amino-terminal, and the other, lacking serine, being a further peptic digestion product of the first.

Sustained peptic digestion converted most of P-II into P-I. Tryptic digestion of P-I yielded two peptides, asparaginylarginine and a tripeptide containing glycine, aspartic acid, and carboxyamidemethylcysteine. An amino acid sequence based on these data is proposed (Table 2) and compared with the known sequences of mouse and human $\kappa$-chains and the human $\lambda$-chain. The rabbit has six of seven residues in common with the human $\kappa$-chain and five of seven in common with the mouse $\kappa$-chain. The mouse and human $\kappa$-chains have six of seven residues in common in this region. On the other hand, the human $\lambda$ sequence is distinctly different (Table 2).

In that, after sustained peptic digestion, more than 80 percent of the radioactivity incorporated into rabbit light chains during interchain cleavage could be recovered as peptides I and II, the bulk of rabbit light chains are of the $\kappa$ variety. Why the rabbit carboxy-terminal regions are so similar to those of mouse and human $\kappa$-chains, whereas the amino-terminal regions are distinctly different, is not at all clear. In the meantime, we maintain that the distinctive amino acid sequences are most readily understood in terms of a $\kappa$ cistron from a single germ line coding for the variable regions of $\kappa$-chains.

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### References and Notes

1. N. Hilschmann and L. C. Craig, *Proc. Nat. Acad. Sci. U.S.* **53**, 1403 (1965); K. Titani, E. Whitely, Jr., L. Avogadro, F. W. Putnam, *Science* **149**, 1090 (1965); K. Titani, M. Wikler, F. W. Putnam, *ibid.* **155**, 828 (1967).
2. C. Milstein, *Nature* **205**, 1171 (1965).
3. L. E. Hood, W. R. Gray, W. J. Dreyer, *Proc. Nat. Acad. Sci. U.S.* **55**, 826 (1966); W. R. Gray, W. J. Dreyer, L. Hood, *Science* **155**, 465 (1967).
4. W. J. Dreyer and J. C. Bennett, *Proc. Nat. Acad. Sci. U.S.* **54**, 864 (1965).
5. R. F. Doolittle, *ibid.* **55**, 1195 (1966).
6. L. E. Hood, personal discussion.
7. P. Gunewardena and K. B. Cooke, *Biochem. J.* **99**, 8p (1966).
8. Iodoacetamide-1-$C^{14}$ was obtained from New England Nuclear. Carboxypeptidase A treated with diisopropylphosphofluoridate (DFP) was purchased from Worthington.
9. J. B. Fleishman, R. H. Pain, R. R. Porter, *Arch. Biochem. Biophys. Suppl.* **1**, 174 (1962).
10. We thank N. Hall and M. Cohn for determining the allotype of our preparations, and Miss C. Glasgow for technical assistance. Supported by NSF grant GB-4619, NIH grant AI-07781 and NIH program project grant GM-12027.

27 March 1967

## Thermoregulation in the Desert Iguana Dipsosaurus dorsalis

Abstract. *The body temperature of desert iguanas implanted with miniature temperature-sensitive radio transmitters was continuously monitored in their natural habitat. Extensive thermoregulatory behavior occurred in retreat burrows prior to morning emergence. Such behavior permits the iguana to emerge from below ground at its preferred body temperature rather than suboptimal temperature at which activity in the burrow is initiated.*

Nearly all studies of body temperatures of reptiles have been based on the thermal categories set forth by Cowles and Bogert (*1*). Such designations as mean preferred temperature and lethal temperature are usually compiled from cloacal temperatures taken with a quick-recording mercury thermometer; although these categories are valuable in presenting a comparative picture of interspecific thermal requirements, they reveal little of the dynamics of daily thermoregulation.

Recently Mackay (*2*) obtained continuous recordings of deep-body temperatures of free-living Galápagos tortoises and marine iguanas by use of biotelemetry. The green iguana was similarly studied (*3*). In both studies miniature temperature-sensitive radio transmitters located within the body cavity proved far superior to mercury thermometers or thermocouple potentiometers in documenting temperature regulation in that the animals were unrestrained and undisturbed.

