VETERINARY NURSING OF EXOTIC PETS

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BVMS (Hons) DZooMed CBiol MIBiol MRCVS

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Preface

Veterinary nurse and veterinary student training in exotic species has come a long way in the last four or five years. Previously often consigned to the category of 'alsorans', exotic species are increasingly seen in general veterinary practice, to the point where the house rabbit has officially become the UK's third most commonly kept pet, after the cat and dog. Even more telling is the fact that numbers of cats and dogs in the UK are on the decline, yet the number of small mammals, reptiles and birds kept by the public continues to rise.

With this increase in these species kept as household pets, improved training in their care has thankfully started to become more important. Many veterinary schools and veterinary nurse training providers are devoting more time to teaching the husbandry and medicine of exotic species. Indeed, 2001 saw the start of the first course in Veterinary Nursing of Exotic Species, run through Edinburgh's Telford College and leading to a City and Guilds recognised qualification.

There is no turning the clock back. Exotic pet species are here to stay. It is therefore our duty as veterinary surgeons and veterinary nurses to ensure that we are up-to-date with the latest husbandry and medical details so that we may offer as good, if not better, levels of care as that provided for more traditional domestic pets.

I hope that this book will help in that quest and may be of use to veterinary nurse, technician and veterinary student alike.

Simon J. Girling

Reptiles and Amphibians

Chapter 7

Basic Reptile and Amphibian Anatomy and Physiology

SERPENTES (SNAKES)

Like the bird, the snake has no diaphragm, so no separate thorax and abdomen. Instead it has a *coelomic*, or common, body cavity.

Musculoskeletal system

All true snakes have no limbs. This distinguishes them from species such as the slow-worm, which is actually a lizard with vestigial limbs. There are some remnants of limbs in one or two of the older evolutionary species of snake such as the boiid family (pythons and boa constrictors). These can possess vestigial pelvic remnants, having claw-like spurs either side of the vent representing the hind limbs.

The snake skull possesses a small cranial cavity containing the brain and a large nasal cavity. The maxilla has 4 rows of teeth, two on either side. The mandible has the more normal two rows of teeth (Fig. 7.1). The teeth vary somewhat between the genera. The more commonly seen non-poisonous species, such as the colubrid family (containing the kingsnakes and ratsnakes) and the boiid family, have simple, caudally-curved, peglike teeth. Some of the more poisonous species have specialist adaptions. Rattlesnakes, for example, have hinged, rostrally situated fangs which swing forward as they strike. All teeth are replaced as they are lost, including fang teeth in poisonous species. It is worth mentioning that owners (other than zoos) of poisonous species of snake, such as pit vipers and rattlesnakes, must be licensed and registered in the United Kingdom under the conditions of the Dangerous Wild Animals Act of 1976.

The anatomy of the snake's head has a number of adaptations that allow it to swallow large prey. In all snakes, the two halves of lower jaw are loosely held together rostrally and the mandibular symphysis can separate. In addition, the snake has no temperomandibular joint. Instead it possesses a quadrate bone, which articulates between a mandible and the skull and allows the mandibles to be moved rostrally and laterally, 'dislocating'. The maxilla also hinges only loosely with the rostral aspect of the cranium so allowing the nose of the snake to be raised, increasing the oral aperture.

The skull articulates with the atlas vertebra via a simple joint containing only one occipital condyle, rather than the mammalian two. The coccygeal vertebrae (those caudal to the vent) are the only vertebrae with no ribs attached. Instead they have paired, ventral, haemal processes between which the coccyeal artery and vein run. This vein can be used for venipuncture both for sampling and for intravenous injections. The site for this is one third the distance from the vent to the tail tip on the ventral aspect.

The ventral scales, known as *scutes* or *gastropeges*, overlie the muscular casing of the snake's torso. This muscle is segmental and supplied by intervertebral nerves. It is by alternately contracting and relaxing these segmental muscles that the snake can propel itself across the ground, the caudal edge of each ventral scute providing friction.

A very few species of snake, such as the glass snake, exhibit *autotomy*. That is, they will shed their tail if roughly handled or caught by a predator. They will regrow their tail later.

Fig. 7.1 Intraoral view of a young Burmese python showing the four upper and two lower rows of teeth, as well as the glottal tube and tracheal entrance, rostral to which is the tongue sheath.

Respiratory system (Fig. 7.2)

Upper respiratory system

The nostrils are paired and open into the roof of the mouth. Snakes, like all reptiles other than crocodilians, do not have a hard palate. When the mouth is closed, the internal nostrils are positioned directly above the entrance to the trachea. This is guarded by the glottis. An epiglottis may be present in vestigial form, but there is often fusion of the cartilages here to form a glottal tube. This tube is rigid enough to withstand the pressures placed upon it when the snake is swallowing whole prey. At rest the glottis is held closed, only opening when the snake breathes. The glottis then opens into the trachea which, in the snake family, is supported by C-shaped cartilages similar to those of the cat and dog.

Lower respiratory system

In the majority of colubrid species, such as ratsnakes and kingsnakes and some Viperidae, the right lung is the major lung, the left having regressed to a vestigial structure. The vestigial left

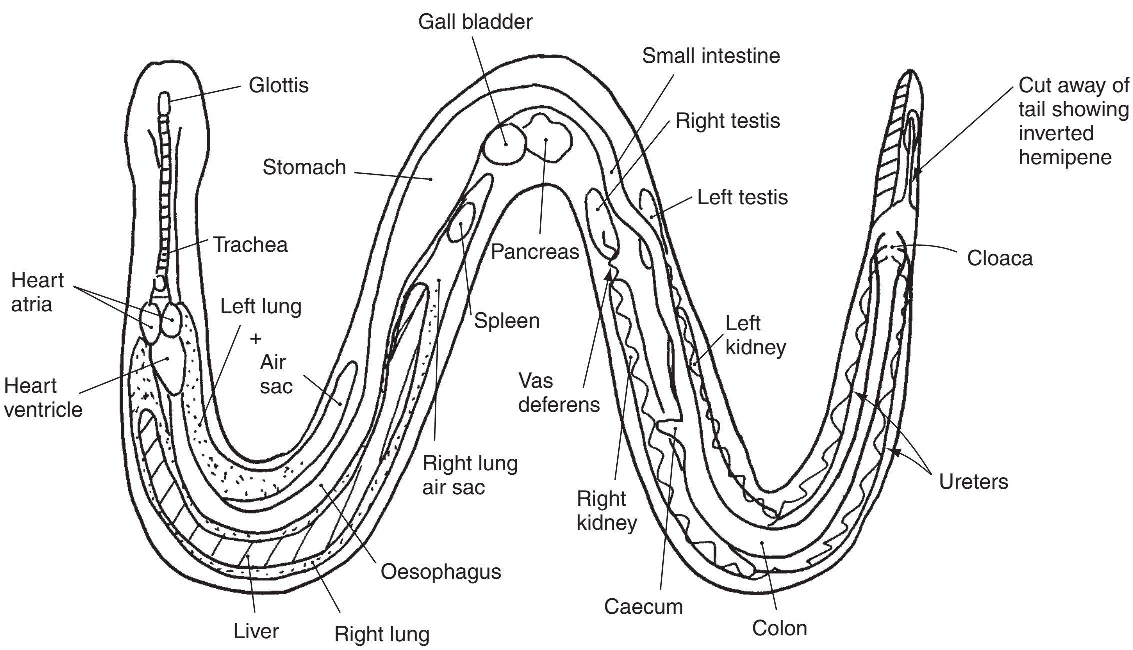

Fig. 7.2 Diagram of a male snake (ventral aspect).

lung is often replaced by a vascularised air sac and so can take part in gaseous exchange. In the evolutionarily older species such as the Boiidae there are two lungs.

The trachea bifurcates at the level of the heart. The lungs occupy the first half of the middle third of the body of the snake. As there is no diaphragm, inspiration is purely due to the outward movement of the ribs and intercostal muscles. This is aided by elastic tissue present within the lung structure, which allows the lungs to expand and recoil. Expiration is facilitated by contraction of abdominal and intercostal muscles, and the elastic recoil of the lungs themselves. A 'tracheal lung' is often present as an outpouching of the lining of the trachea from the open part of the C-shaped cartilages. This is thought to aid respiration when main lungs are being compressed during the swallowing of large prey items.

The stimulus for respiration is a lowered partial pressure of oxygen, rather than an increase in the partial pressure of carbon dioxide, as is the case in mammals.

Digestive system

Oral cavity

The tongue sits in a basal sheath at the rostral end of the oral cavity just in front of the glottis and can be pushed out through the lips even when the mouth is closed through the labial notch. The tongue is *bifid* (split into a forked end) and is used to catch odours on its moist surface. These are then pushed into the roof of the mouth into the *vomeronasal organ*. The vomero-nasal organ is connected to the olfactory region of the brain and is a primitive but effective pheromone and scent detector. The oral cavity contains salivary glands which are stimulated to release saliva during mastication. The mouth is normally free of saliva at other times.

The oropharynx passes on into the oesophagus, which is an extremely distensible muscular tube traveling ventral to the lungs and entering the stomach in the second half of the middle third of the snake's body.

Stomach, associated organs and intestine

The stomach is a tubular organ, populated with compound glands secreting both hydrochloric acid and pepsin (mammals having two separate cells) and separate mucus secreting glands. There is no well-defined cardiac sphincter. The majority of the digestive process occurs in the stomach and is continued by the small intestine. The only substance which cannot be digested is the hair of the prey, known as the 'felt', which is passed out in the stool.

The stomach empties into the duodenum, which is poorly defined from the jejunum and ileum. The spleen, pancreas and gall bladder are found at the point where the pylorus empties into the small intestine. Some snakes have a fused splenopancreas. The gall bladder is found at the most caudal point of the liver, which is an elongated structure extending from the mid-point of the lungs to the caudal stomach.

The small intestine empties into the large intestine, which is distinguished from it by its thinner wall and larger diameter. In the Boiidae there may be a caecum at this junction.

The large intestine empties into the coprodeum portion of the cloaca, which, as with birds, is the common emptying chamber for the digestive, urinary and reproductive systems.

Urinary system

There are paired elongated kidneys (Fig. 7.3), situated in the distal half of the caudal third of the snake's body, attached to the dorsal body wall. The right kidney is cranial to the left and both each has a single ureter which travels across their ventral surface to empty into the urodeum of the cloaca, caudal to the proctodeum. There is no urinary bladder in snakes. The caudal portions of the kidneys in male snakes are the 'sexual segments', enlarging during the breeding season as they provide seminal fluid.

Renal physiology

As with the majority of reptiles, snakes are *uricotelic*, that is that like birds their primary

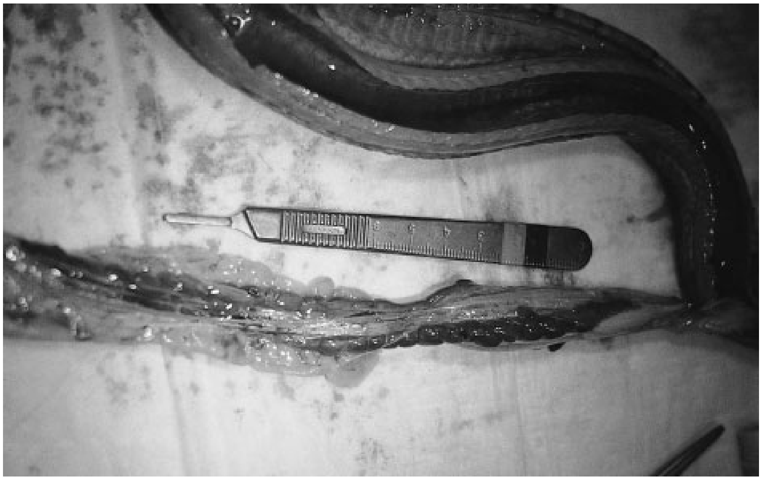

Fig. 7.3 Post mortem showing the elongated lobular right and left kidneys of a corn snake (*Elaphe guttata guttata*) adjacent to scalpel handle.

nitrogenous waste product is not urea but uric acid. This compound is relatively insoluble allowing conservation of water. This is particularly important for reptiles, as they have no loops of Henle in their kidneys therefore they cannot create hypertonic urine as mammals can. To further conserve water, urine in the urodeum portion of the cloaca can be refluxed back into the terminal portion of the gut where more water reabsorption can occur. If the reptile becomes dehydrated, or renal blockage or infection occurs, then excretion of uric acid is reduced and can lead to gout as is seen in birds.

Cardiovascular system

Heart

The heart is three chambered, with two atria and a common ventricle situated within the pericardial sac, but it despite this functions as a four chambered organ. The heart lies in the caudal half of the proximal third of the snake's body, and is mobile, to allow the passage of large food items through the oesophagus above it. There are two cranial vena cavae and one caudal vena cava entering via the sinus venosus (a narrow tube leading to the right atrium from which it is separated by the sinoatrial valve).

Blood vessels

The snake family has paired aortae. They exit one from each of the two sides of the single ventricle of the heart and then fuse into a single abdominal aorta. The pulmonary artery that leads to the lung(s) also arises here.

As with birds, snakes have a renal portal system. The blood supply from the caudal portion of the snake in the coccygeal artery splits into two and can enter the renal circulation or may bypass it via a series of valves. This is important when administering drugs which are nephrotoxic or which may be excreted by the kidneys, as it means they might be concentrated there. They should therefore be administered in the cranial part of the snake.

There is also an hepatic portal system from the intestine to the liver. A ventral abdominal vein lies in the midline, just beneath the ventral abdominal musculature, and must be avoided when performing surgery.

Two external jugular veins run just medial to the ventral cervical ribs, and may be reached to place catheters for intravenous fluid administration via a surgical cut-down procedure. The ventral tail vein has already been mentioned and is useful for venipuncture for blood collection.

Lymphatic system

There are no specific separate lymph nodes as seen in mammals, a situation similar to birds. Instead, as with birds, there are discrete accumulations of lymph tissue within most of the major organs, particularly the liver and intestines. There is also a spleen, as mentioned above, which has loosely arranged red and white pulp. Lymphatic vessels are found throughout the body. A lymphatic sinus, for example, runs the length of the snake just ventrolateral to the epaxial musculature immediately below the skin surface on either side of the body. This may be used for small volumes of fluid administration. In the walls of many of the lymphatic vessels there are muscular swellings known as 'lymph hearts' which aid in the return of the straw coloured lymphatic fluid back to the true heart.

Reproductive system

Male (Fig. 7.2)

The paired testes lie intracoloemically (within the coelom or common body cavity, as snakes like most reptiles have no diaphragm and so no separate thorax and abdomen only a common coelomic cavity). They are situated cranial to each kidney, and caudal to the pancreatic tissue, with the right testis slightly cranial to the left, and are oval in shape. The testes enlarge during the breeding season, often reaching two to three times their quiescent state. Close to the testes lie the adrenal glands. Each testis has a solitary vas deferens leading down to the urodeum portion of the cloaca, where seminal fluids from the reproductive sexual segment of the kidneys are added.

The male snake also has paired penises, known as *hemipenes* in its tail. At rest they are like two inverted sacs either side of the midline and lie ventral to two other small invaginations in the tail which form the anal glands. When a hemipene's lining becomes engorged with blood, it everts, forming a finger-like protrusion through the vent. As with the domestic cat, the hemipenes are often covered in spines and barbs, and they each have a dorsal groove into which the sperm drops from the cloaca, and so is guided into the female's cloaca. The hemipenes therefore do not play any part in urination.

Female

The female has paired ovaries, cranial to the respective kidneys, with the right ovary cranial to the left. There are two coiled oviducts starting with the fimbriae opposite each ovary, and moving through the tubular portion of the infundibulum and on into the magnum. From here the tract merges into the isthmus and then the shell gland or uterus before opening into the muscular vagina. This organ ensures that the eggs are layed only when the timing is correct. The vagina empties into the urodeum section of the cloaca. The vascular supply is from the dorsally suspended oviduct mesentery, rather than the caudocranial route employed in mammals.

Most females are stimulated to reproduce in the spring when the weather warms and the daylight length increases. The tropical boas (such as the *Boa constrictor*) and the Burmese python (*Python molurus*), however, start breeding when the temperature *drops* slightly during the cooler portion of the year.

Some species of snake are *oviparous* (that is they lay eggs), others are *viviparous* (that is they bear live young). The latter are, for example, the garter snakes (*Thamnophis sirtalis*) and the boiid family, which have a vestigial egg structure more closely resembling a placenta. Other species make nests, and some species of python will incubate eggs by contracting and relaxing skeletal muscles, so creating warmth.

Sex determination and identification

Snakes are chromosomally dependent for sex determination, as with most mammals. This is in contrast with the Chelonia, Crocodylia and some Sauria, in which sex may be temperature dependent.

Sex identification is best made by surgical probing. A fine, sterile, blunt-ended probe is inserted through the vent and advanced just to one side of the midline in a caudal direction. If the snake is a male, then the probe will pass into one of the inverted hemipenes to a depth of 8–16 subcaudal scales. In the female, there are anal glands in this region, and so the probe may be inserted only to a depth of two to six subcaudal scales. In some species, such as the boiid family, the males possess a paracloacal spur. This is the remnant of the pelvic limb and may be found on either side of body, ventrally, at the level of the cloaca. In very young snakes it may be possible carefully to evert the hemipenes manually, a technique known as 'popping'.

Skin

The outer epidermal layer in snakes is thrown into a series of folds forming scales, which cover the whole surface of the snake. There are different sizes of scale over the body, with smaller, less raised ones covering the head, to larger and more raised scales over the main portion of the body. Some species have scales with ridges on their surface to add greater grip, other species have smooth scales. In some snakes, such as the sea snakes, the skin is very loose fitting, and apparently has few elastic fibres. Other snakes have elastic skin which relatively quickly returns to its normal shape. The reptile skin has little or no skin glands. Its outer layer, or *stratum corneum*, is heavily keratinised, and composed of three layers of dead cells filled with keratin. These cells become progressively more flattened as they approach the surface. On the ventral surface of the snake there is a single row of scales which span the width of the snake, and are known as the ventral scutes or gastropeges. The caudal edge of each overlaps the cranial edge of the following scale (Fig. 7.4).

Fig. 7.4 The vent of a ratsnake showing the division of the ventral scales from single scutes cranial to the vent to paired scales caudally.

Ecdysis

Ecdysis is the regular shedding of the entire skin. Other reptiles also shed their skin, but the Chelonia and Crocodylia shed individual scutes, and the Sauria shed in patches. Only the Serpentes shed all of their skin (including the clear, fused eyelids, or spectacle) in one go. The stimulus can be dependent on time of year, health status and age of the snake and the process is partly controlled by the thyroid gland.

First the new layer of skin is formed deep to the old one. Once it is complete, the snake secretes a proteinaceous lymph fluid between the new layer of skin and the old one. At this time the snake will become dull in colour, and often exhibits blueing of the eyes. The fluid forces the outer layer of old skin to separate away from the new, and often contains enzymes to help in this process. Once separation has been achieved the fluid is reabsorbed and the snake's eyes may be seen returning to normal. A few days later the snake will shed the old skin. It starts the process by rubbing the corners of its mouth on some abrasive surface. The shedding proceeds with the head skin first and the snake then rolls the old skin back until the tail is the last to emerge.

In a healthy snake all of the skin should come away at once (Plate 7.1). If the skin does not shed the condition is known as dysecdysis. There can be many reasons for this. Disease, dehydration (which causes too little fluid to be produced), scars on the skin surface or lack of an abrasive surface upon which to remove the skin can all be factors. Regular bathing and soft but abrasive damp surfaces may be needed to aid shedding, and any underlying disease should be attended to.

Special cutaneous adaptations in snakes

There are one or two special structures associated with the skin of snakes. These include the lateral spurs of the Boiidae, which have been mentioned earlier. The male possesses larger spurs than the female.

Snakes do not have mobile eyelids. Instead, the eyelids have become fused together and transparent, forming the so-called 'spectacle'.

Many snakes also have special sense organs on the head. The older snake families such as the Boiidae have labial pits – a series of depressions running along the dorsal border of the upper jaw. These function as rudimentary heat sensors. In the more evolutionarily advanced species, such as the pit vipers, the heat sensing organs can actually focus on their prey, and are composed of bilateral, forward-facing pits midway between the nares and the eyes. They are supplied by branches of the trigeminal nerves, and, in the case of pit vipers, may be sensitive enough to detect changes of heat as small as 0.002°C!

Snakes do not possess an external eardrum or middle ear. They can however hear airborne sounds and can of course detect ground tremors.

SAURIA (LIZARDS)

Musculoskeletal system

Lizards have a musculoskeletal system more familiar to those used to dealing with mammalian forms. They possess in the majority four limbs, an axial skeleton and much of the anatomical layout of small mammals. There are some exceptions, one being the slow worm, a native of mainland Britain and northern Europe which resembles a snake, having no obvious external limbs. It is actually, however, a highly evolved lizard with rudimentary limbs.

The skull is more rigid than its snake counterpart, having less mobile jaws. There are four rows of teeth, one to each jaw. These are peg-like in shape and are continually replaced in the Sauria except for the Agamidae and Chameleonidae. There are no fang teeth in Saurians, but the beaded lizard (*Heloderma horribilis*) and the gila monster (*Heloderma suspectum*) have hollow teeth which allow the venom from sublingual venom glands to ooze through them into the prey when they bite them. These two species are therefore currently classified as dangerous wild animals under the Dangerous Wild Animals Act 1976, in the United Kingdom requiring a special licence to keep them in captivity outside of a zoological collection.

The skull articulates with the atlantal cervical vertebra via a single occipital condyle. The thoracic vertebrae and lumbar vertebrae generally have paired ribs either side. The coccygeal vertebrae possess ventral haemal arches between which it is possible to access the ventral tail vein for venipuncture.

In many saurians the tail possesses fracture planes which allow the tail to break off during escape from a predator. These fracture planes occur in the mid to caudal portions of the tail, but not proximally, where vital structures such as the male reproductive organs and fat pads are stored. Only certain species exhibit this tail autotomy. These include most of the Iguanidae, but does not include the Agamidae, monitor lizards and true chameleons. When the tail is regrown in these species, the coccygeal vertebrae are not replaced, instead a cartilagenous rod of tissue forms the rigid structure. In addition the rows of scales over the new tail surface are often haphazardly arranged and do not match the size and shape of the rest of the tail (Fig. 7.5).

Respiratory system (Fig. 7.6)

Upper respiratory system

Lizards have paired nostrils situated rostrally on the maxilla. To the side, or just inside the nares, particularly in iguanids, there is often situated a pair (one on each side) of salt-secreting glands. These are responsible for excreting excess sodium as sodium chloride so helping to conserve water. The sodium chloride may be seen as a white crystalline deposit around the nostrils which is often sneezed out by the lizard. The nostrils enter into the rostral part of the oral cavity, there being no hard palate.

The entrance to the trachea is guarded by a rudimentary larynx which often lacks an epiglottis and vocal folds. Some species, such as the Geckonidae, do possess vocal folds and are capable of producing a variety of sounds. In most species the trachea is supported by incomplete cartilaginous C-shaped rings similar to those of the cat and dog.

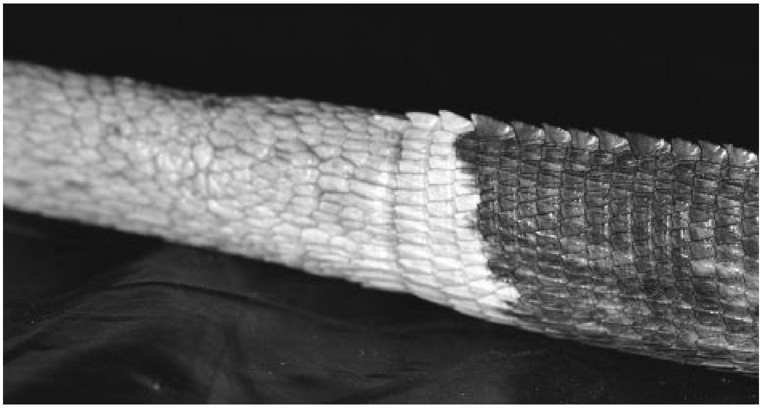

Fig. 7.5 Regrowth of the tail is possible in many species of lizard, but the scales which regrow are arranged haphazardly, and the vertebrae lost are replaced by a rod of cartilage.

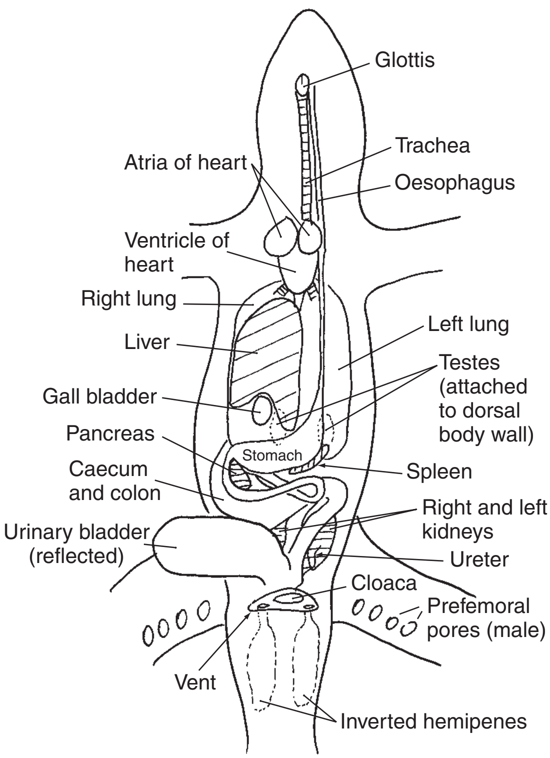

Fig. 7.6 Diagram of male green iguana (ventral aspect).

Lower respiratory system

The trachea bifurcates into two main bronchi in the cranial thorax to supply two lungs. In more primitive lizards the lungs are sac-like structures with large bulla-like divisions and alveoli. In the more advanced lizard species the lungs are more like the mammalian sponge-like system, with finer divisions and more structured alveolar systems. Lizards will often overinflate their lungs, in an attempt to make themselves look bigger, when threatened.

There is no diaphragm in any lizard species, so there is no clear distinction between the thorax and abdomen, rather there is a common body cavity, known as the coelom, as in snakes and birds.

Respiration is thought to be stimulated by falling partial pressures of oxygen in the blood stream. The act of inspiration is due to the mechanical contraction of the intercostal muscles causing an upwards and outwards movement of the rib cage. This is aided by the elastic tissues that are present within the lung structures themselves. Expiration is by contraction of the abdominal and intercostal muscles, and by the elastic recoil of the lung tissue.

Digestive system

Oral cavity

The majority of lizards have a large, fleshy tongue which is frequently mobile. In some species however, such as the chameleons, the tongue has become specialised. It lies coiled in the lower jaw and can be projected out at a flying insect or other potential prey item. The green iguana has a more traditional fleshy tongue, which has a much darker tip. This is not to be confused with pathological changes. A vomeronasal organ is present.

Stomach, associated organs and intestine

The stomach is a simple sac-like structure in most species. The glands are combined hydrochloric-acid- and pepsin-secreting glands lining the walls. There are also separate mucus-secreting glands for lubrication.

The small intestine is better developed in more carnivorous species such as the monitor lizards and the insectivorous water dragons. In herbivorous species it is relatively short. It is poorly divided into jejunum and ileal structures. In a few, mainly herbivorous, species, at the junction between the small and large intestines, lies the caecum. The liver is roughly bilobed in structure and is situated ventral to the stomach and lungs. There is usually a gall bladder, with the primary bile pigment being biliverdin, as with birds, rather than the bilirubin of mammals.

The large intestine is more highly developed in herbivorous species than in carnivorous or omnivorous species. Examples include the green iguana and the chuckwalla. These have a large intestine which is often sacculated and divided into many chambers by leaf-like membranes. These increase the intestinal surface area so that microbes, upon which these species depend for vegetation digestion, may colonise it.

The large intestine then empties into the coprodeum portion of the cloaca. The cloaca itself is then continued, as with birds and snakes by the other two segments, the urodeum which receives the urogenital openings, and the proctodeum which is the last chamber before waste exits the cloaca through the vent.

Urinary system

The kidneys are paired and often bean-shaped organs. Their position is variable depending on the species. In some, such as the green iguana, they are both situated in the pelvis, attached to the dorsal body wall (see Fig. 7.6). Other species, such as chameleons, have longer kidney structures which extend cranially into the coelomic cavity. As with snakes, the males of some species have a specially developed caudal portion of the kidneys, known as the 'sexual segment' which enlarges during the breeding season and contributes to the production of seminal fluid. The kidneys empty into the ureters which empty into the urodeum portion of the cloaca.

Many lizards have a bladder. This is not however like the sterile bladder of mammals, as it is not connected directly to the ureters. Instead, it is joined to the cloaca, and so urine has to enter the cloaca, before entering the bladder. There is some evidence that the bladder is able to absorb some fluid from its contents, or it may function as a fluid storage chamber, flushing its contents back into the caudal large intestine for further fluid absorption.

Renal physiology

The renal physiology is similar to that already described for snakes. The main differences lie in the variable presence of the urinary bladder which may have some water reabsorption capabilities.

Cardiovascular system

Heart

The saurian heart is very similar to the snake model, with paired atria and a single common ventricle which nevertheless functions as two. The majority of the deoxygenated blood is channelled to the pulmonary arteries and the oxygenated blood enters the paired aortae. (Plate 7.2).

Blood vessels

The two aortae fuse dorsally, after giving off paired carotid trunks, to form the abdominal aorta. Lizards also possess a hepatoportal venous supply and a renal portal system, hence, as with birds and snakes, intravenous injection into the caudal half of the lizard of medications which are excreted through the renal tubules, could result in their failure to reach the rest of the lizard's body. It could also increase the toxicity of substances known to be renally toxic if given by this route.

Lizards, like snakes, also possess a large ventral abdominal vein which returns blood from the tail area and passes just beneath the body wall, ventrally and in the midline. This must be avoided when performing abdominal surgery. This vessel can be used, carefully, for venipuncture for blood sampling in lizards, although the preferred vessel is the ventral tail vein. For intravenous use, the cephalic vein may be accessed on the cranial aspect of the antebrachium, via a cut-down procedure, in the larger species.

Lymphatic system

The lymphatic system is similar to that of snakes, with no discrete lymph nodes.

Reproductive system

Male

The paired testes are situated cranial to the respective kidneys in those species which have abdominally positioned kidneys (Fig. 7.6). In those where the kidneys are more pelvic in position, the testes are located just caudal to the end of the lungs and liver, in the middle part of the coelomic cavity. They are supplied by several arteries each and drained by several veins. Both are very tightly adhered to their vascular supply, the left testicle being separated from the left renal vein (into which the left testicular veins drain) by the left adrenal gland. The right testicle is tightly attached to its right renal vein which separates it from the right adrenal gland. This positioning so close to such vital structures makes castrating aggressive lizards a difficult operation. The testes enlarge during the breeding season and regress out of it. Each testis drains into a vas deferens which has a tightly coiled course over the ventral surface of the respective kidney before emptying into the urodeum portion of the cloaca. Some species, such as the Chameleonidae, have a pronounced epididymis extending caudally from each testicle.

The male lizard has paired penises, as with the snake, known as hemipenes. These lie in the base of the tail structure, either side of midline, and function as with the snake family. At rest they are inverted sacs in the tail base. During copulation, one will engorge with blood and evert itself, creating a groove along its dorsal surface. Into this groove sperm and spermatic fluid will drop from the cloaca, and the hemipene will guide this into the female lizard's cloaca.

