Aspects of Light and Reptile Immunity

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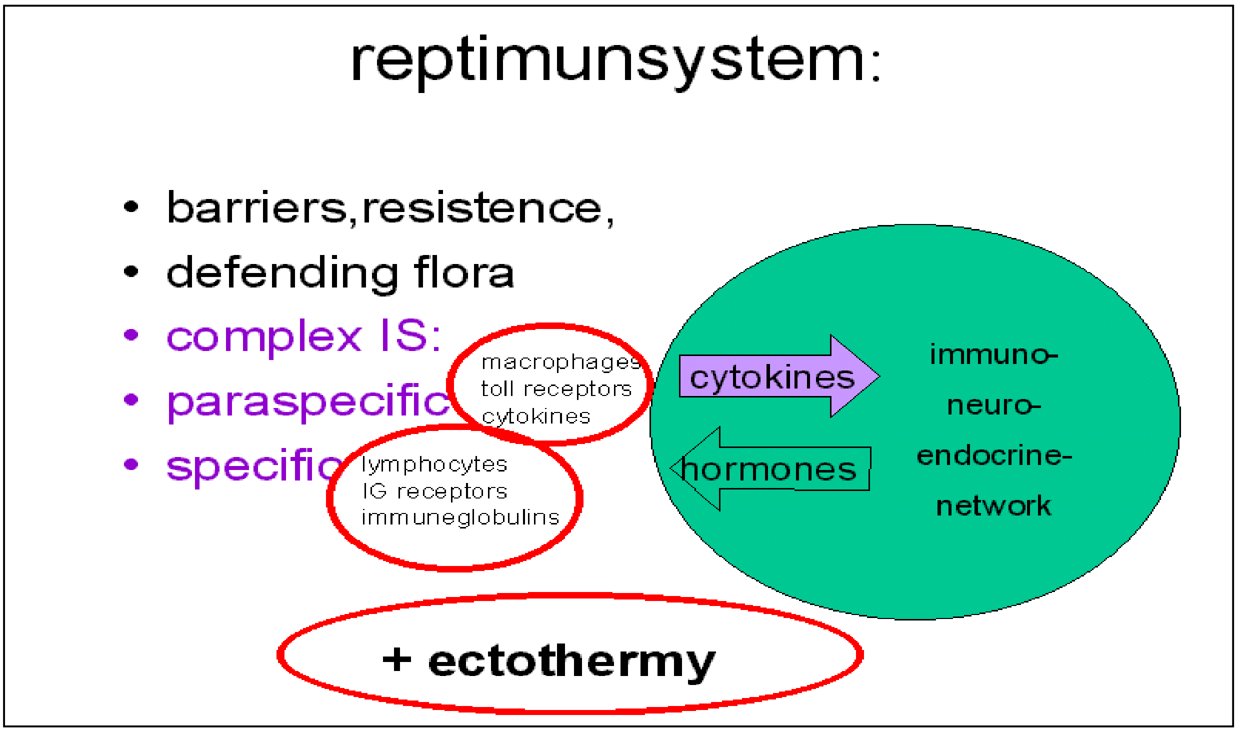
Introduction

Reptiles play an important role in conservation projects, in professional farming ventures for food and raw material, in zoos and private husbandry and as laboratory models in bioscience. Reptiles are different to endothermic vertebrates and differ in physiology. Preventive reptile medicine means improving human-reptile relationship and means supporting a well regulated reptile immune system. Light is an important factor and light means something different to reptiles than to us humans.
To illuminate the effects of light on reptile immunity we must first talk about the reptile immune system and some facts on light and reptile light perception.

