University of Veterinary Medicine Budapest
Department of Exotic Animal-, Wildlife-, Fish- and Honeybee Medicine

Reproductive diseases in female *Python regius*

Nőstény királypitonok (*Python regius*)
reprodukciós megbetegedései

Daniela Ayma Paredes

Supervisor: Dr. Árisz Ziszisz
Department of Exotic Animal-, Wildlife-, Fish- and Honeybee Medicine

2024

Abstract

This thesis explores reproductive diseases in female ball pythons (*Python regius*), beginning with an overview of their biology, anatomy, and husbandry practices. It examines the breeding cycle, maternal behaviors critical to reproductive success, and the impact of morphs developed through selective breeding. The study also addresses the export market, highlighting its influence on breeding practices and pressures on wild populations. Dystocia, a major reproductive disorder, is analyzed with a focus on its types, causes, diagnostic methods, and treatments. Additionally, infectious diseases such as salpingitis and non-infectious conditions like neoplasia are discussed, emphasizing the role of husbandry, nutrition, and breeder practices in reproductive outcomes. This work provides practical recommendations to improve care, promote sustainable breeding, and advance veterinary understanding of reproductive health in this species.

Absztrakt

Ez a dolgozat a nőstény királypitonok (*Python regius*) reprodukciós megbetegségeit vizsgálja, kezdve a biológiájuk, anatómiájuk és tartási gyakorlatuk áttekintésével. Vizsgálja a szaporodási ciklust, a maternális viselkedés startégiáját, valamint a szelektív tenyésztés során kialakult szín és mintaváltozatok hatását a szaporodásbiológiai mutatókra. A tanulmány bemutatja az export piacot, kiemelve annak a tenyésztési gyakorlatra mutatott hatását és a vadon élő populációkra nehezedő nyomást. A tojásrakási probléma, mint fő reprodukciós tünetegyüttes, annak típusai, okai, diagnosztikai módszerei és kezelési lehetőségei is ismertetésre kerülnek. Ezen kívül a reprodukciós fertőző és a nem fertőző betegségek bemutatására is sor kerül, hangsúlyozva a tartási, takarmányozási és tenyésztési gyakorlatok szerepét. A szakdolgozat ajánlásokat ad a tartástechnológia javítására, a sikeres tenyésztés elősegítésére és a reprodukciós betegségek prevenciójára valamint a gyógykezelés állatorvosi vonatkozásaira.

Table of contents

1. Introduction

Ball pythons (*Python regius*), native to West and Central Africa, have become widely recognized and appreciated as pets around the world due to their manageable size, docile temperament, and the wide range of morphs achieved through the practice of selective breeding over time. Some of the most popular morphs, which are presented in this work, underline the strong market demand and the selective breeding practices that drive it. Certain morphs also seem to exhibit specific reproductive pathologies, adding to the importance of understanding reproductive health in this species. For example, morphs like spider and desert, have been linked to neurological conditions and reproductive challenges, reflecting the consequences of selective breeding for aesthetic traits. Global ball python trade, significantly impacts wild populations due to practices like ranching and the collection of gravid females. Balancing conservation goals with the high demands of the pet trade is crucial to sustaining both wildlife and market needs.

This work will also discuss general breeding practices and the breeding cycle of ball pythons, which will help provide a comprehensive foundation for understanding health challenges in this species, helping to clarify the context for later discussions on reproductive diseases.

Female reproductive health is a critical aspect of this study due to its importance in supporting the growing ball python market. This research aims to improve husbandry practices, veterinary care, and understanding of reptilian reproductive biology by addressing reproductive diseases.

This thesis will explore specific female reproductive conditions such as dystocia, infectious diseases (e.g.: salpingitis) and non-infectious ones (e.g.: neoplasia), with a focus on classifying these issues for better understanding and management. These issues arise from a variety of factors, including anatomical, behavioral, and environmental influences and could even overlap each other. Captivity and husbandry practices, such as temperature regulation, humidity levels, enclosure types (e.g., terrariums versus racks) and nutritional issues significantly impact reproductive success. Pet owners and breeders, particularly newer ones, are sometimes unaware of how these factors relate to reproductive diseases, leading to delayed diagnoses and missed opportunities for early intervention. This study aims to fill gaps in knowledge regarding ball python reproductive health, focusing on early intervention and proper care to enhance reproductive outcomes. It will also provide a foundation for future research and advancements in the care, management, and sustainable breeding and conservation of this species.

2. Literature review

2.1. What is ball python?

Ball python, *Python regius* is also known as royal python. It is a constrictor snake native to West and Central Africa. It’s manageable size and ease of care make it a favored exotic pet among reptile enthusiasts and hobbyist. The high demand for exotic pet pythons has created a breeding industry, where the growth is primarily driven by creating new color and pattern varieties through selective breeding of genetic mutations. [1] Their docile behavior also influenced its popularity. When threatened, they usually curl into a tight ball instead of striking, which is how they got their name. Biting happens accidentally when the snake mistakes the feeder’s hand for a prey when providing food [2].

While still found within its original range, ball python exhibits varying conservation statuses across different countries. In the case of Benin, the species has experienced a notable decrease in abundance due to intense collection driven by the pet trade and demand for bushmeat. This exploitation has led to a reduction in both the area of occupancy and the extent of occurrence in Benin. The most sensitive biological stages, such as gravid females and neonates, are particularly targeted, and hunting techniques disrupt nesting habitats. Furthermore, the situation is likely to be aggravated by factors like agricultural mechanization, chemical use, and climate change like: warming, flooding. [3]

Despite its classification as "Least Concern" on the IUCN Red List, there is a lack of population estimates for ball pythons in West African ecosystems, raising concerns about the sustainability of current exploitation levels. In Benin, where these concerns are most acute, the species should be considered threatened, and updated population information is urgently needed. However, local traditions and taboos associated with snake cults in the ball python's range have effectively controlled harvests, maintaining near-zero hunting pressure in sacred areas. [4]

2.2. Taxonomy

“The first description of a python (*Coluber molurus)* was included in Linnaeus (1758). By 1850, 13 species, including the largest species in the genus Python, were identified.“[5] Currently, there are 44 recognized species of pythons, with *Python regius* as one example. Their classification continues to evolve through ongoing molecular and morphological studies [5].

The ball python (*Python regius*) [5] belongs to the class Reptilia [6], order Squamata [2], suborder Serpentes, family Boidae, subfamily Pythoninae, genus *Pythons*, species *Python regius* [6], and it’s considered as a monotypic species [7].

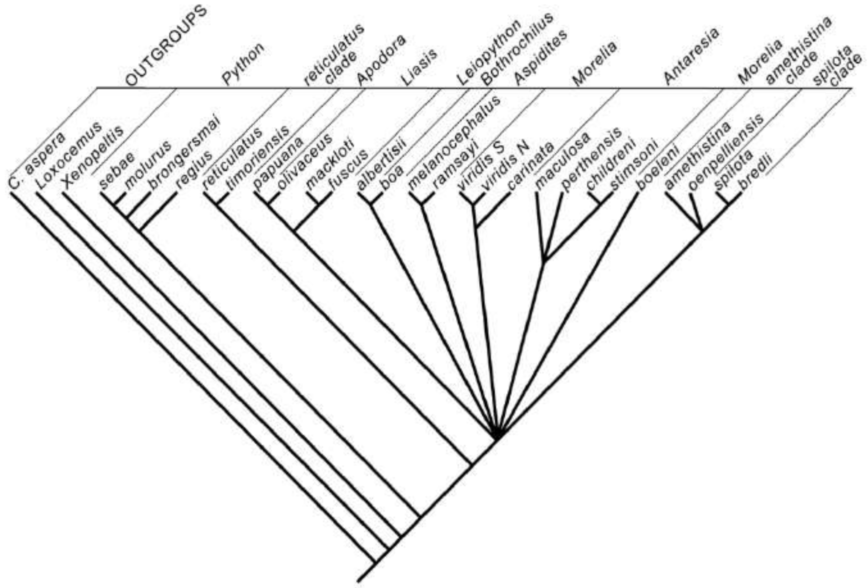

Figure 1:Phylogenic tree of the pythons based from analysis of morphological data and four mitochondrial DNA regions (Rawlings et al.2008)

2.3. Physical characteristics and anatomy

Ball pythons are strong, muscular snakes with slender necks [2]. Their head is quite narrow at the tip, while getting wider at the base of the skull [8]. Wild-type individuals typically have a medium to dark brown base color, accented by lighter brown or yellow patches and bands. Each snake's pattern and shade vary slightly. Ball pythons have five heat-sensing labial pits on each side of their maxilla, which they use primarily to detect prey. Additionally, their eyes lack eyelids and are instead covered by a thin, transparent scale called a "spectacle." This spectacle should normally be shed along with the rest of the skin [2]. Moving further back, their cloaca is composed of three different parts: the urodeum, coprodeum, and proctodeum. The urodeum receives urine output directly from the ureters. The reproductive organs are also placed in the caudal part of the cloaca [9, 10]. Snakes do not have a urinary bladder, they are store the urine in their ureters. The coprodeum secretes waste products, which then pass via the proctodeum and exit through the vent [10]. Since the cloaca is where copulation and the mechanics for potential insemination will take place, evaluation of this organ is crucial. Reproductive success may be reduced or prevented by cloacitis, scent-gland impactions, fecal or urate impaction, and other related issues in the cloaca [42].

Remaining in the same zone, near the vent, both male and female pythons have "spurs," believed to be vestigial pelvic limbs. In males, these spurs assist in gripping during mating [2]. Indeed, their cloacal spurs are longer, thicker and more hooked than females. On the other hand, they wear off with age, so they can't be used as a reliable sexing method. [11]

Figure 2: Python regius, by BHB reptiles

Another method of sexing a ball python is "popping" the hemipenis, which involves temporarily projecting the snake's genitals outside its tail, a technique that is particularly effective with hatchlings. During the first few months, young male pythons are often sexed this way, since they lack proper control of the muscles in this region, making this process easier at that age [12, 13].This reproductive organ, present in the majority of reptiles, remains inverted when not in use, making it possible to manually evert during this method [14]. This method involves securely holding the snake and pressing the vent scale with the thumb, sliding it forward to gently open the vent. Light pressure at the base of the tail reveals hemipenes if present, identifying the snake as male; their absence indicates a female. Proper technique is essential to prevent injury (DAOUES et GERARD, 1997 ; DE VOSJOLI et al., 1994)[13].

Even so, one of the most common ways to determine the sex of a snake is probing. As stated above, the male reproductive organ is called hemipenes and is located at the base of the tail, caudally to the vent. In the case of females, they have hemiclitoris sulci and scent glands in the same area which they do not extend further [15]. The objective of probing is checking whereas the animal has the hemipenal or hemiclitorial sulci. One can use several tools to perform this test such as but it is more common to use ball tip stainless steel probes as they provide rigidity, are easier to clean and are less likely to cause trauma. [10]

To perform the test, one must lubricate the probe with lubricating jelly in order to facilitate the insertion of the probe. It should be inserted in the cloaca with gentle pressure caudally and slightly lateral to the midline [11]. Two people are required to perform the sexing: one maintaining the snake and another doing the procedure. The thumb may be used as an external indicator from the vent once the probe is as far as it can travel inside the animal. The tool is be removed and placed ventrally to the tail to measure the distance travelled by counting the scales. As seen on Fig 3, if the snake is a male, the probe would travel a distance of more than four scales due to the presence of the sulci. However, if it’s a female, the distance would be much shorter: two to four scales of distance maximum. [10] The numbers of scale depth can vary from one species to another and in a ball python, the probe can be inserted up to 12 subcaudals for a male [6] and 2- 4 subcaudals for a female [16].

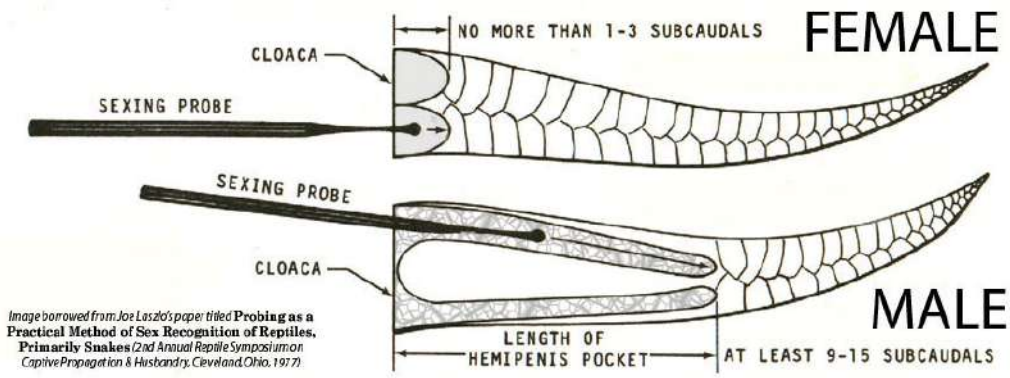

Figure 3:Differences of probing inside snakes: females versus males, from Joe Laszlo, Ohio

Hatchlings typically range from 25 to 35 cm (10 to 14 inches) in length. As they mature, adults usually grow to between 1.1 and 1.5 meters (3.5 to 5 feet), with females larger than males. In some cases, individuals can reach up to 1.8 meters (6 feet). Breeding adults commonly weight around 1.5 kilograms (3 pounds) or more, and particularly large specimens can weigh as much as 4 kilograms (9 pounds) [2].Yet, their sexual maturity occurs earlier. Males are capable of breeding at a weight of around 650 grams [17], while in the case of females, they will be weighting around 1500 grams at that time [18].

Jaws are also bigger in females in relation to their snout to vent length. In ball pythons, which are typically gape-limited predators, the longer jaws of females may enhance their foraging success by enabling them to swallow larger prey. This advantage could explain why females tend to grow larger than males [12].

Ball pythons reach 10 years old in the wild [3] and some can live 20–30 years in captivity, though some have been known to exceed 40 years [2].
Regarding the gonads, the reproductive cycle of female ball pythons exhibits seasonal variation, developing according to the mating season[8]. From July to September, snakes have fewer and smaller follicles, making identification challenging. However, by October and November, the follicles are well-developed, located dorsally in the coelomic cavity near the kidneys, with variable positioning due to the loose connection of the ovaries [19]. If no fertilization occurred, the follicles are re-absorbed [8].
In snakes, the ovaries are asymmetrically positioned within the body, and during ovulation they significantly extend along the coelomic cavity, with the right ovary positioned more cranially than the left. These saccular structures, covered with follicles, are responsible for producing estrogen and facilitating gametogenesis. The right ovary is located near the vena cava, while the left ovary lies close to the left adrenal gland. The oviducts, appearing as small tubular structures lateral to the ureter, change based on reproductive status, becoming more visible in gravid snakes. They serve dual roles, aiding in egg transport and contributing albumin, protein, and calcium for egg formation [9, 19].
These pythons reproduce oviparously, with females usually laying an average of six eggs per clutch. Clutch sizes can vary significantly, ranging from one egg to eleven [18].
In sexually mature males, the paired testes are found dorsally in the coelomic cavity, just cranial to the kidneys. The testes are notably larger in males examined during October and November compared to those in summer. At that time, the right testis may extend to the stomach, with its caudal pole overlapping the cranial pole of the left testis. As they enlarge in the later months, the deferent duct and renal efferent vein are found dorsal to the testis. Ultrasonographic observations are generally a good method to provide valuable insights into reproductive anatomy and seasonal variations in these reptiles [19]. Even if locating the ovaries in young, non-cycling females can be challenging, over time and with repeated reproductive cycles, the follicles become more prominent, situated just caudal to the gallbladder. As mentioned before, ovaries of adult females may occupy a significant portion of the coelomic cavity, and ovarian follicles appearing as hypoechoic spherical structures, aid to proper identification [9].

