ally reinforced with 0.05 ml of a liquid diet of sweetened milk, eggs, and vitamins; later, the schedule was changed so that there was a mean interval between food presentations of 1 min (VI). When rates stabilized on the VI schedule, a 0.5-sec shock delivered through the bar and grid floor was introduced after every response. The intensity of shock was gradually increased for all animals in an ascending order from 0.1 to 0.8 ma in an effort to replicate approximately the procedure of Azrin (*1*) and to avoid the difficulty (if not the impossibility) of reconditioning bar pressing after behavior is completely suppressed by severe punishment (*5, 6*). Each animal was tested at each intensity until its behavior did not change from day to day. This usually required 7 to 10 days. After the last session at a given shock level, there were 5 days under the VI schedule without shock.

At the intensities studied, the rates returned to preshock levels in the absence of the punishment contingency (during VI sessions). Figure 1 shows that the degree of initial suppression, the rate of bar pressing (R) on the 1st day at each intensity (I), is an inverse function of the severity of punishment. This is generally true for each animal as well as for the group data which is not shown. The curve is for the equation $R=36.8\ e^{-5.16(I)}$; it was fitted to the log of the mean rate during the first day of exposure to each intensity by the method of least squares.

Average rates for each animal during its last day at each shock level are plotted in Fig. 2. No animal showed any systematic change in rate from day 1 to any subsequent punishment session at any intensity no matter how long it was exposed to a given shock level (up to 12 days in the present experiment and 15 days in a subsequent study). Therefore, the points in Fig. 1 would be expected to overlap with those of Fig. 2 as indeed they do, and the curve which was fitted to the data of the 1st day may also describe all of the punishment data. Thus, under the conditions of the present experiment, no recovery from shock-induced suppression occurs at any intensity while punishment is being administered and the amount of suppression is an exponential function of the intensity of shock.

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Allergic Encephalomyelitis: Rapid Induction without the Aid of Adjuvants

Abstract. *Rapid production of allergic encephalomyelitis has heretofore required injection of nervous tissue emulsified in immunologic adjuvants. Adjuvants are not required if large doses of a potent nervous-tissue antigen and a highly susceptible strain of rats are used. Susceptibility was increased in animals inoculated beforehand with pertussis vaccine.*

Experimental allergic encephalomyelitis (EAE) was first produced in monkeys by repeated injections of homogenates and extracts of nervous tissue (*1*). The course of treatments lasted many months. One or a few injections of nervous tissue has caused the disease in only an occasional mouse, dog, rabbit, or rat (*2, 3*). With the introduction of Freund's adjuvant, allergic encephalomyelitis could be produced rapidly and regularly after one or a few injections of nervous tissue emulsified in adjuvant (*4*). It is thought that the paraffin-oil emulsion facilitates dispersion of nervous-tissue antigens from the local depot to lymph nodes and other immunologically active sites, and saves the antigen from excessively rapid destruction. The oil and the killed mycobacteria of the adjuvant may promote a cellular environment favorable for sensitization (*5*).

That, in rats, the mycobacterial component of the adjuvant was dispensable was shown when rats developed EAE after a single injection of nervous tissue emulsified in mineral oil without mycobacteria ("incomplete" adjuvant)(*3*). We found this procedure particularly effective in producing EAE in the Charles River CD F (Fischer 344) strain of inbred rats, at least when the antigen was guinea pig spinal cord (*6*). In addition, treatment with pertussis vaccine enhances the susceptibility of mice (*7*) and rats (*8*) to EAE. Based on these considerations, we have developed a procedure for rapid and regular production of experimental allergic encephalomyelitis in rats without the aid of adjuvants.

Female rats, 9 to 11 weeks old, of CD F strain (Charles River Breeding Laboratories) were given free access to Purina Laboratory Chow and tap water. Each received 0.6 or 1.2 ml of pertussis vaccine (Lederle, Phase I, approximately 60 billion organisms per milliliter) diluted to 3.0 ml with saline, intraperitoneally, 4 days before challenge. Previously frozen neural tissues were homogenized with a small amount of distilled water. The volume of each injection was 0.05 ml which contained 40 mg of tissue (wet weight). Injections were made intracutaneously under light ether anesthesia.

A single injection of homogenate of guinea pig spinal cord in the right foot pad was ineffective. However, three, five, or ten injections (120, 200, or 400 mg) in the right foot pad produced the disease in 2 to 3 weeks after the first injection. The incidence and severity were proportional to the dosage (Table 1) but did not depend on whether the injections were given simultaneously on the 1st day or were spread out over a 1- or 2-week period. Omission of prior treatment with pertussis vaccine reduced the effectiveness of injections of nervous tissue. Clinical signs were weakness or paralysis, especially of hind limbs, loss of weight, and occasionally, urinary incontinence. All rats were killed 21 days after the first injection. Histologic examination of spinal cord and brain revealed vascular

Table 1. Production of experimental allergic encephalomyelitis without adjuvants.

