How does my tortoise hibernate?

Siuna A. Reid BVMS CertAVP(ZooMed) MRCVS

Presented to the BCG Northern Symposium at Chester Zoo on
18th October 2014

Tortoises have been kept in Britain as pets for around 150 years (Thomas 2014). Most of the species kept are Mediterranean in origin and most have adapted the ability to hibernate for long periods over the winter to avoid the cold and inhospitable weather. Hibernation is a normal process and is seen in both cold and hot extremes. It is a way of avoiding temperature ranges that are not ideal for the tortoise. Food may be in short supply or non-existent.

The purpose of this talk is to try to unravel the anatomy and physiology that allows the tortoise to survive protracted periods without food.

Ectothermy

Tortoises are ectothermic which means that they receive energy from the sun. In mammals the breakdown of food in the body produces heat as a by-product (Varga 2004). Reptiles acquire heat from the environment. Basking under a heat lamp mimics heat from the sun. Similarly, conduction also provides energy when the reptile lies on a heated surface. In the wild this could be a rock, and in captivity a heat pad either under the vivarium floor or on the side of the vivarium. A 100g reptile compared with a 100g mammal requires 5% of the amount of food on a daily basis (Nagy 1982) (Fig.1). Food is used to repair damaged tissues, lay down fat and make eggs. Heat from the sun or in an artificial environment affects the heart rate, kidney perfusion and gut motility.

During hibernation, ectothermy enables the owner to control the length of hibernation. A gradual reduction in the background temperature slows the tortoise down. Tortoises function best between 25 and 30 degrees C. However, this is also species dependent. As the ambient temperature drops the tortoise starts to slow down. Movement of muscles, including the heart rate, slows until when between 3 and 10 degrees C the tortoise is at the perfect temperature to hibernate. The heart rate may be as slow as 6 beats per minute. As a solar or heat powered animal, fast movement is impossible at hibernation temperatures.

Fig. 1. A 100g reptile's food requirement, which is 5% of a 100g mammal's requirement.

Reptile skin

The skin in reptiles is very specialised. It is the largest organ in the body and often has many scales and horns. These form a formidable defence system and can be involved in attracting a mate. Reptiles are unable to sweat as they do not have any sweat glands. However, the skin has an important role in the production of vitamin D3.

Reptiles shed their skin in order to accommodate growth. Tortoise shedding is done piecemeal and skin flakes off. During the shedding process, the new skin underneath sheds a chemical that helps to separate the layers. It is important to have increased humidity to help the shedding process. Scales are formed by special folds in the layer of skin called the Oberhautchen layer (Fraser & Girling 2004).

Vitamin D production stops completely in tortoises that hibernate as there is no access to ultraviolet light. Hence, it is vital that during the summer months tortoises kept outdoors are not kept under glass. Glass allows the filtration of UVA but not UVB. It is also necessary to supplement UVB light by providing a suitable, new, correctly placed UVB light in all indoor enclosures all year round. Reptiles are unable to store vitamin D3, so constant exposure is necessary (Bernard 1995).

The skeleton

Vertebrates are organisms that have a skeleton. Tortoises are vertebrates and have a specialised skeleton. Over thousands of years the ribs have flattened and fused to form the shell. The shell on top of the body is called the carapace and the lower shell is called the plastron. Tortoises and terrapins also have a specialised neck which allows the head to be drawn into the shell without the windpipe being cut off. The front and back legs are free to move; however,

