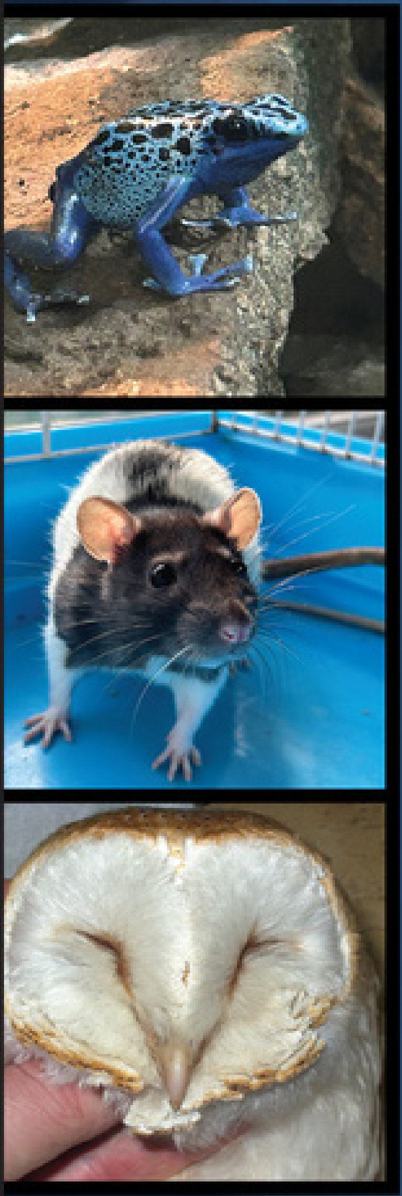

Third Edition

Veterinary Nursing of Exotic Pets and Wildlife

Simon J. Girling

WILEY

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Foreword

Veterinary Nursing of Exotic Pets has been a core textbook for veterinary nurses for over 20 years. The book is an invaluable resource for Registered Veterinary Nurses (RVN), Certified Veterinary Technicians and student vets and nurses both in the UK and internationally. This 3rd edition provides a timely update sharing current best practice across all key species; small mammals, birds, reptiles and amphibians with the addition of a new and much needed wildlife chapter. The addition of this new chapter supports nurses with their knowledge and understanding of wildlife and crucially includes wildlife emergency and critical care medicine as well as the wildlife rehabilitation and release considerations, that need to be made when nursing wildlife. The book provides veterinary nurses all that they will need to support them in the nursing care of these different species. The new appendices are an excellent addition to the book, the first, providing example care plans which can be used as templates to support delivery of care to exotic pets and wildlife. The second appendix is also very important as it provides readers with a list of relevant legislation and guidelines for exotic pets and wildlife to ensure that veterinary nurses, when caring for these different species are working within the scope of their practice within clear legislative frameworks.

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Abbreviations

ACE	angiotensin-converting enzyme
ACP	acepromazine
ACTH	adrenocorticotropic hormone
AI	avian influenza
ALSV	avian leukosis and sarcoma virus
ALT	alanine aminotransferase
APH	African pygmy hedgehog
APHA	Animal and Plant Health Agency
APV	avian polyomavirus
AST	aspartate aminotransferase
AVT	arginine vasotocin
BMR	basal metabolic rate
CDV	canine distemper virus
CK	creatine kinase
CNS	central nervous system
COX	cyclooxygenase
CPDA	citrate/phosphate/dextrose/adenine
CPK	creatine phosphokinase
CPR	cardiopulmonary resuscitation
CRF	chronic renal failure
CT	computed tomography
DEFRA	Department of the Environment, Farming and Rural Affairs
ECF	extracellular fluid
EDTA	ethylenediaminetetraacetic acid
EFA	essential fatty acid
EPEC	enteropathogenic *Escherichia coli*
ERE	epizootic rabbit enteropathy
ET	endotracheal
$ETCO_2$	end-tidal carbon dioxide
FMR	field maintenance requirement
FSH	follicle-stimulating hormone
GALT	gut-associated lymphatic tissue
GFR	glomerular filtration rate
GGT	gamma-glutamyltransferase
GLDH	glutamate dehydrogenase
GnRH	gonadotropin-releasing hormone
HPAI	high pathogenic avian influenza
IBD	inclusion body disease
IPPV	intermittent positive pressure ventilation
LCMV	lymphocytic choriomeningitis virus
LDH	lactate dehydrogenase
LDL	low-density lipoprotein
LPAI	low pathogenic avian influenza
MAC	minimum alveolar concentration
MBD	metabolic bone disease
MCV	mean cell volume
MER	maintenance energy requirement
MHV	mouse hepatitis virus
MRI	magnetic resonance imaging
MuHV	murid herpesvirus
NALT	nasal-associated lymphatic tissue
NSAID	non-steroidal anti-inflammatory drug
NSHP	nutritional secondary hyperparathyroidism
PBA	post-brumation anorexia
PBFD	psittacine beak and feather disease
PBT	preferred body temperature
PCR	polymerase chain reaction
PCV	packed cell volume
PDD	proventricular dilatation disease
PHV	pigeon herpesvirus
PMV	paramyxovirus
POTZ	preferred optimum temperature zone
RER	resting energy requirement
RHD	rabbit haemorrhagic disease
RHDV	rabbit haemorrhagic disease virus
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
SCUD	septicaemic cutaneous ulcerative disease
SMEC	specific minimum energy cost
SMR	standard metabolic rate
SVL	snout-to-vent length
TPeC	*Treponema paraluisleporidarum* ecovar Cuniculus
VHS	vertebral heart score
YPDS	young pigeon disease syndrome

Part I Small Mammals

Chapter 1 Basic Small Mammal Anatomy and Physiology

Classification of small mammals

The commonly seen species of small mammals in veterinary practice are classified in Table 1.1.

RABBIT

Biological average values for the domestic rabbit

Table 1.2 gives the biological parameters for domestic rabbits.

Musculoskeletal system

The skeletal system of rabbits is light. As a percentage of body weight, the rabbit's skeleton is 7–8%, whereas the domestic cat's skeleton is 12–13%. This makes rabbits prone to fractures, especially of the spine and the hindlimbs.