2.4. Distribution and habitat of ball python

It is found in several countries such as: Senegal, Gambia, Guinea-Bissau, Guinea (Conakry), Sierra Leone, Ivory Coast, Ghana, Liberia, Togo, Benin, SW Niger (near the border of Benin), Burkina Faso, Nigeria, Cameroon, Central African Republic, Democratic Republic of the Congo (Zaire), Mali, Uganda, Republic of South Sudan (RSS) [7].

Since ball pythons live in areas close to the equator, there is not much change in the annual light cycle. In their natural habitat, the average temperature is typically warm, sometimes rising to 85°F (29.4°C) [8].

Concerning their preferred habitat, ball pythons are most commonly found in grasslands, savannahs, and farmlands, often residing in rodent burrows [14]. These places have separate wet and dry seasons, which are the ideal environments for these snakes. Although there is minimal precipitation during the dry season, which runs from November to April, humidity levels can still reach 80%. Furthermore, ball python eggs usually hatch around the beginning of the wet season, which is characterized by high humidity and an abundance of food [8].

Several pythons can share a burrow, but brooding females are usually solitary. They are nocturnal hunters, remaining in their burrows during the day [2].

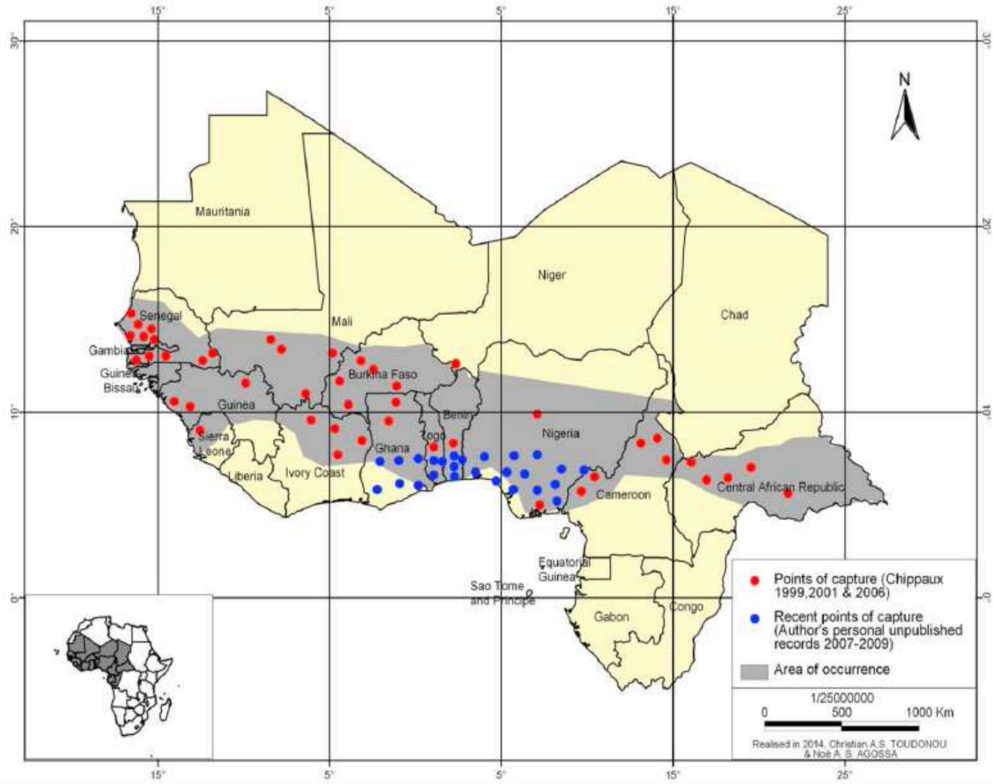

Figure 4: Habitat region of Python regius in Africa from Christian A.S. Toudonou

2.5. Ball python husbandry

As the keeping of ball pythons increases, NGOs such as The Royal Society for the Prevention of Cruelty to Animals (RSPCA) offer several key, though non-binding, recommendations for correct housing. These include providing ball pythons with : (1) a terrarium is spacious enough to allow them to fully stretch out ("i.e., with an enclosure at least as long as the snake's total length, and a width and height each equal to at least a third of the snake's length") ; (2) multiple hiding places within their terrarium to provide secure hiding opportunities ; (3) a water bowl large enough for full submersion ; and (4) suitable substrate that supports hygiene and allows for burrowing behavior [21].

Ball pythons are regarded as relatively sedentary. As an outcome, two studies are in conflict due to their differing results. Some governmental guidelines recommend that enclosures smaller than the snake's full length are adequate for their welfare. In contrast, other guidelines indicate that more "active" snakes need enclosures longer than their entire body length, while "sedentary" species, like ball pythons, do not [21].

Regarding the adequate temperature for keeping, guidelines suggest maintaining an ambient temperature of 28–30°C (82–86°F), a basking area at 35°C (95°F), and a night time temperature of 22–26°C (72–79°F) [22].

Heat lamps, ceramic heaters, and under-tank heaters can create basking zones and temperature gradients. It's important to measure temperatures daily using thermometers, probes, or an infrared thermometer. To prevent thermal burns, ensure snakes can't directly access heat sources. Even without direct contact, ball pythons that burrow may burn themselves near under-tank heaters, so careful monitoring is essential [2].

Concerning the lighting, it is recommended to provide ball pythons with full-spectrum lighting, which simulates natural sunlight by offering visible and ultraviolet (UV) rays. UVB and UVA light can affect mating activity and offer behavioral and psychological advantage. While UVB is crucial for vitamin D3 synthesis in some reptiles, like corn snakes, it's not essential for ball pythons [23,24].

However, some studies show that it positively enhances its natural behavior. Photoperiods should mimic their natural habitat. A 12-hour day/night cycle is ideal for them due to their equatorial origin. Adjusting the photoperiod for mating behavior is optional [10].

Ball pythons need a moderate level of humidity to feel comfortable. It's advised to keep it between 40–70% [15, 24]. In research environments, they are often kept at 50–70% humidity to assure their well-being during the experiment duration [25, 26].

If the humidity levels are incorrect, it could cause harm to the animal. Typical problems linked to air moisture are respiratory issues [15]. Using a humidity gauge helps ensure these levels are accurate and avoid the issues listed above [2].
Clean, fresh water should be consistently available. A dish large enough for the snake to submerge would be ideal.[27].
Ball pythons may soak in water to assist with shedding, drinking, and defecating. This is the reason why water should be checked at least once a day and replace immediately if soiled, with the bowl disinfected. Water should always be replaced at least every two to three days [2]. It can be out of ceramic or plastic as long as it's heavy enough for the animal to hold in it without making it fall over. It is important to note that if the snake is constantly soaking in its water dish it could be a sign of underlying problems (mites, heat) and should be checked. [8].
There are two popular types of housings that we encounter for the keeping of ball pythons: terrariums and racks.
Glass tanks are recommended for their larger size, allowing natural behaviors like climbing, burrowing, and basking, which are crucial for the animal's well-being. The extra space can be decorated to personal preferences, while still including essential elements like hiding spots and a water basin [22]. The decoration also includes substrate and branching, fulfilling the needs of the snake while also contributing to the overall appearance of the terrariums as envisioned by the owner. However, these enclosures come with challenges: they tend to be more expensive due to complex systems needed for proper husbandry, and their larger size can make it harder to maintain consistent heat and humidity. Additionally, snakes may be more prone to escape, as they explore more, and if the terrarium is not securely closed, they could sneak out. In general, this format requires much more caution and responsibilities [22].

Figure 5: Example of a terrarium housing model, from Bewild Reptile rescue

For these reasons, terrariums are more suitable for individuals seeking a pet, housing one or two snakes for educational purposes / personal enjoyment, rather than for breeding [2].

For breeders, racks are more efficient. This type of housing, featuring columns of plastic drawers on tracks or shelves, is ideal for them due to its smaller size since it offers simple arrangements, easy cleaning, and ability to house many animals in a compact space [2, 22]. This model also allows better control of the temperature than terrariums. The lack of items on this model is considered an equal advantage as it can avoid physical accidents to the animal and also prevents additional burns that could happen in snakes burrowing too close to the heat source in glass tanks [22]. Racks come in various sizes and are commonly made of acrylic glass or opaque plastic [22] which enhances the safety of the snakes. Indeed, since these animals naturally lives in rodent burrows[14], the non-transparent materials provide them with a sense of security. In contradiction, this material disadvantages the esthetic of the display. Furthermore, one of the advantages of a terrariums is its ability to enhance the natural behaviors of the animal through the strategic placement of items. In contrast, the rack system presents a disadvantage as it does not provide sufficient space and stimuli for the animal to thrive [22]. However, it can be a good alternative for hatchlings that like small hiding spaces to feel safe and promote feeding [9]

Regardless of which option is chosen, cages should be constructed from durable, nonabsorbent materials like glass, plastic, Plexiglas, or soft mesh screens. This reduces the risk of injury and simplifies cleaning [2] [27].

Figure 6:Example of a rack system model from Cornel's world

There are several substrate options available. Newspaper, butcher paper, and artificial carpeting are practical and easy to clean, making them ideal for people with large collections, those seeking low-maintenance enclosures [2, 27] and even for quarantine options [10]. Bioactive substrates are another appealing option for most snake habitats. These substrates contain bacteria and microorganisms that break down waste, balance moisture and nutrients, and support plant health in the terrarium. Typically, they consist of a mix of peat moss, potting soil, bark, sand, and clay. Once established, they require minimal maintenance: just a weekly stir, spot cleaning, and some water. Aspen and cypress shavings are safe, and easy to clean. However, pine and cedar shavings are to be avoided, as they can irritate the respiratory system. Sand, loose dirt, and walnut shell are available but not ideal unless part of a bioactive substrate, as they can cause health issues by lodging around the eyes, mouth, and nose [2, 10, 27]

As stated before, ball pythons are commonly found in savannas and grasslands, where they mostly take shelter in rodent burrows [14]. Providing a similar hide for them to feel safe is required for a successful maintenance [17]. It is also recommended to fill them with for example; sphagnum moss, to help mimic these natural conditions, as the moisture and confined space offer the security these snakes need to feel safe and even help with shedding and egg laying [16].

Ball pythons are naturally solitary and a need a sense of security, making it important to provide them with hidings with single entrance twice as larger than the snake’s body, ensuring a snug fit. If the hideout is too large, it won’t offer the same level of comfort [9].

At least two hiding spots are recommended: one positioned near the heat source and another at the cooler end of the enclosure. This setup lets the snake choose a comfortable temperature zone depending on its needs. Commercial hiding boxes are sold at pet stores, or homemade alternatives can be made from plastic containers or large dishes, ensuring smoothing any cut edges. Though not essential, smooth rocks, sturdy plants, and branches can enhance the habitat. Non-toxic, durable live plants or branches can also be added [2].

2.6. Feeding of ball python

Ball pythons are carnivorous constrictors that consume their prey in one piece. In the pet trade, mice and rats are commonly available food sources. The prey should be roughly as wide as the widest part of the snake’s body. Thus, newborn ball pythons typically eat "fuzzy" or "hopper" mice, while adults can handle different size of rats [28].

Young or wild-caught ball pythons might initially refuse mice and rats but may accept gerbils, which can be used to scent thawed mice or rats to make them more appealing [10].

Feeding should always involve prey that is freshly killed or frozen-thawed. Since live rodents can inflict serious injuries and may cause the snake to become fearful, it could lead to a refusal of food in the future. Prey items can be purchased frozen or euthanized humanely. If a snake refuses dead prey, using live prey to scent the thawed food can help the snake accept it [2, 10]. Young ball pythons should be fed once a week. Adult ball pythons, typically over three years old, generally need feeding every two to four weeks, depending on factors such as food size, season, and reproductive activity [2]. It is important to emphasize that overfeeding a sedentary python can lead to obesity and constipation [10].
During breeding periods, snakes should be fed weekly, especially females, who may refuse food until after laying eggs [2]. At the same moment, some males can also stop feeding. Close monitoring is needed to make sure none of them loose a large amount of weight [8].
Wild mice are strictly prohibited due to the risk of diseases, parasites and toxic compounds like rodenticides [28].

2.7. Color mutations and how it affects reproduction

The ball python is a very popular exotic pet due to its docile nature and relatively small size as a snake [16]. But also due to the variety of its mutations, also referred as “ morphs “ [29].
In the wild, ball pythons have a mottled color pattern with brown-to-black melanin and red-to-yellow non-melanin pigments. Captive-bred pythons, however, display a wide variety of "color morphs," which include reduced melanin (albino), increased melanin (cinnamon), diminished red-to-yellow pigmentation (axanthic), or more complex color patterns (spider, clown) [30].
At present, thousands of morphs across various species are available. Breeding efforts emphasize the creations and expansion of unique or more vivid colors, distinctive patterns, and modifications in attributes like alignment, size, and the presence or absence of scales [29].
Some specific bred ball python morphs are primarily sold by vendors and breeders at exotic pet expos in North America and Europe, as well as promoted through online videos on platforms like YouTube [21].
Some of the most popular patterns is the spider morph ball python, which gained popularity due to its distinctive skin color change. However, concerns are rising about genetic disorders linked to selective breeding for specific color and pattern variations, and their potential harm to health. Classified as a dominant gene, the presence of one allele is sufficient to produce this morph and the clinical signs linked to it. For instance, "wobble head" syndrome affects the central nervous system, especially in spider morphs [1]. Other morphs also seem to also have a connection with this syndrome, such as champagne, woma, hidden gene woma [6, 29].

Symptoms include head tremors, lack of coordination, erratic twisting movements, difficulty righting themselves, abnormal neck posture, weak muscle tone, and a loose tail grip [1]. These signs also often lead to euthanize the animal [21]. Fecundity in spider morphs is considered unaffected, though severe cases may lead to difficulties during copulation. The wobble condition does not appear to impact the snake's lifespan. However, breeding two spider morphs together is thought to result in a higher rate of egg failure, possibly because the gene mutation could be lethal in its homozygous form [31].

Spider ball pythons are recognized for their distinctive thin black or dark brown lines over a light gold or yellow body, with varying amounts of white rising from the underside but rarely in dark areas. They often display black flecking on the labials and unique head markings. This popular morph is widely used in breeding to create new morphs, and as a dominant mutation, it requires only one parent to pass on the trait [28].

Figure 7: Spider morph of Python regius from Manual of ball python, Vosjoli

Several theories linking the disorder and the morph have been put forward, but none have been tested, which leaves us with no specific cause for Wobble syndrome [1].

There are breeders aiming to outbreed the condition and keeping the characteristic pattern of spider morph, however there is no success until now. Nevertheless, this shows that there is in fact, some connection between the Wobble syndrome and the spider gene [29].

Other morphs have also specific manifestations such as fertility issues for desert and caramel albino morphs, malformations in the case of super cinnamon, super black pastel patterns, and even lethality for super spider, pearl and super champagne colorations [29].

Desert morph is a dominant mutation. It was first imported from Africa in 2001 and didn't have much success at the beginning since its robe was "only" a clear-cut pattern of light-colored markings. However, the attention towards them grew when the community saw the stunning combinations (desert-enchi, desert enchi pinstripe…) involving one desert morph in the recent years. No study has proven that yet, but it's an ongoing matter between breeders that this morph affects the female's fertility, making it difficult to breed [6]. The narrative of big breeders highlights a journey filled with challenges regarding the reproduction of these females. They have experienced typical problems, such as difficulty in passing eggs, others tried to achieve larger-than-usual growth in their snakes to promote fertility, but ended without success since they remained the same size [32].

