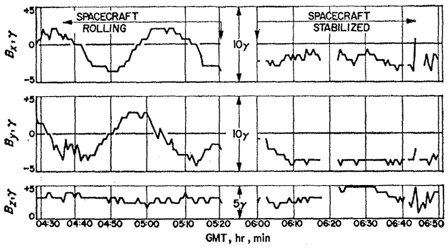

Fig. 2. Interplanetary magnetic field measurements before and after the stabilization of the spacecraft 3 September 1962. The data preceding the gaps in the curves were obtained while the spacecraft was rolling about the Z-axis. The ambient field was relatively undisturbed. B_Z was nearly constant, while B_X and B_Y showed sinusoidal variations produced mainly by the rolling motion. The curves that follow the break in the data were obtained after the spacecraft was stabilized. B_Z was virtually unchanged. B_X and B_Y were also nearly constant after the spacecraft stopped rolling. Note that B_X and B_Y are approximately equal on both sides of the break; the spacecraft orientation corresponding to the data taken just before the break was within 10 degrees of the stabilized orientation.

Preliminary analysis of the Mariner II magnetometer data has also produced some new information. These results, including correlations with the plasma data, do not agree in an obvious way with any simple model of the interplanetary medium (*2*). Averaged over almost any period of several hours, the transverse component of the interplanetary field appears to lie more nearly in, rather than normal to, the plane of the ecliptic (the plane of the earth's orbit). However, there is a substantial, fluctuating component perpendicular to the ecliptic plane. Further investigation should establish whether or not its average, over periods of days, is zero. During the first ten days of the flight, the transverse component was usually directed toward the east, opposite to the direction of planetary motion (see ϕ, Fig. 1). Our earlier speculation (*1*) that in very quiet periods the transverse component might be mainly perpendicular to the ecliptic plane is inconsistent with the Mariner II data for this period. During this same period the range of variations in the radial-field component, ΔB_Z (Fig. 1), was typically 5 to 10 gamma.

When the plasma density and velocity increase during magnetic-storm intervals, the interplanetary field becomes larger and more irregular. Many of the changes in the field components correlate in detail with simultaneous changes in the plasma flux. Often, however, the plasma and field variations cannot be readily correlated. A consistent pattern has not yet been identified that can be ascribed to simple structures or to waves. No correlations have been noted that correspond to the plasma-field correlations observed by Explorer X (*3*) near the earth in which regions of intense plasma flux and intense magnetic flux alternated.

The orientation of the spacecraft, and therefore of the magnetometer, is controlled so that the Z-axis points toward the sun. The orientations of the other two orthogonal axes, X and Y, depend upon the mode of operation of the spacecraft. From 29 August to 3 September the spacecraft was allowed to roll about the Z-axis, so that the X- and Y-magnetometer sensors, although remaining perpendicular to the spacecraft-sun direction, also rotated about the Z-axis. On 3 September the orientation of the X- and Y-axes was stabilized with the Y-axis lying in a plane defined by the sun, earth, and spacecraft.

The magnetometer measurements obtained immediately preceding, and immediately following, the stabilization of the spacecraft about its roll axis are shown in Fig. 2. Since the scientific instruments were inoperative during stabilization, there is a gap in the measurements. The variation in the X- and Y-components during the period preceding the stabilization is attributable principally to the rolling of the spacecraft. The contribution from the transverse interplanetary field, when averaged over many complete revolutions, is zero. The average field values represent the X- and Y-spacecraft field components. Fortunately, the interplanetary field was relatively undisturbed during this period.

The center-to-peak amplitude of the variations in the X- and Y-components is a measure of the transverse component of the interplanetary field. During the period shown in Fig. 2, the component was approximately 3 gamma. The spacecraft made almost one complete revolution (approximately 350°) about the Z-axis between the end of the rolling period and stabilization. Thus, components measured just before, and just after, stabilization are approximately equal. Since the orientation of the Z-axis was not affected by stabilization, and since conditions were magnetically quiet, the measurements of B_Z show very little change (*4*).

