with, or earlier than the earliest evidence of food production in the Middle East. An agricultural complex of root and fruit crops has been attributed to a similar, early "Corded Ware" stratum on Taiwan hypothetically dated between 11,000 and 4200 before present (*9*). The data from Spirit Cave appear to support this early date, and evidences an early agricultural stage before the use of cereals in Southeast Asia. Just prior to 6000 B.C. the quadrangular adze, small slate knives, and cord-marked pottery appeared as intrusive elements in the continuing local Hoabinhian expression.

This evidence for early plant domestication in Southeast Asia combined with evidence for a similar early metallurgical development (*10*) both indicate that prehistoric Southeast Asia was not a culturally backward cul-de-sac. Benedict's recent work (*11*) suggests that a number of major cultural advances (agriculture, plant and animal domestication, metallurgy, and others) originated in areas occupied by Austro-Thai speakers, and from there diffused unidirectionally into areas occupied by Chinese speakers. New archeological and linguistic data suggest that Southeast Asia was a progressive emanating center of early cultural development.

CHESTER F. GORMAN
Department of Anthropology, University of Hawaii, Honolulu 96822

References and Notes

1. The concept of a major post-glacial cultural readaptation in the humid tropics is becoming less acceptable. See K. Flannery, *Amer. Antiquity* **31**, 800 (1966) and R. MacNeish, *Science* **143**, 531 (1964) for similar views from New World archeology.
2. M. Colani, *Mem. Serv. Geol. Indochine (Hanoi)* **14**, 86 (1927); H. van Heekeren and E. Knuth, *Archaeological Excavations in Thailand, Sai-Yok* (Munksgaard, Copenhagen, 1967); J. Mathews, *Asian Perspectives* **9**, 86 (1966).
3. It now appears that domesticated plants were in use during the Hoabinhian period.
4. Spirit Cave is a translation of the local Thai Yai or Shan name for the shelter complex.
5. J. Matthews, thesis, Australian National University, Canberra (1964).
6. G. F. MacDonald and D. Sanger, *Amer. Antiquity* **33**, 237 (1968).
7. Botanical materials, mostly carbonized, were identified by D. Yen (ethnobotanist) and P. van Royen (botanist) at the Bishop Museum, Honolulu. Tree genera were identified from fragmentary remains of seed pericarp. *Cucumis* was represented by one seed, and *Lagenaria* by several fragments of fruit exocarp. The bean identifications were made on two whole carbonized seeds. The individual structure which first suggested a seed of *Pisum* might equally be representative of a form of Palmae. Although common names have been used to describe the remains, the tentative nature of the identifications and the allowance for genetic changes in species in time have obviated the use of binomials.
8. I. H. Burkhill, *Economic Products of the Malay Peninsula* (Governments of the Straits Settlements and Federated Malay States by the Crown Agents for the Colonies, London, 1935).
9. K. C. Chang and M. Stuiver, *Proc. Nat. Acad. Sci. U.S.* **55**, 539 (1966); K. C. Chang, *Asian Perspectives* **9**, 140 (1966).
10. W. G. Solheim II, *Curr. Anthropol.* **9**, 59 (1968); also see D. T. Bayard, The Bangkok *Post Sunday Magazine* **22**, No. 229 (18 Aug. 1968), for a report of excavation of early (about 3000 B.C.) bronze from northeast Thailand.
11. P. K. Benedict, *Behavior Science Notes* **1**, 227 (1966); *ibid.* **2**, 203 (1967); *ibid.* p. 275.
12. This research was supported by an NSF predoctoral research grant GS-861, and the Mosher Fund for Southeast Asian Archaeology. In Thailand the work was sponsored by the Fine Arts Department of the Thai government. I thank D. Yen, W. G. Solheim II, P. van Royen, and R. Green for their help in the preparation of this material.

17 October 1968

Environmental Temperatures of Tertiary Penguins

Abstract. *Marine paleotemperatures, determined by oxygen isotope measurement, show that Australasian Tertiary penguins, including giant forms, lived in warm to tropical environments. Evolution from smaller species also occurred in warm environments. Mid-Tertiary fluctuations of sea temperature were controlled by alternating uplift and erosion of "Tasmantis," an unstable meridional landmass occupying and extending beyond the present position of New Zealand.*

Tertiary fossil penguin material from New Zealand, Australia, Patagonia, and Seymour Island has been described and reviewed (*1–8*). Clayton and Stevens (*9*) and Devereux (*10*) have estimated environmental temperatures of Cretaceous belemnites and mid-Eocene to Pliocene benthic deposits in New Zealand, respectively, using the oxygen isotope method of paleotemperature determination. Dorman (*11*) has produced comparable values for Tertiary deposits in southern Australia. Environmental temperatures are therefore known for a period in the evolution of penguins when they were widespread, diverse in size, and generally larger than present forms.

