
People often ask, “What good are lizards?” to which we respond with “What good are people?” Such anthropocentrism is abhorrent. Lizards have as much of a place on the planet as any living creature, including humans. Indeed, they have successfully inhabited Earth for much longer than humans have—lizards will undoubtedly persist long after humans and most other mammals have gone extinct. Lizards are spectacular products of natural selection and have diversified to fill an amazing variety of ecological niches. They are extremely good “model” organisms for study, and understanding their ecology and diversity can be exceedingly informative. What we have learned about lizards is applicable to nearly every conceptual area in modern biology; indeed, in many cases development of entire fields of biology had their origins in the study of lizards. Because many lizards are quite beautiful, they are very popular as pets among herpetoculturists around the world, and some people make their living by breeding many species of lizards in captivity for resale.


Curator of herpetology at the New York Zoological Park, Raymond L. Ditmars in his book, Reptiles of the World (1933), marveled at the diversity of lizards, “Looking down upon the vast Order now engaging the student’s attention, even the most passive of observers cannot refrain from expressing amazement at the array of varied forms. In a subdivision, the Sauria, we shall consider creatures twelve feet long, with claws as long as those of a leopard—animals strong and active enough to leap at the throat of a young gazelle, tear, dismember and devour the prey; and passing such we stop to realize that tiny, limbless and worm-like, slow-moving things, burrowing their life away deep in the ground where they need no eyes—in fact, have none—are also true lizards.” (Figs. 1, 2)

In this two-part paper, I follow the organizational framework of McDiarmid et al. (2012) as a taxonomic review of extant lizard groups. Part II will appear in the next issue. Original standard and scientific names are used. To update these names, use The Reptile Database (Uetz and Hošek 2013) and Standard English and Scientific Names: Checklist of the Standard English Common Names of Amphibians & Reptiles (Crother 2012) if occurring in North America. A complete reference called Grzimek’s Animal Life Encyclopedia was published on all reptiles in 2003, with chapters written by experts in herpetology (Hutchins et al. 2003). Some lizard families have been only superficially investigated in zoos: Anguidae, Agamidae, Dibamidae, Amphisbaenidae, Bipedidae, Rhineuridae, Trogonophidae, Lacertidae, Gymnophthalmidae, Teiidae, Cordylidae, and Xantusiidae.

History

In May 1849, the London Zoo, founded in 1828, opened the first zoo reptile building in the world, a modified carnivorous mammal facility which used the dens as enclosures for lizards and other reptiles (Keeling 1992). The second zoo reptile building at London, designed and constructed specifically for reptiles, was opened in August 1883 (Guillery 1993) and is currently a
tropical bird building today. The newest London Reptile House was designed by curator Joan Beauchamp Procter in 1926–1927 and is still in use. The building included a center island to house venomous snakes and other potentially dangerous reptiles and a “Reptiliary” housing iguanas. New zoo design features were incorporated: differential heating, “Aquarium principle lighting” (illuminating enclosures from above), elaborate naturalistic displays, and better visitor traffic.

Philip Lutley Sclater, Secretary for the Society (1859–1902), compiled nine editions of an inventory (“List of the vertebrated animals now or lately living in the gardens of the Zoological Society of London”) beginning in 1862. In 1872, his revised list included tuataras and many lizard taxa such as the Moloch, Bearded Dragon, mastigure (Uromastyx), Shingleback Skink and other skinks, several chameleons, as well as lacertids and iguanids to round out the collection. Books on the husbandry of lizards began to appear during the Victorian era in greater numbers (Murphy and McCloud 2010). For instance, A. D. Bartlett (1899) had written *Wild Animals in Captivity Being an Account of the Habits, Food, Management and Treatment of the Beasts and Birds at the ‘Zoo,’* which treated the habits of lizards such as the Stump-tailed Skink, Thorny Devil, iguana, and chameleon. These books had a practical application in that private fanciers used the zoo protocols, particularly those from the London Zoo, though it must be stressed that these Victorian fanciers, mostly women, went on to develop many innovative techniques. Later, London Zoo curator E. G. Boulenger published an excellent book with many photographs called *Reptiles and Batrachians* (1914). He included many observations on lizards living in the collection.

Jon Coote (2001) speculated that many reptiles, especially lizards, arrived at the London Zoo in good condition in the nineteenth century because those responsible for transporting them were given specific instructions for their care: “Correspondents should engage some individual of the ship’s company to take charge of the animals on board and guarantee him a handsome recompense on bringing them safely to their destination…” Food was also important for reptiles on the long sea journeys and correspondents were advised: “ants eggs, which are abundant in tropical climates, may be preserved in a jar, well tied down and with the addition of the Blattae or cock-roaches so generally obtainable on board in all their stages of growth, and of meal worms, which are equally abundant in the bread room…”

During that time, there was closer cooperation between zoo workers and private herpetoculturists than there is now. Until 1903, keepers at the London Zoo were able to trade or sell surplus animals to the general public and they supplied herps to amateur British herpetoculturists. Reverend Gregory Bateman (1897) purchased a pair of tuatara from the Zoo for £2.00 ($3.00) and other species were offered for sale in London. Prices were reasonable: small monitor lizards—5 shillings (38 cents US), Common Tegus—about £2.00 ($3.00), Red Tegus—£3.00 to £8.00
Stanley Smyth Flower published monographs and papers on amphibian and reptile longevities. In his 1937 publication, he mentioned that varanids and large iguanids are often kept in captivity but it is surprising that only two lizard taxa had reached twenty years in captivity—Slow-Worm (Anguis fragilis) for 32 years and Cunningham’s Skink (Egernia cunninghamii) for 20 years. In North American collections, Snider and Bowler (1992) listed one anguid, one cordylid, three gekkonids, four iguanids, three skincids, one varanid, and a number of helodermatids passing twenty years in captivity. Carey (1973) provided some notable longevity records for captive iguanas.

