

(*Myotis*) which have been examined. Neither has the nucleus been observed in the cat.

Galambos and Davis (5) have reported the presence of nerve cells in the acoustic nerve of the cat between the internal auditory meatus and the medulla. In our investigations of the cat such cells were found but were quite unlike the cells of the acoustic nerve nucleus. The cells described by Galambos and Davis are probably those which comprise the interstitial nucleus of Lorente de Nó (1; 6).

J. M. HARRISON
W. BRUCE WARR
R. E. IRVING

Psychological Laboratory,
Boston University,
Boston 15, Massachusetts

References and Notes

1. R. Lorente de Nó, *Laryngoscope* 43, 327 (1933).
2. D. Bodian, *Anat. Record* 65, 89 (1936).
3. C. U. Ariëns Kappers, G. C. Huber, E. C. Crosby, *Comparative Anatomy of the Nervous System of Vertebrates, Including Man* (Hafner, New York, 1960).
4. J. M. Harrison and B. Warr, *J. Comp. Neurol.*, in press.
5. R. Galambos and H. Davis, *Science* 108, 513 (1948).
6. Supported in part by the National Science Foundation (G8678) and in part by the Graduate School of Boston University.

22 August 1962

Membrane Potential of Toad Ventricle: Changes Produced by Vagal Stimulation and Acetylcholine

Abstract. Reduction produced by vagal stimulation and application of acetylcholine in the duration of the membrane action potential in the toad is clearly demonstrated in the ventricular fiber as well as in the atrium. Vagal innervation of the ventricle is thus demonstrated. Vagal innervation of the ventricle is considered to be less extensive than vagal innervation of the atrium.

The experiments reported here were made to investigate the effects of vagal stimulation and of acetylcholine on the membrane potential of the ventricular fiber in the toad.

The heart was excised, with its nerve supply, and cut open along the midline to expose the endocardial surfaces. The ventricle was pinned on a cork plate in a bath, with the epicardium underneath, and driven with electric stimuli of a fixed strength and rate (24 or 40 per minute). The vagus was stimulated with rectangular pulses of 1-msec duration, at 20 cy/sec and maximal strength for 2.5 seconds.

In order to avoid the influence of

acetylcholine liberated in the atrium by the stimulation, an experimental arrangement was set up as follows. A bath of Ringer solution, in which the preparation was placed, was divided into two parts by a partition with a semicircular notch. The partition was set in such a manner that the atrioventricular ring of the preparation lay across the notch. The space between the preparation and the partition was compactly plugged with vaseline-soaked cotton. The Ringer solution in the ventricular side of the bath was thus completely separated from that in the atrial side, so that the acetylcholine liberated in the atrium could no longer diffuse to the ventricular surface through the environmental solution. That it could not do so was ascertained by the fact that no appreciable changes in ventricular membrane potential were produced even several minutes after the introduction of acetylcholine at a high concentration (10^{-4} g/ml) into the atrial side of the chamber. Thus, if any changes occur in the ventricular membrane potential within a few minutes after vagal stimulation, they cannot be attributed to the effect of acetylcholine liberated at the atrium. The membrane potential of a ventricular fiber of the apical area was recorded by means of a glass-pipet microelectrode.

The effects of vagal stimulation are shown in Fig. 1. An acceleration of the repolarization process was observed a few seconds after stimulation (Fig. 1, middle) and attained the maximum value after 1 minute (Fig. 1, bottom). The duration of the action potential was thus reduced from 990 to 457 msec, or by 54 percent. The amplitude of overshoot decreased in 1 minute from 32 to 14 mvolt, or by 56 percent, without any changes occurring in the resting potential. The effects of acetylcholine application were quite similar to those of vagal stimulation. In the example shown in Fig. 2, the duration of the action potential was reduced from 242 to 73.5 msec, or by 70 percent, when acetylcholine in a terminal concentration of 10^{-6} g/ml was applied. The degree of reduction in the duration of the ventricular action potential brought about by these procedures was smaller than that observed in atrial fibers, which are considered to be less developed than the ventricular fiber.