Our purpose was to explore in detail, by use of telemetry, regulation of temperature in the desert iguana *Dipsosaurus dorsalis*, a species previously studied with conventional techniques (*4*), in Tahquitz Canyon, Palm Springs, California, during the last week of May 1966. An enclosure (10 by 7 m, with walls 1 m high) was constructed of corrugated cardboard around a section of desert floor containing several burrows of kangaroo rats, which desert iguanas prefer for retreat (*4*). Several creosote bushes within the enclosure shaded about one-fourth of it. The floor carried an antenna grid comprising 25 loops of 14-gauge copper wire; they were 10 m long, 0.25 m wide, and spaced 0.1 m apart. Each loop was connected to a switchboard with coaxial cable so that signals could be recorded by way of any one antenna or any combination. Thus one could monitor each animal individually except when infrequently two lizards positioned themselves on the same antenna transect; and one could record movements and body temperatures of lizards underground to a depth of 0.25 m. Lizards that climbed the creosote bushes were received to a height of 0.4 m.

The tails of four male desert iguanas, captured within 100 m of the enclosure, were banded with colored paint for identification. Through a paraasagittal incision 1 cm long just anterior to the left hind leg, a thermal transmitter (*5*) was inserted in the body cavity. Since the telemeter (1 by 2 cm, 1 g) was about two-thirds the size of an iguana's egg, we felt that it would not cause discomfort to a male lizard. The incision was tightly sutured with nylon thread, and the animals were held for several hours to see that no hemorrhaging occurred. Implanted lizards were released into the enclosure during the late afternoon of the day of capture. Two unoperated animals also were released as behavioral controls; there was no difference in their behavior.

Temperature recordings and behavioral observations were made on all surface-dwelling lizards from a blind

Table 1. Selected deep-body temperatures of four desert iguanas implanted with thermal transmitters; all but the last item were recorded in a natural habitat. Numbers of temperatures appear in parentheses.

| Time, conditions | Body temperature (°C) | |
|---|---|---|
| | Mean | Range |
| Emergence from burrow (17) | 38.9 | 35.5–40.0 |
| Retreat to burrow (16) | 39.2 | 35.0–42.0 |
| Initiation of morning activity in burrow (16) | 31.0 | 28.0–34.0 |
| Cessation of afternoon activity in burrow (14) | 36.0 | 32.5–37.2 |
| Preference throughout 2 days (40) | 38.0 | 35.2–45.7 |
| Preference throughout 2 days in laboratory gradient (40) | 39.0 | 35.7–44.0 |

outside the enclosure at 15-minute intervals for 7 days. In addition, the system of antenna transects permitted recording of body temperatures and movements of subsurface animals. Underground activity was unobtainable only when lizards moved through a burrow segment running directly parallel to an antenna loop. Temperatures of burrow, ground surface, and air also were monitored with a portable thermistor recorder. All transmitters and thermistors were calibrated with the same standardized Schultheis thermometer.