In the early twentieth century, papers on lizard husbandry and captive management began to regularly appear, written by London Zoo curators such as E. G. Boulenger (1913, 1920) and Joan Proctor (1928) and many European and New World herpetologists (see Card and Murphy 2000, Murphy 2007, 2009–2010 for descriptions). In 1955, an extraordinary four-volume set by Wilhelm Klingelhofer named Terrarienkunde appeared and was THE husbandry reference book for decades in Europe. Toward the end of the century, zoo herpetologists became better at recognizing signs of reproductive and other behaviors and recording these observations in scientific journals. Many books focused on captive lizards: Lizards in the Terrarium (jes 1887), a two-volume work called Lizards (Rogner 1997), Encyclopedia of Terrarium (Bruins 1999), Biology, Husbandry, and Medicine of the Green Iguana (Jacobson 2003), Vivarium Life (Leutscher 1952), Firefly Encyclopedia of the Vivarium (Alderton 2007), Reptiles, Amphibians, and Invertebrates (Bartlett et al. 2001), Handbuch der Terrarienkunde (Stettler 1978), Das Terrarium (Kahl et al. 1980), two-volume Die Terrarienrichter (Nietzke 1969, 1972), Guide to Lizards, All about Lizards, and Giant Lizards (Sprackland 1977, 1992, 2010), Breeding Terrarium Animals (Zimmermann 1983), The Completely Illustrated Atlas of Reptiles and Amphibians for the Terrarium (Obst et al. 1988), Reptiles and Amphibians: Their Care and Behavior (Vogel 1964), and The Lives of Captive Reptiles (Petzold 2008). Exciting new possibilities appeared in the literature such as investigating the evolution of social cooperation in lizards (Dickinson and Koenig 2003; Sinervo and Clobert 2003) and manipulating clutch and offspring size (Sinervo 1994). Ethologists and other researchers from the academic community began working jointly with zoo colleagues on projects in zoos and aquariums, resulting in improved studies (see Sajdak 1983; Chiszar et al. 1993; Chiszar and Smith 2005; Garrett 2005 for reviews). Reviews focusing on the nutrition of carnivorous and herbivorous lizards were published (Allen and Oftedal 1994; Baer 1994). David Crews and Leslie Garrick (1980) provided many examples for inducing lizards to reproduce in captivity. In the United States, researchers such as Gordon Burghardt, Charles Carpenter, David Chiszar, William Cooper Jr., Gary Ferguson, William Gehrmann, James Gillingham, Harry Greene, Thomas Jessen, Hobart Smith, and Paul Weldon, were pioneers who used zoo and aquarium collections to broaden their studies. William Cooper Jr. has used zoo collections as a resource for his studies on lizard feeding behavior for many years. Examples include varanoid lizards (Heloderma suspectum and Varanus exanthematicus), geckos (Rhacodactylus), and skinks (Tiliqua scincoides and Trachydosaurus rugosus). Susan Barnard from Zoo Atlanta and her associates have published a number of papers on parasitism and husbandry in zoo lizards (see Murphy 2007). Backues and Ramsey (1994) performed an ovarietomy for treatment of follicular stasis in lizards. Two important overviews by Stamps (1997) and Fox et al. (2003) examined social behavior and spacing patterns in lizards.

$$4.50 \text{ to } 12.00 \text{ depending upon size, Bearded Dragons—}10 \text{ shillings to } £1.00 \text{ (75 cents to } $1.50)\text{, Green Anoles—as low as half-a-crown (16 cents), European Chameleons—}3 \text{ shillings and } 6 \text{ pence (30 to 65 cents), British Common Lizards—}4 \text{ to } 6 \text{ pence each (6 to 9 cents).}$$

Beginning in 1882, Johann von Fischer from Vienna began to publish a large number of papers on captive lizards: Ringed Agama (Oplurus torquatus), European Chameleon (Chamaeleo cubicrus), Cape Spiny Lizard (Uromastix capensis auct), Stumrelschwanz Lizard (Trachyosaurus asper), iguana (Iguana tuberculata), Cylindrical Lizard (Gongylus ocellatus), Pygmy Lateral Fold Lizard (Ablepharus pannonicus), Schleuderschwanz (Uromastix acanthinurus), Common Skink (Scincus officinalis), Spotted Lizard, Eremias paradoxus, Worm Lizard (Trogonophis wiegmanni), and various lacertids. His seminal book on captive management was called Das Terrarium, seine Bespflanzung und Bevölkerung (1884) and includes recommendation for many mixed lizard combinations.

**Fig. 3.** Two of the rarest lizards in the world are shown here. Top: The Jamaican Land Iguana (Cyclura collei) was described by John Edward Gray as Colley’s Cyclura in 1845. Illustration from Catalogue of the specimens of lizards in the collection of the British Museum. This species was thought to be extinct until rediscovered in 1970. It now faces another threat due to plans to alter the habitat. Bottom: This male Grand Cayman Island Iguana (Cyclura nubila lewisi) allows itself to be groomed with a toothbrush by standing immobile as its entire body is brushed.
The late Thomas Huff from Reptile Breeding Foundation in Canada identified a condition that he called “captive stagnancy.” He believed that changing environmental factors was key to improving reproductive behavior and his solution was to change exhibit furniture, potential breeders, temperature, and so on to induce courtship and copulation (see Huff 1980). Warwick et al. (1995) addressed the issue of stress. Methods for egg incubation and raising neonates became more refined (see Packard and Phillips 1994). Earlier, reptile eggs were discarded in many instances because it was believed that hatching them was impossible. The importance and provision of ultraviolet light for reptiles held in indoor enclosures were highlighted in key papers by Gary Ferguson and associates (1996; Jones et al. 1996), William Gehrmann (1971, 1987, 1994), Carol Townsend (1979) and Townsend and Charles Cole (1985), and Jozsef Laszlo (Murphy 2007). Philip Regal (1980) examined temperature and light requirements. From Toledo Zoo, R. Andrew Odum (1984) stressed the importance of water quality.

Lawson et al. (2008) stressed the importance of science in zoos and aquariums. Dave Chiszar, Hobart Smith, and I argued that assessing the competence of captive-produced herps is as important as breeding the animals (Chiszar et al. 1993). We were surprised to discover that captive and wild Komodo Dragons have significantly different body temperatures (Wikramanayake et al. 1999; Walsh et al. 1999). If released into the wild, would captives with lower temperatures adjust thermoregulatory patterns upward? If deficits brought on by captivity are identified, can these be remediated? How can this be done? What necessary studies will be in place to assess survivability in the wild? These challenging issues have only been minimally addressed and there are some impressive exceptions: West Indian iguanas (Cyclura) serve as examples of successful field studies and reintroductions.

