total output of fluorine in the excreta, they calculated a retention of only 1.7 mg/day. More balance studies of this type are needed before safe dosage levels of rock phosphate for human consumption can be considered.

References

1. HODGE, H. C., and SOGNNAES, R. F. *Dental Caries and Fluorine.* Washington, D. C.: American Association for the Advancement of Science, 59 (1946).
2. MILLER, B. F. *Proc. Soc. Exptl. Biol. Med.*, **39**, 389 (1938).
3. MCCLURE, F. J. *J. Dental Research*, **22**, 37 (1943).
4. MCCLENDON, J. F., and FOSTER, W. C. *Ibid.*, **26**, 233 (1947).

Manuscript received October 24, 1952.

Synergistic Actions of Carbon Dioxide with DDT in the Central Nervous System

George H. Pollock and Richard I. H. Wang

Departments of Psychiatry and *Pharmacology, University of Illinois College of Medicine, Chicago*

From clinical observations, physiologic, electroencephalographic, and pathologic studies of cats, monkeys, and dogs, it appears that the cerebellum is the chief portion of the nervous system on which DDT acts (*1, 2*). Histologic degenerative changes resulting from DDT are usually restricted to the cerebellum, especially the dentate and roof nuclei (*1*). Previous investigation of compounds which acted initially on the cerebellum revealed the definite synergistic convulsant activity of the inhalation of carbon dioxide with these compounds (*3*). Accordingly, it was decided to investigate the actions of carbon dioxide on the central nervous system in animals that had ingested DDT.

Thirty-two normal cats, weighing 1.5–3.0 kg, were placed on an ample diet and observed carefully for a week. Then 300–500 mg/kg of DDT, carefully mixed with the diet, was consumed at a single meal. Usually within 24 hr the animals were seen to have generalized, fine tremors and were markedly ataxic. When they were held by the nape of the neck, "running movements" were observed, but no grand mal convulsions were seen. These animals were prepared for acute electroencephalographic recording in the following manner. Under divinyl ether anesthesia, a tracheal cannula was introduced, the femoral veins isolated, and the skull including the area over the cerebellum exposed. Ether anesthesia was then discontinued and paralysis induced with 20 mg/kg of dihydro-β-erythroidine intravenously. Respiration was maintained artificially through a Palmer respirator designed to allow adjustment of stroke volume and rate and the introduction of any desired gas mixture. Screw electrodes were placed bilaterally, 2 over the cerebellum, 2 over the parietal cortex, and 2 over the frontal cortex. Bipolar and monopolar (reference electrode usually on nose) recordings of the electrical activity of the brain and the electrocardiogram were obtained on a Grass 8-channel electroencephalograph. Gas mix-

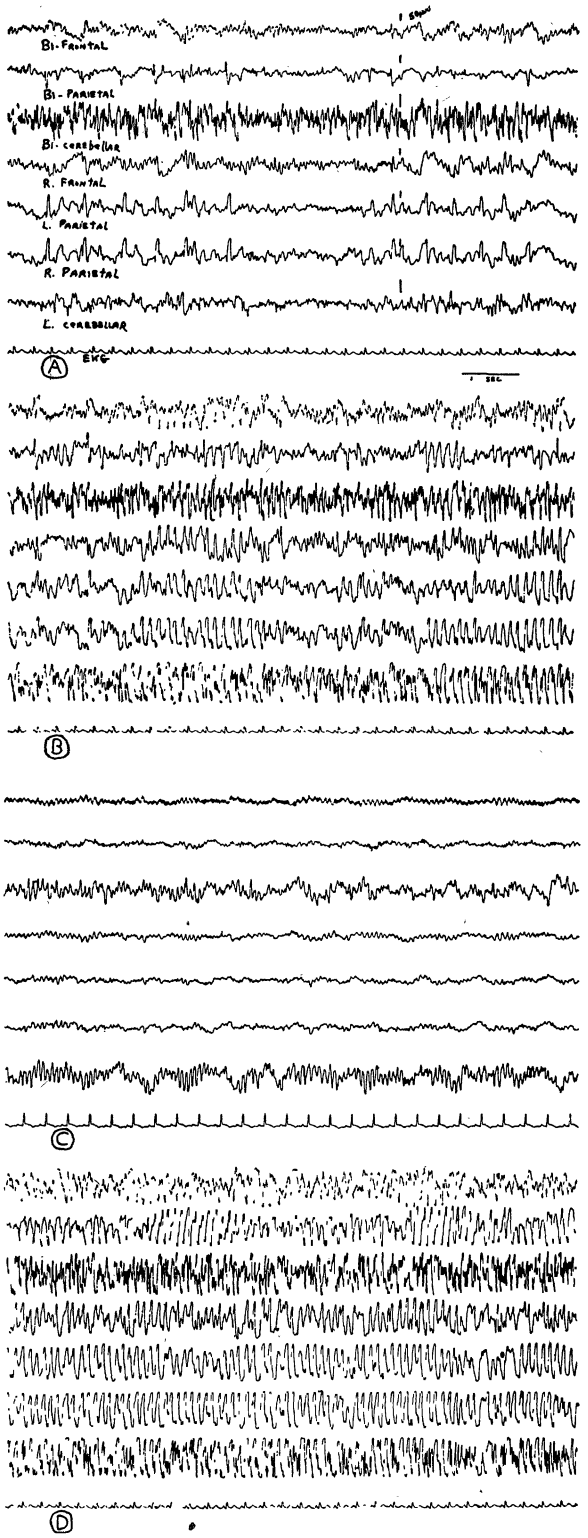

FIG. 1. A. Pre-CO_2 record of a cat that had been fed 400 mg/kg of DDT a day previously. B. Record shortly after the administration of 30% CO_2–70% O_2. C. 30% CO_2–70% O_2 administered for 3 min. D. Record shortly after the removal of the gas mixture.

tures containing 30% CO_2–70% O_2 were obtained commercially.