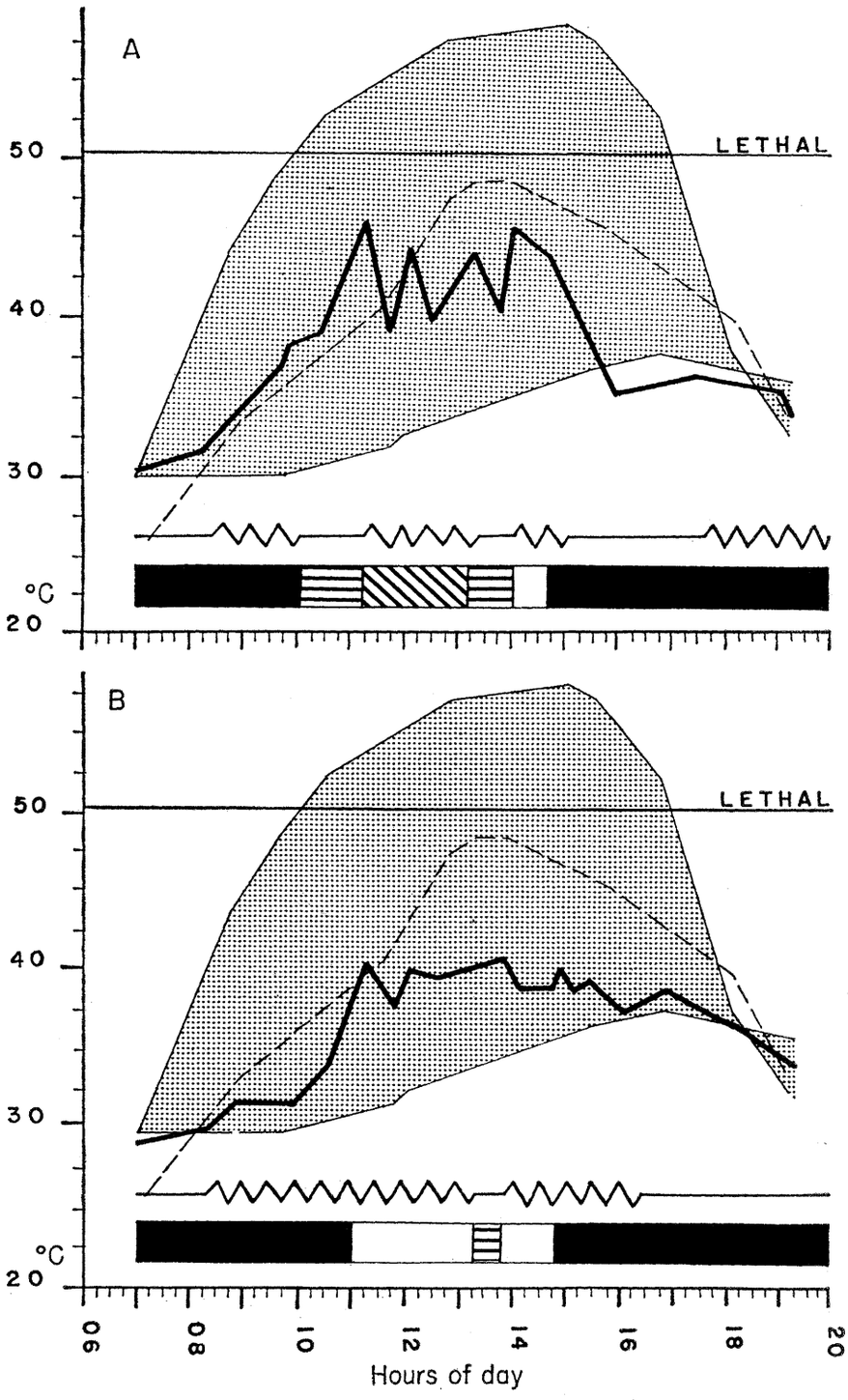


Fig. 1. Daily deep-body temperatures of two desert iguanas A and B. Heavy solid line represents deep-body temperature recorded by telemetry. Stippled area denotes temperature range available to animal; the upper limit represents the temperature of the ground surface in full sun; the lower limit, the burrow temperature 8 cm below ground. Broken line denotes temperature of ground shaded by a small bush. Serrated portions of the horizontal line beneath stippled area indicate periods of lizard activity. Black portions of bar at bottom of graph indicate that the lizard was in burrow; oblique hatching, in partial shade; horizontal hatching, in full shade; clear areas, in full sun.

Body temperatures were recorded for each lizard immediately upon emergence from or retreat to the burrow system (Table 1). The means for emergence and retreat were very similar: 38.2° and 39.2°C, respectively. Norris (*4*) also recorded no active temperatures on the surface below 35°C, which may be the lower thermal limit for normal surface activity in this species. The relatively high body temperature at which daily activity ceased either above or below ground (36.0°C) also supports this idea. However, subsurface activity was initiated at a significantly lower temperature ($\bar{x}$, 31.0°C) and often continued for more than 1 hour before emergence (Fig. 1). Such activity in a burrow was usually accompanied by increase in body temperature. We interpret this increase to be thermoregulation in the burrow in which warmer segments nearer the surface are sought and occupied prior to emergence. This behavior is highly adaptive, since it enables the iguana to attain during sequestration the preferred body temperature for surface activity.