Figure 8: Desert Moprh Ball Python, by Justin Kobylka Reptiles in The street ball journal

Designer morphs are created in captivity by combining various foundational traits or through the inbreeding of a single variety, leading to new and distinctive ball pythons with a different colors and patterns. Most of these designer morphs are codominant, resulting in remarkable combinations that generate many distinct appearances [8, 17]. The discovery of the Pastel Jungle in 1997 changed the way ball pythons are bred, and was a key moment in this process. As the first codominant ball python mutation, not only did it demonstrated the power of codominant genetics but also helped launch the creation of numerous designer morphs in the years that followed [17, 28].

One of the outcomes of this extensive breeding industry is the existence of more than 7,600 different ball python morphs today [33]. This diversity is a direct result of processes like combining multiple dominant and codominant traits, as seen in the mojave bee morph. It's a combination of a mojave, pastel, and spider morph (dominant /codominant /codominant genes).

This triple combination is notably easier to achieve using dominant or codominant morphs compared to relying solely on simple recessives. The results of this cross often exceed expectations, as the hatchlings tend to be far more visually striking than initially anticipated. The mojave traits enhance the bumblebee morph, brightening the yellow and altering the pattern. Mojave bees can also be produced by crossing a mojave with a bumblebee [8].

On a different note, the development of several popular morphs is influenced by artificial selection and the management of isolated populations, which can result in small breeding groups, significant inbreeding, and reduced genetic diversity [29].

2.8. Breeding cycle

These snakes don't have the same puberty time between sexes. Male ball pythons typically reach sexual maturity between 16 and 18 months, while females mature later, around 27 to 31 months [3].

As stated previously, for males, they are capable of breeding at a sexual maturity weight of around 650 grams [17] , while in the case of females, they will be weighting around 1500 grams at that time [18].

In the wild, their breeding season runs from November to January [34] which correlates with the raining season [18], then lay their eggs one month later [8]. In captivity, they are generally active from September through February, with females laying eggs from February to August. However, a recent study indicates that captive breeding can occur year-round, including winter period [2].

The average clutch size is 6 eggs, but the size can vary from 1 to 11 [18]. In captivity, ball pythons typically produce one clutch of eggs per year, though some breeders accelerate the process to obtain two clutches annually. It is possible to breed a female ball python safely up to twice a year; however, exceeding this limit can be harmful, as it deprives the snake of adequate recovery time, potentially affecting its overall health [17].

In the case of males, they can typically breed with around five females per season. While it's possible to attempt breeding with more, it's generally not recommended, as frequent copulations can increase the risk of hemipene infections, which, in severe cases, may require surgical intervention. It is advisable to manage breeding carefully, aiming for one or two matings per female each month to give the male sufficient downtime to recover and maintain his reproductive health [28].

Females curl around their eggs shortly after oviposition and remain with them until they hatch, which can take over two months. As the smallest member of the Python genus, *Python regius* is a relatively small species of python and is native to warm tropical lowland habitats. Due to its smaller size and the warm environment it inhabits, this snake is not expected to exhibit strong endothermic brooding abilities [35].

However, research has shown that brooding can significantly enhance the reproductive success of ball pythons, even in such environments, by reducing water loss from the eggs and preventing desiccation. Females lose only around 5.9% of their body mass over the two-month brooding period, demonstrating that this intensive parental care does not entail high energy expenditure [34]. Within an hour after laying their eggs, females form a turban-like coil around the clutch. Their posture is unique, with the posterior third of their body rotated 90 degrees so that their ribs and ventral scales are positioned laterally [35]. This tight coiling behavior forms a protective posture around the clutch, which is observed as critical for maintaining stable incubation conditions [36].

The concave shape of the female's ventral surface nests the eggs securely, and every 3 to 4 hours, she briefly loosens her coils to inspect them. This inspection involves nosing and tongue-flicking among the eggs without disturbing their arrangement. Occasionally, she will uncoil fully to reposition any dislodged eggs before resuming her brooding posture [35]. Similar behaviors, where python mothers delicately inspect and adjust their eggs, are observed across python species, suggesting this may be an evolved mechanism to ensure clutch stability [20].

If an egg is dislodged, the female retrieves it by either looping a curl over it or encircling the entire clutch before recoiling. Females leave their eggs unattended only for essential activities, such as drinking or shedding, with absences being less frequent at night [35].

Figure 9: Female python forming a turban like coil around her clutch, Manual of Ball python, Vosjoli

However, if the egg is not recovered, this could indicate that its not viable anymore and the mother keeps it separate from the others to avoid potential contamination like molding [28].
Female ball pythons display incubation behavior similar to *Python molurus* and *Morelia spilotes,* remaining with their clutches for over two months until hatching. They however generate less metabolic heat than larger species, resulting in only a slight rise in body temperature. The eggs, comprising about one-third (32%) of the female's pre-oviposition mass, reflect a significant energy investment. While this type of incubation doesn't provide thermal advantages, it likely protects the clutch from predators like small mammals and birds [36]. Additionally, maternal behaviors such as coiling and attendance during incubation can enhance reproductive success by influencing the timing and viability of the clutch [35]
Furthermore, it is suggested that maternal attendance shortens the incubation period by 15-20% compared to eggs left unattended in identical conditions, reducing the time the eggs are vulnerable to predation. In predator-rich environments, this additional parental care could significantly boost the female's fitness by increasing the likelihood of her clutch surviving until hatching [35, 36]. This active maternal involvement not only protects the eggs but also ensures more optimal conditions for embryonic development, making it crucial for reproductive success [34].
The mother's presence plays a critical role in regulating the hydric balance of her clutch. They coil so tightly around their eggs that the clutch is completely concealed. This tight coiling forms a "bell" around the eggs, creating a humid micro-climate that significantly reduces evaporation, thereby maintaining essential moisture levels for embryo development. The primary benefit of maternal care in ball pythons may be maintaining humidity rather than temperature [36].
Gravid females show similar behaviors to non-gravid females, except they refrain from eating. Despite this, their oxygen consumption rates are disproportionately higher than those of non-gravid snakes or post-hatch females. During the approximately 150-day gestation period, a gravid female weighing 1.85 kg and resting quietly at 30°C metabolizes about 91 g of fat, a 33% increase compared to a non-gravid snake of similar size [35]. This increased metabolic rate is also associated with enhanced reproductive investment, where the female prioritizes the keeping of resources to support egg development, even at the cost of her own nutritional intake. Studies have shown that such adaptations are crucial for maximizing reproductive success in environments where energy availability may be limited [37]. The eggs, composed mainly of yolk and albumin, are metabolically inactive during ovogenesis, but their mass still significantly contributes to the mother's total weight. The elevated oxygen consumption in gravid ball pythons likely reflects both the maintenance metabolism of the mother and the physiological

demands of egg production, including the conversion and mobilization of resources into the developing eggs [35].
Their reproductive lives are considered long since they can still breed during their twenties. One female has been recorded to lay her eggs at the age of thirty five years old [17].

2.9. Breeding method in ball python

Reproductive behavior and follicular development in ball pythons are triggered by a conditioning phase that typically includes a slight temperature drop months before breeding. One effective method involves gradually lowering the room temperature from 31°C to 28°C during the day and from 29°C to 24°C at night, decreasing by about 2°C every two days while maintaining a warmer area (29–31°C) for the snake to access [18]. Such adjustments are significant, as they mimic natural seasonal changes, promoting reproductive readiness and enhancing hormonal responses [34].Some experts also suggest adjusting the photoperiod alongside the temperature changes. Adult female ball pythons have small follicles in their ovaries throughout the year. However, during the breeding season, an increase in body weight and environmental changes encourage follicular growth, though these follicles are reabsorbed if fertilization does not take place [18].

In captivity, conditions are adjusted during the breeding season, and males are introduced into the female's enclosure or vis versa leading up to ovulation.
The male will first court the female using their cloacal spurs to stimulate the her, initiating mating. If the female is receptive, she will raise her tail, or the male will have facility to raise it leading to copulation. If she isn’t, she will reject him and it’s advised to separate them to avoid further damages. Developing follicles is the key to an acceptant female and will release pheromones who will attract males [28]. Males generally cohabit well, but when breeding season approaches, they can start to fight. It’s a harmless attack mostly consisting in wrestling and pushing but it has a beneficial outcome which is to stimulate an inactive male to breed right after. Breeders often encourage them by putting males together before placing one of them with a female, ensuring better success [17]. Copulation is established when both tail snakes are interlaced together. This process can last for 24 hours.
Examined from a clinical aspect, ovulation is associated with noticeable or discreet swelling in the lower third part of the body, caused by the follicles, the sacs in the ovary that contain the eggs, which will be more and more visible from the outside once it’s starting to develop [28], though no studies definitively link this enlargement with vitellogenesis [18].

The only way to be completely certain that a ball python is gravid is through an X-ray or ultrasound performed by a veterinarian. Gravid females will have visible eggs, confirming their pregnancy [18].

Figure 10: Lock induced fertilization, from Ball -python.net

In understanding the behavior of gravid ball pythons, it is helpful to examine thermoregulatory patterns observed in other snake species during pregnancy. Various studies indicate that gravid females in ectothermic species often seek cooler areas in their environment to avoid overheating from the additional metabolic demands of pregnancy. For example, Moniz and MacKessy (2024) observed that egg laden Prairie Rattlesnakes actively select cooler microhabitats to manage their body temperature, a behavior that may help mitigate thermal stress associated with gestation. Although specific studies on ball pythons are limited, it is likely that gravid female ball pythons exhibit similar thermoregulatory behaviors, such as spending time away from heat sources, soaking in water dishes, or even positioning themselves belly-up to maximize cooling. Such behaviors can thus be considered adaptive responses, helping gravid ball pythons avoid overheating and maintain optimal conditions for pregnancy, aligning with known patterns in other snake species [38]. If feed refusal is generally an alarming situation in snakes, it is an expected behavior from gravid females. This is another indicator of a potential pregnancy [28].

The gestation period for ball pythons typically ranges from 44 to 54 days [17].

Reproductive events in ball pythons are often timed using their shed cycles. After mating, the female will shed, typically followed by ovulation around 4 to 5 weeks later. Another shed occurs about 20 to 21 days after ovulation, signaling the start of pre-oviposition. Finally, the female will lay her eggs approximately 4 to 30 days after the pre-oviposition shed [11, 18]. These eggs can either be left for maternal incubation or removed for artificial incubation. When a female incubates her eggs, she should remain undisturbed, with careful monitoring of temperature and humidity. The mother coils around the eggs, adjusting her grip to regulate temperature by loosening or tightening as needed [18]. In many professional breeding operations, eggs are typically artificially incubated. Females incubating their own eggs take longer to regain sufficient weight for future reproduction than those with artificially incubated eggs. Proper monitoring of the reproductive cycle, including gestation and egg-laying, is vital for successful breeding outcomes [18].

It is well known that ball pythons can be easily stressed by frequent manipulation [16]. Therefore, reliable methods for assessing reproductive health and stress friendly are critical. Recently, non-invasive techniques for monitoring ovarian function have been developed to decrease handling stress [18] and also helps the risk diminution of oviduct tearing [11].
While palpation is commonly used to evaluate reproductive status, it can be difficult and risky, particularly with larger specimens. With radiography, though useful for locating soft tissues, often lacks details [18] and may require sedation to keep the animal motionless [15].
Other than that, ultrasound is the most commonly used method by veterinarians to evaluate reproductive activity in mammals and reptiles. Ultrasound provides a reliable evaluation of internal structures, including non-calcified ones, and can often be performed using light manual restraint [18].

2.10. Egg incubation

Ball python eggs are white, generally between 71 and 96 millimeters long, with diameters ranging from 46 to 55 millimeters, averaging 50 millimeters in a sample of 20 eggs. Their weight varies from 65 to 103 grams [17].

There are two main incubation methods. Whether to allow the female to incubate the eggs or to do it manually with an incubator. If the female is a good maternal as shown in previous lines, and her enclosure provides her with most requirements, maternal incubation should be possible. However, she would have to be kept alone in a proper temperature and humidity [28].

The ideal incubation temperature for ball python eggs is around 91°F (32.7°C), which supports proper embryo development and successful hatching. Eggs typically hatch after approximately 57 days under stable conditions. Maintaining a consistent temperature between 30°C and 32°C is crucial, as fluctuations can lead to developmental issues, lower hatch rates, or even embryo mortality [17].

Figure 11: Ball python eggs in an incubator from Ball python breeder UK

Humidity is equally important, with normal or wild-type eggs requiring a level of almost 100%. Insufficient humidity can cause the eggs to dry out and collapse, while excess moisture can lead to fungal growth. In both cases, rapid adjustment is required.

If an incubator is used, it's best to stabilize it a couple of weeks before the eggs arrive. Many quality incubators are available, and choice depends on the owner's preference. Suitable substrates like perlite or vermiculite are commonly used for egg placement; however, they should be free of additives and not overly wet to prevent mold and egg loss.[28].

Displacing eggs from their mothers can be another tricky task since they often adhere to each other [37] and the female might not be cooperative [28]. This could lead to difficult manipulation and increasing risks such as simply dropping the egg, or damaging the shell which would increase water loss [28, 37].

Under normal conditions, ball python eggs collapse about two weeks before hatching; if they don't, the environment may be too dry. Fertile eggs are white, flexible, and goose-sized, containing a live embryo, while infertile ones may appear similar initially. It's best to check eggs by candling to prevent mold spread, as infertile eggs eventually turn yellow and collapse [28]. For candling, using a small flashlight against the egg in a dark room. A fertile one will emit a pinkish glow, revealing thin red blood vessels inside the shell, whereas an infertile one typically glows yellow with no visible blood vessels [17].

Figure 12: Candeling of 49 days old eggs of Python regius, pastel-pastel crossing. They hatched a few days later (video from PhilaTV)

Good incubation mainly lays on the temperature and the humidity, and if the values are not properly reached, it affects some eggs which would then contaminate the ones that managed to survive and bring the whole clutch down. It's important to recognize a dead egg to discard them as soon as possible. They have mold, green / blue water marks and after some time begin to smell [28].

In ball pythons, yolk absorption is vital, nourishing the hatchling until its first meal and sealing the umbilicus once complete, preparing the snake for hatching. Occasionally, some hatchlings linger in the egg; if fully nourished but reluctant to emerge, gentle assistance may be needed. While some remain for unknown reasons, others may have skeletal deformities requiring euthanasia. Artificial incubation makes this process more challenging, as desiccation often solidifies unabsorbed yolk, leaving a heavier residual mass linked to lower hatchling weight and hatching issues, highlighting the importance of controlled conditions for healthy development [28, 36].
Occasionally, egg cutting may be employed prior to hatching to assist newborns that could struggle to emerge. This intervention, also considered unnecessary to some breeders, carries the risk to damage blood vessels and should be done with caution to avoid disrupting natural processes [6].