Female

The female lizard has much the same anatomy as that described for the snake.

Egg-producing physiology

Reproductive physiology in the female lizard is broadly similar to that of the avian patient. Some species, such as some of the Chameleonidae, are *ovoviviparous*. That is, they produce live young instead of laying eggs, although the *eggs are produced* internally. Some species are viviparous, in which a form of placenta or thin-walled egg structure allows the foetus to develop and live young are produced. Many other species are oviparous, i.e. they lay eggs. One or two species are *parthenogenic*: that is the females produce entire females with no need for a male lizard – some species of *Lacerta* and *Hemidactylus* (geckos) are capable of this.

Reptile eggs are generally soft shelled and more leathery than those of their avian cousins. Sexual maturity varies according to the species, green iguanas, for example, reaching it at 2–3 years.

Sex determination and identification

Sex determination is largely dependent on chromosomes. However, geckos as a family are temperature dependent, with 99% of eggs incubated between 26.7–29.4°C being female whereas if the temperature was greater than 32.2°C, 90% of the offspring would be male.

Sex may be identified by surgical probing as mentioned above. This is often the only method available for some species such as the beaded lizard, some monitors and the gila monster. However, in most other species there are external physical differences. These include the prominent pre-femoral pores of males that are seen on the caudoventral aspect of the thigh of iguanids (see Fig. 7.6). Some male lizards have a series of pre-anal pores just cranial to the vent. Males have wider tail bases than the females to house the large hemipenes (Fig. 7.7). Some males have greater ornamentation (Fig. 7.8). Male green iguanas and plumed basilisks have larger crests, male Jackson's chameleons have horns, male water dragons have larger crest spines and many male geckos have a wider vent size and hemipenal bulge.

Fig. 7.7 Eversion of a hemipene in a male leopard gecko to remove a hemipenal plug (accumulation of dried secretion).

Fig. 7.8 Greater ornamentation: more spines and larger dewflaps as well as brighter colouration distinguish the male green iguana.

Skin

Lizard skin is much the same as that of snakes. The scales in most cases are much smaller than the snake equivalent.

Special cutaneous adaptations in lizards

There are some specialised skin glands and structures in lizards. The males of certain species, such as the green iguana, have secretory glands or pores. The green iguana's are on the ventrocaudal aspect of the femoral area. Some geckos have precloacal pores.

Many lizards have large numbers of chromatophores in their skins. These are connected to neural networks, allowing them to alter the colour they produce according to external stimuli and mood. This ability is seen in the chameleons, and, to a lesser extent, in green iguanas and many other species.

Unlike snakes, lizards have a tympanum, located ventrocaudal to the eye, and a middle ear.

Many males will have large amounts of ornamentation on their body surface for display purposes. Examples include the male green iguana which often has large coloured scales on the head and a bluish sheen to the head and neck colouring. Others, such as male anoles, have extendable chin flaps which are often brightly coloured and can be 'flashed' in display. Some males such as the male plumed basilisks, have larger nuchal crests than the female.

Many lizards, such as the green iguana have a parietal eye (Plate 7.3). This is a special adaptation on the very top of the skull midway between the eyes. It is connected directly, via neural pathways, to the pineal gland in the brain and it is responsible for informing the lizard about light intensity and daytime lengths. These in turn influence feeding and reproductive behaviour. In the tuatara, which is found in New Zealand, a primaeval lizard in its own class of the reptile family, this parietal eye actually has a vestigial lens within it.

CHELONIA (TORTOISES, TURTLES AND TERRAPINS)

Musculoskeletal system

Chelonia have a rigid upper and lower jaw structure similar to that of the lizard family, but unlike lizards they have no teeth. Instead, the maxillae and mandibles are edged with tough keratin to form a horny beak, similar to that seen in birds. The skull articulates with the atlantal cervical vertebra via a single occipital condyle, similar to birds and other reptiles. There are two strong muscles attached to the back of the chelonian skull, connecting it to the point of fusion of the cervical vertebrae with the shell. These are responsible for the retraction of the head in *Cryptodira*, those species which can pull their heads back into the shell. There are some turtles (the side necked or *Pleurodira* turtles) which, as their name suggests, fold their head sideways into the shell, rather than fully retracting it in a craniocaudal manner. The thoracic vertebrae are fused with the dorsal shell, becoming flattened and elongated. The same is true of the lumbar and sacral vertebrae. The coccygeal vertebrae emerge distally to form the mobile tail.

Chelonia are distinguished from other animals by the presence of their shell. This structure is composed of fused *living* dermal bone covered by keratinised epidermis. It therefore can feel sensations and pain and so should never be used to tether tortoises to ropes or chains. The shell is composed of an upper section, known as the *carapace* (Fig. 7.9), and a lower, flatter ventral section, known as the *plastron* (Fig. 7.10). These two sections of the shell are connected either side between the fore- and hind limbs by the pillars of the shell. The carapace is a fusion of dermal bone, ribs, thoracic and lumbar vertebrae.

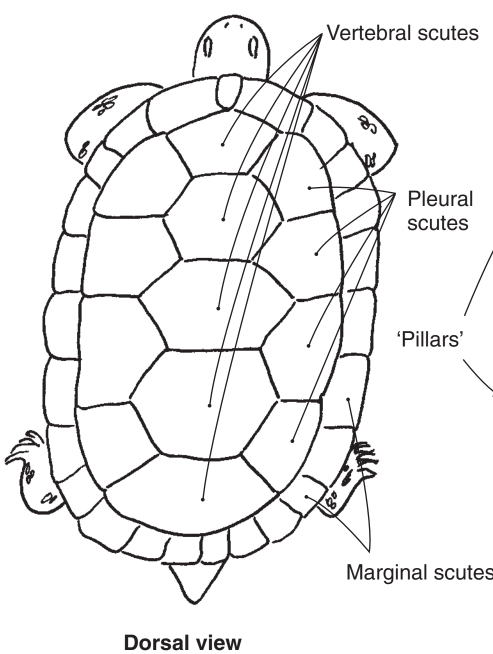

Fig. 7.9 Dorsal view of carapace.

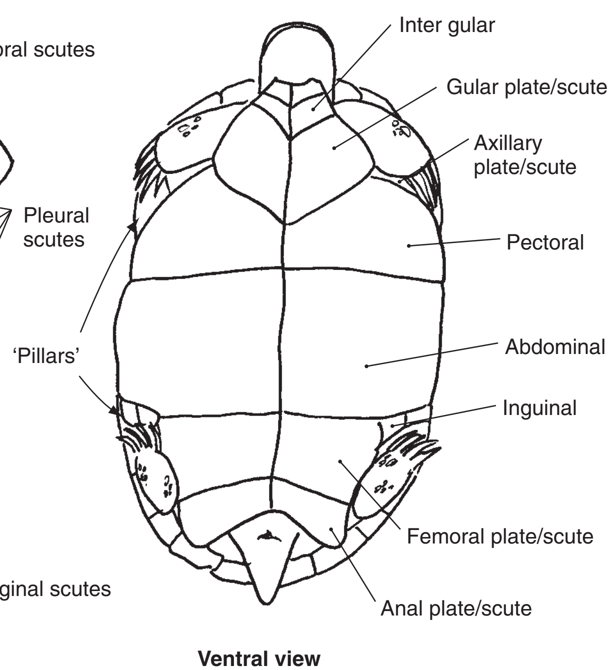

Fig. 7.10 Ventral view of plastron.

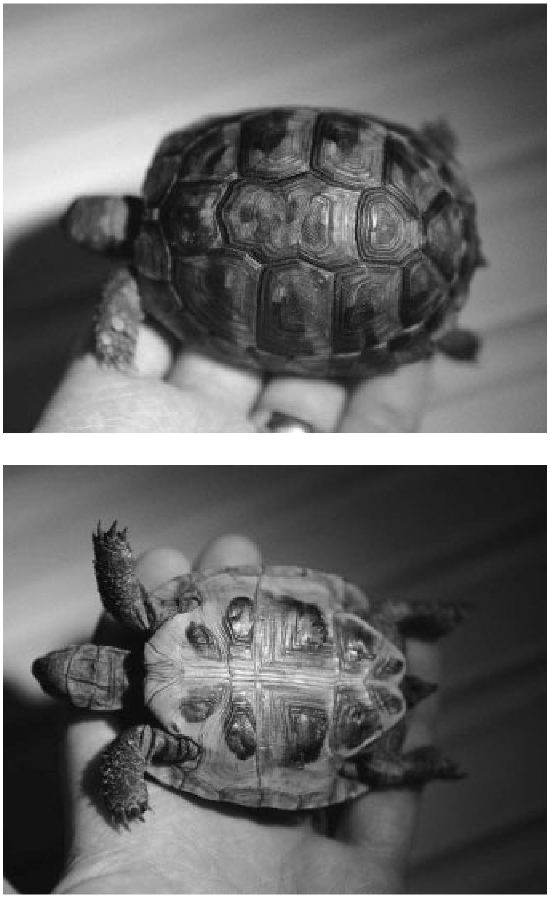

Fig. 7.11 Dorsal and ventral view of female tortoise.

The *scutes* (the individual segments of the shell epidermis) are given specific names (Fig. 7.11). They do not overlie directly the bone sections of the shell, there is some overlap. Some tortoises, such as the box turtle (*Terrapene carolina*), possess a hinge to the plastron allowing them to close themselves into their shells even further. Some of the Mediterranean species of tortoise such as the spur-thighed tortoise (*Testudo graeca*) can have caudal plastral hinges. This can be particularly useful in females, when they can increase the caudal exit space of the shell for egg laying.

Another unusual feature of Chelonia is that the scapulae are to be found on the inside of the shell, i.e. *inside* the ribcage, due to the shell structure. This is unique in the animal world. In addition the elbow joint is effectively rotated through nearly 180 degrees to cause the twisted forelimb so characteristic of tortoises.

The fore- and hind limbs are supplied with extensive muscles making them extremely strong for their size.

Respiratory system (Fig. 7.12)

Upper respiratory system

Chelonia have paired nostrils leading to the rostral portion of the oral cavity. As with other reptiles (excepting the crocodylians) there is no hard palate. The entrance to the trachea is guarded by the glottis, which, as with lizards and snakes, is closed at rest. It opens into the trachea, which has complete cartilaginous rings, and bifurcates relatively far cranially, often in the neck area, allowing the chelonian to breathe easily even when the neck is withdrawn deep into the shell.

Lower respiratory system

The two bronchi supply two lungs. These structures are situated in the dorsal aspect of the coelomic cavity against the inside of the carapace, and above the liver and digestive system. Between the lungs and the rest of the body organs there is a membrane but no true diaphragm. The lungs are sponge-like in structure and contain smooth-muscle and elastic fibres, forming essentially a non-collapsible structure. In some aquatic species the lungs have air sacs that act to increase buoyancy.

Respiration is aided by movement of the limbs and neck which act to pump the air into and out of the confined lungs. In addition, there are muscles attached to the membrane that separates the lungs from the rest of the viscera. In breathing, these contract and relax. Many chelonians can survive without breathing for several hours if necessary. The stimulus for respiration is, as with other reptiles, a fall in blood partial pressure of oxygen.

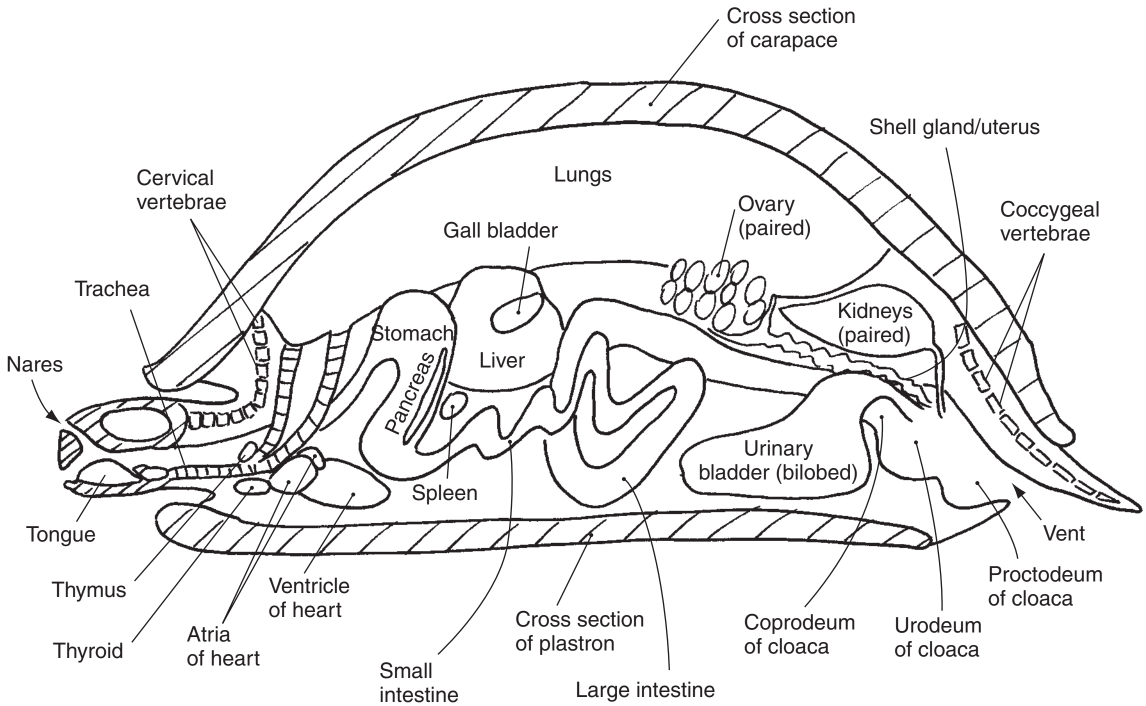

Fig. 7.12 Section through the midline of a female tortoise.

Digestive system

Oral cavity

The tongue is relatively tightly attached, but is fleshy in structure with the glottis at its base. Salivary glands secrete mucus only when eating to lubricate food. The pharynx is wide and passes into a distensible smooth-muscle covered oesophagus. Many of the aquatic turtles have caudally curved spines present in the caudal pharynx and oesophagus, which are thought to aid in swallowing slippery prey such as fish.

Stomach, associated organs and intestine

The stomach sits on the left side ventrally in the mid-coelomic cavity. It has a strong cardiac sphincter, making vomiting in the healthy chelonian rare. The stomach leads to the duodenum and a short but highly coiled small intestine. At the junction of the small and large intestine lies the caecum which is often a rounded bag-like object. The large intestine itself has a large diameter and, for the herbivorous chelonia such as tortoises, is the principle site of fermentation. It then narrows to form the rectum. Next come the coprodeum, the urodeum and then the proctodeum of the cloaca, and finally the vent.

The liver is a bilobed structure situated transversely across the mid-section of the coelomic cavity, dorsal to the digestive system, and ventral to the lungs. There is a gall bladder to the right of the midline.

Urinary system

The paired kidneys are situated caudally within the shell, tightly adhered to the ventral surface of the inside of the carapace and caudal to the acetabulae of the pelvis. There is a difference in the marine species where the kidneys are situated cranial to the acetabulae. Two ureters empty into a urogenital sinus, a common chamber for the opening of the urinary and reproductive systems, which also connects with the urinary bladder. The latter organ is a large, bilobed, thin-walled structure which has some ability to reabsorb water. The urogenital sinus empties into the urodeum portion of the cloaca.

Cardiovascular system

Heart

As with lizards and snakes, the chelonian heart is a three-chambered organ situated within the pericardial sac. The two cranial vena cavae and one caudal vena cava merge to form the sinus venosus, which enters the right atrium.

Blood vessels

Paired aortae give rise to the carotid arteries that supply the head and neck. They then curve dorsally to fuse into the abdominal aorta. Just before fusing, the left aortic arch gives rise to arteries supplying the digestive tract, and the right aortic arch produces the brachiocephalic trunk that supplies the head and forelimbs. The abdominal aorta then courses down the ventral aspect of the vertebrae, supplying the shell and dorsal structures via intercostal arteries. The shell itself has a blood supply arising from cranially placed subclavian and caudally placed iliac arteries which anastomose widely.

The venous return of blood follows a similar pattern to lizards and snakes. Another bypass system exists whereby blood from the caudal vessels may cross from one side of the body to the other via transverse pelvic veins. From these, the blood may enter the paired abdominal veins which run along the floor of the ceolomic cavity. It is these latter vessels which must be carefully negotiated when performing abdominal surgery in chelonians.

Lymphatic system

The lymphatic system is essentially the same as in the snake and the lizard. The spleen is situated close to the caecum.

Reproductive system

Male

The testes are internal and often yellow cream coloured oval organs cranial to the kidneys. As with the liver, there may also be some dark pigmentation to the testes. The testes empty into the associated epididymal organs that overlie their surface. The sperm then enter the vas deferens, which courses over the ventral surface of the kidneys, and enters the urogenital sinus adjacent to the urodeum portion of the cloaca.

The phallus is a large fleshy organ, and, unlike snakes and lizards, there is only one of them. It lies on the ventral aspect of the cloaca at rest. When engorged, the free caudal end of the phallus is projected through the vent and curves cranially. In so doing a dorsal shallow seminal groove is formed to guide sperm into the female's vent.

Female

Paired ovaries are suspended from the mid-dorsal aspect of the coelomic cavity. They shed their ova into the infundibulum portion of the oviduct. This is connected to similar structures as in the snake and lizard families, including a magnum and a uterus. This finally connects to the smooth-muscle lined vagina which is responsible for keeping the oviduct closed to the outside world until egg laying occurs. The oviducts empty into the urogenital sinus and then into the urodeum portion of the cloaca.

Reproductive physiology

Folliculogenesis is stimulated by the time of year. In those chelonians such as the Mediterranean species of tortoise, hibernation is an important factor. This period is necessary for the preprogramming of the thyroid gland and the reproductive cycle. Two bouts of egg production can occur per year. On average 10–30 eggs are laid each year, depending on the species. Most Mediterranean tortoise species do not become sexually mature until they are 7–10 years of age.

The female tortoise will start to form fertile eggs after a successful mating. These are carried in her reproductive system for a period of time varying anywhere from 4 weeks to 3–4 years which means that it is possible for Mediterranean species to carry eggs through hibernation. The female can also store the sperm from a successful mating for long periods of time, eventually allowing fertilisation to occur many months to years after exposure to the male, a factor which makes identification of the father sometimes rather difficult!

Sex determination and identification

As with many reptiles, tortoise sex determination depends on the temperature at which the eggs were incubated. Spur-thighed tortoises (*Testudo graeca*) will produce males if the eggs are kept at 29.5°C and females if kept at 31.5°C. It seems that this fact can be applied to a large number of other tortoise species, with males being predominantly produced at the lower temperatures, and females at the higher ones. If the temperature range is kept from 28–31°C, a mixture of sexes is likely to be achieved.

Male Chelonia have longer tails, the vent being found on the tail caudal to the edge of the carapace, in order to house the single phallus. Males of many Mediterranean species of tortoise and turtles possess a dished plastron, and a narrower angle to the caudal plastron in front of the cloaca than the egg bearing female. Some female Mediterranean species have a hinge to the caudal part of the plastron to allow easier egg laying. The male of the box turtle (*Terrapene carolina*) has red coloured irises whereas the female has yellow/brown ones. The female leopard (*Geochelone pardalis*) and Indian starred tortoises (*Geochelone elegans*) have longer hind limb claws for digging than the males. The male red-eared terrapin (*Trachemys scripta elegans*), has longer forelimb claws than the females. Some males, such as the Horsfield's tortoise (*Testudo horsefieldii*), have a large, hooked scale at the tip of their tails. In some species there is a size difference between the sexes, the female of the Indian starred tortoise and the red-eared terrapin species is larger than the male when full grown, but the reverse is true of the red-footed tortoise (*Geochelone carbonaria*).

Skin

The skin covering the head, neck, limbs and tail of the chelonian is much the same as that of snakes and lizards. Many species of tortoise have enlarged scales over their forelimbs, and some have horny spurs on their hind limbs. The skin is particularly tightly adhered to the underlying bony structures over the distal limbs and the head.

Tortoises and most other Chelonia have visible auditory membranes covering the entrance to the middle ear. These lie caudoventral to the eyes at the rear of the skull.

The shell is formed from the fusion of islands of bone produced within the chelonian's dermal layer the skin, rather than from the limbs or ribs. The overlying epidermis is highly keratinised and pigmented. The lines joining individual scutes on the shell are not directly above the corresponding suture lines in the bony part of the shell. There is some considerable overlap which reinforces the structure.

CROCODYLIA (CROCODILES, ALLIGATORS, CAIMANS, AND GHARIALS)

Musculoskeletal system

The body plan for the Crocodylia is not dissimilar to that of the Sauria. The basic structure is a quadruped reptile, with an elongated tail, but instead of the short- to medium-length head, the crocodylians have elongated jaws. This is particularly accentuated in the long thin jaws of the fish eating gharial family.

The teeth are continually replaced and are held in crude sockets. One of the distinguishing features between the more bad-tempered crocodiles and the alligator family is that the fourth mandibular tooth on either side is visible in the crocodiles. In the alligator subfamily the tooth is hidden in a maxillary pocket.

The articulation point of the upper and lower jaws is located at the rear of the skull, giving more room for teeth and allowing a larger gape. The jaws are powered by strong temporal and pterygoid muscles, allowing immense crushing forces to be applied. Interestingly though, the muscles responsible for opening the jaws are relatively weak, hence once closed and taped shut a crocodilian cannot easily open its mouth again.

There are eight pairs of ribs arising from the thoracic vertebrae, with additional dermal bones embedded in the ventral body wall known as *gastralia* or floating ribs. There are also thickened transverse processes of the sacral vertebrae which float freely alongside the respective vertebral bodies and have also been called ribs. The femur is proportionally longer than that of the saurians, leading to a raised appearance to the crocodylian hindquarters.

Respiratory system

Upper respiratory system

The nares of the Crocodylia are frequently protected by lateral skin flaps which can be contracted medially to close them when submerged. The nasal passages have excellent neural endings in the ethmoid/olfactory chamber area allowing an acute sense of smell. The crocodiles have a true hard palate that separates the oral and nasal passages. The internal nostrils open caudally, therefore the glottis guarding the trachea is also situated caudally.

The entrance to the larynx is guarded by the glottis but also by gular and a basihylar fold which originate in, respectively, the floor and roof of the oropharynx and can close access to the glottis from the mouth when a crocodilian is submerged. This allows them to drag prey underwater at the same time preventing any water from entering the caudal aspect of the pharynx. Providing its nostrils are above water, the crocodilian can still draw air in through the nasal passages.

The trachea is composed of complete cartilage rings, similar to Chelonia and birds.

Lower respiratory system

The trachea bifurcates within the 'chest' into two primary bronchi, each supplying a well-formed lung structure. The lungs are basic in design, and do not contain well-defined lobules, as do their mammalian counterparts, although they are very well vascularised. There are air sacs more caudally which can be inflated to provide some buoyancy. More importantly, they can function as a gas reserve, allowing them to remain submerged for up to 1–2 hours before anaerobic respiration takes over. The lungs are also different from other reptiles in that there is a muscular, crude diaphragmatic structure separating the dorsally-situated lung fields from the ventrally-situated heart and digestive system. The diaphragm as well as the intercostal muscles are important for respiration in crocodylians.

Digestive system

Oral cavity

The crocodylian tongue is large and fleshy, but immobile. Caudally, the floor of the mouth forms a transverse fold, as does the palate above. This shuts the oropharynx off completely from the glottis and nasopharynx.

Stomach, associated organs and intestines

The crocodilian stomach is large and divided into two areas, known as the *body* and the *pars pylorus*. The body area is heavily populated by mucus-secreting glands and surrounded by a thick band of smooth muscle. It is in this area that stones swallowed by the crocodilian may be found, and therefore this area seems to be responsible for grinding and massaging food into smaller pieces, similar to the action of the avian gizzard. The pars pylorus has acid and pepsin secreting glands and empties into the small intestine through the well-developed pyloric sphincter.

The small intestine meets the large intestine at the ileocaecal sphincter. The large intestine empties into the coprodeum portion of the cloaca, which opens into the urodeum, then the proctodeum before ending at the vent to the outside world.

Urinary system

There are paired kidneys located in the caudal abdomen, and extending into the pelvis. The aquatic crocodile kidney excretes waste protein nitrogen as ammonia rather than as the more usual reptilian uric acid, although the latter can also be produced, particularly when the animal is dehydrated. Osmoregulation, the maintenance of the electrolyte and water balance within the body, is not solely performed by the kidneys, as with many other reptiles. Instead, there are salt-secreting glands in the mouth which aid excretion of excess sodium as sodium chloride. There are no truly marine crocodilians, although the salt water crocodile and the American crocodile will spend time in brackish water and will venture out into the sea.

The oral salt-secreting glands of the alligator subfamily are not as highly developed, reflecting their more freshwater habitat. The kidneys empty through the ureters which travel into the urodeum portion of the cloaca.

Cardiovascular system

Heart

The crocodilian heart is different from that of other reptiles in that it has four chambers, similar to the mammalian model. There is however a small 'hole in the heart' between the two ventricles, known as the *foramen of Panizza*, which allows some mixing of oxygenated and deoxygenated blood.

The rate of mixing is dependent on the pressures within the left and right ventricles. While the animal is breathing, the left ventricle has higher pressure and so blood moves from the oxygenated side to the deoxygenated side. More important for the crocodilian is what happens when he is submerged and not breathing. The increased pulmonary resistance so produced forces blood from the right ventricle to the left and out through the abdominal aorta, decreasing the blood flow to the non-functional lungs and sending it back around the body. The left ventricle blood, still returning from the lungs and so still relatively well oxygenated, is diverted through the brachicephalic trunk to the head and heart muscle which need more oxygen to keep functioning. This allows the crocodilian to function in conditions of reduced oxygen and anaerobic metabolism for up to 6 hours!

Blood vessels

The basic structure of the blood vascular system is similar to the lizard's. There are paired aortae from the right and left ventricles which fuse to form a single abdominal aorta after giving off the brachicephalic trunk which supplies the head and forelimbs.

The venous system has many parallels with the Sauria. There is an hepatoportal system supplying the liver directly from the intestines and a renal-portal system wherein the blood returning from the hind limbs and tail enters a venous circle around the kidneys.

There is a large venous sinus caudal to the occiput of the skull on either side of the midline which may be used for venipuncture. Alternatively, the ventral tail vein may be used for blood sampling purposes.

Lymphatic system

The lymphatic system parallels the saurian system.

Reproductive system

Male

The testes are long, thin organs situated medial to their respective kidneys either side of the caudal vena cava. The vasa deferentia travel to the urodeum portion of the cloaca. The testes enlarge during the reproductive season.

On the ventral aspect of the cloaca lies the phallus. This is a fibrous organ which has little erectile tissue, but once everted forms a dorsal groove into which the semen is deposited. There are two accessory ducts entering this groove which supply seminal fluids from the caudal kidney area.

Female

The paired ovaries are also to be found medial to their respective kidneys. Each ovary is slightly flattened and has a central medullary area which is supplied with nerves and blood vessels. The rest of the reproductive system consists of the fimbria or ostium which catches the ova, then there is a muscular portion followed by the isthmus and the shell gland or uterus. The paired oviducts open into the urodeum of the cloaca, adjacent to the clitoris.

Reproductive physiology

Follicular activity is triggered by increasing day length in March–May, there being one cycle per year. An average clutch of follicles varies from 20–80 per cycle.

Sex determination and identification

This varies with species. In the case of alligators and caimans, the lower incubation temperatures (from 28–31°C) produce all females. An intermediate temperature (from 31–32°C) produces males and females and a higher temperature (from 32–34°C) produces all males. In the case of crocodiles, temperatures at the lower end of the range (from 28–31°C) also produce all females. Intermediate temperatures (from 31–33°C) produce some females but a predominance of males. For higher temperatures (from 33–34°C), predominantly female crocodiles, with some males, are produced.

The best method of sex identification is by manual palpation of the ventral surface of the cloaca for the presence of the phallus. This is an obvious structure if present, as otherwise the cloaca is completely smooth walled. The crocodilian involved must be in dorsal recumbency and adequately restrained in order to perform this!

Skin

The epidermis and dermis of Crocodylia is composed of thickened scales which are joined together like a patchwork quilt by elastic tissue. The skin is tightly attached to underlying bone over the feet and the skull. The skin covering the dorsum has layers of dermal bone present within it, making this area extremely thick and impossible to penetrate for injections. The caimans have areas of bone in the skin covering their ventral surface as well.

Specialised skin areas

Within the majority of the scales of the crocodile subfamily are present *integumentory sense organs* (ISO). These are absent in the alligator subfamily. Their function is to determine underwater pressure sensations which can be used to locate prey whilst submerged.

Overview of reptilian haematology

The cells found in the reptilian bloodstream broadly mirror those seen in mammals. There are however a few important differences:

- The reptilian (and amphibian) erythrocyte is oval in shape rather than biconcave and has a nucleus even when fully matured.
- The reptile, like the avian patient, has a slightly different version of the mammalian neutrophil, known as the *heterophil*. This white blood cell has a bilobed nucleus, like the neutrophil, and contains cytoplasmic granules, but these stain a variety of colours with Romanowsky stains, rather than remaining neutral as seen in neutrophils. The heterophil performs similar functions to the neutrophil, being a first line of defence for infection. However, although its numbers *may* be increased during infections, they may stay the same, in which case the only tell-tale sign of an inflammatory process occurring is vacuolation and degranulation of the cell (the so-called 'toxic' cell). This makes cytological examination more important than cell counts in reptiles.
- An additional mononuclear cell is the *azurophil*. It stains a blue red colour and is a large, single nucleated cell with moderate cytoplasm present. It is found normally in small

numbers, but if elevated in lizards and chelonia, it suggests an inflammatory/infectious process. It is particularly associated with chronic granuloma formation.

- Eosinophils and basophils are present in most species, basophils being common in turtles. Basophils generally stain blue, and are small spherical cells with a non-lobed nucleus. The eosinophil is a larger spherical cell with eosinophilic cytoplasmic granules and a mildly-lobed to elongated nucleus. However, in the green iguana they often stain blue!
- Lymphocytes may vary with the season showing a decrease in the 'winter'/colder months in tropical species. Unlike mammals, the B-lymphocyte can change into the plasma cell form within the bloodstream during chronic or severe infections of reptiles. Hence, the eccentrically placed nucleus and pale staining 'clock-face' cytoplasm of the plasma cell may be seen in blood smears of reptiles.
- The thrombocytes (platelets) of reptiles, like avian species, are also nucleated.

Most importantly, when collecting blood samples from reptiles, it is better to do so into heparinised containers for haematology, rather than potassium EDTA tubes used in birds and mammals. This is because the blood cells, particularly erythrocytes, of many species (particularly the Chelonia) will rupture in potassium EDTA. An air-dried smear for staining made at the time of sampling is also useful, as heparin interferes with the Romanowsky stains.

AMPHIBIANS

Musculoskeletal system

The body plan of amphibia in general varies greatly within the family from the classic lizard shape of the salamanders and newts, through to the tail-less quadruped form of the anurans (frogs and toads) through to the worm-like caecilians.

In the case of the anurans and the salamanders, the skeletal structure is very basic but similar to the saurian model described above. The main differences lie in the anurans which have long femurs, tibias and fibulas, and metatarsals which are developed into the well-muscled hind limbs. There is a basic spinal column of cuboid vertebral bodies joining to the primative pelvis caudally and the single occipital condyle of the skull cranially.