Reptile immune system

As a class reptiles are positioned phylogenetically between higher and lower vertebrates, so is their defense system (correctly they are sauropsides together with birds and the line goes right through this superclass). Immunologists distinguish between unspecific defense mechanisms: barriers, defending bacterial flora and natural resistence and the complex immune system (IS): paraspecific (innate) and specific (anticipating) IS. Cellular/ molecular protagonists of paraspecific IS and specific IS are macrophages, toll-like receptors, cytokines and lymphocytes, immune-globulin-superfamily-receptors, immune globulins, respectively. Don't reduce immunity to antibodies (= immune globulins)! Paraspecific IS is 100 times older than specific IS and life without the paraspecific IS is impossible. Reptile paraspecific IS is very well developed, whereas their specific IS is handicapped lacking germinal centers, variety of immune globulins and immune globulin design. Last but not least reptilian ectothermy stresses specific IS far more than paraspecific IS. In conclusion reptile IS is heavily paraspecific. Overall the reptile IS is a mobile brain, a communication system, permanently watching body's integrity, that informs, modulates and regulates other systems like metabolic, neural and hormone system AND reciprocal. We are talking about an interdependent supersystem: the immune-neuro-endocrine network. Immune cell cytokines trigger the hypothalamus, who answers with hormones back regulating the immune cells. This scenario gives us first hints how light may influence reptiles IS (1, 2, 3, 4, 5). See illustration1 for a schematic overview on reptile defense system.

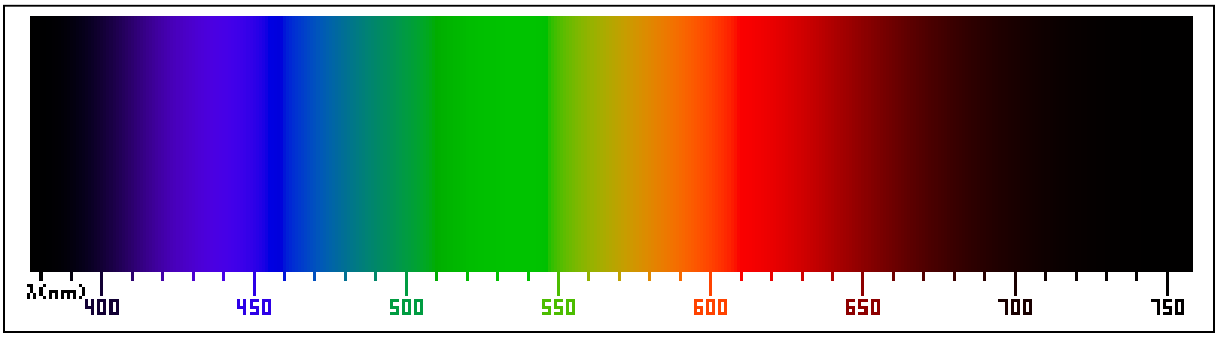
Illustration1:



Light

Light on earth is the sum of electromagnetic sun radiation, filtered through kilometers of atmosphere. What we call photo-environment is a continuous spectrum from a very distant and very hot black body radiator. We structure this spectrum into bands of different wavelengths (measured in nanometers = nm) from infrared to ultraviolet, and the human visible spectras red green blue "in between". This definition, this "view" is heavy anthropocentric and based on human photo receptor design (eyes, retina) and human information processing (brain). The invisible infrared provides additional warmth to our endothermic body , the invisible UV-A suntan and UV-B vitamin D3. The human visible spectras "in between" supply color and contrast for habitat orientation. The hue of human perceived color habitat, depends on the color temperature of light in ° Kelvin (° K) reaching surface, as on what spectras atmosphere and clouds filter and on our specific human spectral sensitivity. The "warm" reddish hue comes from emphasizing the red spectras when blue is filtered (about 3000° K: long way through atmosphere: sunrise, sunset), the "cool" blueish hue when blue spectras are favored and the red spectras filtered (up to 10000° K: clouds). Sunny daylight lies at 6000° K. Another aspect is light intensity received (illuminance). Illuminance first depends on latitude, season, daytime, clouds, shade and is measured in Lux, calculated as "adjusted watt"/m2 = Lumen/m2 (watts weighted at human spectral sensitivity) and second how long this illuminance is provided depending on seasonal daylength . See Illustration2: the continuous sun spectrum visible for humans. Note that we only see three colors (red green blue) and all other colors are mixed in our brain depending on wavelength composition and intensity. For further information please look up Wikipedia online lexikon.

Illustration2 (from wikipedia "light"):



Is this the same for reptiles? How do reptiles see the world? What do reptiles make out of this sun or light spectras, this photo-environment? There is a reptile Lux and a reptile hue we hardly can imagine!