P. J. COLEMAN, JR.
University of California, Los Angeles
LEVERETT DAVIS, JR.
California Institute of Technology, Pasadena
E. J. SMITH
Jet Propulsion Laboratory, Pasadena
C. P. SONETT
Ames Research Center, Moffett Field, California

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23 November 1962

Lysergic Acid Diethylamide: Its Effects on a Male Asiatic Elephant

Because of his remarkable intelligence, his extended life span, his capacity for highly organized group relationships, and his extraordinary psychobiology in general, the elephant is an animal of great interest to the zoologist and the comparative psychologist. It has only been in recent years that the physiology of the elephant has received the attention of scientists (*1*). There is now a growing interest in this animal on the part of psychiatrists (*2*).

One of the strangest things about elephants is the phenomenon of going "on musth." This syndrome, a form of madness which occurs almost exclusively in the males, begins with early adulthood (when the elephant is between 12 and 20 years old) and continues to occur once or twice a year until after the involutional period (around age 45 to 50). As he enters a period of musth, the bull elephant begins to show signs of restlessness and irritability, his eyes water, and the slit-like bilateral temporal gland (located midway between the eye and ear) starts to excrete a brown, sticky fluid. Within 48 to 72 hours there is a violent change in the animal's behavior. Normally cooperative and tamable, the elephant now runs berserk for a period of about 2 weeks, during which time he may attack or attempt to destroy anything in his path.

That the activity of the bull elephant during musth is not simply a sexual excitement (like rut) is suggested by the fact that he is as likely to attack a female as to mount her during this period. Furthermore, mating behavior on the part of the bull elephant occurs at any time of the year that a receptive cow becomes available (*3*).

Because he goes on musth, the male elephant can be a most dangerous beast even in his role as a working animal in Asia. There are fewer than a dozen male elephants captive in the United States. Several have been destroyed in the past because of the hazard they created. Nearly all of the elephants in zoos, menageries, carnivals, and circuses are females, most of them Indian (Asiatic) rather than the larger African subspecies.

The male elephant's periodic madness is an almost unique phenomenon in nature, and it provides an interesting opportunity for psychiatric research. What is the mysterious fluid excreted by the temporal gland during musth? Does a simultaneous internal secretion intoxicate the animal? Or is the elephant's glandular disturbance merely a reflection of a more profound inner periodic hormonal thunderstorm which also disrupts his brain and behavior?

Recently we decided to attempt to induce experimentally a behavioral aberration that might resemble the phenomenon of going on musth. The animal involved was Tusko (estimated age, 14 years), a male Indian elephant (*Elephas maximus indicus*) that was being boarded at the Lincoln Park Zoo in Oklahoma City. D-Lysergic acid diethylamide (LSD) (*4*) was chosen as the psychotomimetic agent because of its well-known personality-disrupting effect upon humans and other animals. Should Tusko's reaction to an injection of LSD resemble going on musth, we wanted to see whether there would occur simultaneously an excretion of the temporal glands and, if possible, to collect some of the fluid.

A dose of 100 to 200 μg (0.1 to 0.2 mg) of LSD administered orally to humans has usually sufficed to produce for several hours a marked mental disturbance in some ways similar to the naturally occurring psychoses and reactions of delirium. Higher dosages (up to 0.02 mg/kg) have produced a marked sympathomimetic effect, with dilatation of the pupils, hyper-reflexia, hypertension, elevated temperature, tremor, sweating, illusions, vivid visual hallucinations, and grossly disorganized psychotic thought and behavior. No lethal doses in man have been recorded, although there have been instances of the misuse of LSD in its clinical application to human subjects (*5*).