The skull possesses a mandible and maxilla with, in many cases, simple peg-like, open-rooted and continually replaced teeth. The eye sockets are large in anurans, as is the well developed eardrum that leads to the middle ear. Sight is mainly based on movement rather than sharp focus, but the sense of hearing is very good, although low frequency sounds are transmitted through the bones of the forelimbs, and high frequency ones through the actual eardrum.

The majority of anurans have five digits on the forelimbs and four on the hind limbs. Many salamanders and newts have four digits on their forelimbs and four or five digits on their hind limbs. Many salamanders will show autotomy or tail shedding when roughly handled as with many saurians.

Many amphibians possess vestigial rib structures, and the majority also have a sternum. The pectoral and pelvic girdles are fused to the spine, giving increased rigidity to the body structure.

The caecilians have a much simpler body plan with few if any bones. Their body plan is more worm-like, although they are amphibians rather than insects, but they do possess jaws, a primitive skull and a fibrocartilaginous spinal column. They also have small eyes and nostrils in the head.

Respiratory system

In aquatic amphibians such as the primitive *axolotl*, gills are still present. Indeed, as an amphibian metamorphoses through from egg to larval or tadpole form it will also have gills, although these may be lost as the adult form is reached.

Terrestrial amphibians, such as many of the anurans, have an internal lung structure. This is often no more than a simple air sac structure. There are no internal alveolar areas to this lung, although it may be folded to increase its surface area. No diaphragm is present, giving a continuous body cavity or coelom, hence respiration for those amphibians possessing lungs occurs due to intercostal muscle and limb movements pulling the chest wall up and outwards.

Many amphibians will use the skin surface for gaseous exchange, whether they possess an internal lung structure or not. Indeed the skin is often solely used for gas exchange during periods of low oxygen requirement, such as during hibernation. For other skin breathers, such as the plethodontid salamanders, other adaptations, such as increasing the skin's surface area by having folds of skin, or by having 'hairs' on their surface (for example, the African hairy frog), or reducing oxygen demands/metabolic rates, are necessary.

Digestive system

Most adult amphibians are carnivorous, and their digestive systems are adapted to this diet. The majority possess a tongue which can be projected at high speed towards their prey. It is covered in fine sticky cilia, as in many anurans, enabling it to capture flying prey. The salamanders, newts and most anurans have vestigial peg-like teeth. There are frequently cilia within the oral cavity and oesophagus, which aid in the propelling of food into the stomach. Terrestrial amphibians also have mucus-secreting salivary glands to aid in the swallowing of prey.

The stomach is simple in nature, possesses mucus-secreting glands and, in the majority of cases, combined acid- and pepsinogen-secreting glands. The small intestine is short, and little defines its finish and the start of the rectum which empties into the cloaca.

The liver is frequently dark coloured due to melanin pigmentation for protection from ultraviolet light, necessary due to the thin nature of amphibian skin.

Urinary system

As with the reptile family, amphibians cannot concentrate urine beyond plasma tonicity. The main excretory product of aquatic amphibians such as caecilians and aquatic newts and the axolotl, is ammonia. This is actually excreted, as with fish, through the gills if present, and the skin if not, rather than the kidneys.

In terrestrial amphibians, urea is the main waste product of nitrogen metabolism and this is excreted through a primitive paired kidney structure. The cloaca of these species (chiefly the anuran toad family) may also have a pocket forming a primitive bladder. One or two amphibians can produce uric acid. The kidneys empty into ureters which travel to the urodeum portion of the cloaca, before either refluxing into the bladder (if present) or emptying through the vent.

Cardiovascular system

Heart

The circulatory system changes dramatically during the metamorphosis of the amphibian. At the larval stage the circulatory system is more fish-like, with a two chambered heart possessing only one atrium and one ventricle. When the adult form is achieved the heart has divided itself into three chambers by producing an intra-atrial septum, and also rerouted its circulation away from the gill arches of the larvae to the adult respiration organ (the skin, lungs or again gill arches).

Blood vessels

As far as the more peripheral vascular system is concerned, the amphibians differ from the reptiles in that the caudal body drainage goes through the hepatic portal system rather than the renal portal system. This is important for the administration of hepatically metabolised drugs or hepatotoxic drugs in the caudal half of an amphibian.

Lymphatic system

There is a large lymphatic drainage system, with paired dorsal lymph sacs in anurans lying cranial to the hind limbs laterodorsally. These help propel lymph fluid as well as draining it via lymph hearts back to the true heart. They may also play a role in electrolyte balance through the skin overlying them.

Reproductive system

There are paired internal testes or ovaries depending on the sex. There is some variation in the size of the gonads during the reproductive season, and basic hormones resembling the activity of FSH and LH are produced.

In the female there are paired oviducts which are responsible for producing the jellylike material that coats the ova. Most amphibians fertilise their eggs outside the body, but one or two species of anuran, and the caecilians, do have a form of phallus for internal fertilisation. Indeed some caecilians are viviparous and actually secrete a uterine milk to nourish the foetuses within the oviduct.

When hatched, the amphibian then metamorphoses through a series of changes, often known as *instars*, one of which we all know as the ‘tadpole’ of the anurans which has external gills and a tail and no legs initially. The stimuli for the metamorphosis seem to come from various external sources, such as environmental iodine levels, as well as internal hormonal influences from the thyroid gland.

Skin

The terrestrial amphibian has a thin stratum corneum which provides extra cutaneous protection above that seen in aquatic species. It also reduces water loss from the skin. The skin is shed regularly, similarly to a snake, and is frequently then eaten by the amphibian. The skin contains many glands which secrete oils and mucus in to further protect against water loss, but amphibians always have to have access to damp conditions or free water to survive.

Many of the toad family have poison glands located in their parotid glands which are used as a form of protection. A similar ploy is used in the poison arrow tree frogs which secrete neurotoxins onto the surface of their skin.

Some anurans, such as the midwife toad *Xenopus laevis*, have claws, but most have very fragile skin, which, as mentioned above, may have gas exchange as well as water and electrolyte exchange capabilities.

Some male amphibians can be identified by skin colour or ornamentation. The male great crested newt has a larger crest than the female, for example, and many male frogs and toads have a swelling in the ‘thumb’ area of the hand which contains scent glands. Male caecilians often have a phallus in the cloaca.

Chapter 8

Reptile and Amphibian Housing, Husbandry and Rearing

There are many good books available on the husbandry of reptiles and amphibians, and some are listed at the end of this chapter. This chapter will therefore provide only a brief overview of the main points in housing and caring for reptiles and amphibians.

Vivarium requirements

Dimensions and construction

Vivarium designs vary, as does their construction material. The main aim though is to ensure that they are durable, easily cleaned for hygiene reasons and that they provide enough space for the captive reptile to demonstrate normal behaviour (Plate 8.1). Strict cage dimensions are therefore difficult to quantify, as each situation should be judged on its own merits. However some general principles apply (Fig. 8.1).

For species which are more arboreal (tree climbing) in nature, such as the green iguana, and many snakes, such as the boa constrictor and Burmese python, the emphasis in cage design should be more on vertical height rather than horizontal space. For species such as the tortoise family however, the provision of too much vertical space is pointless, as they are not renowned for their tree-climbing tendencies! Horizontal space is thus more important.

Cage materials commonly used include perspex, reinforced glass and fibreglass (Figs 8.2 and 8.3). Wood should be avoided unless it is sealed to prevent moisture damage and rotting. Glass and clear perspex are useful when showing off a collection, but care should be taken as many reptiles cannot see the tank sides, and so may continually rub their snouts along the inside of the vivarium, causing severe abrasions which can become infected. Often the provision of a tape strip on the outside of the glass at reptile level allows them to appreciate that a barrier exists and prevents this problem.

Heating

Reptiles are ectothermic by nature – that is they rely on the environment to provide sufficient heat to warm them to their *preferred body temperature* (PBT). To do this the reptile must be provided with a preferred optimum temperature zone (POTZ) within which it may position itself in order to maintain its PBT. This necessitates the provision of some form of artificial heating within the tank, or vivarium, as it is more commonly known.

Two main forms of heating are advised. A background, continuous heat source is important to raise the vivarium temperature above the background room temperature. This is often provided in the form of a radiant heat mat. This is a mat which emits heat continuously, and is placed on the *outside* of the vivarium, usually on the back wall of the tank (Fig. 8.1). It then radiates heat through the tank wall. Placing it on the outside of the tank avoids the possibility of the reptile chewing, urinating or defaecating on it, so increasing hygiene and safety. The size of the available mats vary, but in general a rough rule is that one third to one half of the longest side of the tank should be covered with the mat. Some form of insulation on the outside of the mat, increasing reflection of heat into the vivarium, is also useful.

In addition, the vivarium requires a focal hot spot, which may be provided in the form of a ceramic or infra-red heat bulb. This should be suspended from the ceiling of the vivarium, and should be protected from the reptile to avoid the

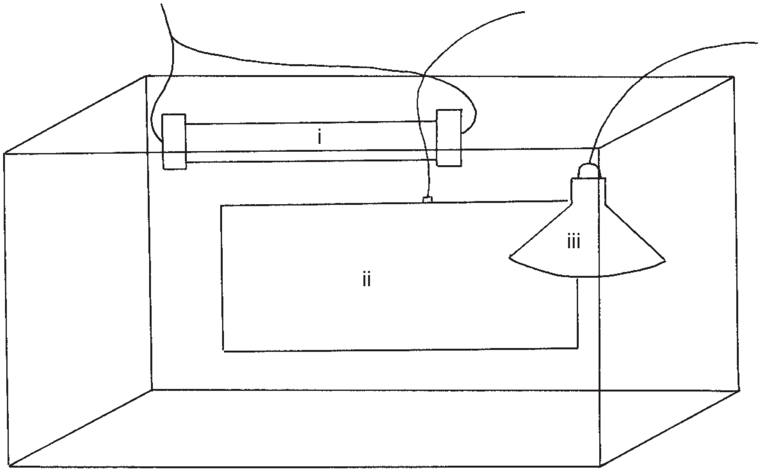

Fig. 8.1 Basic diagrammatic representation of a vivarium: (i) ultraviolet light source (on inside of tank as glass filters out UV light); (ii) radiant heat mat, usually placed on outside of tank for hygiene reasons; (iii) focal heat source such as a heat lamp to provide a temperature gradient.

Fig. 8.2 Basic layout of traditional plastic tank.

Fig. 8.3 More sophisticated tank system made of moulded fibreglass.

risk of burns. The bulb should be attached to the mains via a thermostat, which will allow maximum and minimum tank temperatures to be set. The importance of a focal heat source is that it provides a temperature gradient, allowing the reptile to bask underneath the heat source or to escape to a cooler end of the tank when overheated. The reptile can then maintain its PBT by positioning itself at different points in the tank during the course of the day.

The temperatures required for different species of reptile will naturally differ depending on the part of the world from which they originate. Mediterranean tortoises may cope adequately outside in the warmer British summers, but leopard geckos will require more desert-like temperatures for normal homeostasis systems to work properly. A list of some species and their temperature requirements is given in Table 8.1.

Humidity

Humidity can also be important. Many species of reptile come from dry desert regions, but equally many originate in tropical rain forests. Therefore their tolerance of water moisture in their environment will vary. A water dragon, basilisk or garter snake, all used to living near or in water, will require a 75–90% humidity level. This may be difficult to maintain in a heated environment, as the hotter the air the more water droplets the air can hold, and so the relative humidity levels drop. Thus, spraying the enclosures frequently, using a hand-held plant mister, with previously boiled and then cooled water is useful. Alternatively, the provision of water baths, or damp substrate within the tank can be used to increase humidity. Care should be taken over hygiene levels though, as a too damp and soiled substrate can lead to skin infections such as blister disease, a common problem in garter snakes. In the case of reptiles from more arid climates, such as the Mediterranean tortoises, leopard geckos and bearded dragons, a relative humidity of between 25–50% is often adequate. This is around the normal level of the average centrally heated home.

Lighting

Lighting is particularly important for the growing juveniles of many species. In the wild, many of these reptiles live in parts of the world where the intensity of the sun's ultraviolet rays is high. These ultraviolet rays stimulate a number of functions in the reptile, often encouraging mating at certain times of year, and may act as a general appetite stimulus. This seems to be the role of the A section of the ultraviolet waveband.

The B waveband of the ultraviolet spectrum is important in all species in encouraging the production of vitamin D_3 from precursors in the reptile's skin. Vitamin D_3 is intimately involved in the metabolism of calcium and bone growth within the juvenile reptile. A lack of ultraviolet light therefore can be responsible for the presence of metabolic bone disease in several species, particularly the green iguana and the Mediterranean tortoises (see section on reptile and amphibian diseases p. 171).

Artificial ultraviolet lighting is therefore important in these species, and should be provided on the *inside* of the vivarium. This is because glass and perspex will filter out the UV rays if the light is placed on the outside of the tank. In addition, the light source should be positioned close to the reptile, i.e. within 30–45 cm. This is because the intensity of these artificial lights is relatively low, and the inverse square rule tells us that the intensity of the light diminishes with the square of the distance from its source (e.g. the intensity at 2 m from the source is a quarter of that 1 m from its source).

Some species are not so susceptible to ultraviolet deprivation, including more nocturnal species such as the leopard gecko and many snakes. The theory is that these species gain sufficient preformed vitamin D_3 in their diets to cope. This is important if the owner is not feeding them correctly, as metabolic bone disease may then be seen.

Table 8.1 Preferred optimum temperature zones for selected species of reptile.

Species	Temperature range (°C)
Mediterranean tortoises	20–27
Green iguana	25–32
Leopard gecko	25–34
Water dragon	24–30
Bearded dragon	25–32
Corn snake	23–30
Burmese python	25–30

Cage 'furniture' and environmental enrichment

Many reptiles are relatively poorly adapted to captivity, being wild animals in a confined space, and so it is important to ensure that their environment adequately caters for their requirements.

As previously mentioned, many arboreal species, such as the green iguana and members of the python family, enjoy exploring vertical space. They should therefore be provided with branches and ramps up which they may climb. It is often useful to provide an elevated basking spot which they can lie out on near to the focal heat source.

In the case of ground-dwelling species, the provision of some form of floor furniture is important. Tortoises are in general best kept singly, except when breeding of course, or in the case of small hatchlings which prefer to be in groups. In these cases the provision of visual barricades which they can hide behind and so get out of view of one another is useful.

All reptiles should be provided with a hide. This is an area to which they can escape to digest food in peace, and to escape the view of other reptiles, predators and nosey humans! This is important particularly for many snakes which will often refuse to eat their prey in the open, but rather prefer to take it back into the hide area away from view. The size of these areas does not need to be that large, in the case of most species a space 2–2.5 × the size of the reptile housed is sufficient.

Flooring

The substrate of the vivarium, or floor covering, is important. It is vital that any substrate used is non-toxic to the reptiles housed and is easily cleaned. In many cases the provision of newspaper, or unbleached household paper is perfectly sufficient, although possibly not so aesthetically pleasing, as more naturalistic substrates. Care should be taken with smaller reptiles with newspaper, as the ink from the newsprint may prove irritant.

Other substrates used commonly include bark chippings, sand, coral and peat. Bark chippings are a good choice for deep litter situations, particularly when providing enough substrate for a pregnant female to dig a nest in which to lay eggs. However, the chips should not be of cedar as the resins from this can be irritant. It is also more difficult to monitor the cleanliness of bark chippings as faeces and urine may fall into the substrate and so avoid detection.

Sand is useful for desert species such as leopard geckos, collared lizards, sand boas etc., but care should be taken with any reptile on this substrate as if the diet contains mineral deficiencies, or there is intestinal parastism present, many species will consume the sand and may suffer intestinal blockages.

Peat can be useful for species requiring damper conditions such as water dragons, red-footed tortoises etc., but care again should be taken with the hygiene of this substrate, as waste materials may build up unnoticed. Coral is not advised as a substrate for ecological reasons as well as the tendency for reptiles to eat the substrate and suffer gut impactions.

Aquatic species and amphibians

Species requiring fresh water to bathe or live in include all amphibians, red-eared terrapins, soft-shelled turtles, water and garter snakes. Some, such as the terrapins and turtles, require large areas of free water, some, such as frogs and toads, a small area but damp environmental conditions (Fig. 8.4).

In the case of freshwater species, tap water may be used, but it should be conditioned first, that is the water must first be dechlorinated. This may be done by standing it in an open container for 24 hours prior to use or by using any commercial dechlorinating tablets available from aquarists. In addition, the tap water should be allowed to come up to room temperature before being introduced to avoid cold shocking the reptile or amphibian.

Where large areas of water are provided, it is important to keep them clean. It is advisable for terrapins and soft-shelled turtles that their habitat provides an area in which they can immerse themselves completely in water, and an area into which they can pull themselves out to bask and dry themselves off, preferably with a focal heat source above it. It is often advisable to remove them from the water and place them in a separate dry or water-containing feeding tank. This is because they are extremely messy eaters and will quickly contaminate their water with food. The food acts as a substrate for bacteria, and this can increase the risk of shell infections and septicaemia. An alternative would be a powerful water filtration device placed in the tank to cope with the large volumes of organic debris produced. Even if a

Fig. 8.4 Example of hospital tank provision for an amphibian, in this case an Argentinian horned frog.

feeding tank is provided, regular water changes or filtration is required, as they will of course still urinate and defaecate in their water.

Many anurids, such as White's tree frogs and fire-bellied toads, will appreciate a small amount of free water, but the rest of their vivarium should be well-supplied with moisture-retaining substrate such as mosses or peat substitute mulches. These retain moisture and increase the humidity of the tank, ensuring protection of the sensitive amphibian's skin. Other amphibians, such as newts and salamanders, require more access to free fresh water and precautions similar to those mentioned for freshwater turtles and terrapins should be taken. In addition, for all these species, the construction of the vivarium should ensure that it is waterproof!

Egg incubation of reptiles

It is necessary for successful egg incubation to use an incubator. The basic components of a reptile egg incubator are as follows: the basic requirement is for a plastic, perspex or toughened glass tank, with a plastic lid containing aeration holes that can be covered to regulate humidity and temperature. Nesting substrate is placed into small open containers within the above tank, and the eggs are placed in slight depressions within the substrate. A useful substrate is the loft insulating material vermiculite. Alternatives include damp sand, sphagnum moss or even peat. When the eggs are retrieved from the nest site particular care should be taken to maintain the same position of the egg in the incubator. The eggs should not be turned or touched during the incubation process as this can cause significant foetal mortality.

The tank requires a source of humidity and heat production. There are two methods for providing these. The containers containing the eggs and substrate may be placed onto a wire mesh which divides the tank into a top and a bottom compartment. The bottom compartment may then be three quarters filled with filtered water, and a thermostatically controlled water heater placed into it. This technique will provide heat and moisture, and is good for the higher-moisture-requiring species, such as the water or garter snakes which need an average 80% humidity.

An alternative set-up is to attach a thermostatically-controlled radiant heat mat to the outside of the tank. The tank is then completely filled with the substrate, which is kept moist by regular misting with a plant sprayer, and by placing shallow containers of filtered and previously boiled water in amongst the eggs. This provides a drier atmosphere, more suitable for the desert dwelling species.

Care should be taken not to allow the humidity to drop below 50%, as reptile eggs are porous and excessively dry conditions will dehydrate the foetus inside and lead to high levels of mortality. Equally, excessive levels of humidity will lead to an increased risk of fungal infection of the shell and contents and again higher mortality rates. It is therefore important to have both a thermometer and a humidity gauge within the incubator, and both should be monitored regularly.

Temperatures for incubation of reptile eggs vary from 26–32°C with an average incubation period in snakes of 45–70 days. Incubation periods vary from 45–70 days in smaller lizards to 90–130 days for iguanas and larger lizards.

For chelonians, the colder, northerly climes of the United Kingdom mean the incubation of eggs in an outside environment is not possible because of the high incubation temperatures required. It is therefore necessary to remove the eggs from wherever they have been laid by the female and transfer them to a purpose-built incubator for hatching. Once laid the eggs will hatch for most tortoise species in 8–12 weeks depending on the temperature at which they are incubated.

Further reading

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Chapter 9

Reptile and Amphibian Handling and Chemical Restraint

Handling the reptilian patient

Is there a need to restrain the reptilian patient?

Reptiles are less easily stressed than their avian cousins, and so restraint may be performed without as much risk in the case of the debilitated animal. However, it is still worthwhile considering factors that may make restraint dangerous to animal and nurse alike.

- Is the patient in respiratory distress? For example, consider pneumonic cases, where mouth breathing and excessive oral mucus may be present and where excessive manual manipulation can be dangerous.
- Is the species of reptile a fragile one? Day geckos are extremely delicate and prone to shedding their tails when handled. Similarly some species such as green iguanas are prone to conditions such as metabolic bone disease wherein their skeleton becomes fragile and spontaneous fractures occur.
- Is the species an aggressive one? Some are naturally so, e.g. snapping turtles, tokay geckos and rock pythons.
- Does the reptile patient require medication or physical examination, in which case restraint is essential.

It should be noted that many species of reptile have a normal bacterial flora in their digestive systems which frequently includes species such as the Salmonella family. These bacteria are found in abundance all over the body of the reptile. Personal hygiene is therefore very important when handling these patients to prevent zoonotic diseases.

The need for restraint therefore needs to be considered carefully before physical attempts are made.

Techniques and equipment involved in restraining reptile patients

Because of the variety of reptile species and their diversity, this section is easier considered under specific Orders of reptile.

Sauria

This Order includes the members of the lizard family such as geckos, iguanas, chameleons and agamas.

Lizards come in many different shapes and sizes, from the four-foot-long adult green iguana to the 4–5 inch-long green anole. They all have the same structural format, with four limbs (although these may be vestigial in the case of the slowworm for example) and a tail. Their main danger areas to the handler are their claws and teeth, and in some species, such as iguanas, their tails – which can lash out in a whip-like fashion.

Geckos other than tokay geckos are generally docile as are lizards such as bearded dragons. Others, such as green iguanas, may be extremely aggressive, particularly sexually mature males. They may also be more aggressive towards female owners and handlers as they are able to detect pheromones secreted during the menstrual cycle.

They are best restrained by grasping around the shoulders (the pectoral girdle) with one hand, from the dorsal aspect, so controlling one forelimb with forefinger and the thumb and the other between middle and fourth finger. The other hand is used to grasp the pelvic girdle from the dorsal aspect, controlling one limb with the thumb and forefinger, the other again between middle and fourth finger. The handler may then hold the lizard in a vertical manner, with head uppermost, placing the tail underneath his or her arm (Figs 9.1a and 9.1b). It is then possible to present the head and feet of the lizard away from the handler to avoid injury. The handler should allow some flexibility as the lizard may struggle and overly rigid restraint could damage the spine.

Fig. 9.1(a) Approach large green iguanas from the dorsal aspect with two hands, one over the shoulder area and one over the pelvic area.

Some of the more aggressive iguanas may need to be pinned down first. Here, as with avian patients, the use of a thick towel to control the tail and claws is useful. Gauntlets may be necessary for particularly aggressive large lizards or for those which may have a poisonous bite (the gila monster and the beaded lizard). It is important to ensure that you do not use too much force when restraining the lizard, as those with skeletal problems, such as metabolic bone disease, may be seriously injured. In addition, lizards, like other reptiles, do not have a diaphragm and so over zealous restraint will lead to the digestive system pushing onto the lungs and increasing inspiratory effort.

Day geckos and other fragile species are best examined in a clear plastic container. Other geckos have easily damaged skin and latex gloves and soft cloths should be used for examination. When handling small lizards, they may be cupped

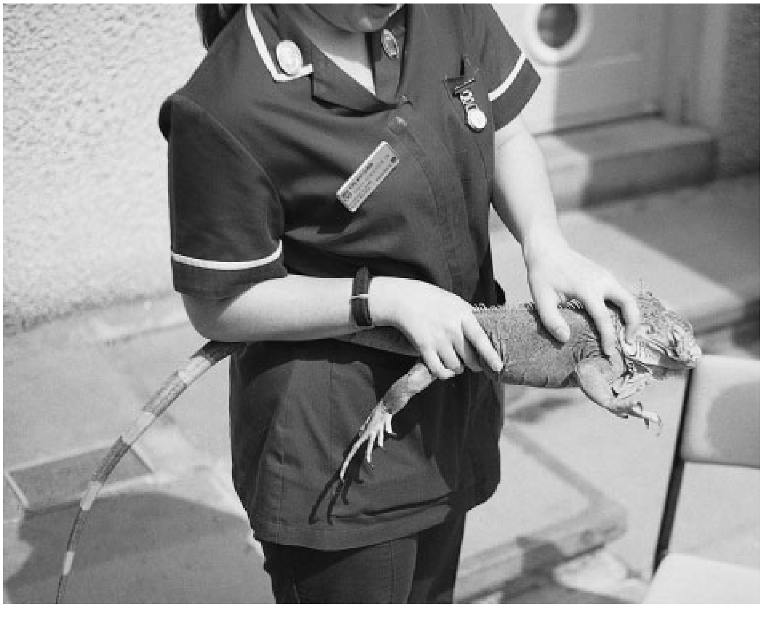


Fig. 9.1(b) The iguana may then be firmly but gently controlled. Tucking the tail underneath the arm prevents eye injuries.

Fig. 9.2 Docile species such as the bearded dragon, *Pogona vitticeps*, may be cupped in the hand for routine examination.

in the hand (Fig. 9.2, Plate 9.1) and their heads controlled by holding between the index finger and thumb to prevent biting.

It is important that lizards are never restrained by their tails. Many will shed their tails at this time, but not all of them will regrow. Green iguanas for example will only regrow their tails as juveniles (less than 2.5–3 years of age). Once they are older than this, they will be left tail-less.

Vago-vagal reflex

The vago-vagal reflex can be used to place members of the lizard family into a trance-like state. The eyelids are closed and gentle digital pressure is applied to both eyeballs. This stimulates the autonomic parasympathetic nervous system resulting in a reduction in heart rate, blood pressure and respiration rate. Providing there are no loud noises or environmental stimulation, after 1–2 minutes the lizard may be placed on its side, front, back etc. allowing radiography to be performed without using physical or chemical restraint. A loud noise or physical stimulation will immediately revert the lizard to its normal wakeful state.

Serpentes

The Serpentes are the snake family, which includes a wide range of sizes from the enormous anacondas and Burmese pythons, which may achieve lengths of up to 30 feet or more, down to the thread snake family which may be a few tens of centimetres long. They are all characterised by their elongated form and absence of limbs. The danger areas for the handler are their teeth (and in the case of the more poisonous species such as the viper family their fang teeth), and, in the case of the constrictor and python family, their ability to asphyxiate their prey by winding themselves around the victim's chest and neck.

With this in mind, the following restraint techniques may be employed. Non-venomous snakes can be restrained by controlling the head initially. This is done by placing the thumb over the occiput and curling the fingers under the chin (Plate 9.2). Reptiles, like birds, have only the one occipital condyle so it is important to stabilise the occipitoatlantal joint. It is also important to support the rest of the snake's body so that not all of the weight of the snake is suspended from the head. Allow the smaller species to coil around the handler's arm, so the snake is supporting itself (Fig. 9.3).

In the larger species (longer than 10 feet) it is necessary to support the body length at regular intervals. This often requires several handlers. Indeed, it is *vital* to adopt a safe operating practice with the larger, constricting species of snake. A 'buddy system' should be operated, as with scuba diving, wherein any snake longer than 5–6 feet in length should only be handled by two or more people. This ensures that if the snake were to enwrap one handler, the other could disentangle him or her by unwinding from the tail end first. Above all it is important not to grip the snake too hard as this will cause bruising and the release of myoglobin from muscle cells. This will lodge in the kidneys, causing damage to the filtration membranes.

Fig. 9.3 Allowing the snake to coil itself around the handler's hand and arms is preferable to over-zealous restraint in non-aggressive species such as this small Burmese python.

Poisonous snakes (such as the viper family, rattlesnakes etc.) or very aggressive species (such as anacondas, reticulated and rock pythons) may be restrained initially using snake hooks. These are 1.5–2 ft steel rods with a blunt shepherds hook on the end. They are used to loop under the body of a snake to move it at arms length into a container. The hook may also be used to trap the head flat against the floor before grasping it with the hand. Once the head is controlled safely the snake is rendered harmless. Exceptions include the spitting cobra family where handlers should wear plastic goggles, or a plastic face visor as they can spit poison into the prey or assailant's eyes and mucus membranes causing blindness and paralysis.

Chelonia

The Chelonia include all land tortoises, terrapins and aquatic turtles.

Chelonia vary in size from the small Egyptian tortoises weighing a few hundred grams all the way up to adult leopard tortoises at 40 kg and the Galapagean tortoise family which can weigh several hundred kilograms. The majority of Chelonia are harmless, although surprisingly strong. The exceptions include the snapping turtle and the alligator snapping turtle, both of which can give a serious bite. Most of the soft-shelled terrapins have mobile necks and can also bite. Even red-eared terrapins may give a nasty nip!

For the mild-tempered Mediterranean species, the tortoise may be held with both hands, one on either side of the main part of the shell behind the front legs (Plate 9.3). To keep the tortoise still for examination, it may be placed onto a cylinder or stack of tins, raising its legs clear of the table as it balances on the centre of the underside of the shell (plastron) (Plate 9.4).

For aggressive species it is essential that you hold the shell on both sides behind and above the rear legs to avoid being bitten. Chemical restraint is necessary in order to examine the head region in these species.

For the soft-shelled and aquatic species, soft cloths and latex gloves may have to be used to prevent damaging the shell.

Crocodylia

The Crocodylia include fresh- and salt-water crocodiles, alligators, fish-eating gharials, and caimans. Their dangers to the handler lie in their impressively arrayed jaws and often their sheer size – an adult bull Nile crocodile may weigh many hundreds of kilograms and may live for up to 50 years or more.

Small specimens may be restrained by grasping the base of the tail in one hand whilst the other is placed behind the head. For slightly bigger specimens, a rope halter or noose may be tied around the snout so securing it closed. All of the major muscles in the crocodylian jaws are involved in closing not opening them, hence relatively fine rope or tape can be used to keep the mouth closed. The rest of the animal is restrained by pinning it to the ground.

Always approach crocodylians from head on, as their binocular vision is poor (although the alligator family does have some). Care should be taken when close to the crocodylian for head and tail movements both are directed at the assailant at the same time!

Much larger crocodiles require teams of people, with nets and snout snares in order to quickly clamp the jaws closed and to restrain the dangerous thrashing tail. Chemical immobilisation via dart guns is another option to be seriously considered.

Principles of chemical restraint

Chemical restraint is necessary for many procedures in reptile medicine, ranging from minor procedures such as extracting the head of a leopard tortoise or box turtle from its shell, to enabling a jugular blood sample to be taken or to carrying out coeliotomy procedures because of egg-binding. Before any anaesthetic or sedative is administered, an assessment of the reptile patient's health should be made. Considerations include:

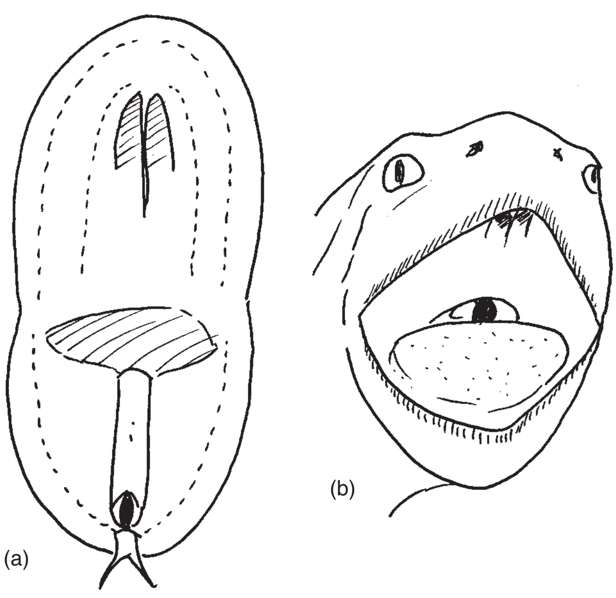
- Is sedation or anaesthesia necessary for the procedure required?
- Is the reptile suffering from respiratory disease or septicaemia?
- Is the reptile's health likely to be made worse by sedation or anaesthesia?

