currently increasing at 7 percent per year.

If the generated electricity is valued at the current residential rate of 2 ct/kw hr, the solar energy would represent a potential total yearly return of $200. For the system described the peak power capability of the rotary equipment would have to be 11 kw. The costs of the rotary equipment, assuming that an inexpensive induction motor design is used for the alternator, would probably be less than $1000. At the present state of technical development the cost of a large-area semiconductor converter would be prohibited. For instance, the fabrication of a 100 m^2 panel from currently available solar cells would cost in the neighborhood of $250,000. It is worth remembering, however, that this cost is predominately one of fabrication and will be greatly reduced when new techniques—for instance, evaporative methods of fabrication—are developed.

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6 August 1959

Pavlov the Empiricist

I am grateful to Conway Zirkle for his letter [*Science* **128**, 1476 (1958)] calling attention to a 1958 translation of a 1957 article by A. L. Takhtadzhan in *Botanichesky Zhurnal* in which an "article" (Zirkle's designation, Takhtadzhan does not call it so) in a 1927 issue of *Pravda* by I. P. Pavlov on the inheritance of acquired characters is cited. I missed the Takhtadzhan article (the *Botanichesky Zhurnal* is not my usual pabulum), and while I heard of the Pavlov item in *Pravda*, I could not locate the particular issue at the time of writing my article [*Science* **128**, 758 (1958)]. I have now seen the issue (13 May) and would like to report on it and on some related information and interpretation.

Pavlov did not "publish" an "article" in *Pravda*, not even a letter. What happened was that M. Levin reviewed in *Pravda* a 28-page popular pamphlet by E. Smirnov, "The Problem of the Inheritance of Acquired Characters," published by the Communist Academy, and took Smirnov to task for patent bias in favor of the inheritance of acquired characters and for including the Pavlov experiments as alleged positive evidence for it (that was in 1927). Levin stated: "The problem of Pavlov's mice has been taken off the docket by Pavlov himself. Comrade Gutten addressing Academician Pavlov on the significance of his experiments [on inheritance], recently received from him an unambiguous answer. Here is what the conscientious scientist, used to heeding seriously the requisites of the methodology of the natural sciences, writes:

1 March 1927

'Most esteemed Mr. Gutten:
The first experiments with the hereditary transmission of conditioned reflexes in white mice have not yet been confirmed with improved methods and stricter control, so that I should not be classed among those authors who affirm such transmission.

With true respect,
IV. PAVLOV.'"

Again, I should like to note that my article did not say that nothing was published in Russian about the inheritance experiment before 1949. What it said was that Pavlov's report of it, published in 1923 in four places in English, did not appear in Russian before 1949. The experiment itself was communicated to the 1923 Russian physiological conference by Studentsov, who actually performed it and published it as an abstract in Russian in the *Fiziotogichesky Zhurnal S.S.S.R.* [**7**, 312 (1924)]. The data in the Studentsov abstract differ slightly from those in Pavlov's report: Studentsov reports 298, 114, 29, 11, and 6 conditioning trials for the five successive generations versus Pavlov's rounded figures of 300, 100, 30, 10, and 5.

Zirkle, like B. Gruenberg whom he quotes and like a number of other American scientists, tends to attribute Pavlov's initial acceptance of the inheritance data to "an over-zealous assistant" (presumably Studentsov, who, incidentally, appears to have ended—and begun—his scientific career with the experiment, there being no published mention of him since then). It seems, however, reasonable to assume that Pavlov would not have been so gullible if he had not shared the Lamarckian predisposition, common to Russian bioscientists—and to the intelligentsia in general—even before the Revolution, and if he had reviewed critically the general evidence on the topic; moreover, it might be added that the experiment was performed with mice and not with dogs, and with a "free-running" and not a "harness" technique—both new to the Pavlov laboratory. And these factors, plus Pavlov's sense of his historical destiny as an innovator and tester of nature, were probably the basis of his failure to repudiate formally the inheritance doctrine even after he obtained no evidence in support of it. "Have not yet been confirmed" and "the question . . . must be left open" are the expressions used by him in the aforementioned letter and in the footnote to the 1927 English translation of his *Conditioned Reflexes* (*1*).

