

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.

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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

required to build the ridge is unknown, but, on any reasonable assumption of rate of vulcanism, it was at least 10^7 years.

The Hawaiian region has had a prolonged and complicated history with intermittent vulcanism, formation of platforms and benches at sea level, and both local and regional subsidence. It may be anticipated that systematic surveying and dredging of drowned erosional terraces on the sides of the Hawaiian and other island groups will rapidly increase knowledge of the history of the Pacific basin and its faunas.

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Diffusion of Carbon Monoxide through Thin Layers of Hemoglobin Solution

Abstract. The facilitation of carbon monoxide flux through a thin layer of hemoglobin solution is increased in the presence of oxygen. This is consistent with the hypothesis that the facilitation results from diffusion of carbon monoxide—hemoglobin as well as carbon monoxide, but that the overall process is partially limited by the reaction rates of carbon monoxide and hemoglobin.

Scholander and Hemmingsen (1, 2) have reported that O_2 passes through thin layers of hemoglobin (Hb) or myoglobin solution at rates several times faster than N_2 . On the supposition that this phenomenon represents diffusion of HbO_2 in addition to O_2 , a supposition that appears reasonable to others as well (3), an even greater facilitation of CO

flux through hemoglobin solution would be expected, provided its partial pressure was low. Therefore we used an apparatus modeled after that of Scholander, in which a 0.015-cm-thick Millipore filter separated two gas mixtures, both at atmospheric pressure (Fig. 1), to measure the CO flux when the filter was saturated with hemoglobin solution or water. The filter holder was made of stainless steel and the filter itself was supported on a screen of similar metal. Additional circuitry was added (i) to provide convective mixing of both gas mixtures by two electrical heating coils (flow of approximately 6 ml/min), (ii) to permit replacement of the gases on either side of the filters, and (iii) to provide collection of samples by means of a needle stuck through a rubber vaccine bottle top. Both chambers were evacuated and then filled with their respective gas mixtures at atmospheric pressure. Each time a sample was removed (2 ml) an equivalent volume of mercury was added. This procedure was found to maintain the pressure in each chamber within 1 to 2 cm-H₂O of atmospheric pressure as determined with a water manometer. The gases were kept saturated with water at the vapor tension of saline. At the start of an experiment the total volume of gas in the lower circuit was 102 ml and in the upper circuit was 42 ml. The exposed area of the filter paper was 7 cm².

The filter paper was soaked with water or with hemoglobin solution, the excess was wiped off, and the paper was clamped in the holder. The two chambers were then evacuated and the gas mixtures were added. Two-milliliter gas samples were removed alternately from each chamber every 15 minutes for about 2½ hours and analyzed in a gas chromatograph. In most experiments the lower chamber contained about 1.5 percent neon and varying concentrations of CO up to 2.5 percent, in addition to O_2 and N_2 . The upper chamber contained the same O_2 concentration as the lower but no CO or neon. The hemoglobin solution was prepared from thrice-washed, freshly drawn, human red cells which were lysed by freezing and thawing, after which they were reconstituted to 120 percent of the original volume with bicarbonate buffer (pH 7.4). The average final Hb concentration was 10.8 g/100 ml. Carbon monoxide flux showed no trend after the first 30 minutes; therefore we concluded that a steady state had been reached by that time.

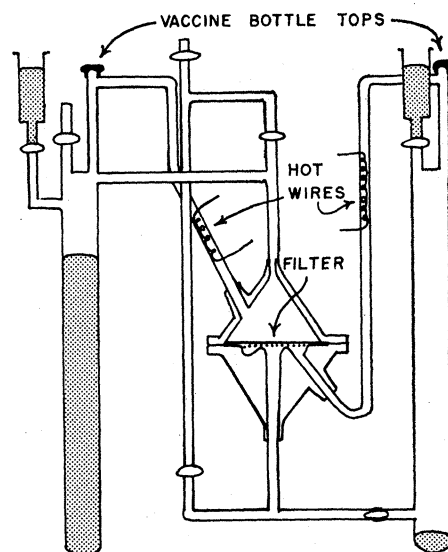


Fig. 1. Diffusion apparatus, which was immersed in a temperature-regulated bath at 37°C. Volume of the upper chamber and tubing, 42 ml; that of the lower chamber and tubing, 103 ml.

Results of more than 25 experiments on 14 preparations are presented in Fig. 2. The analytical error in each point is less than 0.01 mm³/min. The "unfacilitated" diffusion of CO was calculated as the diffusion rate of neon

$$(\text{mm}^3/\text{min}) \times 0.018/0.016 \times (20/28)^{1/2}$$

0.018 and 0.016 being the Bunsen solubility coefficients of CO and neon (4), respectively, in water. The transfer of CO is enhanced as much as 15-fold by the presence of the hemoglobin in solution. It seems reasonable to assume that this facilitation results from the diffusion of COHb in addition to dissolved CO, and that the [COHb] and [O₂Hb] at each surface of the film are in equilibrium with [CO] and [O₂] in the respective gas phases. Knowing these gas tensions it was possible for us to calculate the equilibrated [COHb] by means of

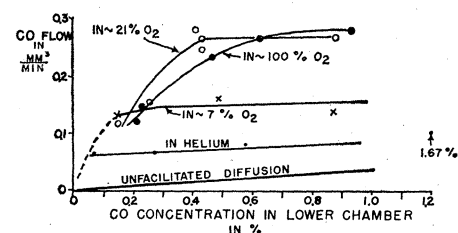


Fig. 2. Flux of CO through hemoglobin solutions as a function of CO concentration in the gas of the lower chamber, at different O_2 tensions. Gaseous CO concentration of the upper chamber was approximately zero initially. Gaseous O_2 concentrations were the same in both chambers.