Skull

Unlike many rodents the mandible is narrower than the maxilla, and the temporomandibular joint has a wide surface area, allowing lateral movement of the mandible in relation to the maxilla. The hemi-mandibles are fused rostrally with a fibrocartilaginous ligament which is also unusual for many rodents.

Axial skeleton

The spinal formula is generally C7, T12, L7, S4, Ca16 (where C represents cervical vertebrae; T, thoracic vertebrae; L, lumbar vertebrae; S, sacral vertebrae; Ca, coccygeal vertebrae). However, many rabbits have 13 thoracic and 6 lumbar while some have 13 thoracic and 7 lumbar vertebrae so there is considerable breed and individual variation. The cervical vertebrae are box-like and small and give mobility. The thoracic vertebrae possess attachments to the 12 (usually) paired ribs, which are flattened in comparison to cat's ribs. The first seven pairs of ribs articulate directly with the sternum. The last five pairs do not, with the most caudal three pairs being unconnected to the rest and so are free floating. The pelvis is narrow and positioned vertically. The iliac wings meet the ischium and pubis at the acetabulum, where an accessory bone unique to rabbits, called the os acetabuli, lies. The pubis forms the floor of the pelvis and borders the obturator foramen which is oval in rabbits.

Appendicular skeleton

The scapula is slender and there is a hooked supra-hamate process projecting caudally from the hamate process. The scapula articulates with the humerus which in turn articulates with the radius and ulna. In rabbits, the ulna fuses to the radius in older animals and the two bones are deeply bowed. The radius and ulna articulate with the carpal bones, which in turn articulate with the metacarpals and the five digits.

The femur is flatter than a cat's ventrodorsally, and the tibia and fibula are fused in the rabbit. The tibia articulates distally with the tarsal bones where there is a prominent calcaneus bone. The tarsals articulate with the metatarsals which articulate with the four hindlimb digits.

The hindlimbs are well muscled and powerful.

Respiratory anatomy

Upper respiratory tract

Rabbits, like horses, are nasal breathers, with the nasopharynx permanently locked around the epiglottis. For this reason, upper respiratory disease or evidence of mouth breathing is particularly problematic. The nasolacrimal ducts open onto the rostral floor of the nasal passage. The epiglottis is not visible easily from the oral cavity, making direct intubation difficult. It is narrow and elongated and leads into the larynx which has limited vocal fold development. The larynx leads into the trachea which has incomplete C-shaped cartilage rings for support.

Lower respiratory tract

The trachea bifurcates into two primary bronchi. There are two lungs, which are relatively small in proportion to the overall rabbit's body size. This means that even minor lung disease may cause serious problems. Each lung has three lobes (although the right lung caudal lobe is subdivided into medial and lateral segments), with the cranial ones being the smallest (see Figure 1.1). Rabbits do not have respiratory bronchioles leading to alveoli rather they have so-called vestibules that contain the alveoli (Cruise and Brewer, 1994).

Respiratory physiology

The main impetus for inspiration derives from the muscular contraction and flattening of the diaphragm. The lung parenchyma possesses a cellular population that is well supplied with anaphylactic mediating chemicals. These are strong enough to cause fluid extravasation and blood pooling, as well as spasms within the walls of the main pulmonary arterial supply, leading to rapid right-sided heart failure when their release is triggered.

Digestive system

Oral cavity

The dental formula is:

$$I\,2/1\,C\,0/0\,Pm\,3/2\,M\,3/3.$$

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Table 1.1 Classification of commonly seen small mammals.

Order	Lagomorpha	Rodentia							Eulipotyphla	Didelphimorphia	Diprotodontia	Carnivora
Suborder		Myomorpha		Hystricomorpha			Sciuromorpha					Caniformia
Family	Leporidae	Muridae	Cricetidae	Caviidae	Chinchillidae	Octodontidae	Sciuridae		Erinaceidae	Didelphidae	Petauridae	Mustelidae
Species	Domestic rabbit (*Oryctolagus cuniculus*)	Rat (*Rattus norvegicus*) Mouse (*Mus musculus*)	Gerbil (*Meriones unguiculatus*) Syrian hamster (*Mesocricetus auratus*) Russian hamster (*Phodopus sungorus*) Chinese hamster (*Cricetulus griseus*)	Guinea pig (*Cavia porcellus*)	Chinchilla (*Chinchilla lanigera*)	Degu (*Octodon degus*)	Siberian chipmunk (*Eutamias sibiricus*) Eastern chipmunk (*Tamias striatus*)	Black-tailed prairie dog (*Cynomys ludovicianus*)	African pygmy hedgehog (*Atelerix albiventris*)	Virginia opossum (*Didelphis virginiana*)	Sugar glider (*Petaurus breviceps*)	Domestic ferret (*Mustela putorius furo*)

Table 1.2 Biological parameters for the domestic rabbit.

Biological parameter	Domestic rabbit
Weight (kg)	1.5 (Netherland dwarf) to 10 (New Zealand whites and Belgian hares)
Rectal body temperature (°C)	38.5–40
Respiratory rate at rest (breaths per minute)	30–60
Heart rate at rest (beats per minute)	130 (New Zealand whites) to 325 (Netherland dwarf)
Gestation length (days)	29–35 (average 31)
Litter size	Typically 5–8
Birth weight (g)	30–100
Weaning age (weeks)	4–6
Age at sexual maturity (months)	
Male	5–8
Female	4–7
Lifespan (years)	6–13

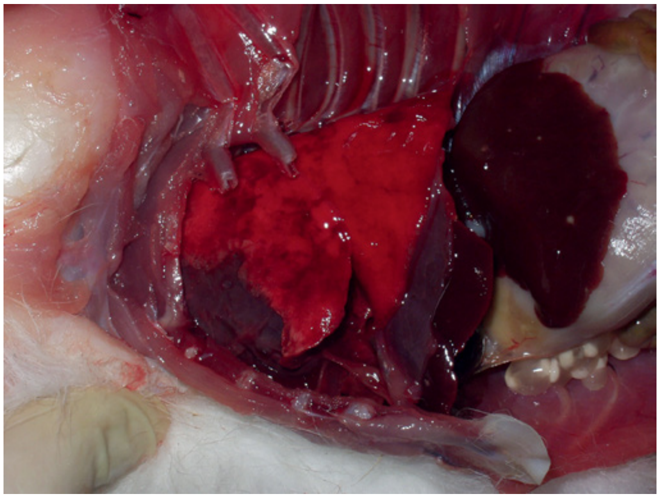

Figure 1.1 Lateral post-mortem view of a rabbit with the chest wall removed. The structures from left to right (cranial to caudal) are the dark-red heart, bright-red lungs (three lobes), darker brown diaphragm and liver, and pale cream stomach (Fraser and Girling, 2009).