Before discussing the administration of chemical restraint it is important to understand the reptilian respiratory system.

Overview of reptilian respiratory anatomy and physiology

The reptilian patient has a number of variations on the basic mammalian respiratory system.

The reptile patient has a glottis similar to the avian patient, which lies at the base of the tongue. This is more rostral in snakes and lizards and more caudal in chelonia (Figs 9.4a,b). At rest the glottis is permanently closed, opening briefly during inspiration and expiration. In crocodiles the glottis is obscured by the basihyal valve which is a fold of the epiglottis. This fold has to be deflected before they can be intubated (Bennett, 1998).



(a) (b)

Fig. 9.4 Intraoral views of (a) Snake, showing 6 rows of teeth, and the glottal tube with the entrance to the trachea located rostrally, just behind the tongue sheath. (b) Tortoise, showing large fleshy tongue, at the base of which is the glottis.

The trachea varies between orders. In Chelonia and Crocodylia complete cartilagenous rings similar to those of the avian patient are found, with chelonians having a very short trachea. In some species this trachea bifurcates into two bronchi in the neck. Serpentes and Sauria have incomplete rings, such as those of the cat and dog, with Serpentes having a very long trachea.

The lungs of serpent and saurian species are simple and elastic in nature. The left lung of most serpents is absent, or vestigial in the case of members of the boiid family. The right lung of snakes frequently ends in an air sac. Chelonian species have a more complicated lung structure, and the paired lungs sit dorsally inside the carapace of the shell. Crocodylian lungs are similar to mammalian lungs and are paired.

No reptile has a diaphragm, although crocodylian species have a pseudodiaphragm which changes position with the movements of the liver and gut so pushing air in and out of the lungs. Most reptiles use intercostal muscles to move the ribcage in and out in a manner similar to birds. The exception to this is members of the order Chelonia. These species need to move their limbs, neck and head into and out of the shell in order to bring air into and out of the lungs.

Some species can survive in oxygen deprived atmospheres for prolonged periods – chelonian species may survive for 24 hours or more, and even green iguanas may survive for 4–5 hours. This makes induction of anaesthesia via inhalation of a gaseous anaesthetic agent almost impossible in these animals.

Pre-anaesthetic preparation

Weight measurement

This is important for accuracy as some species of reptile may be very small. Scales accurate to 1 g are therefore advised for smaller reptiles to ensure correct dosage.

Blood testing

It may be advisable to test biochemical and haematological parameters prior to administering chemical immobilising drugs. Blood samples can be taken from:

- Jugular vein in Chelonia
- Dorsal tail vein in Chelonia
- Ventral tail vein in Serpentes, Crocodylia and Sauria
- Palatine vein or cardiac puncture in Serpentes (although they frequently need to be sedated or anaesthetised to collect blood from these routes).

Fasting

Fasting is necessary in Serpentes to prevent regurgitation and pressure on the lungs or heart. It is advisable to ensure that no prey has been offered in the two days prior to anaesthesia. Other reptiles require less fasting. For example, chelonians rarely if ever regurgitate. However, it is important not to feed live prey to insectivores such as leopard geckos 24 hours prior to an anaesthetic as the prey may still be alive when the reptile is anaesthetised.

Pre-anaesthetic medications

The premedications are the same drugs used in cats and dogs to provide cardiopulmonary and central nervous system stabilisation, a smooth anaesthetic induction, muscle relaxation, analgesia and a degree of sedation.

Antimuscarinic medications

Atropine (0.01–0.04 mg/kg intramuscularly) or glycopyrrolate (0.01 mg/kg intramuscularly) may be used to reduce oral secretion and reduce bradycardia, however these problems are not usually of concern in reptile patients. Indeed, antimuscarinics may increase the thickness of mucus secretions, leading to more rapid blocking of the airways.

Tranquilisers

Acepromazine (0.1–0.5 mg/kg intramuscularly) may be given one hour before anaesthetic induction to reduce the levels of anaesthetic required, as can diazepam (0.22–0.62 mg/kg intramuscularly in alligators) and midazolam (2 mg/kg intramuscularly in turtles) (Bennett, 1998).

Alpha-2 adrenoceptor stimulants

Xylazine at 1 mg/kg can be used 30 minutes prior to ketamine in crocodylians to reduce the dose of ketamine needed. Medetomidine, used at doses of 100–150 µg/kg, markedly reduces the dose of ketamine required in chelonians, and has the advantage of being reversible with atipamezole at 500–750 µg/kg.

Opioids

Butorphanol (at 0.4 mg/kg intramuscularly) can be administered 20 minutes before anaesthesia so providing analgesia and reducing anaesthetic required, and may be combined with midazolam at 2 mg/kg.

Fluids

Fluid therapy is, as with avian patients, very important, and correction of fluid deficits should be attempted prior to surgery. Maintenance levels in reptile patients have been quoted as 25–30 ml/kg/day (pages 178–9).

Induction of anaesthesia

It should be noted that reptiles should never be immobilised by chilling or cooling them down. This does not provide analgesia and has serious welfare implications.

Injectable agents

Table 9.1 describes the advantages and disadvantages of injectable anaesthetic agents.

Table 9.1 Advantages and disadvantages of injectable anaesthetics.

Advantages	Disadvantages
Ease of administration	Recovery often dependent on organ metabolism
Prevention of breath-holding on induction	Difficult to reverse rapidly
Reduced costs	Often prolonged recovery times
Easy to administer	Muscle necrosis at site of injection
Low risk to anaesthetist	

Dissociative anaesthetics

Ketamine: ketamine has been widely used in reptile patients. The effects produced vary depending on the species and dosage. Recommended levels range from 22–44 mg/kg intramuscularly for sedation to 55–88 mg/kg intramuscularly for surgical anaesthesia. Lower levels are needed if combined with a premedicant such as midazolam or medetomidine (Bennett, 1996).

Effects are seen in 10–30 minutes but may take anything up to 4 days to wear off, particularly at low environmental temperatures. Its main use is therefore at the lower dose range, to allow sedation, facilitate intubation and maintenance of gaseous anaesthesia in species such as chelonians that hold their breath during gaseous induction.

It is however frequently painful on administration. Also, because ketamine is excreted by the kidneys, it is recommended that it is administered in the cranial half of the body. This is because, in reptiles, blood from the caudal half of the body travels to the kidneys *before* returning to the heart and the anaesthetic may thus be excreted before it has a chance to work.

Steroid anaesthetics

Alphaxalone/alphadolone: this combination allows intubation within 3–5 minutes when administered intravenously. It may be administered intramuscularly, but induction takes longer via this route (25–40 minutes). If used alone, it will provide anaesthesia for from 15–35 minutes at a dose of 6–9 mg/kg for intravenous administration, or 9–15 mg/kg if given intramuscularly. Although recovery time is quicker than for ketamine, it may still take 1–4 hours for full recovery to occur. It can be very useful in chelonians and in general has a wide safety margin.

Other injectable anaesthetics

Propofol: propofol produces rapid induction and recovery, and is becoming the induction agent of choice in many practices specialising in reptile medicine and surgery. Its advantages also include a short elimination half-life and minimal organ metabolism, making it particularly safe to use in debilitated reptiles which frequently have some degree of liver damage.

Its main disadvantage is that it requires intravenous access, although use of the intraosseous route has been shown to be successful in green iguanas at a dose of 10 mg/kg. As with cats and dogs, propofol also produces a transient period of apnoea and some cardiac depression. In this situation intubation and positive pressure ventilation is necessary.

Doses of 10–15 mg/kg in chelonians given via the dorsal coccygeal (tail) vein have successfully induced anaesthesia in under one minute. This allows intubation and maintenance on a gaseous anaesthetic if required. Alternatively, propofol can be used alone providing a period of anaesthesia of 20–30 minutes.

Depolarising muscle relaxants

Succinylcholine: this is a neuromuscular blocking agent and produces immobilisation without providing analgesia. Therefore it should only be used to aid the administration of another form of anaesthetic or for transportation, and not as a sole source of anaesthesia. Recovery is dependent on liver metabolism and its use in animals with possible liver disease should be avoided.

It can be used in large Chelonia (such as the giant Galapagoas species) at doses of 0.5–1 mg/kg intramuscularly and will allow intubation and conversion to gaseous anaesthesia. Crocodilians can be immobilised with 3–5 mg/kg intramuscularly, with immobilisation occurring within 4 minutes and recovery in 7–9 hours. Respiration usually continues without assistance at these doses, but is important to have assisted ventilation facilities to hand as paralysis of the muscles of respiration can easily occur.

Gaseous agents

The gaseous anaesthetics used for induction will be discussed in the next section on maintenance of anaesthesia, however a table listing their advantages and disadvantages is presented below.

Table 9.2 Advantages and disadvantages of gaseous anaesthetic.

Advantages	Disadvantages
Ease of administration via face-mask/ induction chamber Pain free Minimial tissue trauma	Breath-holding (Chelonia particularly) Environmental pollution Health risk to anaesthetist Risk with dangerous reptiles during handling

Maintenance of anaesthesia

Injectable agents

Dissociative anaesthetics

Ketamine: ketamine may be used on its own for anaesthesia at doses of 55–88 mg/kg intramuscularly. It is worthwhile noting though that as the dosages get higher the recovery time also increases, and in some cases it can be as long as several days. It should be noted that doses above 110 mg/kg will cause respiratory arrest and bradycardia.

Ketamine may be combined with other injectable agents to provide surgical anaesthesia. Examples of these combinations include:

- Midazolam at 2 mg/kg intramuscularly with 40 mg/kg ketamine in turtles (Bennett, 1996)
- Xylazine at 1 mg/kg intramuscularly, given 30 minutes prior to 20 mg/kg ketamine in large crocodiles (Lawton, 1992)
- Medetomidine at 100 μg/kg intramuscularly with 50 mg/kg ketamine in kingsnakes (Malley, 1997).

Other injectable anaesthetics

Propofol: propofol may be used to give 20–30 minutes of anaesthesia after administration, allowing minor procedures such as wound repair, intraosseous or intravenous catheter placement or oesophagostomy tube placement to be carried out.

It may be topped up at 1 mg/kg/min intravenously or intraosseously, but apnoea is extremely common and intubation and ventilation with 100% oxygen is frequently required.

Alphaxalone/alphadolone: this injectable combination can be used for induction and also for short periods of anaesthesia (average 25 minutes) at 6–9 mg/kg intravenously. Intramuscular doses may be given but onset of anaesthesia may take 20–30 minutes. Its disadvantages include a prolonged recovery time (1–4 hours), the need for relatively large doses and the need to intubate many reptiles due to relaxation of the muscles which keep the glottis open to allow breathing.

Gaseous agents (see also Table 9.2)

Halothane

Halothane is the anaesthetic gas most widely available in general practice and can be used in reptile anaesthesia, both for maintenance and induction. Face-mask or induction chambers can be used for induction at levels of 4–5%, although certain species, such as Chelonia, can hold their breath for long periods making gaseous induction difficult. Maintenance can be achieved at 1–2.5%. Disadvantages of halothane are:

- It can induce myocardial hypoxia and dysrhythmias
- 15–20% of halothane is metabolised by the liver before recovery can occur. As many diseased reptiles have dysfunctional or impaired livers, this makes its use limited.
- It can excite reptiles in the early stages of anaesthesia
- Cardiac arrest and apnoea frequently occur simultaneously, reducing available resuscitation response times.

Isoflurane

Isoflurane is the gaseous maintenance anaesthetic of choice. Although more expensive than halothane, isoflurane is minimally metabolised in the body (0.3%) and has a very low blood–gas partition coefficient (1.4 compared with 2.3 for halothane in human trials). This means that it has a very low solubility in blood, so as soon as isoflurane administration is stopped the reptile starts to recover, excreting it from the lungs. In addition it has lower fat solubility than halothane and so excretion from the body is quicker still. Isoflurane still has excellent muscle relaxing properties and is a good analgesic. Apnoea *precedes* cardiac arrest, unlike the case with halothane anaesthesia.

It can be used to induce anaesthesia by face-mask application or, in those species not exhibiting breath-holding capabilities at levels of 4–5%, by induction chamber. It is also possible to adapt the cases of 20 ml and 60 ml syringes to form long thin face-masks to induce snakes. Isoflurane can then be used to maintain anaesthesia, preferably via endotracheal tube, at levels from 2–3% depending on the procedure.

A summary of the advantages of isoflurane over halothane may been seen in Table 9.3.

Nitrous oxide

Nitrous oxide can be used in conjunction with halothane or isoflurane, reducing the percentage of gaseous anaesthetic required for induction and maintenance of anaesthesia. Its other advantages include good muscle relaxation and excellent analgesic properties, making it useful in orthopaedic procedures.

Disadvantages of nitrous include its tendency to accumulate in hollow organs. This may prove a problem for herbivorous reptiles as they often have capacious hind guts and nitrous oxide can accumulate there. Nitrous oxide also requires

Table 9.3 Comparison of halothane and isoflurane gaseous anaesthetics.

Halothane	Isoflurane
Organ metabolism required for recovery	Minimal organ metabolism required for recovery
Induces cardiac arrhthymias	Relatively few arrhthymias induced
Cardiac arrest and respiratory arrest coincide	Respiratory arrest precedes cardiac arrest
Good analgesia	Good analgesia
Blood gas partition coefficient 2.3	Blood gas partition coefficient 1.4
Highly fat soluble	Lower fat solubility than halothane

some organ metabolism for full excretion and so may be a problem in a seriously diseased patient.

Aspects of gaseous anaesthesia maintenance for reptiles

Inhalant gaseous anaesthesia is becoming the main method of anaesthetising reptiles for prolonged procedures. The reptile patient should preferably be intubated to allow the inhalant anaesthetic to be delivered in a controlled manner.

Intubation

Intubation is straightforward in reptiles as they do not have an epiglottis and the glottis, which acts as the entrance to the trachea, is relatively cranial in the majority of species. It is useful to note that the glottis is kept closed at rest, so the operator must wait for inspiration to occur to allow intubation. Reptiles produce little or no saliva when at rest or not eating, so blockage of the tube is uncommon.

In Serpentes, the glottis sits rostrally on the floor of the mouth just caudal to the tongue sheath and is easily visible when the mouth is opened (Fig. 9.4a). Intubation may be performed in the conscious patient if necessary, as reptiles do not have a cough reflex. The mouth is opened with a wooden or plastic tongue depressor and the endotracheal tube inserted during inspiration. Alternatively, an induction agent may be given and then intubation attempted.

In Chelonia, the glottis sits slightly more caudally at the base of the tongue (Fig. 9.4b). The trachea is very short and the endotracheal tube should only be inserted a few centimetres otherwise there is a risk that only one or the other of the bronchi will be intubated, leading to only one lung receiving the anaesthetic. An induction agent such as ketamine or propofol is advised for chelonians prior to intubation due to their ability to breath-hold and difficulty in extracting the head from the shell.

Sauria vary depending on the species of lizard, most having just a glottis guarding the entrance to the trachea (Fig. 9.5). Some species possess vocal folds, notably some species of gecko (Porter, 1972). Some may be intubated consciously, but most are better induced with an injectable preparation or by face-mask using gas. Some species may be too small for intubation. Plate 9.5 shows an intubate green iguana.

Fig. 9.5 Intraoral view of a spiny-tailed iguana showing fleshy tongue. Glottis is caudal to this structure.

Crocodylia have a basihyal fold (Bennett, 1998) which acts as an epiglottis and needs to be depressed prior to intubation. Because they are potentially dangerous, these species require some form of injectable chemical sedation or induction prior to intubation.

Intermittent positive pressure ventilation (IPPV)

If intubation is performed on a conscious patient, anaesthesia may be induced, even in breath-holding species, by using positive pressure ventilation. This has some advantages as it leads to rapid post-operative recovery.

Many species require positive pressure ventilation during the course of an anaesthetic. Chelonia for example are frequently placed in dorsal recumbency during intracoelomic surgery. As they

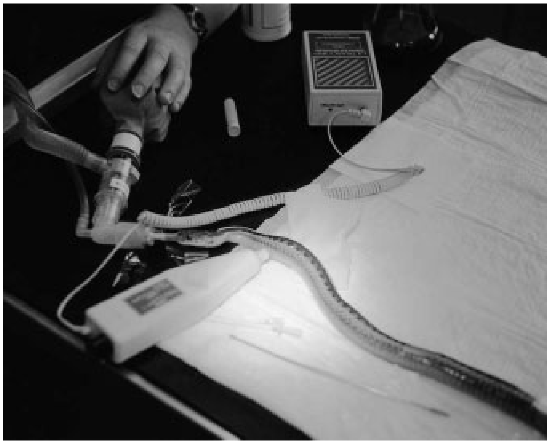


Fig. 9.6 Manual bagging of a garter snake. Note Doppler probe to monitor heart sounds, and Mapleson C circuit for smaller species.

have no diaphragm, and the lungs are situated dorsally, the weight of the digestive contents pressing on the lungs will reduce inspiration and slowly lead to hypoxia. This is in addition to the fact that most inspiratory effort is induced by movement of the chelonian limbs, which are hopefully immobile during anaesthesia! Also, if a neuromuscular blocking agent such as succinylcholine has been used, positive pressure ventilation may be needed as respiratory muscle paralysis may occur.

The aim of IPPV is to inflate the lungs with an oxygen and anaesthetic mixture enough for an adequately oxygenated state to be maintained and for the animal to remain anaesthetised. To this end it is sufficient to ventilate most reptiles two–six times a minute and no more, at a pressure of 10–15 cm water (100–150 mm mercury). As with birds, a ventilator unit makes life much easier, but, with experience, manual 'bagging' of the patient with enough pressure just to inflate the lungs and no more can be achieved (Figs 9.6 and 9.7). A rough guide is to inflate the first two fifths of the reptile's body at each cycle (Malley, 1997).

Anaesthetic circuits

For species weighing less than 5 kg, a non-rebreathing system with oxygen flow at twice the minute volume is suggested (Bennett, 1998). This

Fig. 9.7 Mechanical IPPV using a ventilator in a green iguana. Note again Doppler probe and cranial position of the heart in iguanids.

approximates to 300–500 ml/kg/minute for most species. Ayres T pieces, modified Bain circuits and Mapleson C circuits may all be used.

Additional supportive therapy

Recumbency

Many chelonians are placed in dorsal recumbency for intracoelomic surgery. Other groups of reptiles may also be placed in this position for similar techniques. The use of foam wedges, or positional polystyrene-filled vacuum bags, is essential to maintain stability.

Snakes may become extremely flaccid during surgery. In order to provide stability they may be strapped to a long board or wedged in place with foam wedges or vacuum bags. In any case, it is important to keep the body wall of non-chelonian species free of constraint and to use IPPV if necessary.

Maintenance of body temperature

Maintaining body temperature is important for successful recovery. Body temperature can be monitored using a cloacal probe attached to a digital thermometer. Reptiles should be maintained as near to their PBT (preferred body temperature) as possible (pages 127–8) which lies in the range 22–30°C for most species. This can be done by placing the reptile onto a circulating water heating pad during anaesthesia and room temperature should be kept up to reduce heat losses. Warmed subcutaneous or intracoelomic fluids can be given during and after surgery.

Hot water bottles, or hot-water-filled latex gloves may also be used, but must be wrapped in towelling to prevent direct contact with the reptile. Care should be taken when these cool down, as they may then draw heat *away* from the patient rather than provide it. The use of clear drapes will also help to keep heat in as will the utilisation of light sources for surgery, many of which radiate heat.

Fluid therapy

Fluid therapy is covered in more detail from page 175. However it should be noted that, as with small mammals, post-operative fluid therapy may enhance the recovery rate and improve the patient's return to normal function. Recommended fluid volumes are 20–25 ml/kg every 24 hours across the species (Frye, 1991). They should not exceed 2–3% body weight in chelonians.

Table 9.4 Stages of anaesthesia in reptiles (adapted from Bennet, 1998 and Malley, 1997).

Stage 1
— Limb movements reduced
— Righting reflex present (reptile will flip back onto its feet after being inverted)
— Snake tongue withdrawn after being grasped
— Responds to noxious stimuli
— Muscles are tense
— Writhing movements occur
— Vent stimulation reflex present
— Palpebral reflex present

Stage 2
— Righting reflex ceases
— Tongue withdrawal reflex much reduced
— No response to noxious stimuli
— Muscles start to relax
— Writhing movements cease
— Vent reflex reduced
— Palpebral reflex diminished

Stage 3
— Righting reflex ceased
— No voluntary motion
— Tongue withdrawal reflex totally absent
— No response to noxious stimuli
— Muscles totally relaxed
— Snakes: Bauchstreich reflex (where stroking of the ventral scales produces movement in the body wall) much reduced
— Laryngeal reflexes lost in alligators
— Chelonia still have a corneal reflex
— Vent reflex much reduced – loss of this indicates anaesthesia is too deep

Stage 4
— Extreme depression and death (Chelonia lose corneal reflexes just before entering this phase).

Monitoring anaesthesia

Table 9.4 shows the stages of anaesthesia seen in reptiles.

Monitoring the heart rate and rhythm can be extremely difficult with a conventional stethoscope as the reptilian scales interfere with sound transmission and the presence of the three-chambered heart reduces the clarity of the beat. Some of this can be overcome by placing a damp towel over the area to be auscultated, deadening the sound of the scales, but in many cases the best solution is to use a Doppler probe. This is an ultrasound probe unit attached to a microphone which responds to fluid movement, converting it to sound (Fig. 9.8).

ECG leads may be attached to the patient to give an electrical trace of heart activity. To minimise the crushing effect of the alligator forceps on the leads, they may be attached to hypodermic needles which can then be attached to the patient. In snakes, ECGs can still be made, even in the absence of limbs. The leads are placed two heart lengths cranial and caudal to the heart. In some saurians, such as iguanas, skinks, chameleons and water dragons, the heart is situated far cranially so the forelimb leads are better placed cervically.

Fig. 9.8 Doppler probe monitoring of heart sounds in an anaesthetised red-eared terrapin.

Respiratory flow monitors are not very useful due to the need for IPPV in most reptile species Pulse oximeters are, however, useful, with reflector probes being used *per cloaca* or *per os* to measure the percentage saturation of the haemoglobin with oxygen.

Recovery and analgesia

Recovery

Reptiles often recover rapidly from isoflurane anaesthesia. But, if other injectable drugs were used, such as alphadalone/alphaxolone or ketamine, recovery may be prolonged. It is essential at this time to keep the reptile patient calm, stress free and at its optimum preferred body temperature. It may also be necessary to keep the patient intubated and on IPPV with oxygen, if high doses of the above agents have been used, until the reptile is once again breathing for itself. The use of doxapram at a dose of 5 mg/kg by intramuscular or intravenous injection is useful to help stimulate respiration. It should be noted, however, that the stimulus for reptiles to breathe is a falling blood partial pressure of oxygen, and not a rising partial pressure of carbon dioxide, so IPPV with 100% oxygen may actually inhibit respiration. IPPV with atmospheric air may therefore be preferable once any gaseous anaesthetic has been flushed from the airways.

Fluid therapy during this period will also help to speed recovery, especially from agents such as ketamine which are cleared through the kidneys. Once recovery is complete, the reptile should be encouraged to eat, or, if anorectic, the patient should be assist fed, stomach tubed etc.

Analgesia

Analgesia is an important aspect of post-operative recovery. Reptiles which have been provided with analgesia have been shown to have a quicker return to normality, eating, normal behaviour etc. than those who have not.

Opioids

Butorphanol at 0.4 mg/kg intramuscularly, intravenously or subcutaneously and buprenorphine at 0.01 mg/kg intramuscularly have been recommended (Lawton, 1991; Bennett, 1998).

Non-steroidal anti-inflammatory drugs (NSAIDs)

NSAIDs also seem to be beneficial. The following have been recommended: carprofen at doses of 2–4 mg/kg intramuscularly initially, and then 1–2 mg/kg every 24–72 hours thereafter (Malley, 1997); meloxicam at 0.1–0.2 mg/kg orally every 24 hrs; ketoprofen at 2 mg/kg intramuscularly every 24 hours (Bennett, 1996); flunixin meglumine at 0.1–0.5 mg/kg intramuscularly every 24 hours (Lawton, 1992). It should be noted that all of these are potentially nephrotoxic and have gastrointestinal ulcerative side-effects, hence fluid therapy should be given and patients should be closely monitored for side-effects.

Overview of amphibian anaesthesia

Techniques and equipment involved in restraining amphibian patients

Examination of the amphibian patient should be performed at that species' optimum preferred body temperature, as with reptile patients. A rough guide is between 21–24°C, which is lower than the more usual 22–32°C reptile housing conditions.

The examination table should be covered with paper towels (unbleached) that have been soaked in dechlorinated water – preferably purified water. More purified water should be on stand-by to be applied to the amphibian patient to prevent dehydration during the examination.

Initially it is useful not to restrain the amphibian patient until the extent of any problem is assessed, as many have severe skin lesions which are extremely fragile. Once an initial assessment has been made, the patient may be restrained manually. First, it is advisable to put on a pair of non-powdered hypoallergenic latex gloves in order to minimise irritation to the amphibian's skin caused by either the handler's normal acidic skin environment or by the powder in many prepacked latex gloves. The wearing of gloves is also essential in species such as the toad family or the arrow tree frogs whose skin can produce irritant or even potentially deadly toxins which can be absorbed through unprotected human skin. It may also be necessary to wear goggles when handling some species of toad – the giant toad *Bufo marinus* can squirt a toxin from its parotid salivary glands over a distance of several feet.

When handling the amphibian patient the method of restraint will obviously depend on the animal's body shape. The elongated form of salamanders and newts will require similar restraint to that of a lizard, with one hand grasping the pectoral girdle from the dorsal aspect, index finger and thumb encircling one forelimb, second and third fingers the other, with the opposite hand grasping the pelvic girdle, again from the dorsal aspect in a similar manner. Some salamanders will shed their tails if roughly handled so care should be taken with these species.

Large anurans (members of the frog and toad family) can be restrained by cupping one hand around the pectoral girdle immediately behind the front limbs with the other hand positioned beneath the hind limbs. Care should be taken with some species which have poison glands in their skin, as mentioned above, and in the case of species such as the Argentinian horned frog care should be taken with their bite. This species will eat whole small rodents when adult and can inflict unpleasant bite wounds.

Aquatic urodeles should be examined only in water as removal causes skin damage. Some of the larger urodeles, such as the hellbender species (*Cryptobranchus* spp) can also inflict unpleasant bite wounds on handlers, so firm restraint is required.

Smaller species and aquatic species may be best examined in small glass jars.

Aspects of chemical restraint in amphibians

There are three main routes of administration of anaesthetic and sedative agents to amphibians: injections, inhalant gaseous anaesthetics and in-water methods.

In-water anaesthetic agents

There are two main medications for this route – MS-222 and benzocaine.

MS-222

This is tricaine methanesulphonate, an anaesthetic used commonly in fish restraint. It is a water soluble white powder. A range of 1–2 g/l water is required to anaesthetise most frogs and urodeles, but a solution of 3 g/l is required for most toads (Wright, 1996). A much reduced level of 0.5 g/l can be used for tadpole anaesthesia.

It is best to use the amphibian's own water to minimise environmental changes, and to place this into a plastic bag, or plastic-lined box. This is useful as many amphibians go through an excitated stage during anaesthesia, and the slight give in the plastic bags reduces skin damage. It is also important to ensure any anurans and other non-gilled amphibians can raise their nostrils above the water, otherwise they will drown.

Anaesthesia induction will take 20 minutes or so, with respiration rate reducing. Respiration may even stop, although cardiac function persists. During the induction period, the ventrum of the amphibian will redden and anurans will become excited, making leaping movements.

Initial anaesthesia is manifested by the inability of the amphibian to right itself, and loss of the corneal reflex, but with pain reflexes still intact. A deep plane of anaesthesia is when all of these are abolished and only the heart-beat can be seen as a sign of movement. The level of anaesthesia can be maintained by trickling the anaesthetic solution over the amphibian's body once the amphibian is removed from the solution. Reversal is achieved by trickling fresh, distilled, oxygenated water over the amphibian's skin.

Benzocaine

This is related to MS-222 and can be used to anaesthetise many adult amphibians at solutions of 0.2–0.3 mg/l water. It is more soluble in ethanol than in water and so is often dissolved in a small volume of this before it is added to the water. Recovery occurs some 60 minutes after rinsing the amphibian with benzocaine-free water.

It is worth noting that both anaesthetics are acidic in nature and hence will lower the pH of the water solution. It may be necessary to add a buffer solution to the water to correct this.

Injectable anaesthetic agents

Ketamine may be used, but is less preferable to MS-222. This is because relatively large volumes are required (75–100 mg/kg (Bennett, 1996)), and the anaesthetic takes a variable period to take effect – from 10 minutes to 1–2 hours. Injections may be made intramuscularly, intravenously into the midline ventral abdominal vein or subcutaneously.

Inhalant gaseous anaesthetic agents

Isoflurane

This may be used, either in an induction chamber at dose of 2.5–3%, or, in the larger species of toads, by dripping it directly onto the toad's skin. Some of the larger species may also be intubated, but anaesthesia is often erratic, as alternative respiratory routes are available to amphibians (cutaneous or buccopharyngeal routes – i.e. the amphibian can breathe through its skin or oral membranes). Some of the more fragile species, such as the smaller urodeles or caecilians may actually suffer severe skin irritation during gas chamber induction due to the direct irritant effect of the anaesthetic on the skin.

Halothane

This anaesthetic has the same problems as isoflurane, but in both cases the larger anuran species may be anaesthetised by this method.

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Chapter 10
Reptile and Amphibian Nutrition

Classification

Reptiles and amphibians may be classified in a number of different ways, one of which is according to their diet. Of the commonly seen species there are four main categories as defined by diet. These are:

- **Carnivores** are predominantly the members of the snake family, which will eat whole avian, amphibian or mammalian prey. To do this they have powerful crushing jaws. Some have poison fangs while others, such as the boa and python species, rely on suffocating their prey.
- **Herbivores** come from a variety of species, from the tortoise family, for example the Greek or spur-thighed tortoises, through to the lizard family, for example the green iguana.
- **Insectivores** are predominantly from the lizard family, for example the leopard geckos, collared lizards etc., and from the amphibians, for example the frogs, salamanders etc.
- **Omnivores** are from a variety of reptile species, and the term may be used to refer to reptiles which change their eating habits during the course of their life. For example, the bearded dragon starts off as an insectivore, but becomes more and more dependent on fruit and vegetable matter as it gets older.

In all of these cases, the individual species have become highly evolved to cope with certain types of food. We also know that many of these creatures in the wild have a changing food supply throughout the year, so what may form a staple diet in the summer does not necessarily apply come the winter.

