University of Veterinary Medicine, Budapest

Institute of Animal Breeding, Nutrition and Laboratory Animal Science

Department for Animal Nutrition and Clinical Dietetics

Non-infectious diseases of captive reptiles

Literature review

Lisa Bonaci

Supervisor: Nikoletta Hetényi, research fellow

Department for Animal Nutrition and Clinical Dietetics

2023

Abstract

The key to maintaining healthy reptiles in captivity is to mimic their innate environment as strictly as possible. Conditions such as habitat components, dietary substance, lighting, temperature, and humidity differ for each species and must therefore be followed carefully to ensure proper husbandry and nutrition. Inadequate conditions predispose to several non-infectious diseases ranging from metabolic derangements to renal disease and malnutrition. These are, without a doubt, one of the major concerns in herpetological medicine; although treatment is possible for most cases, proper education regarding reptile care and dietary needs is a must for the prevention of recurrence.

Many reviews and papers have been published regarding disorders originating due to improper housing or nutrition. This thesis aims to summarize the current information regarding the etiology, clinical signs, and prevention of the most important non-infectious diseases of captive reptiles.

Összefoglaló

A kedvtelésből tartott hüllők egészségének megőrzéséhez szükséges, hogy a lehető legnagyobb mértékben a természetes élőhelyhez igazodó környezetet biztosítsunk. A tartási igények, mint a megvilágítás, hőmérséklet és páratartalom igény, csakúgy, mint a táplálási szükségletek fajonként eltérnek és ezen tényezők ismerte nélkülözhetetlen a megfelelő tartási körülmények biztosításához. A nem megfelelő környezet hajlamosít a nem fertőző eredetű megbetegedések kialakulására, mint az anyagcserezavarok, a vesebetegség vagy az alultápláltság. Minden kétséget kizáróan ezek a hüllőgyógyászatban felmerülő legfontosabb problémák. Annak ellenére, hogy az estek többségében lehetséges a gyógykezelés, a tulajdonosok hüllőtartással és táplálással kapcsolatos tudásának bővítésé meghatározó a megelőzés szempontjából.

Számos, a táplálási vagy tartási hibára visszavezethető megbetegedéseket tárgyaló irodalmi áttekintést és közlemény elérhető. Ezen szakdolgozat célja, hogy összefoglalja a fogságban tartott hüllőket érintő legfontosabb nem fertőző eredetű betegségek kóroktanát, klinikai tüneteit és megelőzési lehetőségeit.

CONTENT

Abbreviations

UV:	Ultraviolet
UVA:	Ultraviolet A
UVB:	Ultraviolet B
RH:	Relative humidity
PGS:	Pyramidal growth syndrome
MBD:	Metabolic bone disease

1. Introduction

Currently, there are 11,940 reptilian species enlisted in the Reptile Database; a few of which are increasingly seen as pets in the veterinary field [1]. The class *Reptilia* consists of four orders: *Crocodilila* (crocodiles, alligators, caimans, gharials), *Testudines* (turtles, tortoises, terrapins), *Squamata* (lizards, snakes), and *Sphenodontia* (tuatara). It comprises all sauropsid amniotes except for *Aves* (bird species) [2]. Reptiles are phylogenetically the first group of vertebrates which have adapted to a terrestrial lifestyle. Nowadays, reptiles are kept in captivity as display animals in zoological collections, for educational purposes in academic institutions, and for private collectors and breeders who sell produced animals in the pet trade.

Reptiles' organ systems are quite similar to those of mammals. A primary difference, however, is that they are ectothermic vertebrates that rely on external temperature and behavior patterns to manipulate their inner body temperature to stay within the preferred range. This is known as the optimal **temperature** zone which differs per species and fluctuates by season, age, and gender. This is what ultimately defines their basal metabolic rate, which is known to be lower than that of mammals and birds due to core reptilian nature, low energy expenditure, and deficient nutritional requirements. Knowing the preferred optimum body temperature is vital for the long-term captive maintenance of a particular species [3]. An optimal temperature is imperative for normal digestion, assimilation, and excretion. A lack of such would lead to a decreased immune humoral response with the possibility of invasion by external pathogens resulting in secondary disease. A higher optimal temperature zone, on the other hand, would predispose to localized burns or even systemic effects leading to physiologic heat death [4]. Other imperative factors for suitable captive husbandry include housing, heating, lighting, humidity, substrate, enclosure hygiene, and nutrition.

Housing: It is recommended to quarantine all new animals for at least 3 months after purchase before adding to the established collection of animals to prevent the inevitable spread of disease. Different species from different geographical locations must never be put in the same enclosure as this would compromise one/both species. This is valid for several reasons, such as unnecessary competition for resources and different habitat requirements. Some species, especially chameleons, are so territorial that isolation is recommended for their long-term survival in captivity. It is important to note that certain reptile species have diverse resistance and susceptibility to disease. Specific pathogens can infect ‘carrier’ species which would show no clinical signs of illness but would be able to transmit it to other species causing disease. For example, the protozoan parasite *Entamoeba invadens* is associated with high morbidity and mortality in affected snakes and lizards but is relatively harmless in Chelonians due to the commensal relationship between the protozoan and their gastrointestinal tract’s flora. Therefore, subclinical Chelonians can potentially serve as a source of infection to other susceptible species kept in a mixed reptile collection, especially if poor quarantine and hygiene practices are utilized in the collection’s management [5]. Similarly, what is known to be ‘normal’ bacterial microflora in one species might prove rapidly fatal in others. This phenomenon is commonly seen when carnivorous and herbivorous reptiles are housed together. Furthermore, overcrowding one’s habitat must also be avoided to prevent increased competition for food, water, basking sites, and the buildup of waste material. These actions would contribute to stress and decreased immunity, exposing reptiles to injury and secondary disease [6].

Heating and lighting: Different heaters are available for different species. For example, a heat mat is more suited for a ball python rather than a tortoise. This is because underfloor heating is not recommended for burrowing species, as these burrow to escape solar heat. All heaters, however, should be thermostat controlled, properly screened from reptiles, and positioned in a way that would offer a thermal gradient to allow reptilians to regulate their body temperature. Broad-spectrum ultraviolet lighting is beneficial for all reptile species to maintain healthy lifestyles. It is primarily important for the photobiosynthesis of vitamin D_3, which in turn is vital for the absorption and homeostasis of calcium. Chelonians and most diurnal lizards rely immensely on UVB light for vitamin D_3 synthesis and calcium regulation whilst other reptile species mainly get their vitamin D_3 orally via diet. Other reported beneficial effects of UV lighting include increased appetite and brightening of skin colors. Photoperiod (daily cycle of light and darkness) requirements differ between tropical and seasonal species. This affects the behavior and reproduction rate of a species [7].

Humidity requirements can vary widely between species. Desert species, for instance, require a humidity value of 10-30%, whereas species originating from tropical climates require over

50%. Excessively low humidity can lead to dry skin and dysecdysis whilst high humidity can result in dermatological infections, mainly of fungal origin [6].

Hygiene is also essential for long-term maintenance. Poor hygiene results in stress which allows secondary organisms to invade reptiles' compromised immune systems and thrive. The choice of disinfectant used is also important to prevent toxic materials from coming into contact [6].
All in all, if these mentioned environmental factors are not optimal, even a perfectly balanced meal could be useless due to improper digestion.

Diet, feeding management, and the risks of nutritional disorders should be considered for all reptile patients, regardless of the patient's origin and apparent health status. The most common problem which arises in reptile practice is malnutrition; nutrient imbalance caused as a result of poor feeding management, undernutrition, or deprived diets. Malnutrition is mainly caused due to dietary deficiencies of calcium, vitamin D_3, and vitamin A in tortoises and lizards. Nonetheless, toxicities arising from excessive supplementation of nutrients are also possible, especially those of vitamin A and D_3. Obesity and starvation are also commonly seen due to the overfeeding or underfeeding of reptiles respectively [8]. Unlike other *Animalia* classes, certain reptile species can go up to weeks without a food source. However, this is not the case for water intake. Lack of water predisposes herpetological species to severe dehydration, which is often a consequence of inadequate husbandry, low humidity levels, improper temperature gradients, and so on. Owners need to acknowledge that water needs in captivity should mimic those of the animals' natural habitat. For instance, the water requirement of a tropical Redfoot tortoise *(C.carbonaria)* contrasts drastically with that of a desert Egyptian tortoise (*T. kleinmanni*). Misinformation or misidentification of species' needs could lead to chronic dehydration, having ample consequences in reptiles. The most common outcome is an increase in uric acid concentration in the blood, which deposits in certain areas of the body resulting in swelling, known as gout. Another possible result of chronic dehydration is renal hypoperfusion which increases susceptibility to chronic kidney disease which subsequently predisposes to metabolic bone disease (MBD) [9].
This thesis aims to comprehensively enlist the most common disorders of captive reptiles that arise as a result of improper husbandry and feeding management.

2. Literature Review

2.1. Husbandry-associated problems

2.1.1 Temperature

Reptiles depend on external sources like ambient heat and thermoregulatory behavior to uphold their desired body temperature. This is crucial for facilitating optimal biological processes and enhancing physiological functions such as growth and reproduction. The preferred body temperature varies greatly among species and must be understood when dealing with these exotic species [10]. For instance, research revealed that the Aldabra giant tortoise (*Aldabrachelys gigantea)* exhibits an optimal body temperature range of 25.8 to 31.7 °C; this is where the highest activity levels were observed. Temperatures exceeding 32°C led to reduced activity as the tortoise sought out shaded areas to cool down, whilst temperatures surpassing 36-38°C degrees resulted in fatality due to overheating in the wild. The latter is known as the maximum critical temperature, which together with the minimum critical temperature form the critical thermal zones of body temperatures. The survival of reptiles is ultimately restricted by the critical thermal zones, dictating where and when they can exist successfully [11]. In contrast, the New Guinea Short-necked turtle (*Emydura albertisi)* has a much lower thermal preferendum of 17-20°C [12].