The occurrence of specimens representing eight genera of Australasian fossil penguins, together with curves of Devereux and Clayton and Stevens, is shown in Fig. 1; Dorman's curve (not shown) agrees substantially with Devereaux's except for slightly higher temperatures. Material from South Island (New Zealand) sites is likely to have been deposited at temperatures within $\pm 2°C$ of the curve; the single North Island specimen (*4*) and the Australian material seem to have been deposited within $\pm 3°C$.

Fluctuations in sea temperature during the Tertiary in the New Zealand area can be explained if a regional pattern of temperature zonation and circulation similar to or slightly warmer than contemporary systems is assumed, with uplift and erosion of land controlling the local movements of water masses. New Zealand's present orientation deflects part of the warm Pacific Trade Wind Drift southward along its eastern seaboard. Subtropical waters also wash the northern and western shores of the North Island, and mix with cooler western water in the Tasman Sea. Simultaneously, the southern end of New Zealand diverts westerly flowing water from the Tasman Sea southward to blend with water from the West Wind Drift, bathing the southwestern, southern, and eastern shores of the South Island in mixed cool temperate waters (*12*). From Upper Cretaceous to early Miocene times, a long narrow landmass ("Tasmantis") extended over the New Zealand region from New Caledonia to a latitude south of the present position of Campbell Island (Fig. 2); earth movements and marine transgressions intermittently converted Tasmantis into an archipelago throughout the early Tertiary (*13*). A shallow sea lay to the east, its shores advancing westward through the late Cretaceous to deposit limestone and mudstone, and later greensand and calcareous inshore materials were deposited along the present flank of the South Island.

As a meridional barrier extending beyond the present limits of New Zealand, Tasmantis would have diverted more of the tropical counterclockwise circulation southward along the east coast, reduced the warm component of the Tasman Sea current, and shielded its own eastern flank from the cooling effects of mixed Tasman and West Wind Drift waters from the south. Such a barrier existed during the Middle and early Upper Cretaceous (Fig. 2a), breaking down with marine transgressions in the late Upper Cretaceous, Paleocene, and early Eocene, and reforming through the late Oligocene and Lower Miocene (*13*). During periods of marine transgression, cool westerly water would cross Tasmantis to penetrate the eastern sea, restoring a zonal pattern of surface temperatures to the eastern coastal waters in latitudes 42° to 43°S (Fig. 2b). Changes in sea temperature (Fig. 1) closely follow postulated land movements. Temperatures were tropical during the Middle Cretaceous, falling to 13°C during the Paleocene transgression and rising to 22°C with the reestablishment of Tasmantis during the Eocene. They remained high through the Kaiatan and early Runangan stages of the Upper Eocene, dropping during the late Runangan and early Whaingaroan (Fig. 2b) to about 13°C after the marine transgression which obliterated central Tasmantis (*13*). Temperatures rose again with the reestablishment of land connections through the late Oligocene and Lower Miocene (Fig. 2c), fluctuated through the Middle Miocene, and