*Family Iguanidae.*—West Indian Land Iguanas (Cyclura) face a perilous future. Jeffrey Lemm and Allison Alberts from San Diego Zoo Global in California have worked for many years with these iguanid lizards. Their recent comprehensive book (Lemm and Alberts 2012) covers evolution and biogeography, species accounts, natural history, husbandry, nutrition, health and medical management, and conservation. The San Diego Zoo has been an integral player in iguana research and conservation over many years through publication of books and papers by Alberts and colleagues.

The Jamaican Land Iguana (Cyclura collei) was described by John Edward Gray as Colley’s Cyclura in 1845 (Fig. 3). Four years later, one was donated to London Zoo and lived in the Zoo for 3 years, 4 months, and 29 days (Coote 2001). Concern about the iguana’s future accelerated following the introduction of the Indian Mongoose on Jamaica in 1872 and things were critical by 1916 when this iguana was only found on a few small islets off the coast of Jamaica where the predaceous mongoose had not been introduced. In 1940, a total of 22 specimens were brought into captivity to try to save the species from extinction but none ever reproduced. The lizard was later thought to be extinct. A hunt was made but the species remained in 2000. Two years later, the population crashed precipitously and only 15–25 lizards were left. In 2003, five iguanas were hatched at the Indianapolis Zoo and two more lizards two years later. Described in 1940, the lizard was widely distributed in dry habitats over most of the island but is now restricted to a few remnant populations, due to human development, feral animals, and habitat destruction. Be sure to read Burton’s *Little Blue Book* (2010) about the challenges of conserving this species. He highlights the contribution by retired National Zoo curator Dale Marcellini in developing the conservation strategy. Marcellini suggested to me on many occasions that fieldwork should always be planned in a place where one could sit on the veranda of a four-star hotel with a refreshing drink in hand and watch lizards with binoculars—Dale called this plan “Resort Research”! Another amazing field account was written by Quentin Bloxam, who nearly died while working on conserving this taxon on Grand Cayman Island (see Murphy 2007:63). Sarah Kuppert (2013) described interactive male and female head bob displays at Smithsonian National Zoological Park (SNZP). This adult male allowed itself to be groomed with a toothbrush by standing immobile to allow its entire body to be brushed. The keeper pulled off dried skin by spraying these areas beforehand with water (Fig. 3).


C. B. “Si” Perkins, Curator of Reptiles at San Diego Zoo, and G. Allan Hancock mounted trips in 1932 and 1933 to the Galápagos Islands to study and collect animals for the Zoo (see Banning 1933 for additional information). Hancock’s ship was the state-of-the-art Valero III, nearly 200 feet in length. He was a bit of a prig, insisting that his fellow passengers—a group of scientists including Perkins—dress for dinner and moreover, cease smoking and drinking. For those of us who are not focused on the latest in apparel and enjoy a bit of whisky and strong cigarettes in the evening, this trip would have been unendurable. The notation “No cocktails tonight” appeared daily in the Perkins diaries (Campbell 1978).

During the first trip, Hancock and Perkins decided to move 40 Galápagos Land Iguanas (Conolophus suberistatus; Fig. 4.) from Baltra Island (known also as South Seymour Island) to North Seymour Island which contained no iguanas. As Perkins wrote in his diaries, their reason: “... in a few years come down and see if anything has happened. A good idea, I believe.” (Campbell 1978). Twenty more iguanas were translocated on the second trip.

Baltra was an American airbase during World War II in the 1940s and several thousand military and support personnel were stationed there, in part to guard the Panama Canal. Several factors contributed to the disappearance of these lizards—habitat destruction, introduction of feral animals, and using the lizards for target practice.

There appeared to be virtually no successful reproduction or recruitment on North Seymour for the subsequent 47 years so a pair of adults was brought to the Charles Darwin Research Center on Santa Cruz Island to begin a captive colony; additional iguanas were included in this potential breeding group later (Cayot et al. 1994). These iguanas reproduced and survived, particularly because feral cats and dogs had been reduced on Baltra. In June 1991, 35 five-year-old iguanas were repatriated to Baltra and 24 were released the next year. This head-starting program was truly an accomplishment deserving praise, thanks to Perkins and Hancock.

Ray Pawley from Chicago Zoological Park (Brookfield Zoo) maintained a colony of Marine Iguanas (Amblyrhynchos cristatus) in a large exhibit in the reptile building (1965, 1966, 1969, 1971). I visited the Zoo on a number of occasions and was impressed by the overall health and activity of these lizards. This species is challenging to maintain successfully in captivity but one of his saurians lived for over six years.

Dennis Desmond told me that his adult female Green Iguana (Iguana iguana) would sleep with a furry toy virtually every night and the lizard often wrapped its forelimbs around this unusual object (see photo in Murphy 2007). Dedekind (1977) recorded his observations made during hatching and raising of a Green Iguana in the Berlin Tierpark (Fig. 5.). Mendelssohn (1980) provided recommendations on care, based on reproduction in a colony at Tel Aviv University in Israel. Howard (1980) bred them at the Twycross Zoo and Banks (1984) at Melbourne Zoo. Wallach (1966) described hypervitaminosis D in Green Iguanas. Bosch and Werning (1996) discussed the captive management of Green Iguanas and other iguanids. Wallach and Hoesl (1968) documented fibrous osteodystrophy in Green Iguanas. Zwart and Van de Watering (1969) described pathology and etiology of abnormal bone formation in this species. The reproductive biology of Green (Iguana) and Desert (Dipsosaurus) iguanas has received attention (Judd et al. 1976). Day et al. (2000) provided a species account of the Lesser Antillean Iguana (Iguana delicatissima). Bosch and Werning (1996) wrote a manual on iguana care.

Arnett (1979) reproduced the Fiji Banded Iguana (Brachypholis fasciatus) at Knoxville Zoo and over 100 young have been produced at San Diego Zoo (Fig. 6.). In 2008, a new species was described (B. bulabula) and a breeding program has been initiated by San Diego Zoo. Boylan (1989) bred the Fijian Crested Iguana (B. vitiensis) at Taronga Zoo in Sydney, Australia. Carpenter and Murphy (1978) noticed aggressive behavior and color change between males in the Fiji Island Iguana at Dallas Zoo.