Since reptiles cannot generate internal heat, they face an elevated risk of hypothermia when subjected to less-than-ideal temperatures. Colder temperatures decelerate several metabolic processes such as digestion, which can result in gastrointestinal diseases such as impaction, bloating, and putrefaction of food within the gut. This is often encountered in varanids which fail to bask after a large meal. The inability to digest feed results in gas production due to abnormal fermentation, which in severe cases can lead to life-threatening bloat. Moreover, when unable to reach their desired body temperature, reptiles exhibit reduced activity which consequently leads to decreased food and water intake. Over time, the hypothermic reptile will become lethargic, severely dehydrated, and in need of critical care [13]. To the touch, the affected reptile will feel very cold with a rigid body. When handled, it will exhibit unresponsiveness with minimal to no response to deep pain stimuli. Hypothermic reptiles often experience compromised immune systems which increase susceptibility to secondary conditions such as respiratory infections and chronic disorders like shell deformities and MBD [14].

Exposure to cold temperatures can also inhibit renal tubular function and increase uric acid levels in reptiles, predisposing to gout [15]. If left untreated, hypothermia can lead to cellular necrosis (especially of digits and tails) and peripheral nerve degeneration due to decelerated nervous system processes [16].

Hypothermia can easily be prevented with knowledge of the species' preferred body temperature and by using external heat sources to achieve it such as infrared lamps, ceramic heaters, spotlights, heat mats, and cables. The enclosure should be large enough to provide a thermal gradient and thus allow the reptile to thermoregulate. The ambient temperature within the enclosure should ideally remain within a range of 2-3 degrees above or below the reptile's preferred body temperature during daylight hours. The warmest area of the enclosure, typically the basking spot, should be maintained at a temperature slightly higher than the reptile's desired body temperature. During night-time, the temperature is allowed to decline by 5 degrees [17]. Additionally, employing a natural thermal gradient is beneficial for reptiles as it minimizes stress and mimics the species' natural habitat. For example, a recommended practice is to lower the ambient temperature by a few degrees during winter to mimic natural seasons and stimulate mating behavior [18].

All heat sources must be frequently monitored to prevent burns and maintained by an accurate thermostat. Most burns in captive reptiles result from animals coming into direct physical contact with heating equipment. This can be prevented by using a protective guard which separates the reptile from the heat source or by placing the heat source external to the enclosure. Thermal burns can cause skin and underlying tissue necrosis, potentially leading to infections that can extend the duration of treatment and worsen prognosis [13]. The choice of heating method depends on whether the species is heliothermic or thigmothermic. Heliothermic reptiles such as lizards and tortoises seek radiant heat from the sun diurnally and therefore benefit from heat lamps. On the other hand, thigmothermic reptiles such as the nocturnal ball python (*Python regius*) and crepuscular leopard gecko (*Eublepharis macularius*), rely on conduction for heat and thus can be effectively heated using heat pads, provided that they are thermostat-controlled to avoid malfunctions causing overheating [19].

2.1.2 Air Humidity

Air humidity is another significant environmental factor to consider. Understanding the ideal humidity levels specific to each species is essential in preventing many husbandry-associated diseases in captivity. An ideal humidity range for numerous reptiles, including commonly kept ones like pythons, boas, and iguanas, falls between 50-60% [20]. However, needs vary from 20% for desert species (such as Collared Lizard - *Crotaphytus* species) to 90% for rainforest species (like Water Dragons - *Physignathus* species). Nonetheless, even desert species require higher humidity levels during ecdysis. Therefore, it is advisable to establish a humidity gradient within the vivarium by creating a humidity chamber containing damp materials like vermiculite or sphagnum moss which would be utilized by reptiles just before shedding their skin [6]. Sphagnum moss is preferred due to its acidic nature which helps deter the growth of mold and bacteria.

Humidity is influenced by variables like temperature, water surface area, and ventilation [6]. A study carried out at the Long Island Reptile Museum revealed that enclosures with open screen tops promoted substantial diffusion gradients and airflow, which made it difficult to maintain consistent temperature and humidity levels. As a result, insufficient humidity led to chronic dehydration, and, in certain instances, conditions like gout were even observed in lace monitor (*Varanus varius*) and Egyptian spiny-tailed lizard (*Uromastyx aegyptia*) species [21].

Suboptimal humidity often leads to dysecdysis, a condition characterized by improper shedding and retention of shed skin. Among reptiles like turtles, tortoises, and Crocodilians, the shedding process typically involves the periodic removal of small segments, scales, or scutes. Lizards tend to shed their skin in several larger fragments, whilst snakes should shed in one intact piece [22]. In cases of dysecdysis, the outermost epidermal layer of dead skin fails to properly detach or separates into fragments instead of a whole piece in the case of snakes. A stuck piece of shed may act as a lever, potentially harming the underlying epidermis. Tears in the epidermis compromise the physical protective barrier of the integument, allowing secondary bacterial and fungal invasion which results in pyoderma. Additionally, without proper treatment, retained shed can also constrict distal appendages leading to ischaemic necrosis which is a common finding in lizards. Similarly in snakes, retained spectacles are frequently observed and must be carefully removed to prevent ocular damage such as reduced vision or increased susceptibility to further ophthalmic disorders (Figure 1). A recommended practice is to soak reptiles around sloughing time in a basin containing lukewarm water for 15-30 minutes to help remove the stuck shed [23]. Dysecdysis cases are typically multifactorial and might also be in conjunction with parasitism, traumatic injury, or systemic disease which must be addressed when treating [22].

Figure 1: Ulcerative lesion in the center of a retained spectacle in a Ball python (*Python regius*).
Source: Dr. Raoul Stafrace.

In Chelonians, high humidity is required for proper shell growth and development. A study carried out on African spurred tortoises (*Geochelone sulcata*) revealed that dry environmental conditions (24.3-57.8% relative humidity) resulted in the pathological formation of carapacial humps, also known as pyramidal growth syndrome (PGS) [24]. Pyramiding in tortoises is mainly encountered in captivity and has been correlated with many factors such as excess intake of dietary protein, calcium deficiency, overfeeding, and lack of sunlight or exercise [25]. Wiesner *et al*.'s study concluded that the main contributing factor for PGS was inadequate humidity since variable dietary protein only had a minor impact on pyramidal growth. Humid conditions of 45-99% RH were proven to inhibit scute pyramiding. Therefore, it was decided that areas with RH of nearly 100% should be provided for hiding at all times to minimize pyramiding [24].

Long-term absence of humid conditions can lead to chronic dehydration, especially in species such as chameleons which rely solely on water droplets on leaves or branches for hydration. Dehydration can quickly progress to kidney failure and subsequently death. Therefore, in these reptile species, it is essential to mist the enclosure three to four times daily to prevent dehydration whilst also maintaining the ideal relative humidity [18]. Cases of low humidity should be corrected by using a humidifier [20]. However, constantly high humidity levels must also be avoided since dampened substrate creates a favorable environment for the growth of opportunistic pathogens (mostly *Fusarium* species) increasing susceptibility to mycosis and other skin infections [6]. Blister disease is a common consequence of constant moist conditions in snakes: mainly water, garter, and king snakes. As a result of lying on damp and dirty substrates, the reptile's skin becomes moist and infected, forming blisters in the epidermal layer of body scales which are initially fluid-filled and swollen. Over time, they become infected by opportunistic bacteria (such as *Pseudomonas*) which might progress to subcutaneous abscessation or necrosis. If left untreated, the infection can enter the bloodstream causing fatal septicaemia [26]. Small reptiles or reptiles with weak immune systems are most susceptible to death from blister disease and therefore must be treated as soon as possible [27]. Humidity-related problems can easily be prevented by using a simple RH meter for monitoring [18].

2.1.3 Lighting

Ultraviolet-B radiation (280-320 nm) is very important for reptiles in terms of health and welfare. UVB is required for the conversion of 7-dehydrocholesterol from the skin to vitamin D, which in turn, is needed for the regulation of calcium and phosphorus in the body [28]. Apart from playing a role in normal reptilian growth, vitamin D has also been proven to enhance reproduction, behavior, appetite, and natural color [7]. Reptiles deficient in vitamin D show an increased susceptibility to MBD and hatching failure despite having developed embryos [28]. Lack of UV light in diurnal reptiles may also cause chronic stress and further immunosuppression. Further investigation is needed regarding possible long-term problems resulting from suboptimal lighting, such as pyramiding in tortoises or ulcerative dermatitis in turtles [7].