The premolars and molars look physically similar and are often referred to simply as 'cheek teeth'. It should be noted that some breeds of rabbit, particularly the lop breeds, may have fewer cheek teeth in the maxilla (five instead of six on each side).

All rabbit teeth are elodont, growing continuously throughout life and the root apices are open (aradicular) with germinal tissue located at the apices producing the new tooth enamel and dentine. The premolar/molar enamel is folded providing an uneven occlusal surface with the ipsilateral jaw which allows interlocking (so-called interlocking lophs). Wear is kept even by the lateral movement of the mandible across the maxilla, allowing independent left and right arcades to engage in mastication. The incisors help differentiate Lagomorpha from Rodentia as rabbits, pikas and hares have two smaller incisors, or 'peg teeth', behind the maxillary incisors, whereas rodents have only two upper incisors. The larger (rostral) incisors only have enamel on the labial surface, whereas the smaller (caudal) maxillary peg teeth have enamel on the labial and lingual sides. This creates a wedge-shaped bite-plane where the lower incisors close immediately behind the upper large incisors and fit into a groove made by the peg teeth. The permanent rostral incisors are present at birth, although the peg teeth are replaced by permanent peg teeth at around the second week of life. The deciduous premolars present

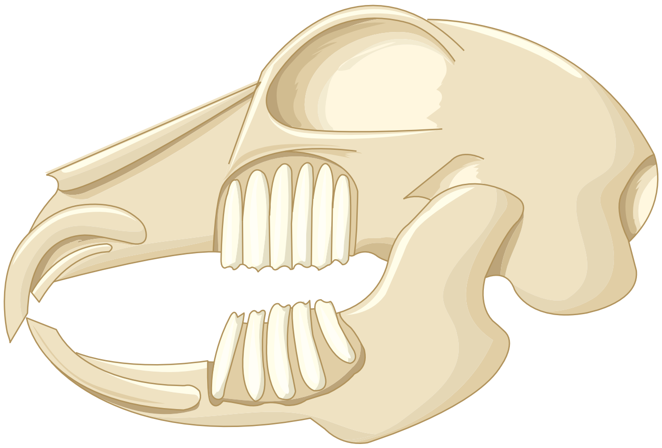

Figure 1.2 Lateral diagram of a normal rabbit skull showing the presence of the diastema, the smaller maxillary incisors (peg teeth) caudal to the main maxillary incisors and the relationship of the incisor and cheek teeth roots to the eye socket and jawbones.

Figure 1.3 Lateral post-mortem view of a rabbit skull with the skin removed showing the presence of the diastema, and the occlusal surface of the cheek teeth demonstrating interlocking lophs.

at birth are replaced and joined by permanent molars by the fourth week of life. There are no canines; instead, there is a gap, or diastema, between the incisors and premolars (see Figures 1.2 and 1.3).

Stomach

The stomach is a large, simple structure, with a strong cardiac sphincter (see Figure 1.1). This makes vomiting in the rabbit virtually impossible. There is a main body, or fundus, and a pyloric section with a well-formed pyloric sphincter. The lining of the wall of the fundus contains acid-secreting and separate pepsinogen-secreting cells. The pH of the stomach contents is surprisingly lower than that of a cat's or dog's at 1.5–1.8. In addition, a healthy rabbit's stomach never truly empties of food.

Small intestine

The total length of the small intestine in the average rabbit may be some 2–3 m. It is difficult to determine the divisions between duodenum, jejunum and ileum as they all have a similar diameter. The duodenum is however split into descending, transverse and ascending segments. It receives the bile duct and pancreatic duct at separate sites.

Caecum and large intestinal anatomy

At the junction of the ileum and caecum lies the sacculus rotundus. This is a swelling of the gut infiltrated with lymphoid tissue and a common site for foreign body impactions. The caecum is large, sacculated and spiral-shaped, finishing in a blind-ended, thickened, finger-like projection known as the vermiform appendix, which also contains lymphoid tissue. The bulk of the caecum is thin-walled and possesses a semi-fluid digestive content where bicarbonate ions are secreted to buffer volatile fatty acid (VFA) production by the bacteria it contains.

The start of the large intestine is the ampulla coli which sits near to the sacculus rotundus and caecum. It is a smooth-walled portion of the gut with some lymphoid infiltration of its walls, unlike the rest of the large intestine. It is also distinguished by bands of fibrous tissue (known as taeniae) that create sacculations (each one also known as haustra). The surface area of the lining of the haustra is further increased by small projections (known as warzen or warts). At the end of the proximal colon, the taeniae and haustra cease, and the gut is then known as the fusus coli. Its walls are thickened and smooth because of the presence of large numbers of nerve ganglia which act as pacemakers for contraction waves in the large bowel. The distal descending colon has no haustra and continues through the pelvis to empty via the rectum and anus. The whole of the caecum and large intestine occupy around half of the abdominal cavity, predominantly on the right-hand side. There are a couple of para-anal glands just inside the anus, one on either side, that empty their secretions onto the faecal pellets.

Large intestinal physiology

Two types of faecal pellets are produced by the rabbit. One is a true faecal pellet, comprising waste material in a dry light-brown spherical form. The other is a much darker, mucus-covered pellet known as a caecotroph. The caecotroph is eaten directly from the anus, as soon as it is produced, which in the wild is during the middle of the day when the rabbit is underground. In captivity, they are often produced overnight, but may be produced at any time. The caecotroph contains plant material from which all of the nutrients have yet to be extracted and the mucus covering it protects the contents from the acidic pH of the stomach, allowing some further fermentation to occur while the caecotroph is still in the stomach before it eventually breaks down and the bacterial proteins are released. Caecotrophs are therefore a significant source of microbial protein (24.4–37.8%), accounting for 15–25% of the total amino acid requirement and 9–15% of the digestible energy needs (Griffiths and Davies, 1963; Lebas, 1989).

