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ROUNDTABLE

Ultraviolet Light and Reptiles, Amphibians

Ultraviolet lighting is integral for the growth and maintenance of many reptile and amphibian species. But providing an adequate source of light can be challenging. Many disease processes seen by veterinarians are attributed to ultraviolet lighting deficiencies. In mammals, disease due to excess ultraviolet lighting has been noted, and some veterinarians feel this may be a potential issue in reptiles and amphibians.

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1). What is ultraviolet light?

Driggers: Ultraviolet light is a band of electromagnetic energy between 200 and 400 nm. It is an invisible form of light, which unknowingly and profoundly affects many animal species in both physiological and psychological ways.

Gehrmann/Ferguson: Based on explanations from Cromer (1994) and Endler (1990) we paraphrase as follows. Ultraviolet light is a form of electromagnetic radiation adjacent to one side of what is commonly called the visible spectrum based on human perceptual acuity. It may be described as either waves or particles called photons. The various waves are characterized by either wavelength or frequency. Lighting engineers prefer to work with the wave model, while photobiologists, working with processes such as photosynthesis or vision, prefer to work with the photon model. Waves may be quantified as irradiance or power density (watts per area), or energy per time (dose, i.e. joules per second per area). Photons can be quantified as photon flux or photon irradiance (mols of photons/sec/area/nm) for any given wavelength. Photons differ by the amount of energy they carry, which is wavelength-dependent.

Gyimesi: Ultraviolet light is radiation just beyond the violet end of the visible spectrum. UV radiation is the spectrum extending from 100 - 400 nm, which made up of shorter wavelengths than visible light (400 - 700 nm) and infrared radiation (700 - 3,200 nm).

2). What are the different spectrums of ultraviolet light?

Driggers: The three bandwidths of ultraviolet within the UV spectrum are UVA, UVB, and UVC. UVA is from 320 -400 nm. UVB is from 290 - 320 nm. UVC is from 100 - 290 nm.

Gehrmann/Ferguson: Ultraviolet light is generally divided into three regions of the light spectral distribution. The wavelength cutoffs between the categories are not consistently reported, but the International Commission on Illumination (CIE)-approved ranges are as follows (Angelo, 2002). Long wavelength UV is called UVA and ranges from 400 to 315 nm. Medium wavelength UV is called UVB and ranges from 280 to 315 nm. Short wavelength UV is called UVC and ranges from 280 to 100 nm. Because 290 nm wavelengths are the shortest to naturally reach the earth's surface, it is often reported as the lower limit for UVB by some researchers (Gehrmann, 1994A, Ullrey and Bernard, 1999).

Gyimesi: Ultraviolet light is subdivided into three distinct bands. UVC, from 100 - 280 nm, is normally filtered by the earth's atmosphere. UVB, between 280 - 315 nm, and UVA, between 315 - 400 nm reach the earth and are an integral component of natural light.

3). Why is ultraviolet light important for reptiles?

Driggers: It plays a role in calcium metabolism through an apparent vitamin D3 precursor. It plays a role in photoperiod regulations. Reptiles from the equator region typically have a more consistent ability to be exposed to UV with 12 hr of light exposure year around. Photoperiods have profound reproductive influences on reproduction and behavior.

Gehrmann/Ferguson: UVC is unavailable to reptiles in nature, because it is absorbed in the stratosphere by the ozone layer. It is damaging to animal tissue and its only beneficial use from artificial sources is as a disinfectant, rapidly killing

potentially pathogenic microorganisms in a cage or environment when the reptile is temporarily removed. It can cause photobiosynthesis of vitamin D3 (MacLaughlin, *et al,* 1982), but the detrimental effects far outweigh this beneficial effect.

UVB is available in nature to amphibians and reptiles and has both detrimental and beneficial effects. Documented detrimental effects on vertebrates include tissue damage, potentially causing death, and vitamins A and D degradation (Kiesecker and Blaustein, 1995, Blaustein, *et al,* 1996, Tang, *et al,* 1994, Webb, *et al,* 1989, Remenyek *et al,* 1999). The detrimental effects for amphibians are currently being emphasized by researchers and are assigned an important role in the decline of amphibian populations (Blaustein, *et al,* 1995). To our knowledge such effects on natural reptile populations have not been documented. The beneficial effects of UVB include primarily its role in the photobiosynthesis of vitamin D3 (Holick, *et al,* 1995, Ferguson, *et al,* 2003), which ironically it can also degrade (Webb, *et al,* 1989), and possibly the disinfecting of pathogenic external parasites from a reptile's skin (Pritchard and Greenhood, 1968). UVB may be visible to some lizards, and its perception useful for vitamin D photoregulation (Ferguson, *et al,* 2003).

UVA definitely can be visually perceived by some lizards and plays a role in social communication (Alberts, 1989, Fleishman, *et al,* 1993). UVA, when reflected from a reptile's surface, can also be potentially detected by avian predators (Bennett and Cuthill, 1994). Accordingly, UVA has been documented to be beneficial for social communication but may be detrimental regarding predator detection. UVA can cause degradation of vitamin A in the skin (Tang, *et al,* 1994), which could lead to vitamin A deficiency.

Gyimesi: Providing ectotherms with a source of ultraviolet light mimics nature. So just as herpetoculturalists attempt to provide a species with a diet and thermal gradient that is consistent with its natural history, it seems appropriate to also provide ultraviolet light. The fact that many reptiles have been documented seeking out UV light sources suggests it is important to their well-being. UVB light is responsible for the cutaneous conversion of 7-dehydrocholesterol to pre-vitamin D3 in many species. This photobiogenesis of vitamin D3 is important in many animals for absorption and homeostasis of calcium. There is wide variation in which species rely on UV light for vitamin D3 synthesis and which get most of their vitamin D3 orally via diet. UVA light appears to have influence on psychology and behavior. In some species, UVA light has been shown to initiate and maintain normal agonistic, reproductive, and signaling behaviors (Gehrmann, 1994A). Anecdotally, UV light has been reported to act as an appetite stimulant in reluctant feeders and may aid in prey recognition in some species. Failure to provide UV lighting may act as a chronic stressor in some captive ectotherms and may contribute to maladaptation and immunosuppression. There are reports of some species becoming more active and vigorous after exposure to UV light. Subjectively, UV light exposure also seems to enhance natural colors. There are likely still unknown benefits that make UV light important to provide for captive ectotherms.