The intensity of UVA and UVB required is dependent on the species in question. Diurnal species (such as the green iguana, water dragon, or bearded dragon) require high intensities of UVB (UV index 5.0-8.0), whilst nocturnal species such as snakes that consume whole prey, require minimal or no UVB exposure since their carnivorous diets provide enough vitamin D_3 to satisfy their nutritional needs [7]. Some nocturnal lizards (such as the leopard gecko) still require additional vitamin D_3 supplementation together with their insectivore diet. Ideally, UVB is derived naturally from sunshine. However, if access to the sun is not possible, UV lamps should be utilized to increase vitamin D supply [28]. Along with a high-quality, broad-spectrum light source, reptiles should also be provided with a shaded area, which can be achieved by adding plants, to provide a light gradient [29]. The duration of light needed is contingent on the individual's habitat in the wild. Most equatorial species require a 10–12-hour photoperiod which should be gradually reduced by up to two hours over the winter to stimulate hibernation and reduced activity [7]. It is advised to turn off any light sources at night as studies in prairie rattlesnakes (*Crotalus viridis*) revealed resultant suppressed activity [28]. Owners must be reminded that any artificial UVB source should be replaced every 6-9 months due to their limited exposure. Furthermore, UVB sources that are too intense (such as blacklights) should be avoided since they have been reported to cause ocular disorders [6].

2.1.4 Water requirements

Water must always be made available to any animal species. Most kept reptiles such as snakes, lizards, and tortoises often drink out of a shallow bowl filled with water. Some lizard species such as the crested gecko (*Correlophus ciliatus*) or mourning gecko (*Lepidodactylus lugubris*) tend to lick water droplets which condense off the sides of their enclosure, therefore misting is advised in these species. Chameleons mostly benefit from water drippers with catch systems since they typically drink from water droplets which form in nature. Frequent water changes are a must in preventing bacterial colonization which can lead to mouth rot or stomatitis. A recommended practice is to fill the water bowl with acidified water to suppress the multiplication of *Aeromonas hydrophila*, whilst simultaneously cleaning the water-bowl every 1-2 days [30].

Water bowls should be positioned so they will not spill and create high humidity conditions which aid in blister disease in snakes or shell rot in tortoises [31]. Shell rot is caused by fungi and bacteria which colonize tortoises' shell resulting in hyperemia, ulceration, and fibrin deposition. If left untreated, the infection will rot through the bone and into the body cavity, resulting in septicaemia and death [32]. Good water quality is crucial for the health of aquatic species. Feces and food debris buildup must be prevented as would otherwise cause rapid changes in the salinity, pH, and nitrogen levels of the water, promoting pathogenic multiplication. Therefore, the use of a high-quality water filtering system together with commercial water testing kits is recommended [33].

Many reptile species, such as the young Garter snake (*Thamnophis sirtalis*), experience marked water loss from their dermis. Unless provided with a water source, they will become desiccated within 3-4 hours. Furthermore, reptiles being treated with medication must be provided with lots of water to avoid renal failure [30]. Dehydration is commonly seen in captive reptiles due to incorrect husbandry. Clinical signs may include but are not limited to, loss of skin turgor, wrinkling of the integument, and anorexia. If left untreated, dehydration leads to reduced renal perfusion and increased cardiac load which predisposes the affected reptile to renal damage. As a result, plasma uric acid increases, leading to the precipitation of uric acid salts in joints (referred to as articular gout: Figure 2), on serosal surfaces (mainly the pericardial sac), and parenchymal organs (mostly the kidney, liver, and lungs). Formed urate microcrystals destroy kidney tubules, resulting in granulomatous lesions referred to as tophi, which over time, become heavily mineralized with calcium, causing potential renal failure [34]. This leads to the steady deterioration of the reptile patient whose kidneys fail to undergo normal regulatory mechanisms such as the excretion of toxic metabolites. In reptiles, diseases of the renal system account for a significant amount of morbidity and mortality, and therefore attention must be paid to its prevention, which centers on maintaining proper hydration via correct husbandry practices [35].

Figure 2: Swollen digit in a black-throated monitor (*Varanus albigularis microstictus*) resultant of articular gout. Source: Dr. Raoul Stafrace.

Renal injury caused by dehydration may have many other consequences, one of which is MBD. This is known as renal secondary hyperparathyroidism, which together with nutritional secondary hyperparathyroidism form the two most presented types of MBD. Renal secondary hyperparathyroidism is more commonly observed in older animals. Its pathogenesis typically starts when kidney function deteriorates and fails to maintain adequate levels of calcium and phosphorus in the blood. This is often resultant of chronic renal insufficiency which is mainly caused by dehydration, high protein intake, or primary renal injury. As a result, phosphate filtration decreases leading to hyperphosphatemia. Concurrently, calcium is retained, thus reptiles suffering from renal hyperparathyroidism are often hypocalcaemic with high phosphorus levels [36]. Hyperphosphatemia and renal failure have a negative impact on the normal synthesis of calcitriol from 25-hydroxycholecalciferol in the kidney. This decreases calcitriol production which is the most active form of vitamin D. Calcitriol is needed to increase the absorption of intestinal calcium. If inadequate calcium levels are absorbed, calcium is resorbed from the bones as compensation. Over time, osteopenia develops which weakens the bones, leading to osteoporosis, osteomalacia, and MBD [37]. Reptiles typically present as lethargic with painful limbs, lameness, and reluctance to move due to bone brittleness and possible fracturing. Prognosis is poor in most cases since treatment is mainly supportive, hence it is of utmost importance to focus on the prevention rather than the treatment [36].

2.2 Nutritional disorders

Reptiles have evolved to occupy various ecological niches and therefore possess varying nutritional demands which are often challenging to mimic in captivity. Despite increasing knowledge in the nutritional field, poor feeding practices and imbalanced diets are still encountered and are one of the leading causes of non-infectious diseases in captive reptiles. In general, reptiles can be grouped into herbivores, omnivores and carnivores [33]. Rodent-eating carnivores, like many snakes, typically encounter minimal nutritional issues. However, challenges may emerge when fed overweight rodents or rodents which have been frozen for a long time, resulting in the loss of water-soluble vitamins. Insectivorous reptiles should be provided with a variety of insects such as crickets, waxworms, locusts, mealworms, and flies which, before being fed, should be nutrient-loaded and dusted with calcium and vitamins to provide a complete diet [38]. A significant factor in achieving successful lizard husbandry is the provision of insects as a food source, with 80% of the outcome contingent on their availability and quality [39].

Nutritional disorders vary among species and feeding strategies and may result from imbalances in essential nutrients such as protein, vitamins, and minerals. These disorders can also arise due to defects or other health conditions that hinder the proper utilization of nutrients [40]. For example, herbivorous reptiles such as green iguanas (*Iguana iguana*) are more prone to develop MBD resultant of calcium deficiency from inadequate diets, whilst snakes are more susceptible to generalized starvation rather than nutritional deficiency due to their consumption of whole prey. The most frequently encountered nutritional disorders include MBD resulting from calcium and vitamin D_3 deficiencies, hypovitaminosis A, visceral and articular gout due to dehydration, and starvation [41]. Given that most diets are inadequate (such as insectivore diets which are low in calcium and vitamin D) and only a few animals possess the ability to synthesize essential nutrients like vitamins and minerals, supplementation is essential and must be provided orally via diet. Through the correct and selective use of nutritional supplements, a range of common problems like growth irregularities, juvenile diseases, and fertility disorders can be prevented or mitigated at a low cost [39].

2.2.1 Metabolic bone disease of nutritional origin

MBD is a term used to describe a range of medical disorders that have an impact on the structural integrity and functionality of bones. The most common causes of MBD in captive reptiles include inadequate dietary calcium and vitamin D_3, lack of UVB exposure, imbalanced calcium-to-phosphorus ratio (mostly phosphorus excess) in the diet, and inadequate temperature zones. In captivity, animals may not receive adequate UVB exposure due to multiple factors, including the inability of ultraviolet light to penetrate materials like Perspex or glass or the infrequent replacement of ultraviolet bulbs. Furthermore, UV light must be provided with a basking zone which is necessary for the temperature-dependent conversion of pre-vitamin D_3 in the skin to vitamin D_3 [37].

MBD is mostly seen in actively growing reptiles, reproductively active females, and herbivorous and insectivorous species on a calcium and vitamin D-deficient diet and/or inadequate imbalances in the calcium: phosphorus ratio of the diet [34, 37]. This is referred to as nutritional secondary hyperparathyroidism. In captivity, the ideal calcium-to-phosphorus ratio of herbivorous diets should be greater than 2-3:1 or higher. Wild tortoise diets are high in calcium; thus, this ratio can be up to 4:1 [33]. An excess of phosphorus rather than calcium results in hyperphosphatemia. The body reacts by signaling to the parathyroid glands to secrete parathormone, which induces the resorption of calcium from the hydroxyapatite crystals in the mature bone matrix. As a result, bones weaken and develop a sponge-like consistency [34]. Demineralization of bony tissue leads to more pliable bones which may deform, fracture, or swell due to fibrous thickening. In Chelonians, MBD is evident through the softening and pyramiding of the shell, resulting in a weakened plastron and carapace (Figure 3, 4). In lizards, bowing of the mandible is common due to tongue muscle contraction of demineralized bone. The affected reptile often presents as weak and lethargic, with stunted growth and loss of movement. Additionally, prolonged hypocalcemia leads to nerve and muscle dysfunction, which is seen as twitching digits, hyperesthesia, seizures, tongue dysfunction, or prolapse of the cloaca, colon, hemipenis, or oviduct. In reproductive females, demineralized eggs may lead to dystocia or follicular stasis [42]. Prevention and therapy must focus on correcting underlying husbandry issues, while also providing essential supportive care and supplementation. Diets must be improved to correct the inverse calcium-to-phosphorus ratio. Any concurrent conditions like dehydration or secondary infection should be addressed immediately [40].

