that where the races occur together the chemical types retain their identity are best explained by an environmental sorting by habitat of physiological races determined by genetic factors. The sample blocks were very small and the chemically different plants in blocks made up of mixtures (about half of the 98 blocks) were necessarily capable of growing within a few centimeters of each other. Two types of plants were found in 24 percent of the blocks, three types in 22 percent, and four types in 4 percent. The accumulating phenolic substances in these lichens seem to be a phenotypic expression of the genetically determined physiological races that is equivalent to morphologic traits in other organisms—for example, the highly zoned species of plants (other lichens and benthic algae) and animals (barnacles, limpets, and mussels) in the littoral communities below the *Ramalina* belt. Seen in this light, the selection of habitat by these morphologically similar but chemically different races of lichens results from the same phenomenon that produces zonation in species of strikingly different morphology, namely, the physiological differences that underlie and delimit the amplitude of ecologic tolerance (*10*). Although we might expect that genetically defined physiological races revealed phenotypically by complex chemical constituents (rather than by morphological traits) and associated with distinct habitats would be a common product of evolution in plants, no examples other than the one described here seem to be known.

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References and Notes

1. M. E. Hale, Jr., *The Biology of Lichens* (Edward Arnold, London, 1967), pp. 138-144.
2. O. Björkman, *Brittonia* **18**, 214 (1966).
3. W. L. Culberson, in *McGraw-Hill Yearbook of Science and Technology* (McGraw-Hill, New York, 1964), pp. 262–263.
4. W. L. Culberson, *Science* **139**, 40 (1963).
5. C. F. Culberson, *Phytochemistry* **4**, 951 (1965).
6. W. L. Culberson, *Brittonia* **19**, 333 (1967).
7. J. R. Lewis, *The Ecology of Rocky Shores* (English University Press, Ltd., London, 1964), pp. 192–236.
8. Part of each sample was extracted with acetone at 50°C. Chromatograms were run to 10 cm on Merck precoated, analytical-layer SiO_2-F_{254} plates in a solvent system of benzene, dioxane, and acetic acid (95 : 25 : 4, by volume); they were viewed in shortwave ultraviolet light, sprayed with 10 percent H_2SO_4, and heated in an oven at 100°C. The following substances were identified: hypoprotocetraric acid (dark gray, 0.18); norstictic acid (yellow, 0.30), usually accompanied by an unknown substance (orange, 0.08); stictic acid (orange, 0.22), often with norstictic acid and always with two unknown substances (orange, 0.15; brown, 0.01); protocetraric acid (dark gray, 0.02); and salazinic acid (yellow-brown, 0.09). Samples showing no spots for medullary substances on the chromatogram were retested by treating the residue with a solution of 20 percent K_2CO_3 and 10 percent KOH (1 : 1, by volume). Crystals of the red complex salt of norstictic acid were observed in a few preparations, and these samples were counted as the norstictic acid type. But some samples, which showed no positive crystal test and a second negative chromatogram, were scored as the acid-free type. These samples always gave notably small, sometimes nearly invisible, residues from the acetone extract.
9. Norstictic acid is probably the precursor of stictic acid, to which it would be converted by O-methylation. Although plants with stictic acid often contain some norstictic acid, there is a definite upper level to the concentration of norstictic acid with respect to stictic acid, and norstictic acid is invariably the minor constituent in plants also producing stictic acid. Plants producing norstictic acid without stictic acid are considered distinct. They also contain an unknown substance, not found in the stictic acid plants, that probably results when the mechanism for the conversion of norstictic acid to stictic acid is blocked.
10. At least some chemical races of morphologically uniform lichens show no differences in habitat ecology. In the only other case studied [M. E. Hale, Jr., *Brittonia* **15**, 126 (1963)], differences in the local distribution of chemical races of *Cetraria ciliaris* were not associated with any apparent environmental factors, and the differences in the overall geographic ranges of the races appeared to be the consequence of macroclimatic and historical factors.
11. Supported by NSF grants GB-1239 and GB-4494, NIH grant GM-08345, and Duke University Research Council. We thank Professor G. F. Asprey for laboratory facilities at University College, Cardiff; Professor J. G. C. Anderson of that institution for the identification of the substrate rock; and Professor W. D. Billings for criticism of the manuscript.

