$m = 10^{-2} d^3 B_n$, where $d$ is the distance to the detector in centimeters. Therefore, in lower Fig. 2A, by assuming $d = 6$ cm, N27 indicates that there are a total of about 60 $\mu$g of can particles in the stomach (*8*).

Fields larger than about $20 \times 10^{-7}$ gauss, as in lower Fig. 2A and lower Fig. 2C, can be detected with the simple and relatively inexpensive flux-gate magnetometer (*10*), in an urban environment, without the need for a shielded room. Because of this, two applications of this simple technique for the measurement of FC are suggested.

The first involves the asbestos worker. This subject in my measurements had been processing chrysotile asbestos (*9*) at a Quebec mine. His map showed $B_n \approx 150 \times 10^{-7}$ gauss at the lungs, but his chest x-ray was normal. This implies that a magnetic measurement can be a more sensitive indicator of FC actually present in the lungs, including asbestos, than an x-ray. (The arc welder of Fig. 2C also had a normal x-ray.) Therefore, if the ratio of magnetite to asbestos is known, flux-gate measurements may be useful in a mine area to monitor the accumulated asbestos in miners' lungs, in order to avoid the harmful effects of extreme accumulation (*11*). To check the simplicity of this technique, the magnetic field of the subject was measured outside the shielded room with a flux-gate magnetometer, and indeed the lung field was easily seen, well above the noise. The asbestos density, estimated from a field of $150 \times 10^{-7}$ gauss (*8*), is 75 $\mu$g per cubic centimeter of lung.

The second application is the use of magnetite inhalation as a harmless tracer in determining rates of lung clearance and other processes. In the past, radioactively tagged (nonmagnetic) $\alpha\,Fe_2O_3$ dust has been used to measure lung clearance rates in humans (*12*), which gave knowledge of how the lung cleansed itself of fine dust. The magnetite inhalation tests presented here yield maps which resemble that of the welder in lower Fig. 2C, with lung fields of about $25 \times 10^{-7}$ gauss; with the inhalation of a larger amount of magnetite, these fields would have been readily measurable with the flux-gate magnetometer outside the shielded room. The inhaled magnetite particles, as well as any FC in the lungs, show an interesting new phenomenon which is seen when a sequence of maps of a subject is recorded during the first few hours after a magnetization. The phenomenon consists of the continuous decrease of all $B_n$'s, which drop by as much as a factor of 6 during the first hour; the decrease is most probably due to continuous rotations of the particles by some viable process in the lungs. The resulting relaxation curve is reproducible for each subject but varies from subject to subject; hence, this curve presumably contains information on both the particles and the condition of the lung. These results suggest that magnetite inhalation offers a new and useful probe of the lung.

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### References and Notes

1. In the terminology used here, if a magnetic field is changing with frequencies slower than 0.1 hz, it is called steady and is produced by either d-c or stationary ferromagnetic material; if it is changing faster than 0.1 hz, it is called fluctuating and is produced by alternating current.
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3. Suggestions were made by various associates, especially Prof. E. Rosenberg and A. Sandoval.
4. SQUID (superconducting quantum interference device) refers to a class of magnetic detector which is based on the Josephson effect, is extremely sensitive, and responds to d-c. The particular form I use was developed by Dr. J. Zimmerman and has been described in J. E. Zimmerman, P. Thiene, J. T. Harding [*J. Appl. Phys.* **41**, 1572 (1970)] and in D. Cohen, E. A. Edelsack, J. E. Zimmerman [*Appl. Phys. Lett.* **16**, 278 (1970)].
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6. There are various tape erasers which are available commercially and are light enough to be held in one hand. The unit I use, a Robbins model TM-100, produces an amplitude of about 1000 gauss at a distance of 3 cm when powered by 208 volts.
7. Some magnetically hard particles, even though magnetized by the earth's field of about 0.5 gauss, cannot be demagnetized with the eraser I used. The demagnetization of ferromagnetic particles is discussed by T. Nagata in *Rock Magnetism* (Maruzen, Tokyo, 1961), p. 156.
8. The remanent magnetic moment of magnetite dust, after magnetization at 500 gauss, is about 6 electromagnetic unit/g. In the gastrointestinal tract, FC from cans is estimated to have $\lesssim 12$ electromagnetic unit/g, similar to that of magnetite.
9. The fibers of chrysotile, which constitute 95 percent of the world's asbestos supply, occur with adhered magnetite particles which give asbestos its ferromagnetism and are difficult to remove in milling and refining. It is here assumed that the ratio by weight of magnetite to asbestos is 0.04, although it is higher before milling and lower after refining.
10. Flux-gate magnetometers have an equivalent input noise of $\lesssim 5 \times 10^{-7}$ gauss, root-mean-square, in a bandwidth of 0 to 1 hz. Urban magnetic noise can usually be canceled out by the use of a differential input, such as with Automation Industry's MF-5000, used here for the tests with the asbestos worker.
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13. The Francis Bitter National Magnet Laboratory is supported by the National Science Foundation. The author is an Established Investigator of the American Heart Association. This research was supported by grants from the American Heart Association (70-734), the National Science Foundation/RANN (GB-28136 and contract C670-2), and the National Institutes of Health (HE 13777-01). I thank Dr. G. Gibbs, Dr. R. Murphy, Mrs. A. Mackler, Dr. A. Langer, and Prof. I. Selikoff for supplying asbestos information and samples, Prof. H. Hardy for comments about the lung tests, and E. Givler for his low-field engineering, and the many other people who have given help and encouragement.