It is well known that the mammalian ventricle has very little innervation and that its membrane potential is unresponsive to the action of acetylcholine (1). In cold-blooded animals, on the other

hand, the contractile force (2) and electrocardiogram (3) of the ventricle have been reported by some authors to be affected by vagal stimulation. But the findings of these authors cannot be regarded as direct evidence of vagal innervation of the ventricular muscle because the possibility that acetylcholine

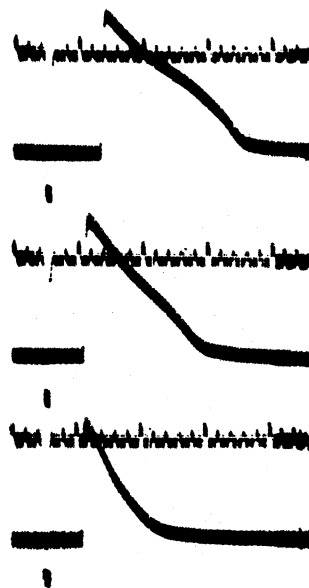


Fig. 1. Changes in membrane potential brought about by vagal stimulation in a ventricular fiber. (Top) Control; (middle) a few seconds after stimulation; (bottom) 1 minute after stimulation. The time is indicated in 100-msec periods (small pips) and 500-msec periods (large pips). Calibration of voltage on the left base:—indicates 100 mvolt from the extracellular potential (time base) level.

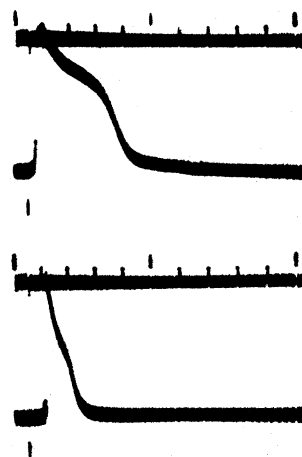


Fig. 2. Changes in membrane potential brought about by the application of acetylcholine (10^{-6} g/ml) in a ventricular fiber. (Top) Control; (bottom) 2.5 minutes after the application of acetylcholine. The time is indicated in 100-msec periods (small pips) and 500-msec periods (large pips). Calibration of voltage on the left base: dash indicates 100 mvolt from the extracellular potential (time base) level.

liberated in the sinus and atrium by vagal stimulation reaches ventricular fibers by diffusion is not excluded. The results of our study demonstrate clearly and conclusively that in the toad the ventricle is innervated by the vagus and that the action potentials of ventricular fibers are affected by endogenous and exogenous acetylcholine. The similarity in the effectiveness of acetylcholine and vagal stimulation on the ventricular muscle had not previously been reported except in an early study of frog ventricle (4), in which the duration of the monophasic action potential recorded by a suction electrode was shortened by applying acetylcholine in a concentration of 2×10^{-4} g/ml. The distribution of vagal fibers in the ventricle must be very sparse as compared with the distribution in the atrium, since the period of latency prior to change in action potential brought about by vagal stimula-

tion was always much longer for the ventricular fiber than for the atrial fiber. The observations reported here suggest that, in cardiac muscles of vertebrates, there may be an ontogenetic and phylogenetic gradient in sensitivity to vagal stimulation and acetylcholine—that is, the more developed cardiac tissue may be the less sensitive.

T. AZUMA
H. HAYASHI
K. MATSUDA

Department of Physiology,
Faculty of Medicine,
University of Tokyo, Tokyo, Japan

References and Notes

1. B. F. Hoffman and E. E. Suckling, *Am. J. Physiol.* **173**, 312 (1953).
2. L. Haberlandt, *Z. Biol.* **63**, 305 (1914); F. B. Hofmann, *Z. Exptl. Med.* **11**, 156 (1920).
3. A. Samojloff, *Arch. Ges. Physiol.* **155**, 471 (1914).
4. B. Lueken and E. Schütz, *Z. Biol.* **99**, 186 (1938).

19 September 1962

A Drowned Miocene Terrace in the Hawaiian Islands

Abstract. A highly fossiliferous sample dredged in September 1961 from a submerged terrace at a depth of 500 to 520 meters off Honolulu contains a reef fauna suggesting deposition at depths of 10 meters or less. The corals and pelagic foraminifers indicate a probable Miocene age. The Hawaiian rise was in existence prior to that time, and the submarine terrace and associated reef were subsequently submerged to their present position.