The importance of the burrow in thermoregulation can be easily understood (Fig. 1). As ground surface temperatures in shaded areas of the enclosure approach the lethal range for *Dipsosaurus* (*1*, *4*), subterranean retreats offer the only suitable thermal relief. Norris (*4*) observed that the desert iguana climbs the vegetation at such times to escape near-lethal temperatures, but we noted very little climbing activity; it was never associated with body temperature significantly above the preferred mean.

Two days after termination of the field work, the four implanted lizards were placed in individual photothermal gradients in the laboratory (*6*) equipped with an antenna system; after 2 days for adjustment they were monitored over a second 2-day period. The mean body temperature recorded under gradient conditions was compared to a randomly selected segment of body temperatures obtained in the field enclosure from surface-dwelling lizards; there was no significant difference. In addition, both means compared close-

ly to means obtained in the field on many individuals with mercury thermometers (*4*). Such data further support the validity of reptile body temperatures obtained in laboratory thermal gradients (*7*).

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**References and Notes**

1. R. B. Cowles and C. M. Bogert, *Bull. Amer. Museum Nat. Hist.* **83**, 267 (1944).
2. R. S. Mackay, *Nature* **204**, 355 (1964).
3. S. M. McGinnis and C. W. Brown, *Herpetologica* **22**, 189 (1966).
4. K. S. Norris, *Ecology* **34**, 265 (1953).
5. R. S. Mackay, *Nature* **179**, 1239 (1957).
6. R. C. Stebbins, *Copeia* **4**, 681 (1963).
7. S. M. McGinnis, *Science* **152**, 1090 (1966).
8. We thank M. Falkenstein for assistance.

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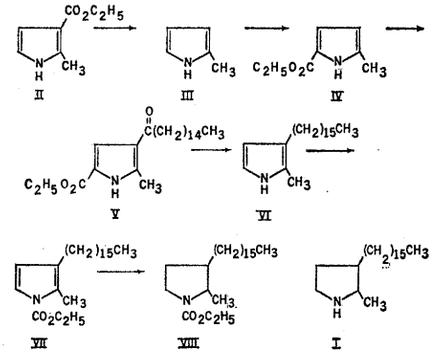
## Fire Ant Venom: Synthesis of a Reported Component of Solenamine

Abstract. *2-Methyl-3-hexadecylpyrrolidine was synthesized. It has hemolytic activity as has solenamine, but it apparently does not have the insecticidal activity of the fire ant venom. As judged by gas chromatography, the structure is not a component of solenamine.*

The venom of the imported fire ant (*Solenopsis saevissima richteri* Forel) (*1*) possesses considerable insecticidal activity toward the boll weevil *Anthonomus grandis* Boheman and the rice weevil *Sitophilus oryzae* (L.). This venom is composed of two phases, namely an alkaline carrier in which fine droplets of a greater density are suspended (*1*). The latter material apparently is associated with the insecticidal activity and exhibits infrared absorption at 5.70 $\mu$. Blum *et al.* (*1*) obtained this venom, referred to as "milked venom," by stroking the abdomens of major fire ant workers with a fine capillary until the stings were everted. The droplets were then collected in the capillary from the end of the sting.

From homogenates of whole ants, Adrouny *et al.* (*2*) prepared a material that possessed the potent necrotoxicity of the milked venom. This material (a mixture) was termed "solenamine" to avoid its premature identification with the toxin. Adrouny reported that solenamine was indeed the principal—and very likely the sole—toxic component of the venom. The consistent similarity in chemical and biological properties between milked venom and solenamine led him to expect the latter to perform also as an insecticide (*2*).

By gas chromatography, solenamine was found to be composed of two amines for which the structures 2-methyl-3-hexadecylpyrrolidine (I) and the corresponding 3-pyrroline were proposed (*2*). Blum and his associates (*1*) had ascribed the insecticidal activity to a carbonyl-bearing compound that Adrouny *et al.* did not mention.