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# Iguanid Lizard from the Upper Cretaceous of Brazil

*Abstract.* Pristiguana brasiliensis, *new genus and species, from the Upper Cretaceous Baurú Formation of Brazil, is the oldest fossil referable to the living lizard family Iguanidae. It resembles living primitive South American iguanids in some features, but also shows similarity to members of the related family Teiidae. Iguanid fossils do not appear in North America until the early Eocene, probably by waif dispersal from South America during the late Paleocene or early Eocene. A southern continental (Gondwanan) origin of iguanids is more plausible than the northern one often suggested.*

The lizard family Iguanidae is a primitive group distributed today in South America, Central America, and southwestern North America; two genera also occur on Madagascar and one on the Fiji and Tonga islands. The few fossils correctly referable to the family are currently being studied (*1*). Most of these fossils are North American forms that do not antedate the early Eocene (*2, 3*), a situation unusual in view of the present extensive Neotropical radiation and generic diversity among iguanids (at least 55 Recent genera are currently recognized). Fossil iguanids occur in the Paleocene of Brazil (*1, 4*), but the specimen described here is of particular interest because it is the first Mesozoic record of the Iguanidae and the earliest record of the family.

Class Reptilia
Order Lacertilia
Family Iguanidae
*Pristiguana brasiliensis*
n. gen., n. sp.

*Holotype*: Divisão de Geologia e Mineralogia (DGM) No. 552, portion of a disarticulated skeleton of one individual, exposed on a small block of reddish sandstone (Fig. 1). Preserved elements include frontals, left dentary with teeth, right surangular, left pterygoid, left humerus, and several unidentifiable fragments (Fig. 2).

*Locality*: Pierópolis, Minas Gerais, Brazil.

*Horizon*: Baurú Formation, Upper Cretaceous.

*Etymology*: Latin, *pristinus*, early.

*Diagnosis*: Iguanid lizard differing from all known members of the family in having relatively elongate preorbital region of frontal; among iguanids shares primitive large splenial of mandible with *Morunasaurus, Enyalioides*, and *Hoplocercus*. Differs from the latter genera principally in frontal proportions, and from *Morunasaurus* in particular in lacking flared tooth crowns.

*Description*: Individual elements disarticulated but closely associated on rock surface; dentary nearly complete, slightly broken posteriorly, maximum length as preserved 9.1 mm; teeth essentially homodont, 20 teeth as preserved, total original number probably not more than 21 or 22; posterior teeth bluntly tricuspid, with side cusps not sharply set off from main cusp; tooth shafts columnar, crowns not flared; 4th, 9th, 16th, and 18th teeth with replacement pits at base; teeth approximately 1.2 to 1.3 mm high; dental gutter slight; symphysis not well developed; Meckelian canal fully open to symphysis and broadly open posteriorly; internal mental canal simple, opening under 13th tooth from front of jaw; splenial articulation facets indicate that splenial bone reached anteriorly to 9th tooth from front of row; labially, teeth protrude about one-third to less than one-half of their height above parapet of jaw; about seven small external alveolar foramina present on labial dentary surface; posterior dentary area broken, but existing portion shows no indication of posterolabial coronoid bone extension onto dentary.