Proportionately much larger doses have been required to obtain comparable results in lower animals. In order to produce in the rhesus macaque a sensory blockade sufficient to cause loss of position sense and temporary blindness, Evarts gave doses as large as 0.5 to 1.0 mg/kg (*6*). Similar doses must be given to produce a similar effect in the cat. The effecting of even a transient rage reaction in the cat usually requires intravenous administration of at least 0.15 mg/kg. Doses up to 6.5 mg/kg given intravenously are required to kill a cat.

The amount of LSD finally administered to Tusko, by intramuscular injection was 0.1 mg/kg, or 297 mg, in 5 ml of distilled water, since the animal weighed an estimated 6500 to 7000 pounds (2954 to 3182 kg) (**7**). If the elephant's sensitivity were of the order of that of a human being, this would represent a considerable overdose. However, if the elephant's dose requirements in milligrams per kilogram were similar to those of other animals (including primates and cats), such a dose would at best be of borderline effectiveness. Since massive doses of succinylcholine had been used by one of us (W.D.T.) in attempts to destroy elephants in the field, and since even enormous doses (20 ml of a saturated solution given intramuscularly) were found to require almost 30 minutes to produce a reaction, we considered that the elephant possessed substantial resistance to neurotropic agents and predicted that we were unlikely to see much reaction with this dosage of LSD.

Early in the morning of the day for administering the control, 2 August 1962, Tusko received 1.5 million units of benzathine penicillin G as a control or placebo injection which would also protect him from infection. The medication was injected into the gluteal muscles by a cartridge-syringe fired from a rifle powered by compressed CO_2. The elephant's immediate startle response to the injection, and his subsequent 2 or 3 minutes of restlessness followed by normal behavior throughout the day, were recorded on motion-picture film and noted by observers. The procedures employed on the control day were devised to document behavior with which Tusko's response to the next day's experimental situation could be compared.

At 8 A.M. on the second, or experimental, day the LSD was similarly injected. Tusko began trumpeting and rushing around the pen, a reaction not unlike the one he had shown the day before. However, this time his restlessness appeared to increase for 3 minutes after the injection; then he stopped running and showed signs of marked incoordination. His mate (Judy, a 15-year-old female) approached him and appeared to attempt to support him. He began to sway, his hindquarters buckled, and it became increasingly difficult for him to maintain himself upright. Five minutes after the injection he trumpeted, collapsed, fell heavily onto his right side, defecated, and went into *status epilepticus*. The limbs on the left side were hyperextended and held stiffly out from the body; the limbs on the right side were drawn up in partial flexion; there were tremors throughout. The eyes were closed and showed a spasm of the orbicularis occuli; the eyeballs were turned sharply to the left, with markedly dilated pupils. The mouth was open, but breathing was extremely labored and stertorous, giving the impression of high respiratory obstruction due to laryngeal spasm. The tongue, which had been bitten, was cyanotic. The picture was that of a tonic left-sided seizure in which mild clonic movements were present.

At 8:20 A.M. promazine hydrochloride was administered intravenously into the ear in an attempt to alleviate the animal's marked spastic reaction. Over a period of 11 minutes 2800 mg was given. The violence of the tonic aspect of the seizure appeared to be relieved partially by these measures, and respiration improved. However, over the next hour the picture changed very little. Abdominal tympany developed. Despite a last-minute effort to save the animal with an intravenous injection of pentobarbital sodium, he died 1 hour and 40 minutes after the LSD had been injected.