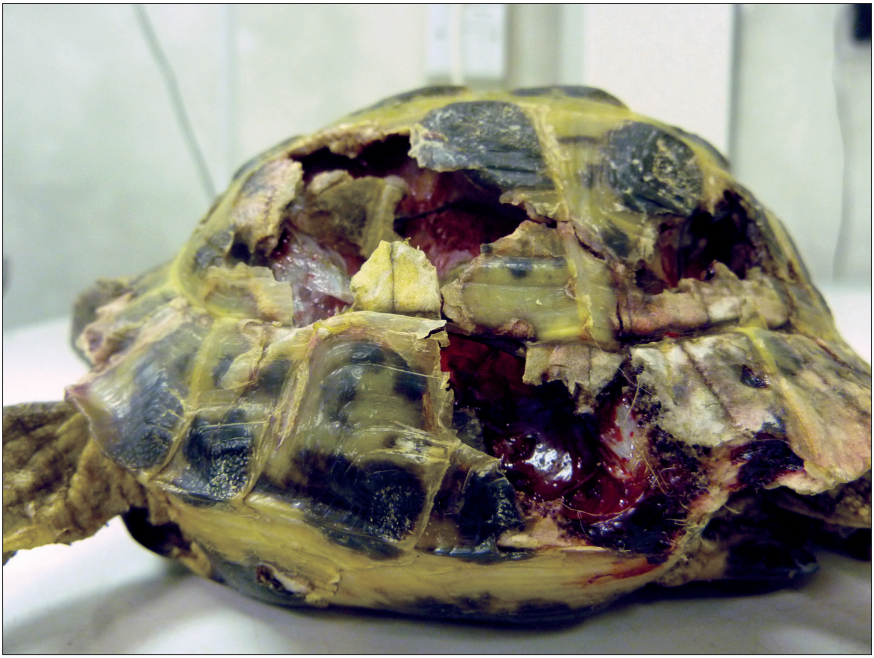


Fig. 2. The effect of a dog attack on a thin-shelled tortoise shows the importance of a strong skeleton and shell.

the pelvis and back bone are fused within the shell. The skeleton is part of the shell and the shell is part of the skeleton!

A proper diet and a strong skeleton are vital for survival. Damage to the shell is far more severe when the shell is substandard. Dog bites and crushing injuries are far more serious when the skeleton is weak (Fig. 2).

Bones give the body a permanent structure and are a surface onto which muscles and tendons attach. The skeleton also helps to protect the internal organs as well as providing new white and red blood cells in the bone marrow. Calcium is stored in bones and is removed to make muscles function and stored when there is excess calcium in the diet.

A good store of calcium within the bones is necessary during hibernation. Calcium is required to allow muscles to contract. This includes the heart which is a specialised muscle. Poor stores, such as a weak, soft skeleton, prevent the tortoise from being able to draw on the reserves in the body. Death in hibernation is highly likely.

Eyes

Unlike other reptiles, tortoises do not have spectacles (fused lower and upper eyelids that are transparent) but they do have an upper and lower eyelid.

Also, there are little bones in the white of the eye called scleral ossicles to strengthen the eyeball (Millichamp 2004). The reptilian eye is able to see in colour and can visualise ultraviolet light. Diurnal animals have an oval iris although the tortoise has comparatively poor eyesight compared with its cousin the lizard.

Care should be taken during hibernation as tortoises have delicate structures. Although many people hibernate their tortoises outside, it is generally not advisable due to the large fluctuations in temperature. Tortoises' eyes are also quite delicate and prone to frost damage.

The lungs

The purpose of the respiratory system is universal. Breathing in provides the body with oxygen and breathing out removes waste carbon dioxide. Comparatively, the reptile lung is much simpler than a mammal lung. The windpipe or trachea is made up of semicircular rings of cartilage. The trachea in tortoises splits into the right and left bronchi high up in the neck, to allow the tortoise to breathe when the head is drawn into the shell. However, there are no tracheal cilia in the trachea of reptiles. Cilia are small tufts on the cells within the trachea which move forward and back, much like an elevator, and move mucus and debris out of the lungs.