Surangular with adductor muscle crest extending back to small posterior supraangular foramen at posterodorsal end; notch present ventrally for posterior extension of dentary.

Frontals fully fused, but a faint impression of suture line present on anterior third of bone; deep nasal incisions present anteriorly; faint prefrontal incision present laterally, a small sliver of frontal extending forward between nasal and prefrontal incisions. Posteriorly a deep indentation for parietal eye present on frontoparietal border; posterolateral extensions of frontal not marked; dorsal surface of frontal smoothly rounded, not depressed or sculptured; orbital constriction not extreme.

Pterygoid with short row of five or six teeth present on anteromedial border.

Humerus 9.7 mm long as preserved, distal ends missing; bone appears to have been of normal lacertilian form, but is relatively short.

*Discussion*: The occurrence of the parietal foramen on the frontoparietal border, coupled with the presence of columnar, bluntly tricuspid dentary teeth and the presence of pterygoid teeth, indicate that *Pristiguana* can be referred to the lizard family Iguanidae. Three living iguanid genera retain the primitive lizard condition of large splenial found in *Pristiguana* (as interpreted from the large size of the lingual opening on the fossil dentary); these are the morunasaurines *Enyalioides, Hoplocercus*, and *Morunasaurus*, all from South America. The presence of teeth on the pterygoid is a primitive character-state in iguanids (and other lizards); they also occur in *Morunasaurus* and *Hoplocercus*. The dentary teeth of *Pristiguana* are similar to those often seen in iguanids, especially the tropidurine genera (*5*), but lack the slightly flared crowns common in many tropidurines and other iguanids. Teeth of the fossil also resemble those of the Cretaceous teiid *Leptochamops* from North America (*6*), although such tooth types occur in other groups of Recent lizards, such as gerrhosaurs.

Fig. 1. *Pristiguana brasiliensis*, DGM No. 552. Type specimen showing relationship of individual elements on rock surface. Dentary has been turned over and the teeth prepared. Matrix retouched around bones for contrast (× 2).

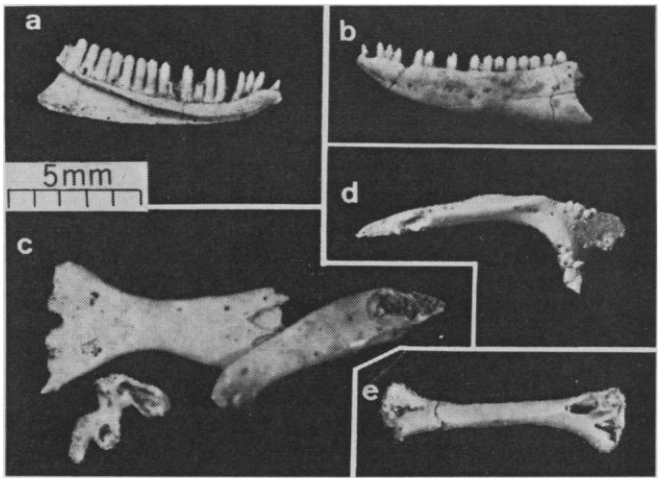
The frontal is unusual for iguanids in having a relatively elongate preorbital region. The ratio of frontal width (at frontoparietal suture) to total frontal length as measured in 48 iguanid species (representing 42 genera) ranges between 0.7 and 1.2, with a mean of 1.0. This ratio is 0.6 in *Pristiguana*, significantly lower than that of the majority of iguanids and less than that of any iguanid measured, but about the same as the figure common in many lizards of the family Teiidae (Fig. 3).

The relatively short humerus lacking the distal ends and the relatively smooth frontals with a faint indication of their former median suture may indicate that these remains are from a relatively young animal.