Ogle: Ultraviolet light is important for reptiles because of its beneficial impact on their physiological and psychological well being. Many reptiles respond to UV lighting by behaving more like they would in nature. Colors brighten, feeding increases, and reproductive behavior typically increases for many different kinds of reptiles when UV is added. Some species, once exposed to a good source of UV lighting have shown a marked aggressive or flighty tendency not apparent under previous indoor conditions without UV. Reptiles are generally healthier with exposure to UV lighting. For a successful management program in terms of keeping and breeding reptiles, UV lighting can be one of the most beneficial resources available.

Owens: After three decades with the fundamental knowledge that reptiles benefit from the presence of ultraviolet light, there remains insufficient experimental data regarding specific aspects of light and its absolute advantages to reptile health and welfare. However, the extensiveness and duration of captive reptile husbandry along with several key studies have supplied us with enough anecdotal and scientific insight to make certain assumptions concerning reptiles and the value of ultraviolet light. For instance, it is understood that both quantitative and qualitative aspects of light play a role in behavior and in the physiology of many taxa of reptiles and amphibians. Ultraviolet light, temperature, and photoperiod can influence reproductive cycles, metabolism, and appetite.

4. How are ultraviolet light levels measured or assessed?

Driggers: My practice has just purchased a UV meter that allows me to assess the UV intensity. The least expensive and qualitative way is to place a small piece of newspaper where the reptile basks for its ultraviolet. The paper usually turns a yellowish cast in two to three days if the bulb is producing enough unfiltered UV and is close enough distance from the basking area.

Gehrmann/Ferguson: UV irradiance can be measured by spectroradiometers, which generate spectral power distributions for the entire light spectrum resolved into narrow 1-2 nm bands (Bernard, 1995, Ullrey and Bernard 1999). Unfortunately, these instruments are very expensive (about $30,000) and are not portable. UV irradiance can also be measured by broadband radiometers that are dedicated to a portion of the entire light spectrum, such as UVA or UVB. These are much less expensive ($500 - $3,000), smaller and. much more portable (Gehrmann, 1987, Gehrmann, *et al,* in press). Their drawback is that their spectral resolution may be much broader (say about 30 nm for UVB meters) than that of a spectroradiometer (1-2 nm). So, for measuring the most effective part of the UVB range for vitamin D synthesis (295 + 3 nm, MacLaughlin, *et al,* 1982) the radiometer output will include too much of the spectrum and may not accurately reflect the biosynthetic potential of a UVB light source. Furthermore, some radiometers are manufactured for very specific light sources, such as artificial light generated from a monochromatic UVB lamp, which has comparatively little UVA and visible light. Thus, they may not be accurate for more complex light sources such as natural light or artificial light from a fluorescent tube. Light energy of different wavelengths, particularly infrared, may bleed into the detector and artificially elevate the reading. Even more troubling, the currently available UVB radiometers such as UVP Inc, Spectronics® Corp and Gigahertz-Optik® give different irradiance values from the same UVB light source. This is partly because of uncontrolled bleed-in of non-UVB light in some of the meters and for other reasons intrinsic to the translationof photon input into output peculiar to a given brand of radiometer (Angelo, 2002, Gugg-Helminger, 2002).

The solution to the latter problem is to standardize the readouts of the various brands of radiometer to an independent measure of vitamin D photobiosynthetic potential. An in-vitro model was developed by the Vitamin D, Skin and Bone Laboratory of Boston University Medical Center directed by Michael Holick (Lu, *et al,* 1992). This model consists of a boron-silicate ampoule containing an alcohol solution of 7-dehydrocholesterol or provitamin D, the precursor to vitamin D. Exposure of the ampoule to UVB causes conversion of provitamin D to previtamin D and vitamin D in proportion to the UVB irradiance. This model can serve as the independent measure to standardize the radiometers when exposed to a particular light source. Using these models we are currently attempting to standardize three popular radiometers mentioned above with several popular artificial UVB sources and the sun (Gehrmann, *et al,* in press).

Gyimesi: Radiometers are available that can be calibrated to measure certain wavelengths of UV light. UV output, or irradiance, is typically measured in microwatts/cm2. At this time, quality radiometers are likely cost-prohibitive for the average herpetoculturalist. An indirect method of assessing UVB sources is with the use of vitamin D conversion ampules. These ampules, containing 7-dehydrocholesterol, are an in vitro marker of biological activity and can be placed in exhibits where an animal might bask. During exposure to UVB light, the 7-dehydrocholesterol is converted to previtamin D3. The percentage of conversion, as determined in the laboratory, sheds light on the effectiveness of the UVB source and quality of the basking site.

5. What are the different sources of ultraviolet available for keeping reptiles?

Driggers: My typical recommendations are based upon both safety and effectiveness. I take into consideration what will do the most good and "above all do no harm." I typically use Reptisun® products by ZooMed® and use different strengths based upon the reptiles' closeness to the equator and known photo regulation practices in wild observations.

Gehrmann/Ferguson: The preferred source of UVA and UVB is the sun at temperate (late spring through early fall) or tropical latitudes (Chen, 1999). Unfortunately, this is difficult to provide for most captive reptiles, which must be kept indoors in many instances.

The most powerful artificial UVB source that can be obtained commercially is the fluorescent sunlamp. Sunlamps have even more photobiosynthetic potential (determined by exposure of in-vitro models) than natural sunlight (Ferguson, unpubl. data). Unfortunately, the strong UVB and measurable UVC generated by these bulbs can cause serious damage to both the reptile and keeper and are not recommended for general use in herpetoculture (Ferguson, *et al,* 2002).