2.11. Hatchling care

Newly hatched snakes measure around 38-40 cm snout to vent length [37].
After being removed from the incubator and cleaned of any incubation medium, they should be housed together in an enclosure with proper humidity to ensure successful shedding [17], which is around 10 days [28]. Humidity is important, since not enough can cause shedding issues and stress [17]. After that, it's required to keep them in separate housings to facilitate feeding and avoid cannibalism even if it's rare. Housing temperatures would be around 25 - 28°C with an obligatory basking temperature range of 32-35°C [25], a hiding spot and their water dish [28].
Paper substrate could be good for the first days as they are generally used for quarantine which helps good monitoring of the snake [17].
Hatchlings should be placed in a 10 gallon tank (50 x 25 cm) for ideal size where they can feel safe [16].
Freshly hatched ball pythons usually begin feeding on baby fuzzy rats or mice around two weeks post hatching. If a hatchling refuses its first meal, it's best to try again for a period of four weeks post first shedding [17]. Various methods, such as heat, movement, and scent, can stimulate a feeding response in snakes. Initially, offering live prey may encourage hatchlings to feed, but they should never be left unattended with it, as the prey can defend itself, potentially causing injury or death [28].
If this still doesn't work, assist feeding may be required. This involves gently holding the snake behind the head, using the thawed prey to open its mouth, and carefully inserting the prey into the beginning of the throat while avoiding the glottis (windpipe). Light pressure on the head ensures the prey is secured in the snake's mouth [17].

2.12. Export market

The ball python is the most frequently traded CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) -listed live animal exported from Africa, with exports largely handled by three countries: Benin, Ghana, and Togo. The USA is the largest importer of these pythons, although Ghana exports to a wider range of countries, particularly in Asia. Ghana also acts as a regional trade hub, re-exporting ball pythons from Benin and Togo, and reports a higher number of captive-bred exports [39].
In Togo, the ranching system is a significant aspect of the trade chain. As documented in recent studies, rural communities hunt gravid females and collect eggs to supply regional snake farms.

This method is reportedly less regulated, as hunters indicate fewer pythons in the wild, suggesting overharvesting risks and inadequate monitoring [4].

Ball pythons are a popular pet worldwide, especially in the USA as stated above. As a species listed under CITES Appendix II, they represent the most commonly traded African animal. From 1996 to 2012, imports of ranched reptiles, dominated by ball pythons, increased by 50 times. Locally, ball pythons are also used for bushmeat, leather, and traditional medicine, but international pet trade poses the greatest risk to their conservation [39].

Some reports indicate that, especially in Benin, the pressure of hunting on wild populations remain concerning, with fewer animals being located within typical hunting zones, increasing distances traveled by collectors, and reports of extirpated local populations [3].

CITES data equally reveal that Benin, Ghana, and Togo have contributed 98.8% of all ball python exports since 1976. These exports have reached over 50 countries, with the USA being the top importer. In recent years (2012–2016), other key importers have included Hong Kong, the UK, France, and Spain. Ghana, in particular, exports more to Asia compared to Togo and Benin, while Western Europe remains a prominent market for all three countries [39].

A current look at only one online marketplace dedicated to reptile trade around the world reveals the immense scale of the ball python industry, with over 51’000 ball pythons presently listed for sale [40]. This example not only demonstrates the popularity of ball pythons but also highlights the significant economic impact of their trade and the active efforts of breeders to meet ongoing demand.

Welfare concerns persist within the trade, especially for ball pythons housed in unsuitable conditions. Many animals are kept in restrictive enclosures that fail to meet the minimum recommendations of animal welfare guidelines. Recent studies emphasize that poor housing and handling practices may cause harm to ball pythons, necessitating stricter regulatory guidelines across trade hubs in Europe and North America [21].

In parallel to this trade growth, veterinarian inspections have been set up in 2005 by CITIES and a written report has been made. This upgrade helped to keep a strict follow of all exportations which improved the management of this business and welfare compared to 2004 where it was still vague, barely known [41].

Additionally, the USA has shifted from re-exporting ranched ball pythons to becoming the fourth-largest exporter of captive-bred pythons [48]. Despite their wide geographic range, the trade is still dominated by Benin, Ghana, and Togo, which transitioned from wild collection to ranching in the 2000s, with Ghana reaching more diverse markets than its neighbors [48].

The reliance on ranching for exports from West Africa, especially from Togo, has led to complex trade structures. Togo's exporters often source snakes from rural hunters and redistribute them through local farms. Some evidence also suggests that illegal trade persists despite the new supervisions, such as direct exports of wild-caught specimens alongside legally ranched ones [41].

2.13. Reproductive diseases in female Ball Python

Ball pythons belong to the most captive-bred group of snakes, which also includes sand boas, corn snakes, milk snakes, and many others. Because they are so popular in captivity, ball pythons frequently experience common medical issues related to breeding, as well as the requirement for veterinary care for these cases [42]. In clinical practices, the reproductive system of female reptiles seems to be more susceptible to illness than that of males [43]. This is why it is crucial to monitor the female's health in order to fully comprehend the progression of the diseases, but it is also critical to examine the eggs when they are produced and the housing management topics that will be covered later [42].

2.13.1 Classification of reproductive disorders

The main reproductive disorder found in ball python is dystocia. This condition has its impact due to its numerous causes and complications. Other diseases whereas they are infective or non-infective are mostly results from it or aren't as common. Nevertherless they still impact the wellbeing of the snake and must be assessed to secure the opportunity for effective treatment and allow the animal to thrive.

2.13.2 Dystocia in Ball python

2.13.2.1 Description of dystocia

The plain definition of dystocia is complicated births, or in this case, laying [44] and despite being infrequently observed in the wild, dystocia is one of the reproductive disorders commonly observed in captive reptiles, especially snakes. Of the 1,600 captive reptiles in a study, 42% had dystocia, with snakes accounting for 39% and lizards for 18% of the cases [45]. Given the prevalence of this condition in snakes, it's unsurprising that dystocia is one of the main reproductive disease encountered in captive ball pythons, that could result from infectious, non-infectious diseases or husbandry issues [16, 42].

2.13.2.2 Pre-Ovulatory and Post-Ovulatory dystocia

One way to explain this disease is thanks to the timeframe of its occurrence: with Pre and Post ovulatory differentiation.

Barten describes them as: First, pre-ovulatory retention, which is also known as follicular stasis, is the condition in which ovaries become swollen with enlarged, sometimes inflamed and necrotic follicles which failed to ovulate after vitellogenesis [9] [46]. Most often, this condition affects lizards, even more in iguanids, agamids, chameleons and varanids and also chelonians kept in captivity [9]. Postovulatory egg retention/stasis, which happens when shelled ova or fetuses are kept inside the oviducts, is the second type of dystocia and snakes are more concerned by this type. It is challenging to keep an eye on and regulate each of these factors to avoid preovulatory egg retention because it is not entirely clear how they impact reproduction. Postovulatory egg retention has a wide range of causes: These include environmental stressors like overcrowding, low humidity or temperature, malnourishment, poor muscle tone, lack of a proper nesting site, metabolic abnormalities like hypocalcemia, infections of the reproductive tract, cloacal infections, systemic infections, irregular egg shape, stricture or torsion of the oviducts, and pelvic canal impingement from misaligned healed fractures, soft tissue masses or uroliths [9, 46].

2.13.2.3 Types and causes of dystocia

Reptiles, and in this case ball pythons, can encounter different types of dystocias within the post ovulatory dystocia: obstructive type and non-obstructive type.

Obstructive dystocia occurs when eggs are unable to pass through the oviduct and cloaca due to anatomical barriers. This blockage can result from abnormalities in either the fetus or the mother. Fetal abnormalities, such as oversized or malformed eggs, are common causes, while maternal factors may include a deformed pelvis, oviductal constriction, or non-reproductive growths, such as abscesses or cloacal calculi which can originate from the urinary tract [9, 47]. Additionally, issues during egg-laying, such as misalignment or fracturing of eggs, can contribute to obstructive dystocia [47]. All of these clinical signs need to be taken into consideration before assessing treatment since they all require a different approach that will be discussed later on.

Many dystocias occur without any identifiable obstructive cause; this is known as non-obstructive dystocia. In these instances, the eggs or fetuses are of physiological size and shape, and the female appears anatomically normal which makes the cause even more difficult to determine [47]. Non-obstructive dystocias have been linked to various possible factors such as behavior, husbandry, outer stressors, infectious diseases and nutritional disorders [13, 43, 44].

Behavioral factors are quite difficult to identify as the main cause of dystocia since females act as usual [47]. A female may experience behavioral dystocia if stress or an inadequate oviposition site prevents her from engaging in her typical egg-laying behavior. For example, many species lay their eggs in an underground chamber or pit that they have dug out. Cage habitats often fail to accommodate for this behavior, and the animal may refuse to deposit eggs in an exposed location on the floor surface [43]. Even though egg retention in the absence of suitable nesting sites is commonly observed in lizards, as noted by DeNardo and Rosenthal [46], this behavior could also occur in ball pythons, though it is less common, based on what we know about their natural nesting habits in rodent burrows [14]. Other stressors, such as recent caging changes, noise, and habitat disturbances, are also important to consider, as they can be even more frequent contributors to egg laying complications in ball pythons related to instinctual dystocia [43].

Non-obstructive dystocias commonly result from poor breeding and housing conditions. This includes breeding individuals that are too young or, conversely, too old. It appears that snakes are prone to dystocia during their first clutch, which may be due to the fact that they are not yet fully mature despite their outward appearance [45]. This is why we can observe multiple insistences on the weight of sexual maturity, which also correlates with age, of the female ball python in reports and books. If the female is bred too early, it may result in infertile eggs, small clutches, and in this case physical exhaustion due to their young body structure, or repetitive breeding, leading to dystocia [8, 13, 45]. It is important to remember it since, unfortunately, there are cases where captive females are under significant reproductive pressure to breed as early as possible. They are fed more often than they should to meet the requirements listed above but will more likely develop other type of issues (Stahl 2001)[9].

Revisiting the housing conditions, snakes have varying needs for humidity and temperature depending on the species; if these are not met, stress can result, sometimes leading to egg-laying complications [45]. This is why it’s important for owners/ breeders to know well the housing factors specific to ball pythons and not mix those values with other popular species [15, 22, 24].

Other potential causes of dystocia include the mother's poor physical health, metabolic disorders such as hypocalcemia or kidney disease, or infections like septicemia or salpingitis, which they will be discussed later on [13].

Nutritional disorders such as obesity and malnutrition are commonly found in ball pythons and have their role to play in the reproductive outcome of females [16, 17, 44]. Because of a decrease in muscle tone, strength, fitness and overfeeding, pythons housed in captivity are more likely to become obese, which also are factors to dystocia [9]. The muscle atrophy that obese females have prevents the complete laying of eggs [45]. This is the type of problem we could encounter in ball pythons that are reared in racks since this system is unable to provide them with suitable conditions to thrive and spend energy [22]. The other side of the nutritional disorder spectrum is long term anorexia which also has its fair share in dystocia since it also affects the general musculature of the female. The reproductive process requires a lot of energy, which is exacerbated by conditions like malnutrition or dehydration. Additionally, captive females are frequently very sedentary, despite not being in poor general condition. Many veterinarians think that these females do not have the adequate muscle strength needed to lay eggs or give birth [45]. This is also commonly known as oviduct inertia [43].

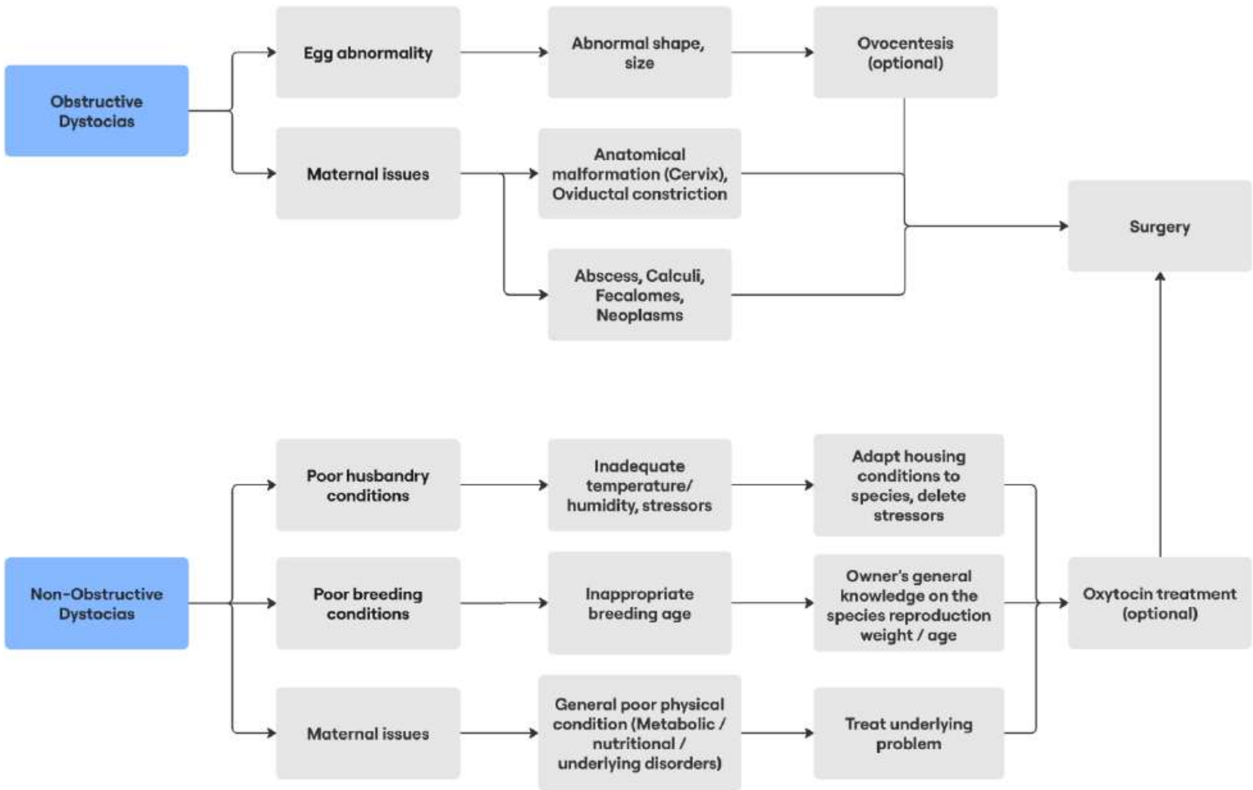

Figure 13: Resume of causes and treatment of Obstructive and Non- Obstructive dystocias

2.13.2.4 Clinical signs

As mentioned before, dystocia can be clinically difficult to assess, since females act as if nothing is wrong, unlike other reptiles like lizards [47].
Clinical signs may be vague or nonexistent, but they may include lethargy, posterior paresis, coelomic cavity distension, straining, cloacal or oviductal prolapse, decreased appetite or anorexia, dehydration, and nesting behavior [9]. Retention of one or two eggs in the oviduct during oviposition is the most common incidence in snakes compared to other reptiles. [9]. Most of the time, the owner comes to the veterinarian with these slight signs, with anorexia being the main cause, without suspecting egg retention is the main issue behind them [46].

2.13.2.5 Diagnostic methods

As stated before, this reproductive disease is commonly encountered in captive ball pythons [16, 42]. Therefore, the ability to diagnose and treat this condition is crucial for exotic animal veterinarians [45].
Most oviparous snakes can easily be diagnosed with dystocia if they have a history of recent oviposition and a visible mass caudally [47] due to the fact that retained eggs occasionally swell and become visible through the body wall [46]. However, pythons' large girth frequently makes it difficult to visually identify the retained eggs, so abdominal palpation is essential [47]. Caution must be used since the oviduct is really fragile and any bad manipulation could result to tearing [42].