Lets have a closer reptocentric look at the middle "visible" spectrum to line out some anthropocentric misunderstandings:

Reptile light perception

Micro and photo anatomical studies of lateral eyes show that most mammals are only dichromates (two different types of cones). Whereas man and old world primates are trichromates (three cone types with peak sensitivity in red green blue, covering 400 to 700 nm), reptiles are tetrachromates (!) with a fourth cone type for UV-A below 400 nm. Additionally peak sensitivities of red, green, blue cones are slightly shifted compared to humans. Reptiles see in the UV-A range and use spectras differently. Behavior studies show that UV-spectras and reptile correct color rendering of artificial light settings is not only necessary for conspecific, interspecific and intersexual recognition, furtheron brightness, contrast and motion perception but also for foraging and who knows (you may allow this unscientific expression) happiness? (6, 7, 8, 9, 10, 11, 12, 13). This shows the difficulty to provide an optimal reptile photo-habitat with artificial light (non-continuous spectrum or lacking UV-A). They are optimized for human sensitivities. We might get an idea of what insufficient light is doing to reptiles, if we take out lets say the "blue" of a digital foto (see illustration3). For further imagination how strange light feels visit the webpage of Bjørn Rørslett: http://www.naturfotograf.com/index2.html

Another photoreceptor is the "third" eye, the pineal organ and connected pineal gland. Pineal cells show highest sensitivity from 600 to 750 nm and are an effective light dosimeter with following thermo, immune and reproduction regulatory consequences (14, 15, 16).

Some reptiles even precisely see at night via infrared. Pit vipers and boid snakes use infrared sensors and a consecuted signal processing, yes, image improvement algorithm to precisely monitor their surroundings from emitted infrared in the dark (17).

Humans use rods not cones for black and white vision under dim conditions. Surprisingly geckos don't have rods, but very sensitive cones for night color vision (18).

We dont know how reptiles see the world, but we definitely know that the reptile immune system can see the world. Where are the connections to the immune system?

Illustration3: digital image with and without blue spectrum

Light immune effects

Whole-body-mediated light immune effects:

First of all reptiles are solarpowered. As ectotherms reptiles try to balance their optimal body temperature behaviourly. Reptiles depend on the infrared spectrum of light as heating source (sunbathing) and indirectly from convection (hot substrate, warm or cool burrows). Warming light is a pivotal factor to reptiles micro climates and micro habitats. This solar calory source itself is the general basis for a well functioning reptile immune metabolism. The specific IS is more susceptible to temperature changes than the paraspecific IS, due to simple chemical and more complex biochemical reasons (hypothalamus-pituitary-adrenal axis and corticosterone). During winter and other unfavorable conditions reptiles have to rely on the paraspecific IS.
Another aspect is drying of skin which provides a less comfortable surface for pathogen bacterial growth and alters and strengthens the defending bacterial flora. Finally UV light itself has direct desinfecting power. Body movement and gut peristaltics to prevent bacterial overgrowth needs an appopriate body temperature and last but not least, in combination with vision it allows foraging and digesting to supply the reptile immune system with nutrients (5, 19, 20, 21).

In addition to this unspecific radiation supports to the reptile defense system mentioned above, there are more sophisticated light effects on reptiles complex immune system.