Several weaker UVA and UVB-emitting fluorescent tubes, such as the Reptisun® 5.0, the ESU Reptile D Light®, and the Sylvania® BL350 blacklight are commercially available. These produce significant but not dangerously high UVB irradiation. While their relative photobiosynthetic potential is still under investigation, reports are accumulating of their ability to adequately sustain healthy vitamin D-condition in lizards (Bernard, 1995, Alien, *et al,* 1996, 1999, Ullrey and Bernard, 1999, Ferguson, *et al,* 2002, Aucone, *et al,* 2003).

Recently, some screw-base, self-ballasted mercury vapor lamps that simultaneously produce infrared heat and UV, such as the Westron® Active UVHeat and ZooMed Power Sun® UV have become available. While their relative photobiosynthetic potential is still under investigation, reports are accumulating of their ability to adequately sustain healthy vitamin D-condition in lizards (Aucone, *et al,* 2003).

Gyimesi: Exposure to the sun is the optimal way to provide UV light. There is no safer, simpler, or more effective substitute to direct, unfiltered sunlight. Natural UV exposure, even in the shade, can be substantial and greater than many UV bulbs on the market. In many climates, year-round access to the sun is not possible. In some species, this may not be required as vitamin D is stored in the body and can be slowly utilized during times the sun is unavailable. How long appropriate vitamin D levels exist in the body once UVB light is no longer available likely varies between species and may partially be dictated by diet. In Komodo dragons housed at the Louisville Zoo, 150 d of access to direct sunlight appeared to be sufficient to maintain normal circulating levels of the vitamin D metabolite, 25-hydroxyvitamin D, for the remaining year (Gyimesi and Burns, 2002). The UVA and UVB radiation that reaches the earth varies due to factors such as latitude, altitude, season, time of day, surface reflection, and cloud cover.

UV does not readily pass through standard glass or Plexiglas®, and is even partially filtered by fine wire mesh. Therefore putting a reptile in an aquarium next to a sunny window is not as effective as intended and may subject animals to dangerously high temperatures due to heat trapping. Typical window glass has been shown not to transmit wavelengths shorter than 334 nm (Ullrey and Bernard, 1999), which would allow some UVA transmission but no UVB. Better transmission is possible through certain UV-permeable acrylics. Windows and skylights made of these materials have been in use in some zoological parks as a means of bringing beneficial natural UV rays indoors. Unfortunately, these materials are not inexpensive and their UV-transmitting capabilities tend to decline over time. The proper placement of . these windows is critical to their effectiveness.

Artificial UV lights marketed as "full spectrum" are available and are often used when access to sun is not an option. One should be familiar with the UVB and UVA output of these lights before purchase. Although this information is often available through the bulb manufacturer, there are unbiased assessments available that compare UV outputs in several of the more common bulbs (Gehrmann, 1997). The UV output from these bulbs decreases over time, even though they may still produce visible light.

Ogle: There are several possibilities for increasing UV exposure for captive reptiles. The most common method used is full-spectrum fluorescent lighting. Incandescent mercury vapor bulbs have recently entered the market and are becoming very popular among zoos and private individuals due to their apparent benefits. These new mercury vapor bulbs produce heat as well as higher levels of UV than fluorescent. Mercury vapor bulbs appear to be the best choice for reptiles ranging from temperate, tropical, and desert habitats. Fluorescent bulbs are still the best choice for montane species where an additional heat source needs to be avoided. The ideal choice for exposing reptiles to UV is the tried and true method of putting the animals outside. Here at the Knoxville Zoo, we feel that most of our breeding successes with chelonians come from our ability to get most of them outside during the summer months.

Owens: While there are many products on the market billed as "full spectrum" or "reptile basking lights", there are very few that emit UVB light. Fluorescent bulbs have been manufactured for quite a few years that cater specifically to the needs of certain reptiles. There are other companies that manufacture fluorescent bulbs that offer a broad or "full spectrum." Another type of bulb that offers an alternative, and in some cases can be used in conjunction with the fluorescent bulbs, is the mercury vapor or "active UV" bulb. It has been my experience that incandescent bulbs dubbed "daylight" bulbs or "reptile basking" bulbs should not be relied on as a source of ultraviolet light.

6. How should ultraviolet lights be positioned for reptiles in terms of filtration, distance, duration, and frequency of changing?

Driggers: This is a great question, which entails everything there is to know about a reptile's wild niche. As an exotic animal house call practitioner, this is where I feel I make the biggest difference for the owners to understand the captive environments through understanding not only photoregulation, but also thermoregulation and humidity. I find it difficult to separate the aforementioned concepts so this answer will encompass the next question as well.

The obvious answers are that the light is 100% filtered by glass and about 30% filtered by screen. The distance from the reptiles basking spot is also important. The distance and the formula for its determination operate by the inverse square rule. The basic rule is that if the light has to be within 24 in of the basking area to receive any appreciable UV. Moving the UV half the distance or increasing the height of the basking area (if appropriate) will square the intensity of the UV by a factor equal to half the distance the light is from the reptile. In other words if the reptile is 20 in from the UV source and you move the bulb 10 inches closer (or raise the perch) the reptile with get 100 times as much UV. Duration of light depends on the individual's habitat in the wild. Equatorial species need a 12 hr photoperiod and non equatorial species need variable amounts of photoperiod depending on the distance they are from the equator. If the species is being kept in its native area, it is easy to know the seasonal variation in the photoperiod. UV intensity however varies seasonally so any recommendation is a best guess situation. My recommendations for changing the light are every six to eight months, and as a practical matter I have the owner write the date the light was purchased with a felt tip marker and write on the calendar to replace it six to eight months later.