General nutritional requirements

Water

As mentioned in the chapter on avian nutrition the most important thing about the water provided is its quality. Reptiles may defaecate in their water bowls and turtles and terrapins eat in their water. These habits cause pollution and leading to disease.

To prevent this, either the water must have a powerful filter system, or the terrapins/turtles fed in a separate feeding tank which may be cleaned out after feeding.

Vitamin and mineral supplements administered in the water will allow rapid bacterial growth over 24 hours, so bowl hygiene must be rigorous.

The amount of water consumed by individual reptiles and amphibians will depend on the diets being offered as well as on the species. On dry, insect-based diets water consumption will be much higher than for reptiles and amphibians which consume large amounts of fruit and vegetables. Even so a leopard gecko may only consume 5 ml of water in a 24-hour period.

Tap water contains chlorine, which may irritate the skin of sensitive aquatic species such as amphibians or soft-shelled turtles. It is advised that tap water be allowed to stand for 24 hours to let the chlorine escape and to allow it to come up to room temperature.

Renal disease as a result of chronic dehydration is common in captive reptile species. Many of these animals, for example green iguanas and water dragons, come from parts of the world which have high relative humidities – anywhere from 60–100%. If these species are kept in vivaria at their correct temperatures (high twenties to low thirties degrees centigrade) then the air can hold large amounts of water, consequently the relative humidity often drops at these temperatures. Combine this with the fact that many reptiles will not drink from water bowls, instead preferring to lick moisture from leaves or cage furniture, and we can see that chronic dehydration can occur. To prevent this, it is important not only to provide drinking bowls, but also to mist the cage, the reptile and the cage furniture several times daily. This is of course less necessary for desert-dwelling species, such as leopard geckos, pancake tortoises etc., but even these species benefit from being misted every now and then.

Reptiles, like birds, are susceptible to renal disease because the waste product of protein metabolism is predominantly the insoluble uric acid. If the reptile is not kept adequately hydrated, it will reduce the excretion of uric acid through the kidneys. This leads to deposition of uric acid inside the body, a condition known as *visceral gout*. Once deposited, the uric acid forms a tough mineralised coating to the lining of blood vessels, the kidneys, the heart and many other organs, leading to hypertension and multiple organ failure.

Maintenance energy requirements (MER)

Every species has a level of energy consumption per day which is needed to satisfy basic maintenance requirements. This is the energy used purely to maintain current status under minimal activity and is the minimum energy requirement to support that reptile or amphibian's life. In reptiles, basic maintenance requirements vary widely depending on activity level and environmental temperature, so calculations are made at that animal's optimum environmental temperature. Energy requirements will also vary according to the animal's stage of life. For example the MER will be more than doubled in active egg laying females during disease or growth.

MER is dependent on the basal metabolic rate (BMR – the energy requirement when at complete rest) and metabolic body weight as follows:

$$\text{MER} = 1.5 \times \text{BMR}$$

$$\text{where BMR} = \text{constant (k)} \times (\text{body weight})^{0.75}$$

The constant, k, varies with family groups, and has been estimated at 10 for reptiles in general.

If the foods offered are so low in kilojoules that the reptile or amphibian has to eat more of it than will fit into its digestive system in 24 hours, that animal will rapidly lose condition (Figs 10.1 and 10.2).

For example, vegetables such as lettuce and celery have an energy content of 12.6 kJ/g dry matter (or in real terms 0.75 kJ/g wet food), whereas meat-based foods such as rodent prey have a much higher energy density of 19–21 kJ/g dry matter (or in real terms 6–7.5 kJ/g wet food) (Donoghue, 1998). From this we can see that in 'as fed' terms, i.e. wet food, one would need to feed eight times as much weight of vegetable matter to give the same energy dose in animal prey. This volume may well exceed the gut capacity of the reptile or amphibian.

Conversely many pet reptiles and amphibians will continue eating until their digestive tracts are full, and if all they are offered is high energy density food then they will rapidly achieve their MER, exceed it and become obese.

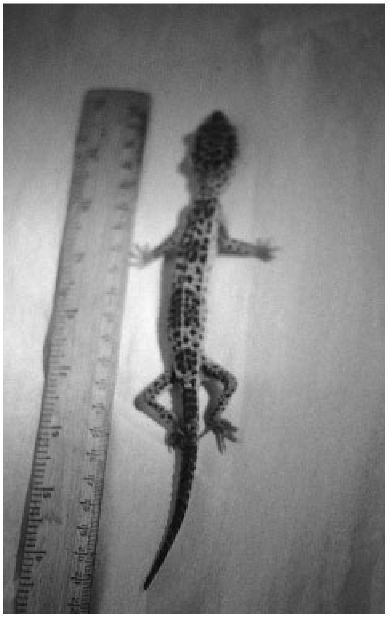

Fig. 10.1 Malnutrition in a leopard gecko.

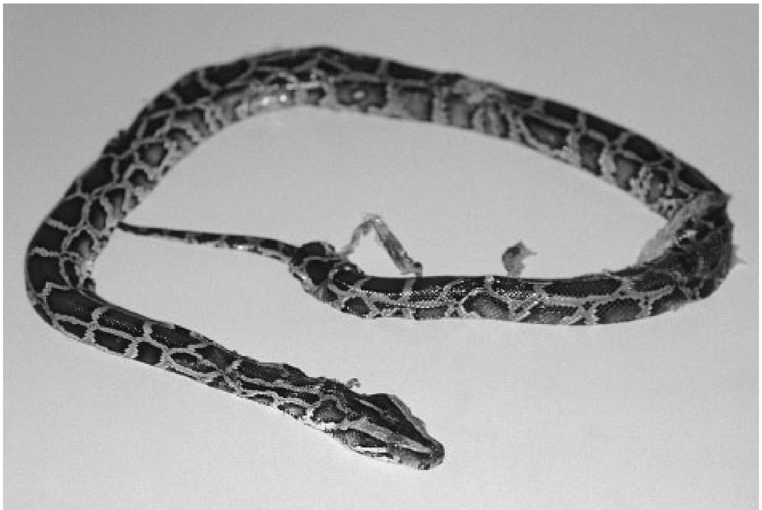

Fig. 10.2 Malnutrition and blister disease in a Burmese python.

Protein and amino acid requirements

Proteins are assembled from groups of amino acids – indeed a protein can contain up to 22 amino acids. In general terms, for humans, and it seems for reptiles and amphibians, ten amino acids are essential and need to be provided in the diet. The others may be manufactured from these ten. The essential amino acids are:

- leucine
- lysine
- methionine
- phenylalanine
- threonine
- tryptophan
- isoleucine
- valine
- arginine
- histidine.

In addition, it is known that for diets low in the amino acids methionine or arginine, an extra supplement of the amino acid glycine is required.

Proteins are therefore assessed on their ability to provide these essential amino acids, with poor proteins supplying only non-essential ones. This is quantified by the term *biological value*, a high-biological-value foodstuff containing more of the essential amino acids.

For herbivorous reptiles, levels of 25% protein content as metabolisable energy in the diet have been shown to be adequate (Donoghue, 1998). Most of this protein source in herbivores seems to come from leafy greens, but deficiencies are seen in herbivorous reptiles fed high cellulose, low protein foods such as the ubiquitous lettuce, and fruits. Chronic protein deficiencies are often presented as gradual wasting conditions, with increased susceptibility to infections.

Deficiencies in amino acids in carnivorous reptiles and amphibians is extremely rare because they eat whole prey. This gives them a 30–60% protein content as metabolisable energy. Herbivorous deficiencies specific amino acids are possible although not well documented.

In general, waste products of protein metabolism in land-based reptiles are converted into the relatively insoluble uric acid. Alligators may produce ammonia as the waste product, as may many amphibians, depending on their state of hydration, but adult frogs may excrete urea. Protein excesses, such as those produced by feeding cat or dog foods to predominantly herbivorous species, can lead to an excess production of uric acid and visceral gout, renal failure and death may result.

Fats and essential fatty acids (EFAs)

Fats provide high concentrations of energy. They also supply the reptile or amphibian with essential fatty acids, which are required for cellular integrity and as the building blocks for internal chemicals such as prostaglandins (which play a part in reproduction and inflammation). Fats also provide a carrier mechanism for the absorption of fat-soluble vitamins such as vitamins A, D, E and K.

The primary EFA for reptiles is linoleic acid, as it is for mammals, with the absolute dietary requirement of this fatty acid being 1% of the diet. If the diet becomes deficient in this essential fatty acid a rapid decline in cellular integrity occurs. This is manifested clinically by the skin becoming flaky and inelastic and prone to recurrent infections, and also to fluid loss through the skin which in turn leads to polydipsia (Wallach & Hoff, 1982).

In herbivores, less than 10% of the diet on a dry matter basis is composed of fats, the chief energy sources being carbohydrates and proteins. However, fermentation of fibre in the lower bowel produces short-chain fatty acids which can be used for energy. For carnivores, fat forms a major part of the energy source in the diet, as much as 40–70% of the calories, with protein chiefly making up the rest.

The problem of overconsumption of fats in pet reptiles which are not exercising regularly is well known and high fat foods such as dog and cat food fed to herbivores, or extremely fat rodent prey fed to snakes, are prime culprits for this. Obesity can lead to a number of problems, high amongst which is fatty degenerative change in the liver (*hepatic lipidosis*) which can lead to liver failure. This is particularly common in tortoises.

Carbohydrates

Carbohydrates are primarily used for rapid energy production. This is particularly important in herbivores which consume plant matter only, and so gain the majority of their energy source from carbohydrates and proteins. Carnivorous reptiles do not utilise carbohydrates much at all.

Fibre

Dietary fibre is extremely important for herbivorous reptiles. Indeed, the presence of fibre acts both as a bulking agent, encouraging gut motility, and as a source for fermentation by the intestinal microflora, essential for fatty acid and B vitamin production. Snakes and other carnivores do not have a dietary fibre requirement, and indeed if provided will not be utilised. Ultimately it will dilute the energy concentration of the diet necessitating feeding more frequent and larger meals.

Vitamins

These compounds are grouped together although they are widely differing in nature, but all animals have a requirement for various numbers of these. They are categorised into fat soluble (vitamin A, D, E and K) and water soluble (the B vitamin complex and vitamin C).

Fat-soluble vitamins

Vitamin A: in herbivore reptiles the most important plant precursor in terms of how much vitamin A can be produced from it is beta-carotene. Carnivorous reptile and amphibians will gain the preformed vitamin A in their prey food.

Hypovitaminosis A is a frequently seen problem in chelonians, particularly tortoises and young red-eared terrapins. If a deficiency in vitamin A occurs then mucous membranes become thickened and oral and respiratory secretions dry up. This is due to blockage of salivary and mucous glands with cellular debris – a condition known as *squamous metaplasia*. This leads to poor functioning of the ciliary mechanisms which have a role in removing foreign particles from the airways. Swelling of the periorbital membranes – a condition known as *xerophthalmia* – is also seen.

Vitamin A's role in immune system function means that a deficiency makes respiratory and digestive tract infections more common. The most frequently seen example of this is the increased susceptibility to pneumonias seen in red-eared terrapins and manifested in the lop-sided position they adopt when swimming. This is because of lung collapse or congestion which reduces buoyancy on the affected side.

Tortoises may suffer more frequently from upper respiratory tract infections when a deficiency is present. Evidence of sterile pustules and cornified plaques inside the mouth are commonly seen, with overgrowth of the beak due to hyperkeratosis.

Vitamin A also has a role in bone growth and structure, the normal function of secretory glands such as the adrenals and also in reproductive function. Finally renal damage may occur in hypovitaminosis A, with evidence of oedema in the inguinal and axillary regions secondary to failure of the renal tubular filtration system.

Because it is fat soluble, vitamin A can be stored in the body, primarily in the liver. Recommended minimum dietary levels are 200–300 IU/kg for reptiles (Wallach & Hoff, 1982).

Hypervitaminosis A rarely occurs naturally but may be induced by overdosing with vitamin A injections at 1000 times or more the daily recommended doses. If this occurs acute toxicity develops with mucus membrane and skin sloughing and frequently death within 24–48 hours. Vitamin A supplements are therefore often given orally as, due to slower absorption, this reduces the risk of this condition developing.

Vitamin D: vitamin D_3 is the most active form for calcium homeostasis, and plants are not effective as suppliers of this compound.

Cholecalciferol, the precursor of vitamin D_3, is manufactured in the reptile or amphibian's skin in a process enhanced by ultraviolet light. For this reason indoor animals produce much less of this compound unless supplied with an effective artificial ultraviolet light source.

Hypovitaminosis D_3 causes problems with calcium metabolism, and leads to rickets. This is exacerbated by low calcium high phosphorus-containing diets. A typical sufferer would be a young growing reptile, kept indoors with no ultraviolet light supplementation and fed on a low calcium diet – for example lettuce/celery/cucumber for herbivores, or meat only/day old mice/chicks for carnivorous species. The condition so produced is referred to as 'metabolic bone disease'.

An animal so affected is frequently apparently 'well-muscled', due to poorly mineralised bones which increase their thickness to maintain their strength. There is often flaring of the epiphyseal plates at the ends of the long bones, with concomitant bowing of the limbs. Green iguanas and other herbivorous species such as terrestrial chelonians are particularly susceptible, with the lizards showing *rachitic rosettes* (Frye, 1991) due to flaring of the epiphysis in the ribs at the costochondral junction.

Chelonia develop 'lumpy shell', a deformity of the carapace in particular, where the edges roll upwards creating a 'Cornish pasty' effect, and the muscles which attach the limbs to the inside of the shell, pull the carapace downwards creating pits either side cranially and caudally (Fig. 10.3). Recommended maximum levels are 50–100 IU/kg every other day.

Hypervitaminosis D_3 occurs due to over supplementation with D_3 and calcium and leads to calcification of soft tissues, such as the medial wall of the arteries, and the kidneys, creating hypertension and organ failure. This often occurs in herbivores such as tortoises fed on tinned cat and dog food.

Vitamin E: hypovitaminosis E may occur due to a reduction in fat metabolism or absorption, such as can occur in small intestinal, pancreatic or biliary diseases, or due to a lack of dietary green plant material for herbivores. A relative deficiency will occur in species eating large amounts of polyunsaturated fats, for example marine fish such as tuna and mackerel. These use up the

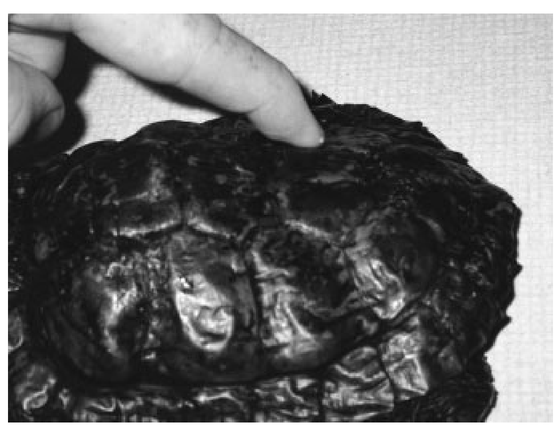

Fig. 10.3 Red-eared terrapin, *Trachemys scripta elegans*, with hypovitaminosis D_3.

body's vitamin E reserves. A condition called steatitis, wherein body fat starts to necrose, has been seen in gharials (a fish-eating crocodilian) (Frye, 1991) and terrapins.

Hypervitaminosis E is extremely rare.

Vitamin K: because of its production by gut bacteria, it is very difficult to get a true deficiency, although absorption will be reduced when fat digestion or absorption is reduced as in biliary or pancreatic disease. The consumption of warfarin and coumarin derived compounds (as found in sweet clovers) can increase the demand for clotting factors, and this may also be seen in snakes consuming prey which has been killed by these rodenticides. Disease so caused is characterised by increased internal and external haemorrhage, but vitamin K also has some function in calcium/phosphorous metabolism in bone so this may also be affected. Frye (1991) has recorded disease in crocodiles exhibiting gingival bleeding without petechiation. Recommended minimum levels for reptiles are 1 ppm (Wallach & Hoff, 1982).

Water-soluble vitamins

Vitamin B_1 (thiamine): a source of thiaminases, enzymes which destroy thiamine, is raw salt-water fish which may be fed to some snakes, crocodilians and turtles, such as garter snakes, red-eared terrapins and gharials. There are thiamine antagonists as well in blackberries, beetroot, coffee, chocolate and tea when considering herbivores. When a relative deficiency occurs, neurological signs such as opisthotonus, weakness and head tremors may be seen. In garter and water snakes, a classical inability to right itself occurs, with the snake continually flipping onto its back. In addition, fungal infections are reported as more likely after a B_1 deficiency. The recommended minimum level for reptiles is 20–35 mg/kg food offered. In addition, if sea-fish such as smelt, which are high in thiaminases, are to be fed, cooking the fish for 5 minutes at 80°C deactivates the thiaminase. In a reptile with thiamine deficiency, doses of 50–100 mg/kg body weight should be given. Because of this problem it is often advised feeding garter and water snakes on rodent prey rather than sea-fish. They may be encouraged to eat this by wiping the rodent prey with the fish to which it is accustomed to cover the scent.

Biotin: deficiencies do occur commonly in gila monsters, beaded lizards and monitor lizards all of which enjoy raw eggs in the wild. In this state the majority of eggs are fertile, and contain little avidin (an antibiotin vitamin). However, unfertilised hen's eggs are high in avidin and so a relative biotin deficiency may occur. Deficiencies produce muscular weakness, occasionally with skin lesions. It is therefore recommended that minimal levels of raw eggs are fed to such reptiles.

Folic acid: a deficiency of folic acid is rare but can lead to severely impaired cellular division. This can lead to a number of obvious problems such as females reproductive tracts not maturing, a macrocytic anaemia due to failure of red blood cell maturation and immune system cellular dysfunction. A relative deficiency of folic acid may occur in some individuals fed a very high protein diet, as folic acid is needed to produce the waste products of protein metabolism in reptiles, uric acid. In addition there are inhibitors of folic acid in some foods such as cabbage and other brassicas, oranges, beans and peas, and the use of trimethoprim sulphonamide drugs also reduces gut bacterial folic acid production.

Vitamin B_{12}: vitamin B_{12} is produced generally by intestinal bacteria and so deficiencies are uncommon but may occur after prolonged antibiotic medication. Deficiency produces slow growth, muscular dystrophy in the legs, poor hatching rates, high mortality rates and hatching deformities in young reptiles and amphibians.

Choline: choline may be synthesised in the body, but not in enough quantities for the growing reptile. Because of interactions, the need for choline is dependent on levels of folic acid and vitamin B_{12}. Excess protein therefore, as with folic acid, increases choline requirements, as does a diet high in fats. Deficiency causes retarded growth, disrupted fat metabolism and fatty liver damage.

Vitamin C: there is no direct need for this vitamin in reptiles and amphibians as vitamin C may be produced from glucose in the outermost portions of the kidneys. However, during disease processes, particularly those which affect liver function, it may be beneficial to the recovery process to provide a dietary source of vitamin C. It is required for the formation of elastic fibres and connective tissues and is an excellent anti-oxidant similar to vitamin E. Deficiency leads to 'scurvy' where there is poor wound healing, increased bleeding due to capillary-wall fragility and bone alterations. Deficiency has been postulated as the cause of skin splitting in snakes fed rodent prey that had been starved for 24–48 hours prior to being fed (Frye, 1991). This allowed the emptying of their gastrointestinal tract, and hence reduced levels of vitamin C from the plant material therein. It has also been suggested that increasing vitamin C levels by supplementation at levels of 10–20 mg/kg intramuscularly or orally (Frye, 1991) may be useful in the treatment of chronic infections, such as 'mouth rot' in snakes.

Minerals

As with mammals there are two main groups of minerals, those classified as macro-minerals, i.e. those present in large amounts in the body, such as calcium and phosphorus, and micro-minerals, or trace elements, such as manganese, iron and cobalt, which are all necessary for normal bodily function.

Macro-minerals

Calcium: calcium has a wide range of bodily functions, the two most obvious being its role in the formation of the skeleton and mineralisation of bone matrix, and its requirement for muscular contractions. The active form of calcium in the body is the ionic double charged molecule Ca^{2+}. Low levels of this form, even though the overall body reserves of calcium are normal, leads to hyperexcitability, fitting and death, conditions seen in gravid female egg-bound green iguanas.

The ratio of calcium to phosphorus is important – as one increases the other decreases and vice versa. This is controlled by the hormones calcitonin, parathyroid hormone and the accessory hormone vitamin D_3. A ratio of 2:1 calcium to phosphorus is desirable in growing reptiles, and 1.5:1 for adults. In high egg laying periods though, to keep pace with the output of calcium into the shells, a ratio of 10:1 may be needed.

Calcium deficiency causes nutritional osteodystrophy, or metabolic bone disease, and is often accompanied by deficiency in vitamin D_3. Normal levels of vitamin D_3, however, may exacerbate this disease as they encourage further calcium resorption. Deficiency may be seen in lizards such as green iguanas and water dragons, and chelonians fed on high fruit, lettuce, celery etc. diets. Diets with excessive levels of oxalates, compounds which bind up calcium and prevent it being absorbed, such as spinach and beetroot or rhubarb leaves, can also lead to a deficiency.

Calcium deficiency may also be seen in insectivorous species, such as geckos, and bearded dragons, fed on insects without supplementation (Fig. 10.4). Insects have little or no calcium, their tough outer coat is made of a protein known as chitin. To provide adequate calcium therefore, the insect must be dusted with a calcium powder *immediately* before being fed (if not, by the time the reptile has caught the insect most of the powder has fallen off!). Alternatively, the insect is pre-fed on a calcium supplement. This is mixed in with the insect's food and fed for the 24–48 hours prior to feeding the reptile, so that the insect's gut is pre-loaded with calcium.

Extensive resorption of calcium occurs from the bones during dietary deficiencies, leaving only fibrous tissue. This is considerably weaker and so the 'bones' thicken to maintain their strength. Even so the bones are weakened, and bowing of long bones and spontaneous fractures occur in lizards, collapsing of spinal vertebrae and deformities in most reptiles and deformed, lumpy shells in chelonians. Excessive calcium in the diet (>1%) though reduces the use of proteins, fats, phosphorus, manganese, zinc, iron and iodine, and can lead to soft tissue mineralisation if in conjunction with adequate or excessive vitamin D_3 levels. Red-eared terrapins have been shown to have a

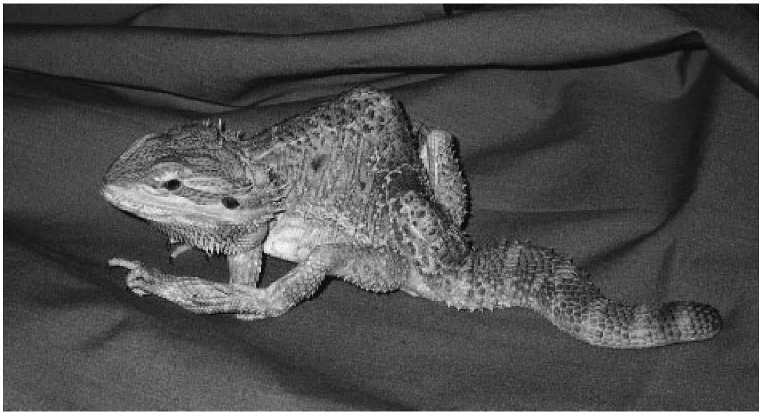

Fig. 10.4 Bearded dragon, *Pogona vitticeps*, with metabolic bone disease and resultant spinal and limb deformity.

requirement for 2% calcium on a dry matter basis (Kass *et al*., 1982).

Phosphorus: phosphorus is widespread in plant and animal tissues, but in the former it may be bound up in unavailable form as phytates. Levels of phosphorus are controlled in the body as for calcium, the two being in equal and opposite equilibrium with each other. Therefore, if dietary phosphorus levels exceed calcium levels appreciably the parathyroid glands become stimulated to produce more parathyroid hormone and nutritional secondary hyperparathyroidism occurs. This leads to progressive bone demineralisation and renal damage due to high circulating levels of parathyroid hormone. High dietary phosphorus also reduces the amount of calcium which can be absorbed from the gut, as it complexes with the calcium present there. This can be a problem in reptiles fed pure meat with no calcium or bone supplement, and in herbivores which are predominantly fruit and lettuce consumers as these are high phosphorus low calcium foods. Green vegetables or supplementation with calcium powders may therefore be necessary. In addition, low calcium/high phosphorus levels frequently allow bladder stones to form in those species (such as chelonians, green iguanas etc.) that have a bladder.

Magnesium: most magnesium is absorbed from the small intestine, and is affected by large amounts of calcium in the diet which reduce magnesium absorption. Deficiencies rarely occur, but muscular weakness can be the result.

Potassium: as with mammals, potassium is the major intracellular positive ion. Rarely is there a dietary deficiency, but severe stress can cause hypokalaemia through increased kidney excretion because of elevated plasma proteins. This can lead to cardiac dysrhythmias, muscle spasticity and neurological dysfunction.

Sodium: sodium is the main extracellular positive ion and regulates the body's acid base balance and osmotic potential. In conjunction with potassium, it is responsible for nerve signals and impulses. Rarely does a true dietary deficiency occur, but hyponatraemia may occur due to chronic diarrhoea or renal disease. Many reptiles have salt glands found outside the kidneys responsible solely for the excretion of excess sodium whilst conserving water. The green iguana's salt glands, for example, are present inside the nostrils, and white crystalline deposits of salt may be seen here and are frequently sneezed out. It may be necessary to supplement the diet of marine species with sodium chloride if kept in fresh water situations, or if fed freshwater plants or fish.

Chlorine: this is the major extracellular negative ion and is responsible for maintaining acid–base balances in conjunction with sodium and potassium. Deficiencies are rare.

Micro-minerals (trace elements)

These elements include zinc, copper, iron, manganese, cobalt and sulphur all of which have an important part to play in cellular function. However, so far no actual deficiencies specifically related to these elements have been reported in reptiles or amphibians. The exception is iodine.

Iodine: iodine's sole function is in thyroid hormone synthesis, which affects metabolic rate. Deficiency causes goitre and fluid retention (*myxoedema*). It has knock-on effects on growth, causing stunting and neurological problems and in amphibians may prevent metamorphosis from intermediate tadpole stages to the adult form. In reptiles it is most often encountered in giant terrestrial tortoises, which will exhibit goitre swelling of the neck. It can also occur due to overfeeding with iodine-binding plants, such as cabbage, cauliflower, broccoli, kale and Brussels sprouts. Excess iodine added to the water may cause species such as the amphibian axolotl (a neotenic salamander – that is its 'adult' form has the external gills more typical of a tadpole or intermediate lifestage) to shed its external gills. Levels of 0.3 μg/kg body weight have been quoted (Donoghue & Langenburg, 1996).

Specific nutritional problems in reptiles

Below are some common presentations of nutritional problems in reptiles.

Post-hibernation anorexia (PHA)

PHA occurs in the Mediterranean species of tortoise (Hermann's, Greek or spur-thighed, marginated and Horsefield's), which hibernate during the winter months. The commonest presentation is that of an inappetant tortoise after coming out of hibernation, often with signs of systemic or respiratory tract infections (such as the 'runny nose syndrome') and often with a low body weight in relation to length (a low Jackson's ratio). In addition the blood glucose levels are frequently below 3.2 mmol/l, which appears to be the minimum level required for appetite stimulation (Lawrence, 1987), with high levels of urea.

Dehydration is apparent in these cases, and treatment requires aggressive fluid therapy and nutritional support, using glucose-containing fluids and liquid food stomach tubing, as well as warming the tortoise to its optimum temperature (20–27°C) (Fig. 10.5).

Causes of this condition could involve any one of the following:

- Disease during or prior to hibernation
- Poor nutrition leading to poor fat reserves prior to hibernation
- Owner failure to observe recovery from hibernation for several days, so no food offered at the critical time
- A period of cold weather immediately after recovery.

It is the rising plane of blood glucose post hibernation that acts as the stimulus for appetite in these chelonians, and failure of this rise, due to malnutrition or failure to eat whilst the levels are still high, may lead to unresponsive anorexia.

To prevent PHA, therefore, it is important to attend to disease *prior* to hibernation, and, if severely affected or underweight, the tortoise should not be hibernated, but kept indoors at its

Fig. 10.5 Spur-thighed tortoise, *Testudo graeca*, with post-hibernation anorexia.

optimum temperature range and fed throughout the winter. The tortoise should also be checked regularly once in hibernation, around once or twice a week, to ensure if the tortoise does come out of hibernation early, it has food and water available immediately. Bathing the tortoise immediately after waking in warm water, cleaning the nose, eyes and mouth especially can also stimulate appetite, and no tortoise having recovered from hibernation should be allowed to rehibernate that same winter. Finally, stomach tubing with fluids and soluble carbohydrates, such as the basic sugar and protein containing liquid food Critical Care Formula produced by VetArk or vegetable baby food porridges, early on in the course of the problem can be useful.

Visceral and articular gout

Gout is a condition caused by the unique way that many reptiles deal with the waste products of protein metabolism. Most reptiles are uricotelic, that is the main excretory product of protein metabolism is uric acid. This compound is relatively insoluble in water, which has its advantages as reptiles are therefore able to reduce the water lost in excreting it. Unfortunately, if the reptile becomes dehydrated, either acutely or chronically, or consumes diets with excessive protein levels, particularly a type of protein called purines, or suffers kidney damage, then uric acid levels build up in the bloodstream. If allowed to do so, they will eventually exceed the precipitation point and form crystals inside the body.

Diet is important, as purine proteins which are found mainly in animal protein, are converted readily to uric acid on degradation in the body. Therefore, if herbivorous species, such as green iguanas, which are not used to large volumes of purines, are fed a diet rich in animal protein, such as cat or dog food, they will produce excessive amounts of uric acid and develop gout.

There are two forms of gout, *visceral* and *articular*. Articular gout can easily be diagnosed ante mortem, as it causes gross swelling and inflammation in the joints where the uric acid crystals form. Visceral gout is more difficult to diagnose ante mortem, because it occurs where uric acid crystals are deposited in the soft tissues of the body, primary sites being the kidneys, the pericardial sac, the lungs, spleen and liver. Once deposited, it is almost impossible to move the crystals medically and permanent damage is often done.

Obesity

Obesity is a common problem in many reptiles and amphibians kept in captivity. Many species are overfed because of owners' ignorance of natural feeding intervals and of food types commonly eaten in the wild. Examples include feeding dog food to tortoises and green iguanas, both of which are totally herbivorous in the wild but both of which will eat meat if offered it. The resulting problems are as mentioned above with excess protein causing gout, excess calcium and vitamin D_3 causing soft tissue mineralisation and excess animal fat causing fatty liver syndrome (hepatic lipidosis) wherein the liver cells are filled with fat deposits impeding their function. Snakes also suffer from these conditions when fed overfat laboratory rodents, or simply fed too often. A rough idea of feeding frequencies is given in Table 10.1.

The aim should be a reptile which does not appear emaciated, but lean.

Hypoglycaemia in crocodilians

It has been reported that crocodiles kept in high density conditions, or are otherwise stressed, are prone to hypoglycaemic fits (Scott, 1992). It is interesting to note that crocodiles' blood sugar levels vary throughout the year, being lower in the winter and highest in the summer. A rising blood sugar level appears to be the stimulus to eat, as seems to be seen with Mediterranean tortoises after hibernation.

Environmental temperature and its effects on nutrition

Because reptiles and amphibians are ectothermic, that is they rely on their surroundings to maintain their body temperature, environmental temperature is important in all aspects of husbandry.