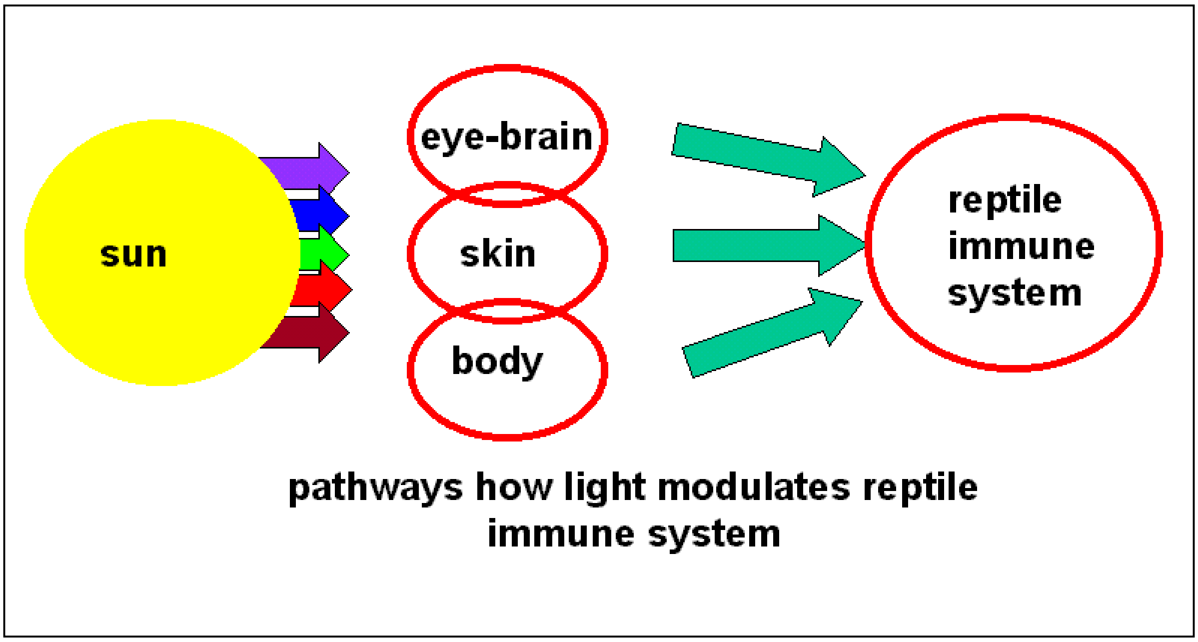
Eye-brain–mediated light immune effects:

The lateral eyes transduce light signals to the brain vision center and with an alternate pathway to the hypothalamus pituitary axis. From there modified hormone patterns are created which heavily influence the reptimunsystem (5, 22).
The pineal eye regulates serotonin and melatonin synthesis in the pineal gland, rhythm and amount correlated to light exposure. Both neuro-hormones modulate the reptile immune system (22, 23).

Skin-mediated light immune effects:

Immune cells under the skin directly react on deep penetrating (red) spectrum and modify immune function (22).
UV-B regulates vitamin D3 endo-synthesis in the skin (main D3 source in many reptiles), which then is hydroxylated to bioactive calcitriol (1,25-hydroxy-cholecalciferol). Cytokines (interferon) trigger immune cells to D3 hydroxylation and immune cell populations (macrophages) are upregulated via calcitriol receptors. Calcitriol also attaches to immune cells to stimulate production of antibacterial cathelizidin and defensin. That might also explain anticancerogen side effects of D3. Whereas calcitriol regulating capacity on calcium metabolism is often mentioned, this direct D3 immune effects are overlooked (24, 25). Noteworthy calcium itself plays an important role in long distance immune cell communication via nanotubes (26, 27). See illustration4 how sun light and artificial light influences the reptimunsystem.