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Gekkonid Lizards Adapt Fat Storage to Desert Environments

Abstract. Coleonyx v. variegatus *is adapted to feed voraciously after deprivation of food and to withstand long periods without food. In 4 days specimens converted enough food into reserves to increase their weight by about 50 percent. Total deprivation of food resulted in very gradual loss of weight, which, if maintained, would result in 4 days of feeding being sufficient to sustain the animal for periods of 6 to 9 months.*

Fat tails of many geckos, certain skinks, and other lizards have long been considered to serve as areas for deposition of fat to be drawn upon when food is scarce (*1*). Experimental studies of the adaptable value of these reserves, especially under natural or simulated natural conditions, are lacking. Cogger (*2*) kept alive without food specimens of the Australian geckos *Oedura marmorata*, *O. monilis*, and *O. lesueurii* at ambient temperatures (Sydney) for between 9 and 12 months; this time was reduced by approximately 75 percent in the absence of water. It has generally been assumed that fat reserves have been evolved for use during hibernation, but I suggest that they are drawn on most extensively by species living in areas where, for seasonal reasons such as drought, food often may be unavailable for long periods during hot weather. Under such conditions the animal has a high metabolic rate, and large reserves may be necessary to ensure its survival. In a study of the *O. marmorata* complex (*3*), I showed that the greatest tail enlargement took place in the northern half of Australia where there is no hibernation but where prolonged shortage of food probably occurs during hot, dry weather.

Ground geckos of the genus *Coleonyx* inhabit North and Central America, ranging from the arid desert regions of the southwestern United States to the jungles of Panama. Klauber (*4*) has shown that *C. v. variegatus* is a desert form inhabiting southwestern Utah, Arizona, extreme southern Nevada, southern California, and northwestern Mexico. Several authors (*4–6*) have noted that these geckos are numerous in spring but rare later in the year; it has been suggested that they descend into holes as the ground dries and the weather becomes hotter (*5*). They hibernate between October and March, and their optimum temperature is between 27° and 29°C (*7*). It is recorded that *C. v. variegatus* eats its shed skin (*8*), a habit that may be an important source of protein under fasting conditions (*9*). In referring to their voracious appetite. Smith (*10*) notes that food (chiefly beetles and spiders) consists of items of all sizes, some so large that they must be forced down by serpentine movements of the jaws.

Colonies of *C. v. variegatus* were maintained in captivity in Scotland and Australia for many months and bred successfully. The vivarium temperature rose to 29° to 30°C during the day (heat supplied for 12 hours daily) and fell to 16° to 18°C at night. The geckos had continuous access to water and were fed mainly on *Tenebrio* larvae.

While the food requirements of active, adult males and nongravid females

Table 1. Percentage increases in weight [means ± S.D. (g)] of ten adult *C. v. variegatus* given abundant food after prolonged fasting, with no food for 36 hours before weighing; S.D. appear in parentheses.

Days since first feeding	Increase (%)
5	47.6 (± 7.4)
10	89.9 (±26.0)

probably approximate only two or three large *Tenebrio* larvae per week, starved individuals readily consumed as many as six or eight in rapid succession; they were able to change their appearance from emaciated to well fed within 5 days of feeding. This change was accompanied by weight increases of about 50 percent (Table 1). During 10 days ten adults increased their weight by more than 80 percent. (No food was given for 36 hours prior to weighing so as to allow for digestion and defecation.) Fat was deposited throughout the body as well as in the tail. The volume of the tail increased on average 125 percent during the first 5 days. When after 11 days one female gecko had increased its weight from 4.27 to 7.89 g, it shed the complete tail in a fight; the tail weighed 1.15 g. Thus it is evident that in *Coleonyx* only a small part of the fat storage occurs in the tail. According to Klauber (*4*), *C. v. variegatus* is eaten extensively by nocturnal desert snakes, especially *Phyllorhynchus*, which, when not large enough to engulf the full-grown gecko, consumes its tail. Because of this high rate of tail autotomy, storage of sizable reserves of fat in areas other than the tail has survival value.

The loss of weight by ten adult specimens kept for 75 days, without food but with access to water under the temperature conditions described above for the colony, was recorded: the mean loss was 14.2 percent; standard deviation for the sample, 7.2.