In all the animals the spontaneous rhythm of the cerebral cortex as well as that from the cerebellum was significantly modified by the ingestion of DDT. The amplitude of the cerebellar activity was markedly increased over that seen in normal control animals. Spikelike waves appeared, although electrical fits were not observed. The cerebral rhythms showed similar activity, but definitely after that seen in the cerebellum (Fig. 1 A). Shortly after the administration of the carbon dioxide mixture (Fig. 1 B), but more usually after its removal, there was marked intensification of all electrical activity, and in eight animals seizures were either observed in the cerebellar leads exclusively or appeared in the cerebellum first and then after a short lag period were also seen in the cerebral cortex. The inhalation of the 30% CO_2–70% O_2 mixture sometimes caused a decrease in amplitude and increase in frequency of the electroencephalogram (Fig. 1 C); however, upon its removal, the typical seizure patterns appeared (Fig. 1 D). In four animals where DDT in doses of 500–1000 mg/kg was ingested, the clinical picture described above appeared 4–6 hr later, and the animals usually died within 12–24 hr after DDT feeding.

Previous work (*4*) showed that high concentrations of carbon dioxide in oxygen increased the frequency but lowered the amplitude of the normal cat EEG. Seizures induced electrically or with Metrazole were antagonized when the gas mixture (30% CO_2–70% O_2) was inhaled. Interestingly, it was found that with Metrazole seizures appeared in the thalamus first and then in the cerebrum (*5*). It is noted that, with convulsants potentiated by carbon dioxide, the fits are either confined to or first seen in the cerebellum and then appear in the cerebral cortex (*3*). This seems to explain the observations on the gross behavior of the animals under the influence of the convulsants and also the histopathology found in the cerebellum. Convulsants antagonized by CO_2 do not show fits first in the cerebellum (*4*).

It is not easy to explain why carbon dioxide can act synergistically with DDT and other cerebellar convulsants. We know that the cerebral cortex can have its threshold for stimulation raised by carbon dioxide. It may be that, once the cerebellar convulsant has been introduced, the additional release from cortical inhibition by carbon dioxide is sufficient to permit seizure activity to start subcortically. The fit is then in turn transmitted to the cerebral cortex. As yet no explanation is offered as to why these seizures start when the CO_2 mixture is first applied or shortly after it is removed. The most likely explanation is that a certain critical level of CO_2 must be maintained for a critical period of time and that this combination of circumstances is sometimes realized during induction with CO_2 and sometimes on the way out.

The oral ingestion of DDT causes gross symptoms of cerebellar involvement. This is also seen when electroencephalographic recordings of cerebral and cerebellar activity are made. Shortly after the introduction or removal of 30% CO_2–70% O_2, definite electrical seizures are seen in the cerebellum exclusively or initially, and later appear in the cerebral leads. This potentiating effect of CO_2 with DDT appears in contrast to the antagonistic actions of CO_2 on seizures induced electrically or with Metrazole.

References

1. HAYMAKER, W., GINZLER, A. M., and FERGUSON, R. L. *Am. J. Med. Sci.*, **212**, 423 (1946).
2. CRESCITELLI, F., and GILMAN, A. *Am. J. Physiol.*, **147**, 127 (1946).
3. POLLOCK, G. H., and BAIN, J. A. *Ibid.*, **160**, 195 (1950).
4. POLLOCK, G. H. *J. Neurophysiol.*, **12**, 315 (1949).
5. POLLOCK, G. H., and GYARFAS, K. *Arch. intern. pharmacodynamie*, **89**, 252 (1952).

Manuscript received October 20, 1952.

Recent Changes in Sea Level Along the New England Coast: New Archaeological Evidence

Elso S. Barghoorn

The Biological Laboratories* and *Botanical Museum*, *Harvard University, Cambridge, Massachusetts

Submergence of the Atlantic coast of North America in relation to the tidal plane has long been a problem of interest to geologists, to geographers, to students of plant ecology, and, in more recent years, to archaeologists. Within the past decade archaeological interest has been greatly stimulated by the discovery in New England of extensively submerged aboriginal occupation sites (*1, 2*), and by the striking contrast between past and present tidal conditions in coastal estuaries. Paleobotanical and stratigraphic studies of peat and other plant-bearing sediments found in association with archaeological horizons indicate a progressive encroachment of the sea on shoreline vegetation. These factors, in conjunction with a few recent determinations of the absolute age (*3*) of occupation sites, have focused renewed attention on the problem of coastal stability and its geologic and archaeological implications.

Evidence that has been advanced in the past to demonstrate geologically recent and continuing tidal changes on the Atlantic coast is quite diverse and in part contradictory. Many of the earlier controversies resulted from efforts to prove a priori one theory or another of the geologic consequences resulting from retreat of the Wisconsin ice sheets and subsequent crustal movements of the continental margins. Botanical evidence derived from studies of coastal and estuarine salt marshes and their sedimentary record of peat was variously used to support arguments both for coastal stability and for continued coastal subsidence (*4–6*).

More recently, however, discovery and extensive investigation of the Boylston Street fishweir, a structure excavated at considerable depth in sediments de-