Marcellini and Jessen (1991) documented avoidance learning by the Curly-tailed Lizard (Leiocephalus schrebersi). Petzold (1962) successfully bred the Northern Curly-tailed Lizard (Leiocephalus carinatus) at Berlin Tierpark. Gibson and Buley (1996) described captive management and breeding of Madagascar Spiny Iguanas (Oplurus c. cuvieri) at Durrell Wildlife Conservation Trust. Vogel (1992) outlined care and breeding of the Cercasch- headed Iguana (Laemanzac serratus) over several generations in the Exotarium of Frankfurt Zoo. At Dallas Zoo, we received a group of lizards confiscated by U.S. Fish & Wildlife Service, which included Casque-headed Iguanas (Laemanzac longipes), Smooth-helmeted Iguanas (Corytophanes cristatus), Hernandez Smooth-helmeted Iguanas (Corytophanes hernande siti), Common Monkey Lizards (Polychrus marmoratus) (Fig. 7), and Tree Runners (Plica plica). All but the last taxon was kept at ca. 72°F (22°C) ambient temperature with a basking spot. A colleague told me that he found a Smooth-helmeted Iguana resting on a tree trunk in the field and did not move for over a week until a large beetle passed by. At Dallas Zoo, a group of Baja California Rock Lizards (Petrosaurus thallassinus) and Banded Rock Lizards (P mearnsi) were displayed in a large enclosure (Fig. 8). These lizards were hardy and constantly active. Bayard Brattstrom visited and suggested that we arrange two hotspots above two platforms where these lizards would learn to shuttle back and forth between them. A timer would be used for tripping a relay switch to turn one or the other off; both would not be on simultaneously. An intriguing display showing shutting thermoregulation (see Regal 1980:83 for another view) but we never got around to doing it.

Reproduction and behavior of the Green Crested Basilisk (Basiliscus plumifrons) were described by Pawley (1972) at Brookfield Zoo, Blake and Stewart (1980) at Edinburgh Zoo, Olexa (1976) at Prague Zoo, and Banks (1983) at Melbourne Zoo. Kuppert (2013) recorded head bob displays at National Zoo. Stunkard and Gandal (1966) identified a digenetic tetradome, Parahaplometroides basiliscae from the mouth of a basilisk at New York Zoological Park. At Dallas Zoo, a mixed exhibit of Common Basilisks (Basiliscus basiliscus), Western Basilisks (B. galeritus), and Brown Basilisks (B. vitatus) were visible to the visitor.
Fig. 6. The Fiji Island Iguana (*Brachylophus fasciatus*) here pictured in “Proceedings of Scientific Meetings of the London Zoological Society” is certainly impressive but it is at risk due to human factors. The San Diego Zoo is playing a significant role in developing captive assurance colonies.

Fig. 7. Illustration of Common Monkey Lizard (top right) (*Polychrus marmoratus*) by H. R. Schinz (1833), *Naturgeschichte und Abbildungen der Reptilien*. I saw one in the wild in Guyana and it was virtually invisible in a bush. It remained immobile when I reached for it and only moved when I grasped it.

Fig. 8. Illustration of Baja California Rock Lizard (*Petrosaurus thalassinus*) and Banded Rock Lizard (*P. mearnsi*). An interesting exhibit using these lizards could be developed to show shuttling thermoregulation. See text.
Fig. 9. There are beautiful images in "Proceedings of Scientific Meetings of the London Zoological Society" between 1861–1929. An adult male Frilled Lizard (Chlamydosaurus kingi) from Australia flared its frill with open mouth, stood bipedally, made a series of grunts and rushed toward the keeper at Dallas Zoo. New employees found this display to be unsettling when witnessed the first time and, of course, were never forewarned by their perverse co-workers.

Fig. 10. Illustration of Bearded Dragon (Pogona barbata) in Baron Georges Cuvier's *Le règne animal...*, published in 1836–1839. This lizard is hardy in captivity and is highly variable in color.

Fig. 11. Illustration of Egyptian Spiny-tailed Lizard (Uromastyx aegyptius) in Baron Georges Cuvier's *Le règne animal...*, published in 1836–9. The Oklahoma City Zoo was successful at keeping members of this genus in large enclosures with a sandy substrate and high temperatures.

Fig. 12. A small group of Common Flying Lizards (Draco volans) was kept at Dallas Zoo where males regularly displayed to each other by extending dewlaps and partially extending wings, and bobbing the body. This illustration represents a different species (D. lineatus) but is included to show the head and body of this unique lizard. Publications of London Zoological Society between 1860–1921 had beautiful lizard illustrations such as Flying Lizards (Draco). To see a complete list of all amphibians and reptiles, consult *Transactions of the Zoological Society of London: an index to the artists, 1835–1936*, compiled by Nina J. Root and Bryan R. Johnson, and *Proceedings of the Zoological Society of London: an index to the artists, 1848–1900*, compiled by Nina J. Root and Bryan R. Johnson (1986).
when entering the reptile building. The enclosure was large and high; the lizards were active, climbing branches and the rock façade. At Dallas Zoo, a number of beautiful *Sceloporus* were kept over the years: Adler's Spiny Lizard (*S. adleri*), Yarrow's Spiny Lizard (*S. jarrovii*), Mexican Emerald Spiny Lizard (*S. formosus*), Blue Spiny Lizard (*S. serrifer cyanogenys*), Crevice Swift (*S. torquatus*), Crevice Spiny Lizard (*S. poinsettii*), and Eastern Fence Lizard (*S. undulatus*). Brasfield et al. (2008) examined reproductive and thyroid hormone profiles after a period of brumation and Rich and Talent (2008) recorded the effects of prey species on food conversion efficiency and growth in the Western Fence Lizard (*S. occidentalis*). The Coachella Valley Fringe-toed Lizard (*Uma inornata*) and Colorado Desert Fringe-toed Lizard (*U. notata*) were maintained in a large outdoor exhibit with an extensive sandy area. The lizards were removed to an indoor holding area in the winter. Foster et al. (2015) maintained and reproduced the Yuman Fringe-toed Lizard (*U. rufopunctatus*) at Phoenix Zoo. In central Texas, semi-arid places with limestone ledges and slabs called Texas holey rock (popular in cichlid aquaria) have the most beautiful male Eastern Collared Lizards (*Crotaphytus collaris*) which were kept on display at Dallas Zoo. The Reticulated Collared Lizard (*C. reticulatus*) from the Rio Grande Valley in south Texas was also exhibited. Both species fed well on small lizards (*Uta, Urosaurus, Sceloporus*) and insects. I was surprised when a cage mate (*Sceloporus serrifer cyanogenys*) larger than the Eastern Collared Lizard had been killed and swallowed, later to be regurgitated after being partially digested. This predaceous saurian reminded me of a miniature *Tyranosaurus rex*.