Reptiles do not have a diaphragm which also means that they are unable to cough. Tortoises have a structure known as a pseudodiaphragm (Fig. 3). This is a large internal sheet of tissue that spreads between the legs and

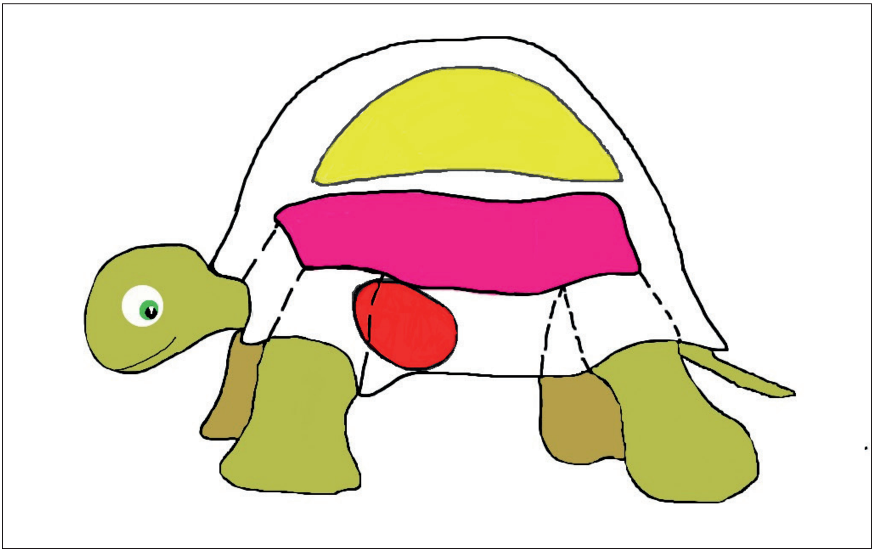


Fig. 3. Diagram showing tortoise lungs: yellow – lungs; pink – pseudodiaphragm; red – heart.

makes a compartment between the lungs and the intestinal system. To move the pseudodiaphragm, the front and back legs are pushed out causing air to be dragged into the lungs. This combination of no diaphragm, no cilia and simple spongy lungs can mean a lung infection can be devastating and potentially life-threatening.

As tortoises have sensitive lungs, infections during hibernation are common. Great care is needed to ensure that your tortoise is in the best of health before hibernation is attempted. Any signs of respiratory disease such as a runny nose, mouth breathing and neck stretching should not be ignored. Even during hibernation, if any of these symptoms are observed, the tortoise should be immediately taken to the veterinary surgeon for treatment.