Figure 3: Severe MBD in a Hermann's tortoise (*Testudo hermanni*). Note shell malformation and concurrent septicemic cutaneous ulcerative disease.
Source: Dr. Nikoletta Hetényi

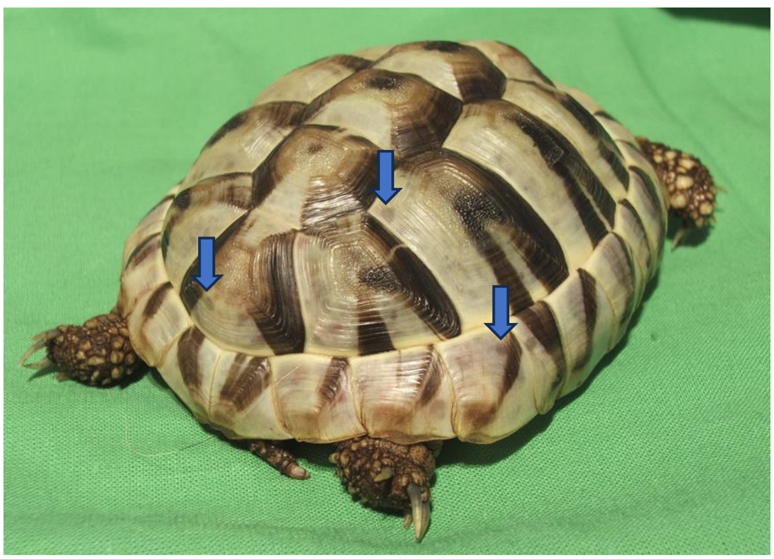

Figure 4: Hypoplastic osteoporosis in a Hermann's tortoise (*Testudo hermanni*). Indicated by the presence of dark grey spots on the carapace, signaling the absence of osteoid in the bone.
Source: Dr. Nikoletta Hetényi

2.2.2 Vitamin and mineral deficiencies

Numerous conditions associated with hyper- and hypovitaminosis have been recognized and documented in captive reptiles. Among these, **hypovitaminosis A** is the most frequently encountered vitamin deficiency, particularly among aquatic or semi-aquatic turtles and insectivorous reptiles (like chameleons and geckos) that are provided with inadequately supplemented diets [34]. Vitamin A plays a crucial role in various biological processes, including vision, growth, reproduction, and immune system function. Its primary function revolves around maintaining the integrity of normal epithelial tissues. While the absorption of carotenoids is likely prevalent in most animals, the conversion of provitamins into active vitamin A is limited in many carnivorous and omnivorous species due to the absence of necessary enzymes. Consequently, they are at a heightened risk of developing hypovitaminosis A. In contrast, herbivorous reptiles possess the ability to synthesize vitamin A from dietary carotenoids found abundantly in plant material. Thus, the occurrence of hypovitaminosis A in herbivorous reptiles is highly unlikely unless they experience prolonged anorexia, resulting in the depletion of vitamin A reserves in their liver. Similarly, carnivorous snakes, turtles, and lizards consuming whole prey also rarely suffer from hypovitaminosis A [40].

Hypovitaminosis A typically involves an increased frequency of replacing normal cuboidal or columnar epithelial cells (such as those found in mucosa and gland ducts) with stratified keratinizing epithelium [43]. The ongoing multifocal squamous metaplasia and hyperkeratosis of the epithelium of many organs lead to clinical disease, primarily in the respiratory, ocular, endocrine, gastrointestinal, and urogenital systems (in decreasing order) [34]. The continued desquamation of cells and concomitant decrease in normal secretory activity leads to the buildup of keratin debris, which together with decreased humoral and cellular immunity function, predisposes to secondary infection [43].

In aquatic turtles (such as red-eared sliders), the most frequent and distinctive signs of hypovitaminosis A include eyelid swelling, conjunctivitis, ocular oedema, xerophthalmia, and middle ear abscessation. Often, periocular lesions affect both eyes, leading to vision loss, which in turn results in anorexia and lethargy. Eyelid swelling and closure, especially in turtles and chameleons, occurs as a result of metaplasia and expansion of the harderian and lacrimal glands, secondary to vitamin A deficiency. In chronic cases, increased desquamation and eyelid closure also lead to debris buildup in the conjunctival sac. In panther chameleons (*Furcifer pardalis*), a diet deficient in vitamin A is also associated with ocular discharge, tail tip necrosis, reduced reproductive capacity, and skeletal anomalies like vertebral kinking. In severe instances of hypovitaminosis A, metaplasia of the epithelium subsequently blocks internal organs like the kidneys, ureters, and pancreas with desquamated debris, potentially leading to systemic illness and organ failure. For instance, crocodiles fed a vitamin A-deficient diet developed squamous metaplasia and hyperkeratosis of the renal tubules which led to visceral and renal gout [43].

Preventing hypovitaminosis A revolves around offering an appropriate species-specific diet. For carnivorous or omnivorous reptiles, it is advisable to provide whole prey instead of only feeding muscle meat. Removing internal organs during feeding should be avoided, as this would eliminate vital organs such as the liver which serves as the primary storage site for retinols. Invertebrates typically have a low vitamin A content, which is why it is crucial to improve their nutritional profile by gut-loading and dusting them with a vitamin A-containing supplement. Herbivorous reptiles are unlikely to experience vitamin A deficiency if they are provided with a varied diet of vegetables, as they can synthesize vitamin A from dietary precursors [37]. Therefore, in these species, the supplementation of retinols should be avoided due to the elevated risk of toxicity [43].

Hypovitaminosis E has been reported in captive aquatic and semi-aquatic Chelonians, snakes, and Crocodilians, especially those whose diet consists primarily of fish high in unsaturated fatty acids, such as mackerel, mullet, smelt, or obese small mammals. It is not an absolute but a relative deficiency of vitamin E due to high fat intake. Vitamin E has antioxidant properties and prevents unsaturated lipids from oxidation. The pathogenesis behind vitamin E deficiency centers around the ingestion of unsaturated or rancid fatty acids, which without sufficient amounts of vitamin E, are peroxidized into ceroid; a waxy brown pigment. Ceroids are mainly deposited in fat, inducing a granulomatous inflammatory reaction known as steatitis or yellow fat disease [34]. Other possible outcomes include skin sloughing, fat necrosis, nutritional myopathy, and secondary infections [42]. A typical clinical finding includes the presence of firm subcutaneous fatty nodules along with anorexia [43]. Vitamin E deficiency can be prevented by providing a varied diet containing low amounts of unsaturated or rancid fatty acids, whilst also supplementing vitamin E in the diet [34].

Vitamin B_1, commonly known as Thiamine, is a water-soluble vitamin exclusively synthesized by bacteria, fungi, and plants [37]. Thiamine plays a crucial role in the cognitive function of all living organisms and therefore must be obtained orally through dietary intake. Induction of **thiamine deficiency** is commonly seen in captive fish-eating reptiles and semi-aquatic turtles which are fed fish high in thiaminase enzyme, such as goldfish or fathead minnow. This deficiency can also result from improperly thawed frozen fish, which, when thawed slowly at room temperature leads to the depletion of thiamine due to thiaminase enzyme activity [40]. As prevention, it is recommended to thaw frozen fish in the refrigerator to avoid thiaminase activation, or in hot water (80°C) for 5 minutes to denature thiaminase. Similarly, offering frozen-thawed vegetables containing phytothiaminases could also lead to thiamine deficiency in herbivorous reptiles. Thiamine is highly labile and undergoes quick deterioration when stored naturally. Consequently, thiamine-containing supplements should not be used beyond their expiration date, as recent studies have shown that expired supplements resulted in thiamine deficiency in *Anolis* lizard species. A typical outcome of thiamine deficiency includes nerve degeneration, which leads to necrotizing encephalopathy and neuritis. Thus, clinical findings consist of neurological deficits such as fine muscle tremors, torticollis, incoordination, opisthotonus, and sudden death [43].

Furthermore, reptiles which heavily consume eggs, such as monitor lizards and certain snake species, may experience a **deficiency in biotin: Vitamin B_7**. This deficiency is linked to the presence of avidin in raw egg white, which has anti-biotin activity. Wild reptiles typically eat embryonated eggs containing higher biotin levels, when compared to the unfertilized eggs fed in captivity, and are therefore less prone to being deficient. Also, the egg yolk is rich in biotin. In captivity, clinical signs of biotin deficiency are mainly neurological, however, other signs such as muscle weakness, the fracturing of keratin filaments such as scales, beaks, and claws, together with dysecdysis are possible [42].

Lastly, iodine is an important mineral required for proper thyroid function. It plays a crucial role in the synthesis of thyroxine and triiodothyronine hormones, thereby influencing nutrient, carbohydrate, and fat metabolism. In reptiles, **iodine deficiency** has been linked to neoplasia of the thyroid gland and consequent deficiencies of thyroid hormones, leading to nutritional secondary hypothyroidism. Myxedema, cardiac disease, and goiter have been reported in Chelonians. Hypoiodinism usually results from excessive intake of plant material containing goitrogens, such as broccoli, cabbage, kale, and bok choy (*Brassica* genus). Therefore, feeding such plants routinely or abundantly should be avoided [43].