In 1890 and 1897, three specimens of Ditmars' Horned Lizard (*Phrynosoma ditmarsi*) were collected somewhere near the United States–Mexican border but the site was not recorded. The first lizard was deposited in the collection of the American Museum of Natural History in New York. The second and third specimens were donated to Raymond L. Ditmars who was able to observe one for about a year until it died (Ditmars 1951). Both were preserved and sent to Leonhard Stejneger at United States National Museum in Washington, DC. Stejneger described the lizard in honor of Ditmars (Stejneger 1906). No additional specimens were found alive until 1970. In a brilliant plan to discover the lizards’ location, two of the preserved lizards’ stomachs were examined, and insect remnants, plant fragments, and small pebbles were saved and sent to specialists for identification and a possible locale was pinpointed, based on known distributions of these animal, vegetable, and mineral clues. With this additional information, Ditmars’ Horned Lizard was rediscovered. To pursue this amazing story, consult Ditmars (1951), Roth (1971, 1997), Lowe et al. (1971), Montanucci (1989), and Sherbrooke et al. (1998). Montanucci (1984, 1989) outlined breeding, captive management and Densmore et al. (1994) described a molecular husbandry. At Metro Toronto Zoo, Barker and Cranfield (1988/1989) identified *Schellackia* (*Lainsonia*) sp. in chuckwallas. Aucone et al. (2003) compared two artificial ultraviolet light sources used for Chuckwalla (*S. obesus*, now *S. ater*) husbandry.

Gamble et al. (1996) investigated plasma Itraconazole pharmacokinetics in spiny lizards (*Sceloporus* spp.) at Dallas Zoo. A number of spiny lizards, chuckwallas, and other southwestern U.S. desert lizards were kept in a large outdoor exhibit with a sizeable hibernaculum and rocky crevices. The herbivorous chuckwallas were fed fruits and vegetables in large metal trays, attracting a number of hymenopterans. Granite Spiny Lizards (*S. orcutti*) would congregate around the trays, carefully snatch the insects at mid-body and immediately and violently bang them against the rocks. I watched hundreds of feeding episodes and as far as I could tell, no lizard was ever stung. Keeper Mark Doles studied maternal care in this colony (Doles 1998). He asked two questions: how long would a female continue to rebury her nest if excavated and could she discriminate between her nest and another dummy hole nearby? Read his paper to answer both questions. A hint—females excavated multiple exploratory holes but abandoned all but one for oviposition.

Knight Anoles (*Anolis equestris*) at Dallas Zoo displayed to smaller anoles (*A. sagrei, A. carolinensis*) that were used as food. Instead of trying to flee from the larger lizards, the food anoles sometimes displayed head bobs, lateral compression, and dewlap extension. On rare occasions, they continued the display even while being swallowed. Rosenberg (1941) covered behavior and husbandry in *A. equestris* and *A. ricordii*. One of the most interesting anole exhibits showing their lifestyle was at Lincoln Park Zoo in Chicago during the 1950s where a large planted exhibit housed Brown and Green Anoles from Florida. This stately enclosure was reminiscent of a Victorian terrarium or Wardian fern case, viewable from all sides, with intricate and ornate ironwork and was the first display visible as one entered the reptile house. These lizards were very active: fighting, courting, ovipositing, hatching, and feeding. One day at Dallas Zoo, I felt a tremendous pain on my left earlobe as I was speaking on the telephone. One of my beloved employees had attached a large male *A. carolinensis* to the lobe and it insisted on hanging on for some minutes. My gentle nature toward my co-workers was seriously challenged.

In my view, the most productive zoo scientist studying iguanid lizards is Allison Alberts, Chief Conservation and Research Officer for San Diego Zoo Global. She is the co-founder and past co-chair of IUCN Iguana Specialist Group and president of International Iguana Foundation. She has studied endangered iguanas in Cuba, Costa Rica, Turks and Caicos Islands, Fiji, and also Komodo Dragons. To prove my point, consult the bibliography at the end of this paper.

*Family Agamidae.—*Murphy et al. (1978) observed defensive behavior in the Angle-headed Dragon (*Gonocephalus dilophus*, now *Hysilurus dilophus*) at Dallas Zoo. This spectacular adult lizard emitted a series of grunts and hissing sounds as it leaped bipedally toward an intruder. Specialized motor patterns included lateral presentation with open mouth, tongue rolled forward, gular sac expanded, sidehopping, tail lashing, and color change. An adult male Frilled Lizard (*Chlamydosaurus kingii*) from Australia flared its frill, stood bipedally, made a series of grunts and rushed toward the keeper at this Zoo (Fig. 9). In 2004, nine Javan Humped-headed Lizards (= Chameleon Forest Dragon, *Gonocephalus chamaeleontinus*) hatched at Denver Zoo.

Almandarz (1969) placed Bearded Dragon (*Amphibolurus barbatus*) eggs in a portable baby incubator and seven hatched at Lincoln Park Zoo (Fig. 10). Van Aperen (1969) bred them at the Melbourne Zoo. Sherriff (1989) outlined the maintenance and breeding of the Inland Bearded Dragon (*Pogona vitticeps*) at Edinburgh Zoo. Morley (1992) bred the Nobbi (*Amphibolurus barbatus*).
Dallas Zoo in the 1970s, two Sri Lankan lizards were displayed: Mountain Horned Iguana (*Ceratophora stoddartii*) and Sri Lanka Horned Agama (*C. aspera*). At the same time at Fort Worth Zoo, a spectacular adult pair of Lyre-headed Lizards (*Lyriocephalus scutatus*) was exhibited in a large planted enclosure.


Coburn (1975) described post-mortem removal and artificial hatching of Rainbow Lizard eggs (*Agama agama*) at the Cotswold Wildlife Park, Oxfordshire UK. A small group of Common Flying Lizards (*Draco volans*) was kept in a large planted exhibit at Dallas Zoo where they lived for several years (Fig. 12). Males regularly displayed to each other by extending dewlaps and partially extending wings, and bobbing the body but I never saw them lock jaws or bite each other. Some ant colonies lived in the enclosure and were intermittently picked off by the lizards.