A necropsy confirmed the impression of death by strangulation secondary to laryngeal spasm. Tusko's sexual maturity, previously suggested by the observation of his copulatory behavior with a receptive female and by the

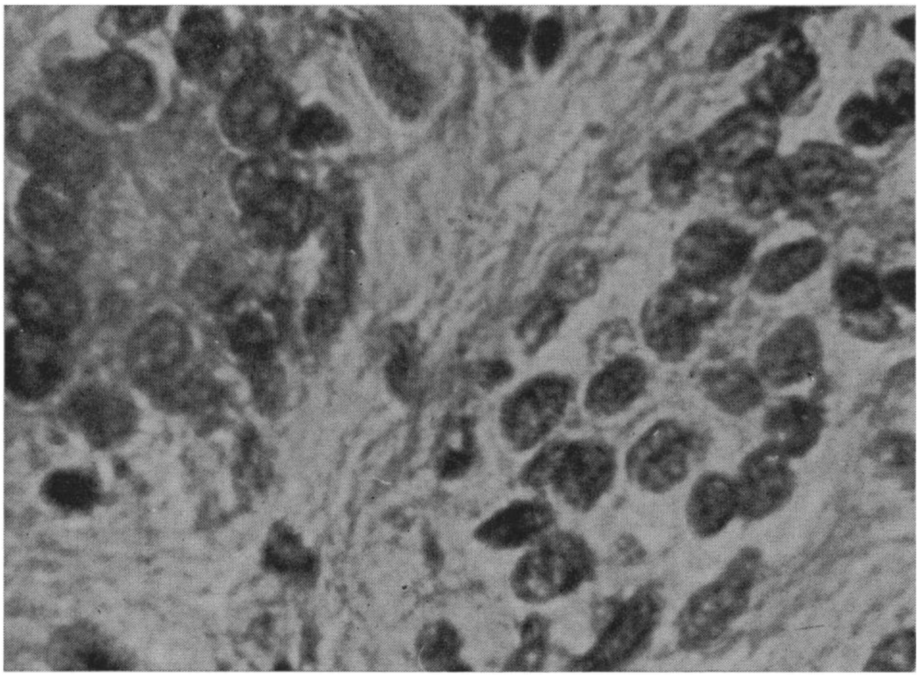

Fig. 1. Cross section of temporal gland of the male Asiatic elephant Tusko, showing two types of glandular cells. Those on the left show a uniformly eosinophilic cytoplasm. Those clustered on the right show a more vacuolated cytoplasm and perhaps slightly smaller nuclei. (Hematoxylin and eosin stain) (About × 376)

report of his prior episode of going on musth, was confirmed at necropsy by the finding of adult testes with well-developed spermatogenic elements and numerous mature spermatozoa. Blood samples were collected from cerebral veins and from the heart at the vena cava. Serum sodium (137 and 138.5 milliequivalents per liter) was in the range that is normal for human beings, but potassium was high (9.7 and 10.0 meq./lit.). The pericardial fluid contained sodium (100.0 meq./lit.) and potassium (3.8 meq./lit.) but no ceruloplasmin. Unfortunately, clear cerebrospinal fluid was not obtained. The brain content of serum ceruloplasmin (41.7 mg per 100 kg) was substantially lower than the heart content (51.0 mg per 100 kg); both values are higher than normal values for human beings (15 to 35 mg per 100 kg) (*8*).

Immediate dissection of the temporal gland revealed no characteristic dark brown fluid in the duct. However, the microscopic structure of the temporal gland (see Fig. 1) is unique, to our knowledge and to that of several individuals whom we consulted. Of great interest is the finding that two distinct types of cells are present, supporting the possibility that the gland may function as both an exocrine and an endocrine organ (*9*).

It is known that individual differences in reaction to drugs exist among elephants as among humans. Even so, the elephant's rapid collapse and death are remarkable. It is possible, but unlikely, that the LSD was delivered intravenously; with injection of the type used it is not possible to take the usual precautions, but the instantaneous explosive injection would probably collapse a vein. The possibility of anaphylactic shock seems remote, since the picture was not truly characteristic of anaphylaxis, and it would be difficult to postulate the basis for sensitization. However, since Tusko's former owner reported one instance of his having gone on musth, autosensitization cannot be completely ruled out. This would imply, of course, a close biochemical similarity between LSD and the unknown but perhaps potent intoxicant in the musth secretion. Sensitization on any other basis seems highly improbable.

