terocular transfer of the discrimination.

An easier problem, the discrimination of stationary from moving dots, was then tested on the four split-brain monkeys in the same apparatus. Half the animals had the stationary stimulus positive and half had the moving stimulus positive. All monkeys used the hand contralateral to the eye that was unoccluded. Again no significant transfer was seen (mean initial transfer, 52 percent; mean savings, 22 percent).

It should be noted that use of large fields of moving dots, which would look more like the visual flow patterns discussed by Gibson, rather than the small fields used here might reveal a contribution of midbrain mechanisms to discrimination (*9*). Alternatively, tests not involving learning at all might be more likely to show a midbrain contribution to spatial perception. However, under the present conditions it would seem that forebrain mechanisms are the likely candidates for discriminating movement.

A rather striking variability in the savings scores for the four discriminations involving direction of movement was noticed for each split-brain monkey. Although the mean savings score was nearly zero, there were several cases of large positive and negative scores. This variability could be attributed to a strong tendency for the left hemisphere to learn the discriminations more quickly than the right, regardless of whether it was the first or second hemisphere to be taught the problem. Table 2, which contains the raw data on which part of Table 1 is based, presents the trials to criterion for each hemisphere and the ratio of right hemisphere trials to total trials for the two hemispheres. The data for each monkey are arranged in the same order that was given above for the presentation of stimuli; therefore, the right eye was trained first on the first and third discriminations, and the left eye first on the others. Of the 16 discriminations, 13 were learned more quickly by the left hemisphere, as indicated in the third column by ratios greater than 0.50. A t test on the median ratios shows this to be significant at $P < .05$ [$t(3) = 3.2$]. No such "cerebral dominance" effect was seen on two pattern discriminations previously trained in the same apparatus to each of these split-brain monkeys. This control, plus the fact that it was the left hemisphere that was retracted during surgery, makes it unlikely that the asymmetry found in learning these spatial discriminations was artificially induced. It seems probable that the dominance relates to the orientational aspects of the stimulus rather than to the movement, since no cerebral dominance was seen on the discrimination of moving from stationary dots.

CHARLES R. HAMILTON
Department of Psychology, Stanford University, Stanford California 94305
JENNIFER S. LUND
Department of Ophthalmology, University of Washington School of Medicine, Seattle 98105

References and Notes

1. J. P. Schadé and D. H. Ford, *Basic Neurology* (Elsevier, New York, 1965), p. 30.
2. D. Denny-Brown, *Proc. Roy. Soc. Med.* **55**, 527 (1962); J. M. Sprague and T. H. Meikle, Jr., *Exp. Neurol.* **11**, 115 (1965); P. Pasik, T. Pasik, M. Bender, *Brain* **92**, 521 (1969).
3. R. E. Myers, *Arch. Neurol.* **11**, 73 (1964).
4. J. M. Sprague, *Science* **153**, 1544 (1966).
5. P. Pasik, T. Pasik, P. Schilder, *Exp. Neurol.* **24**, 421 (1969).
6. D. Ingle, *Psychol. Forsch.* **31**, 44 (1967); R. Held, *ibid.*, p. 338.
7. G. E. Schneider, *ibid.*, p. 52; *Science* **163**, 895 (1969).
8. C. B. Trevarthen, *Psychol. Forsch.* **31**, 299 (1968).
9. J. J. Gibson, *Brit. J. Psychol.* **49**, 182 (1958).
10. M. Straschill and K. P. Hoffman, *Brain Res.* **13**, 274 (1969); P. Sterling and B. G. Wickelgren, *J. Neurophysiol.* **32**, 1 (1969).
11. M. W. Fischman and T. H. Meikle, Jr., *J. Comp. Physiol. Psychol.* **59**, 193 (1965); T. Pasik, P. Pasik, M. B. Bender, *Arch. Neurol.* **15**, 420 (1966); K. V. Anderson and D. Symmes, *Brain Res.* **13**, 37 (1969).
12. H. Kluver, in *Visual Mechanisms*, H. Kluver, Ed. (Jacques Cattell, Lancaster, Pa., 1942), p. 253.
13. L. Weiskrantz, *Neuropsychologia* **1**, 145 (1963); N. K. Humphrey and L. Weiskrantz, *Nature* **215**, 595 (1967); I. T. Diamond and W. C. Hall, *Science* **164**, 251 (1969).
14. B. G. Wickelgren and P. Sterling, *J. Neurophysiol.* **32**, 16 (1969).
15. P. Black and R. E. Myers, *Science* **146**, 799 (1964); M. S. Gazzaniga, *Neuropsychologia* **4**, 183 (1966).
16. C. B. Trevarthen, *Science* **136**, 258 (1962); P. Black and R. E. Myers, *Trans. Amer. Neurol. Ass.* **93**, 191 (1968).
17. The optic chiasm was sectioned in the control monkeys by a transbuccal approach. Before the monkeys were killed, the rest of the cerebral commissures were sectioned and the animals were tested for lack of interocular transfer of four pattern discriminations as a functional test of the completeness of the optic chiasm section. One of the four monkeys (SRH) showed significant transfer. Histological results confirmed that the optic chiasm was incompletely sectioned in this animal. One other monkey (ABE) also had some fibers remaining but did not transfer the four pattern discriminations interocularly. The remaining two animals were completely sectioned. The four split-brain monkeys were operated on by a dorsal craniotomy. Histological verification of the surgery has not yet been obtained, but the lack of interocular transfer on a series of pattern discriminations suggests that the surgery was successful. Furthermore, the nature of the present results is such that the interpretation would not be affected by some surviving fibers.
18. R. W. Sperry, in *The Harvey Lectures* (Academic Press, New York, 1968), p. 293.
19. We thank S. B. Tieman, L. Winter, R. Brody, S. Berman, and W. Farrell for assistance. Support was provided by PHS grant NB-06501 (C.R.H.) and an Evelyn Neizer postdoctoral fellowship (J.S.L.).