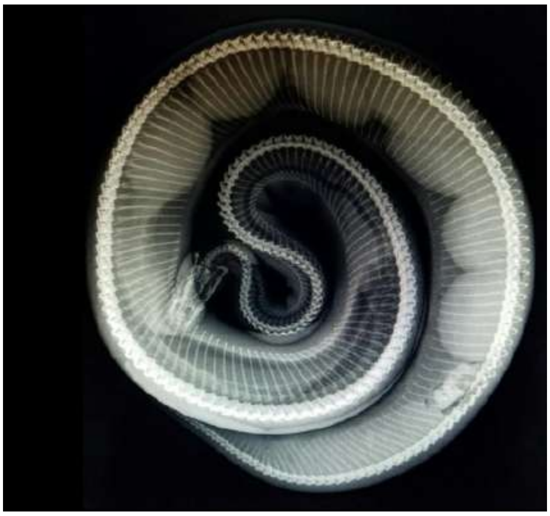

Figure 14: Radiography of a female desert ball python with dystocia, by Justin Kobylka Reptiles in The street ball journal

Even if it is possible to locate eggs by feeling the coelomic cavity, several diagnostic methods are often needed to establish a definitive diagnosis of dystocia and to develop proper treatment for the patient. Among those crucial elements of the diagnostic assessment of the dystocic reptile are radiography and ultrasound [9].
This is why knowing the history, for example if the female laid other eggs recently, is extremely important to assess the situation, as it completes the imaging results [46]. In addition, snakes lay soft-shelled eggs which turns out radiolucent that can be sometimes hard to distinguish in radiograph due to poor shell mineralization, especially in the early post-ovulatory stage, this adds up to the importance of history taking during a veterinary consultation [47].
Usually, post-ovulatory ova are more likely to be oval in shape and form a linear association, especially as oviposition draws near [9]. Either imagery tools can help with verifying egg counts, anomalies, and relative egg sizes [42].

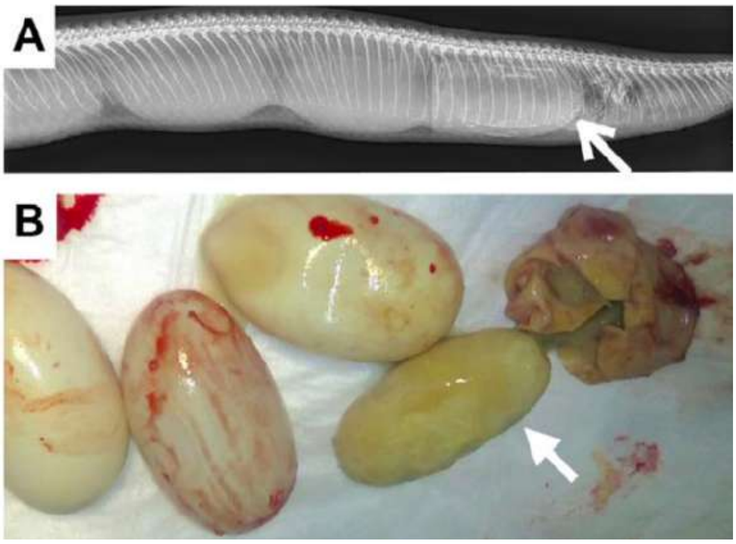

Figure 15: Impact of radiography in a female Python regius retaining eggs: (A) Profile radiography; (B) Extracted eggs post operation from the same snake. One egg is malformed and solidified (arrow) and surely was the reason of the dystocia (Di Girolamo, Selleri 2017)

Eggs have a hyperechoic perimeter on ultrasound examination, which corresponds to the mineralized shell. In squamates, the yolk is hyperechoic and the albumin is typically hypoechoic. Blood should be drawn in order to evaluate any underlying or coexisting conditions. In reptiles, dystocia may be accompanied by dehydration, hypocalcemia, infection, and renal insufficiency; therefore, a complete blood count and full biochemical analysis or, minimum, serum calcium, phosphorous, and uric acid values should be performed. Other clinical findings should be taken into consideration when interpreting the results [9].

The caudal tail vein, located along the ventral midline one-quarter to halfway down the tail (distal to the female musk glands or male hemipenes), is the main site for blood collection. A needle angled at 45–60 degrees should reach the vertebral body for withdrawal. If this fails, cardiac puncture can be attempted, with the heartbeat visible on the ventral cranial third of the body. Anesthesia is recommended for easier handling [9].

Veterinarians agree that while palpation and imaging methods are important to have a more comprehensive view on the situation, are not useful unless the owner provides with history (medically, husbandry, reproductive), which is why it's so important for them to keep track on their pets [46]. CT could also be an additional tool for diagnosis and determine a prognosis, as well as cloacal endoscopy for differential diagnosis [42]. It is also necessary to consider the animal's overall condition. It may be premature to diagnose dystocia or egg retention in an animal who is alert and responsive, has good muscle tone, is still eating or has been anorexic for few weeks, and has normal laboratory parameters. They should be closely watched, and radiology and clinical examination should be repeated as necessary. Egg retention is suspected and treated if none of the normal conditions listed above are present. The severity of the symptoms determines how intense the approach should be [46].

Differential diagnosis of dystocia includes: Faecal impaction, ascites, foreign bodies, salpingitis, cystic calculi, cysts, granulomas, neoplasia or simply a gravid female without complications [9, 46]

2.13.2.6 Complications

A dystocia's long-term prognosis for future normal reproduction improves with early diagnosis and treatment. In the contrary, several repercussions might occur. Complications with dystocia can vary from dehydration or starvation to more severe problems like increased prevalence for recurrence, infertility, or even death of the embryos in utero or the female herself. Metabolic imbalances, like hypocalcemia are also a consequence not only a predisposition. There is also physical pressure on major blood vessels and surrounding organs. Torsion of the oviduct [46], prolapse of the oviduct and oedema of the cloacal mucosa can result to dystocia as well [9]. In cases of egg retention, infertile, dead, and decomposing eggs have been observed to contribute to bacterial septicemia in snakes. The retained eggs often swell and develop changes in their shell surface, which, although likely a result of retention, worsen the condition. Egg retention has been specifically linked to bacterial septicemia, as seen in cases involving pathogens like *Aeromonas* and *Pseudomonas*. For instance, a female ball python infected with these bacteria required surgery to remove several retained eggs, all of which were infected. Despite the intervention, the snake succumbed to septicemia a few days later, highlighting the severe risk of infection associated with retained eggs [48].

In some cases, oviductal rupture can happen which leads to ectopic eggs in the coelomic cavity. Eggs themselves can break due to trauma of being mishandled which could lead to peritonitis [46] or egg yolk coelomitis [9].

2.13.2.7 Treatment and management

The treatment of this disease will depend strongly on the type of dystocia and which diagnosis is established. If there is a case of obstructive dystocia, like enlarged or malformed eggs, ovocentesis or surgery will be advised [43].

For procedures requiring general anesthesia, considering common protocols, preanesthetic rehydration is the best option whenever possible. Regarding preventative analgesia, meloxicam (0.1 mg/kg IM) or Butorphanol (1-2 mg/kg IM) are one of the most popular approaches [16]. General anesthesia in reptiles can be administered through several methods,

Ketamine alone (60-80 mg/kg IM) can be useful for light anesthesia and can be combined with butorphanol for better muscle relaxation. Induction with a combination of Propofol (5-10 mg/kg IV) and ketamine then intubation and maintenance with isoflurane (1-3%) or sevoflurane is also an option if deeper anesthesia is needed. More combinations are possible. The tail vein is generally used for intravenous injections, but it is also possible to use intracardiac injection [9, 49]. During the operation, heat must be supplied with the help of a heating matt to avoid hypothermia [45]

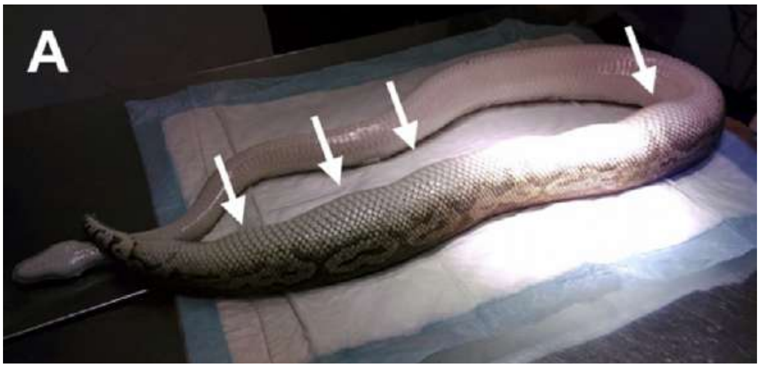

Figure 16: Anesthetized Python regius in dorsal recumbency. Noticeable eggs are evident thanks to several coelomic swellings (arrows) by Nicola Di Girolamo, DMV and Paolo Selleri, DMV,

Following induction but before surgery, it is feasible to carefully use manual palpation one final time to perhaps extract any stuck eggs since anesthesia loosens the oviductal sphincter. This relaxation increases the likelihood of success and lowers the risk of injury from the probing operations, although attention is still required to prevent prolapse or rupture [47]. If this still results unsuccessful, the next solutions are offered.

Ovocentesis is a percutaneous aspiration, performed either through the snake's ventrum or cloaca, used in oviparous snakes in which there are only a few eggs retained and positioned relatively close to the vent. With this method, a sterile needle (approximately 20 gauge) is inserted into the most distal egg through the snake's sterilized ventrum, aspirating the contents of the retained egg or eggs. While drawing in, vigilance must be employed to avoid complications like contaminating the coelomic cavity with said egg contents.

When the egg's yolk is removed, it becomes smaller and simpler for the snake to expel or the practitioner to take out. This procedure can be repeated for the following eggs. If natural oviposition is preferred after this procedure, oxytocin 1-10 units/kg is injected intramuscularly one hour following the administration of calcium glubionate 360 mg/kg (1 mL/kg) PO or calcium gluconate (100 mg/kg) SC, IM post deflation to accelerate the passing of the reduced ova. It is recommended that the snake be housed in isolation and given a nesting box filled with wet pine shavings. The aspirated egg must be surgically removed if it is not ejected within 48 hours with ovocentesis due to the possibility of infection or coelomitis from leftover yolk pouring through the newly formed hole in the eggshell[11, 42, 46, 47, 49]

Different surgical techniques can be required if manual removal or ovocentesis proves ineffective, depending on the condition of the oviducts and surrounding tissues. An ovariosalpingectomy or a salpingectomy on one or both sides [47].

The first approach is recommended in cases of illness or to stop dystocia or reproduction in the future. The latter method makes it possible for later on reproduction. Due of their high number, the blood vessels to the oviducts in the broad ligament are clamped, ligated, or stapled in groups for ovariosalpingectomy. Once more, hemostatic clips are advised to minimize tissue manipulation and shorten the duration of operation. The ends of the ligated oviductal stumps may be oversewn if they are considered too big. Ending like an ovariectomy: handling the ovary gently is necessary to prevent rupturing it and putting too much strain on the blood supply, which could cause it to dislodge or rupture. Adrenal glands are housed with the ovaries in a large mesovarium, next to the renal veins. The vessels are tied off and clamped. Since hemostatic ligating clips are simpler to use and guarantee hemostasis in the constrained space, they are recommended over sutures. Whether ovariosalpingectomy or a salpingectomy is performed, it is important to protect the ventral abdominal vein [46].

Clients must be informed of the potential consequences because a given tissue state ultimately determines the method choice and affects survival rates and future reproduction.

Most of these procedures are straightforward and start with a ventrolateral incision made between the first and second rows of dorsal scales over the region where the trapped egg is located. The entrance to the oviduct is accessed after this incision, and the confined egg is extracted. Although it is possible to remove more through this same opening, it is usually better to make a different entry for each one of them because trying to push multiple eggs down the oviduct may result in needless damage [47].

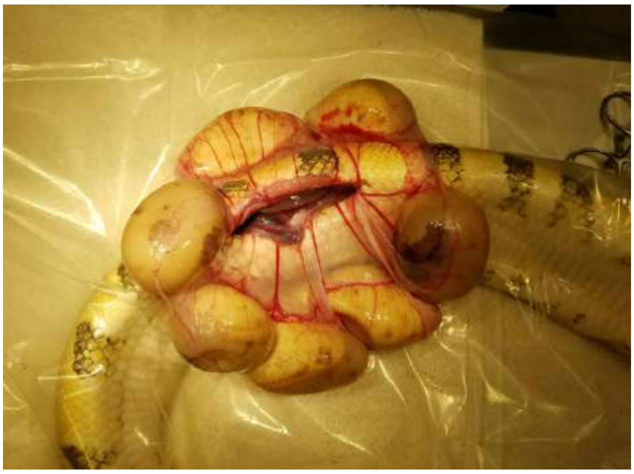

Figure 17: Same female desert Python regius as Figure 14, during operation to extract retained eggs, by Justin Kobylka Reptiles in The street ball journal

At the end, it is advised to close the oviduct and the celom using a simple continuous suture pattern and a fine, long-lasting absorbable suture, for example 5-0 Vicryl and then use a non-absorbable suture with an everting pattern for skin closing [42, 47].

Some surgeons choose to leave the oviduct open, doing so may raise the possibility of stricture formation or scarring. Removing harmed reproductive tissue can be required in cases where adhesions or significant tissue damage are widespread. It is usually advised to remove the nearby ovary as well if an oviduct is removed. A partial salpingectomy may be necessary to preserve the ovary, or more skin incisions may be necessary to reach the entire tract due to the linear alignment of reproductive organs [47].

Long-term dystocia is more likely to require a salpingectomy, either by itself or in association with an ovariectomy. Remarkably, reptiles who have had a portion of their reproductive system removed can still use the remaining ovary for reproduction in later breeding seasons but could also lead to a new dystocia [47].

If the reason of obstructive dystocia is known other than anatomical problems regarding the egg or the female, treatment of the obstruction should be attempted to enable the normal ejection of fetuses or eggs. Treatment for a fecaloma that blocks the passage of eggs or fetuses includes giving the animal a warm water bath two or three times a day to soften the stools and rehydrate the cloacal area. If this doesn't work, a feeding tube can be used to provide 1 mL/kg of paraffin oil. Before feeding, paraffin oil can be injected into a piece of prey if the animal is not anorexic. Surgery will be necessary if these methods prove ineffective [45].

As discussed above, urinary problems, and in this example, uroliths, can be source of obstructive dystocia. Species with bladders, like chelonians, are more likely to have this disease. However, bacterial infections, hypovitaminosis, or severe dehydration are frequently associated with the development of urinary calculi in the distal ureters in snakes. Obstruction may result from large stones pressing on one or both oviducts. Diagnostic techniques include cloacoscopy, ultrasonography, and radiography, where calcium stones seem more radiopaque (Reavill & Schmidt, 2010; Holz, 2018) [45]. They are also sometimes visible or palpable through the cloaca. In that case it is possible to even take it out manually. The appearance of the urolith will be rough, white and crumbly [9].

Other obstructive dystocia such as malformations of the pelvis or oviducts, or to masses, will also be treated surgically (Meredith, British Small Animal Veterinary Association, 2002; Schilliger, 2004) [45].

Coming up to the non-obstructive dystocias. If the practitioner has ruled out any type of obstruction disease causing the egg laying difficulties, the following options are open.

Manual palpation is one of the most popular techniques used to try to remove retained eggs or fetuses from snakes. By firmly rubbing a finger down the python's ventrum, eggs are "milked" out. Despite some hobbyists' claims of acceptable success if self-performed, there are significant risks involved. A common consequence of physical palpation is oviductal rupture, which might result in worsening problems, even death as stated above. This is why this manipulation should be done by a professional [47]. Before the procedure, a cloacoscopy can be done to visualize the retained egg, the distal oviducts, and the cloaca. By using this imaging method, a saline solution can be injected to widen the oviduct and lessen the egg's adherence to the wall. For this, a 1.9 mm rigid endoscope works well. To get a full view of the cloaca, the animal is turned as necessary while in ventral or dorsal recumbency. One drop of warm saline solution (0.9% NaCl) at 30°C is given roughly every three to four seconds. The retained egg or fetus can then be delicately relocated using the endoscope or forceps when it has been identified[45].