2.2.3 Improper feeding practices

Obesity is frequently encountered in captive reptiles as a result of improper diet and husbandry. Common causes include frequent feeding of high-fat diets, overconsumption due to unlimited food access and lack of exercise [37]. Recent studies have also suggested that the absence of hibernation in captivity could be a potential factor behind obesity in certain species. As a result, a surplus of energy is generated when energy intake exceeds the species' energy expenditure, leading to a positive energy balance and subsequent obesity. Fat accumulates in subcutaneous tissues, within the coelom and some parenchymal organs such as the liver. The obese reptile patient typically presents with excess fat over the vertebral column and possible coelomic distension which must be differentiated from ascites or tympany. Some species of geckos, such as the leopard gecko (*Eublepharis macularius*) also store fat in their tail, which considerably thickens as a result of weight gain [43]. The infiltration of fat into liver cells can lead to liver enlargement and dysfunction, which may manifest as anorexia, jaundice and, in severe cases, death. This condition is referred to as hepatic lipidosis; a common pathological finding in tortoises and lizards which are fed diets high in fat [42]. Obesity may have other outcomes, such as dystocia and a shorter life expectancy. Hence, it is crucial to inform owners about appropriate dietary choices and feeding frequencies. For instance, lean prey is recommended for carnivorous reptiles, whilst herbivorous species should have diets rich in fiber. Insect feed should be low in fat, therefore, a recommended practice is to feed the adult form of an insect (such as the mealworm beetle) rather than the larval form (mealworm), as its nutritional content is much lower in fat and higher in protein. Lastly, expanding the reptile's enclosure or modifying its habitat to stimulate natural hunting behaviors can be considered to promote more exercise [37].

Similarly, suboptimal husbandry and diet are the most common environmental causes resulting in **anorexia and cachexia** in captive reptiles. Reduced food intake may result due to several causes, such as feeding inappropriate food items and having improper environmental conditions in captivity such as low temperature, overcrowding, frequent handling, and other unsuitable husbandry practices causing stress. As a result, caloric intake will be reduced, leading to a loss of muscle mass and adipose deposits, and eventual dehydration unless water consumption is ensured. Typical clinical signs of anorexia include prominent vertebral processes and iliac crests, wrinkled skin and enophthalmos. It is physiologic for many gravid females and snakes before ecdysis to refuse feed and thus undergo temporary anorexia, which is normal behavior in these cases and must not be mistaken as pathologic. Once again, starvation can be prevented by knowing species-specific requirements and maintaining proper husbandry [43]. A recommended practice is to monitor the reptile's body condition by regular weighing. Most species have average body weights recorded and therefore can be compared when suspecting anorexia. Deviations in body weight are typically indicators of underlying disease and should be addressed immediately [37].

2.3 Other non-infectious disorders

2.3.1 Toxicological problems

Various toxicities have been reported in reptiles. For instance, **lead toxicosis** was detected in a spur-thighed tortoise (*Testudo graeca*) after having ingested a lead shot. The affected Chelonian presented with gut stasis, anemia, renal failure, and possible neurological disease [42]. A similar case was recorded in a common snapping turtle (*Chelydra serpentina*) which was found containing fishing gear and lead weights in its alimentary tract. Furthermore, lead poisoning was also identified in a group of alligators which were fed pre-killed nutria. The source of lead contamination was traced back to the shot that was used to kill the nutria [44]. Similarly, high doses of pyrethrin, given to reptiles as a form of mite treatment, are the leading cause of **organophosphate poisoning** resulting in neurological signs such as opisthotonos, head tilts, seizures, and death [42]. In addition, over-supplementation of vitamin A leads to iatrogenic **hypervitaminosis A,** typically characterized by flaking, ulceration, blistering, and eventual whole sloughing of the skin. Consequent epidermal and dermal separation may be complicated by secondary bacterial or fungal infection. Vitamin A intoxication cannot be reversed; thus, emphasis must be made on its prevention. Herbivorous reptiles are highly unlikely to develop vitamin A deficiency, therefore supplementation in such species should be avoided unless a deficiency has been diagnosed. Even if deficiency is confirmed, vitamin A should not be supplemented in higher than recommended doses or for long periods of time due to its extended storage in the liver. Furthermore, excessive feeding of raw liver should be avoided [37]. Lastly, gentamicin, an aminoglycoside antibiotic, is normally indicated for *Pseudomonas* infections. However, several studies have exposed the development of **nephrotoxicity** following administration of gentamicin. As a result, damaged kidneys led to visceral gout and subsequent precipitation of uric acid in many extrarenal sites. As prevention, reptiles should hardly be given any food during treatment in attempt to reduce the amount of uric acid circulating in the body [20].

2.3.2 Overgrown beaks

Overgrown beaks are encountered in Chelonians with a 2% prevalence [45]. The leading cause of beak overgrowth is the provision of soft food diets which lack abrasive qualities, hence preventing the natural wear of the beak. Decreased foraging times have also been suspected of playing a role due to the reduced tearing action associated with grazing. Additionally, any condition resulting in the failure of naturally wearing the upper and lower beaks, such as trauma or abnormal jaw development, can result in uneven beak proportions. For instance, MBD in calcium-deficient tortoises causes distorted growth of the upper rhamphotheca and consequent keratinous overgrowth [46]. In general, overgrown beaks interfere with feeding and might result in malocclusion or subluxation of the temporomandibular joint, especially if the maxilla is affected. Therefore, prevention is essential by providing abrasive feed or substrate, such as cuttlefish or limestone blocks, to facilitate natural wear or by trimming when necessary to correct overgrowth [47].

2.3.3 Gastro-intestinal diseases

Typical gastrointestinal presentations in reptiles include **vomiting, regurgitation, diarrhea, constipation and inappetence.** Many factors are responsible for gastrointestinal-related emergencies, however, most cases stem from inadequate husbandry and nutrition. For example, rough handling or suboptimal temperatures, especially after feeding, may cause regurgitation in snakes. On the other hand, lizards and tortoises rarely vomit, however, are more prone to intestinal disease caused by the ingestion of foreign bodies. It is common for both lizards and Chelonians to consume sand, soil, stones or other substrates present in their enclosures. Certain *Boidae* snakes kept on paper towels have been reported to ingest pieces of tissue when fed directly on the substrate. The ingested substrate can usually (depending on the substrate in question) be palpated within the digestive tract. Other clinical signs encountered may include lethargy, dehydration, and inappetence. Foreign body ingestion in reptiles may have life-threatening consequences, such as total obstruction of the gastrointestinal tract or perforation leading to severe peritonitis. Therefore, feeding directly on indigestible substrate should be avoided at all costs [48].

Feeding practices also play a role in reptile indigestion. For instance, feeding many prey items at once can obstruct the digestive tract. Similarly, low-fiber diets typically result in constipation, seen as reduced fecal output and straining when defecating. Constipation may also be caused by other husbandry-related factors such as inadequate exercise, suboptimal environmental temperature and humidity, together with a lack of water source causing chronic dehydration. Low temperature leads to decreased motility in the gastrointestinal tract, whilst chronic dehydration may form urate plugs blocking the exit of feces and hence aiding in constipation. Metabolic disorders such as hypocalcemia have also been reported as a contributing factor. Other extramural causes include nephritis, neoplasia, abscesses, or ovostasis. Frequent soaking in warm water promotes hydration and healthy defecation in most reptiles. Furthermore, psyllium has laxative properties and can be given in cases of constipation [43].

Fecal consistency varies between reptiles and mainly depends on their species-specific diet. Therefore, knowledge regarding normal fecal consistencies is required to avoid misdiagnosing soft feces or diarrhea. Diarrhea is mostly common in herbivorous species which are fed diets low in fiber and/or high in fermentable carbohydrates. Therefore, providing adequate amounts of fiber whilst avoiding food items high in fermentable sugars (unless suitable for the species) is ideal. Treatment focuses on determining the underlying cause and correcting it. Ruling out parasitosis is a must for all gastrointestinal-related disorders. Prevention centers around maintaining an adequate diet (such as increasing fiber in fiber-lacking diets) and husbandry (thus optimizing temperature, humidity, and so on) [43].

2.3.4 Urogenital disorders

Egg binding or stasis, commonly known as dystocia, is a condition characterized by the female's inability to pass mature eggs into the reproductive tract. This disorder is common in many captive reptile species and is frequently associated with improper husbandry and nutritional deficiencies. Furthermore, egg stasis can be classified into two types: pre-ovulatory stasis and post-ovulatory stasis [49].

Post-ovulatory stasis develops when ovarian follicles are ovulated into the oviduct without any eggs, or only a portion of eggs, being laid [49]. It mainly onsets due to hypocalcemia, leading to weakness of the animal together with other possible signs of muscle fasciculation, seizures, or pathologic fractures. If a female reptile is reproductively active and simultaneously has poor husbandry conditions, it is typical for hypocalcemia to develop due to the body's extra demand for calcium during egg production. As a result, the affected female will experience difficulty ovipositing shelled eggs/fetuses. Other possible causes of dystocia include lack of nesting material and suitable space, improper temperatures, lack of water access, malnutrition of the female, improper calcification or malformation of the eggs, fractured pelvic bones, and cystic calculi. Evidence of dystocia may vary, but possible clinical findings include decreased stool production, anorexia, lethargy, signs of discomfort, straining, and prolapse of the cloaca or distal reproductive tract [48]. Most cases present with a persistent mass located caudally and a previous history of laying. Lizard species are easier to diagnose as will be visibly distended with eggs, however, are more sensitive to ovostasis and can prove fatal within days. In comparison, certain snake species are more resilient and can survive longer periods of dystocia [42]. In tortoises, it is sometimes possible to palpate the coelomic cavity or pre-femoral fossa to reveal the presence of eggs, however, a more definitive diagnosis would require radiography or ultrasonography. Fluid found within the coelomic cavity is indicative of coelomitis and requires antibiotics due to the increased risk of sepsis. Reptiles presented with coelomic or follicular abnormalities, depression and lethargy require immediate intervention to undergo ovariectomy or salpingohysterectomy. Additionally, dystocia cases related to severe hypocalcemia require instant correction of calcium, electrolytes, temperature, and hydration [48].