**Family Chamaeleonidae**—Most chameleons have been difficult to keep for extended periods in captivity (Fig. 13). In 1818, the Menagerie of the Imperial Cabinet (Vienna) had chameleons from North Africa and eggs were laid in 1845 but did not hatch. The menagerie received many chameleons as gifts from various sources between 1818–1851. Duméril (1854–1855) found that captive chameleons fared poorly between 1851 and 1855 at the Menagerie Jardin des Plantes, Paris for although more than 160 were kept, none lived more than 13 months. Females often died from reproductive complications—no eggs were ever hatched. See Andreone et al. (2005), Andrews (2005, 2008), Andrews and Donoghue (2004), Andrews et al. (2004), Andrews et al. (2008), Ferguson et al. (2003, 2007), Karsten et al. (2008, 2009) for recent success stories.

Johann von Fischer was the first to document copulatory behavior and reproduction in Common Chameleons (*Chamaeleo vulgaris*, now *C. chamaeleon*) in 1882 and 1884 (see Murphy 2005 for English translation; Fig. 14). He attempted to incubate nearly 800 eggs but most never hatched. The first Veiled Chameleon (*Chamaeleo calyptratus*) obtained by the London Zoo was caught in Aden, South Yemen, on 15 March 1885 and donated on 3 June 1885 by Lt.-Col. J. W. Yerbury (Coote 2001). Sarah Kuppert (2013) described color changes during courtship in this species at Smithsonian National Zoological Park (SNZP) (Fig. 15). Gary Ferguson and colleagues published a book on care of Parson’s, Panther, Veiled, and Jackson’s Chameleons in 2007.

At the now-defunct Belle Vue Zoo in England (see Bennett and Barnaby 1989 for this sad story), average longevity for 24 chameleons between the years 1898–1901 was slightly over three months and none survived for one year (Flower 1925). Raymond L. Ditmars had problems with chameleons which rarely survived longer than five or six months (Ditmars 1933). Flower (1925) found that chameleons rarely lived one year in captivity. An exception was the South African Dwarf Chameleon (*Bradytopodion pumilum*) which have live young. In 55 years, only 15 chameleons of many species out of nearly 770 survived over one year, a rather depressing situation. By 1928, sixteen different species of chameleons had been exhibited alive in London but mortality...
rates were high. At the Giza Zoological Gardens in Egypt where Flower was director, 200 chameleons were maintained at the zoo between 1898–1924 but none lived for as long as four years.

See Ferguson et al. (2004) for color variation, natural history, conservation, and captive management of the Malagasy Panther Chameleon (Furcifer pardalis). This work included reproductive and nutritional data on five captive generations at Texas Christian University; an overall history of chameleons in captivity was included. Gary Ferguson has worked in a zoo setting for many years to investigate the captive biology of chameleons (Ferguson 1994; Ferguson et al. 1993, 1996, 2004). Early on when he brought his herpetology class to Dallas Zoo for the annual visit I asked him if he had ever seen a living chameleon. He replied no, which he said was saddening for an avid lizard ecologist. Luckily, we had a female Jackson’s Chameleon (Trioceros jacksonii) that had recently given birth and the neonates were being maintained outside in a large screened cage. When he viewed these tiny lizards—going into I would characterize as a catatonic state, staring motionless on his haunches with no perceptible movement—I knew he was doomed. I offered some to keep in his lab in Fort Worth and he jumped at the opportunity—the rest is history!

These young Jackson’s Chameleons were inaccurate at first as they tried to catch live crickets, often missing wide right or left. Occasionally, the tongue tip stuck firmly to the cage so the chameleon had to walk to the tip to reel in the tongue. The adults were kept in a large planted enclosure that covered the entire lobby of the reptile building at Dallas Zoo. Some of the trees were over 20 feet (6 m) high. When new males were first put into the enclosure, they spotted each other immediately and quickly moved toward each other to engage in male-male combat (Kommentkampf). After the struggle, the dominant chased the subdominant around the entire enclosure and eventually drove it to the very top of the highest tree. As the dominant lizard came closer, the loser released its grip, fell to the substrate, and quickly dashed away. We tested this multiple times with a series of males and the outcome was always the same; no loser suffered injuries. Females did not flee but rejected male advances by opening mouths, lateral body compression, color change, and rocking back-and-forth.

On the floor of this exhibit, a number of large Ficus trees were placed—each with a single chameleon—and encircled with a sheet metal barrier at the base to keep the lizards separated as these highly territorial lizards were incompatible. Daily feeding demonstrations were held and were exceedingly popular with visitors. Occasionally, sarcophagid fly larvae would be missed by the chameleons and would escape into the flower pots whereupon these insects hatched in the exhibit and were later plucked off by the lizards. One day, a fly landed on the inside of the glass at an adult human’s eye level and a visitor witnessed the chameleon tongue up front and personal. She emitted a scream rivaling the decibel level of a jet plane and fell backwards into the crowd, taking a few small children to the floor with her.

Gary Ferguson, Rick Hudson from Fort Worth Zoo, and I traveled to Kenya to collect specimens for Texas zoos and preserve a series of Jackson’s Chameleons for a description of what became a new taxon, now Triceros jacksonii xantholopus Eason, Ferguson, Hebrard 1988 (see Ferguson et al. 1991). We were hosted by Nairobi Natural History Museum, which includes a snake park. Chameleons were regularly collected as food for mambas and boomslangs living in a large pit. Jim Hebrard, then in the zoology department at University of Nairobi, kindly allowed us to stay at his apartment in the city but the space was so packed with other herpetologists—Butch Brodie, Ron Nussbaum, Tom Madsen, Ken Dodd, and a couple of other persons—that the living quarters were mindful of a homeless shelter. Gary, Rick, and I spent much time collecting on Mt. Kenya. Gary brought along some tree-climbing equipment to scale trees but the first trial was less than impressive—he ascended about six feet, lost his balance, and fell to the ground. The equipment remained unused for the rest of the trip. We hired local villagers to help collect for us but virtually all were terrified of chameleons, believing that the lizard’s sharp claws were deadly poisonous. They were clearly conflicted, a few Kenyan shillings per lizard versus instantaneous death. Only one person actually held a chameleon—all of the others carried these saurians on the end of very long branches, both holding on for dear life. The villagers were stunned when we allowed these creatures to crawl on us—women screaming and children running away at full speed. One surprising and unexpected fact was the...
High-casqued Chameleons (Trioceros hoehnelii) were spaced about 3 m (10 ft) apart within juniper bushes and hedge-rows at the vet station a few miles out of town and the bongo acclimation center at the base of Mt. Kenya. Jackson’s Chameleons were usually found higher in trees, especially at night, and several males might be found in the same tree. An exciting followup to our research in the 1980s was recently published by Jan Stipala. He has found two additional clades on the west side of Mount Kenya and at higher elevations than where we looked.