There is an optimum preferred temperature zone that will allow their enzymes and metabolic pathways to function at their optimum levels, so

Table 10.1 Feeding frequencies and food types for various reptile species.

Species	Feeding frequency and food types
Herbivores (e.g. iguanas, tortoises)	Daily grazing of food advised
Small insectivores (e.g. leopard geckos, collared lizards)	Fed 2–3 times weekly on live insect prey 'to appetite'
Small carnivores (e.g. garter snakes, corn snakes)	Fed 2–3 times weekly on rat pups,'fuzzies' (furred baby mice) or 'pinkies' (nude baby mice) according to size
Medium carnivores (e.g. kingsnakes, ratsnakes)	Fed 1–2 times weekly, adult mice or small rats
Large carnivores (e.g. boa constrictors, Burmese pythons)	Fed once weekly or fortnightly (the larger the snake the less often) on adult rats or small rabbits

environmental temperature will influence the rate of digestion of the food offered. It may take 2–3 days for a rat consumed by a large boa constrictor to pass through its digestive system if kept within its preferred temperature zone of 25–30°C, but if kept 5–10°C cooler this will often slow down to 5–7 days, and if kept much lower than this digestion may not occur before the prey item becomes rancid inside the snake. Similarly, if kept at too high a temperature, the reptile may not be stimulated to eat at all and dehydration and heat stress may set in.

A general guide to feeding reptiles

Fresh food should always be fed to reptiles. It should also be remembered that at the increased temperatures of most vivaria, the food offered will spoil very quickly and will need to be replaced frequently.

Snakes

It is important to note that it is illegal to feed live vertebrate prey to another animal in the United Kingdom. All rodent prey fed to snakes and lizards must therefore have been humanely killed first. In addition, live prey may damage the reptile if the latter is not hungry and does not kill the prey quickly.

To encourage anorectic snakes to eat, a number of tricks may be employed including:

- Warming the prey briefly before offering by heating it in a pot of hot water
- Breaking the prey item open to release the scent of blood
- Teasing the snake by moving the dead prey item around the cage with forceps, to mimic live prey
- Trying a variety of colours of prey – some snakes will only take dark-furred rodents
- To get a snake (such as a garter or water snake) used to eating rodent prey after only eating fish or amphibians (hog-nosed snakes), wipe the rodent to be offered with the previously taken food item to transfer scent
- Ensure that there are plenty of areas to hide; some boids and pythons like to consume their prey in a box or hide
- Leave the prey in overnight because some species prefer to hunt at night
- Choose the next smallest size of rodent, so if adult mice were previously offered try fuzzies, if juvenile rats, try adult mice, etc.

NB The term 'pinkies' refers to nude neonatal rat and mice pups, 'fuzzies' refers to week-old rat and mice pups with a thin covering of fur and 'furries' refers to juvenile rat and mice pups between 1–3 weeks of age which have a soft but longer covering of fur.

Refeeding syndrome

If anorexia in a snake or other reptile has persisted for some time it is essential to rehydrate the patient before attempting to feed. Indeed, initial feeding after this should be started off at very low levels. This is because excess calories and proteins cause a rapid uptake of glucose from the bloodstream into the cells, which takes potassium and phosphorous with it. This can lead to a life-threatening hypokalaemia and hypophosphataemia. The monitoring of blood phosphorus and potassium is therefore to be recommended when treating chronically anorectic reptiles, whether carnivorous or herbivorous.

Herbivores

If using a commercial pelleted food for iguanas or tortoises, then be sure to soak the pellets thoroughly before feeding, otherwise they swell up inside the reptile causing colic and bloat. Commercial pelleted diets are a useful adjunct to the diet of herbivorous reptiles and many companies now produce iguanid and chelonian diets which are well supplemented with minerals and vitamins and also contain moderate levels of fibre for gut motility enhancement.

The feeding of certain foods to herbivores should be prohibited. Animal proteins are one, as are certain fruit and vegetables. We have already discussed the problems of excessive volumes of largely water-containing vegetables such as lettuce, cucumber and celery, the goitrogenic properties of cabbage, kale, broccoli and cauliflower and the anti-calcium effect of oxalate-containing plants such as spinach, beetroot and rhubarb leaves. In addition, fruits such as banana can cause a sugar ferment in herbivorous reptiles causing colic, as well as adhering to the mouthparts and encouraging local infection. Avocados have an extremely high fat content and should not be fed to herbivorous reptiles due to potential secondary fatty degeneration of the liver.

Sample diet for green iguanas

Pelleted soaked commercial food may be fed at around 25% of daily intake. The rest can be based on the following: Up to half of the plant material offered can be made of calcium-rich vegetables such as kale, dandelions, chicory, watercress, cabbage, flat-leaved parsley, basil, coriander etc. The other half may be made up of other vegetable matter such as peas, beans, carrots, sweet peppers, courgettes or marrows, cauliflower florets and flowers of plants such as nasturtiums, dandelions, roses etc. To this mixture can be added small amounts of fruit such as apples, pears, tomatoes, plums, strawberries, raspberries, melon, passion fruit, papaya etc., or fibrous foods such as bran cereals, brown bread and cooked brown rice.

This combination should be thoroughly mixed so as to prevent selective feeding and to it should be added a supplement of calcium in the form of calcium lactate or gluconate, or a natural calcium source such as cuttlefish or oyster shells. In addition the use of a vitamin D_3/calcium supplement once or twice a week, particularly for growing iguanas and egg-laying females, is advised.

Sample diet for Mediterranean tortoises

The majority of the diet is to be composed of vegetable matter of a leafy nature such as dandelions, kale, watercress, flat-leaved parsley, chicory and bok-choy. To this may be added peas, beans, hay or dried grass, fresh grass (not cut), grated carrot, grated pumpkin and sweet peppers.

To this may be added small volumes of fruit such as apples, pears, melon, papaya, passion fruit, strawberries, plums, flowers such as dandelions, nasturtiums, roses and sprouted seeds such as mung beans, lentils, and chick peas.

For more tropical species, such as the red and yellow footed tortoises (*Geochelone carbonaria* and *Geochelone denticulata*), the amount of fruit and flowers may be doubled.

For grassland species, such as leopard tortoises (*Geochelone pardalis*) and Indian starred tortoises (*Geochelone elegans*), a good provision of fresh uncut grass or good quality hay is advised.

For more omnivorous species, such as box turtles (*Terrapene carolina*), up to 50% of the above fruit and vegetable diet may be replaced with adult maintenance dry dog foods (soaked), mealworms, crickets, earthworms and even baby mice (pinkies). Juveniles of this species tend to be more carnivorous than the adults.

In all of these diets it is recommended that daily supplementation with calcium lactate or gluconate be included, with a calcium/vitamin D_3 supplement added once or twice weekly depending whether the tortoise is a juvenile (higher requirement) or an adult (lower requirement).

Diets for snakes and insectivorous species have been mentioned. The latter need calcium supplementation as discussed in the section considering calcium as a macro-mineral which may either be dusted onto the insects, or pre-fed to them to load their digestive contents with the calcium.

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Chapter 11

Common Reptile and Amphibian Diseases

Skin disease

Dysecdysis

Dysecdysis occurs when the normal process of skin shedding (known as *ecdysis*) fails. It occurs in snakes, and to a lesser extent, lizards. The process of ecdysis involves the forming of a new skin beneath the old one. Once this is complete, a series of proteolytic enzymes and lymphatic fluid is secreted between the new skin layer and the overlying old one. This lifts the old layer and separates the two, and makes the snake appear dull and lack-lustre with the eyes noticeably blueing. This lasts for 5–7 days on average in the snake. Once complete the fluid is reabsorbed, and the snake appears to return to its normal hue. After a further 5–7 days the skin is shed, in the case of the snake, in one piece, from the head end first. It is initiated in snakes by rubbing the face on an abrasive surface to loosen the first piece of skin. When the separation fails to occur, whether in part or totally, the condition is known as dysecdysis.

The causes of dysecdysis are many and varied, but can include any condition which can cause dehydration so reducing lymphatic fluid available to separate the skin layers. If the reptile is malnourished dysecdysis may occur due to a lack of proteolytic enzymes. Alternatively old scars, a lack of an abrasive surface in the vivarium upon which to start the process or severe ectoparasitism may also cause dysecdysis (Fig. 11.1).

Scale rot

Scale rot is a colloquial term for a range of conditions affecting the reptile skin which result in severe infections.

Septicaemic cutaneous ulcerative disease (SCUD)

Septicaemic cutaneous ulcerative disease (SCUD) is a condition seen in aquatic chelonians. It is caused by the bacterium *Citrobacter freundii* which, once it has gained access to the bloodstream, produces ulcers in the skin and loosening of scales with general debilitation and, in many cases, death (Fig. 11.2).

Blister disease

This is a form of scale rot seen in snakes, particularly semi-aquatic species such as garter or water snakes. It can however occur in any species which is exposed to a persistently damp substrate. The outer layer of skin develops blisters of a clear fluid which become secondarily infected with environmental bacteria such as *Aeromonas* spp or *Pseudomonas* spp. These can progress to envelop the whole of the ventral aspect of the snake, and lead to septicaemia. Occasionally these conditions may involve a fungus such as *Aspergillus* spp.

Abscesses

Abscesses have recently been quoted as being more accurately termed *fibriscesses* (Huchzermeyer & Cooper, 2001) due to the unique nature of reptile and avian abscess formation. Instead of the liquid pus we are more familiar with in mammals, reptiles and birds form a solid, caseous, dried swelling surrounded by a thick shell of fibrous tissue. This is due to the lack of lysozymes (a form of destructive enzyme found in macrophages and other immune system cells) that help liquefy foreign matter. Instead the reptile engulfs the material in immune system

Fig. 11.1 Dysecdysis in a lizard with a subcutaneous abscess.

Fig. 11.2 SCUD in a red-eared terrapin, *Trachemys scripta elegans*.

cells and to contain the problem further throws up a thick connective-tissue wall around the area, forming a solid swelling (Fig. 11.1). These may form anywhere, but a common site in chelonians is the middle ear, causing a bulging of the ear drum. The pathogens involved are frequently Gram negative species, although the presence of fungi in abscesses has been well recorded.

Erythema, petechiae and ecchymoses

These three conditions may all be present at the same time or may appear individually.

Erythema is the reddening of skin tissues due to vascular congestion beneath. It can be seen in reptiles as a pink hue to the areas between scutes in the case of chelonians (Fig. 11.2) and crocodylians, or the more generalised reddening of the skin seen in snakes. Erythema is often suggestive of a generalised medical condition such as septicaemia.

Petechiae are the pin-point haemorrhages seen in many reptiles. They can be seen in areas such as caused by the mouth, where they often suggest the incidence of an oral infection such as 'mouth rot'. They may be seen over the whole of the body suggesting the possibility of septicaemia. Other conditions include clotting deficiencies such as are caused by the consumption of rodent prey which has itself consumed a warfarin-type poison.

Ecchymoses are larger areas of haemorrhage, and may be caused by severe local infection or conditions mentioned above.

Overgrown beaks and claws

Overgrown beaks are common in chelonians, and are often due to a lack of abrasive foodstuffs or abrasive surfaces from which to eat them. The beak may become so overgrown that the reptile is unable to feed itself. Beaks may be trimmed using a slow-speed dental drill, or a battery-powered hand-held drill in much the same way as a bird's overgrown beak can be trimmed.

Overgrown claws can also be a problem in lizards and chelonians due to the lack of abrasive substrates in their environment. It should be noted however that some species have perfectly normal apparently 'long' claws. An example is the male red-eared terrapin which uses his claws as a display aid to attract and mate the female. Otherwise, trimming the claws with a standard pair of feline claw clippers is advised.

Pigment changes

An example of a physiologically normal colour change is seen in the Chameleonidae which will often blend with their surroundings and darken in colour as they become stressed. Green iguanas often become yellow brown in colour as they become stressed or unwell, and many of these species will exhibit darkening at the site of an injection. Areas of previous trauma may become whitened.

Ectoparasitic

Mites

The most commonly seen mite in snakes is *Ophionyssus natricis* which appears as red to dark-coloured pin-head mites hiding under the overlapping edges of scales. They may be seen in water dishes in which the reptile has been bathing. They can cause severe irritation, pruritus and self-trauma, as well as potentially causing anaemia and conditions such as dysecdysis. In addition, they can be responsible for transmitting *Aeromonas* spp bacteria, which may cause septicaemia. There are other mites, such as the cloacal mites of aquatic turtles of the family *Cloacarus* spp. In addition, there is of course the non-parasitic harvest mite or *Neotrombicula autumnalis* which may be brought in on straw and hay bedding material. The adult itself is not irritant but the six legged larval stage is and may cause the reptile to traumatise itself.

Ticks

Wild-caught species are common sufferers of ticks, but ticks are also seen in reptiles kept in owners' gardens, such as tortoises. In the United Kingdom the species *Ixodes ricinus* (the sheep or deer tick) and *Ixodes hexagonous* (the hedgehog tick) are seen. These attach to soft, thin-skinned areas. In tortoises these are naturally the areas around the neck inlet and in front of the hind legs. They may cause local damage and can transmit a range of viral and bacterial pathogens. These include the bacteria *Staphylococcus aureus*, the cause of tick pyaemia and *Borrelia burghdorferi*, the cause of Lyme's disease.

Blowfly myiasis

Myiasis is a particular problem for any reptile kept in insanitory conditions or those with diarrhoea. In particular, tortoises are at high risk during the summer months. Members of the blue bottle, black bottle and green bottle family are all capable of laying eggs on a tortoise. In peak conditions these can hatch into larvae or maggots within 1–2 hours. These then burrow away from the light, into the body of the tortoise causing severe trauma, infections, shock and ultimately death.

Leeches

Leeches tend not to be such a problem in the United Kingdom, but can affect aquatic species all over the world. The family Annelidae are the most dangerous, and cause large wounds which continue to bleed after the leech has detached. These may then become secondarily infected.

Traumatic and spontaneous damage

Traumatic damage can be due to attacks by predators or other reptiles, such as those induced by males fighting over a female. In some species, such as green iguanas, the male mounting the female during mating bites the shoulder area vigorously causing open wounds. In the United Kingdom it is unlawful to feed live vertebrate prey to any animal, but invertebrate live prey can be offered and these can still cause trauma to a sick or anorectic reptile. Finally, injuries from cage furniture, are commonplace. Unprotected heat sources frequently cause severe burns.

Spontaneous skin damage wherein the skin has split as the snake has swallowed prey, has been recorded in some snakes. It has been postulated that this may be due to a deficiency in vitamin C

(Frye, 1991) or even an hereditary defect in skin elasticity.

In some chelonians, scutes may be seen to lift off, often weeping clear fluid beneath them. This is frequently associated with underlying renal disease.

Iatrogenic causes of skin damage are also seen in some reptiles such as chelonians. This can occur after overadministration of vitamin A, which can cause sloughing of the epidermal layer on the head, neck and limbs, exposing the underlying dermis.

Tumours

Fibrosarcomas of the head are commonly seen in lizards and snakes. Melanomas are also seen relatively frequently in pigmented species.

Bacterial

Many bacteria have been mentioned already. Others which have been closely associated with skin disease include *Salmonella* spp. These can cause skin abscesses, septicaemia and areas of skin sloughing. Others such as *Mycobacteria* spp may be seen associated with the appearance of swellings, producing classical tuberculous lesions. The mycobacteria found are more commonly environmental ones rather than the human or cattle tuberculosis organisms.

Fungal

Many of the fungi found in the local environment are found associated with wounds. These include *Aspergillus* spp, *Penicillium* spp and dermatophytes (the cause of ringworm in mammals). Diagnosis is by histopathological demonstration and culture. Plate 11.1 shows fungal granulomatous disease on the tail of an iguana.

Viral

There are more and more cases of viral associated disease being diagnosed in reptiles each day. Herpes viruses causing grey patch disease have been found in turtles, papilloma viruses in lizards, and pox viruses in caimens (a member of the family Crocodylia).

Hereditary

Many species exhibit scale and skin abnormalities. These vary from cleft palates, to failure of scales to develop at all. In addition many colour variations have been specifically bred for.

Digestive disease

Oral ('mouth rot')

'Mouth rot' is the colloquial term for the oral infections, or *stomatitis*, commonly seen in many reptiles. It is particularly seen in snakes and chelonians, in the latter species often after hibernation and associated with anorexia.

The causes are many and varied. In the case of chelonians it has been associated with a herpes virus. In many snakes and tortoises however it is caused by secondary infections with Gram negative bacteria. The initial cause of the damage can be rubbing of the snout on vivarium glass, particularly in snakes. The use of opaque tape stuck to the outside of the glass helps the snake to 'see it', preventing this injury. Stomatitis may also be due to the overzealous force-feeding of anorectic reptiles, or simply due to other disease or stresses leading to reduced immune system function.

Vomiting and regurgitation

These two conditions are seen commonly in members of the snake family, but rarely in chelonians, crocodylians or saurians (lizards).

In snakes, regurgitation may simply occur due to rough handling, particularly soon after the snake has eaten. Snakes will also regurgitate if fed, or force-fed, food and then kept at suboptimal environmental temperatures.

Parasitic

In snakes, one of the more frequently encountered forms of stomach disease is cryptosporidiosis. It is caused by a single-celled parasite, *Cryptosporidia serpentes*, which invades the outer membrane of cells lining the stomach, most specifically the combined acid and pepsinogen secreting cells responsible for starting the digestive process. This

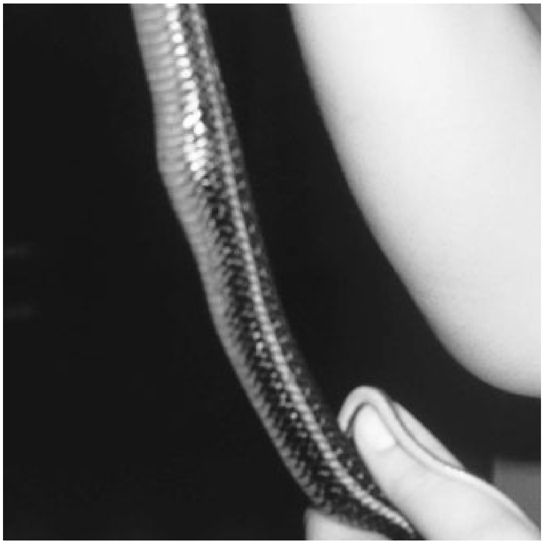

Fig. 11.3 Cryptosporidiosis is a common cause of swellings in the stomach of snakes.

results in a reduction in the ability of the snake to digest food, and the increased risk of gastritis due to opportunistic bacterial infections. With time, it also causes a thickening of the stomach lining as immune system cells move into the area to attempt to contain the problem, and new stomach-lining cells are produced. This narrows the lumen of the stomach and so reduces its elasticity, making it difficult to keep food items down.

Diagnosis of the disease is made on clinical signs and recovery of the egg sachets or oocysts shed in the faeces or recovered from a stomach wash, or via biopsy of the stomach wall. The course of the disease can vary from 4 days in severe cases to 2 years in chronic ones. Externally the snake often shows signs of a mid-body swelling, due to the thickening of the stomach wall. The parasite is passed directly from one snake's faeces or regurgitated fluids to another. The condition is difficult to treat and frequently results in the death of the snake (Fig. 11.3).

Other forms of parasitism may cause vomiting or regurgitation in snakes. These include the nematode worm *Kalicephalus* spp (the snake hookworm) which may cause extensive ulceration of the digestive system. Large numbers of roundworm ascarids may also cause vomiting. In members of the python family the tapeworm *Bothridium* spp has been reported as a cause of vomiting.

Bacterial and fungal

Bacterial and fungal infections, granulomas and abscesses may also cause damage to the stomach, or pressure on it, and so lead to regurgitation or vomiting.

Tumours

Finally, stomach tumours such as gastric adenomas and adenocarcinomas have been reported. These can lead to vomiting, and often physical enlargement of the stomach may be seen externally.

Lizards and chelonians tend not to regurgitate or vomit. They have a better-developed cardiac sphincter in the stomach. However, it may still occur and is often a very grave indicator of poor health status.

Intestinal disease

Parasitic

Snakes: snakes suffer from a variety of nematode and cestode problems. Species involved include the hookworm *Kalicephalus* spp, ascarids, strongyles such as *Strongyloides* spp and tapeworms such as *Bothridium* spp in pythons and *Ophiotaenia* spp in garter and water snakes.

In addition, snakes may suffer from the parasitic condition *entamoebiasis* caused by the single celled parasite *Entamoeba invadens*. Nearly all species of snake may be affected, and its life cycle is direct, i.e. spread directly from one reptile to another. After incubating in the lining of the small intestine, each infective cyst produces eight uninucleate amoebae which invade cells lining the large intestine of the same snake. The amoebae may also penetrate into the blood stream and so end up in the liver via the hepatoportal blood stream. Here they cause a necrotising hepatitis. The symptoms of entamoebiasis include a bloody mucoid diarrhoea, distension of the snake's large intestine, central nervous system symptoms due to liver damage, often septicaemia due to bacterial blood poisoning from the damaged intestines and occasionally vomiting. Diagnosis is by finding the small amoebae or cysts in the faeces (×400 magnification is required). Many herbivorous reptiles, such as green iguanas or Mediterranean tortoises, may carry this parasite without any sign of disease as the 'parasite' feeds off plant material in the herbivore's gut. In carnivores this is not possible and so the parasite damages the gut lining. This is one reason why particular care should be taken to prevent transmitting this parasite when dealing with a carnivorous reptile after handling a herbivorous one.

Chelonians: chelonians are mainly affected by species of the ascarid family such as the large roundworm *Angusticaecum* spp (10–20 cm in length!). Some may be affected by oxyurid pinworms. In most cases no symptoms are apparent. Some worm burdens may be large enough to debilitate a tortoise, particularly prior to and subsequent to hibernation, and occasionally actual intestinal obstructions due to the number of worms present have been recorded. Roundworms are passed directly from chelonian to chelonian in the faeces in the infectious egg form, and may be diagnosed by the detection of these eggs in a faecal smear.

The most important group of intestinal parasites of Chelonia, is the flagellate family. These include *Trichomonas* and *Hexamita* spp. The symptoms produced are rapid in onset and include anorexia, occasionally diarrhoea and frequently the passage of undigested food in the faeces. Additionally, there is often polydipsia, due partly to the inability of the damaged intestines to absorb water, and partly, in the case of *Hexamita parva*, due to kidney damage, as this organism migrates up the ureters from the cloaca into the kidneys. Diagnosis is made by viewing the very fast-moving organisms microscopically using a ×400 magnification, although a fresh faecal specimen is required, as when it dries, the organisms die and so do not move. Transmission is directly from the faeces of one tortoise to another. The prognosis may be extremely poor for any chelonian severely parasitised by this organism, due to its ability to cause irreparable damage to the intestinal mucosa.

Another family of single-celled, mobile parasites afflicting Chelonia is the ciliate family. Organisms such as *Balantidium coli* and *Paramecium* spp may be seen normally in the healthy stool of a Chelonian. But they may be present in such large numbers as to cause weight loss and intestinal damage.

Lizards: worm burdens in lizards are particularly common from the Strongyloides family. Due to the direct life cycle of these parasites (that is the eggs passed in the faeces of one lizard are then immediately infective to other lizards, or even the same lizard), levels may become very high, enough to produce intestinal damage and debilitation. Diagnosis is by finding the eggs in the faeces.

The single-celled parasites of the coccidia family are also important parasites in lizards, particularly the gecko and chameleon families. Clinical signs include anorexia, weight loss, diarrhoea, dysentery and general debilitation. Diagnosis is by finding the eggs or oocysts in the faeces, and the life-cycle is direct.

Cryptosporidiosis has caused problems in some species of lizard, such as the gecko family. As in snakes it is often impossible to treat. The symptoms include weight loss, diarrhoea and anorexia.

Entamoeba invadens may also be seen in carnivorous lizards, producing colic and progressive weight loss with diarrhoea. It does not affect herbivorous lizards though.

Bacterial

In all species, but particularly snakes and chelonians, members of the family Salmonellae are commonly recovered. They are of course potentially zoonotic bacteria. Current advice is that providing the *Salmonella* spp is not causing clinical disease in the reptile, no antibiotics should be given. This is to prevent antibiotic resistance, and on a practical basis no one has satisfactorily proven that such treatment can clear a reptile permanently of the bacterium.

Salmonella spp may be carried by perfectly healthy individuals, but during other disease processes, such as parasitism, or during periods of stress, they can become opportunistic pathogens. Many septicaemic reptiles are being attacked by bacteria present within their own digestive systems that have breached the gut–blood barrier.

Other bacteria found in the normal digestive system of reptiles can act as opportunistic pathogens including many members of the *E.coli* family, *Pseudomonas* spp, *Campylobacter* spp, *Clostridia* spp, and *Aeromonas* spp.

Physical

Foreign bodies are not uncommon in chelonians and lizards, which may consume stones, sand, soil or any other substrate present. There have been a number of possible reasons put forward for this behaviour. It is true that some reptiles will consume foreign objects at the same time as their food item, due to adherence or proximity to it. However, stones may be eaten if the reptile is deficient in some mineral such as calcium in its offered diet. Another possible cause is the presence of internal parasites or indeed to help grind food which is fibrous in nature. Surgery may be required to remove some foreign bodies, although many may be passed with the aid of oral liquid paraffin and fluid therapy.

Other physical obstructions include tumours within the intestines. These are not uncommon, particularly in snakes, and may present as a swelling, or produce symptoms such as vomiting, diarrhoea, constipation or anorexia.

Liver disease

Snakes

Possible causes of liver damage in snakes (*Entamoeba invadens*) have already been mentioned above.

Other parasitic causes include some forms of the single-celled parasites of the coccidia family which gain access to the liver from the small intestine via the bile ducts.

Both a herpes virus and an adenovirus have been isolated from damaged snake livers.

Chelonia

The single-celled flagellate *Hexamita parva* has been associated with intestinal, renal and hepatic disease in Chelonia. Clinical signs have been described as lethargy, weight loss and poor growth rates.

Hepatic lipidosis, or fatty liver syndrome, is common in tortoises fed inappropriate diets, more specifically regular amounts of cat or dog food. The excessive amount of fat consumed causes deposition of fat within the liver cells themselves, enlarging the liver and, more importantly, severely affecting its function. This can lead to jaundice, anorexia and death.

Post-hibernation jaundice is often a temporary finding in tortoises immediately after hibernation. It may however persist, indicating liver damage due to any one of the above or due to hepatitis from bacteria such as *Salmonella* spp and *Aeromonas hydrophila*. In addition some forms of herpes viruses and iridoviruses have been isolated from damaged tortoise and other chelonian livers.

The liver may become calcified due to over-supplementation of the diet with calcium and vitamin D_3.

Lizards

Bacterial hepatitis due to *Salmonella* spp, *Aeromonas* spp or *Pseudomonas* spp have all been recorded. These may be associated with heavy worm burdens, many of which may migrate through or to the liver, often carrying bacteria with them.

Respiratory disease

Signs of respiratory disease

Respiratory disease in reptiles is exacerbated by the inability of many reptiles to remove fluid, mucus and debris from their airways by coughing (Fig. 11.4). This is because reptiles do not possess a true diaphragm, and have no cough reflex. Secretions pool in the dependent parts of the lungs and so make the course of the disease more chronic and difficult to treat. Signs of respiratory disease are given in Table 11.1.

Causes of respiratory disease

Parasitic

These are mainly due to the larger species of worm. However the single-celled parasite *Enta-*

moeba invadens can cause respiratory disease in snakes. The commoner parasites though include the worms known as nematodes. These are represented by:

- *Kalicephalus* spp (the hookworm of snakes). This species can migrate through the skin of the snake, or be eaten. The worm then migrates through the snake's body, often passing through the lungs as it develops, before finally ending up as the adult hookworm in the gut.
- The family Ascaridae (the roundworm family). In carnivorous reptiles, the ascarid infection is frequently acquired via an amphibian or rodent prey item which has been used as its intermediate host. The worm larvae once consumed then migrates through the liver and lungs of the reptile.

Fig. 11.4 Mouth breathing and excess oral mucus are often seen in advanced cases of respiratory disease as in this boa constrictor.

- *Rhabdias* spp (the lungworm of snakes). The snake ingests the infective eggs from the faeces of other snakes or the infective larvae may penetrate the skin of the snake as with *Kalicephalus* spp. The larvae then migrate to the lungs, where they all develop into adult female worms. The eggs are therefore produced by parthenogenesis (female giving birth to female).

Other less common parasitic causes of respiratory disease in reptiles include:

- Flukes such as *Dasymetra* spp which live in the oral cavity and respiratory tract of snakes. These parasites are also known in texts as *renifers* and are rarely pathogenic. Diagnosis is made by finding the fluke eggs in the snake's faeces.
- Pentastomes, also known as 'tongue worms'. These are the adult stage of an arachnid organism related to spiders and ticks, rather than a true worm. It uses the lungs of snakes, crocodiles or lizards as the final host, shedding eggs which are coughed up and swallowed and passed in the faeces. These then are ingested by an intermediate host such as rodents, or even humans, making this a zoonotic disease. The larvae encyst in the intermediate host. If this is then consumed by the reptile, the larvae are reactivated and migrate to the lungs where they can grow to several centimetres in length, causing severe damage. They are generally only found in wild-caught specimens, due to the lack of native prey to transmit the parasite in captivity.

Table 11.1 Signs of respiratory disease in reptiles.

Common signs of respiratory disease in reptiles	Less frequently seen signs of respiratory disease in reptiles
Mouth breathing (particularly snakes) Excess mucus at nares and mouth Lethargy Anorexia	Cyanosis Hypopyon (pus in the anterior chamber of the eye – particularly Chelonia) Subspectacular abscess in snakes (abscess beneath the eye spectacle)

Bacterial

Many bacteria have been isolated from the lungs of pneumonic reptiles. Some are primary pathogens and some are secondary invaders, following damage caused by organisms such as the above-listed parasites, or secondary to septicaemic states or oral infections such as 'mouth rot'. Examples of the bacteria seen in pneumonias include *Aeromonas* spp, *Pseudomonas* spp, *Klebsiella* spp and *Pasteurella* spp.

'Runny nose syndrome' or *rhinitis* seen in Chelonia is mainly seen in members of the tortoise family, particularly the Mediterranean species. No one pathogen has been determined as the true cause, although many bacteria, and a herpes virus have all been isolated.

Bacterial sampling

Gaining access to the bacteria causing the pneumonia may be difficult. There are two main techniques involved in sampling bacteria or parasites that cause pneumonias:

- **Lung wash**: This involves passing a sterile catheter into the trachea of the reptile. This method is usually reserved for snakes and lizards and may be done in the conscious animal due to the lack of the cough reflex. Fractious animals may require sedation. Through this catheter, sterile saline may be infused, at doses equal to 0.5–1 ml per 100 g body weight, and immediately aspirated. This sample can then be cultured to identify the pathogen. Sample collection may be enhanced by holding the reptile upside down whilst aspirating.
- **Direct sampling**: This involves taking a swab directly from the site of the problem. This may be done via laparotomy or endoscopically. In the case of Chelonia, the reptile may be anaesthetised, the shell overlying the pneumonic lesion aseptically prepared and a small hole drilled through to enable the bacteriological swab to be passed.

Viral

Paramyxovirus: paramyxovirus is becoming increasingly commonly seen in snakes in captivity. This virus is highly infectious, being shed in respiratory secretions. It causes a haemorrhagic pneumonia and viraemia which affects other organs as well. There is no current treatment and it can be fatal. Diagnosis is based on clinical signs and serological tests on a blood sample.