Pre-ovulatory stasis is a similar condition which has also been recorded in lizards and Chelonia. In this condition, ovaries produce follicles which enlarge to ovulatory size but fail to ovulate or resorb and therefore are not shed into the reproductive tract. As a result, the ovaries harbor a significant number of yolks (up to 40) which can displace other internal organs and increase susceptibility to secondary diseases such as egg yolk coelomitis and malnourishment. The affected reptile typically presents with depression, inappetence, lethargy and a moderately distended abdomen. Radiography is required to confirm diagnosis and differentiate between pre- and post-ovulatory stasis. Radiographic findings reveal clusters of spherical densities in the abdomen rather than the typical oval-shaped densities, which lack the usual thin, partially calcified shells. The cause of this condition is not entirely clear yet, however, it is believed to be linked to a prolonged absence of a male or brief male exposure after a period of isolation. Treatment is rather emergent and requires surgical ovariectomy [42]. The key to preventing dystocia centers around proper husbandry management, where appropriate lighting, temperature, humidity, and nutrition must be provided [49].

Many cases of **prolapse** have been described in herpetology. Any prolapse seen in snakes, lizards, or Chelonians is emergent and should be addressed immediately. Cloacal prolapses are mainly associated with gastrointestinal, reproductive, or urinary systems. Excessive straining is a common underlying cause of prolapse which typically occurs secondary to other conditions such as dystocia, urolithiasis, impaction, organ dysfunction, intra-coelomic disease, neoplastic mass, or improper husbandry. Most cases are treated by replacing the affected prolapsed structure and determining the underlying cause. However, if prolapsed for a long period of time, might need surgical resection due to tissue necrosis and devitalization. Before replacement, it is recommended to place the affected reptile in a saturated sugar solution bath for 20-30 minutes to decrease swelling of the prolapsed tissue. After, gentle replacement back into its anatomical position can be attempted using a significant amount of lubrication. Affected tissue is often friable and must be handled carefully to prevent further injury. It is important to inform the owner that prolapse replacement is not a permanent solution unless the root cause is pinpointed and resolved, as otherwise, the issue is likely to recur [48]. Similarly, hemipenes and phallus prolapse are mainly seen due to persistent straining, sexual frustration, infection, or irritation due to dried hemipenes secretions. If following prolapse, the hemipenes or phallus is too necrotic or traumatized, it can be surgically removed without compromising urination [42].

Lastly, another clinical finding commonly reported in snakes, Chelonians and lizards is **urolith precipitation** of urate salts. Tortoises and green iguanas are mostly affected. Uroliths, or urinary calculi, are microscopic precipitates or polycrystalline concretions present in the urinary tract. Uroliths are mainly found in the urinary bladder and, when accumulated, are commonly referred to as bladder stones. Certain reptiles, such as snakes, lack a urinary bladder and therefore develop uroliths in the distal ureters instead, where urine is frequently stored in these species. The main cause of urolith formation is currently unknown, however, some proposed etiologies include dehydration, nutritional deficiencies (such as hypovitaminosis A and D) and excessive intake of dietary protein, calcium or oxalates [50]. Calculi can also form around a nidus of bacteria, refluxed egg in females (typically seen in tortoises whose fully developed eggs are retropulsed into the bladder and unable to be passed normally) or a parasite [42]. As a result, the affected reptile will present with inappetence, anorexia, lethargy, constipation, dysuria and possible dystocia or hindered growth. Calculi are unable to be passed through the urethra and are therefore allowed to reach significant sizes over time. Small calculi generally do not cause any lesions or clinical signs. However, large calculi with rough surfaces can irritate the bladder's lining, resulting in hypertrophy of the bladder wall with possible pressure necrosis and epithelial hyperplasia. As a result, cystitis develops leading to hematuria, pain, and discomfort. Treatment mainly revolves around surgical intervention to remove the obstructing and irritating bladder stone. Prevention centers around optimizing nutrition based on species-specific requirements [50].

2.3.5 Traumatic and spontaneous damage

Every reptile's enclosure should be carefully inspected to avoid any **spontaneous damage.** Inadequate environment may lead to rostral abrasions due to the rubbing, pushing, or banging onto abrasive surfaces within the enclosure, leading to superficial or deep lesions which are mainly seen on the tip of the nose. Similarly, substrates provided must be non-irritant and should not contain any aromatic compounds or residues of cleaning products. Such substances will result in contact dermatitis of the reptile's skin seen as erythema, blister formation, exudation, or petechial hemorrhaging. Treatment should be immediate to prevent any secondary infections, and any underlying causes should be corrected to prevent recurrence. Additionally, reptiles should be protected from any predator attacks resulting in traumatic damage like open wounds or shell fractures. Wounds across the body surface are commonly encountered when feeding live prey, especially when unattended (Figure 5). Some species, such as the male iguana, are very aggressive when mating and will repeatedly bite the female's shoulder area when mounting. Shell fractures are mainly due to fall injuries or predator attacks. Reptiles kept outside are commonly attacked; therefore, attention must be paid when constructing outdoor enclosures, making sure that predators like birds, rodents or carnivores have no access to the species [47].

Figure 5: Healing lesions in a ball python (*Python regius*) resultant of rodent bites.
Source: Dr. Raoul Stafrace.

Many lizard species, such as geckos and iguanas, possess the ability to drop a section of their tail in response to a predatory attack. Such behavior is referred to as **caudal autotomy**. These reptiles contain preformed 'fracture planes' in their tail's vertebrae which allow a clean separation with minimal bleeding. This defense mechanism is mainly employed for predator attacks; however, certain over-zealous forms of handling and restraint may threaten the reptile and trigger caudal autotomy, especially if the tail is grasped. Over time, the tail will consequently re-grow, with skin, scales, and muscle tissue mimicking the original components of the tail. Coccygeal vertebrae are replaced by a rod of cartilage instead. Following autotomy, the area should be treated as an open wound. Topical antiseptics like povidone-iodine should be administered to prevent secondary infection [42]. When dropping their tail, reptiles lose most of their fat reserves which were previously stored proximally. Furthermore, tail regeneration requires a lot of energy, so affected reptiles will typically have reduced energy stores, resulting in hindered mating success, locomotion and so on [51].

Lastly, **sepsis** is a life-threatening condition, often encountered secondary to inadequate husbandry. Clinical signs include lethargy, petechial hemorrhaging, stomatitis, ventral erythema in snakes, skin sloughing, and seizures. In Chelonians, sepsis is mainly characterized by superficial to deep abscessation, referred to as 'septicemic cutaneous ulcerative dermatitis'. Intensive treatment is indicated for all septicemic cases. Ceftazidime is a preferred antibiotic option due to its less frequent dosage, broad anaerobic spectrum, lower risk of nephrotoxicity, and its effectiveness in targeting *Pseudomonas* infections [48].

3. Objectives

When I first started researching for my literature review, I found that there were ample articles and studies addressing the subject. My primary focus for my thesis was to provide a comprehensive summary of non-infectious disorders observed in captive reptiles. Given the diverse nature of these disorders, my focus centered on their etiology, clinical signs, and preventative measures. To achieve this, I made sure that I had ample supporting information for each disorder under review. This involved correlating disorders reviewed with their respective underlying husbandry or nutritional problems. My objective was to provide a well-informed and holistic approach on the subject matter, by gathering a variety of peer-reviewed articles and summarizing them comprehensively in a clear and straightforward manner. Additionally, I placed an emphasis on diversity in my selection criteria and strived to encompass various reptile species in different thematic areas.

4. Method

To construct this literature review, a rigorous and systematic search strategy was employed, which involved utilizing several highly regarded academic databases and platforms. This review is based on collecting data in English language studies, including books, conference proceedings, chapters, journal articles, and electronic resources. The key sources for gathering peer-reviewed data included Google Scholar, ResearchGate, ScienceDirect, PubMed, Vin, and HuVeta. The selection of these platforms was deliberate, as they are recognized for their wide-ranging coverage of academic literature, ensuring that a broad spectrum of high-quality research findings was considered. In total, the number of reviewed articles amounted to 51, highlighting the depth and breadth of research conducted.

5. Results

The continually expanding body of knowledge in the field of exotic animal medicine is gradually narrowing the information gap that has historically existed when compared to the wealth of information available for more common companion species. This growth has the potential to significantly influence the health and well-being of a multitude of exotic pets. However, despite the increasing understanding of herpetology, there remains a prevalence of husbandry and nutrition-related disorders among captive reptiles.