The large bowel can produce two types of pellets due to waves of contraction in the large intestine and caecum. The proximal colon can separate out food because the haustra or sacculations of the colon hold on to the smaller particles. The larger particles (often 0.5 mm or more) are pushed towards the lumen of the colon. The haustra then push the small particles (generally 0.3 mm or less) towards the caecum by contracting, and the segmental contractions of the colon itself propel the larger particles towards the rectum producing a waste pellet. When caecotrophs are produced, the haustra dramatically reduce their contractions, and instead the segmental activity drives material from the caecum through the distal colon where it is covered in mucus and then eaten directly from the anus. The caecum is thus the powerhouse filled with microbes that turn the ingesta into VFAs that can either nourish the caecal epithelium (butyrates) or be absorbed and converted to glucose by the liver (acetates). A high-fibre diet is important for maintaining the balance of VFAs, which should comprise predominantly acetates followed by butyrates and then propionates. Decreased levels of fibre increase butyrates and propionates at the expense of acetates, resulting in a reduction in normal gut peristalsis and leading to hypomotility disorders and ileus or gut stasis, as well as the growth of increased amounts of harmful bacteria such as *Clostridium* spp.

Liver

The rabbit liver has four main lobes, a right and left (each of which is divided into anterior and posterior lobules), a quadrate lobe caudal to the gall bladder, and a caudate lobe near the right kidney which is prone to torsions. The gall bladder has an opening separate from the pancreatic duct into the proximal descending duodenum, where there is a mild dilatation immediately distal to the pylorus of the stomach. The main bile pigment is biliverdin, rather than bilirubin as seen in cats and dogs.

Pancreas

The pancreas is split into a left lobe along the greater curvature of the stomach and a more diffuse organ, suspended in the loop of the duodenum. There is one single accessory pancreatic duct, separate from the bile duct, emptying into the intestine at the junction of the transverse and ascending duodenum. The main pancreatic duct regresses during *in utero* development.

Urinary anatomy

Kidney

The kidneys are bean-shaped and unipapillate (one papilla and one calyx entering the ureter) similar to rodents. The right kidney is more cranial than the left and close to the quadrate lobe of the liver. The kidneys are often separated from the ventral lumbar spine by large fat deposits. The number of glomeruli actually increases after birth and some become ectopic forming small cysts, some of which can be seen with the naked eye, in the adult rabbit (Moffat and Fourman, 1964).

A single ureter arises from each kidney and traverses the abdominal cavity to empty into the urinary bladder.

Bladder

The bladder lining is composed of transitional cell epithelium. The urethra in the male rabbit exits through the pelvis and out through the penis. In females, the urethra opens onto the floor of the vagina.

Renal physiology

Rabbit's urine is predominantly alkaline with a pH varying between 6.5 and 8, but it will become acidic if the rabbit has been anorectic for 24 hours or more. Volumes of urine production average around 50–75 mL/kg body weight in a normally hydrated rabbit (Gillett, 1994). The urine contains varying amounts of calcium often in the form of calcium carbonate. This is because rabbits have limited ability to alter how much calcium is absorbed from the gut as they can absorb calcium, assuming dietary levels are sufficient, in the absence of vitamin D. However, supplementary vitamin D will increase the level of calcium absorbed. Any excess calcium must be excreted by the kidneys into the urine. When this occurs it can be seen as a tan-coloured silt in the urine. Porphyrin pigments may also be seen in rabbit's urine. These are plant pigments and make the urine appear anywhere from a dark yellow to a deep wine-red in colour. This may mimic haematuria; therefore, to diagnose blood in the urine, it is necessary to examine it microscopically to visually determine if erythrocytes are present.

Cardiovascular system

Heart

The rabbit heart is small in relation to body size. The right atrioventricular valve usually has only two cusps instead of three. The pulmonary artery also has a large amount of smooth muscle in its wall which can contract vigorously during anaphylactic shock, causing immediate right-sided cardiac overload and failure.

The coronary arterial anatomy of the rabbit heart has significant variability. The main coronary artery is the left but typically half of all rabbit hearts show bifurcation and half trifurcation of the left main coronary artery. Some publications suggest that this is an over-simplification of the anatomy of the rabbit heart, which is commonly used to investigate human cardiac disease, for example suggesting that the right coronary artery may be the major supplier of blood to the myocardium in many rabbits (Morrissey *et al.*, 2017).

Rabbits are often used to study atherosclerosis in humans as they rapidly develop hyperlipidaemia, mainly due to low-density lipoproteins (similar to humans) after being fed high-fat diets. However, they do not naturally form atherosclerotic plaques as humans do, but will develop lipid mural deposits, which will often mineralise in the walls of major vessels such as the aorta in the presence of high calcium-containing diets or advanced kidney disease.

Blood vessels for sampling

Vascular access sites in rabbits include the following.

Lateral ear vein

This runs along the lateral margin of either ear. It may be accessed using a 25 or 27 gauge needle or catheter and used for slow intravenous injections and small volume blood sampling.

Cephalic vein

This runs in a similar position to that seen in cats and dogs. It may be split into two in some individuals, but may be used for intravenous fluids and sampling although it is often a small vessel (see Figure 1.4).

Saphenous vein

This runs across the lateral aspect of the hock, as in cats and dogs, and may also be used for venepuncture.

Jugular vein

The external jugular veins are prominent in the rabbit and form the major part of the drainage of blood from the head and orbit of the eye

Figure 1.4 Cephalic vein access in a rabbit using a pre-heparinised butterfly catheter.

and have few anastomoses with the internal jugular veins. If a haematoma or thrombus forms in the external jugular vein(s) and blocks the lumen, severe orbital swelling and head oedema may occur, with possible damaging effects.

Lymphatic system

Spleen

The spleen is a flattened structure, oblong in nature and attached to the greater curvature of the stomach and is thus found predominantly on the left side. It is relatively small in comparison to body size, possibly because almost half of lymphatic tissue is found in the intestines as gut-associated lymphatic tissue (GALT).

Thymus

The thymus is a large structure in the cranial thoracic compartment even in the adult rabbit. It provides the body with the T-cell lymphocytes.