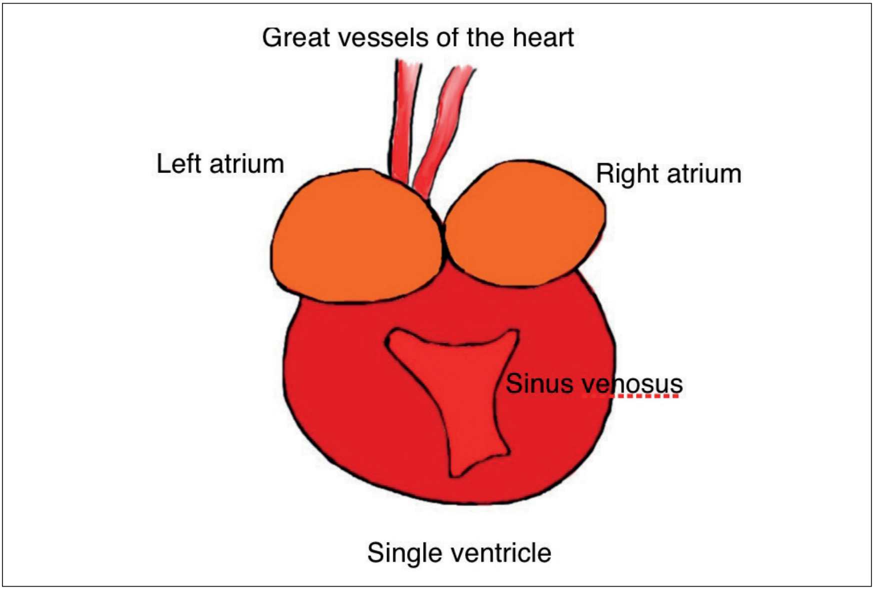
The heart

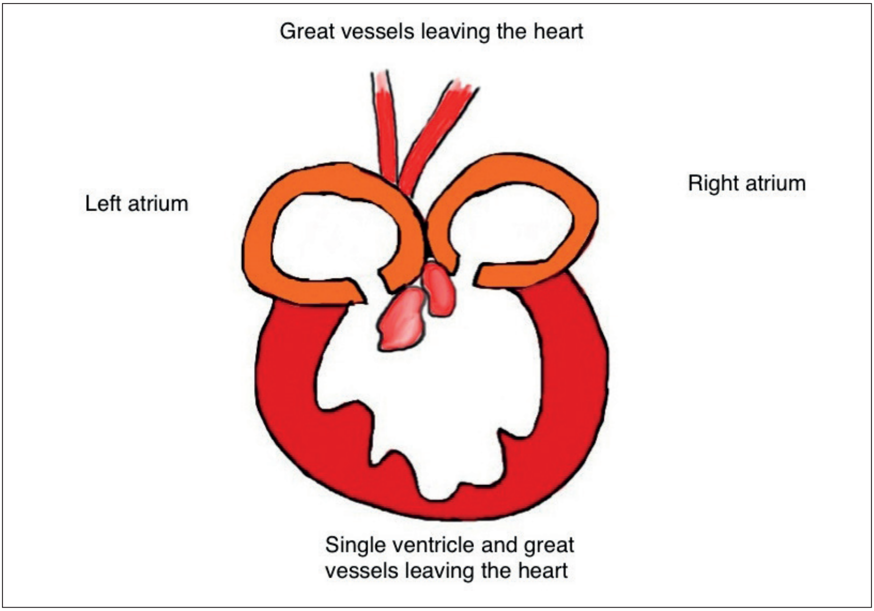
The mammal heart consists of four chambers: two atria and two ventricles. The blood in the mammal heart always flows from right to left (with the exception of the time spent in the uterus when the blood flows from left to right). The reptile heart (Figs 4 & 5) was viewed by many as a precursor or inferior heart to that of the mammal model. On the outside there is a large collecting bag called the sinus venosus. This organ helps to store large quantities of blood returning to the heart. Unlike the mammal heart there are two atria but only one ventricle. The ventricle has three folds that separate the ventricle into the cavum arteriosum, cavum pulmonale and the cavum venosum. When the reptile is functioning normally the blood flows round the body in the same way as it does in a mammal. However, if the reptile experiences an environment with reduced oxygen, or hibernation, the reptile heart can push blood backwards conserving the amount of oxygen used (Overgaard *et al.* 2002).

This is a particularly cumbersome adaptation when trying to anaesthetise reptiles. It is very difficult to anaesthetise a tortoise in an anaesthetic chamber. The tortoise smells the gas and redirects the blood flow reducing the number of breaths and hence not falling asleep! The heart flow direction will reverse during hibernation if there is a lack of oxygen. This is most common in terrapins who often hibernate under the mud at the bottom of a pond. The heart rate will be slow (around six beats per minute) and only small amounts of blood are sent round the body with oxygen, conserving oxygen within the body. A body with excellent calcium storage is also needed to ensure a healthy, beating heart.

The kidneys and bladder

Reptiles have two kidneys that have the same function as the mammal kidney. However, the reptile kidney is unable to concentrate urine due to the absence of a loop of Henle. The microscopic loops of Henle concentrate urine





Figs 4 & 5. The reptile heart: author's representation of the outside and inside of the heart.