Boiid inclusion virus: this has been associated with pneumonia in snakes – primarily pythons and boas. There is no treatment.

Herpes viruses: herpes viruses have been recorded in Mediterranean tortoises associated with upper respiratory tract infections which may lead to secondary pneumonias. Treatment can be attempted with the anti-viral drug acyclovir.

Cardiovascular disease

Infectious disease

There are few pathogens which specifically affect the cardiovascular system. Many of those which cause systemic illness and septicaemia are responsible for cardiac damage. In many cases the damage is due to a bacterial endocarditis which then causes micro-thrombi to seed off into the rest of the body as well as causing heart failure. Many of the Gram negative bacteria seen in reptiles, such as *Aeromonas* spp and *Pseudomonas* spp, are associated with heart disease. Diagnosis requires ultrasonography and radiology to determine heart size and internal structure. Electrocardiograms can also be used to aid diagnosis. Final proof of the organism involved depends on blood culture, which may be performed by direct cardiocentesis in a sedated or anaesthetised reptile.

Parasitic disease

There are several parasitic nematode worms which release microfilaria into the blood stream. These are microscopic young which may be transmitted from reptile to reptile by mosquitos and ticks. These parasites may cause thrombi to develop in any of the major blood vessels, causing ischaemic necrosis or cardiac damage. Other parasites, such as members of the fluke family, have also been isolated. The adult fluke is not normally the problem, but the eggs laid into the blood stream cause thrombi to form and so block capillary beds.

Nutritional disease

Hypoiodinism in chelonians has been associated with cardiac disease and goitre. The feeding of mineral-poor foods such as cucumber and lettuce or goitrogenic foods such as brassicas (e.g. cabbage, Brussels sprouts), may lead to this.

Oversupplementation with vitamin D_3 and calcium may lead to calcification of the *tunica media* of the major arteries, causing a decrease in their elasticity and so increased blood pressure. This may lead to heart failure or aneurysm formation.

Dietary deficiencies in vitamin E and/or selenium can lead to a condition known as white muscle disease, and can cause a dilated cardiomyopathy to develop. It may occur due to a dietary deficiency, or to overfeeding with high fat foods, such as snakes fed overweight rodents or fish, such as tuna and mackerel, which are high in polyunsaturates and increase the demand for vitamin E.

Urinary tract disease

Renal disease and gout

Damage to kidney function in terrestrial reptiles can lead to increasing blood levels of uric acid, the main excretory product of protein metabolism. Uric acid is not very water soluble, which means it rapidly reaches its precipitation point when crystals start to form and come out of solution. This may occur in internal organs such as the heart, kidneys and liver when it is known as visceral gout. It may also occur in the joints, when it is known as 'articular' gout, particularly of the distal limbs.

Many factors can contribute to renal damage and gout. Diet plays a role. Diets high in protein, in species designed for lower levels of protein, such as the herbivorous tortoises and green iguanas, when fed commercial cat or dog foods, cause excessive production of uric acid. In addition, these commercial mammalian diets often have too high levels of vitamin D_3 and calcium for the average herbivorous reptile. This leads to calcification of soft tissue structures, such as the *tunica media* of the arterial walls, and the kidneys themselves, leading to renal dysfunction and elevated blood uric acid levels.

Causes of renal disease

Parasitic

Flagellates, such as *Hexamita* spp, *Trichomonas* spp and *Giardia* spp have been reported in chelonians as well as in snakes and lizards, with involvement of the renal system. *Hexamita* spp are particularly damaging to the chelonian kidneys.

Kidney flukes are found in several species of kingsnake, and members of the Boiidae. They may block renal tubules and in high enough quantities cause kidney failure.

Coccidial parasites have also been seen in snakes, migrating from the digestive system by way of the cloaca, back up the ureters and into the kidneys.

Bacterial

Almost any bacteria found in the digestive system or environment of the reptile has the potential to cause renal disease if that reptile is stressed or debilitated in any way. Stresses can include incorrect environmental temperatures, incorrect feeding, malnutrition, rough and overhandling of the reptile. Bacteria commonly implicated include the *Salmonella* spp, *Aeromonas* and *Pseudomonas* spp. In some chelonians, the bacteria responsible for septicaemic cutaneous syndrome, *Citrobacter freundii*, may also cause disease. These bacteria gain access either via haematogenous spread from the gut, or via the cloaca, ascending the ureters.

Iatrogenic

Iatrogenic causes include certain nephrotoxic drugs, such as the aminoglycoside antibiotic family (e.g. gentamicin, amikacin etc.), and the diuretic frusemide. In addition, if sufficient muscle bruising occurs, such as when too firm a grasp is used when handling the patient, then myoglobin is released. This causes damage to the kidney filtration membrane.

Reproductive tract disease

Egg-binding or post-ovulatory stasis

Dystocia is common in many species of reptile, the commonest being chelonians and many of the lizard family such as green iguanas. It is often due to hypocalcaemia because of an inappropriate diet, however other causes include malformed eggs, fractured pelvic bones, cystic calculi, lack of nesting material or malnutrition of the female.

Dystocias can be difficult to diagnose in snakes, as they normally tend to be relatively quiet creatures. This difficulty is exacerbated in those species (e.g. garter snakes) which are viviparous (that is give birth to live young rather than eggs) in that any abdominal swelling is much less pronounced. Any previous history of passing eggs, and then the presence of a persistent caudally-located mass is of course highly suggestive. In addition, any evidence of a prolapse of the cloaca or distal reproductive tract also indicates dystocia (Plate 11.2).

In lizards, the patient may be obviously distended with eggs, and becomes progressively more moribund and lethargic. Many snakes can survive prolonged periods of dystocia, but lizards are not so resilient and dystocia may prove fatal within days.

Chelonia may show signs of discomfort and straining or they may show no signs at all. Radiographs are often the only way to tell if a chelonian is gravid.

Pre-ovulatory stasis

A condition recorded in both Sauria and Chelonia is pre-ovulatory stasis. This is when the ovaries produce follicles, which enlarge but do not shed into the reproductive tract. This results in two ovaries containing anywhere up to 30–40 yolks, displacing all other coelomic organs. Over time the affected reptile becomes anorectic and lethargic and often succumbs to secondary diseases and malnourishment. The cause of the condition is not fully understood.

Musculoskeletal disease

Metabolic bone disease

The disease is common in young growing lizards and chelonians that are being fed on a calcium deficient diet, often in conjunction with a vitamin D_3 deficiency due to a lack of ultraviolet light. (See also pages 152 and 154.)

The disease presents in lizards as an individual which is often weak and lethargic. The limbs are markedly swollen due to thickening of the bones. A lack of mineralisation causes the now primarily fibrous bone structure to weaken. The bones compensate for this by increasing their width. In addition, pathological fractures are common. Also softening of the jaws is common, and this can cause foreshortening of the mandible, due to the pull of the tongue and neck muscles.

In chelonians the disease is often seen as a softening and pyramiding of the shell. The plastron and carapace are weakened due to the hypomineralisation which allows the muscles to deform their structure. This is particularly obvious over the internal attachments of the fore- and hind limbs where depressions are seen. In some chelonians, for example, the softened shell allows the corners of the carapace to roll upwards.

Fractures

These may be pathological, as is seen in nutritional deficiencies of calcium, often combined with a lack of ultraviolet lighting. Alternatively they may be traumatic in origin.

Autotomy (tail shedding)

Autotomy, or spontaneous shedding, with subsequent regrowth of the tail is seen in some saurian species such as the gecko and iguanid families.

These lizards have fracture planes in their tails allowing a clean break, with minimal bleeding, to occur should a predator attack or a handler be overzealous in restraint attempts. The tail will subsequently regrow, but when it does so the lost coccygeal vertebrae are replaced with a rod of cartilage, and the scale pattern is frequently much more haphazard.

In iguanids, once the individual matures, autotomy is often lost. This can occur over the age of 2.5–3 years in the green iguana for example.

Neurological disease

Nutritional

Hypocalcaemic collapse

This is commonly seen in gravid lizards, such as green iguanas, when the blood calcium levels drop too low. The female becomes flaccidly paralysed, and unresponsive. Occasionally fine muscle tremors will be seen.

Hypovitaminosis B_1

This has been mentioned on page 153. It is seen in primarily fish eating reptiles such as garter snakes. The thiaminases present in salt-water fish break down the vitamin B_1 present in the food leading to a functional deficit. The presenting signs include opisthotonus and a lack of a righting reflex.

Biotin deficiency

This is seen in species fed mainly on unfertilised hen's eggs that contain large amounts of the antibiotin vitamin, avidin. This produces a relative deficiency in biotin which leads to muscle tremor and general weakness. Monitor lizards are commonly affected.

Hypoglycaemia

This is a condition seen in crocodiles. It is unknown why it occurs, but muscle tremor and weakness are seen.

Environmental

This can occur due to freezing injuries. These are seen in chelonians overwintering outside in the United Kingdom. Frost damage causes blindness, vestibular disease and death. There is no treatment.

Parasitic

Acanthamoebic meningoencephalitis is a condition seen primarily in snakes due to the gut parasites of the acanthamoeba family. Fits and opisthotonic seizures are seen. Treatment is generally unsuccessful.

Viral

Paramyxovirus

These have been reported in many species of snake. The virus causes haemorrhagic pneumonias but will also cause neurological signs such as the loss of righting reflexes. There is no current treatment.

Inclusion body disease of boiids

This is another viral condition seen primarily in boas and pythons. In pythons the disease is severe with infectious stomatitis, pneumonia and neurological signs such as loss of the righting reflex, disorientation and blindness often followed rapidly by death. In boas, the disease is fatal in young individuals. In older patients, the disease produces more chronic neurological signs with anorexia, vomiting and pneumonias. Neurological signs are milder, with a loss of ability to chew and swallow prey, and a loss of the striking reflex. There is no treatment for this disease.

Overview of reptile biochemistry

Blood for biochemical parameters is best collected in a heparinised container. This also applies for haematological parameter measurements as potassium EDTA-coated tubes often cause lysis of reptilian red blood cells, particularly in chelonians.

Liver parameters

There are no liver-specific enzymes in reptiles. The use of the enzyme aspartamine transaminase (AST) has been widely noted. Levels in excess of 150–200 IU/l are suggestive of problems, but as there is much species variation and this enzyme is found in the skeletal muscle as well it is only a guide.

Renal parameters

Uric acid is useful for uricotelic species such as most terrestrial chelonians, lizards and snakes. Levels over 450 μmol/l suggest renal problems, but care should be taken in carnivorous species such as snakes to ensure that they have not recently consumed a meal as this will falsely elevate uric acid levels. Uric acid levels will only be pathologically elevated if greater than 75% of the renal mass ceases to function, so this is not a sensitive test. Urea is much less useful, although it has been used in Chelonia immediately after hibernation to assess dehydration. Creatinine appears to be of no use in reptiles.

Glucose

Levels below 3 mmol/l are seen in the hypoglycaemic syndrome of crocodiles. Fits, incoordination and weakness are a common sign in malnourished reptiles, which will also show low blood glucose levels.

Calcium and phosphorus

Calcium levels vary between 2–5 mmol/l in most reptiles. Levels below 2 mmol/l can be seen in gravid female lizards with egg-binding, and young growing reptiles with metabolic bone disease. Calcium levels will increase up to four-fold in females producing eggs. Phosphorus levels vary from 0.3 mmol/l to 1.8 mmol/l. Calcium to phosphorus ratios of less than 1:1 have been used to indicate early renal disease.

Total proteins

Total protein levels are used to indicate general nutritional status and liver function. Dry chemistry techniques such as those commonly used in practice blood analysers are not accurate for albumin and globulin levels. Total protein values of 30–80 g/l have been quoted as normal.

Diseases of amphibians

Bacterial

Redleg

Redleg is a common disease seen in amphibians caused by the bacteria *Aeromonas* spp. It causes ulcerating red wounds, which give it its name (Plate 11.3). The bacteria also causes a septicaemic syndrome with the amphibian becoming bloated and rapidly going into renal and hepatic failure. Poor environmental conditions are often blamed.

Mycobacteria

Mycobacterial infections are caused by environmental species such as *Mycobacterium marinum*, which are extremely resistant species and cause classical tuberculous lesions mainly on the limbs or internal organs. The affected amphibian loses weight rapidly becoming emaciated. There is no effective treatment.

Fungal

Saprolegniasis

This is a common environmental fungal disease seen in all aquatic species. It is seen classically as strands of white, cottonwool-like material adhering to the skin surface (Plate 11.4). The condition is worsened in warmer waters.

Phycomycosis

This is due to common moulds such as *Mucor* spp. These are often darkly pigmented. These moulds will often affect amphibian eggs.

Viral

Herpes virus

A well-known viral condition of the North American leopard frog is casued by the herpes virus that induces a form of renal adenocarcinoma, known as Lucke's renal tumour. The tumour grows during the warmer months, with the virus being shed in the spring to infect other frogs. Renal failure occurs with chronic weight loss and death. There is no treatment for this condition.

Parasitic

Nematodes

The commonest nematode seen in anurans is the lungworm *Rhabdias* spp, the same family group of parasite as is seen in reptiles. In large numbers this parasite may cause pnuemonia. The parasite has a direct life cycle.

Other nematodes of the Strongyloides family may parasitise the gut and coelomic cavity, with large burdens resulting in poor growth and intestinal blockages.

Protozoa

Entamoeba ranurum: can cause damage to the large intestine of anurans, as well as causing liver infections and abscesses. These may lead to weight loss, diarrhoea with blood, anorexia and dehydration. This protozoa has also been associated with kidney damage in some species of toad and ascites and oedema of the limbs may be seen.

Oodimium pillularis: is a motile protozoan which affects many aquatic animals including amphibians. It damages the skin, and in tadpole stages damages the gills leading to anoxia. It is able to swim through the water from amphibian to amphibian and can therefore spread rapidly.

Metabolic bone disease

This is common, particularly in frogs and toads (anurans). There is often softening of the lower jaw which bulges laterally, weakness and paralysis of the limbs, with spontaneous fractures.

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Chapter 12

An Overview of Reptile and Amphibian Therapeutics

FLUID THERAPY

Maintenance requirements

Every reptile or amphibian has a fluid maintenance requirement, that is, fluid intake to replace everyday fluid losses. These losses, as for cats and dogs, occur in several ways, such as urine output, insensible losses through respiration, panting (often referred to as gular fluttering, as with birds) and salivation.

In most reptiles very little water is lost through the skin as sweat as reptiles have little or no skin sweat glands. Amphibians, however, will lose fluid readily across their semi-permeable skin membranes, and so need to remain close to a water source for nearly all of their lives.

Some reptiles will lose water through gular fluttering, examples are members of the Crocodylia as well as many desert-dwelling lizards.

Reptiles in particular are extremely good at conserving water. Most species are uricotelic, excreting uric acid instead of urea as their main form of urinary protein waste product. Uric acid requires very little water to be excreted with it, unlike urea in mammals, and so maintenance requirements are very much lower for these reptiles than for cats, dogs and other mammals. Other reptiles, mainly the aquatic and semi-aquatic species, excrete protein waste products as ammonia and urea. In the case of totally aquatic amphibians, species such as caecilians, ammonia is excreted, whereas the more terrestrial amphibians, such as toads, excrete urea, and one or two may produce uric acid.

Maintenance requirements can therefore vary widely. A desert-dwelling, uricotelic species may be able to cope with some water deprivation, while an ammontelic species, such as an aquatic turtle or amphibian, is used to large, regular fluid intakes and outputs and therefore has a higher maintenance requirement.

However, if a uricotelic reptile is deprived of water for prolonged periods of time, uric acid waste will not be excreted. This leads to a build-up of uric acid in the bloodstream. Once levels exceed 1500 μmol/l of uric acid, precipitation of uric acid crystals occurs inside the body, a condition known as 'visceral gout'. Once uric acid crystals are deposited in and around vital organs, such as the kidneys and heart, they cannot be removed and permanent damage has been done.

The volume of water consumed daily, then, varies from species to species. So do the sources of water. Herbivorous reptiles such as the Mediterranean tortoises get the majority of their daily fluid requirement from their diet. However, other herbivorous species, such as the green iguana, are used to living in tropical rainforest conditions where the relative humidity is 100%. Place this reptile into an arid vivarium and it will, with time, lose fluid progressively through its skin if it is not also provided with daily misting of its tank. Many reptiles will not drink from water bowls, only taking water from droplets on leaves in the wild. An example of this are many of the chameleon family as well as the previously mentioned green iguana.

To add to this, whenever ectothermic species such as reptiles are kept, it is important to take into account the environmental temperature requirements of that species. If the reptile is not kept within its preferred optimum temperature zone (POTZ), then it cannot achieve its preferred body temperature (PBT) and its internal physiological processes will not operate at their optimal rates, leading to inefficient water usage and consumption. A list of optimum temperature requirements can be found on page in Table 8.1.

The effect of disease on fluid requirements

Fluid loss may be rapid, due to water loss alone, such as occurs with acute diarrhoea, thermal burns or vomiting. In this case, the remaining extracellular fluid (ECF) becomes reduced, but is still of the same composition (*isotonic*). Alternatively, fluid loss may be due to long-term anorexia, producing a reduction in electrolytes and creating a *hypotonic* ECF. Finally, water deprivation or oral trauma preventing drinking will lead to increases in the tonicity of the ECF, and create a *hypertonic* dehydration.

With any disease, the need for fluids increases, even if no obvious fluid loss has occurred. This is due to a number of reasons. It may involve renal changes, such as increases in the glomerular filtration rate or reduction in water reabsorption by the collecting ducts so causing increased urine output. Or there may be reduced absorption of water from the small or large intestine.

Respiratory disease is a not uncommon finding in reptiles, especially tortoises and septicaemic snakes. In these animals chronic levels of lung infection can occur, with increased respiratory secretions being the result. Fluid loss via this route can be appreciable.

Another less obvious route is fluid and electrolyte loss through skin disease. Reptiles often suffer from serious burns from unprotected basking lamps and faulty heaters. Not only will there be serious fluid and electrolyte loss via full-thickness skin burns but these reptiles will succumb to secondary skin infections from environmental bacteria such as *Pseudomonas* spp. These produce lesions which resemble chemical or thermal burns, and leave large areas of weeping exudative skin for further fluid loss.

Finally we have to consider the need for fluid therapy during other forms of medical therapy, such as antibiotic treatment. Many of the more commonly seen bacterial infections in reptiles are caused by Gram negative bacteria, therefore the aminoglycoside family of antibiotics (gentamicin, tobramycin, amikacin etc.) has been widely used for treatment. This family of antibiotics has several serious side-effects, particularly in the dehydrated patient. The most serious of these is renal damage if for any reason the drug accumulates in the kidney. This can happen if there is reduced renal perfusion because of dehydration. Levels of the drug then reach toxic concentrations very quickly. The renal damage so caused can be easily enough to kill even a healthy reptile.

Post-surgical fluid requirements

Surgical procedures are more and more frequently being performed on reptiles and amphibians in both routine and emergency situations. Causes of fluid loss include the possibility of intrasurgical haemorrhaging. This will call for vascular support with an aqueous electrolyte solution or, in more serious blood losses (greater than 10% blood volume), colloidal fluids or even blood transfusions.

Even if surgery is relatively bloodless there are inevitable losses via the respiratory route. This is due to the drying nature of the gases used to deliver the anaesthetics commonly used in reptile and amphibian surgery. As many of these species are small in size they have a large lung surface area in relation to volume and hence a greater loss of fluid per unit time/per breath than larger animals. To exacerbate the situation, many patients are not able to drink immediately after surgery, and so the period without water or food intake may stretch to a few hours – enough time for any reptile or amphibian to start to dehydrate. Finally, some forms of surgery will lead to inappetance for a period, as for some forms of head trauma – such as the repair of tortoises that have gone ten rounds with the family lawnmower!

Electrolyte replacement

Other diseases, such diarrhoea, will cause fluid loss and metabolic acidosis due to the prolonged loss of bicarbonate. This is not uncommon in reptiles, and is often due to parasitism, such as amoebiasis, in snakes. There may also be chronic losses of potassium, in cases of chronic diarrhoea, due to the reduced absorption of this electrolyte by the large intestine.

Snakes will vomit after a meal if stressed, and may suffer from diseases of the stomach such as *cryptosporidiosis*, causing loss of fluid and hydrogen ions, and a resultant metabolic alkalosis. Other reptiles such as tortoises will rarely vomit, so the likelihood of fluid loss via this route is less common.

Fluids used in reptilian practice

Lactated Ringer's/Hartmann's

As with cats and dogs, lactated Ringer's solution is useful as a general purpose rehydration and maintenance fluid. It is particularly useful for reptiles and amphibians suffering from metabolic acidosis, such as those described above with chronic gastrointestinal problems, but can also be used for fluid therapy after routine surgical procedures.

Glucose/saline combinations

Glucose/saline combinations are useful for reptiles and amphibians, as they may have been through periods of anorexia prior to treatment, and therefore may well be borderline hypoglycaemic.

There is some evidence that in reptiles, and probably amphibians, the isotonicity of the extracellular fluids is lower than that of mammals. Studies on non-marine reptiles suggest that isotonicity for the majority is 0.8% rather than the 0.9% saline assumed for mammals. Because of this, a number of fluid combinations utilising the above two types of crystalloid support have been derived as follows:

- One third each of 5% glucose with 0.9% saline, lactated Ringer's solution and sterile water
- Nine parts 5% glucose with 0.9% saline to 1 part sterile water.

Many texts still advise that straightforward, undiluted lactated Ringer's solution or 4% glucose with 0.18% saline may be used, and glucose/saline solutions are particularly useful for amphibia, where the use of potassium-containing fluids should be avoided initially.

It is important that whatever fluid is administered it be warmed to the reptile or amphibian's preferred body temperature (approximately 30–35°C) before being given.

Protein amino acid/B vitamin supplements

Protein and vitamin supplements are useful for nutritional support. Products such as Duphalyte® (Fort Dodge) may be used at the rate of 1 ml/kg/day. They are used to replace nutrients in cases where the patient is malnourished or has been suffering from protein-losing enteropathy, such as may occur with heavy parasitism, or a protein-losing nephropathy, as in renal failure. It is also a useful supplement for patients with hepatic disease or severe exudative skin diseases, such as heater burns, in which blood proteins will be reduced.

Colloidal fluids

Colloidal fluids have been used in reptilian practice when intravenous administration has been possible. This limits their usefulness, as some reptiles are just too small to gain full vascular access, although there is some evidence that they may be used via the intraosseous route. They are used when a serious loss of blood occurs, in order to support central blood pressure. This may be a temporary measure whilst a blood donor is selected, or, if none is available, the only means of attempting to support such a patient.

Blood transfusions

Blood transfusions are indicated when the packed cell volume (PCV) has dropped below 0.05 l/l, and they may be given via intravenous or intraosseous routes. Cross-matching of blood groups does not appear to be necessary for one-off transfusions, but the same species should be used each time, i.e. green iguana to green iguana, boa constrictor to boa constrictor. In an emergency, it is possible to transfuse a member of a family group with another from the same group, i.e. iguanid to iguanid and boiid to boiid. Up to 2% body weight as blood may be taken from healthy species (Klingenberg, 1996), preferably into a pre-heparinised syringe before immediately transfusing into the recipient.

Oral fluids and electrolytes

Oral fluid administration may also be used in reptile and amphibian practice for those patients experiencing mild dehydration, and for home administration. Many products are available for cats and dogs, and may be used for reptiles. However, as with the crystalloid fluids, it is advisable to dilute these oral electrolytes by approximately 10%, otherwise their concentration will be greater than the reptile's extracellular fluid (ECF) and so water will move from the body into the gastrointestinal tract rather than the other way around. The inclusion of a probiotic with the electrolytes may aid recovery by normalising gut flora and digestion.

Calculation of fluid requirements

Fluid requirements may be calculated as for cats and dogs. It is worth noting that a lot of the fluid intake is normally consumed in food e.g. in the form of fresh vegetation for herbivorous species. This is difficult to take into consideration, and therefore it is safer to assume that the debilitated reptile will not be eating significant enough amounts for this to matter in the calculation. In any case, levels of fluid replacement rates have received relatively little research. Consequently for the vast number of reptiles and amphibians a calculated guess has to be made!

Frye (1991) recommends that levels of 20–25 ml/kg/day be used for hydration purposes in both reptiles and amphibians, and current literature suggests that rates across several species vary from 10–50 ml/kg/day.

The factor that limits the volume of fluids that can be administered is that, although intravenous and intraosseous routes may also be used, most fluids are given intracoelomically to the debilitated reptile. Reptiles and amphibians do not possess true diaphragms, therefore the thorax and abdomen are all interconnected in a coelom. When fluids are placed in this cavity, it is equivalent to giving intraperitoneal fluids to a mammal, but as there is no diaphragm these fluids can cause pressure to build up on the lungs. Excessive fluids may severely compromise respiration.

Excessive fluids given intravenously or intraosseously may also overload the circulation and cause pulmonary oedema. It can result in cardiac and renal overperfusion and solute wash-out, with potassium in particular being excreted with the increased diuresis causing a hypokalaemic crisis to develop. This may manifest itself initially as an anorectic reptile, but will progress to cardiac arrhythmias, coma and death.

As with cats and dogs, one can assume that 1% dehydration equates with a need to supply 10 ml/kg fluid replacement in addition to the maintenance requirements. It is also possible to make some qualitative assessment of the level of dehydration from the elasticity of the skin. Although reptile skin is not as elastic as mammalian, it should be freely mobile and recoil, albeit slowly, after tenting. Other factors to assess are the brightness of the corneas in species with mobile eyelids. In those without mobile eyelids (e.g. snakes) the collapse of the spectacle (the clear fused eyelids) is suggestive of dehydration. Other assessments of thirst and urate output can be made over 24 hours.

It is possible to estimate the degree of dehydration of a reptile patient as follows:

- 3% dehydrated – increased thirst, slight lethargy, decreased urates
- 7% dehydrated – increased thirst, anorexia, dullness, tenting of the skin with slow return to normal, dull corneas, loss of turgor of spectacles in snakes
- 10% dehydrated – dull to comatose, skin remains tented after pinching, desiccating mucous membranes, sunken eyeballs, no urate/urine output.

The alternative is to compare packed cell volumes and total protein levels to assess dehydration (Table 12.1), again with 1% increase in PCV suggesting 10 ml/kg fluid replacements are needed (this assumes no anaemia in the patient).

Table 12.1 Examples of normal packed cell volumes (PCV) and total blood proteins in selected species of reptile.

Species	PCV l/l	Total protein g/l
Green iguana (*Iguana iguana*)	0.25–0.38	28–69
Tortoise (*Testudo* spp.)	0.19–0.4	32–50
Ratsnake (*Elaphe* spp.)	0.2–0.3	30–60
Boa constrictor (*Boa constrictor constrictor*)	0.2–0.32	46–60

It is important not to exceed 25–30 ml/kg/day as a maximum for reasons mentioned above, whatever the level of dehydration of the patient. So rehydration of severely debilitated reptiles may take days to weeks. As with avian patients, therefore, making good the fluid deficit may need to be split over several days.

Equipment for fluid administration

Catheters

The most useful catheters for small reptiles and amphibians are the series of butterfly catheters available, often adapted from human paediatric medicine. These are extremely useful for the small and fragile vessels in these patients, as they have a short length of tubing attached to the needle. If the syringe or drip set is connected to this piece of flexible tubing, rather than directly to the catheter, there is less chance of the catheter becoming dislodged if the reptile moves. Also, the piece of clear tubing on the catheter allows you to see when venous access has been achieved, as blood will flow back into this area without the need to draw back thus collapsing the fragile veins.

To make effective use of a butterfly catheter, it is advisable to flush it with heparinised saline prior to use to prevent clotting. 25–27 gauge sizes are recommended. They may also be used to give intracoelomic fluids to reptiles, as the conscious patient may continue to move (particularly a problem in snakes) without dislodging the needle.

For larger patients, such as adult iguanas, monitor lizards and Crocodylia, 21–25 gauge over-the-needle Teflon®-coated catheters used for cats and dogs can be used.

Hypodermic or spinal needles

Hypodermic needles are useful for the administration of intraosseous, intracoelomic or subcutaneous fluids.

Intraosseous fluids may be the only method of central venous support in very small patients or patients in which vascular collapse is occurring. The proximal femur, tibia or humerus may be used. Entry can be gained using spinal needles. These have a central stylet to prevent clogging of the lumen of the needle with bone fragments after insertion. 23–25 gauge spinal needles are usually sufficient.

Straightforward hypodermic needles may also be used for the same purpose, although the risks of blockage are higher. Hypodermic needles may also be used, of course, for the administration of intracoelomic and subcutaneous fluids. Generally 23–25 gauge hypodermic needles are sufficient for the task.

Pharyngostomy or oesophageal tubes

Pharyngostomy tubes are often used in reptiles in order to provide nutritional support in as stress-free manner as is possible. They are also useful as a route for some fluid administration, as only liquid formulas will pass through these narrow (3.5–6.5 french) tubes. It should be noted though that in severely dehydrated individuals there is a real possibility that gut pathology may exist, so this route may need to be supplemented by others. This route therefore has limited use in facilitating fluid replacement, and is used mainly for nutritional support and rehydrating and replenishing the gut microflora.

Syringe drivers

For continuous fluid administration, such as is required for intravenous and intraosseous fluid administration, syringe drivers are being used more and more. The units themselves vary from the inexpensive, semi-disposable, battery-operated units available to the veterinary profession, right through to the more expensive digital units requiring mains electricity. As an investment for the practice they are well worthwhile, as they may be used for cat and small dog fluid administration as well. Their advantage is that small volumes, such as a fraction of a ml may be administered accurately per hour. An error of 1–2 ml in some of the smaller species dealt with over an hour could be equivalent to overperfusion of 50–100%! In addition it is almost impossible to keep gravity fed drip sets running at these low rates without blocking every few minutes.

Intravenous drip tubing

Particular fine drip tubing is available for attachment to syringes and syringe-driver units. It is useful if these are luer locking as this enhances safety and prevents disconnection when the patient moves.

Routes of fluid administration in reptile

As with cats and dogs the same medical principles broadly apply with five main routes of administration available as follows:

- Oral
- Subcutaneous
- Intracoelomic
- Intravenous
- Intraosseous.

Table 12.2 gives the advantages and disadvantages of each of the five routes.

Oral

Snakes

The oral route is not very good for seriously debilitated animals, but useful for those with pharyngostomy feeding tubes in place, or if the owner or handler is experienced in stomach tubing. This makes it useful for mild cases of dehydration where owners wish to home treat their pet. A stomach tube is passed by restraining the snake's head gently but firmly and then inserting a plastic or wooden tongue depressor to open the mouth. A lubricated feeding tube is then passed through the labial notch (the area at the most rostral aspect of the mouth without teeth) and to a depth of one third of the snake's length.

Lizards

Gavage (stomach) tubes or avian straight crop tubes or straightforward feeding tubes can be used to administer fluids directly into the oesophagus or stomach. The reptile needs to be firmly restrained to keep the head and oesophagus in a straight line. The mouth is opened with a plastic or wooden tongue depressor and the tube inserted to a depth of one third to one half the torso length of the reptile. This method is often stressful for the reptile. The alternative is to syringe fluids into the mouth, but this risks inhalation in a debilitated reptile. A pharyngostomy tube may be placed for nutritional support, and so may be used for fluid therapy.