Lymph nodes

The root of the mesentery supporting the digestive tract is well supplied with lymph nodes, as is the hilar area of the lungs where the two main bronchi diverge to supply each lung. In addition, there are superficial lymph nodes in the popliteal, prescapular and submandibular areas. Large amounts of GALT exist in the small intestine, sacculus rotundus and vermiform appendix.

Reproductive anatomy

Male

The paired testes can move from an inguinal position within the thin-skinned scrotal sacs to an intra-abdominal position through the open inguinal canal. The scrotal sacs are sparsely haired and lie on either side of the anogenital area.

The accessory sex glands in the buck attached to the urethra in the caudal abdomen include the dorsal and smaller ventral prostate, the bilobed vesicular gland, the bilobed coagulating (sometimes referred to as seminal) gland and a bilobed bulbourethral gland. The prepuce has numerous small preputial glands in the dermis, and there are a couple of inguinal glands situated on either side of the penis which secrete a brown-coloured sebum clearly seen adjacent to the anus.

Female

The ovaries are supported by the ovarian ligament and lie caudal to each respective kidney. The ovarian artery often splits into two parts after leaving the aorta, and it, along with the rest of the reproductive tract, is frequently encased in large amounts of fat.

The uterus is duplex – there is no common uterine body. Instead, there are two separate uteri with separate cervices emptying into the vagina (see Figure 1.5). The vagina is large and thin-walled, with the urethra opening onto its floor cranial to the pelvis. The vulva therefore is a common opening for the reproductive and urinary systems unlike many rodents. It lies just cranial to the anus and is flanked on either side by the inguinal glands, as with the buck.

The doe has on average four pairs of mammary glands extending from the inguinal region to the axillary areas.

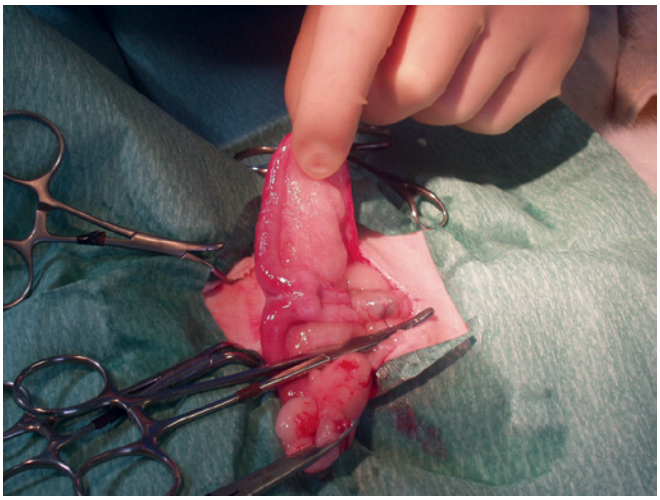

Figure 1.5 Intraoperative view of the uterus and ovaries of a domestic rabbit. Note the significant amount of fat deposition and the two cervices and two separate uterine horns.

Reproductive physiology

Male

The buck rabbit has similar reproductive hormones to those in cats and dogs, but they are on a seasonal time clock triggered by the lengthening daylight of spring. This is mediated through the pineal gland in the brain which has neural links from the eyes and controls the hormone melatonin. It in turn controls the pituitary release of follicle-stimulating and luteinising hormones which then act upon the testes.

Female

Does are induced ovulators. Waves of follicles swell and regress during the course of the season, starting to increase in activity in early spring. If not mated, these follicles will often dominate the cycle for 12–16 days at a time. There is no real anoestrus phase in does; instead, a slight waning in activity for 1–2 days occurs before a return to heat. During peak sexual activity, the vulva is often deeply congested and almost purple in colour and considerably enlarged.

Once mated, the male's semen may form a copulatory plug, which is a gelatinous accumulation of sperm that drops out of the doe's vagina 4–6 hours after mating. Gestation lasts from 29 to 35 days, with the fetus forming a haemochorial placenta (where the outer chorion layer of the fetal placental membrane burrows into the lining of the uterus so that it directly attaches to the blood in the intrauterine vessels) at about day 13. This is a common time for abortions to occur. A pregnant doe will remove fur from her ventrum to line the nest in the latter few days prior to parturition.

Parturition is often referred to as 'kindling'. Dystocia is uncommon. The doe only nurses the kittens once a day for 20 minutes or so, often in the early morning. It is therefore not uncommon for owners to think that the doe is neglecting her young as she will often spend the rest of the time eating and away from the litter.

Pseudopregnancy often occurs after an unsuccessful mating or mounting activity by another buck or doe. A corpus luteum forms and this lasts for 15–17 days during which time the doe may produce milk and build a nest. At this time, the doe is susceptible to mastitis.

Neonatology

The young kits or kittens are altricial in nature, that is, they are totally dependent on the mother for nutrition and survival for the first few weeks of life. They are born blind, deaf and furless. Fur growth appears around day 5–6, the eyes open at day 8–10 and the ears at 11–12. When nursing from the mother kits only suckle once a day consuming 35% of their body weight rapidly over a few minutes (Hudson and Distel, 1983). Weaning occurs around 4–6 weeks of age, with the young taking solid food from 2 to 3 weeks.

Sexing

The young may be sexed from 4 to 5 weeks of age. Gentle pressure is placed on either side of the reproductive or anal area to protrude the vulva or penis. The vulva of the young doe is rounded and has a central slit in midline and projects cranially. The penis of the young buck is more conical and pointed, with no central slit and tends to project caudally when protruded. Once the buck is older, the testes descend into the scrotum.

Skin

Lop breeds, particularly does, have extra skin folds called 'dewlaps' around the ventral neck region. In addition, extra folds of skin may also be found around the anogenital area, leading to increased risk of urine and faecal soiling. The skin is thin and can tear easily.

Rabbits do not have keratinised footpads. Instead they have thick fur covering the areas of the toes and metatarsals which are pressed flat to the ground.

In addition to the para-anal scent glands mentioned above there are a series of discrete submandibular chin glands. These are used to mark territory and also, in the case of does, to mark their young to distinguish them from others. Rabbits also have inguinal scent glands dorsal to the urogenital opening on each side of the anus.

The rabbit has no skin sweat glands except a few along the margins of the lips. This means that they are very prone to heat stress at temperatures greater than 28°C.

