# Effects of Environmental Enrichment on the Behavioral and Cognitive Development of Captive Black Throated Monitor Lizards (*Varanus albigularis*)

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While it is generally accepted that stimulus enrichment plays an important role in the behavioral and physical health of mammals, significantly less attention has been focused on non-avian reptiles, especially in relationship to cognitive development. The Dallas Zoo, in conjunction with the University of Tennessee, studied the effects of environmental enrichment on the behavioral and cognitive development of a group of captive Black-throated monitor lizards, *Varanus albigularis*. Analysis is continuing on the behavioral tests of a group of monitors reared in enriched, rather than standard, environments. The former contained more structure, the animals were fed live rather than dead prey, and they were given novel objects, problems, and social stimuli. Clutchmates reared in standard environments were compared with those in enriched environments and tentative results show that the latter had larger forebrain growth. The effects of habituation and individual differences in response to object introductions and performance tasks will allow further understanding of learning processes in monitors.

The project goals include:

1) Determine if environmental enrichment has an effect on behavioral development of captive monitor lizards.

2) Determine if environmental enrichment has an effect on the cognitive development of captive monitor lizards.

3) Shed light on the learning processes of monitor lizards.

# Restoring Vitamin D in Monitor Lizards: Are Dietary and UVB Sources Equivalent?

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**Project Background**

Vitamin D is an essential nutrient involved in the regulation of calcium and phosphorous in the vertebrate body. Vitamin D-deficiency and pathology related to that condition (e.g. nutritional metabolic bone disease, reproductive failure) can be improved in many vertebrates by increasing vitamin D from two sources: dietary supplementation of vitamin D and UVB-mediated endogenous synthesis of vitamin D. However, the natural importance and relative efficiency of these two sources of vitamin D remain largely unknown.

Research so far has suggested considerable variation among species in the importance of the two sources. Species with naturally high levels of vitamin D in their diet, such as cats, dogs, and polar bears, appear unable to endogenously produce vitamin D from UVB exposure. By contrast, insectivorous and herbivorous lizards with naturally low levels of vitamin D in their diet appear to use mainly the UVB-mediated endogenous source. Preliminary information on herbivorous green iguanas from research by Mary Allen and her colleagues suggests that the dietary route is not only less efficient, but insufficient to maintain proper vitamin D-condition without massive dietary doses likely to cause vitamin D toxicity.

Furthermore, some lizards, such as the Panther chameleon, have been shown by us to voluntarily adjust their exposure to UVB in a gradient depending on their internal vitamin D condition. They appear able to photoregulate their vitamin D condition. Given the lack of knowledge of vitamin D requirements from species to species, it has been suggested for species with this ability that UVB may be a better vitamin D source in captive husbandry than dietary sources, allowing the animal to self-regulate its vitamin D levels. However, knowledge of which species are able to self-regulate is lacking.

Vitamin $D_3$ incorporated from the diet or produced endogenously rapidly enters the blood circulation.

From a previous study by Mary Allen and colleagues, a single large oral dose of vitamin $D_3$ (10 IU/g) in vitamin D-deficient iguanas resulted in a peak concentration in blood in about 24 hours. It was then rapidly converted to 25-hydroxovitamin $D_3$ (calcidiol) in the liver, peaking within 7 days in the blood circulation. Vitamin $D_3$ dropped to near-baseline levels by day 14. Calcidiol returned to deficient levels by day 35. Calcidiol is the most abundant form of vitamin $D_3$ in the body and its blood-levels are considered the best measure of vitamin D-condition. Vitamin $D_3$ and calcidiol are relatively inert biologically. However, the latter is converted as needed to 1,25-hydroxyvitamin D (calcitriol), its hormonally active form, by the kidney.

Our current study is investigating the importance of both sources of vitamin D (dietary and UVB-generated) for restoring and maintaining vitamin D-condition in the Black-throated monitor *Varanus albigularis*. Data will reveal the relative efficiency of the two sources over an extended period. Information from this study will provide background for studying the attractiveness of a UVB source to the lizards and their ability to regulate their vitamin D-condition through basking. Results will provide valuable insight into the captive-management of this and related species regarding calcium/phosphorus balance.

**Summary of Methods and Experimental Design**

Sixteen captive-hatched monitors were raised at the Dallas and Fort Worth Zoos for approximately 2 years, rendering them safe for serial bleeding. Raised and housed individually, their diet and lighting regimens were modified. All sources of dietary vitamin $D_3$ and UVB were removed from their environment. Serum levels of calcidiol were monitored until a significant drop was recorded. Then each individual was given a single dose of either vitamin $D_3$ or UVB. Dose levels were arbitrarily chosen and "bracketed" (varied around the estimated mean) based on levels previously suggested to be adequate for maintaining good vitamin D-condition in herbivorous green iguanas and panther chameleons. Circulating calcidiol levels were monitored at specific time intervals after the single dose to assess changes in level. Based on an observed "post-dose spike" of calcidiol level, weekly doses were begun and maintained for 90 days.

**Preliminary Results**

1) Deprivation of all sources of vitamin $D_3$ resulted in an average of 30% depletion of circulating calcidiol in approximately two months.

2) A single dose of dietary vitamin $D_3$ or UVB resulted in a significant peak of increase in calcidiol at an average of seven days with return to baseline in an average of 14 days.

**Planned study**

1) Statistical analyses will be completed to verify relative efficiency of two sources of vitamin D for restoring and maintaining circulating calcidiol levels.

2) Circulating vitamin $D_3$ levels will be analyzed to see how their patterns coordinate with those of calcidiol.

3) Circulating levels of calcium and phosphorus, as well as bone density, will be compared over the 90 day maintenance period to determine the relative efficiency of the two sources of vitamin $D_3$ for maintaining appropriate calcium/phosphorus balance and bone health.

4) Behavioral studies are planned with the current group of monitors to verify behavioral attraction to UVB. Future studies are being planned with additional juvenile monitors to test their ability to regulate vitamin D-condition via voluntary modification of UVB exposure.

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