Chelonians

The oral route can be used as for lizards and snakes. A pharyngostomy tube may be implanted as described below, and levels of 10 ml/kg at any one time can be administered. Alternatively, a stomach tube may be inserted each time it is needed. The feeding tube is first measured from the tip of the extended nose to the line where the pectoral and abdominal ventral scutes connect. It can then be lubricated and passed after extending the head and gently prising the mouth open with a wooden or plastic speculum (Fig. 12.1).

Placement of pharyngostomy tubes

Pharyngostomy tubes may be placed in any species of reptile, but are particularly useful in chelonians, such as the leopard tortoise (*Geochelone pardalis*) which can retract its head deep

Table 12.2 Advantages and disadvantages of various fluid therapies for reptiles and amphibians.

	Advantages	Disadvantages
Oral	• Minimal stress with experienced handler • Physiological route for fluid intake • Less risk of tissue trauma • Home therapy possible • Rapid administration	• Stressful with inexperienced handler • No use in cases of digestive tract disease • May damage stomach if the stomach tube is inserted too roughly • Rehydration rates are slow • Risk of inhalational pneumonia • Limited volumes may be administered at any one time
Subcutaneous	• Large volumes may be given at one time • Rapid administration possible, minimising stress • Uptake may be better than oral route in cases of digestive tract disease • Minimal risk of internal organ damage during administration	• May be uncomfortable for patient • Risk of muscle and subcutaneous tissue trauma • Rates of rehydration poor if severely dehydrated and peripheral vessels are collapsed • Only isotonic or hypotonic fluids may be administered • Darkening of the skin at injection site in many lizards such as chameleons and iguanas
Intracoelomic	• Large volumes may be administered at one time, increasing dosing intervals • Uptake is faster than subcutaneous route in dehydrated patients • Generally relatively painless route of administration	• Large volumes may cause pressure on the lungs (no diaphragm) • Rehydration rates may still be slow in severely hypovolaemic patients • Only isotonic or hypotonic fluids may be given • Increased risk of organ damage
Intravenous	• Rapid rehydration in even severely dehydrated patients is possible • Colloidal fluids and blood transfusions possible • Use of intravenous catheters and syringe drivers makes accurate, continuous, reduced-stress dosing possible	• Size of reptile may prevent venous access • Species of reptile (e.g. snakes) may make venous access difficult without minor surgery • Veins are more fragile than mammalian vessels • Increased skill levels and equipment requirements
Intraosseous	• Rapid rehydration possible even with collapsed peripheral vasculature • Accurate dosing and continuous perfusion possible • Use of colloidal fluids and blood transfusions possible • Useful in smaller species and species where venous access is difficult	• Not useful in presence of infection (osteomyelitis) or skeletal nutritional disease (metabolic bone disease) • Sedation, local or general anaesthesia is required • Tolerance may be poor in some species

inside its shell, making repeated stomach tubing impossible. It also significantly reduces the stress and trauma of repeatedly passing a stomach tube in long-term anorectic reptile patients.

The steps for placement are as follows:

(1) Sedation or anaesthesia is required, and good analgesia post implantation.

(2) Surgically prepare the site with 0.25–0.5% povidone-iodine, being particularly scrupulous as reptile skin is notoriously dirty. In chelonians, the implantation site is the ventral aspect of the lateral neck, 3–4 cm caudal to the angle of the jaw. In snakes and lizards it is the ventrolateral aspect of the throat region, 5–10 cm caudal to the angle of the jaw.

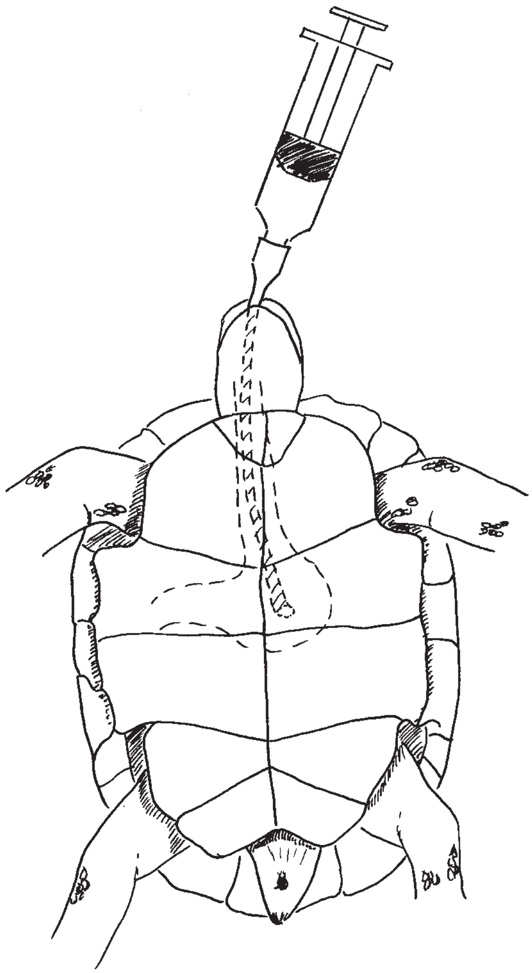

Fig. 12.1 Placement and depth of insertion of a stomach tube in a chelonian.

(3) A pair of curved haemostats is placed in through the mouth and pushed laterally and ventrally, tenting the skin above them.
(4) A sharp incision is made with a scalpel blade, over the point of the haemostats, through the skin and the underlying muscle.
(5) The tubing, preferably as large a diameter as will comfortably fit down the oesophagus (Foley catheters are useful in tortoises), is grasped with the haemostats as they protrude out through the incision, and then pulled into the pharynx and pushed down into the oesophagus.

NB The tube should be measured prior to implantation so the depth of insertion is known. It is measured in tortoises from the site of the tube incision to the mid-portion of the plastron, halfway through the abdominal scutes (page 116). A further length should then be allowed, in order to attach the end of the feeding tube to the dorsal aspect of the carapace.

(6) Once in place, two pieces of zinc oxide tape may be attached to the tube close to the skin surface. Through this, sutures may be placed, attaching this to the skin itself. The tube may then be attached to the midline cranial carapace in tortoises, or taped to the side of the neck for snakes and reptiles, and a bung inserted (Fig. 12.2, Plate 12.1). Care of the tube is as for nasogastric tubes in cats and dogs. For example, plain water should be flushed through the tube prior to administering food to ensure correct placement. This should also be done after feeding to flush food debris out of the tube.

Subcutaneous

Snakes

The lateral aspect of the dorsum of the snake, in the caudal third of its body, is the ideal site for subcutaneous fluid administration. This is a good technique for use for routine post-operative administration of fluids to patients undergoing minor surgical procedures such as skin mass removals. If positioned correctly, there is a lymph sinus running lateral to the epaxial muscles on either side, just subcutaneously, which can be used for moderately large volumes. It may however still be necessary to use several sites.

Lizards

The lateral thoracic area is easily used for smaller volumes of fluids at any one site. There is a risk of the reptile developing a darkened, pigmented area over the injection site, particularly in the chameleon family.

Fig. 12.2 A pharyngostomy tube in place in an anorectic spur-thighed tortoise (*Testudo graeca*).

Chelonians

The subcutaneous route is easily used for post-operative fluids and mild dehydration in this species. Fluids may be given in the area just cranial to the hind limbs, or in the skin folds just lateral to the neck. Relatively large volumes may be given via this route.

Intracoelomic

Snakes

The intracoelomic route is useful for more seriously dehydrated reptiles, as there is a greater vasculature at this site for absorption. The needle or butterfly catheter is inserted two rows of lateral scales dorsal to the ventral scutes in the caudal third of the snake, but cranial to the vent. The needle is inserted so that it just penetrates the body wall, the plunger of the syringe is pulled back to ensure no organ puncture has occurred and the fluids administered. If correctly inserted there will be no resistance to the injection.

Lizards

Because of the positioning necessary for administration, the intracoelomic route may be a stressful method of fluid administration. As for small mammals, the lizard should be placed in dorsal recumbancy with its head downwards to encourage the gut contents to fall cranially and away from the injection site. The needle, preferably 25 gauge or smaller, is advanced slowly to just pop through the abdominal wall in the lower right ventral quadrant. The syringe plunger should be pulled back to ensure that no organ has been penetrated, and the fluids can be administered without any resistance.

Chelonians

The intracoelomic route can be used in tortoises up to a maximum of 20–25 ml/kg/day only, otherwise, due to the confines of the rigid shell, the fluids will place too much pressure on the lung fields. The area cranial to the hind limbs is used, i.e. the same site as for subcutaneous routes, but the chief difference is depth. The concern with this route is that the bladder lies in this area, and if full may be punctured. The other route is the cranial access site. This is located lateral to the neck and medial to the front limb and is more epicoelomic than truly intracoelomic. The needle is kept close and parallel to the plastron and a $\frac{3}{4}$-in needle may be inserted to the level of the hub.

Intravenous

Snakes

There are no major vessels for intravenous use in snakes which are easily accessible. If an intravenous route is to be used one of the following is required.

Ventral tail vein: this is more of a plexus of veins, and may be accessed from the ventrum. The needle is inserted midline, one third of the tail length from the vent, and advanced until it touches the coccygeal vertebrae at a 90-degree angle. The needle is then retracted slightly whilst drawing back on the syringe until blood flows into the hub. Fluids may then be given slowly.

Palatine vein: this is present on the roof of the mouth, as its name suggests, and is paired. Cannulation may be performed with a 25–27 gauge butterfly catheter although the snake usually has to be sedated or anaesthetised to gain access.

Jugular vein: these also can only be accessed in an anesthetised or sedated snake. To gain access, a full-thickness skin cut-down procedure may be performed 5–7.5 cm caudal to the angle of the jaw, two rows of scales dorsal to the ventral scutes. The jugular vein can then be seen medial to the ribs. An over-the-needle catheter is best for this, and should then be sutured in place, therefore a catheter with plastic wings is advised.

Intracardiac: this site can be used in emergencies. The heart may be catheterised under sedation or anaesthesia only. On turning the snake onto its back, the heart may be seen to beat against the ventral scale, approximately one quarter of its length from the snout. A 25–27 gauge over-the-needle catheter may be inserted between the scales, ventrally, in a caudocranial manner at 30 degrees to the body wall into the single ventricle. A bolus may be administered, or it may be taped, glued or sutured in place for 24–48 hours.

Lizards

The intravenous route can be difficult in small lizards, and frequently requires sedation or anaesthesia. Several veins may be tried.

Cephalic vein: this is approached in the anaesthetised lizard by performing a cut-down procedure on the cranial aspect of the middle of the antebrachium, perpendicular to the long axis of the radius and ulna. The vessel may then be catheterised using an over-the-needle catheter, which is then sutured in place. This technique is really only useful for lizards over 0.25 kg in weight.

Jugular vein: this vessel may be accessed via a cut-down technique in the anaesthetised or sedated lizard. An incision is made in a craniocaudal direction from 2.5 cm caudal to the angle of the jaw. An over-the-needle catheter may then be sutured in place.

Ventral tail vein: this is more of a plexus of veins. It is accessed from the ventral aspect of the tail and can be performed in the conscious lizard. It is frequently only suitable for one-off bolus injections, and special care should be taken with species which exhibit autotomy (spontaneous tail shedding) such as day geckos and green iguanas. The needle is inserted at 90 degrees to the angle of the tail and advanced until it touches the coccygeal vertebrae. It is then withdrawn slightly while drawing back on the syringe. When blood flows into the syringe, the infusion may begin (Fig. 12.3).

Chelonians

There are two main intravenous routes, the dorsal tail vein and the jugular veins.

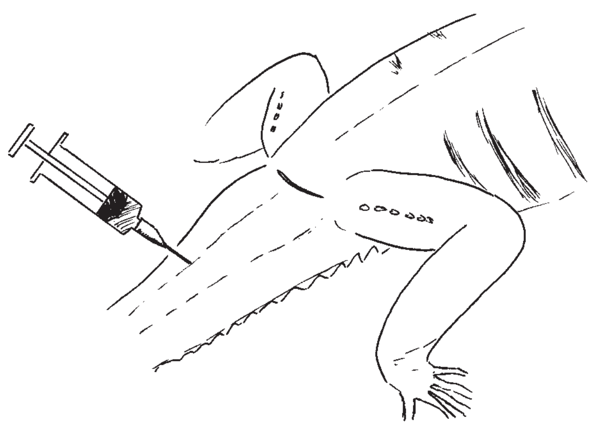

Fig. 12.3 Green iguana in dorsal recumbancy for ventral tail vein fluid administration or blood sampling.

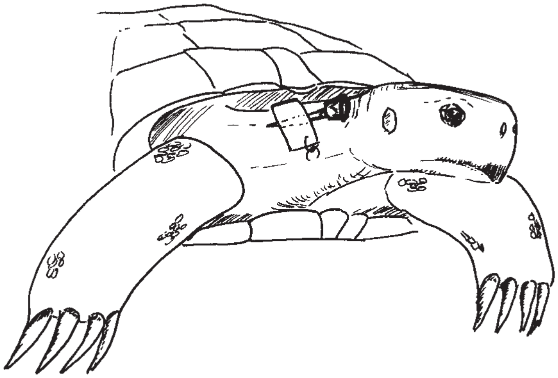

Fig. 12.4 Placement of a jugular catheter in a chelonian.

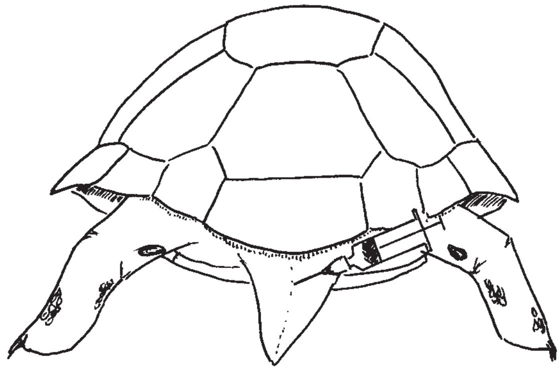

Fig. 12.5 Access to dorsal tail vein in chelonian for fluid administration or blood sampling.

Jugular vein: these may be accessed for catheter placement in the sedated or anaesthetised tortoise. The neck is extended and the head tilted away from the operator to push the neck towards him or her. The jugular vein runs from the dorsal aspect of the eardrum along the more dorsal aspect of the neck (Fig. 12.4). An over-the-needle catheter may be placed directly, or, in thicker-skinned animals, a cut-down technique employed.

Dorsal tail vein: this is more of a plexus of veins. Therefore it is often not possible to give large volumes of fluids, and certainly not possible to place a catheter. Access is midline, on the dorsal aspect of the tail. The needle is inserted at a 90-degree angle until it hits the coccygeal vertebrae. The needle is then pulled back, drawing back on the syringe at the same time, until blood flows into the hub (Fig. 12.5).

Intraosseous

Snakes

The intraosseous route is not possible in the snake.

Lizards

The intraosseous is a good route for the smaller species of lizards, where venous access is restricted or difficult. There are a few access points to choose from. Hypodermic or spinal needles of 23–25 gauge sizes may be used.

Proximal femur: this may be accessed from the fossa created between the greater trochanter and the hip joint. This route may be difficult due to the 90-degree angle the femur often forms with the pelvis.

Distal femur: this is relatively easy to access from the stifle joint. It does restrict the movement of the stifle, but it is easier to bandage the catheter in to this site and access to the medullary cavity of the femur is certainly easier via this route. Sedation or anaesthesia is required. See below for the placement technique.

Proximal tibia: this again is possible in the larger species. Anaesthesia and sedation is needed, and the spinal needle or hypodermic needle may be screwed into the tibial crest region in a proximodistal manner.

Placement of distal femoral intraosseous catheters in lizards

The technique for placement of a distal femoral intraosseous catheter in a lizard is explained in detail below.

(1) Sedation or anaesthesia (local or general) is needed, and in all cases it is advised that good analgesia is administered.

(2) Surgically scrub the area overlying the craniolateral aspect of the stifle joint using povidone-iodine. It is important that placement of the catheter or needle is performed as aseptically as possible.
(3) Take a 20–23 gauge spinal or hypodermic needle and insert it in through the ridge just proximal to the stifle joint, screwing it into the bone in the direction of the long axis of the femur proximally.
(4) Flush the needle with heparinised saline (the advantage of a spinal needle is that it has a central stylet which helps prevent it from becoming plugged with bone fragments).
(5) Tape the needle securely in place and apply an antibiotic cream around the site. It may be worthwhile radiographing the area to ensure correct intramedullary placement of the needle.
(6) Once the needle or catheter has been correctly placed, attach the intravenous tubing and bandage it securely in place by wrapping bandage material around the leg of the patient.
(7) Finally, it may be necessary to immobilise the limb by bandaging it to a splint to prevent dislodgement of the catheter, which should now be attached to a syringe driver.

Chelonians

Two main intraosseous sites can be used.

Plastrocarapacial junction/pillar: this is the pillar of shell which connects the plastron to the carapace. It is approached from the caudal aspect, just cranial to one of the hind limbs. The spinal or hypodermic needle (21–23 gauge) is screwed into the shell attempting to keep the angle of insertion parallel with the outer wall of the shell, so entering the shell bone marrow cavity (Fig. 12.6). In larger older species, the shell may be too tough to allow penetration.

Proximal tibia: this may be approached as for lizards. The area is thoroughly scrubbed with 0.25–0.5% povidone-iodine and the hypodermic or spinal needle is screwed into the tibial crest in the direction of the long axis of the tibia distally.

Routes of fluid administration in amphibians

Cutaneous

The cutaneous route is unique to amphibians and makes use of their semi-permeable skin. It can be used only with mildly dehydrated amphibians, and should only involve the use of dechlorinated, plain water. It should be warmed to the amphibian's preferred body temperature and be well oxygenated before immersing the patient. Absorption will occur across the skin membranes.

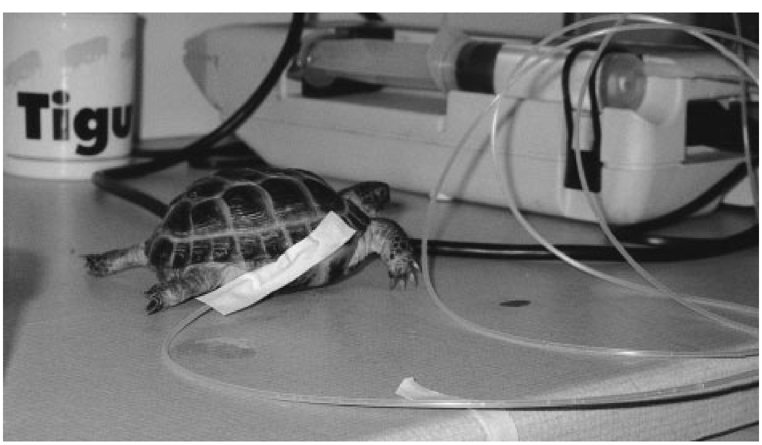

Fig. 12.6 Intraosseous fluid administration via the plastrocarapacial pillars. Note syringe driver in background.

Oral

This route can be used for hypotonic fluid therapy via a small feeding tube inserted orally. The danger is that trauma can easily occur during restraint and opening of the amphibian's mouth during this procedure. In addition the process is moderately stressful.

Intracoelomic

This is accessed in the right lower ventral quadrant of the 'abdomen'. The amphibian should be placed in dorsal recumbancy and with its head down to allow coelom contents to fall away from the injection site.

Intravenous

In the larger anurans and some salamanders, the midline ventral abdominal vein may be used for bolus fluids or blood transfusions. The vessel, as its name suggests, lies midline just below the skin surface and runs from the pubis area of the pelvis to the xiphoid of the sternum. A 25–27 gauge insulin needle may be used to gain access, although the vessel is very fragile and care should be taken not to rupture it.

Treatment of reptilian diseases

As this text is aimed at the veterinary nurse or technician it is not intended to give exhaustive lists of treatments or drug dosages, rather to give an idea of the treatments possible and the techniques useful to aid recovery. For drug dosages the reader is referred to one of the many excellent texts listed in the additional reading list at the end of this chapter.

Metabolic scaling of drug dosages

It should be mentioned that, due to the lack of research, many drugs have not been evaluated in reptiles and amphibians.

Drug doses may (with care) be extrapolated from known doses in other species. However, to do this, the differences in basal metabolic rate (BMR) or metabolism should be taken into consideration (see Chapter 10, on reptile and amphibian nutrition). Reptiles have a much lower metabolic rate than mammals, and this is reflected by the fact that they excrete drugs at slower rates. The environmental temperature at which the reptile or amphibian is kept, due to their ectothermic nature, will also greatly affect their metabolic rate and hence excretion of any drug administered. Therefore, dosages and dose rates are often much lower in reptiles than in mammals.

A formula has been derived to 'metabolically scale' the dosage of a drug in a tested species, such as a dog, to an untried one, such as a snake. For those keen to read more on this subject the reader is referred to the BSAVA Manual of Reptiles (1992 edition).

Reptile dermatological disease therapy

Table 12.3 highlights some of the treatments and therapies commonly used for the management of reptilian dermatological diseases.

Reptile digestive tract disease therapy

Table 12.4 highlights some of the treatments and therapies commonly used for the management of reptilian digestive tract diseases.

Reptile respiratory and cardiovascular disease therapy

Table 12.5 highlights some of the treatments and therapies commonly used for the management of reptilian respiratory and cardiovascular diseases.

Reptile reproductive tract disease therapy

Table 12.6 highlights some of the treatments and therapies commonly used for the management of reptilian reproductive tract diseases.

Table 12.3 Treatment of skin diseases.

Diagnosis	Treatment
Ectoparasites	
Mites	Ivermectin 0.2 mg/kg injection on 2–3 occasions at 10–14 day intervals. Can spray environmental mixture of 0.5 ml ivermectin + 1 litre water with 1–2 ml propylene glycol to aid mixing to remove remaining mites. Fipronil has also been used topically, sprayed onto a cloth and wiped over the reptile
Ticks	Manual removal, topical ivermectin/fipronil. Treat for secondary bacterial infection
Blowflies	Manual removal, often under sedation, antibiosis and treatment of initiating cause
Leeches	Manual removal after applying lignocaine to leech
Bacterial, fungal and viral skin diseases	Mycobacterial infections require surgical excision. For topical fungal infections use enilconazole washes, but difficult to treat if systemic. Some herpes virus infections may be treated with acyclovir topically as ointment or orally once daily at 80 mg/kg (Stein, 1996)
Dysecdysis	(1) Rehydrate patient (2) Treat underlying cause (3) Luke-warm water shallow bathing, allow access to abrasive surfaces for snakes, e.g. wet towels. (4) Retained spectacles in snakes may be removed carefully with viscous tear drops and moistened cotton buds.
Scale rot	(1) Isolate bacteria/fungi involved and obtain sensitivity. (2) Blisters treated topically dilute povidone iodine, silver sulfadiazine cream/enilconazole washes. (3) Parenteral antibiosis (4) Prevention geared to reducing substrate moisture and increase hygiene.
Abscesses	Surgical therapy due to fibrous nature. Requires debridement and topical antiseptic with systemic antibiosis based on culture and sensitivity.

Table 12.4 Treatment of digestive system diseases.

Diagnosis	Treatment
Mouth rot	Antibiosis based on culture and sensitivity. Necrotic tissue should be debrided under sedation/anaesthesia. Topical compounds containing silver sulfadiazine and framycetin are useful. Intralesion injections of antibiotic and vitamin C advised (Frye, 1991). For Chelonian herpesvirus, use topical iodine washes and acyclovir ointment.
Stomach diseases	***Tumours:*** surgical option. ***Nematodes:*** ivermectin 0.2 mg/kg once, or fenbendazole 100 mg/kg orally once, or oxfendazole 60 mg/kg once. Note: dose may require repeating. ***Cryptosporidiosis:*** unrewarding, but metronidazole may be used (may be toxic in indigo and king snakes) or use spiramycin and paromycin. Raising environmental temperature to 80°F may help.
Intestinal diseases	***Nematodes:*** see stomach diseases. **NEVER USE IVERMECTIN IN CHELONIA AS IT IS LETHAL** ***Entamoebiasis:*** metronidazole 160 mg/kg orally once daily for 3 days (beware toxicity in indigo and king snakes). ***Coccidiosis:*** sulfadimidine, orally, 50 mg/kg once daily for 3 days ***Flagellates:*** (Chelonia particularly) metronidazole 260 mg/kg orally once.
Liver diseases	***Entamoebiasis:*** see intestinal diseases. ***Hepatic lipidosis:*** supportive nutritional and fluid therapy. Use of anabolic steroids and thyroxine in Chelonia may be helpful.

Table 12.5 Treatment of respiratory and cardiovascular system diseases.

Diagnosis	Treatment
Parasitic respiratory disease	***Nematodes:*** Ivermectin may be used at 0.2 mg/kg **EXCEPT IN CHELONIA**. Alternatively, fenbendazole and oxfendazole may be used (see intestinal disease treatment, Table 12.4). ***Pentastomes:*** Manual removal or levamisole at 5 mg/kg may help.
Bacterial respiratory disease	Based on culture and sensitivity results. Lung washes may be used to collect samples for this, and to flush out infection if antibiosis is used in the lung wash.
Cardiovascular disease	***Heart failure:*** may use furosemide, but care should be taken as nephrotoxic in the long-term. ***Filariasis:*** Ivermectin 0.2 mg/kg. Raising environmental temperature may help to kill adult worms. ***Goitre:*** Iodine supplement at 2–4 mg/kg orally once weekly (Stein, 1996).

Table 12.6 Treatment for reproductive system diseases.

Diagnosis	Treatment
Dystocia (post-ovulatory stasis, Fig. 12.7)	Provide nesting material and quiet location. Supplement with calcium gluconate 100 mg/kg intramuscularly if you believe hypocalcaemic paralysis has occurred. Oxytocin at 5–35 IU/kg once. Fluid therapy to correct dehydration. Percutaneous/per cloacal aspiration of egg contents via needle and syringe (see Table 6.6) to collapse egg. Surgical caesarian (Fig. 12.8, Plate 12.2) may be required as a last resort.
Pre-ovulatory stasis	Surgical spey advised – seen in Sauria and Chelonia, with supportive therapy initially (Plate 12.3).

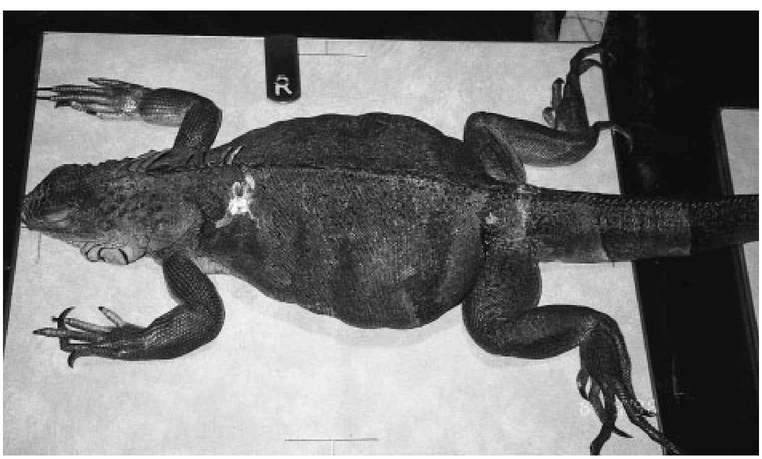

Fig. 12.7 Heavily pregnant female green iguana with post-ovulatory stasis.

Fig. 12.8 Surgical removal of eggs from same iguana.

Table 12.7 Treatment of musculo-skeletal diseases.

Diagnosis	Treatment
Metabolic bone disease	Correction of dietary deficiency and possible UV light deficiency. In cases of hypocalcaemic paralysis 100 mg/kg calcium gluconate intramuscularly is advised.
Fractures	In cases of metabolic bone disease it is better to correct diet and splint fractures than repair surgically. ***Lizards:*** for one fore limb fracture bandage limb to body wall (see Fig. 12.9). For bilateral humeral fractures use a coaption splint. For one hindlimb fracture bandage limb to tail base. For digital fractures ball bandage as for avian patients. ***Chelonia:*** possible to bandage limb into shell. This is useful in cases of metabolic bone disease. Spinal fractures should be splinted as neural control may be regained. All species may require external coaption or internal surgical fixation to mend fractures.
Tail loss	For young iguanids and geckos treat stump as an open wound and dress with topical silver sulfadiazine cream or iodine antiseptic (dilute). For agamids or species not showing autonomy (tail re-growth) and older iguanids which lose this ability, suture the stump surgically.

Reptile musculoskeletal system disease therapy

Table 12.7 highlights some of the treatments and therapies commonly used for the management of reptilian musculoskeletal system diseases.

Reptile neurological system disease therapy

Table 12.8 highlights some of the treatments and therapies commonly used for the management of reptilian neurological system diseases.

Treatment of amphibian diseases

Table 12.9 highlights some of the treatments and therapies commonly used for the management of amphibian diseases.

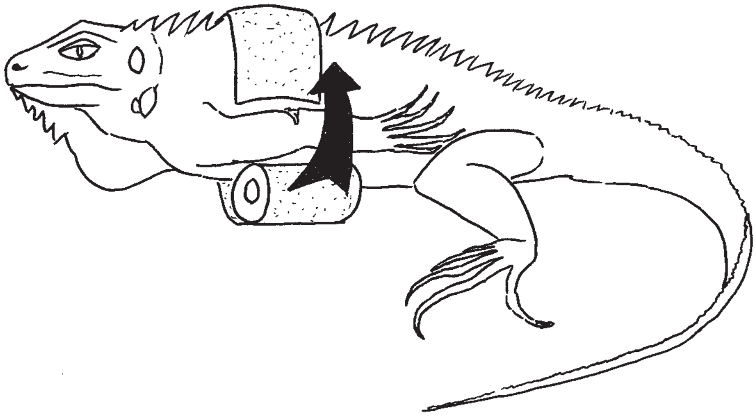

Fig. 12.9 Bandaging a fore limb to the body wall as a conservative method of treating a humeral fracture in a lizard.

Table 12.8 Treatment of nervous system diseases.

Diagnosis	Treatment
Hypocalcaemic tetany	Over the short-term use calcium gluconate 100 mg/kg intramuscularly. Over the long-term, administer dietary calcium, vitamin D3 and UV light supplementation.
Hypovitaminosis B1	Over the short-term, thiamine injections 25 mg/kg once daily. Over the long-term cook food to destroy thiaminases, or change to a non-thiaminase containing diet, or supplement with thiamine at 35 mg/kg of food given.
Biotin deficiency	Over the short-term give a vitamin B complex by injection. Over the long-term, supplement the diet with vitamin B complex powder or stop feeding unfertilised hens eggs.
Hypoglycaemia	Oral administration of 3 g/kg glucose solution (Stein, 1996)

Table 12.9 Treatment of diseases of amphibia.

Diagnosis	Treatment
Redleg	Based on sensitivity results. Enrofloxacin at 5 mg/kg orally daily. Tetracyclines, e.g. oxytetracycline, at 50 mg/kg
Saprolegnia	Dilute topical malachite green (a fish preparation).
Phycomycosis	Dilute topical malachite green (not always successful).
Parasitic nematodes	Fenbendazole orally 50 mg/kg once, or ivermectin 0.2 mg/kg orally once.
Protozoal diseases	*Entamoeba ranarum* in anurans may be treated with metronidazole at 100 mg/kg orally once. *Note*: may be toxic.
Metabolic bone disease	Dietary supplementation with calcium and vitamin D3. Flaked fish foods also contain these two nutrients.

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