Obviously, however, Pavlov's remaining open-mindedness about the inheritance of acquired characters relates little to his status as a thoroughgoing empirical scientist. What does relate is his attitude towards controlling influences of attendant nonempirical sociopolitical and philosophical views. And here Pavlov's record is surely unblemished and strikingly unique and exemplary. He stated in his 1906 Huxley lecture: "Natural science is the work of the human mind directed to nature and investigating nature without borrowing any kind of concept or interpretation from sources other than nature itself" (*2*), and there is not an iota of evidence that in the remaining 30 years of his life he ever in even one instance swerved from the objective. Indeed, just as he resisted any Marxist incursion into his experimental system (*3*), he became in the last years of his life expressly suspicious of what he believed to be distortions of science by religion and other prevailing philosophies. He quotes scornfully Sherrington's saying to him, in 1912: "No, your experiments [on conditioning] will not go over in England because they are materialistic" (*4*), and a later published statement, "*if* nerve activity have relation to mind" (*5*) (italics mine). "Sherrington," Pavlov declared, "is a dualist definitively dividing his being into two halves: a sinful body and an eternal, immortal soul" and assuming that "the brain is a piano, a passive instrument, from which the soul, the musician, can extract any melodies it likes" (*6*)—and he proceeds to label similarly a number of other Western scientists as dualists and animists. Whatever the merits of the labels (*7*), there is no doubt that Pavlov was in all respects an unstinting and uncompromising empiricist and objectivist in a pioneer area in which others often succumb and stray. Perhaps, indeed, he was the 20th century's empiricist par excellence.

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7. In one place (*ibid.*) Pavlov states: "I simply assume that he [Sherrington] is ill, although he is only seventy years old, that these [his views on brain and mind] are symptoms of old age, decrepitude" (Pavlov was 84 at the time). And later, discussing religious-philosophical distortions of science, he concedes: "Take my wife—she is a dualist. She is religious yet she shows no distorted attitude towards things" (*ibid.*). (The excerpts are from informal talks which Pavlov did not prepare for publication, and probably he never thought they would be published.)

7 July 1959

Effect of Dietary Fats on Fatty Acid Composition of Human Erythrocytes and Chick Cerebella

Abstract. Through gas-liquid chromatography it can be shown that increasing the ingestion of linoleic acid-containing fats increases the deposition of linoleic acid in erythrocytes and in brain tissue. Such changes are probably causally related to the tocopherol requirement, the incidence of chick encephalomalacia, and the peroxide hemolysis test. Whether similar mechanisms are involved in the ability of unsaturated oils to lower serum cholesterol levels remains to be determined.

Although it has been generally acknowledged that the composition of depot and plasma lipids can vary with the type of fat ingested, it had not been proved that structural lipids, such as are found in brain or in the stroma of erythrocytes, could also be varied by diet. This report shows that such changes do take place and that they may have physiological significance.

The controlled dietary regimen of the patients whose blood was used in this study was described in previous publications (*1*, *2*) in which the effects of fats on the tocopherol requirement of man were reported. Chick brains were obtained from birds which were fed tocopherol-deficient diets containing lipids with different levels of linoleic acid. The production of encephalomalacia in chicks, with characteristic gross and microscopic cerebellar lesions, depended upon the concentration of linoleic acid-containing fats in the diet, as well as on the absence of tocopherol (*3*, *4*).

Five-milliliter samples of centrifuged packed red blood cells were washed three times with 0.16*M* NaCl and hemolyzed with water (after the addition of 0.2 ml of 0.5-percent *dl*-α-tocopherol to minimize peroxidation), and the lipids were extracted with methylal-methanol (4+1). The lipids were dried under nitrogen, extracted with petroleum ether according to the method of Morris *et al.* (*5*), and methanolyzed according to the procedure of Stoffel *et al.* (*6*). Saponification of blood lipids followed by methylation of the fatty acids gave results which were similar to those obtained by direct methanolysis. Individual cerebella from brains of 1-month-old chicks were similarly prepared after homogenization in methylal-methanol solutions. Most of the methyl esters were chromatographed at column temperatures of 208°C in the Lovelock ionization chamber (*7*) on Apiezon M glass columns having efficiencies of 6000 to 10,000 plates, calculated for methyl stearate according to Desty's method (*8*). The columns were 8 ft long, with an internal diameter of 1 mm. The celite used was 150 to 200 mesh; argon gas pressure was 110 lb; gas flow was 8.5 ml per minute; and time required to complete analyses through C_{22} was 9 hours. The absence of significant amounts of products larger than C_{22} was confirmed through the use of columns containing the succinate polyester of diethylene glycol (*9*) and of high-temperature (300°C) silicone columns with thermal conductivity cells as detectors (*10*). Retention volumes of methyl esters of fatty acids obtained on Apiezon M were similar to those reported by Insull and Ahrens (*11*).