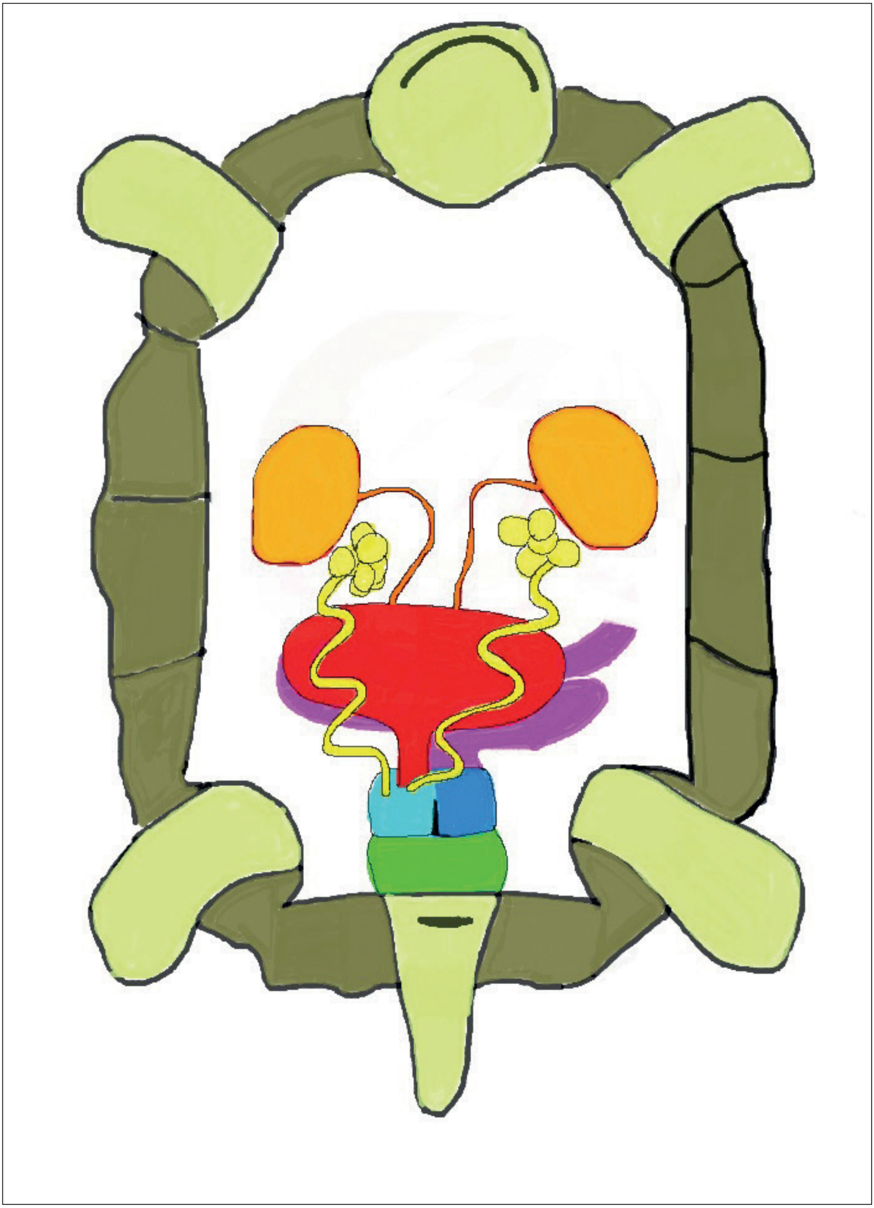


Fig. 6. Anatomy of the tortoise bladder: orange – kidneys and ureters; yellow – ovaries and uterus; red – bladder; pink – colon; pale blue – urodeum; dark blue – coprodeum; green – proctodeum.

in mammals. Without this physiological mechanism, the urine produced has nearly the same concentration as water. Waste protein is also removed from the body as insoluble uric acid. This is seen as a white, thick paste. Mammals produce urea which is much more soluble and is clear.

Tortoises have a bladder (Fig. 6), though not all reptiles have this structure. The bladder is used to store urine, and is also able to redirect urine back into the colon where the water component can be reabsorbed. Tortoises also have a renal portal system (Holtz 1999). This is an alternative blood supply that bypasses the kidneys. During times of extreme stress the blood supply to the kidneys can be cut off without damaging or affecting the ability of the kidney to function.

