at least 3 or 4 years before sufficient clinical data can be accumulated to permit licensing of any. Most investigators are hopeful, but not optimistic, that at least one will be licensed in time to help combat the influenza pandemic that is expected in the late 1970's. Meanwhile, investigators are also looking at other means of immunizing the population.

One problem with either killed or live virus vaccines is the finite probability of nonspecific pathologic reactions to parts of the virus that are not involved in stimulating immunity. Many investigators, including Kilbourne, Davenport, Edwin A. Eckart at the University of Michigan, Purnell W. Choppin of Rockefeller University, New York City, and Geoffrey Schild of the National Institute for Medical Research, London, England, are therefore studying the possibility of using purified antigens obtained from disrupted virus particles. Results from their experiments have been mixed.

Work with influenza and a variety of other virus diseases has shown that the ability of purified antigens to stimulate the production of antibodies is significantly reduced when they are separated from the virion. The origin of this phenomenon is unknown, but many scientists assume that the small size of the isolated antigen makes it nonimmunogenic. There have been some attempts to increase the immunogenicity of isolated antigens by polymerizing them into larger molecules, but these attempts have met with only limited success, suggesting either that the structure of the antigen is changed during polymerization or that its small size is not the only cause of its ineffectiveness.

The immunogenicity of antigens or of killed viruses has been increased by administering them in conjunction with adjuvants—such as alum or emulsified organic liquids—that potentiate the effects of weakly antigenic agents. The mechanism of adjuvant action is unknown. But whatever the mechanism, adjuvants apparently do work. Maurice R. Hilleman and his associates at the Merck Sharp & Dohme Research Laboratories in West Point, Pennsylvania, for example, recently reported that a killed virus vaccine prepared to combat a 1957 A_2 influenza subtype provides protection against a 1968 A_3 subtype when administered with an emulsified peanut oil adjuvant.

Effective adjuvants have never been licensed for use in the United States, however, primarily because the most commonly examined emulsified mineral oil adjuvants have produced tumors when injected into experimental animals. Despite their promise, then, the use of adjuvants will, at the minimum, require the accumulation of a very large amount of new information about their safety and efficacy, and possibly the development of new adjuvants. It is thus likely that live virus vaccines will be introduced first.

In all of the approaches discussed so far, the ability of the influenza virus to undergo antigenic changes remains a major problem. All approaches require the isolation and identification of each newly emerged variant before any start can be made toward vaccine production, so that each new variant is able to infect a large number of people before vaccines are available to control it. Some method must thus be found to anticipate such antigenic shifts before they occur, but only one approach has so far met with any success—acceleration of the pace of the minor mutations that occur within any subtype of influenza virus.

Using a method conceived by S. Fazekas de St. Groth, then at the Commonwealth Scientific and Industrial Research Organization, Epping, New South Wales, Australia, Claude Hannoun and his associates at the Pasteur Institute in Paris have tried to speed those mutations by growing a recent variant of the A_3 influenza subtype in the presence of antibodies specific for that variant. In a manner analogous to that occurring in nature, point mutations in the viral antigens

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Gravity Waves: Correlation with Geomagnetic Storms

Exactly 4 years ago the first report of gravitational radiation was published, and a new field of research was established. Since then many observers have built devices for detecting gravity waves, many have sought to explain what astronomical bodies could produce such waves, and a few have asked what the signals could be, if not gravitational waves from space. The original report was made by Joseph Weber at the University of Maryland, College Park, and he is still detecting coincident signals between detectors at College Park and Argonne National Laboratory outside Chicago.

About 1 year ago a team of Russian researchers found a correlation between some of the events reported by Weber and the planetary geomagnetic activity index K_p (*1*). This index is the mean of measurements of fluctuations of the earth's magnetic field at 12 locations and is primarily an indicator of auroral activity. The Russian paper suggested the possibility that pulsations of the earth's magnetic field could have caused the signals reported as gravitational radiation, but the analysis was based on a very small sample of data, namely, the 17 events originally reported by the group at Maryland.

Last month J. A. Tyson, C. G. Maclennan, and L. J. Lanzerotti at the Bell Laboratories, Murray Hill, New Jersey, evaluated the correlation of a much larger sample of Weber's data with various geophysical, meteorological, and other phenomena (*2*). The sample they analyzed consisted of 262 gravitational radiation events observed over a 4-month period ending 22 December 1969, and is much larger than any sample of raw data Weber and his colleagues have published.

The geomagnetic correlation did not disappear when more data were studied. The Scientists at Bell Laboratories found a relatively high correlation, at 2.7 standard deviations, with the geomagnetic index D_{st}, that measures changes in the ring currents circling the earth in the magnetosphere, and a lower correlation, at 2 standard deviations, with the geomagnetic activity index (K_{FR}) at Fredericksburg, Virginia. Correlations at 2 standard deviations were also found with sunspots and earthquakes (Fig. 1). Whereas K is an index of the activity of components of the magnetic fields in three directions, D_{st} is a measure only of the component parallel to the earth's magnetic axis. If the global ring currents—westward drifts of protons and eastward drifts of electrons—are altered by solar winds, the change is reflected in a variation of the component of surface magnetic field measured by D_{st}.