It is also possible that the LSD was not widely distributed throughout the elephant's body but was somehow rapidly concentrated in the nervous system. If such were the case, the calculation of LSD dosage on the basis of milligrams per killigram of total body weight would be inappropriate, and some other criterion, such as brain size, should be considered. The brain of the mature elephant is about three to four times the size of man's. Tusko's brain weighed 3700 g (as compared with 1300 g for that of the average adult human male).

Other specimens and other dosages must be studied to clarify these issues. Our current predictions and conclusions are these: (i) a chemically induced pseudo-musth will not cause the temporal gland to secrete, but a natural internal secretion of the gland does play a causative role in precipitating the male elephant's madness; (ii) chemically this secretion may well resemble LSD or other known biologically active psychotomimetic substances; and (iii) a male elephant whose temporal glands had been surgically removed early in life might grow up to be a sexually capable but behaviorally tractable animal, one that never went on musth.

It appears that the elephant is highly sensitive to the effects of LSD —a finding which may prove to be valuable in elephant-control work in Africa. The death of Tusko suggests the nature of the danger, and the most likely cause of death should a lethal overdose be taken by a human. Despite efforts by its manufacturer to prevent misuse of the drug, LSD has been increasingly and sometimes irresponsibly administered to humans as a putative adjunct to psychotherapy. The possibility of suicide or even homicide by LSD cannot be ignored. Treatment of an individual *in extremis* from LSD poisoning would be symptomatic, but a possible emergency requirement for anticonvulsant medication, and for a muscle relaxant such as succinylcholine, is suggested from the results of this single experiment (*10*).

LOUIS JOLYON WEST
CHESTER M. PIERCE
Department of Psychiatry, Neurology, and Behavioral Sciences, University of Oklahoma School of Medicine, Oklahoma City
WARREN D. THOMAS
Lincoln Park Zoo, Oklahoma City

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8. The biochemical determinations were carried out by Dr. O. Boyd Houchin, assistant professor of research biochemistry and psychiatry, University of Oklahoma School of Medicine.
9. The necropsy and subsequent anatomical examinations were carried out by Professor William E. Jaques and other members of the department of pathology, University of Oklahoma School of Medicine.
10. The experiment described in this report was supported in part by a grant from the Foundations Fund for Research in Psychiatry, Inc.

25 October 1962

Antarctica: The Microbiology of an Unfrozen Saline Pond

Abstract. A saline pond in a region in Antarctia where other lakes and ponds are frozen remains unfrozen at the prevailing low temperatures. The ecology of the pond is unique. A distinctive aerobic microbial population, though restricted to this natural habitat, adapts to growth in artificial culture. The growth habit of these organisms, as seen in nature and in laboratory culture, indicates a possible relationship between growth at high salt concentration, at low temperatures, and in media of low organic content.

On 11 October 1961 a field reconnaissance by Navy helicopter in the south fork of the Wright Valley (longitude 161°10'E, latitude 77°34'S), Victoria Land, Antarctica, revealed an unfrozen pond, although the ambient temperature was −24°C. Wright Valley is one of several ice-free valleys in the region from which the continental icecap has receded (*1*). During the following 3 months several trips were made to the pond.

This pond, which we named Don Juan Pond, is approximately 200 m wide and 700 m long; the average depth is 11 cm (*2*). Small salt deposits occur on the periphery of the pond. The valley surrounding the pond is carved out of metasediments intruded by granites and dolerites. Overlying this valley and forming the higher ridges and peaks in the area is Beacon sandstone, also intruded by dolerites. The pond was formed by moraines blocking both ends of the valley and, at its inception, was probably 10 or more meters deep. Beach lines, now poorly defined, are present 10 m above the water level on the north side of the valley.