During the initial phases of non-obstructive dystocia, when the patient appears clinically healthy, correcting environmental and husbandry deficiencies may be sufficient to address the issue. Ensuring an appropriate thermal gradient, addressing dehydration with a place with warm water for soaking [42], or parenteral fluids such as Ringer's solution for reptiles which is a composition of one part Ringer lactate solution and two parts 2.5% dextrose / 0.45% saline solution, administered at 10-20 ml / kg every 24 hours [9].
Offering a suitable nesting site can often encourage oviposition [9]. For example, a closed box, such as a shoebox size plastic box with a hole on the side or the top could be a helpful stimulation for females to lay their eggs [42].

A female snake's food and reproductive condition can affect her calcium and phosphorus levels. Snakes typically have a calcium to phosphorus ratio of about 2:1. During the reproductive cycle, a healthy female snake may mobilize a considerable quantity of calcium and phosphorus, leading to the development of hyperphosphatemia (>6 mg/dL) and hypercalcemia (>13 mg/dL). However, if the snake has renal failure, the ratio of calcium to phosphorus is often inverse [10]. If the hematology results indicate hypocalcemia, it will be advisable to check the calcium intake of the python to rule out malnutrition or any underlying disease that could cause this like renal problems [9].
Studies have demonstrated that ball python do not need any UV source to metabolize calcium unlike other reptiles [23]. Their preys contain adequate levels of calcium uptake. However, if the snake hasn't been eating properly, the situation differs and could lead to complications such as hypocalcemia in this case, and more. There also should be a history review as malnutrition could hide other underlying diseases [15].
Hypocalcemia can be medically treated if necessary. In that case, oral calcium glubionate at 360 mg/kg every 6-24 hours or calcium gluconate at 100 mg/kg SC, IM, ICe every 6-24 hours can be given. Parenteral calcium is only advisable for emergencies [9, 49].
In combination with calcium treatment, oxytocin is given intramuscularly (5–30 iu/kg) to promote muscle contraction. If there is no reaction to the first delivery, the dose can be given again in 3–12 hours. In general, snakes are less responsive to oxytocin than other reptiles [9]. However, a study has proven that ball pythons are particularly receptive to this treatment. Administration of 6 iu/ kg oxytocin was given to a female *Python regius* presenting non-obstructive dystocia with a successful oviposition a few hours later. Parental Sulphadiazine (30 mg) was given after as preventive antibiotic [50]. It's essential to keep patients at their ideal

body temperature throughout treatment because heat affects how oxytocin affects oviductal muscles. If a second dose is needed, it should be 50 to 100% of the first one [47].

Cases of follicular stasis or obstructive dystocia, oxytocin is contraindicated [9]. Increased contractions in a clogged oviduct will put more pressure on the eggs, which may cause coelomitis, oviduct rupture, bleeding, or egg fractures, all of which could be fatal for the reptile [45]. If the female has shown active contractions, this drug should also be avoided [47].

Arginine vasotocin, the natural version of oxytocin, described in the literature as potentially more effective, since reptile oviducts are ten times more sensitive to it, is not available for routine clinical use. There were reports that in dystocias, Arginine vasotocin was 73% effective, and 18% of these cases was previously unresolved by oxytocin. The dose of the first drug was 0.01 to 1 μg/kg, administered intravenously or intracoelomically. It's however, still considered as a research drug and has several limitations like the storage must be in the freezer under its powdered form, as it is very unstable. If needed, it must be prepared using a saline solution or sterile water for mixture and should be used within 6 weeks if kept frozen or 5 days if kept cool. It's still considered as a research drug. Minosuberic arginine vasotocin is a less active alternative but more stable, withstanding several freeze-thaw cycles [9, 47].

Cases of non-obstructive dystocia that do not respond to medical management, will require surgical correction. Supportive care includes proper heat support, fluid therapy and nutritional supplementation, analgesia and also antibiotic therapy [9].

2.13.2.8 Prevention

Education is essential for the prevention of dystocia, which can be achieved by maintaining optimal husbandry conditions based on the documented experiences of reputable breeders. This includes ensuring a proper diet, appropriately sized enclosures, adequate lighting and heating, temperature cycling, and suitable nesting sites, while also avoiding the use of subadult or geriatric animals for breeding and prioritizing captive-born reptiles whenever possible. Detailed records, such as copulation dates, basking temperatures, and shedding schedules, should be maintained for each reptile, as they provide valuable insights during veterinary assessments. It is also crucial to seek qualified veterinary care early, before the animal's condition becomes critical [46].

2.13.3 Infectious reproductive diseases

2.13.3.1 Egg Yolk celomitis

Egg-yolk celomitis in snakes often arises from dystocia or improper owner intervention, where attempts to assist with retained ova result in trauma and leakage of reproductive material into the coelom. Retained yolk that remain for several days frequently become degenerative, increasing the likelihood of breakdown and leading to salpingitis. This condition causes inflammation and adherence of abnormal eggs, further obstructing their passage even if the initial issue is addressed. Left untreated, the leakage of reproductive material can result in systemic illness as infections ascend into the intestinal, urinary, or reproductive tracts. The diagnosis is based on history, bloodwork (often showing elevated white blood cell counts or toxic cells), radiographs, ultrasound, and exploratory surgery. For treatment it is typical to remove the abnormal ova surgically, repair or remove the severely damaged oviducts, and flushing of the coelom to prevent the spread of degenerative material. In severe cases, the ovary on the affected side may also need to be removed. Postoperative care includes broad-spectrum antimicrobial therapy for a minimum of three weeks[42].

2.13.3.2 Salpingitis/oophoritis

Bacterial salpingitis (oviduct infection) or oophoritis (infection of ova) are occasionally observed in female reptiles, most commonly when ova are present within the oviducts. Salpingitis frequently occurs alongside bacterial oophoritis, with egg or follicle retention and degradation of yolk material acting as potential predisposing factors. Conversely, preexisting salpingitis may theoretically predispose to oophoritis, making it challenging to determine which condition arose first [43]. Pseudomonas and Salmonella species are among the many bacteria that can cause salpingitis, which usually happens after oviposition or as a result of dystocia or other reproductive disorders [9]. Factors such as concurrent disease or husbandry issues that reduce immune competence can further increase the risk of oviduct infections. Definitive diagnosis can be difficult, as many cases lack cloacal exudate [43]. However, the disease is still associated with the following clinical signs: lethargy, infertility, dystocia, the production of eggs with thickened or uneven shells, deformed eggs, or eggs of variable size. The diagnosis involves identifying oviductal masses in the coelomic cavity through palpation, ultrasonography, radiography or coelioscopy, with additional evidence of infection provided by hematology and biochemistry. Aspiration of the body cavity may reveal inflammatory exudate

or free egg yolk. Early cases may respond to therapy with appropriate antibiotics and anti-inflammatories; however, advanced infections often require surgical intervention, such as ovariosalpingectomy. In valuable breeder animals, removal of infected ova via salpingotomy may be an option. Adhesions between the ova and the oviduct, as well as compromised oviduct wall integrity, are common with oophoritis or salpingitis. If they are suspected to be secondary to dystocia, the use of oxytocin must be cautious, as one of the risks would be the oviduct rupture, leading to infection spreading into the coelomic cavity [9, 43].
Preventative measures focus on maintaining species-specific environmental conditions and husbandry practices, although the underlying causes of the disease are not fully understood.
Differential diagnosis for these diseases within the other palpable/visible internal swellings in the reproductive tract are dystocia, slugs and normal gravid female[9].

2.13.3.3 Cloacitis

Inflammation of the cloaca, commonly observed in snakes can result from various causes, one being linked to extension of enteritis, which can be bacterial, viral, fungal, or parasitic in nature, or as a secondary infection following urate impaction caused by dehydration or constipation. Reproductive activities are also a common cause. During oviposition or parturition, particularly in cases of dystocia. Courtship and copulation can cause trauma or inflammation in the cloaca, potentially leading to active infections. Sexually transmitted diseases can occur in snakes, with bacteria such as mycobacterium and protozoal organisms being transmitted during courtship and copulation [9, 42]. A new study has found granulomatous disease infecting the breeding male cloaca, caused by a novel Actinomyces species (Ball Python Actinomyces), resulting in cloacitis. While a majority of breeding females didn't display any signs, they have an important role as they are considered a reservoir to this bacterium. Incidences tend to grow with repeated exposure during copulation [51].
Signs of early cloacitis include blood or malodorous discharge from the vent, and while the disease progresses, tenesmus, visible swelling or ulceration of the cloaca, vent, or surrounding tissues, even necrotizing.
In some cases, cloacoliths, consisting of inspissated purulent material and urates, may be observed. If left untreated, the infection can ascend into the gastrointestinal, urinary, or reproductive tracts, potentially leading to systemic illness.
Diagnosis is typically based on a thorough history and physical examination, which often reveal both the condition and its underlying cause. Endoscopic evaluation of the cloaca is the most

effective method for obtaining diagnostic information, allowing for sample collection for culture, sensitivity testing, biopsy, cytology. Treatment is guided by the results of diagnostic testing but generally involves gentle cleaning with dilute chlorhexidine, the application of antibiotic cream, and placing the animal on a non-adherent substrate, such as newspaper or cotton towels. In severe cases, parenteral antibiotics and anti-inflammatory therapy are recommended to manage the condition effectively [9, 42].

2.13.3.4 Cloacal prolapse

The distal gastrointestinal system, the bladder, the male hemipenes, and the female oviduct may all protrude through the cloaca and exit through the vent in snakes. The most common cause of cloacal organ prolapse is severe pushing from an underlying reason [52], but it could also happen iatrogenically if there has been bad manipulation. Infectious issues such as roundworms in the intestinal tract can also lead to intestinal prolapse through the cloaca [9].

However, the most common cloacal prolapse in ball python is the oviduct prolapse [16]. The oviduct and shell gland may evert and prolapse in severe dystocia instances. The sensitive tissue is often traumatic, oedematous or even necrotized [9] and the trapped ova are frequently still inside the oviduct. Firstly, the surface of the prolapsed tissue should be cleaned with tempered saline or dilute chlorhexidine, but always with caution due to the situation [9].A celiotomy will probably be required to evaluate any replacement tissue, however in certain cases, it might be able to minimize the prolapsed tissue. A salpingostomy can be used to remove any retained eggs prior to attempting to reduce the oviduct. The salpinx can then be closed as previously mentioned for dystocia surgery; however, the oviductal ligament and the prolapsed tissue are frequently severely injured, making tissue repair impossible. Removal of the oviduct may be required in some situations. In order to prevent future ovulation and egg-yolk celomitis, a celiotomy may be required to remove the ipsilateral ovary if the oviduct or shell gland is removed [42, 53].

Due to the extended ovaries of snakes, removing one usually necessitates multiple celiotomy incisions that involve most of the lower third of the snake's length in order to access the entire ovary. After that, the snake patient receives broad-spectrum antibiotic treatment for at least three weeks [42, 53]. However it is essential to assess the cause of the prolapse, otherwise there might be a risk of reoccurrence [9].

Figure 18: Oviductal prolapse in ball python with dystocic eggs (from Nicola Di Girolamo, DMV and Paolo Selleri, DMV, Rome, Italy)

2.13.4 Non-infectious reproductive diseases

2.13.4.1 Cloacal and ovary neoplasia

Snakes are the most prone to neoplasia compared to other reptiles[15]. Ovarian tumors are more commonly found in the reproductive tract of old females [43].

Nodular lesions may be neoplastic, whether they have an ulceration or not. According to reports, fibrosarcomas are the most prevalent tumor in snakes. They most commonly grow in the subcutaneous area of the intramandibular region, but they can also spread to internal organs [9]. Numerous ovarian and oviductal tumors, such as hemangiomas, granulosa cell tumors, fibromas, leiomyosarcoma, tubular adenoma, and carcinomas, have been observed in snakes [43]. Though rare, the latter were reported in the cloacal region [54].

Animals who are affected may experience gradual weight loss, loss of appetite, and generalized malaise and lethargy. Palpable lumps in the coelomic cavity or noticeable abdominal distension are present in a few individuals. It is possible to confirm the existence of neoplasia through exploratory surgery, radiography, ultrasonography, and needle aspiration of masses [43]. It is also claimed that a mast cell tumor needs to be stained with acid-Schiff staining on a regular basis in order to identify granules and distinguish it from fibrosarcomas [9]. Concerning the hematology results, snakes generally have the capacity to exhibit inflammation without overt leukocytosis (>12 x 10^3 cells/mL). Many of these situations will result in a severe case of monocytosis or azurophilia (20–50%), even though the leukocyte count may be within the recognized reference ranges (6–10 x 10^3 cells/mL)[10]. Surgery can be a solution but it depends on the position of the tumor and unfortunately, radiotherapy has proven unsuccessful due to its damage to surrounding tissues and not treating the problem directly[15].

2.13.4.2 Infertility

It is essential to keep complete records on breeding pairs of snakes in order to spot abnormalities with reproductive performance. To identify and resolve any possible issues, the breeder and veterinarian should examine each pair's or individual's reproductive approach. The two primary categories of snake infertility are fecundity abnormalities and fertility disorders [55].Fecundity is a measure of reproductive performance, as indicated by the number of live offspring produced, whereas infertility is the inability to conceive. Extreme temperatures, environmental toxins (such as insecticides and disinfectants), excessive radiation (like X-rays), improper cycling, abnormalities of the reproductive anatomy, over or under conditioning, incompatible pairs, or excessive/aggressive copulation are some of the factors that frequently cause infertility in male or female snakes prior to conception. Contrarily, fecundity disorders arise when conception occurs but the clutch or litter size is smaller, resulting in a higher number of sterile eggs [42], or commonly named slugs [18]. Developing embryos can potentially be harmed by environmental conditions that affect fertility, such as pollutants and severe temperatures. Fecundity can also be further decreased by maternal health problems during pregnancy, such as poor fat reserves, malnutrition, anomalies of the reproductive anatomy, underlying diseases [42], or disorders that cause dystocia as mentioned in the topic above [46]. A full analysis of snake infertility factors is accessible in various sources [42]. A clinical examination to rule out underlying disease processes, an ultrasound examination of the ovaries to confirm vitellogenesis, as well as the oviduct for signs of salpingitis, an endoscopic examination of the reproductive tract, and a review of husbandry and nutrition are some methods for evaluating infertile females [9].

3. Objectives

The primary objective of this study is to explore reproductive diseases encountered in female ball pythons, particularly conditions such as dystocia, salpingitis, cloacal prolapse, and infertility with their respective treatments. The study aims to assess the impact of various factors, including husbandry practices like temperature regulation, humidity levels, and enclosure types, on reproductive success. Special attention is given to understanding how selective breeding practices, particularly those involving morphs like spider and desert, influence their reproductive health**.** The study also seeks to explore how the growing exotic pet trade and breeding practices influence reproductive challenges in captivity, particularly concerning gravid females. One of the objectives is to evaluate the impact of global exportation practices, such as ranching and the collection of gravid females, on breeding outcomes and reproductive health in captive ball pythons.

Additionally, the study aims to assess how environmental stressors, such as light cycles, enclosure space, and nutrition (including calcium and vitamin D_3 supplementation), impact reproductive outcomes, as these factors are often overlooked in the current literature.

Ultimately, the research intends to provide recommendations for improving veterinary care, breeding standards, and husbandry practices to reduce reproductive health problems in captive female ball pythons.