The complex question has some simple solutions, but can only be accomplished with owners that have the perspective of "what is the best I provide for my reptile?" not "what is the minimum I can get by with for this reptile?" The simple solution is habitat construction with complete microhabitats. The fundamental questions include: how does this animal live in the wild, what niche and/or niches is it known to utilize, how do these niches (microhabitats) change seasonally, is the species of concern nocturnal, diurnal, crepuscular or seasonally variable, is the species of concern an obligate carnivore, opportunistic, omnivorous, or herbivorous, is this species aquatic, sub-terrestrial, terrestrial, semi arboreal, arboreal, and is the species of concern from a tropical area, desert area, or deciduous area (humidity variability)?

Microhabitats can only be constructed with space. Compartmentalization will allow less space to be used, but sufficient space is the key. Practically speaking, I recommend for an owner to build or purchase (new or used) an entertainment center large enough for the adult reptile. (The bigger, the better.) Entertainment centers are ideal because of the compartments (TV, stereo, and knickknack shelves, and dark storage areas). A hole-saw can be used to drill out the enclosure between compartments. The hole should be as small as possible but should allow for the adult reptile to gain access to the desired niche. The niches to be designed are species specific, based on substrates, viewable areas, lights (UV and basking), perches/logs, humidity chambers (using plastic boxed to fit into a compartment with appropriate substrate), aquatic areas, cross-air ventilation, dark warm areas, dark cool areas etc.... The process of cage design allows owners to bond with their reptile/amphibian and to educate them during the process. My goal is to get the process started and to educate in general designs.

Gehrmann/Ferguson: The bottom-line answer for this question is a resounding, "We don't know for most species." It all depends on many factors including the dietary vitamin D intake, UV and temperature requirements of the species, and whether it is a juvenile, male or female. If reproduction is not the goal, requirements may be less (Ferguson, *et al,* 1996).

For panther chameleons we have determined experimentally that exposing individuals 12 hours/day to UVB irradiance of 5-15 microwatts/cm2 (measured with a Spectronics® UVB radiometer, or about 20 - 60 measured with a UVP UVB radiometer) from hatching through maturity is optimal (Ferguson, *et al,* 2002). This regime will result in healthy adults with no signs of nutritional metabolic bone disease and in viable eggs with healthy neonates. Higher and lower values than this range result in hatching failure. A Reptisun® 5.0 or Sylvania® 350BL blacklight bulb positioned so the lizard is always within 10 - 20 cm from the light source will provide this UVB environment (Gehrmann, *et al,* in press). The bulb probably should be replaced every 12 to 18 m. Desert-dwelling lizards may need more than this. Deep shade dwelling diurnal or nocturnal but sun-exposed lizards, like *Uroplatus,* may need some but less UVB (Rick Hudson, pers. comm.). Many nocturnal lizards and most whole-animal eating snakes probably require no UVB. Turtle species probably vary in their UVB requirements (Bernard, 1995, Pritchard and Greenhood, 1968). Until the UVB environments of more species are rigorously monitored in the field or in captivity or subjective data is accumulated and published on "this is what seems to work CONSISTENTLY for species X", trial and error is probably necessary.

Again, dietary vitamin D intake will modify UVB requirements. There are strong suggestions from our work on panther chameleons and from the literature that some lizards (and perhaps some aquatic turtles) are able to "perceive" UVB light and respond to it in a regulatory fashion regarding their vitamin D-condition (Ferguson, *et al,* 2003). Depriving panther chameleons of dietary vitamin D causes them to voluntarily expose themselves more to strong UVB in a gradient than those given high dietary vitamin D. By implication, if we don't know the UVB requirements of a species, we can provide it a gradient from a moderate irradiance to shade, and it will regulate its dosage. We also have some preliminary data that UVB and visible light gradients should be coordinated. In other words, if the visible light gradient produced by a floodlight is at one end of the cage, and the UVB gradient produced by a Sylvania® 350 blacklight is at the other end, the lizard may not respond appropriately to the UVB (Ferguson, unpublished data). So the UV and visible light sources should be placed close together or come from the same bulb.

Gyimesi: Positioning of artificial lights depends on many factors such as the make of the bulb, whether it produces a focal output of UV (spot) or more diffuse output (flood), enclosure design/size, species the bulb is intended for, wattage, heat output, etc. There should be no glass or plastic between the animal and the bulb, and ideally no fine wire mesh. UV output is highest closest to the bulb and decreases with distance. Many bulbs produce low to negligible quantities of UV light at distances at/over 12-18 inches. There are newer bulbs on the market that emit a higher output of UV light making them more effective at greater distances and thus more practical for larger enclosures. My understanding is that artificial bulbs tend to degrade at about the same rate, therefore higher output bulbs have a longer useful lifespan than lower output bulbs. Because the cutaneous conversion of pre-vitamin D3 to vitamin D3 is a temperature dependant process. it is ideal to provide appropriate heat at the basking site. Some of the newer self-ballasted bulbs emit both UV light and heat.

Ogle: When using UV lighting, there should be nothing blocking the transmission of UV. Glass or plastic cage tops will filter out most, if not all, UV. With standard fluorescent UV lights, the recommended distance for exposure is 18 in. We get the best results by placing lights no more than 12 in away from most of our lizards and tortoises. I feel that the closer they are the better. This is especially the case for some of our tortoise species which come from arid, lowland situations such as Cape tortoise, *Homopus s. signatus,* Egypytian tortoise, *Testudo kleinmanni,* Malagasy spider tortoise, *Pyxis a. arachnoides,* and finally pancake tortoise, *Malacochersus tornieri,* where natural UV exposure in the wild would be much greater. We have recently begun to add the mercury vapor bulbs, and because of the heat emitted they are kept at a greater distance from the animals than the cool fluorescent bulbs. Since the mercury bulbs put out a lot more UV, there should be no negative effect because of the increased distance. We keep our lights on for the duration of the day, and the animals always have access to hide areas if they need them. Ideally the fluorescent lights should be changed out every six months per the recommendation of the manufacturers. The mercury vapor bulbs supposedly need only to be replaced when they burn out.