Pyrrolidines and 3-pyrrolines have been previously investigated for their insecticidal activities. Studies of the common firebrat *Thermobia domestica* (Packard) with 2-substituted pyrrolidines and their corresponding 3-pyrrolines (*3*), as well as studies with nicotine, were reported.

To synthesize compounds with the two proposed structures, I obtained 2-methyl-3-hexadecylpyrrole from which the pyrrolidine could be obtained by hydrogenation and from which the 3-pyrroline could be prepared by reduction with zinc and acid. Addition of bromine to vinyl acetate, followed by addition of ethyl acetoacetate and ammonia, produced crude 2-methyl-3-(ethoxycarbonyl)-pyrrole (II); this compound was saponified and decarboxylated yielding 2-methylpyrrole (III) (*4*). The available $\alpha$-position was blocked by phosgenation in the presence of a tertiary amine and then by treatment with ethanol. The resulting 2-methyl-5-(ethoxycarbonyl)-pyrrole (IV) has on several previous occasions been subjected to the conditions of electrophilic substitution, with the position of the new substituent being assigned *ortho* to the 2-methyl group (*4, 5*). The structural assignments apparently were based on mechanistic reasoning. In this case, treatment of 2-methyl-5-(ethoxycarbonyl)-pyrrole with palmitoyl chloride in the presence of aluminum chloride produced 2-methyl-3-palmitoyl-5-(ethoxycarbonyl)pyrrole (V) [melting point (m.p.), 110° to 111°C] in high yield (*6*). I justified the assignment of the 3-, rather than the 4-, position by the proton nuclear magnetic resonance (NMR) spectrum of the subsequently obtained 2-methyl-3-hexadecylpyrrole (VI). This latter intermediate was synthesized by saponification and decarboxylation to 2-methyl-3-palmitoylpyrrole (m.p., 65.5° to 66.5°C), which gave 2-methyl-3-hexadecylpyrrole upon reduction with lithium aluminum hydride. Purification by sublimation (100°C, 0.05 mm-Hg) produced a white crystalline solid (m.p., 48° to 49.5°C) which turned brick-red when exposed to air at ambient temperature overnight. The NMR spectrum revealed two aryl protons at 5.81 and 6.32 parts per million (ppm) (*6*). These same protons appear at 5.82 ($\beta$ C-H) and 6.28 ppm ($\alpha$ C-H) in 2,3-dimethylpyrrole, but 2,4-dimethylpyrrole absorbs at 5.57 and 6.08 ppm (*7*). Thus there is no doubt that I have synthesized a 2,3-dialkylpyrrole, that is, electrophilic substitution occurred *ortho* to the methyl group of 2-methyl-5-(ethoxycarbonyl)-pyrrole.

All attempts to reduce 2-methyl-3-hexadecylpyrrole to the 3-pyrroline by known procedures with zinc and acid (*7, 8*) were uniformly unsuccessful. Although alkylpyrroles are very acid-labile, NMR spectra of protonated alkylpyrroles can be obtained if concentrated acid solutions of these pyrroles are used (9). However, an attempted reduction in concentrated acid was not successful.

This pyrrole was quite resistant to hydrogenation with a rhodium catalyst at 3 atm; these conditions are sufficient to reduce 2,5-dimethylpyrrole, for example (*10*). Reaction of the pyrrole with potassium, followed by treatment with ethyl chloroformate, produced 1-(ethoxycarbonyl)-2-methyl-3-hexadecylpyrrole (VII) (purified by column chromatography and sublimation at 100°C and 0.05 mm-Hg; m.p., 35.5° to 36.5°C). This compound was easily hydrogenated to the pyrrolidine (VIII) with 5 percent rhodium-on-alumina catalyst in ethanol at 3 atm. The ethoxycarbonyl group was removed with hydrobromic acid, and the pyrrolidine (I) was purified by sublimation (80°C at 0.025 mm-Hg; m.p., 34° to 37°C). Gas-phase chromatography of this material revealed two components (~4 : 1) with close retention times. The NMR spectrum of this mixture showed the absence of aryl and olefinic absorption.