4. Materials and Methods

This study employs a systematic literature review methodology to gather and analyze data on reproductive health issues in female ball pythons. The primary sources of data were academic and veterinary sources, including peer-reviewed journal articles and veterinary textbooks. Articles from databases such as Google Scholar, PubMed, and ResearchGate were essential in providing current and relevant research on reproductive diseases, husbandry practices, and the impact of selective breeding on the reproductive health of ball pythons. These sources were carefully analyzed to explore reproductive pathologies, such as dystocia, salpingitis, cloacal prolapse, and infertility, with a particular focus on how environmental factors and breeding practices contribute to these issues.

In addition to academic articles, veterinary textbooks on reptile care and reproduction were consulted to obtain foundational knowledge regarding the reproductive anatomy of female ball pythons, as well as common health problems and their treatment. These texts provided insights into managing reproductive diseases in captivity. For up-to date statistics, websites such as the world of ball python and morph market were consulted, as well as personal case studies from breeders.

Data were synthesized to identify key patterns and correlations between environmental and husbandry factors, such as diet, enclosure design, and selective breeding, and their influence on reproductive health. An analytical method was employed using thematic analysis to identify specific patterns within the information, focusing on key themes such as breeding practices, morph-related health issues, environmental stressors and female reproductive diseases. This method helped categorize findings and draw correlations between selective breeding, reproductive disorders, and environmental factors. Special attention was given to the potential link between selective breeding for morphs like spider and desert and the occurrence of reproductive disorders, though it remains a subject of suspicion rather than a confirmed association. Additionally, the influence of the exotic pet trade**,** particularly the export market**,** was considered. The study explored how the pressures of international demand, especially the collection of gravid females for export, may impact reproductive health by introducing stress and altering breeding cycles in captive populations. This aspect is essential to understanding the broader context in which reproductive health issues arise in captive ball pythons. The search for relevant literature focused on specific keywords such as “Ball pythons,” “*Python regius*,” “reproductive diseases,” “dystocia,” “salpingitis,” “cloacal prolapse,” “infertility,” “selective breeding,” “breeding practices,” “morphs,” "husbandry practices,” “environmental stressors,” “temperature regulation,” “humidity,” and “enclosure types.” Additional keywords like “veterinary care,” “diagnosis,” “treatment protocols,” “exportation,” “ranching,” and “collection of gravid females” were used to ensure comprehensive coverage of all aspects related to breeding and reproductive health. Studies and conference proceedings that met inclusion criteria were selected based on their focus on reproductive diseases in ball pythons. The research prioritized studies that examined breeding practices, morph-related health issues, and the influence of husbandry factors on reproductive outcomes. Articles and conference proceedings discussing the impact of exportation practices, such as ranching and gravid female collection, were also included to explore their effects on reproductive health in captive populations.

5. Results

The study found that dystocia is a prevalent reproductive health issue in female ball pythons. The disease was classified according to its occurrence, its types, causes, complications and treatment which then helped to present accordingly other pathologies whereas they would be infectious or non- infectious. Infectious diseases include egg yolk celomitis, salpingitis, cloacitis and sometimes prolapses. Non-infectious involves neoplasms and infertility. Other complications resulting from dystocia such as hypocalcemia, septicemia and death were not classified as reproductive diseases unlike some of the above but their reference significantly contributes to understanding the broader health implications and the urgency of timely diagnosis and intervention.

Sorting out dystocia and highlighting post-ovulatory type was essential to picture what is more commonly observed in ball pythons and what significant complications it can lead to if left untreated. Post-ovulatory was further classified into obstructive and non-obstructive types. Non-obstructive dystocia typically results from suboptimal husbandry conditions, such as improper temperature regulation, humidity levels, and inadequate enclosure types, which could also lead to the decline of the maternal physical capacity and also interfere with the normal egg-laying behavior. The environmental factors prevent the smooth passage of eggs, leading to difficulty in laying. On the other hand, obstructive dystocia occurs when a physical blockage, such as a larger or deformed egg is stuck in the reproductive tract and prevents the passage. This can also happen with a fecaloma or calculi. Maternal issues can also occur with cervix malformations. They all require more immediate veterinary intervention to resolve.

It was revealed that diagnosing dystocia can be challenging as snakes don't always show visible clinical signs. This is why reliance on palpation, imaging, bloodwork and most importantly, taking history is essential. Ways of prevention such as regulating husbandry measures to the species, nutrition adjustments, suppression of stressors and most importantly education on the species were assessed against the diseases.

The study also examined the potential impact of selective breeding, particularly for morphs like spider and desert, which may be linked to reproductive health problems. While the exact relationship is not definitively proven, it is suspected that these morphs may contribute to certain reproductive disorders, possibly due to genetic predispositions. Even if it was shown that severe cases of spider morph englobe both sexes difficulties to perform the act of mating due to the wobbling condition and the outcome of egg failures in case of homozygous breeding. Desert morph is until now, the only one focused on the female's fertility only. Proving that there could be a genetic factor relying this cause. Moreover, spider is not the only morph presenting motoric conditions, other ones such as champagne, woma and hidden gene woma do too and caramel albino morph appears to show signs of infertility, even if it's not mentioned for which sex. All of them were simply mentioned in articles but none has been individually studied in detail and handled.

The research also explored the influence of the exotic pet trade on reproductive health in ball pythons. While the collection of gravid females and trade practices can negatively impact health, the growing demand in the ball python market further exacerbates the pressures on wild populations and breeding operations. Regulations have been established but reports suspect that they are not enough.

Broad observations from the literature further emphasize the importance of early intervention and education among breeders to prevent reproductive issues. A lack of awareness regarding optimal husbandry practices, particularly for novice breeders, frequently leads to preventable health complications. These findings highlight the multifaceted nature of reproductive health challenges in female ball pythons, encompassing a wide range of diseases influenced by husbandry, genetics, and trade pressures. While the classification of dystocia provided a foundational understanding of its prevalence, types, and complications, the exploration of other reproductive pathologies, both infectious and non-infectious, broadened the scope of the analysis. The role of selective breeding and the exotic pet trade emerged as critical factors contributing to these challenges, with growing evidence pointing to their impact on both individual health and broader population sustainability.

These results set the stage for a deeper exploration in the discussion chapter, where the implications of these findings will be analyzed.

6. Discussion

The findings of this study emphasize the crucial role that husbandry practices play in the reproductive health of female ball pythons. Proper environmental management—such as maintaining optimal temperature and humidity levels, as well as providing adequate enclosure types and nesting sites—is essential for successful breeding. The study also examined the potential impact of selective breeding, particularly for morphs like spider and Desert, which may be linked to reproductive health problems. While the exact relationship is not definitively proven, desert morphs are notably associated with female infertility, presenting a clear case for further research into genetic predispositions. In addition, neurological conditions linked to morphs such as champagne, woma, and hidden gene woma raise further ethical concerns. These morphs, like spider, are bred for their unique patterns but often display motoric impairments, such as uncoordinated movements, which compromise their overall welfare. Although the health issues of these morphs are well-documented anecdotally, they remain under-researched scientifically, emphasizing the need for targeted studies to inform ethical breeding practices.

The spider morph, on the other hand, has been a subject of ongoing debate within the breeding community. Despite the emerging evidence suggesting that the spider morph may be associated with certain reproductive health problems, many breeders continue to deny any such link, claiming there are no issues with the morph. This resistance to acknowledging the problem highlights the need for increased awareness and transparency within the breeding community. Addressing these issues openly and encouraging more studies into the reproductive health of spider ball pythons could lead to more informed breeding practices and better welfare for these snakes.

The mojave bee morph exemplifies the creative potential of selective breeding, combining several traits into a single snake. It highlights the extensive genetic possibilities that breeders have explored, showcasing the ability to incorporate multiple dominant or co-dominant traits into a single lineage. However, this pursuit of increasingly complex morph combinations may inadvertently compound genetic risks, as traits linked to health issues are passed along with aesthetic features as the spider and desert morph have shown. This underscores the importance of balancing innovation with responsibility to ensure that breeding practices do not unintentionally compromise animal welfare.

The growing interest in unique and rare morphs not only places demands on breeding practices but also contributes to broader pressures within the exotic pet trade. This demand could drive breeders to increase production efforts, often intensifying their breeding programs to meet market expectations. Such pressures may further strain reproductive health, as breeders may prioritize volume over animal welfare. One example of this is the widespread use of rack systems, which allow breeders to house more animals in smaller spaces, making it easier to control temperature and humidity levels. However, while these environmental factors can be easily managed, rack systems do not address the behavioral needs of the snakes, such as space to burrow, climb and hide, which can lead to stress. As a result, it can be a difficult decision for breeders to determine whether to prioritize the efficient use of space or the well-being of the animals. While researching on incubation methods, it has been stated that breeders tend to prefer incubators instead of maternal coiling, even though there have been numerous advantages to it such as protection, maintaining stable microclimate and being constantly present and on the outlook of any possible pathologic egg. The reason behind this would be that the female is available sooner for the next mating when she is not occupied with her clutch, making the priority of quantity noticeable. Some expert breeders manage to create optimal environment for the eggs, but it has been shown that maternal incubation leads to better hatchlings health wise, and less mortality.

So, while increasing demand for ball pythons places additional pressure on captive breeding programs to meet market expectations, as shown with the numerous behaviors of some breeders, the harvesting of wild pythons for the pet trade remains a concern, particularly in the context of illegal activities, which didn't stop even with the emergence of regulations and suggests that captive breeding isn't meeting enough demands. It has been shown that in the harvesting of wild pythons, the majority of this population includes hatchlings and gravid females. As this work demonstrates, stress can be a predisposing factor to reproductive diseases and these particular females are first in line to experience it.

Concerning the reproductive related diseases in females, it was helpful to note that there are different types of dystocia, pre-ovulatory and post-ovulatory types and obstructive and non-obstructive. Pre-ovulatory dystocia, characterized by the retention of follicles within the ovaries, often results in follicular stasis, where the follicles fail to develop further or ovulate. While less commonly observed in ball pythons, it is nevertheless useful to mention it for those who are unfamiliar with this disease for better acknowledgment. Moreover, this condition contrasts with post-ovulatory dystocia, which involves the retention of fully shelled eggs within the oviduct and / or the cloaca and is more frequently encountered. Obstructive dystocia typically arises from physical barriers, such as oversized or malformed eggs, oviductal strictures, fecalomas, or calculi, which prevent the normal passage of eggs. Non-obstructive dystocia, however, is commonly associated with environmental factors like suboptimal temperature, humidity, or inadequate nesting conditions, which disrupt the physiological and behavioral processes required for oviposition. Recognizing these distinctions is crucial for identifying the underlying causes and implementing appropriate interventions. When egg retention occurs, even partially, it can also lead to disruptions in maternal behavior. Even if clinical signs are mostly discreet, displaying lethargy is still one of them. For instance, a female python retaining one or more eggs may be unable to fully express critical behaviors like coiling and maintaining a stable microclimate for her clutch. These behaviors are essential for the viability of already-laid eggs, and their absence can leave the eggs exposed to dehydration or infection, reducing hatching success. Additionally, the strain caused by retained eggs may compound the female's reproductive challenges, highlighting the need for timely interventions to support both maternal and clutch health. In addition to dystocia, other reproductive diseases such as egg yolk coelomitis, salpingitis, cloacitis, and oviduct prolapse were classified as infectious conditions, while neoplasia and infertility were noted as non-infectious diseases. These conditions, though less commonly reported than dystocia, are significant contributors to reproductive health challenges. For instance, egg yolk coelomitis and salpingitis are often a consequence of dystocia rather than independent causes. Cloacitis, often observed in females, may arise due to stress, dehydration, or improper substrate, emphasizing the importance of careful environmental management. Neoplasms, though rare, further complicate reproductive health, requiring prompt veterinary intervention. Non-infectious conditions like oviduct prolapse are frequently linked to the physical strain of oviposition, especially in cases of poor nutrition or obesity, while infertility is suspected to have both environmental and genetic components.

The management of reproductive diseases in female ball pythons requires a multifaceted approach that addresses not only treatment but also prevention and owner education. Treatments for conditions like dystocia, egg yolk coelomitis, cloacitis, and neoplasms often depend on the severity of the disease and the clinical presentation. For example, in cases of obstructive dystocia where eggs are physically retained, surgical intervention such as salpingotomy or salpingectomy may be necessary. These procedures require meticulous planning, including appropriate anesthesia protocols tailored to the species. Isoflurane is commonly used for maintenance due to its safety profile in reptiles. Non-surgical approaches, such as the combination of calcium - oxytocin administration, may be employed for non-obstructive dystocia, but their efficacy varies depending on the condition's underlying cause and species. With Ball Python, it has been shown that it works well unlike other reptiles and even snakes. Clinical signs often provide the first indication of reproductive diseases, but they can be subtle, necessitating detailed history-taking from the owner. Signs like anorexia, lethargy, or abnormal behavior should prompt immediate evaluation. Diagnostic tools such as radiography, ultrasonography, and bloodwork are invaluable for confirming conditions like egg retention or infections. These diagnostics also allow veterinarians to assess the extent of the disease and determine whether surgery is required. Prevention plays a pivotal role in mitigating reproductive diseases. Optimal husbandry conditions, including proper temperature, humidity, and nesting sites, significantly reduce the risk of conditions like dystocia and cloacitis. Additionally, educating owners about the specific needs of their ball python, including the importance of monitoring reproductive cycles, is critical. Owner knowledge also enhances history-taking during veterinary visits, as detailed observations about the snake's behavior and environment can aid in early detection and intervention. Surgical techniques and interventions remain the backbone of treatment for severe cases, but they must be complemented by supportive care and a focus on minimizing stress during recovery. Antibiotics are often required for infections like egg yolk coelomitis, while hydration and nutritional support are essential for post-surgical recovery. These interventions underline the importance of a comprehensive approach to treatment, combining veterinarian expertise with proactive care strategies to ensure long-term health.

Reproductive complications can lead to the death of female ball pythons, particularly in the context of dystocia. Hypocalcemia plays a dual role, acting both as a cause and consequence of dystocia. On the one hand, inadequate calcium intake, poor dietary balance, or renal disease can lead to hypocalcemia, weakening the musculature required for oviposition and increasing the risk of egg retention. On the other hand, prolonged dystocia depletes the calcium reserves of the female, exacerbating this metabolic imbalance. While light exposure is critical for calcium metabolism in some reptiles, ball pythons primarily rely on dietary sources for calcium regulation, rendering UV light less relevant. However, dietary deficiencies or prolonged anorexia can disrupt calcium balance, contributing to the severity of these conditions. Septicemia, often a result of retained eggs or infections like egg yolk coelomitis, poses an immediate life-threatening risk, necessitating prompt veterinary intervention. Infertility, while not life-threatening, remains a significant consequence of chronic reproductive challenges, potentially resulting from repeated dystocia, inadequate husbandry, or genetic predispositions. If septicemia or dystocia remains untreated, these conditions can progress to systemic failure and, in severe cases, death, underscoring the critical importance of early diagnosis and management. If septicemia or dystocia remains untreated, these conditions can progress to systemic failure and, in severe cases, death. This highlights the need for prompt diagnosis, timely intervention, and preventative measures to safeguard the health of affected females.