Owens: Many factors are involved when considering the positioning of an artificial source of UV light, all of which can have an effect on the intensity of UV that actually reaches the reptile. Utilizing a UVX-Radiometer, at the San Diego Zoo, we have tested the intensity of UVA and UVB in terms of filtration and distance in a limited number of situations.

One recurring result is that any obstruction between the light source and the animal is going to filter, to some degree, the UV intensity. Screen and mesh commonly used in screen cage tops and arboreal style cages can filter out 40 - 50% of the UV intensity. One of the most shocking observations is that . . very little UVA or UVB is detected beyond 12 - 18 cm from "full spectrum" fluorescent and blacklight bulbs that are commonly used in zoos and in the private sector. In contrast, mercury vapor bulbs emit UV to a much greater measurable distance. Most manufacturers recommend that their bulbs be changed every six months. In the case of one brand of mercury vapor bulb, the UVB intensity was very high. We haven't tested the longevity of bulbs, but through random sampling on a small number of bulbs, it does appear that fluorescent blacklight bulbs emit beneficial UVA and UVB longer than a six-month period. Our experience, so far, coincides with the manufacturers claim that there is UV emission throughout the life of the mercury vapor bulbs.

7. What are your recommendations for the following groups, in terms of UV lighting?:
a). lizards
b). snakes
c). crocodilians
d). turtles and tortoises
e). amphibians

Driggers: See #6

Gehrmann/Ferguson: a). lizards - All diurnal lizard species should be given a UVB gradient. The UVB requirement will vary with dietary vitamin D intake and with species. We need more research.

b). snakes - Most snakes probably don't need a UVB gradi-. ent, except strongly diurnal species that are known to bask, e.g. racers, maybe water snakes. We need more research.

c). crocodilians - Most species probably require UVB gradients. We need more research.

d). turtles and tortoises - Tortoises may not require a UVB . gradient, basking aquatic species probably do. We need more research.

e). amphibians - Some species may need UVB gradients, many are seriously injured by any strong exposure. We need . more research.

Gyimesi: Ideally, all ectotherms should be provided with access to direct, unfiltered, year-round sunlight. Even crepuscular and nocturnal species may reap some benefits in nature from early morning or late evening UV. Unfortunately, this is typically not possible.

a). Lizards include a diverse group of species with varied UV light demands. Nocturnal lizard species such as eyed skinks, *Chalcides ocellatus,* and leopard geckos, *Eublepharus macularius,* develop normally when the diet is the only source of vitamin D3, however most diurnal species, including day geckos, *Phelsuma madagascariensis,* green iguanas, *Iguana Iguana,* and Komodo dragons, *Varanus komodoensis,* appear to be more dependent on UVB exposure. Therefore it is important to be familiar with the lifestyle of the species and provide UV light for most diurnal, basking lizards, especially juveniles. Many lizard species likely also benefit from UVA exposure.

b). Snakes do not appear to require UVB light for vitamin D3 photobiogenesis, and therefore many herpetoculturalists

tend not to provide UV lighting in captivity. They likely receive all the required vitamin D3 orally via their carnivorous diet. UV light however is not detrimental when provided appropriately and may benefit many specimens.

c). Crocodilians likely benefit from UV light but seem to rely more on dietary sources of vitamin D3 to meet their calcium needs. In fact crocodiles and alligators raised in the skin trade are often reared as youngsters in indoor, dimly lit pens to minimize conspecific aggression and competition. These crocodilians do not appear to develop nutritional secondary hyperparathyroidism provided the calcium, phosphorus, and vitamin D3 content of the diet is appropriate. This apparent ability to develop normally without UVB light may be due to their nocturnal lifestyle and carnivorous diet. Nevertheless, there may be long-term consequences of depriving crocodilians of UV light. For instance, some have observed that egg fertility rates appear to be lower in crocodilians housed indoors compared to the higher fertility rates reported in both wild and captive outdoor-housed crocodilians. Additionally, malocclusion seems to be seen more commonly in crocodilians in captivity than those in nature. It has not been verified whether these observations correlate directly to UV light needs.

d). Turtles and tortoises also likely profit from UV exposure. How much they rely on the sun for vitamin D3 photobiogenesis however, is not clear and likely varies between species. The Louisville Zoo has successfully raised star tortoises, *Geochelone elegans,* red-footed tortoises, *Geochelone carbonaria,* and yellow-spotted Amazon river turtles, *Podocnemus unifilis,* under very weak UVB emitting bulbs, without any evidence of nutritional secondary hyperparathyroidism. Whether long-term suboptimal lighting contributes to other problems such as scute pyramiding in tortoises or ulcerative dermatitis in aquatic turtles requires further investigation.

e). Although the spectral requirements for amphibians are largely unknown, most literature recommends the use of ultraviolet lighting in amphibian husbandry. In general, amphibians prefer subdued lighting. Nutritional secondary hyperparathyroidism is not uncommon in captive amphibians, however many cases may stem more from dietary imbalances than UV light deficiency.

Ogle: a). Generally I would recommend UV for all lizards, as it will do no harm as far as I know and should be beneficial. The groups that I feel that it is of the utmost importance for would be the families *Varanidae, AgamIdae, Iguanidae, Chamaeleonidae,* and *Cordylidae.* Most of these families have species that are highly diurnal and need UV for basic physiological processes. In my experience, *Varanus* spp. and chameleons *(Chamaeleo* spp., *Furcifer* spp.) show improved appearance from UV, and the overall health of the animal is as different as night and day between animals exposed to UV and those that have not. This should hold true with many other taxa of lizards as well. Other than *Phelsuma* spp., many people do not use UV lighting for geckoes, but in my experience, UV helped in getting fertile eggs and hatchlings from *Uroplatus* geckoes (i.e. *phantasticus* and *sikorae).*

b). As far as I know there has been limited work on UV lighting and snakes, but I certainly do not doubt that there are possible benefits for long-term health and propagation with many taxa of snakes.