*Faunal associates of* Pristiguana: The vertebrate fauna of the Baurú Formation also includes crocodilians, dinosaurs, and turtles (*7*).

*Significance of* Pristiguana: The discovery of *Pristiguana brasiliensis* is of great interest on systematic, paleontologic, zoogeographic, and phylogenetic grounds.

The antiquity of *Pristiguana brasiliensis* marks it as one of the earliest records of a modern lizard family. Late Jurassic lizards from Europe are referable to the modern superfamilies Lacertoidea, Scincoidea, Anguioidea, and perhaps Iguania, but cannot clearly be referred to modern families in these groups (*8*). Several features of *Pristiguana* make it necessary to discuss the possibility of referring it to the family Teiidae rather than to the Iguanidae. The dentary of *Pristiguana* resembles that of the Cretaceous teiid *Leptochamops* (*6*) in having straight-sided tricuspid teeth and in having a broadly open Meckelian groove. Also, in the North American Cretaceous presumed teiid *Polyglyphanodon* (*9*), there is an iguanid-like parietal foramen lying on the frontoparietal border, notching the frontal as in *Pristiguana*. These teiid-like resemblances may be significant, yet we believe that they do not affect reference of *Pristiguana* to the Iguanidae. In *Leptochamops* and the majority of teiids, the teeth are well separated and relatively shorter than in *Pristiguana*; in addition the Meckelian groove is more widely open in teiids than in *Pristiguana* although secondary restriction or closure of the groove has occurred in parallel in both families. In *Polyglyphanodon* (unlike Recent teiids) the frontals are paired and rhomboidal, although the latter shape may in part result from the relatively large size of the animal. Recent teiids lack a parietal foramen, as do referred parietals of Cretaceous forms (*6*); some Recent teiid species do have a poorly defined unossified area on the frontoparietal border that may represent this structure, but it may alternatively be related to skull kinetics. The Late Jurassic *Euposaurus* has been referred to the Iguania (near the Agamidae) on the basis of skull proportions and in having the parietal foramen on the frontoparietal border (*8*). In these features as well as in having all of the dermal midline skull elements paired, there is as great or greater similarity of *Euposaurus* to the primitive Late Triassic eolacertilian *Kuehneosaurus* (*10*), suggesting that a position of the parietal foramen on the frontoparietal suture may represent a primitive character-state for lizards. Alternatively such a foramen position could result from the relatively short parietal and braincase region of all of the above fossil forms. We do not believe that any of this affects the