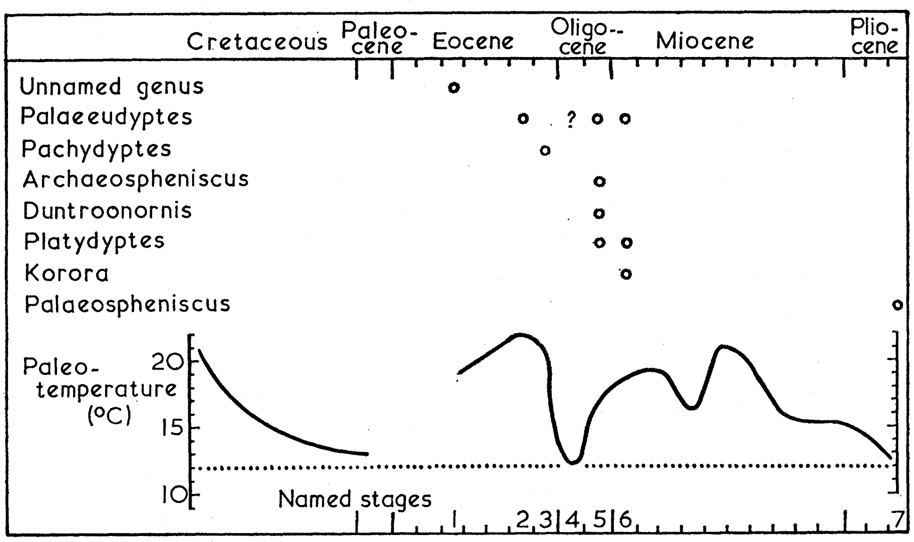

Fig. 1. Paleotemperatures and the occurrence of Australasian fossil penguins. Numbered geological stages in sequence: (1) Heretaungan; (2) Kaiatan; (3) Runangan; (4) Whaingaroan; (5) Duntroonian; (6) Waitakian; and (7) Waitotoran. Figure shows the relevant portion of Clayton and Stevens' curve (*9*) and Devereux's (*10*); the latter, originally presented for subsurface waters in 41°S, is here taken without change to show surface temperature 2° to 3° farther south. Clayton and Stevens' data are assumed correct for surface waters in the same area. Geological stages follow Hornibrook's (*15*) revised correlation.

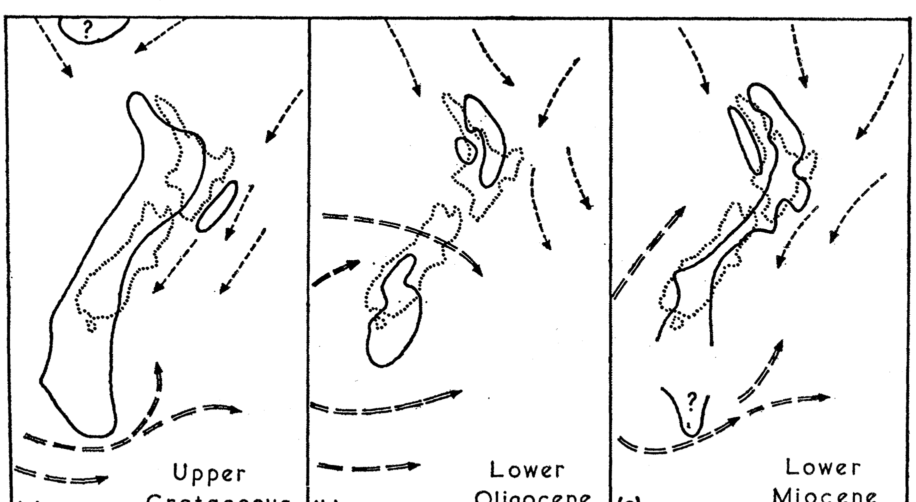

Fig. 2. Tasmantis in relation to the present position of New Zealand. The single arrows indicate warm currents; double arrows indicate cold currents. Solid outline indicates Tasmantis; dotted outline indicates recent New Zealand. Tasmantis diverts cold water southward, allowing warm currents to wash the east coast in the latitude of South Island (a and c). The breakdown of Tasmantis allows cold currents through at the same latitude (b). [After Fleming (*13*)]

finally began the steady decline which preceded the Pliocene-Pleistocene glaciation.

The earliest known fossil penguins —*Palaeeudyptes, Pachydyptes,* and an unnamed genus (*1*)—inhabited tropical to subtropical waters in the New Zealand area during the late Eocene. *Palaeeudyptes* is also recorded from the late Eocene of southern Australia (*6*). These were the largest penguins recorded; as estimated from Simpson's (*5*) humeral index, *Palaeeudyptes* and *Pachydyptes* stood over 1.2 m tall. The unnamed genus is known only from fragments of humerus, which indicate birds of similar size or slightly smaller. *Palaeeudyptes* persisted in New Zealand through the late Oligocene-Miocene warming, and may have been present in the cooler early Oligocene; Marples (*1*) doubtfully ascribes the type specimen to the Whaingaroan.