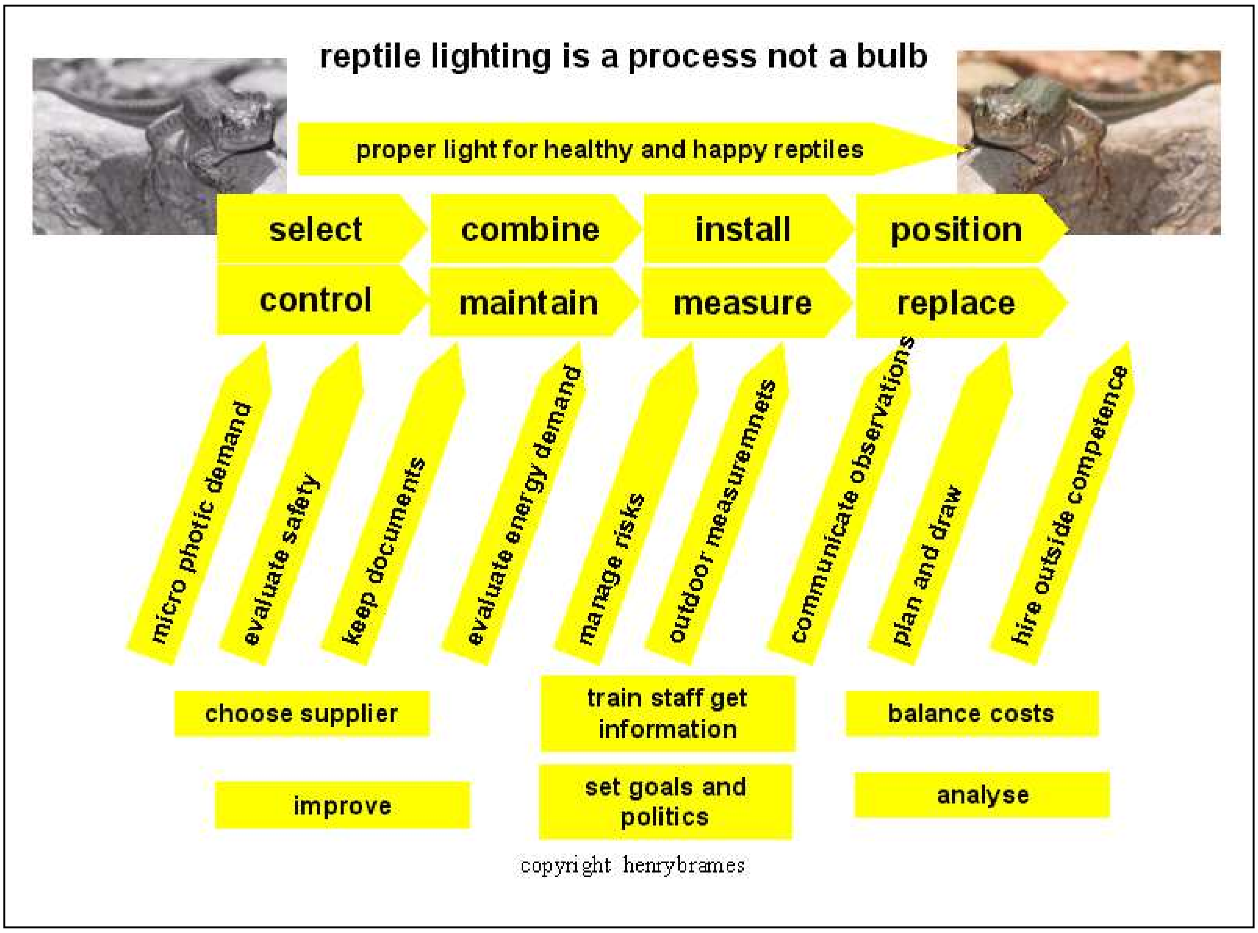
Illustration4:



Conclusions

For decades herpetoculture is a discussion on heating and lighting. Preventive reptile medicine outlines the importance of a well regulated reptile immune system and found strong relations to lighting. Improving reptile lighting (a combination of lamp, position, reflectors, control and maintanance) is still and will be further in future a top theme simulating habitats in vivarias. Reptile lighting is a process not a bulb! See the process model of reptile lighting in illustration5:

Illustration5:



Preventive reptile veterinarians observe and appreciate hitech reptile light improvements: there is a move from incandescent / halogen lamps to fluorescent fulspectrum tubes / compact lamps, metall halid lamps and self / external ballasted mercury vapor lamps or combinations of them with reliable UV-B, UV-A, visible light intensity and colortemperature. What future are LED-lamps promising? Proper controled lighting systems and maintainance are part of reptile enrichment. Referring to over 9000 reptile species and microhabitats there is not one reptile illumination that fits all. An upcoming topic of concern misinterpreting geographic climate datas as microhabitat demands is acute and chronic overradiation. Hard enough for us upright-walking endotherms: Lets improve our reptile feeling. You may not see your reptile but your reptile might very well see your eye color.

Summary

Reptiles perceive light different than humans and other mammals. They are tetrachromats with additional view in the UV-A below 400 nm and have shifted peak sensitivities of red, green and blue cones compared to humans. Their ectothermic and heavily paraspecific immune system (reptimunsystem) makes light not only modulating but pivotal supporting their defense system and immune-neuro-endocrine network. Endosynthesis of vitamin D3 via UV-B is important for mineral metabolism but also for immune regulation. Preventive reptile veterinarians, technicians and scientists have to be aware of known (and unknown) aspects of different reptile light physiology and enhance their research and consulting activities.

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