c). This is another order that I have limited experience with as the Knoxville Zoo currently holds only three species (American alligator, *Alligator mississippiensis,* Chinese alligator, *A. sinensis,* and Cuvier's dwarf caiman, *Paleosuchus palpebrosus).* The American alligator is kept outside and has exposure to natural sunlight, the other two species are maintained indoors with just fluorescent lights for UV. Under such conditions, *P. palpebrosus* has reproduced successfully on three occasions. The specific UV needs of crocodilians are beyond my level of expertise.

d). The use of UV with chelonians is highly recommended. In my experience with tortoises, exposure to UV is a key to maintaining/breeding many species. In 1993 the Knoxville Zoo was given the opportunity to acquire 5.5 star tortoises, *Geochelone elegans* from a confiscation. The following year they were added to our outside tortoise exhibit, where they began to adjust and gain weight. Reproductive activity was first observed in this group in 1995, and since then over 160 hatchlings have been produced. Other zoos have similar group numbers and set-ups but without the access to outside enclosures, and they have not experienced the same level of breeding success with G. *elegans.* UV lighting is one component of our current project with *Pyxis a. arachnoides.* Manipulating a cool season, where the sexes were separated, then introducing them outdoors in late spring, has increased our group's activity, and copulation has since been documented. For the first time we have received eggs from our females.

Unfortunately, due to our high humidity during the summer months, not all of our tortoise species can be given outside access, at least not for extended periods. The fluorescent UV lights have worked well for our arid species, and have helped us maintain healthy groups.

Our collection of turtles is mostly of temperate origin and has seasonal access to natural UV light. Even a few of our more tropical species are given outside access during the summer, but fluorescent UV is a standard when inside. In 1986, our curator, Bern Tryon, began an outdoor breeding program for bog turtles, *Clemmys muhlenbergii,* which has been extremely successful due to natural, seasonal changes in UV light and temperature.

e). Due to lack of experience with amphibians I have no comments or recommendations for them.

Owens: a). Many species of lizards have special receptors for light such as the pineal eye or receptors in their skin, and many lizards have other adaptations in their skin to limit UV absorption. All of these anatomical and physiological adaptations, spread through many families of lizards, reflect the strong role light plays in many lizard species' life histories. On that assumption, I would recommend a source of UV for all lizards that best matches its typical microhabitat and how the animal uses it within its ecosystem. For example, open-habitat arid species may not only tolerate intense UV, but may require it to meet metabolic needs. Personally, I have seen members of many families of lizard behaviorally respond to intense irradiation of UV combined with increased tempera-ture. Alberts (1989) and other researchers have shown that certain behaviors are more likely to occur in the presence of UVA. Based on my limited understanding about the role of UVA and UVB, I would recommend both forms for diurnal members of the families *Iguanidae, Varanidae, Agamidae, Cordylidae,* arboreal forms of *Gekkonidae,* arboreal forms of *Anguidae, Chamaeleonidae, Teiidae,* and *Lacertidae.* In situations where UV requirements are unknown, I would initially recommend a conservative approach to UV exposure to those captive lizards.

b). No comment or recommendations

c). It is widely accepted that many species of crocodilians need some exposure to UV for long-term health. My personal experiences with crocodilians are anecdotal. One observation is that some crocodilians seem to retain their scales or lack color when not exposed to UV light.

d). It appears that UV is indispensable for captive maintenance and breeding of many chelonians. There are many health issues that appear to be due to, at least in part, inadequate UV exposure varying from retained scutes to metabolic bone disease (MBD). Many shell diseases or skin conditions can be treated by exposing the animals to natural sunlight. Natural sunlight or an artificial source of high quality UVB emission is preferred for raising hatchlings, juveniles, and gravid female chelonians to avoid common health problems such as MBD. It has been my experience that appetite, activity, and reproduction all increase when tortoises are exposed to natural sunlight.

e). My personal experience with amphibians in captivity is limited. I have not seen detrimental consequences from keeping a UV source on diurnal amphibians. It may be shown that some diurnal amphibians require UV. Our captive husbandry for anurans of the genera *Atelopus* and *Dendrobates* includes the use of high quality UV emitting bulbs.

8. Are there any particular species you have ultraviolet lighting concerns for?

Driggers: All herbivores and any young rapidly growing young reptile or amphibian (UV deficiency often coupled with dietary phosphorus excess [NSHP]).

Gehrmann/Ferguson: Diurnal basking species in general appear to need a moderate to high UVB environment, presented as a gradient.

Gyimesi: Emphasizing my response in #7, diurnal, basking lizards seem to be most at risk for developing hypovita-minosis D and secondary musculoskeletal problems, particularly young, growing individuals. Over the years at the Louisville Zoo, we have seen suspected and confirmed cases of UV light deficiency in bearded dragons, *Pogona vItticeps,* brown basilisks, *Basiliscus basiliscus,* green-crested basilisks, *Basiliscus plumifrons,* Komodo dragons, *Varanus komodoen-sis,* crocodile monitors, *Varanus salvadorii,* panther chameleons, *Furcifer pardalis,* Western chuckwallas, *Sauromalus obesus,* sail-finned lizards, *Hydrosaurus* sp., prehensile-tailed skinks, *Corucla zebrata,* and great-plated lizards, *Gerrhosaurus major.*

As a side point, human studies have shown that increased skin pigmentation can dramatically reduce the cutaneous pho-tobiogenesis of vitamin D3. This explains why African Americans living in the United States are more prone to hypovitaminosis D (Bell, *et al,* 1985). Whether darkly pig-mented reptiles and amphibians have higher UV requirements warrants investigation.

Ogle: To the best of my knowledge there is no reason to be concerned about ultraviolet lighting with reptiles, but I would certainly be interested in knowing if there was.