Four other genera of fossil penguins first appear in New Zealand Oligocene and Miocene deposits, and Simpson (*6*) refers an unidentified humerus and femur to the Oligocene of southern Australia. *Platydyptes* and *Archaeospheniscus* were slightly taller than the largest modern penguins (*Aptenodytes forsteri*); *Duntroonornis* and *Korora* were smaller, similar in size to modern crested penguins (*Eudyptes*). Sea temperatures were warm temperate to subtropical, rising steadily throughout the late Oligocene and early Miocene. No fossil penguins have so far been identified from Australasian Middle or Upper Miocene deposits. A single humerus from the New Zealand Waitotoran (Upper Pliocene) is referred to *Palaeospheniscus* (*2*), a genus of small penguins previously reported only from the Lower Miocene of Patagonia (*5*). Except for the doubtful early Oligocene *Palaeeudyptes,* this is the only genus of Tertiary New Zealand penguin which appears to have lived in a cool temperate climate with sea temperatures below 13°C.

Fossil penguins of Patagonia and Seymour Island are referred entirely to the Lower Miocene (*5, 8*). Precise paleotemperatures have not been established; contemporary land flora and fauna indicate a cold temperate climate on Seymour Island, with Patagonia possibly warmer (*5*). Both areas supported large, medium-size, and small penguins contemporaneously; of five Patagonian genera and four others from Seymour Island, only *Palaeospheniscus* occurs also in Australasia. Modern genera have not appeared in the fossil record; they are grouped by Simpson (*5*) in a subfamily distinct from fossil genera.

Modern penguins live in sea temperatures ranging from 25°C at the Galápagos Islands to −1.8°C in Antarctica. Three species, including two of the smallest, live where mean annual sea temperatures exceed 16°C; five, including the largest, live where sea temperatures rarely exceed 0°C. Most species live in waters with mean annual temperatures between 3°C and 15°C, in situations where the difference between summer and winter mean sea temperatures does not usually exceed 5° to 8°C (*12*). The largest living penguins inhabit cold and the smallest warm water; but there is no correlation between environmental temperature and body size throughout the family. Chill and overheating are countered by fat, plumage thickness, and heat-regulating areas in the face, flippers, and feet (*12*). Present evidence indicates that the largest fossil forms, together with medium-size and smaller species, lived for long periods in environmental temperatures equal to the warmest in which modern penguins are found.

Origins of penguins are uncertain, but evolution from petrel-like, flying ancestors during the Cretaceous or early Tertiary seems probable (*5*); major adaptations of foot and wing are already complete in Eocene fossils. In other families of diving birds, flying and wing-swimming are compatible up to a body weight of about 1 kg; further increase in body size—which facilitates sustained diving (*14*)—involves loss of flight as weight outstrips permissible wing area. Thus flightlessness must have been forced on protopenguins which were approximately the size of the smallest modern forms (*Eudyptula* of New Zealand and southern Australia), with subsequent diversification during the late Cretaceous or early Eocene that produced the variety of larger forms capable of exploiting deeper layers of pelagic water. The absence of a polar ice cap throughout this period allowed cool temperate conditions to extend south to the polar continent, with only a moderate zonal temperature gradient in high latitudes. Thus penguin evolution up to the mid-Miocene must have occurred in cool temperate or warmer conditions, with the diversity of size related to diving depth rather than environmental temperature. Disappearance of the larger penguins from the fossil record may be due either to predation or to competition from toothed whales and seals which diversified and spread during the mid-Tertiary.

BERNARD STONEHOUSE*
University of Canterbury,
Christchurch, New Zealand

References and Notes

1. B. J. Marples, *Palaent. Bull. Wellington No. 20* (1952).
2. ———, *Rec. Canterbury Mus.* **7(3)**, 185 (1960).
3. ———, in *The Evolution of Living Organisms*, G. W. Leeper, Ed. (University Press, Melbourne, Australia, 1962).
4. B. J. Marples and C. A. Fleming, *N.Z. J. Geol. Geophys.* **6(2)**, 189 (1963).
5. G. G. Simpson, *Amer. Mus. Natur. Hist. Bull. No. 87* (1946).
6. ———, *Rec. S. Aust. Mus. Adelaide* **13**, 51 (1957).
7. ———, *Proc. Roy. Soc. Victoria* **71**, 113 (1959).
8. B. J. Marples, *Sci. Rep. Falkld. Isl. Depend. Surv. No. 5* (1953).
9. R. N. Clayton and G. R. Stevens, *Proceedings of the Spoleto Conference on Palaeotemperatures and Isotopic Oceanography, July 1965* (Consiglio Nazionale Delle Ricerche, Laboratorio di Geologia Nucleare, Pisa, 1967).
10. I. Devereux, *N.Z. J. Sci.* **10(4)**, 988 (1967).
11. F. H. Dorman, *J. Geol.* **74(1)**, 49 (1966).
12. B. Stonehouse, *Advan. Ecol. Res.* **4**, 131–196 (1967).
13. C. A. Fleming, *Tuatara* **10(2)**, 53 (1962).
14. B. Stonehouse, *Ibis* **109 (4)**, 600 (1967).
15. N. de B. Hornibrook, in *Tertiary Correlations and Climatic Changes in the Pacific*, K. Hatai, Ed. (Proc. 11th Pacif. Sci. Congr., Sendai, 1967).
16. I thank R. J. Adie and J. T. Kingma for helpful discussion.
* Present address: Department of Biology, Yale University, New Haven, Conn. 06520.