Rats (No.)	Dose of cord (mg)*	EAE characteristics	
		Clinical incidence (%)	Histologic severity (0–4)†
	Pertussis treatment		
6	40	0	0
11	120	9	1.0
25	200	24	1.3
40	400	68	3.0
	No treatment		
16	400	31	1.1

* Wet weight of guinea pig spinal cord tissue, as 80 percent aqueous homogenate, divided into 1 to 10 injections all in right foot pad. Different schedules of administration are combined for brevity (injections simultaneous or spread out over 1 to 2 weeks). † Group average, graded individually from 0 to 4 according to number and severity of lesions in spinal cord and hindbrain.

and perivascular inflammatory lesions with perivascular demyelination, typical of experimental allergic encephalomyelitis. Almost every rat that received ten injections had lesions. The type and severity of clinical signs and histologic lesions did not differ from those encountered when the disease was produced with the aid of adjuvants.

For further study, 400 mg of tissue homogenate were administered in ten injections, five on the 1st day and five 1 week later in the same site, in groups of 10 or 11 rats that had been treated with pertussis vaccine. With this schedule, intracutaneous injections of homogenate of guinea pig cord in the tail or in the right flank were almost as effective as in the right food pad. However, homogenates of rat cord or human white matter injected in the foot pad had much less activity than guinea pig cord; there were relatively mild histologic lesions in eight and three rats respectively, and no definite clinical signs of disease. Guinea pig peripheral nerve tissue was inactive. Guinea pig cord homogenate produced much less disease in Hemlock Hollow Wistar rats (no clinical signs, lesions in only four rats) than in CD F rats, even though the former strain is known to be highly susceptible to experimental allergic encephalomyelitis produced with nervous tissue and adjuvants (*8*). Variation in susceptibility of individual animal strains to EAE is well known in guinea pigs, mice (*9*), dogs (*2*), and rats (*6*, *8*).

Thus, the rapid production of severe, clinically manifest EAE, without the aid of adjuvants, required the injection of large doses of nervous tissue of a particular type into a highly susceptible strain of rats. Prior treatment with pertussis vaccine was helpful but not essential. It is possible, but not proven, that pertussis vaccine may act by enhancing the inflammatory response to the inoculum (*8*). The effectiveness of homogenate of guinea pig spinal cord cannot be ascribed entirely to its heterologous character, because human white matter, also heterologous, had little potency. It has been reported, with various animal species as recipients, that certain heterologous nervous tissues are more likely to produce encephalitis than others (*10*). High dosage may be required because of the rapid destruction or inefficient utilization of the antigenic components of nervous tissue. Or, it is possible that the excess of nervous tissue assumed the role of adjuvant. These problems are being studied.

It is probable that experimental allergic encephalomyelitis in animals is related to human postinfectious and postvaccinal encephalomyelitis, and there is some possibility of a connection with multiple sclerosis (*11*). In none of these human situations is there evidence for a pathogenic link akin to the adjuvant customarily used in the experimental disease studies. Therefore, the elimination of the adjuvant may facilitate investigation of relationships among these human and experimental diseases (*12*).

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Estimate of Neutron Albedo on the Moon's Surface Resulting from Cosmic Radiation

The moon does not seem to possess an atmosphere: measurements indicate less than 10^{-9} that of the earth (*1*). The surface of the moon is thus exposed to bombardment by cosmic radiation. The result is that the nuclei on the surface undergo spallation yielding various radioactive nuclei as well as neutrons, some of which constitute an albedo. To obtain an estimate of the neutron albedo resulting from such considerations, the intensity and composition of cosmic radiation, the composition of the moon's surface, and the cross section for the production of neutron albedo must be known.

Cosmic radiation consists of protons, helium nuclei, and other multiple-charged nuclei. The intensities and relative abundances have been extensively studied by means of balloon and rocket experiments near the earth. The absolute intensities seem to vary appreciably with the solar cycle. In addition, there is a large increase of proton abundance when there are solar flares. In the present consideration we shall take the proton intensity as 0.2 particle per cm^2 per steradian (*2*), and the intensity of helium nuclei as one-ninth of the proton intensity. The proton intensity is for energies greater than 600 mev; recent experiments have shown the existence of particles with lower energies but their intensity has not been well determined.

The composition of the surface of the moon can only be inferred from telescopic observation. The present calculation is made for two types of rocks—chondrite and basalt—which probably constitute the moon's surface.

The neutron production in the interaction of proton having energies of 190 mev with various elements has been studied by Gross (*3*). We assume these values for all energies since these neutrons result from lowering the excitation of the target nucleus and these values should constitute a lower limit.

The interactions (stars) of protons produced in the top 1 cm^3 of the moon's surface shall be considered first. The cross sections for protons in various nuclei are well known. The star-production rates and neutron-albedo intensities for basalt are shown in Table 1.

It is seen from the table that the total neutron albedo for the top 1 cm^3 of the surface is 2.12×10^{-2} sec^{-1}. To obtain the total number of neutron albedos from a column of 1 cm^2, we note that we have to multiply the above number by a mean free path of neutron absorption in the rock which is calculated to be approximately 8 cm. We can assume a uniform rate of production within this range since the absorption of primary radiation is compensated by secondary production. Thus, the neutron albedo due to proton interaction is 0.17 neutron per cm^3 sec^{-1}. A similar calculation yields the contribution due to interactions of helium nuclei to be 0.09 giving the total neutron albedo as 0.26 neutron per cm^2 sec^{-1} for basaltic rock. The corresponding value for chondritic rock (high iron) is 0.35 neutron per cm^2 sec^{-1}.

The estimates presented should constitute lower limits since particles with