Owens: There are many sources of artificial UV light available to reptile keepers. I feel that it is equally important to choose the right source of artificial UV as it is to house the reptile in such a manner as to properly utilize the UV made available. UVB light can be injurious to eyes and care should be taken to offer a refuge away from the light.

9. What are the clinical signs of ultraviolet light deficiency in reptiles/amphibians?

Driggers: Twitching, seizures, swollen limbs, poor growth and reproductive production, anorexia, gut stasis, constipation, opportunistic infections, and potentially pyramiding.

Gehrmann/Ferguson: Our major findings with the panther chameleon are nutritional metabolic bone disease, especially if calcium and dietary vitamin D are also deficient in the diet. In reproductive females, even with adequate dietary vitamin D and calcium, we observed hatching failure without substantial UVB (Ferguson, *et al,* 1996).

Gyimesi: UV light deficiency should be considered in ectotherms that are poor feeders, are not vibrant or vigorous ("poor doers"), or have a poor reproductive history. In cases of hypovitaminosis D induced by minimal to no UV light exposure, signs may include an abnormal posture, osteopenia, deformities (facial bones, long bones, spine), hypotonia, muscle weakness, muscle tremors, lameness, poor growth, pathologic fractures, paradoxical soft tissue mineralization, and fibrous osteodystrophy.

10. What diagnostics help to determine ultraviolet light deficiency in reptiles/amphibians?

Driggers: Ionized calcium, cholecalciferol level, radiographs, and often times viewing the cage (glass filtering UV) can be suggestive diagnostically. A UV meter would help solve UV assessment in the cage.

Gehrmann/Ferguson: No comment.

Gyimesi: An ectotherms' appearance, feeding history, reproductive history, activity level, etc. may lead to a presumptive suspicion. In patients with hypovitaminosis D from inadequate exposure to UV light (and/or inadequate oral intake of vitamin D3), a physical exam will assist with screening for musculoskeletal disease. Plain radiography is a useful tool to subjectively assess bone density and screen for deformed long bones, scoliosis, pathologic fractures, and soft tissue mineralization.

In addition, measurement of the circulating 25-hydroxyvitamin D (25-OH-D) concentration can be very useful. 25-hydroxyvitamin D determination is considered the most useful assessment of overall vitamin D status in humans and many animals. Markedly elevated levels suggest hypervitaminosis D while very low or undetectable levels represent impending or frank hypovitaminosis D. As is often the case, the challenge lies with interpreting results, as "normal" reference ranges for most species are unknown. We have sent our samples to the Endocrinology Department within the Animal Health Diagnostic Laboratory at Michigan State University. They have validated their test in at least one species of reptile, the Komodo dragon, *Varanus komodoensis,* (Gyimesi and Burns, 2002). Although useful in many species, this test does not appear to be meaningful in chelonians. Vitamin D physiology and metabolism in chelonians is poorly understood.

11. How is ultraviolet light deficiency treated in reptiles/amphibians?

Driggers: Hopefully with phototherapy predominately and calcium where needed. Potentially administering a vitamin D injection. I also rule out concomitant disease with Woodwork and fecals to ensure more than one etiology is not affecting the reptile or amphibian.

Gehrmann/Ferguson: No comment.

Gyimesi: Provide UV light! As previously discussed, access to direct unfiltered sunlight is preferred. At the Louisville Zoo, we have seen dramatic improvements in several species after exposure to sun. When access to sun is not possible, artificial UV sources can be used. In cases of nutritional secondary hyperparathyroidism, a review of the diet, vitamin and mineral supplementation, and enclosure temperature gradient is also indicated. The use of oral or parenteral vitamin D3 or 25-OH-D has a place in some cases, however this form of treatment carries more inherent risks than simply providing UV light.

12. What are the clinical signs of over-exposure to ultraviolet light in reptiles/amphibians?

Driggers: The same signs as UV deficiency except they usually result from renal secondary hyperparathyroidism. In acute overexposure, I have seen sun burns occur over the top of bony prominences such as the ribs and the pelvic bones of iguanas.

Gehrmann/Ferguson: Excessive sunlamp exposure has caused hyperkeratosis in side-blotched lizards (Gehrmann, 1994A), skin darkening, lethargy, eye-closure, anorexia and death in iguanas (Hibma, 1999) and egg hatching failure (Ferguson, *et al,* 2002) and skin tumors (Ferguson, unpub lished data) in panther chameleons.

Gyimesi: I have not recognized this in clinical practice. Intuitively, I would think that this rarely occurs in nature as animals instinctively self-regulate their exposure to sun. I suppose over-exposure can occur in captive ectotherms if not provided with the option of moving out of the sun or away from high output artificial UV sources. To my knowledge, hypervitaminosis D from ultraviolet light over-exposure has not been reported and is physiologically unlikely to occur. I have read about UV-induced epidermal ulcerations and hyperplasia as well as corneal damage in amphibians.

13. What are the concerns of over-exposure to ultraviolet light on the skin of mammals? What about reptiles and amphibians?

May: The skin of higher vertebrates consists of two layers the epidermis and the dermis, with a layer of fat below referred to as the panniculus. The epidermis in mammals is made up of four specialized cell layers and is relatively thin in haired regions (Scott, *et al,* 2001). The thickest epidermis in mammals is found on the footpads and the planum nasale The dermis is a critical component to the connective tissue system of the body and allows for movement and shape retention. This layer also contains adnexal structures, such as hair follicles, glands, blood vessels and nerves (Scott, *et al,* 2001) In reptiles this layer can become extremely thick, especially over the dorsum, and serves as protection. Some species of reptiles can form horns or skin that is "studded" (Harkewicz 2001).

In humans and domestic animals over-exposure to ultraviolet light can result in clinical changes in the skin. These changes are classified as photodermatitis, solar dermatitis or solar keratoses.

Photodermatitis is subdivided into phototoxicity and photo-sensitivity. Phototoxicity is the classic sunburn reaction, which is a dose-related response to ultraviolet light. Photosensitivity is most commonly observed in large animal species and is seen when the skin displays an increased sus-, ceptibility to damage secondary to the production of, ingestion of, injection of or contact with a photodynamic agent (Scott, *et al,* 2001). Cases have been recognized in canine patients but are less common.