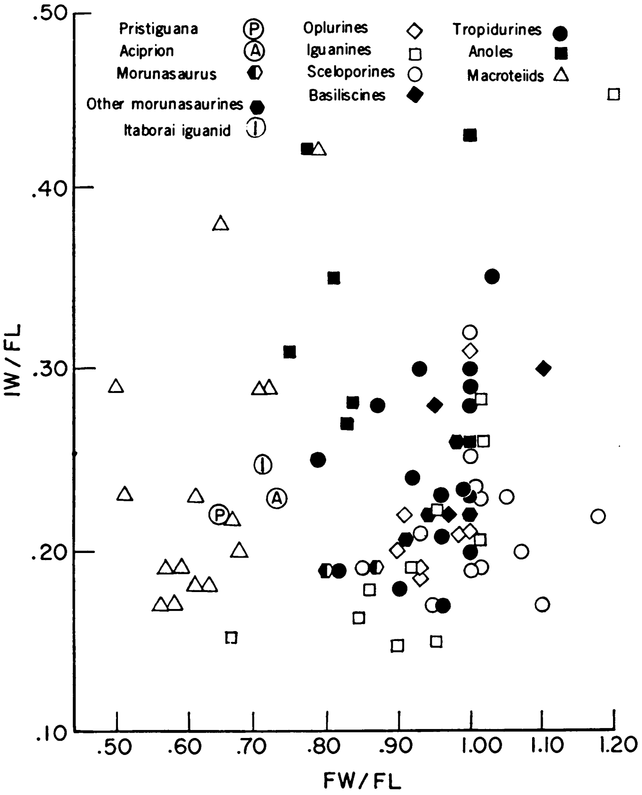


Fig. 2 (left). *Pristiguana brasiliensis*, DGM No. 552. Type specimen. (a and b) Left dentary in lingual (a) and labial (b) view; (c) frontals, right surangular, and small irregular bone probably part of braincase; (d) left pterygoid in ventral view; (e) left humerus. Pterygoid, nasal incisions of frontal, and dentary articulation surface on surangular slightly retouched for contrast. Fig. 3 (right). Ratios of frontal proportions in iguanid and teiid lizards; *IW*, interorbital width; *FL*, midline frontal length; *FW*, maximum posterior width. Only "macroteiid" genera have been plotted, as the "microteiids" differ from them in many character-states and the systematic position of the latter group of genera has not yet been fully clarified.

iguanid reference of *Pristiguana*, for the latter is in all details a completely modern type of lizard rather than an archaic form. In this context, foramen position in *Pristiguana* argues more strongly for iguanid than teiid relationships, but a possible explanation of the teiid similarities appears below.

The relationships of *Pristiguana* within the Iguanidae are not clear. That it is primitive is indicated by the widely open Meckelian groove of the dentary and the presence of pterygoid teeth. There is no suggestion of resemblance to the oplurine iguanids except in the form of the teeth, and as noted above this is a tooth type common in the family. These resemblances to the most primitive living iguanids shown by *Pristiguana* are based on shared primitive rather than derived states. The elongated frontal proportions of *Pristiguana* are probably primitive, as the following discussion shows. *Aciprion*, an Oligocene morunasaurine-like iguanid from North America, has frontal proportions intermediate between those of Recent morunasaurines and *Pristiguana*, while one of the Paleocene iguanids from Brazil (*1*) approaches the latter still more closely (Fig. 3), perhaps indicating a trend, still perceptible in primitive living iguanids, toward shortening of the preorbital frontal region. This trend may be related to the more passive mode of feeding characteristic of iguanids. Known Jurassic lizards and the Triassic *Kuehneosaurus* fall closer to teiid than to iguanid frontal proportions, although these data are derived from photographs or drawings and consequently were not included in Fig. 3. In frontal proportions, even the Recent morunasaurines (most primitive of iguanids) are specialized relative to *Pristiguana*. Although slight, this evidence may indicate that *Pristiguana* represents the most primitive iguanid known. While it may be related to the morunasaurines, such a relationship requires more direct evidence for confirmation.

Until now, no iguanid fossils have been described before the early Eocene although undescribed records from the Paleocene have been cited (*1, 4*). The lack of fossil iguanids is surprising in view of the generally primitive structure of the group and their presumed ancient establishment in the New World. Their absence has recently been explained in part by presuming the group to have been of considerable antiquity in South America, with entrance into North America as a relatively late (that is, late Paleocene or early Eocene) event, probably by waif dispersal (*1*), contrary to the often suggested northern origin of the group (*11*). Thus iguanids are probably of southern continental (Gondwanan) origin, and iguanids must have reached Madagascar by dispersal through Africa, which did not separate fully from South America until the mid-Cretaceous (*12*). That no fossils of iguanids have been found in Africa is not important in this context as the record there of pre-Miocene herpetological groups is essentially nonexistent. The late entrance of iguanids into North America, the known presence of iguanids in the Paleocene of Brazil, and the discovery of *Pristiguana* strongly support this interpretation.

Evidence is beginning to accumulate that iguanids and teiids are related (*13*), an hypothesis that runs counter to generally held views. Although the evidence (particularly osteological evidence) is still meager, this relationship deserves continued careful investigation. The long, teiid-like frontal is one of the most significant features of *Pristiguana*. Two interpretations are possible. It may indicate a primitive character-state consistent with a common origin of the Iguanidae and Teiidae. Since these frontal proportions occur sporadically in other generalized lizards, it is also possible that *Pristiguana* (and *Aciprion* and *Morunasaurus* in lesser degree) shares with the teiids the generalized frontal proportions of primitive lizards. These two interpretations may overlap; that no decision about which of these alternatives is preferable can be made at present does not diminish the significance of *Pristiguana*, but highlights the need for new fossil material and more osteological studies of Recent lizards.