The presence of many vibrissae or sensitive hairs around the lips and chin are important since rabbits cannot see anything immediately below their mouths, and so rely on touch to manipulate food towards the mouth.

Eyes

Rabbits have prominent eyes, which allow a near 360° field of vision. There is a prominent third eyelid, which moves from the medial canthus of the eye and possesses a large amount of reactive lymphoid tissue within its structure and a Harderian tear gland at its base. This is often enlarged in the buck during the breeding season and possesses two lobes in both the sexes. The optic disc is above the horizontal midline of the eye unlike the domestic cat or dog and the retina has no tapetum lucidum.

There is a significant orbital venous plexus that makes enucleation of the globe complicated. A retrobulbar plexus also exists which can become engorged with increased mediastinal pressure (such as a thymic tumour) resulting in bilateral exophthalmos (Wagner *et al.*, 2005). Tears drain from the eye via the nasolacrimal duct which starts at a single ventromedially located punctum, rather than the paired openings seen in cats and dogs. There is a small lacuna or swelling of the duct shortly after its start, located medial to the canthus of each eye. The duct then moves ventral to the root of the main maxillary incisor on each side before opening onto the floor of the rostral nasal passage. This path around the root of the maxillary incisor means occlusion of the duct can occur with dental disease or with incisor root elongation, resulting in epiphora and dacryocystitis.

Haematology

The most notable feature is the esosinophilic staining of the rabbit neutrophil, making it easily mistaken for an eosinophil and meaning it is often referred to as the pseudoeosinophil. Many rabbits have more lymphocytes than pseudoeosinophils, resembling other mammals such as cattle, rather than cats and dogs, in which the neutrophil is the commonest white blood cell. Romanowsky-stained blood smears from rabbits, as with other small mammals, often show significant polychromasia and anisocytosis as the lifespan of the erythrocyte is short, 57 days, indicating a relatively high turnover of red cells.

RAT AND MOUSE

Biological average values for the rat and mouse

The normal biological values for the rat and mouse are given in Table 1.3.

Musculoskeletal system

Skull

The skull of both species is elongated. The eyes are laterally situated, and there is a long snout and a shallow cranium. The maxilla is narrower than the mandible. The temporomandibular joint is elongated craniocaudally, allowing the mandible to move rostrally and caudally in relation to the maxilla. This allows the incisors to be engaged for gnawing, while the molars are disengaged. Alternatively, the molars may be engaged for mastication prior to swallowing, while the incisors are disengaged. The two procedures cannot occur at the same time. The rostral symphysis, joining each half of the mandible, is also articulated allowing movement of each hemimandible independently of the other.

Axial skeleton

The pelvis of the female mouse is joined at the pubis and ischial areas midline by fibrous tissue. This allows separation of the pelvis during parturition in the mouse. There are no fibrous areas to the pelvis of the female rat and consequently no pelvic separation occurs.

The vertebral formula of the domestic rat is:

$$C7, T13, L6, S3-4, Ca27-36$$

The vertebral formula of the domestic mouse is:

$$C7, T13, L6, S4, Ca26-34$$

Table 1.3 Biological parameters for the rat and mouse.

Biological parameter	Average range rat	Average range mouse
Weight (g)	400–1000	25–50
Rectal body temperature (°C)	37.6–38.6	37–38
Respiration rate at rest (breaths per minute)	60–140	100–280
Heart rate at rest (beats per minute)	250–450	500–600
Gestation length (days)	20–22	19–21
Litter size	6–16	8–12
Birth weight (g)	6–8	0.5–1.5
Weaning age (days)	21 (average)	21 (average)
Age sexual maturity (weeks)		
Male	8	6
Female	10	4–7
Oestrus interval (days)	4–5	4–5
Lifespan (years)	3–4	2–3

Appendicular skeleton

The scapula articulates at its coracoid process with the clavicles as well as the humerus. There are four metacarpal bones in the rat, with four digits. Occasionally the vestigial remnant of digit 1 is present. Mice have five metacarpal bones and five digits in the forelimbs.

The hindlimbs have a strong laterally bowed fibula in both species. The tibia articulates with five metatarsal bones at the hock joint. Consequently there are five digits in the hindlimbs of both of these species. Rats and mice are plantigrade in their stance, meaning they walk with the whole of the metatarsal bone area flat to the ground.

Male rats may still have open growth plates in many of their long bones well into the second year of their lives, whereas mice close their growth plates in the first 3–4 months of life.

Respiratory system

The nares of both species are prominent and surrounded by an area of hairless skin containing some sweat glands.

There is a vomeronasal organ in the floor of the nasal passages, accessed via two small stoma in the roof of the mouth just caudal to the maxillary incisors. This organ is responsible for detecting pheromones secreted by other individuals. At the junction of the nasopharynx lie significant amounts of lymphoid tissue referred to as nasal-associated lymphatic tissue (NALT).

The right lung of the rat is divided into three distinct lobes, the right lung of the mouse into four lobes and the left lung in both species is undivided. The chest cavity itself is smaller in proportion to the abdominal cavity than is the case in cats and dogs, meaning that rats and mice have little respiratory reserve.

Digestive system

Oral cavity

The lips of mice, and particularly rats, are deeply divided exposing the upper incisors, with large areas of loose folds of skin forming the cheeks.

Both species have pigmented yellow/orange enamel coating the labial aspect of the incisors. The maxillary incisors are one-third to one-quarter of the length of the mandibular incisors. There is a chisel shape to their occlusal surfaces due to the absence of enamel on the lingual aspect of the incisors making them wear quicker on this side. The mandibular incisors are also mobile and loosely rooted in the lower jaw. Their dental formula is

$$I1/1 C0/0 Pm0/0 M3/3.$$

There is no evidence of any deciduous or 'milk' teeth being present in either species. The molars have a limited period of growth with long narrow roots (varying between three and five per tooth depending on the species and molar) being brachydont in nature. Unlike rabbits there is no overlap between maxillary and mandibular molar occlusal surface, each molar occluding fully with the corresponding molar in the ipsilateral jaw.

Both species have a diastema. In the case of rats, this gap is particularly noticeable and large enough to allow them to draw their cheeks into the gap to effectively close off the back of the mouth. This enables them to gnaw, without consuming the material they are nibbling.

The tongue is relatively mobile and its surface is covered with small, backward-pointing papillae.