8 September 1970

Energy and Epilepsy

The report by Sanders *et al.* (*1*) relating decreased concentrations of adenosine triphosphate (ATP) in rat brains coincident with the onset of seizures deserves critical debate. Their conclusion that the common denominator and possible etiological factor of various convulsants (for example, hypoxia, hydroxylamine, Metrazol, and methionine sulphoximine) is a fall in the amount of ATP in the brain contrasts with previous results. It has been found that, when mice are given insulin, Metrazol, or methionine sulphoximine, seizures occur without a significant drop in ATP (*2*). Conversely, with secobarbitone anesthesia and electroshock, significant decreases in ATP occur without behavioral signs of a seizure. Similar dissociation in metabolism and seizures has been found in monkeys, dogs, and mice after treatment with Metrazol or electroshock (*3*). Cortical discharge and increased cerebral blood flow occur during a convulsion in the absence of demonstrable metabolic changes in blood or brain energy substrates when animals are paralyzed and well ventilated.

Part of the discrepancy in the findings of Sanders *et al.* may be due to methodology. They attribute the low control ATP value in part to a delay in the freezing of the rat brain. Other investigators have circumvented this by using only the outer cortex of the smaller mouse brain (*2*). A delay in freezing would prolong anoxic catabolism and would bias tissue samples toward low ATP; this trend would be accentuated by any condition that either limited energy supply, such as hypoxia, or increased energy consumption, such as Metrazol.

Both the report by Sanders *et al.* and the hypothesis by Hillman (*4*) focus attention on the possibility that a failure to supply ATP to the sodium pump may cause an electrolyte imbalance that initiates a convulsive discharge. This idea warrants careful documentation, but unfortunately at present the

evidence indicates instead that seizures can begin, proceed, and stop independently of ATP concentrations in the brain.

ROBERT C. COLLINS
Laboratory of Neurochemistry, National Institute of Neurological Diseases and Stroke, Bethesda, Maryland 20014
FRED PLUM, JEROME POSNER
Department of Neurology, Cornell University Medical College, New York, New York

References

1. A. P. Sanders, R. S. Kramer, B. Woodhall, W. D. Currie, *Science* **169**, 206 (1970).
2. L. J. King, O. H. Lowry, J. V. Passonneau, V. Venson, *J. Neurochem.* **14**, 599 (1967); J. Folbergrova, J. V. Passonneau, O. H. Lowry, D. W. Schulz, *ibid.* **16**, 191 (1969).
3. F. Plum, J. B. Posner, B. Troy, *Arch. Neurol.* **18**, 1 (1968); R. C. Collins, J. B. Posner, F. Plum, *Amer. J. Physiol.* **218**, 943 (1970).
4. H. Hillman, *Lancet* **1970-II**, 23 (1970).

1 September 1970

It should be pointed out that in our report we were dealing with the relation between energy and the onset of convulsions. We agree with Collins *et al.* that the role of cerebral metabolism in the initiation and perpetuation of seizure activity merits continued critical evaluation. There exists, in fact, a large volume of literature on this subject, most of which we believe is consonant with our results. Our report is unique insofar as it describes concentrations of adenosine triphosphate (ATP) in the brain immediately before seizures deliberately induced by methods that provide a predictable and brief preictal interval.