Overall, this research highlights the intertwined roles of husbandry practices, breeder education, and selective breeding in shaping the reproductive health of captive ball pythons. Most reproductive diseases, such as dystocia, egg yolk coelomitis, and cloacitis, can be easily prevented when basic husbandry standards are maintained, ensuring proper animal welfare for the species. While ball pythons share many care requirements with other reptiles, this study emphasizes moments where their needs diverge, such as the successful use of oxytocin for non-obstructive dystocia, their reliance on dietary calcium rather than UV light, or their predisposition to specific conditions like hypocalcemia and dystocia. These unique factors underscore the importance of adapting care to the species, particularly for breeders, who face higher risks of encountering such challenges compared to hobbyists. Raising awareness about these distinctions and promoting responsible breeding practices can lead to improved reproductive outcomes, reduced preventable mortality, and better overall welfare. Future studies exploring the long-term effects of breeding practices and husbandry innovations could provide further insights into sustainable strategies for captive management. Additionally, as the passion for creating new morphs continues to grow, there is an urgent need for more in-depth scientific research to go beyond the superficial understanding of their genetics and associated health concerns. By addressing these gaps, breeders can make informed decisions that balance innovation with animal welfare, ensuring selective breeding contributes positively to the species overall health and well-being.

7. Summary

This thesis investigates the reproductive health of female ball pythons (*Python regius*), a species highly valued in the global exotic pet trade. Emphasis is placed on reproductive diseases, including dystocia, egg yolk coelomitis, salpingitis, neoplasia, and their relationship with husbandry, selective breeding, and environmental factors. The study highlights the challenges posed by morph-specific pathologies, such as infertility in desert morphs and the breeding complications observed in spider morphs, which are exacerbated by intensive breeding practices aimed at satisfying market demands. Results indicate that poor husbandry, including inadequate temperature, humidity, and enclosure designs, significantly contributes to reproductive disorders. Stress associated with improper nesting conditions, overfeeding, or insufficient nutrition impacts reproductive success. Observations also reveal that maternal behaviors, such as coiling around clutches, are critical for successful reproduction, yet are often disrupted in captive settings. Such disruptions, along with inappropriate incubation techniques, can lead to lower hatching success and increased embryonic mortality. Additional findings suggest that high reproductive pressures, particularly in inexperienced breeders, lead to delayed diagnoses and ineffective care strategies. In terms of management, evidence suggests that improving information provided to breeders, focusing on early intervention, and tailoring husbandry to replicate natural environments can mitigate risks and enhance reproductive outcomes. The global trade and export market, particularly ranching practices in West Africa, also play a critical role in reproductive health. The collection of gravid females from the wild creates stress that not only impacts individual health but also pressures wild populations. Captive breeding practices, although beneficial for reducing wild harvests, frequently compromise welfare due to the prioritization of aesthetics over health. Export systems, such as those in Ghana, Benin, and Togo, are evaluated for their impact on the species, highlighting the need for stricter oversight and better welfare standards. Conclusions underscore the necessity of balancing market demand with conservation and welfare. Implementing stricter regulations, promoting ethical breeding practices, and addressing the needs of breeders and veterinarians are essential. This work contributes to veterinary knowledge by providing a framework for understanding and addressing reproductive health challenges in ball pythons, advocating for sustainable and ethical approaches to their care and management.

8. References

1. Starck JM, Schrenk F, Schröder S, Pees M (2022) Malformations of the sacculus and the semicircular canals in spider morph pythons. PloS One 17:e0262788. https://doi.org/10.1371/journal.pone.0262788

2. Rizzo JM (2014) Captive Care and Husbandry of Ball Pythons (Python regius). J Herpetol Med Surg 24:48–52. https://doi.org/10.5818/1529-9651-24.1.48

3. Toudonou CAS (2007) Ball python Python regius. Laboratory of Applied Ecology, University of Abomey-Calavi

4. D'Cruze N (2020) Searching for snakes: ball python hunting in southern Togo, West Africa. Nat Conserv 38:36. https://doi.org/10.3897/natureconservation.38.47864

5. Barker DG, Barker TM, Davis MA, Schuett (2015) review of the systematics and taxonomy of Pythonidae: an ancient serpent lineage | Zoological Journal of the Linnean Society | Oxford Academic. Zool. J. Linn. Soc. 1–19

6. Broghammer S (2012) Python Regius - Atlas of colour morphs keeping and breeding. NTV Natur und Tier-Verlag, Münster, Germany

7. Uetz P, Hallermann J, Hosek J (2014) Python regius (SHAW 1802). In: Reptile Database. https://reptile-database.reptarium.cz/species.php?genus=Python&species=regius. Accessed 26 Nov 2024

8. Sutherland C (2009) Ball pythons : a complete guide to Python regius, T.F.H Publications. Neptune City, NJ : T.F.H. Publications

9. Doneley B, Monks D, Johnson R, Carmel B (2017) Reptile medicine and surgery in clinical practice, First edition. Wiley Blackwell, Hoboken, New Jersey, USA

10. Mitchell MA (2004) Snake care and husbandry. Veterinary Clin North Am Exot Anim Pract 7:421–446, vii–viii. https://doi.org/10.1016/j.cvex.2004.02.007

11. Barten S (2013) Ball pythons: natural history, husbandry, diseases, and techniques. In: CABI Databases. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20133225629. Accessed 29 Sep 2024

12. Aubret F, Bonnet X, Harris M, Maumelat S (2005) Sex Differences in Body Size and Ectoparasite Load in the Ball Python, Python regius. J Herpetol 39:315–320. https://doi.org/10.1670/111-02N

13. Laroche CT (2009) Le python royal en captivité: élevage, pathologie et santé publique. Thèse pour le doctorat vétérinaire, Faculté de médécine de Créteil

14. Grzimek B, Murphy JB, Schlager (19) Grzimek's animal life encyclopedia, 2. ed. Gale, Detroit

15. Rowland M (2011) Veterinary care of snakes. In Pract 33:534–541. https://doi.org/10.1136/inp.d7317

16. Fisher P (2005) Unusual Pet Care, Adapted from Exotic DVM, Volume 2.4 © Zoological Education Network 2005

17. De Vosjoli P, Klingenberg R (1994) The Ball Python manual, First edition. Advanced Vivarium Systems, Lakeside, California

18. Bertocchi M, Pelizzone I, Parmigiani E, Ponzio P, Macchi E, Righi F, Girolamo ND, Bigliardi E, Denti L, Bresciani C, Ianni FD (2018) Monitoring the reproductive activity in captive bred female ball pythons (P. regius) by ultrasound evaluation and noninvasive analysis of faecal reproductive hormone (progesterone and 17β-estradiol) metabolites trends. PLOS ONE 13:e0199377. https://doi.org/10.1371/journal.pone.0199377

19. Banzato T, Russo E, Finotti L, Milan MC, Gianesella M, Zotti A (2012) Ultrasonographic anatomy of the coelomic organs of boid snakes (Boa constrictor imperator, Python regius, Python molurus molurus, and Python curtus). Am J Vet Res 73:634–645. https://doi.org/10.2460/ajvr.73.5.634

20. Di Ianni F, Albarella S, Vetere A, Torcello M, Ablondi M, Pugliano M, Di Mauro S, Parma P, Ciotola F (2023) Demonstration of Parthenogenetic Reproduction in a Pet Ball Python (Python regius) through Analysis of Early-Stage Embryos. Genes 14:1744. https://doi.org/10.3390/genes14091744

21. D'Cruze N, Paterson S, Green J, Megson D, Warwick C, Coulthard E, Norrey JD, Auliya M, Carder G (2020) Dropping the Ball? The Welfare of Ball Pythons Traded in the EU and North America. Animals 10:413. https://doi.org/10.3390/ani10030413

22. Hollandt T, Baur M, Wöhr A-C (2021) Animal-appropriate housing of ball pythons (Python regius)—Behavior-based evaluation of two types of housing systems. PLOS ONE 16:e0247082. https://doi.org/10.1371/journal.pone.0247082

23. Hedley J, Eatwell K (2013) The effects of UV light on calcium metabolism in ball pythons (Python regius). Vet Rec 173:345. https://doi.org/10.1136/vr.101555

24. Divers S (1996) Basic reptile husbandry, history taking and clinical examination. In Pract 18:. https://doi.org/10.1136/inpract.18.2.51

25. McFadden MS, Bennett RA, Kinsel MJ, Mitchell MA (2011) Evaluation of the histologic reactions to commonly used suture materials in the skin and musculature of ball pythons (Python regius). Am J Vet Res 72:1397–1406. https://doi.org/10.2460/ajvr.72.10.1397

26. Waas S, Werner RA, Starck JM (2010) Fuel switching and energy partitioning during the postprandial metabolic response in the ball python (Python regius). J Exp Biol 213:1266–1271. https://doi.org/10.1242/jeb.033662

27. de Vosjoli P (1999) Designing Environments for Captive Amphibians and Reptiles. Veterinary Clin North Am Exot Anim Pract 2:43–68. https://doi.org/10.1016/S1094-9194(17)30139-1

28. Sutherland C (2006) Ball python care, 1st edition. Neptune City, NJ : T.F.H. Publications, Neptune City, New Jersey, USA

29. Schrenk F, Starck JM, Flegel T, Kiefer I, Tebrün W, Pees M (2022) Comparative Assessment of Computed Tomography and Magnetic Resonance Imaging of Spider Morph and Wild Type Ball Pythons (python regius) for Evaluation of the Morphological Correlate of Wobble Syndrome. J Comp Pathol 196:26–40. https://doi.org/10.1016/j.jcpa.2022.05.003

30. Brown AR, Comai K, Mannino D, McCullough H, Donekal Y, Meyers HC, Graves CW, Seidel HS (2022) A community-science approach identifies genetic variants associated with three color morphs in ball pythons (Python regius). PLoS ONE 17:e0276376. https://doi.org/10.1371/journal.pone.0276376

31. Rose MP, Williams DL (2014) Neurological dysfunction in a ball python (Python regius) colour morph and implications for welfare. J Eotic Pet Med 23:. https://doi.org/10.1053/j.jepm.2014.06.002

32. Kobylka J (2016) Fertility in Desert females – An Overview and Case Study. In: Ball Str. J. https://jkrballstreetjournal.com/2016/07/17/fertility-in-desert-females-an-overview-and-case-study/. Accessed 20 Oct 2024

33. The big morph list. In: World Ball Pythons. https://www.worldofballpythons.com/morphs/. Accessed 26 Nov 2024

34. Aubret F, Bonnet X, Shine R, Maumelat S (2005) Energy expenditure for parental care may be trivial for brooding pythons, Python regius. Anim Behav 69:1043–1053. https://doi.org/10.1016/j.anbehav.2004.09.008

35. Ellis TM, Chappell MA (1987) Metabolism, temperature relations, maternal behavior, and reproductive energetics in the ball python (Python regius). J Comp Physiol B 157:393–402. https://doi.org/10.1007/BF00693366

36. Aubret F, Bonnet X, Shine R, Maumelat S (2005) Why do female ball pythons (Python regius) coil so tightly around their eggs? Evol. Ecol. Res. 1049–1061

37. Aubret F, Bonnet X, Shine R, Maumelat S (2003) Clutch Size manipulation, hatching success and offspring phenotype in the ball python (Python regius). Biol J Linn Soc Biol 78:263–272. https://doi.org/10.1046/j.1095-8312.2003.00169.x

38. Moniz HA, Buck JH, Crowell HL, Goetz SM, Ruiz TD, Taylor EN, Boback SM (2024) High thermal quality rookeries facilitate high thermoregulatory accuracy in pregnant female rattlesnakes. J Therm Biol 124:103948. https://doi.org/10.1016/j.jtherbio.2024.103948

39. Harrington L, Green J, Muinde P, Macdonald D, Auliya M, D'Cruze N (2020) Snakes and ladders: A review of ball python production in West Africa for the global pet market Launched to accelerate biodiversity conservation. Nat Conserv 41:. https://doi.org/10.3897/natureconservation.41.51270

40. Ball Pythons For Sale. In: MorphMarket. https://www.morphmarket.com/all/c/reptiles/pythons/ball-pythons. Accessed 26 Nov 2024

41. Ineich I (2006) Les élevages de réptiles et de scorpions au Benin, Togo et Ghana, plus particulièrement la gestion des quotas d'exportation et la définiton des codes "source" des

specimens exportes. Environ Policy Law 4:76. https://doi.org/10.1016/S0378-777X(78)80178-4

42. Stahl SJ (2002) Veterinary management of snake reproduction. Vet Clin Exot Anim Pract 5:615–636. https://doi.org/10.1016/S1094-9194(02)00017-8

43. E. Burgess M (2010) Common reproductive pathologies in reptiles. Society for Theriogenology

44. Funk RS (2004) Diagnosing and treating reproductive disorders in snakes. Proc Annu Conf Assoc Reptil Amphib Vet 11:35–40

45. Pellegrin C (2019) La dystocie chez les ophidiens: étiologie, diagnostic et prise en charge. Thèse d'exercice, Ecole nationale vétérinaire de Toulouse

46. DeNardo D, Barten SL, Rosenthal KL, Raiti P, Nathan R (2000) Dystocia. J Herpetol Med Surg 10:8

47. DeNardo D, Mader DR (2006) Chapter 53. Dystocias, Second. Sauders Elsevier, London

48. Millichamp NJ, Lawrence K, Jacobson ER, Jackson OF, Bell DA (1983) Egg retention in snakes. J Am Vet Med Assoc 183:1213–1218

49. Carpenter JW (2013) Exotic animal formulary, 4th ed. Elsevier Saunders, St. Louis, Missouri, USA

50. Morgan DR (1988) The use of oxytocin to relieve dystocia in a royal python (Python Regius) (Serpentes: Boidae). J Herpetol Assoc Afr. https://doi.org/10.1080/04416651.1988.9650187

51. Tillis SB, Iredale ME, Childress AL, Graham EA, Wellehan JFX, Isaza R, Ossiboff RJ (2021) Oral, Cloacal, and Hemipenal Actinomycosis in Captive Ball Pythons (Python regius). Front Vet Sci 7:. https://doi.org/10.3389/fvets.2020.594600

52. Mader D (2006) Cloacal Prolapse. In: Reptile medecine and Surgery. pp 751–755

53. Lock BA (2000) Reproductive surgery in reptiles. Veterinary Clin North Am Exot Anim Pract 3:733–752, vii. https://doi.org/10.1016/s1094-9194(17)30072-5

54. Smith HM, Betz TW (1965) A case of fatal cloacal tumor in a snake. Br J Herpetol 3:199–200

55. Ross RA, Marzec G (1990) The reproductive husbandry of Pythons and Boas. Institution of herpetological research

Thesis progress report for veterinary students

Name of student: Daniela Ayma Paredes……………………

Neptun code of the student: KEQGT7……………………………………………………

Name and title of the supervisor: Dr. Árisz Ziszisz …………………………………

Department: Exotic Animal-, Wildlife-, Fish-, and Honeybee Medicine…

Thesis title: Reproductive diseases in female Python Regius

Consultation – 1st semester

	Timing			Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2023	10	29	Select the topic	
2.	2023	12	07	Disscuss different approaches of data collection	
3.	2024	02	22	Disscuss the result of data collection	
4.	2024	03	04	Selection of the collected information	
5.	2024	04	04	Schedule for the next semester	

Grade achieved at the end of the first semester: ……… 5 ………………………

Consultation – 2nd semester

	Timing			Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2024	05	13	Thesis writing check	
2.	2024	08	30	Thesis writing check	
3.	2024	10	01	Results evaluation	
4.	2024	10	20	Creation of a summary	
5.	2024	11	22	Finalization of the thesis	

Grade achieved at the end of the second semester: ....5..............................

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,

Állatorvostudományi Egyetem
Dr. Ziszisz Árisz
4010
Egzotikusállat- és Vadegészségügyi Tanszék

....
signature of the supervisor

Signature of the student: ....

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

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