Stomach

The stomach of the mouse and rat is elongated and narrow. In the rat, in particular, the stomach is divided into two regions: cranial is the proventricular region, covered by a thin whitened lining of aglandular mucosa; caudal is the pyloric region, covered by a redder, thicker, glandular mucosa. The oesophagus enters the stomach halfway along the length of its lesser curvature and has an abdominal section. This, combined with a strong cardiac sphincter, makes vomiting extremely difficult. Both species have separate hydrochloric acid-secreting (parietal) and pepsinogen-secreting (chief) cells with additional mucin-secreting cells.

Small intestine

The small intestine comprises the largest portion of the gastrointestinal tract. In the rat the bile duct enters the first part of the duodenum direct from the liver, which has no gall bladder. The mouse does have a gall bladder which empties into the first part of the duodenum. The ileum is most easily distinguished by the presence of lymphoid deposits (Peyer's patches).

Large intestine

The ileum enters the large intestine at the junction of the caecum and the large intestine on the left side of the abdomen. The caecum is a medium-sized organ in the mouse and rat, reflecting their omnivorous nature, and forms a blind-ended pouch which is flexed back on itself and is approximately one-third the total length of the large intestine.

Liver

The liver is divided in both species into four lobes. There is a gall bladder present in the mouse but not in the rat. The liver sits cranial to the stomach. Biliverdin is the prominent bile pigment in rats and mice.

Pancreas

The pancreas lies along the proximal aspect of the duodenal loop. In both species, it empties through a series of ducts into the bile duct. Its function appears to be the same as in cats and dogs, producing both insulin and glucagon for glucose homeostasis and the digestive enzymes amylase, lipase and trypsinogen.

Urinary system

Kidney

The kidneys are bean-shaped. The right kidney sits in a depression in the right lobe of the liver, and the left kidney is slightly more caudal. Each empties through its ureter which enters the bladder at the trigone area. Mice often excrete urine drop by drop as it is generally highly concentrated and small in volume (1.5–2 mL per day). Mouse urine also contains an inherently high level of the so-called mouse urinary protein (MUP), whose function is believed to be pheromone transport. Male mice excrete greater levels of MUP than female mice.

Bladder

The bladder, which is lined with transitional epithelium, empties through the urethra. In the female mouse and rat, the urethra empties through a separate urinary papilla rather than onto the floor of the vagina as it does with higher mammals. The female mouse and rat therefore have three orifices caudoventrally: the anus most caudally, the reproductive tract entrance next cranially and the urinary papilla the most cranial of the three.

Cardiovascular system

Heart

The heart of the mouse and rat has four chambers, as in other mammals. As with rabbits, the chest compartment is relatively small in comparison to the abdomen, and the heart therefore appears relatively large in relation to the rest of the chest. The heart occupies the fourth to sixth rib spaces.

Blood vessels for sampling

Useful vessels from which to sample blood are the lateral tail veins. These are best accessed after first warming the tail, or lightly sedating the mouse or rat to allow dilation of the vessels. A 25–27 gauge needle or butterfly catheter is required. Some mild pressure at the tail base allows further dilation.

In the rat, the femoral vein may also be used for sampling. This is found on the medial aspect of the thigh, close to its junction with the inguinal area, just caudal to the femur. This vessel is best used only under anaesthetic due to the difficulty of accessing it in a conscious rat.

For small capillary samples, a microcapillary tube may be gently pushed into the medial canthus of the eye socket in the anaesthetised rat or mouse. This collects blood from the orbital sinus.

Lymphatic system

Spleen

The spleen of male mice is often twice the size of that in females. In both species, it is a strap-like organ sitting along the greater curvature of the stomach.

Thymus

The thymus is an obvious organ in the cranial chest, and may be split into several smaller islands of tissue. It is frequently still present in the adult rat or mouse.

Lymph nodes

The lymph nodes follow similar patterns to those seen in the rabbit. The mesenteric lymph nodes can become very prominent in certain bacterial infections.

Reproductive anatomy

Male

The male rat and mouse reproductive systems are nearly identical in design.

The testes are large and can move between the abdomen and the scrotal sacs, although somewhat inhibited by a large fat body attached to the tail of each testicle extending through the open inguinal canal. Each testis descends into the scrotum around the fifth week of age in the rat and the third to fourth week in the mouse.

The vasa deferentia are joined by the opening of the small ampullary glands which open into a swelling of the vas deferens known as the ampulla just before they join the urethra. Other accessory sex glands, including the vesicular glands, the coagulating glands (which are joined together) and the two parts of the prostate (the ventral and dorsal lobes), open into the urethra itself. As the urethra exits the pelvic canal, a paired bulbourethral gland also empties into its lumen.

These accessory sex glands produce nutrients and supporting fluids for the spermatozoa. In addition, the coagulating glands are responsible for allowing a plug of sperm to form in the female's vagina immediately after mating. The penis has an os penis in both species. There is a preputial gland in the small prepuce that is used for territorial marking. Male mice and rats have no nipples.

Female

The rat uterus has two separate uterine horns which come together at a single cervix, but with separate cervical canals for each horn. From the outside these appear to merge to form a common uterine body, and so it is sometimes referred to as bicornuate in nature. The vagina itself has no lumen in the immature rat. Instead, at puberty, the solid mass of tissue forms its own lumen, breaking through to the surface at the time of the first ovulation.

The mouse uterus is almost exactly the same except that the two separate uterine horns do fuse just before the cervix, making it truly bicornuate and there is just the one cervical opening into the vagina. The vagina is also non-patent in the immature state.

Mammary tissue is extensive in both female rats and mice. In mice there are normally five pairs of mammary glands, three in the axillary region, with mammary tissue extending dorsally nearly to midline. The other two pairs of glands are in the inguinal region, with mammary tissue extending around the anus and tail base. In rats there are more commonly six pairs of mammary glands. Three are located in the axillary region, again with some tissue moving onto the lateral chest wall. The other three glands are inguinally located.

Reproductive physiology

The female rat and mouse are non-seasonally polyoestrus. The commonest time for heat to occur is during the night. The first cycling activity occurs around 8 weeks of age in the female rat, with the cycle lasting 4–5 days in total. Ovulation is spontaneous and occurs towards the end of the 12-hour-long heat. There is a reduction in reproductive activity in the female rat over 18 months of age.