Collins *et al.* have accurately emphasized the importance of apnea and increased muscular activity in earlier studies of cerebral metabolism during seizures (*1*). Their experiments confirm that cerebral energy expenditure increases three- to fourfold during electrically induced seizures (*1*), under which conditions the content of ATP and creatine phosphate (CP) is maintained at normal amounts only when the animal is both paralyzed and ventilated with 100 percent O_2. We cannot, however, accept the implication that our observation of cerebral ATP depletion before induced endogenous seizures is somehow invalidated by studies of cortical ATP after administration of an electroshock to otherwise normal brain supported in this manner.

In response to the other remarks, we wish to point out the following: (i) In the reference quoted in which Metrazol was employed (*2*), depletion of either brain ATP (in animals breathing room air) or creatine phosphate (in animals breathing 100 percent O_2) was, in fact, observed in the earliest assays, obtained 15 minutes after Metrazol administration (7 to 8 minutes after disappearance of seizure activity in animals breathing room air). Furthermore, our data reveal an interictal return of cerebral ATP toward normal amounts after the administration of Metrazol (*3*, figure 1), emphasizing the necessity for measurements before the onset of seizure. (ii) Our report specifically addresses itself to the apparent contradiction provided by recent studies of cerebral energy metabolism before seizures induced by methionine sulphoximine (*4*). (iii) We have no laboratory experience with hypoglycemic (insulin-induced) seizures, largely because the onset of convulsions—2 to 4 hours—is sufficiently protracted and unpredictable to preclude immediate preictal assay. (iv) The investigators (*2*) who used secobarbitone anesthesia and electroshock actually reported "generalized clonic jerks from 3 to 6 seconds after stimulation" (*2*). By 6 seconds, a 28 percent decrease in brain ATP and a 67 percent decrease in CP was, in fact, reported. Both values represent over 80 percent of the total depletion of high-energy phosphate content measured after electroshock. When using phenobarbitone and electroshock, they observed clonic movements between 2 and 10 seconds after stimulus, which coincided with decreased brain ATP. We do not interpret these findings as a demonstration of "dissociation" between seizure activity and brain energy stores.

With respect to the observations concerning ATP assay technique, we would like to point out that our experience with brain ATP measurements in over 4000 rats and mice suggests that one-half of a rat head (approximately 15 g) freezes faster than a whole mouse (20 to 30 g) with intact circulation (*1*). We find no advantage in the use of Freon at −150°C (*1*) over liquid propane at −187°C. Brain ATP in control animals varies from study to study depending on experimental conditions. Control values in mice have been reported to range from 1.48 (*2*) to 3.02 μmole/g (*4*). Thus, within any given experiment, we consider the variance to provide the best criterion of assay validity; in this respect our values compare quite favorably with those of Collins *et al.* (*1*), who froze the intact animal and assayed the whole brain rather than the cortex.

Finally, we believe our data strongly support but do not by any means confirm the view that deficient energy metabolism plays a significant role in seizure genesis.

AARON P. SANDERS
RICHARD S. KRAMER
BARNES WOODHALL
WILLIAM D. CURRIE
Division of Radiobiology and *Division of Neurosurgery, Duke University Medical Center, Durham, North Carolina 27706*

References

1. R. C. Collins, J. B. Posner, F. Plum, *Amer. J. Physiol.* **218**, 943 (1970).
2. L. J. King, O. H. Lowry, J. V. Passonneau, V. Venson, *J. Neurochem.* **14**, 599 (1967).
3. A. P. Sanders, R. S. Kramer, B. Woodhall, W. D. Currie, *Science* **169**, 206 (1970).
4. J. Folbergrova, J. V. Passonneau, O. H. Lowry, D. W. Schulz, *J. Neurochem.* **16**, 191 (1969).

27 October 1970

Asteroid Landing

In their article entitled "Mission to an asteroid" Alfvén and Arrhenius (*1*) have made certain gross oversimplifications and omissions. These are as follows:

1) There is some reason to believe that asteroids have high axial rotation rates. Eros, for example, has an axial rotation period of 5 hours, 16 minutes (*2*). This important characteristic of asteroids was not included in either of Alfvén and Arrhenius' tables. Without adequate preplanning to include the rotational motions and rates of the asteroid, an asteroid might be chosen upon which it would be impossible to land. Eros, being roughly brick-shaped (*3*) with a "mean diameter" of 20 km (*2*), very probably has complex precessional motions. To attempt to land on or contact a planetary body without knowing how its surface moves presents no mean task. This task is certainly not "simpler than the landing on the moon," a landing that was well-prepared for with computerized trajectories and photographic surveys.

2) The various statements concerned with the gravitational-dependent properties (for example, escape velocity and "weight") might be in serious error if they were calculated from simple con-