Solar dermatitis is an actinic reaction on white skin, light skin or damaged skin (i.e. depigmented or scarred skin), which is not covered by hair. Most of the damage associated with this syndrome is a direct result of damage to the dermis via ultraviolet ray penetration through the thin epidermis. Clinically, solar dermatitis presents as erythema and lichenifi-cation, with comedone formation if the skin affected is on the trunk or extremities. The most common areas affected are at the junction of haired and hairless skin of the canine nose and the ear tips of white cats (Scott, *et al,* 2001, Hargis, 1981).

Solar keratoses are premalignant hyperplastic and dysplastic changes in the epidermis that may progress to squamous cell carcinoma. Solar-induced hemangiomas and hemangiosarco-mas have also been reported. These lesions typically develop in non-pigmented and sparsely haired areas and can be a result of direct or reflected ultraviolet light. Clinically, chronic inflammatory and proliferative lesions may be present for several years prior to the development of neoplastic lesions (Hargis, 1981).

In contrast, there is very little information regarding detrimental effects due to over-exposure to ultraviolet light on the skin of reptiles. It may be assumed that similar syndromes do not occur in reptiles due to the thickness of the epidermis and abundant pigment present when compared to the skin of mammals. Comments regarding albino reptiles were not encountered.

Concerns regarding overheating and thermal burns associated with ultraviolet light have been reported. Necrosis and bacterial skin infections secondary to thermal burns can be problematic (Harkewicz, 2001). In addition, burns from sun-lamps can result from prolonged exposure, to UVB rays (Gehrmann, 1994A and 1994B, Barten, 2002).

A fatal UVB toxicity was reported in the side-blotched lizard, *Ufa stansburiana,* and was associated with anorexia, decreased motor activity and decreased response to stimuli. Thickening of the epidermis was associated with a change in the color of the skin. In this report such changes were reversible if UVB exposure discontinued at this point (Gehrmann, 1994A).

Amphibian skin is much thinner than reptile skin, with the epidermis normally 2-5 cell layers thick. Consequently the effects of damage to amphibian skin can result in serious conditions. Thermal burns are a concern in these species as even minor burns can be life threatening. In addition, squamous cell carcinoma has been reported in the leopard frog however, the relationship to over-exposure to ultraviolet light is unclear (Reavill, 2001).

14. What are the concerns of over-exposure to ultraviolet light on the eyes in mammals? Any concerns in reptiles/amphibians?

Adkins: The major concerns of over-exposure to ultraviolet (UV) light on the eyes of mammals are cataract formation, corneal damage resulting in corneal ulcers and retinal damage resulting in scotomas (blind spots). In humans, the cornea filters wavelengths ranging from 200 - 300 nm and the lens absorbs the majority of the wavelengths from 300 - 400 nm. There are two regions within the UV spectrum that can result in damage to the lens, 290 - 325 nm and 365 nm. UV light is implicated in the pathogenesis in cataracts in humans. Exposure to the UV spectrum around 320 nm can result in retinal damage, as neither the cornea nor the lens adequately filters this part of the spectrum. UV light induces temporary corneal or permanent retinal damage due to industrial (humans) or experimental (non-human primates) exposure to lasers. The amount of tissue damage depends on the wavelength of light and the duration of exposure.

There is little information available on the effects of UV light on reptiles and amphibians. In general there is tremendous conservation among species in basic ocular anatomy and physiology, however, there are some notable differences in reptile and amphibian ocular anatomy. It is possible that UV light may have the same effects on the eyes of these species as it has on mammalian eyes.

Siamese crocodiles, *Crocodylus siamensis,* have high concentrations of the UV absorbing compounds, ascorbate and urate, in their aqueous humor. These substances may protect their lenses and retinas from UV damage. The nictitating membrane in crocodiles may also provide some protection from UV radiation.

The European common frog, *Rana temporaria,* may be protected from UV radiation by their environment and/or nocturnal behavior. Experimental effects of UV radiation (280 - 315 nm) on tadpoles, Pacific tree frogs, *Hyla regilla* and red legged frogs, *Rana aurora,* resulted in the development of cataracts. This may occur in nature as a result of habitat destruction. The lens of the diurnal painted dwarf gecko, *.Lygodactylus picturatus,* contains a novel protein that may protect the retina from ultraviolet light.

Since reptiles and amphibians have some unique ocular structures, other mechanisms for protection from UV light may be discovered in the future.

15. What diagnostics help to determine over-exposure to ultraviolet light in reptiles/amphibians?

Driggers: History, calcium levels (in males)- r/o ovulation with females by lipid profile, radiographs (calcification of great vessels of the heart, renal mineralization, etc.... I would perform a cloacal exam to palpate the size of the kidneys (biopsy if abnormal in size or shape).

Gehrmann/Ferguson: No comment.

Gyimesi: No comment.

16. How is over-exposure to ultraviolet light treated in reptiles/amphibians?

Driggers: Usually it is not a single causation problem with UV over-exposure. It is usually multifactorial but the result is usually the same (dystrophic calcification of the soft tissues).

This scenario usually leads to decrease blood flow to the kidneys that are hypo-functional already, leading to renal failure. Treatments are largely ineffective, but I give phosphate binders such as aluminum hydroxide and soak them daily in water. I would remove them from UVB light sources and allow UVA to continue. I recommend store bought greens and add Metamucil to the salad mix (if still eating). I would tailor my treatment specifically however to the signs the individual is having with the disease, again treating secondary disease and administering supportive care as needed. I have placed catheters and given IV fluids from time to time, but it seems like if a reptile or amphibian needs IV fluids, it was an emergency three months ago and the owners are acutely recognizing a chronic problem.

Gehrmann/Ferguson: No comment.

Gyimesi: No comment.

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