Reptiles constitute an incredibly diverse and extensive group of animals, encompassing thousands of species. These creatures are distributed across various regions worldwide, having adapted to a wide spectrum of climates, habitats, and natural dietary sources, with each species having evolved both anatomically and physiologically to thrive in its native environment. As a result of this diversity, reptiles of different species exhibit highly distinctive captive and nutritional requirements. Replicating their natural dietary and environmental conditions in captivity can prove to be a challenging endeavor. This complexity, combined with the reptiles' remarkable ability to mask signs of illness, presents a formidable challenge for veterinarians when formulating general recommendations for their care. Although proficient clinical diagnostics and therapeutic interventions are invaluable in addressing numerous medical cases, it is essential to recognize that a lasting and comprehensive resolution of many issues can only be achieved by understanding and rectifying deficient husbandry and nutritional practices. After reviewing numerous articles, it became clear that many non-infectious diseases in reptiles stem from improper husbandry or nutrition. Most clinical cases result from inadequate conditions such as temperature, lighting, humidity, and dietary requirements, which should be species-specific and adequately provided to ensure success in captivity. Unfortunately, many reptile owners are poorly educated in herpetology and proper husbandry management, increasing prevalence of non-infectious disease. Therefore, emphasis must be placed on educating reptile owners thoroughly to avoid a wide range of diseases which can be easily prevented with proper care.

6. Discussion/Conclusions

Considering the objectives of my literature review and the findings I have come across, it can be deduced that prior research has provided valuable insights into extensively studied non-infectious diseases. However, it is crucial to recognize that not all diseases have received the same level of research attention. For example, further investigation is required to fully understand the etiology of pre-ovulatory stasis and urolith formation in reptiles, therefore aiding in their prevention. Additionally, due to the vast diversity of reptile species, there is a scarcity of precise information regarding the appropriate husbandry and nutritional needs of each individual species. For instance, exact requirements for temperature, humidity and lighting have not been scientifically proven for all existing species, and available literature only serves as recommendations based on experience and anecdotal information. Similarly, guidelines regarding most preventative/treatment protocols are only suggestive, and further scientific investigation is required to fully understand exact dosages and possible adverse reactions. For example, most vitamin supplements only offer a general dosage guideline (irrespective of species), offering a degree of toxicity risk in some species.

Despite my efforts to gather data from a diverse array of sources, it's important to acknowledge that each study bears its unique set of inherent limitations, which may exert a potential influence on the resulting findings. It is within this context that a call for further exploration becomes indispensable, as research conducted within this scientific framework holds the key to equipping veterinarians and caretakers with the indispensable insights required to deliver well-founded guidance concerning the husbandry and nutritional prerequisites of reptiles.

However, the real progress, I believe, would be to enhance the education of reptile owners concerning potential non-infectious diseases and the corresponding measures for prevention. Most diseases can easily be prevented with proper husbandry and nutrition. Therefore, it is of utmost importance to ensure that reptile caretakers are well-informed about correct husbandry management and the potential consequences of neglecting these crucial aspects. This includes but is not limited to creating suitable enclosures, maintaining proper temperature and humidity levels, and providing an appropriate diet tailored to the specific species' requirements. Such education not only fosters the well-being of these unique reptiles but also acts as a powerful prevention strategy against non-infectious diseases that can often arise due to suboptimal care. In addition to husbandry practices, owners should be equipped with the knowledge and skills necessary to monitor their reptiles effectively. This involves teaching them how to observe their reptiles for any early signs or symptoms of illness, and when to seek professional help. Early detection is paramount in ensuring prompt intervention and treatment, which can make a significant difference in the prognosis of many health issues. Educating them on the appropriate timing for consulting a reptile specialist can help prevent minor health concerns from escalating into more serious conditions. By promoting such awareness, we can foster a culture of responsible reptile ownership and ensure long and healthy reptile lives in captivity.

7. Summary

In general, reptile owners frequently encounter an array of challenges resulting in elevated mortality, poor reproductive rates, and major disease outbreaks within captive collections. It is worth emphasizing that a significant portion of the health issues that afflict reptiles can be unequivocally traced back to inadequacies of husbandry and nutrition. To successfully address these challenges, one must delve deeply into an intricate understanding of the unique requirements, behaviors, and natural habitats exhibited by the diverse reptilian species under their care.

As the earliest vertebrate group to adapt to a terrestrial lifestyle from a phylogenetic perspective, reptiles have undergone significant adaptations over time to thrive in diverse environments. Therefore, it is imperative when maintaining them in captivity, to replicate their natural habitats as similarly as possible. Failures in adequately replicating essential factors such as temperature, lighting, humidity, social requirements, and dietary intake are at the core of non-infectious diseases in reptiles. This literature review comprehensively lists the most commonly observed non-infectious diseases in captivity, with their etiologies, clinical signs and preventative measures highlighted. Conclusively, most encountered disorders resultant of improper husbandry include hypothermia from suboptimal temperatures, thermal burns induced by unprotected heating equipment, dysecdysis and pyramiding resultant of low humidity values, and chronic dehydration and subsequent gout due to absence of water sources. Similarly, the most frequently reported disorders from a nutritional perspective encompass MBD from calcium and vitamin D_3 deficiencies, hypovitaminosis A due to imbalanced turtle or insectivore diets, and starvation from calorie deficits. Unfortunately, these disorders are often identified at a stage where treatment becomes more challenging. Thus, it is significant to emphasize the importance of prevention, which centers around educating reptile caretakers about species-specific requirements, proper husbandry techniques, and maintaining a well-balanced dietary intake. This approach ensures that optimal care is provided for reptiles in captivity, thereby preventing non-infectious diseases. Given the intricate nature of this subject, it is highly recommended that the reader refers to the provided literature for a deeper and more comprehensive understanding of non-infectious diseases in captivity.

8. References/Bibliography

1. Uetz P (2022) Species Numbers (as of December 2022). http://www.reptile-database.org/db-info/SpeciesStat.html. Accessed 25th September 2023.
2. Sfetcu, N. (2014). Reptiles: Crocodiles, Alligators, Lizards, Snakes, Turtles. Nicolae Sfetcu. 15
3. Walczyńska A., Kiełbasa A., Sobczyk M. (2016). 'Optimal thermal range' in ectotherms: Defining criteria for tests of the temperature-size-rule, Journal of Thermal Biology: 60(41-48). https://doi.org/10.1016/j.jtherbio.2016.06.006.
4. Tobias Wang T., Zaar M. et Al (2002). Effects of temperature on the metabolic response to feeding in Python molurus. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology. 133(3:509-527). https://doi.org/10.1016/S1095-6433(02)00250-7.
5. Mayer, J., & Donnelly, T. M. (2013). Clinical Veterinary Advisor: Birds and Exotic Pets. Entamoebiasis 100-101. ISBN: 9781-4160-3969-3.
6. Divers, S. (1996). Basic reptile husbandry, history taking, and clinical examination. In Practice, 18(2), 51-65. https://doi.org/10.1136/inpract.18.2.51
7. Adkins, E., Driggers, T., Ferguson, G., Gehrmann, W., Gyimesi, Z., May, E., ... & Klaphake, E. (2003). Ultraviolet light and reptiles, amphibians. Journal of Herpetological Medicine and Surgery, 13(4), 27-37. http://dx.doi.org/10.1016/j.cvex.2017.04.004
8. Donoghue, S., & McKeown, S. (1999). Nutrition of captive reptiles. Veterinary Clinics of North America: Exotic Animal Practice, 2(1), 69-91. https://doi.org/10.1016/S1094-9194(17)30140-8
9. Johnson, R. J., Lozada, L. S., Lanaspa, M. A., Piani, F., & Borghi, C. (2022). Uric acid and chronic kidney disease: still more to do. Kidney International Reports. https://doi.org/10.1016/j.ekir.2022.11.016
10. Raske, M., Lewbart, G. A., Dombrowski, D. S., Hale, P., Correa, M., & Christian, L. S. (2012). Body temperatures of selected amphibian and reptile species. Journal of Zoo and Wildlife Medicine, 43(3), 517-521. https://doi.org/10.1638/2011-0244R.1

11. Falcón, W., Baxter, R. P. et Al (2018). Patterns of activity and body temperature of Aldabra giant tortoises in relation to environmental temperature. Ecology and Evolution, 8(4), 2108-2121. https://doi.org/10.1002/ece3.3766
12. Wappel, S. M., & Schulte, M. S. (2004). Turtle care and husbandry. Veterinary Clinics: Exotic Animal Practice, 7(2), 447-472. https://doi.org/10.1016/j.cvex.2004.03.002
13. Mendyk, R. W., Augustine et Al (2014). On the thermal husbandry of monitor lizards. Herpetological Review, 45(4), 619-632.
14. Bacon, J. P. (1976). Thermoregulation in Varanus komodoensis in captivity—a preliminary report. Proc. Amer. Assoc. Zool. Parks and Aquar. 1976:211–214.
15. Coulson R.A., Hernandez T. (1964). Biochemistry of the Alligator. Louisiana, USA, Louisiana State University Press, Baton Rouge1964: 74-79
16. Munday, K. A., & Blane, G. F. (1961). Cold stress of the mammal, bird and reptiles. Comparative Biochemistry and Physiology, 2(1), 8–21. doi:10.1016/0010-406x(61)90069-x
17. Rouffignac M. (2007), The Challenges of Housing Sick and Injured Reptiles. https://www.vin.com/apputil/content/defaultadv1.aspx?pId=11242&id=3860721. Accessed 25th September 2023.
18. Chris Marshall MRCVS (1993) Housing and Husbandry of Snakes and Lizards, Veterinary Nursing Journal, 8:2, 38-45. https://doi.org/10.1080/17415349.1993.11012510
19. O'Malley B (2008) Reptiles--Raise Your Confidence on Husbandry and Health Care. https://www.vin.com/apputil/content/defaultadv1.aspx?pId=11268&id=3866674&print=1
20. Jacobson, Elliott. (1981). Diseases of Reptiles. Part I. Noninfectious Diseases. Compendium on Continuing Education for the Practising Veterinarian -North American Edition-. 3. 122-126.
21. MENDYK, R. W. (2015). HERPETOLOGICAL HISTORY. Herpetological Review, 46(4), 547-555.
22. Suedmeyer, W. K. (1995). Noninfectious diseases of reptiles. In Seminars in Avian and Exotic Pet Medicine (Vol. 1, No. 4, pp. 56-60). 10.1016/S1055-937X(05)80011-8