Studying chameleons in Africa is unique. One night we were using flashlights and headlamps to spot chameleons since when sleeping they become much lighter in color and stand out against the vegetation. As we walked on the trail, we could hear large mammals crashing through the bush. A Tree Hyrax suddenly emitted a call that was blood-curdling and nearly caused cardiac arrest for all of us. At that moment, we realized that this was our first field experience where we potentially could be killed and eaten by animals and so we decided to retire from collecting at night in dangerous settings. When we reached the lodge for a few drinks, elephants, cape buffalos, rhinos, wart hogs, and other mega-mammals were gathered around a pool illuminated at night for the tourists, and a leopard ran in front of our car as we left. Returning to our small hut for another well-needed drink on the patio after a starry night of chameleon stalking, a group of hyenas encircled us and they were much too close; we decided to retire earlier than planned. What was interesting was these predators were absolutely silent in their approach and we only knew of their presence when we turned on a flashlight and spotted eye-shine.

Brodie and Nussbaum were studying caecilians (Afrocaecilia = Boulegengerula taitana) in the Taita Hills near Nairobi and suggested that we enlist the villagers to help with collecting because they were not afraid of chameleons but rather viewed these lizards as a source of income. When we arrived at the village, adults and children rushed the car and gave us a verbal price list using scientific names, reproductive condition, health, and sizes; for example, a gravid female Böhme’s Two-horned Chameleon (Kin-yago boehmei) was a steal at two Kenyan shillings. Soon, we were inundated with hundreds of herps, made our choices and purchased them, and were frantic to leave since the locals insisted that we buy all of the remaining ones. As we left the village, people ran after the car and threw more animals through the open windows on us, free of charge! Once we were out of sight, these animals were released.

The introduced Hawaiian stock of Jackson’s Chameleon was definitely Chamaeleo j. xantholophus, the taxon described by Ferguson and colleagues. At Dallas Zoo, chameleons from this place seemed to adapt more easily to captivity when compared to the Kenyan lizards. Perhaps one reason is the daily temperature fluctuation is much less dramatic in Hawaii. It was so cold at night on Mt. Kenya, we slept in our jackets inside of heavy sleeping bags.


Why do some chameleons do poorly in captivity? Here is a hint from a section in one of my earlier papers (Murphy 2009): “A new challenge is the recent study by Karsten and associates which explains why some imported animals could probably never have been successfully kept in captivity for extended periods. They found that Labord’s Chameleon (Furcifer labordi), from arid southwestern Madagascar, is an “annual” lizard living mostly as an egg for about nine months and then only four or five months outside the egg. These lizards reach sexual maturity in two months. This may mean that the brief life span of chameleons in captivity might, for some species, actually represent the natural adult life span. So questions are asked and suggestions given by the authors in their abstract: ‘Consequently, a new appraisal may be warranted concerning the viability of chameleon breeding programs, which could have special significance for...’
species of conservation concern. Additionally, because *E. labor-di* is closely related to other perennial species, this chameleon group may prove also to be especially well suited for comparative studies that focus on life history evolution and the ecological, genetic, and/or hormonal determinants of aging, longevity, and senescence.’ Flower’s statement about chameleons being short-lived reptiles written over 80 years ago was prophetic.”

Final thought: When Gary Ferguson and I traveled to Madagascar to do research for our books (2004, 2007), we spent one evening looking at a list of all chameleons in the country in order to predict the likely future for all of them. This was not a detailed scientific study but rather based on our observations in the field, discussions with colleagues, and literature. We concluded, much to our horror, that probably two-thirds were at serious risk of extinction and these were mostly taxa that lived in primary forest or fragile areas modified by humans. Weedy species such as the Panther Chameleons were common even in places with high human densities so they may well provide a starting point for a new chameleon radiation.

Infraorder Gekkota.—Dale Marcellini from National Zoo published several papers on acoustics, vocal and visual displays of geckos (1977, 1978). Demeter and Marcellini (1981) recorded courtship and aggressive behavior of the Streak Lizard (Gonatodes vittatus) at National Zoo. Heinrich Dathe (1942) recorded the birth of a Panther or Tokay Gecko (Gecko gecko) at Leipzig Zoo, Brodský (1969) at Prague Zoo, and Petzold (1963) bred this species at Berlin Tierpark. I witnessed a Tokay Gecko’s bit- ing power in person as I watched the San Antonio Zoo’s curator pick one up whereupon it turned and bit him on the finger. The pressure was so great, the lizard’s eyes sank into their orbits. It held on for one hour and nothing was successful at dislodging it, including holding it under water, until it released my colleague, probably from boredom. Frolow (1981, 1987) outlined reproduction of the Skink Gecko (Teratoscincus scincus) in Moscow Zoo. As part of initial keeper training at Dallas Zoo, new employees were told to clean this gecko’s enclosure and the impressive defensive display was startling to all—we were accused of being sadists. Benefield et al. (1981) propagated Western Banded Geckos (Coleonyx variegatus) at Tulsa Zoo. From the Houston Zoo, Neitman (1983) described captive hatchling of the tuberculate geckos of the genus Coleonyx. Risley (1989) observed breeding of the Namib Gecko (Chondrodactylus angulifer) at London Zoo. Astreiko and Popovskaya (1999) from Tula Exotarium in Russia investigated the potential of breeding and raising the African Fat-tailed Gecko (Hemithoneyx caudicinctus) under laboratory conditions. At Dallas Zoo, we kept the Namib Sand Gecko (Pachydactylus rangei) and a group of Flying Geckos (Psychosoon kuhli; Fig. 16). Both taxa did well in captivity. We also maintained several Cayman Island geckos with the strange standard name of Woodslave (Aristelliger praesignis) in the family Sphaerodactylidae. We displayed the lovely Marbled Bow-fingered Gecko (Cyr todactylus marmoratus) from Peninsular Malaysia, Marbled Velvet Gecko (Oedura marmorata) from Australia, and Walberg’s Gecko (Homopholis walbergii) from Africa.