The Scripps Institution of Oceanography's research vessel *Argo* took visiting scientists on an excursion cruise on 2 September 1961 during the 10th Pacific Science Congress in Hawaii. Sounding and sampling techniques were demonstrated, but it was hoped that fossils which would establish for the first time a pre-Pleistocene age for the Hawaiian Islands might be dredged during the cruise.

A single haul was made at 500 to 520 meters 10 kilometers southwest of Honolulu on the edge of a well-developed, drowned terrace (1). A shallow basin separating the terrace from Oahu seems to indicate that the fossils could not have been derived from elsewhere. The almost flat profile appears to represent the results of erosion and construction when the terrace was near sea level. The depth of the dredge haul was established within a few tens of meters because little scope was let out and the large and rapid variations in tension on the cable made it obvious when the dredge was on the bottom.

The haul comprised about 100 kilograms of nonindurated as well as moderately indurated calcareous sediments, reef corals (one head nearly 400 mm in diameter), and associated organisms. No volcanic material was present. Four stages in the history of the sample can be recognized: (i) formation of a shallow-water deposit, including reef corals and associated organisms as well as some adventitious planktonic foraminifers, and development of borings, apparently after sediments were partially consolidated; (ii) submergence of the deposit to greater depths; (iii) deposition of a gray "ooze" in the holes and cavities of the consolidated sediment; and (iv) development of manganese oxide coating. The development of the coating was, at least in part, contemporaneous with deposition of the gray "ooze," for some planktonic foraminifers in surface cavities may be covered by manganese oxide.

In preliminary studies of the indurated (geologically oldest) portions of the sample, 25 foraminifers, 10 hermatypic corals, 12 gastropods, 6 pelecypods, and 5 ostracods have been recognized. Most of the organisms are characteristic of the coral reef environment, but fortunately a few planktonic foraminifers are present. Because of the position of Hawaii within the Pacific basin, evaluation of the age is not easy. However the fairly common representatives of the reasonably well-

known (2) planktonic foraminifer *Globigerinoides quadrilobatus* [= *G. trilobus auct.*] plexus suggest a lower limit of early Miocene. This is supported by the coral *Fungia* (3). The upper age limit is less definite. Adult specimens of the *Globigerinoides quadrilobatus* plexus in the sample lack the characteristic prominent, sacculifer-like, final chambers that normally occur on late Miocene and younger specimens (4), and thus, as negative evidence, suggest an age earlier than late Miocene.

Eight of the ten corals are related to species now living in the area. Of these eight, five [*Fungia* n. sp., aff. *F. scutaria* Lamarck; *Leptastrea* n. sp. *A*, aff. *L. purpurea* (Dana); *Leptastrea* n. sp. *B*, aff. *L. transversa* Klunzinger; *Pavona* n. sp. *A*, aff. *P. gigantea* Verrill; *Pavona* n. sp. *B*, aff. *P. duerdeni* (Vaughan)] are new, and the remaining three [*Acropora* sp., cf. *A. echinata* (Dana); *Pocillopora molokensis* Vaughan (?); and *Porites lobata* Dana (?)] cannot certainly be assigned to living species. A sixth new species is referred to a genus (*Platygyra*) seemingly not now living in the Hawaiian Islands. To judge from the data on Pacific fossil corals summarized by Wells (5), the 60 percent of extinct species strongly supports an age not younger than late Miocene (Tertiary *g*). If the three equivocally identified species should prove to be new, an older age (early to middle Miocene, in accord with the evidence from the *Globigerinoides quadrilobatus* plexus) would be favored.

All of the corals are hermatypic types, suggesting a reef habitat, and probably indicating depths of less than 10 fathoms. Many of the other identified organisms from the indurated portion of the sample support these inferences. Thus this dredge haul establishes (i) that a shallow platform capped with a coral reef existed at the present site of the island of Oahu during the Miocene and (ii) that the terrace has subsequently been drowned to a depth of 500 meters.

Available echograms show that terraces exist at depths down to 1000 meters on the slopes of many islands and banks in the Hawaiian Islands. Consequently the history of Oahu applies in a general way to the entire chain. Formation of the terraces was preceded by the construction of a vast volcanic ridge 4 to 5 kilometers high above the abyssal sea floor. The time