23. Mitchell, M. A., & Diaz-Figueroa, O. (2004). Wound management in reptiles. Veterinary Clinics: Exotic Animal Practice, 7(1), 123-140. https://doi.org/10.1016/j.cvex.2003.08.006
24. Wiesner, C. S., & Iben, C. (2003). Influence of environmental humidity and dietary protein on pyramidal growth of carapaces in African spurred tortoises (Geochelone sulcata). Journal of Animal Physiology and Animal Nutrition, 87(1-2), 66-74. https://doi.org/10.1046/j.1439-0396.2003.00411.x
25. Pingleton, M. Understanding Pyramiding. https://tortoiselibrary.com/health-and-medical-2/understanding-pyramiding/
26. Goodman, G. (2007). Common dermatoses in reptiles. In Practice, 29(5), 288-293. https://doi.org/10.1136/inpract.29.5.288
27. János, D., Imre, K., Herman, V., & Nicolae, C. (2012). A case of blister disease to a boa constrictor. Vet. Med, 88-91.
28. Oonincx, D., & van Leeuwen, J. (2017). Evidence-based reptile housing and nutrition. Veterinary Clinics: Exotic Animal Practice, 20(3), 885-898. https://doi.org/10.1016/j.cvex.2017.04.004
29. McGeough, R. (2016). Furcifer pardalis (Panther Chameleon)–A brief species description and details on captive husbandry. Biology, Engineering, Medicine and Science Reports, 2(2), 27-38. https://doi.org/10.5530/BEMS.2016.2.6
30. Zwart, P. (2001). Pathophysiology: Assessment of the husbandry problems of reptiles on the basis of pathophysiological findings: A review. Veterinary Quarterly, 23(4), 140–147. doi:10.1080/01652176.2001.9695103
31. Cannon, M. J. (2003, October). Husbandry and veterinary aspects of the bearded dragon (Pogona spp.) in Australia. In Seminars in Avian and Exotic Pet Medicine (Vol. 12, No. 4, pp. 205-214). WB Saunders. https://doi.org/10.1053/S1055-937X(03)00036-7
32. Assan Kasim, M., Senthil Kumar, K., & Palanivelrajan, M. (2017). Shell rot infection in red eared turtle. Int. J. Adv. Biol. Res, 7, 634-635.
33. Kischinovsky, M., Raftery, A., & Sawmy, S. (2017). Husbandry and Nutrition. Reptile Medicine and Surgery in Clinical Practice, 45–60. doi:10.1002/9781118977705.ch4

34. Frye, F. L. (1984). Nutritional disorders in reptiles. In Diseases of amphibians and reptiles (pp. 633-660). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4615-9391-1_25
35. Wilkinson, S. L., & Divers, S. J. (2020). Clinical management of reptile renal disease. Veterinary Clinics: Exotic Animal Practice, 23(1), 151-168. https://doi.org/10.1016/j.cvex.2019.09.002
36. Klaphake, E. (2010). A fresh look at metabolic bone diseases in reptiles and amphibians. Veterinary Clinics: Exotic Animal Practice, 13(3), 375-392. https://doi.org/10.1016/j.cvex.2010.05.007
37. Carmel, B., & Johnson, R. (2017). Nutritional and metabolic diseases. Reptile medicine and surgery in clinical practice, 185-195.https://doi.org/10.1002/9781118977705.ch15
38. Divers, S. J. (1999). Clinical Evaluation of Reptiles. Veterinary Clinics of North America: Exotic Animal Practice, 2(2), 291–331. doi:10.1016/s1094-9194(17)30126-3
39. Mariais, J., & Morgan, D. R. (1990). Reptile Husbandry. The Journal of the Herpetological Association of Africa, 38(1), 3–7. doi:10.1080/04416651.1990.9650272
40. Mancinelli, E. (2015). Overview of common nutritional disorders of captive reptiles. Vet Times, 21(09).
41. Donoghue, S. (1998, July). Nutrition of pet amphibians and reptiles. In Seminars in Avian and Exotic Pet Medicine (Vol. 7, No. 3, pp. 148-153). WB Saunders. https://doi.org/10.1016/S1055-937X(98)80006-6
42. Girling, S. J. (2013). Common reptile and amphibian diseases. Veterinary nursing of exotic pets, 297-318. https://doi.org/10.1002/9781118782941.ch21
43. Mans, C., & Braun, J. (2014). Update on common nutritional disorders of captive reptiles. Veterinary Clinics: Exotic Animal Practice, 17(3), 369-395. https://doi.org/10.1016/j.cvex.2014.05.002
44. Mitchell, M. A., & Diaz-Figueroa, O. (2005). Clinical Reptile Gastroenterology. Veterinary Clinics of North America: Exotic Animal Practice, 8(2), 277–298. doi:10.1016/j.cvex.2005.01.008
45. Varshney, J. P. (2018). Overgrown beak syndrome in chelonians. Blue Cross Book, (38), 81-82.

46. Pellett, S., Stocking, D., & Wissink-Argilaga, N. (2015). Tortoise feeding and nutritional requirements. Companion Animal, 20(4), 240-245. https://doi.org/10.12968/coan.2015.20.4.240
47. Schoemaker, N. J. (2016). Of scutes and scales: dermatologic conditions in reptiles with emphasis on chelonians. In SPONSORS OF THE 8 TH WORLD CONGRESS OF VETERINARY DERMATOLOGY (p. 426).
48. Music, M. K., & Strunk, A. (2016). Reptile critical care and common emergencies. Veterinary Clinics: Exotic Animal Practice, 19(2), 591-612. https://doi.org/10.1016/j.cvex.2016.01.009
49. Amata, A. C., Faisalb, N. H., Abd Kadirc, S. N., Fadzild, F., Evelyn, C., Corneliuse, C. G., & Sharipuding, N. N. M. (2014). Diagnosis and Surgical Intervention for Pre-ovulatory Egg Stasis in a Green Iguana (Iguana iguana). Journal of Wildlife Research, 2(4), 45-48.
50. Reavill, D. R., & Schmidt, R. E. (2010). Urinary tract diseases of reptiles. Journal of Exotic Pet Medicine, 19(4), 280-289. https://doi.org/10.1053/j.jepm.2010.10.007
51. Zwart, P., & Gröne, A. (2016). Pathologies of tails in reptiles.

9. Acknowledgements

First and foremost, I would like to express my sincere gratitude to my supervisor, Dr. Nikoletta Hetényi for her consistent guidance and inspiration. I am gratefully indebted to her valuable advice, vast knowledge and immense experience which motivated me to complete this literature review with success. I would also like to thank the Institute of Animal Breeding, Nutrition and Laboratory Animal Science for letting me write this literature review under their supervision. Additionally, I'd like to extend my heartfelt appreciation to Ehren Borg for all his help and advice in writing this thesis. Lastly, this endeavor would not have been possible without my parents, Anna and Chris Bonaci, who enabled me to pursue my dream of studying veterinary medicine in Budapest whilst also providing unwavering support throughout the years gone by.

Disclaimer: This work is funded by the Veterinary Sciences Scholarships Scheme – Ministry for Education and Employment.

10. Thesis progress report for veterinary students

UNIVERSITY OF VETERINARY MEDICINE, BUDAPEST

founded in 1787, EU-accredited since 1995

INTERNATIONAL STUDY PROGRAMS

secretary, student@univet.hu

Thesis progress report for veterinary students

Name of student: Lisa Bonaci

Neptun code of the student: YJY5D8

Name and title of the supervisor: Nikoletta Hetényi, research fellow

Department: Department for Animal Nutrition and Clinical Dietetics

Thesis title: Noninfectious diseases of captive reptiles

Consultation – 1st semester

Timing				Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2023	02	27	Online consultation: table of contents, references.	
2.	2023	04	21	Asking for updates	
3.	2023	04	26	First draft	
4.	2023	06	09	Literature review	
5.	2023	06	22	Literature review	

Grade achieved at the end of the first semester: 4

Consultation – 2nd semester

Timing				Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2023	09	28	Literature review	
2.	2023	10	04	Corrected manuscript	
3.	2023	10	25	Thesis update	
4.	2023	11	02	Final thesis	
5.	2023	11	03	Plagiarism check	

Grade achieved at the end of the second semester: 4

The thesis meets the requirements of the Study and Examination Rules of the University and the Guide to Thesis Writing.

I accept the thesis and found suitable to defence,

..........Dr. Vitéz Nóra..........
signature of the supervisor

Signature of the student: ....

Signature of the secretary of the department: ....

Date of handing the thesis in....03.11.2023......................

11. Supervisor approval

I, the undersigned Nikoletta Hetényi, as the supervisor, declare that I have read and approved the thesis "Non-infectious diseases of captive reptiles" of the student Lisa Bonaci, 6th year. Furthermore, I declare that the uploaded thesis has been successfully checked for plagiarism and that any matches found comply with the University guidelines/rules.

Budapest, 2023. 11.08.

supervisor