Several papers on the long-term Madagascar Giant Day Gecko (*Phelsuma madagascariensis*) colony at National Zoo have been published by Béla Demeter and colleagues (1976, 1994). Bloxam and Townson (1980), Bloxam and Vokins (1978), Langebaek (1979), Wheler and Fa (1995) and Cooper et al. (1998) described breeding, research, and medical management at Jersey Zoo. Bloxam and Townson (1980), Bloxam and Vokins (1978), Langebaek (1979), Wheler and Fa (1995) and Cooper et al. (1998) described breeding, research, and medical management at Jersey Zoo. Demeter and colleagues (1976, 1994) under laboratory conditions. At Dallas Zoo, we kept the Namib Sand Gecko (*Coleonyx variegatus*) at Tulsa Zoo. From the Houston Zoo, Neitman (1983) described captive hatchling of the tuberculate geckos of the genus *Coleonyx*. Risley (1989) observed breeding of the Namib Gecko (*Chondrodactylus angulifer*) at London Zoo. Astreiko and Popovskaya (1999) from Tula Exotarium in Russia investigated the potential of breeding and raising the African Fat-tailed Gecko (*Hemithoneyx caudicinctus*) under laboratory conditions. At Dallas Zoo, we kept the Namib Sand Gecko (*Pachydactylus rangei*) and a group of Flying Geckos (*Psychosoon kuhli*; Fig. 16). Both taxa did well in captivity. We also maintained several Cayman Island geckos with the strange standard name of Woodslave (*Aristelliger praesignis*) in the family Sphaerodactylidae. We displayed the lovely Marbled Bow-fingered Gecko (*Cyr todactylus marmoratus*) from Peninsular Malaysia, Marbled Velvet Gecko (*Oedura marmorata*) from Australia, and Walberg’s Gecko (*Homopholis walbergii*) from Africa.


Leopard Geckos (*Eublepharis macularius*) are so prolific in captivity, one could consider them a laboratory animal (see Thorogood and Whimster 1979; de Vosjoli et al. 2005). Author Philippe de Vosjoli considers this species to be the first domesticated lizard, like goldfish and parakeets. An array of color and
pattern morphs are now available on dealers’ pricelists—a pair of amelanotic lizards was being offered for US $1000 each. Ernie Wagner from Seattle Zoo wrote an interesting and important paper in 1980 showing skewed sex ratios based on egg incubation temperatures. See also his other papers (1974, 1979).

Kaverkin et al. (1994) described husbandry and reproduction of a eublepharid gecko, *Goniurosaurus kuroiwa splendens*, at Moscow Zoo. We kept the African Fat-tailed Gecko in the late 1960s at Dallas Zoo, which has now become a staple with herpetoculturists. One of the most spectacular eublepharids at Dallas Zoo was the Cat Gecko (*Aeluroscalabotes felinus*). A small group was kept in a cool room ca. 72°F (22°C) ambient temperature with a damp paper towel substrate. These lizards were very secretive and could not be placed on exhibit. As they grew, they all regularly pulled off skin with their mouths and swallowed it.

Some of the rarest geckos in zoo collections are any of the eight species of the genus *Naultinus* from New Zealand. There was a colony of eleven male and ten female Green Tree Geckos (*N. elegans*) at the National Zoo maintained by Béla Demeter and colleagues. These geckos were wild-caught and sent by Auckland Zoo in 1985. All of these smallish lizards in the genus are spectacularly colored and relatively easy to maintain in captivity, much like day geckos. All of the *Naultinus* survived over a minimum of several years. The National Zoo specimens were kept as groups of four in cages measuring ca. 3 ft × 3 × ² ft (1 m × 1 m × 0.6 m) with an ambient temperature of 72°F (22°C) and a small lamp provided as a thermal gradient. No courtship was observed so the lizards were watched throughout the night for two consecutive days to see if things improved—they did not and no reproduction occurred. Many examples are pictured in Sharel (1966).

One of my most exciting experiences was seeing the New Caledonian Giant Gecko (*Rhacodactylus leachianus*) at the Zürich Zoo for the first time in 1969. Curator René Honegger pulled a huge tame one from its enclosure and it rested quietly on his arm. I was truly thunderstruck. I vowed that we must have this species in Dallas so when a pair became available from a dealer for a princely sum, we jumped at the chance. I called gecko expert and Villanova University professor Aaron Bauer and asked for recommendations as to how to maintain this taxon successfully. He provided relevant environmental data and suggested cage furniture such as vertical tree limbs for a large display. Soon the geckos began to lay eggs, which we incubated at ca. 80°F (26°C). At least 60 hatched but all were males, suggesting Temperature Dependent Sex Determination. The adults vocalized when threatened, a deep guttural croaking noise. I long to see a living example of the world’s largest gecko, named Kawekaweaue (*Hoplodactylus delcouri*) of Maori legend, the presumably extinct giant from New Zealand (Bauer and Russell 1986). The type specimen was found in the basement of the Marseille Museum of Natural History, unlabeled and likely there for over a century. What was intriguing was this lizard was 54% larger than *R. leachianus*—about two feet long and thick as a man’s wrist. What an awesome display that creature would make! I tried to convince my bosses to fund a collecting trip to try and find this gecko but I was summarily dismissed as a lunatic, who had taken complete leave of his senses.

At Dallas Zoo, we kept two pygopodids: Burton’s Legless Lizard (*Lialis burtonis*) and Common Scaly-foot (*Pygopus lepidopus*) (Fig. 18). We fed anoles, geckos, and skinks to the *Lialis* and I was constantly amazed by the cranial kinesis that allowed the jaws to wrap around the prey in the thoracic region to prevent breathing—this flexibility was very efficient in causing death. Banks et al. (1999) managed and bred the Striped Legless Lizard (*Delma impar*) at Melbourne Zoo.

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**Literature Cited**