Water is taken into the body by the tortoise swallowing the water through the mouth or by sucking water into the vent (Fig. 7). Within the vent there are three compartments. The proctodeum is closest to the vent and stores urine, faeces, uric acid and eggs. Immediately behind this area lie the urodeum and coprodeum. The urodeum is directly connected to the bladder and also the uterus or vas deferens. The coprodeum is connected to the colon. Between the coprodeum and the urodeum there is a muscular flap, allowing fluid to be directed from the bladder to the colon.

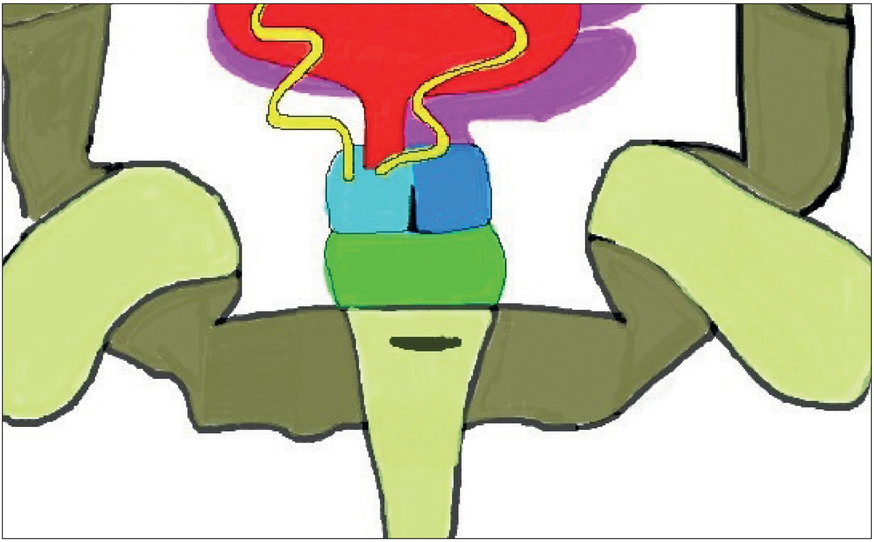


Fig. 7. The vent: yellow – ovaries and uterus; red – bladder; pink – colon; pale blue – urodeum; dark blue – coprodeum; green – proctodeum.

The bladder plays a vital role during hibernation. As the heart rate slows, the blood supply to the kidneys is cut off. The renal portal system keeps the kidneys alive and water is stored during the hibernation period in the bladder. When water is required by the body, it can be reabsorbed by flushing the water into the colon. From here it is reabsorbed into the blood stream, preventing dehydration and maintaining organ function. Dehydration is common during prolonged hibernation or with a sick tortoise and poor hibernation technique.

The reproductive system

Male tortoises have two testicles that lie within the body. The penis is called the phallus. It is a long spatulated organ with a hollow groove running its length. This is for the transference of sperm and is not involved in urination as it would be in mammals (Johnson 2004). Female tortoises have two ovaries, an infundibulum, magnum and uterus. This is similar to the mammal ovaries and uterus except that the uterus has been adapted to produce calcified eggs. Reptile eggs have separate poles. After egg laying, the poles quickly separate. The air sac rises to the top. In order to preserve the foetus inside, the egg must be maintained in the same position throughout incubation. Female tortoises can lay eggs spontaneously without the presence of a male.

Egg production is common in females. If eggs have developed in the ovaries in the period before hibernation these remain present and dormant until spring. Egg production involves huge amounts of energy so storing the eggs until needed is an effective conservation of energy. Hibernation is another method of controlling reproduction in females helping to slow reproduction down (Licht 1984). Excessive egg production can lead to a thin undernourished tortoise. This is not ideal for hibernation.

The nervous system

The neurological system of reptiles is well developed. The brain weight to body ratio is higher than that of most fish and many mammals. Reptiles have the same neural pathways as mammals indicating that they are able to sense and experience pain (Bradley 2001). Outside hibernation is not recommended as frostbite of the brain is common.