The correlation of Weber's data with geomagnetic events could be accidental, but it takes on an aura of importance when compared with the other correlation that has been known for quite some time: that Weber's pulses seem to occur preferentially when his detectors are oriented toward the center of the galaxy. When sorted into groups according to sidereal time (time relative to the fixed stars), the events in the larger sample peak at about 18^h sidereal time (near the galactic center), with a frequency of occurrence that is 3 standard deviations above the mean. No sidereal variation is observed in the occurrence of D_{st} during the time of analysis. Therefore, if no assumptions are made about the efficiency of the detector for picking up magnetic or gravitational signals, it would appear that the source of many of the events in the sample is equally likely to be of geophysical as of astrophysical origin.

With a different sample of data either one or both of the correlations could disappear, although this appears unlikely. Identifications of objects at 3 standard deviations above the mean have been known to disappear before in other types of astronomy with digital signals, such as x-ray and gamma ray observations. Many observers insist on a 5 standard deviation measurement, and some insist on 7 before they will accept a firm identification. "It really depends on how exciting the result is," according to one commentator. "I saw people quite excited recently about a 1½ standard deviation bump in a gamma ray spectrum."

Tyson doesn't think that the statistical findings are overwhelmingly significant. "All correlations of this type will, during some period of time, show a positive result, even if you're correlating with a random signal," he says. "There is no gigantic breakthrough here, no proof or disproof. Just a statistical caveat." But he thinks that the analysis does point out a sizable possibility that at least some of the events in the sample could be caused by geomagnetic fluctuations.

How could the experimental apparatus used by Weber have detected magnetic fluctuations? The sensing systems are built around large aluminum bars approximately 1 meter in diameter and 1.5 meters long (*Science*, 27 February 1970) and are largely free of ferromagnetic materials except in two

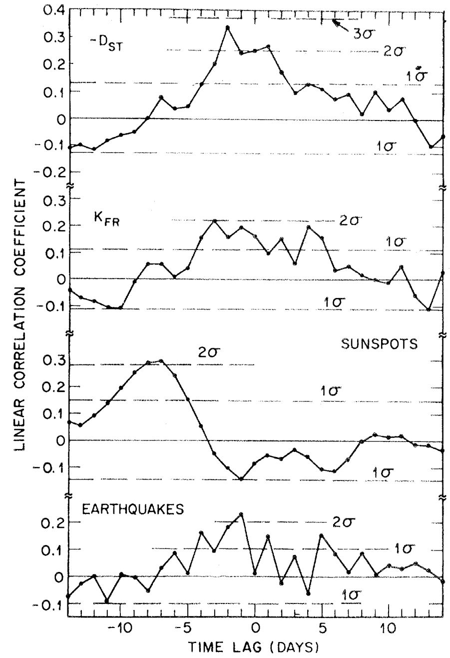

Fig. 1. Correlations of reported gravity wave events with two geomagnetic indices, sunspots, and earthquakes. D_{st} is a global index sensitive to magnetic changes caused by ring currents in the magnetosphere, and K_{FR} is an index of all geomagnetic activity at Fredericksburg, Virginia. Dashed lines labeled 3 σ indicate the three standard deviations.

places. The supports for the aluminum bar are made of alternating layers of steel and rubber, designed to isolate the bar from vibrations. The steel could be shaken by fluctuations of the earth's magnetic field, and very low frequency fluctuations could penetrate the steel vacuum tank that encloses both the aluminum bar and its supports.

Low frequency fluctuations are well known geomagnetic phenomena that are classed as *pc* 1 through *pc* 5 events, with frequencies ranging from 1 cycle per second to 1 cycle per 5 minutes. The *pc* 1 magnetic pulsations carry more energy than the others, and occur more often a day or so after magnetic storms than at other times. Thus, geomagnetic fluctuations could conceivably have shaken the steel supports. Such low frequency fluctuations would not make the aluminum bar—tuned to the much higher frequency of 1660 hertz—oscillate unless there was some nonlinearity in the system. But any system becomes nonlinear if it is struck hard enough, and the problem is particularly severe with gravitational detectors because the signal expected is so weak. According to Tyson, there are probably nonlinearities in the sensing systems built by all researchers.

At the time data for the sample in question were obtained, there was an inductor across the input to the preamplifier that processed signals in the Maryland system. Although the inductor has since been removed, it had an iron core and could have acted as a magnetometer if it were not completely shielded.

While the statistical correlations present no reason to favor a geomagnetic source (particularly because Weber's system was specifically designed to detect gravitational signals), it appears that a plausible alternative has been proposed. Meanwhile the attempts of other experimenters to corroborate Weber's results have been unsuccessful.

Last summer Vladimir Braginski at Moscow State University looked for coincident pulses of gravity waves for 20 days without success (*Science*, 11 August 1972), and he has reportedly looked for another month without positive results. The question whether or not Braginski's detectors are less sensitive than Weber's is still disputed, however. At the Texas Symposium on Relativistic Astrophysics, which was held in New York last winter, Tyson reported finding no gravitational pulses after 6 weeks operation with a large detector 100 times more sensitive than Weber's antennas were in 1969–70. Tyson's antenna is sensitive to a frequency slightly different from Weber's (710 as compared to 1660 hertz).

At a recent meeting in Oxford, England (at which no U.S. scientists were included), several more negative results were reported. Using a detector slightly smaller than Weber's, Ronald Drever at the University of Glasgow has so far detected no gravity events, and two detectors operated in coincidence, at the Max Planck Institute in Munich, Germany, and the European Space Research Institute in Frascati, Italy, have not detected any pulsations either, according to a recent report of the meeting (*3*).

Although no material that has been actually published contradicts the work by the researchers at Maryland, it seems that contradictory findings will be published soon. But gravitational antennas far more sensitive than the first generation models have been built, and the new field of research is not likely to die.

—WILLIAM D. METZ

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