Two features of Fjerdingstad's experiments (*3*) suggest that the goldfish he used had a low level of arousal in both summer and winter: (i) the animals required 10 days to learn a shock avoidance task to the 80 percent criterion and (ii) the experiments were done without aerating the water in the test aquariums. In my experience, winter goldfish can be trained to learn to avoid a shock in about 50 trials in a period of 3 hours to a criterion of 90 percent correct responses. This was achieved by vigorously aerating the water and not overfeeding the animals (that is, feeding once a day); the last feeding was 18 hours before the onset of the training. No such results could be obtained with summer animals. It seems possible that Fjerdingstad's results for training situations that require a period of several days are not influenced by the level of arousal of the animals, so that both his summer and winter animals correspond to my summer goldfish.

V. E. SHASHOUA
McLean Hospital Biological Research Laboratory, Harvard Medical School, Belmont, Massachusetts 02178

References

1. V. E. Shashoua, *Science* **181**, 572 (1973).
2. B. W. Agranoff and R. E. Davis, in *The Central Nervous System and Fish Behavior*, D. Ingle, Ed. (Univ. of Chicago Press, Chicago, 1968), p. 196.
3. E. J. Fjerdingstad, in *Chemical Transfer of Learned Information*, E. J. Fjerdingstad, Ed. (North-Holland, Amsterdam, 1971), p. 199.
4. I thank the Grant Foundation and the National Institutes of Health (National Institute of Neurological Diseases and Stroke) for their support of the research.

30 January 1974