On the basis of these data it appears that *C. v. variegatus* is remarkably adaptative to its environment in that it can consume, and convert into reserves, vast quantities of food within periods of a few days. During periods of food deprivation these reserves are used most economically, even at fairly high ambient temperatures. More specifically, specimens can consume enough food in 4 days following deprivation to enable them to fast for a period of 6 to 9 months, if the rate of weight loss recorded during the first 75 days is maintained throughout. Inasmuch as not all arid-area geckos are similarly adaptative, the situation recorded in *C. v. variegatus* must be seen as a special adaptation to its particular environment. [The Australian desert gecko *Lucasium damaeum*, for example, has no fat tail; captives quickly became emaciated when deprived of food for 2 to 3 weeks (*11*).]

It is noteworthy that in gekkonid genera the regrown tail can become much thicker than the original (*12*); such is true of *Coleonyx*.

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References

1. E. R. Waite, *The Reptiles and Amphibians of South Australia* (Government Printer, Adelaide, 1929).
2. H. G. Cogger, *Proc. Linnean Soc. N.S.W.* **82**, 167 (1957).
3. H. R. Bustard, in press.
4. L. M. Klauber, *Trans. San Diego Soc. Nat. Hist.* **10**, 133 (1945).
5. J. Van Denburgh, *Occasional Papers Calif. Acad. Sci.* **10**, 1 (1922).
6. R. Hardy, *Proc. Utah Acad. Sci. Arts Letters* **21**, 71 (1944).
7. L. M. Klauber, *Bull. Zool. Soc. San Diego 14* (1939), p. 1.
8. C. F. Kauffeld, *Amer. Midland Naturalist* **29**, 342 (1943); E. D. Cope, *Rept. U.S. Nat. Museum 1898* (1900), p. 155.
9. H. R. Bustard and P. F. A. Maderson, *Herpetologica* **21**, 306 (1965).
10. H. M. Smith, *Handbook of Lizards* (Comstock, New York, 1946).
11. H. R. Bustard, *Herpetologica* **21**, 294 (1965).
12. A. C. L. G. Günther, *The Reptiles of British India* (Ray Society, London, 1864).

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Experimental Allergic Encephalomyelitis in Agammaglobulinemic Chickens

Abstract. *White Leghorn chickens were subjected to bursectomy and total body irradiation at hatching, thus rendering them agammaglobulinemic. At 4 weeks of age, these chickens and control chickens received lyophilized bovine spinal cord emulsified with complete Freund's adjuvant. Agammaglobulinemic chickens developed the lesions of allergic encephalomyelitis with the same frequency and intensity as the controls. Our findings support the contention that antibodies are not necessary for the development of experimental allergic encephalomyelitis.*

Experimental allergic encephalomyelitis (EAE) has been considered a manifestation of the tuberculin-type delayed hypersensitivity to central-nervous-system antigens (*1*). This conclusion is based on the following observations: (i) EAE can be passively transferred with sensitized lymphocytes, but not with specific antibody-containing serums (*2*); (ii) the onset of disease of the central nervous system (CNS) is temporally related to delayed hypersensitivity to CNS antigen injected intradermally; and (iii) the onset of EAE cannot be correlated with the appearance of circulating complement-fixing antibodies (*4*). As with delayed hypersensitivity, the role of humoral antibodies in the pathogenesis of EAE has been a source of controversy and confusion (*5*). Paterson and Harwin (*6*) have shown that complement-fixing antibody to brain antigen may protect animals against the development of EAE. On the other hand, Appel and Bornstein (*7*) demonstrated a complement-dependent factor in the serums of afflicted animals which produces demyelination in cell cultures of CNS tissue. By way of contrast, Janković and Išvaneski (*8*) found that chickens subjected to bursectomy at hatching, deficient in antibody responsiveness, developed EAE with the same frequency and intensity as controls did. In their study, chickens subjected to thymectomy at hatching, with a depressed, delayed reaction to allergy, were more resistant to the induction of EAE. They interpreted these findings as an indication that humoral antibody was not necessary for the production of EAE and that the pathological process was dependent on the developmental integrity of the thymus-dependent lymphoid system, that is, the small lymphocyte. Recently, these conclusions have been questioned because birds subjected to bursectomy in the newly hatched period can produce antibodies of the 19*S* class quite well, particularly if repeatedly immunized (*9*).

Cooper *et al.* (*10*) have since shown that newly hatched chicks subjected to both bursectomy and total body irradiation become agammaglobulinemic and do not produce antibodies even to repeated injections of antigen. Although these animals are agammaglobulinemic, they retain their capacity to manifest delayed skin sensitivity and to reject homografts of skin. We used this