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# Hypothermia of Broad-Tailed Hummingbirds during Incubation in Nature with Ecological Correlations

Abstract. *The first continuous recordings of natural hypothermia, and the only evidences of hypothermia during incubation, were obtained from temperature sensors embedded in synthetic hummingbird eggs placed in the nests. Resorting to this energy-conserving process was infrequent and could be correlated with reduced opportunity for energy intake.*

The energetics of hummingbirds are of special interest because of high ratios of surface (heat dissipating) to volume (heat producing) (*1*), intense metabolism (*2*), and slight insulation (*3*). The energy reserves of a hummingbird must be sufficient to meet the costs of nocturnal maintenance and the resumption of foraging at daybreak. A limited energy supply can be conserved by entry into hypothermic torpor, wherein the normal 38° to 43°C range in body temperature is "abandoned" and heat production is reduced during the nocturnal fast (*4, 5*).

Previous information on torpor of hummingbirds has come for the most part from the laboratory, where the nutritional state of captive birds has been questioned (*6, 7*). There is a paucity of quantitative records of torpid birds under natural conditions. Thus patterns of entry and the factors causing them had been unknown.

All previous recordings of nocturnal nest temperatures have shown that female hummingbirds do not become hypothermic during incubation. The maintenance of a high thermal gradient from nest to environment is especially remarkable in the cold nights of mountain climates (*8*). From continuous monitoring of nest temperatures and environmental data, we have found the first evidence of torpor in incubating female hummingbirds. The torpor can be correlated with weather conditions that posed chilling demands upon marginal energy reserves.

Nest temperatures of the broad-tailed hummingbird (*Selasphorus platycercus*) were recorded in the vicinity of Gothic, Gunnison County, Colorado (elevation 2900 m in the Elk Mountains), in the summers of 1971 and 1972. Thermistors and thermocouples were embedded in synthetic eggs of Silastic medical elastomer (Dow-Corning 382) and connected to recording potentiometers. The temperatures recorded were toward the hen's end of the temperature gradient from bird to air. This also provided a time account of the hen's absences from the nest, which showed as cooling "spikes" (displacements in the trace).

On 8 June 1972, three nests were being monitored. Two of the nests, located approximately 1 km apart, showed the same pattern (Fig. 1). The lower temperatures and solar irradiation for this day, compared with days preceding and following (Fig. 2), resulted from heavy, steady rain during the periods of 0830 to 0945 and 1520 to 1710. The amount of rain was not recorded at Gothic, but 5½ km to the south (Crested Butte) there was 1.6 cm of rain. During the rain, the two females remained on the nests, missing several normal, periodic, feeding sorties characteristic of the daytime (cooling spikes, Fig. 1, a and b). Approximately 21 and 12 percent of the normal activity daylengths of 14.75 to 15.25 hours, respectively, were unavailable for feeding. There were 18 and 7 percent fewer departures from the nests than normal for the day. Despite continuation of foraging 15 and 18 minutes later than normal that evening, this must have decreased the total energy intake significantly.

The night of 8 June was clear and cold. At 0100, the temperature of the synthetic egg in nest 1 began a steady decline from 31° to 6.5°C (readable to ± 0.2°C). At 6.5°C the temperature stabilized, remaining as if regulated, while the air temperature in Gothic continued a slow decline to − 1°C (readable to ± 1°C) on the valley floor. The minimum temperature at the nest site before sunrise was + 2°C (readable to ± 0.5°C). The body temperature of the female hummingbird, though unrecorded, was probably slightly higher than the 6.5°C "egg" temperature. Air velocities during the period of hypothermia were 0 to 4 km hr$^{-1}$, mostly under 1½ km hr$^{-1}$.

Since the females move relative to the orientation of the sensor "eggs," one could argue that the cooling cycles (Fig. 1, a and c) represent cooling of "egg" from movement rather than hypothermia of the hen. However, the "eggs" cooled much faster when the female departed to feed, even in the mildness of midday. The nocturnal cooling was more gradual despite a colder environment, an indication that a larger mass, hen plus clutch, was cooling as a unit. This and the consistency of the pattern and the timing of the gradual arousal convince us that the females had been hypothermic.

At nest 5 entry into torpor began later, about 0245. This later recourse to torpor correlates with the fact that