The influx of water into this basin is limited. During the summer two small streams drain the moraine to the west. The only other source of moisture is snow falling directly into the small catchment area immediately surrounding the pond. The snowfall averages only a few inches per year. The water is beige-to-brown in color (*3*); this is attributable in part to pyritic particles in suspension. The *p*H was 5.4 and probably remains stable, since there is little or no decay of organic matter. The water temperature followed the temperature of the ambient air; from October to December it ranged from −24° to −3.0°C, with no variation from surface to bottom. At no time during the period of study was the water frozen. The freezing point of freshly collected samples was −48° ± 1°C.

The water of Don Juan Pond was compared to the water of Barghoorn and Nichols Pond (*4*) and also to seawater (*5*) (Table 1). The specific gravity of Don Juan pond water was 1.2514, and the specific conductance was 790,000 μmho. The concentrations of dissolved solids in Don Juan pond water, in Barghoorn and Nichols pond water, and in seawater were 474,000, 132,620 and 34,480 parts per million, respectively. The salinity of Don Juan Pond was approximately 13.7 times that of seawater and 3.6 times that of Barghoorn and Nicholas Pond. Two deuterium determinations (*6*) of the pond water gave concentrations of 123.8 ppm and 124.0 ppm. By contrast, a deuterium determination on ocean water in the vicinity of McMurdo Sound gave a concentration of 160.0 ppm. These data, together with the fact that the pond is over 400 feet above sea level and 35 miles from the present coast, suggest a nonmarine origin for the water. The extraordinaryily high salt content is probably due to the weathering of the surrounding rocks, followed by increases in concentration through evaporation.

Samples of water for microbiological studies were collected in sterile flasks and returned to the Biological Laboratories at the Naval Air Facility, McMurdo Sound, Ross Island. The water was kept for several days at −22°C before laboratory study was begun. Examination of the water samples and sediments showed bacterial rods and cocci which grew in the form of colonies. Microscopic examination of bottom sediments from the pond revealed a diatom frustule, but no growing algae were present.

Table 1. Minerals in solution in antarctic waters. Composition (ppm)

Mineral	Don Juan Pond	Barghoorn and Nichols Pond	Seawater
Ca	114,000	1,130	400
Mg	1,200	4,890	1,272
Mn	<0.05		
Na	11,500	33,200	10,556
SO_4	11	16,150	2,649
Cl	212,000	58,000	18,980
CO_3	0	330	
HCO_3	49		140
NO_3	12.7		
S	0	<0.1	
Fe	23.7		
K	160		380

Live microorganisms were determined by pour plates of water samples in nutrient agar, peptone glucose-acid agar, and Proteose-peptone thioglycollate agar. The latter medium was also used to test for growth under anaerobic conditions. In addition, 100 ml aliquots were passed through Millipore filters to concentrate the organisms, and these concentrates were cultured on the several media. All plates were incubated at 20°C for 3 weeks. Three types of bacteria (*7*), *Bacillus megaterium, Micrococcus* sp., and *Corynebacterium* sp., appeared in all the media. A single yeast species (*8*), *Sporobolomyces*, which resembles *Sporidiobolus* (*9*), developed only on the sugar media. No anaerobes developed in the anaerobic plates. The fact that these isolates from an environment of remarkably high salinity and temperatures below 0°C will grow at room temperatures on artificial substrates is indicative of a high degree of adaptability. A pure culture of each bacterial isolate grew in visible clumps at temperatures ranging from 0° to 25°C when inoculated into Don Juan pond water that had been sterilized by filtration. The organisms grew more rapidly at the lower temperatures when saline pond water was used in compounding the peptone media than when

Table 2. Temperature and chemical measurements of inland water in Antarctica.

Lake	Temp. (°C)	*p*H	Conductivity (μmho)*	Chloride (mg/liter)*
Bonney (edge)	3.6	7.35	105–210	30
Vanda (edge)	2.8	7.2	112	30
Vanda (60 m)	16.0*	6.4	250,000	80,800

* Data of Armitage and House (*10*).