4 October 1968; revised 26 November 1968

Viscosity of Argon at High Temperatures

Abstract. *New data for the viscosity of argon at high temperatures indicate that the accepted data are substantially too low at temperatures above 600°K.*

Recent work (*1*) has emphasized the need for a systematic redetermination of the viscosities of the inert gases. Despite the large quantity of data on the viscosities of these gases, considerable doubt has been expressed about the accuracy, particularly at high temperatures (*2*). In the course of investigations of the intermolecular potential energy of argon atoms, Barker and Pompe (*3*) suggested, as did earlier workers (*4*), that the experimentally determined viscosity coefficient might be too low by as much as 10 percent at 1500°K. Barker and Pompe ascribed this discrepancy to an incorrect esti-

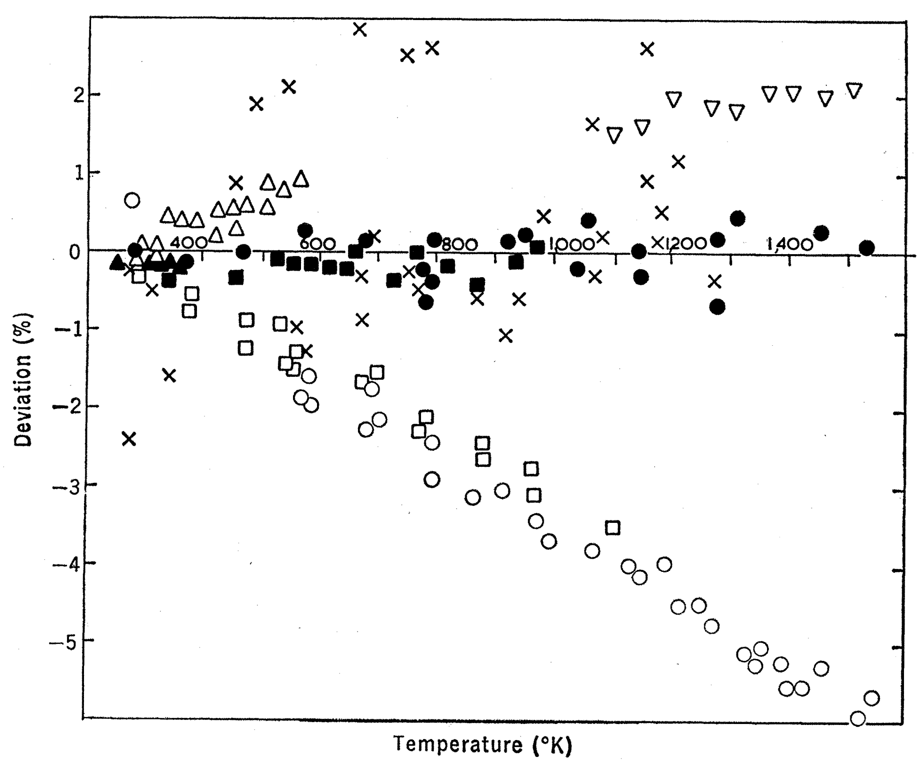

Fig. 1. The deviations of the viscosity of argon from Eq. 2. Solid circle, this work; solid square, Rigby and Smith (*14*) (corrected to the standard nitrogen viscosities of Dawe); solid triangle, Clarke and Smith (*5*); open circle, Vasilesco (*8*); open square, Trautz and Zink (*7*); open triangle, Kestin and Whitelaw (*10*) and DiPippo (*11*); inverted triangle, Guevara *et al.* (*12*); X, thermal conductivity data (*13*).