How does my tortoise hibernate?

The descriptions above are a basic outline of the comparative anatomy of tortoises. The physiological and anatomical differences make tortoises unique and enable them to sustain long periods without food, water and even oxygen.

As the temperature drops in the environment the tortoise or terrapin prepares for hibernation. The temperature determines the speed of the heart. Reptile hearts are able to redirect the blood flow conserving oxygen. During hibernation ideal temperatures are between 3 and 8 degrees centigrade. Often the heart rate will drop to six beats per minute. During this period, the blood supply to the kidneys is cut off. Water is conserved as it is not pushed through the kidneys. Urine already present in the bladder acts as a store and dehydration is corrected by redirecting urine through the urodeum into the colon for reabsorption. The metabolism is also temperature dependent. Reducing the rate of metabolism helps to preserve fat reserves and reduces the amount of oxygen required to metabolise stored fat.

In summary

A successful hibernation depends on the ability of the tortoise to consume enough food and prepare for the prolonged period of starvation. In the wild, this would amount to a few weeks. In Britain, tortoises have 'successfully' been hibernating for 5 to 6 months every year. There is a constant ferocious battle between the needs of the body and the need to hibernate. Growth and reproduction also require extra calories, all putting huge demands on our rather humble but very much loved tortoise.

Tortoises and terrapins have been successfully hibernated outdoors. However, care has to be taken to avoid damage from gardening implements, danger from frostbite and losing them in the garden. There is also a risk from dogs or rats digging up and attacking hibernating tortoises. It can also be challenging completing hibernation when the temperatures fluctuate or are persistently high.

References

Bradley, T. (2001). Pain management considerations and pain associated behaviours in reptiles and amphibians. Proceedings of the American Zoo Veterinarians 2002, p. 39.

Bernard, J.B. (1995). Spectral irradiance of fluorescent lamps and their efficacy for promoting vitamin D synthesis in herbivorous reptiles. PhD thesis, Michigan State University.

Frazer, M.A. & Girling, S.J. (2004). Dermatology. In: *BSAVA Manual of Reptiles* 2nd edn. (eds Girling, S. & Raiti, P.) pp. 184-197.

Holtz, P. (1999). The reptilian renal-portal system: influence on therapy. *Zoo and Wildlife Medicine* 28: 386-393.

Johnson, J. (2004). Urogenital System. In: *BSAVA Manual of Reptiles* 2nd edn. (eds Girling, S. & Raiti, P.) pp. 261-272.

Licht, P. (1984). Reproductive cycles of vertebrates: Reptiles. In: *Marshall's Physiology of Reproduction* Vol. 1 (ed. Lamming, G.E.). Churchill Livingstone Melbourne, pp. 206-282.

Nagy, K.A. (1982). Energy requirements of free-living iguanid lizards. In: *Iguanans of the World* (eds Burghardt, G.M. & Rand, A.S.). Noyes Publications, Oak Ridge, NJ, pp. 49-59.

Millichamp, N.J. (2004). Ophthalmology. In: *BSAVA Manual of Reptiles* 2nd edn. (eds Girling, S. & Raiti, P.) pp. 199-209.

Overgaard, J., Stecyk, J.A.W., Farrell, A.P. & Wang, T. (2002). Adrenergic control of the cardiovascular system in the turtle *Trachemys scripta*. *Journal of Experimental Biology* 205: 3335-3345.

Thomas, R. (2014). Tortoises and the exotic animal trade in Britain from medieval to 'modern'. *Testudo* 8(1): 56-68.

Varga, M. (2004). Captive maintenance and welfare. In: *BSAVA Manual of Reptiles* 2nd edn. (eds Girling, S. & Raiti, P.) pp. 6-17.

Further reading

McArthur, S., Meyer, J. & Innis, C. (2004). Anatomy and Physiology. In: McArthur, S., Wilkinson, R. & Meyer, J. *Medicine and Surgery of Tortoises and Turtl*es, Blackwell, Oxford, pp. 35-79.