Some of the analyses of chick cerebella were conducted on Apiezon L columns, which required lower gas pressures and took less time for complete analyses, but fewer separation plates were achieved with these faster-acting columns. The resolution of all known fatty-acid components was not obtained by the techniques used. For example, the "linoleic acid" peak includes any linolenic acid which may be present, and the "oleic acid" may contain other C_{18} monoenoic isomers.

As to fatty-acid content, erythrocytes from 19 subjects who for 2 years received a controlled diet of 2300 calories containing 60 gm of corn oil were compared with those from eight patients who had received the regular institutional diet ad libitum for the same period (Table 1). An increased ratio of "linoleic acid" to "oleic acid" was observed in subjects given the corn oil diet. Percentages of linoleic acid in chick cerebella were much lower than those in human erythrocytes, but again relatively larger ratios of "linoleic" to "oleic" acids (.078) were observed in samples from chicks on the corn oil diet, as compared with those obtained from birds on the cod liver oil diet (.014). Lower "linoleic"-acid levels were also seen in cerebella from birds which were fed diets containing very little linoleic acid, such as 4 percent coconut oil, 10 percent oleic acid, and fat-free diets, which, incidentally, do not require tocopherol supplementation for normal chick growth. In all cases, both in the series reported and in subsequent experiments, the linoleic-acid content of a given tissue was higher in subjects that had been fed high levels of linoleic acid than in individuals that had received the lower levels of linoleic acid.

The increase in the linoleic-acid content of the erythrocytes in individuals on diets containing corn oil helps explain why it has been so difficult to obtain normal data on the peroxide hemolysis test (*1*) after long-term feeding of tocopherol-low corn oil diets, followed by tocopherol supplementation (*2*), since the rate of oxidation of linoleic acid is about 12 times that of oleic acid. The data on chick-brain fatty acids help to explain the high incidence of cerebellitis in chicks on diets

Table 1. Fatty-acid composition (percentage ± standard deviation) of human erythrocytes and chick cerebella from subjects that had been fed diets high and low, respectively, in linoleic acids. Number of subjects in parentheses.

Fatty acid	Human erythrocytes		Chick cerebella	
	Corn oil diet (19)	Institution diet (8)	4% Corn oil diet (4)	10% Cod liver oil diet (4)
Lauric	0.5 ± 0.5	0.4 ± 0.2	0.2 ± 0.2	0.1 ± 0.1
Myristic	0.8 ± 0.6	0.7 ± 0.3	0.7 ± 0.4	0.6 ± 0.3
Palmitoleic	0.5 ± 0.2	0.6 ± 0.4	1.2 ± 0.2	1.4 ± 0.6
Palmitic	27.2 ± 2.6	30.2 ± 3.1	36.8 ± 3.8	39.5 ± 6.6
"Linoleic"	15.3 ± 1.6	8.3 ± 1.5	2.0 ± 0.9	0.5 ± 0.2
"Oleic"	17.1 ± 1.5	20.4 ± 3.3	26.5 ± 4.1	33.6 ± 2.2
Stearic	19.2 ± 1.4	20.4 ± 1.8	19.4 ± 0.2	17.3 ± 2.4
C_{20} Penta+tetraene	10.0 ± 3.2	10.4 ± 3.6	4.9 ± 3.2	1.3 ± 1.0
C_{20} Triene	2.0 ± 0.8	1.9 ± 0.7	0.8 ± 0.4	0.3 ± 0.1
C_{22} Hexaene	1.1 ± 2.3	1.2 ± 0.7	2.4 ± 2.4	2.3 ± 2.2
C_{22} Pentaene	1.6 ± 1.0	2.1 ± 1.0	2.0 ± 1.9	0.7 ± 0.5
Others	4.7 ± 2.3	3.4 ± 2.2	3.1 ± 1.7	2.4 ± 0.7
Linoleic:oleic ratio	0.90 ± 0.13	0.42 ± 0.10	0.078 ± 0.048	0.014 ± 0.005
Plasma cholesterol	167 ± 36	184 ± 40 (mg %)		