During mating, the semen deposited in the female rat's vagina forms a copulatory plug which sits in the cranial vagina, blocking the cervix. This dries and falls out within a few hours of mating, but seems to play an important role in the success of mating. It is often eaten rapidly after being passed.

Gestation length is around 21 days. The placentation of the rat and mouse is discoidal and haemochorial – the area of attachment is disc-like with the chorion of the placenta in contact with the bloodstream of the dam's uterus. There may be a bloody mucous discharge from the vagina around 14 days, which is normal. This stops within 2–3 days. Mammary development occurs at around days 12–14 and at that stage the fetuses may be palpated.

Parturition is rarely complicated. There is no separation of the pelvis in the female rat, although the female mouse's pelvis does separate at the ischial and pubic sutures. Parturition occurs in the afternoon and is followed by a postpartum oestrus.

Pseudopregnancy is seen in both rats and mice. During this time the female may build a nest; there may be some mammary development and no signs of a heat for up to 2 weeks.

There are a couple of important physiological reproductive phenomena in mice and rats. One of these is the Whitten effect. This is when a group of anoestrus females will all come into heat spontaneously some 72 hours after being exposed to the pheromones of a male. This has beneficial effects when it comes to successful rapid breeding. The other is the Bruce effect. This is when a female in the early stages of gestation will reabsorb the embryos and come back into heat when presented with a new male. By preferentially allowing successful mating with a new male, this is thought to have a beneficial effect on genetic diversity. The Lee–Boot effect occurs when mature female mice, kept in large groups in the absence of males, exhibit suppressed oestrus cycles, leading to prolonged dioestrus and the spontaneous development of pseudopregnancy.

Neonatology

Rat and mouse pups are altricial. They are born blind, deaf and hairless. The ear canals open around days 4–5 and the eyes at around 2 weeks of age. The first few hairs are also seen in the first week of life. The pups are born without teeth, the incisors becoming visible at 1–2 weeks of age with the molars developing later.

The female rat and mouse are prone to cannibalism if disturbed with their young in the first few weeks after parturition. It is therefore important to leave the female rat and mouse alone during this period, only disturbing them to replenish food and clear the worst of any cage soiling.

Sexing

Sexing may be done from 4 to 6 weeks of age. In males the urinary papilla is slightly larger than the female and further away from the anus. It may be possible in the sexually mature female to see the small reproductive tract entrance as a transverse slit between the anus and urinary papilla. Also, in male mice and rats, no nipples are visible. In mature males, if the rat or mouse is gently suspended in a vertical position with the head uppermost, the testes will often descend into the scrotal sacs and are then obvious.

Skin

Rats and mice possess no generalised sweat glands and so are prone to heat stress at temperatures above 26–28°C. There are some sweat glands present on the soles of the feet as well as the nares.

There is a layer of brown fat between the shoulder blades dorsally; its function is not clearly known, but it decreases with age and may play a role in thermoregulation.

The tails of rats and mice are relatively hairless. As rats age, there is an increasing number of coarse skin scales present on the tail surface making blood sampling difficult. Rats should not be grasped by the tip of the tail as the skin may slough in this region. Sensory innervation of the hairless skin of the forepaws in mice is up to three times greater than the innervation to the hairless skin of the hindlimbs.

White fur will often yellow in rats as they age, and most rats will show evidence of a yellow hue to the skin on the back with time.

The vibrissae around the lips and nose are important for detecting vibrations and determining where food is due to their inability, as with rabbits, to see food immediately below their mouths. The vibrissae are innervated by the trigeminal nerve.

Eyes

Rats and mice have a prominent set of small eyes located laterally. Both species have a third eyelid located at rest in the medial canthus of the eye. The albino breeds lack pigment in their irises or retinas, and so their eyes appear pink red. These albino breeds should therefore be exposed to dimmed lighting during the day otherwise retinal damage can occur. Both species have the ability to see in the ultraviolet light spectrum. There are three main tear glands: the Meibomian (producing an oil film to stabilise tears); the lacrimal (two forms producing aqueous tears); and around the base of the third eyelid, the Harderian gland (producing aqueous tears and porphyrin pigments).

Haematology

The haematological parameters are similar to those seen in cats or dogs, except that the lymphocyte, as opposed to the neutrophil, is the most common white blood cell. Basophils are rarely seen in mice in the circulation. Erythrocyte turnover is high, with the average lifespan of the mouse erythrocyte being 30–40 days; therefore, as with rabbits, when a blood smear is stained using Romanowsky stains, a high degree of polychromasia and anisocytosis is considered normal. Howell–Jolly bodies (leftover fragments of nuclear DNA) are also commonly seen in erythrocytes.

GERBIL AND HAMSTER

Biological average values for the gerbil and hamster

Table 1.4 gives the average normal biological values for gerbils and hamsters.

Musculoskeletal system

Skull

The skull of the gerbil is not dissimilar to that of the rat or mouse; in the hamster, the skull is shortened, particularly in the Russian and Chinese hamster subspecies. The mandibular symphysis of adult hamsters often does not fuse allowing some independent hemimandible movement when chewing.

Axial skeleton

The axial skeleton is much the same as for the rat and mouse, except the hamster has far fewer coccygeal vertebrae.

The vertebral formula of the Syrian hamster is

$$C7, T13, L6, S4, Ca6-14$$

The vertebral formula of the gerbil is

$$C7, T12/13, L6/7, S4, Ca14-26$$

Appendicular skeleton

Gerbils have a longer femur and tibial length, giving them longer hindlimbs equipped for jumping. Their normal stance is bipedal, standing erect on their hindlimbs. Hamsters are a much shorter-legged creature, stockier in build, and walk predominantly on all fours.

The forelimbs have four digits, and the hindlimbs have five in both species.

Respiratory system

As with rats and mice, the chest cavity is small in relation to the abdomen, but the situation is not so pronounced as that seen in rats. Hamsters have a single left lobe and four to five right lobes to the

Table 1.4 Biological parameters for the gerbil and hamster.

Biological parameter	Russian hamster	Syrian hamster	Gerbil
Weight (g)	30–60	90–150 (male larger)	70–120 (male larger)
Rectal body temperature (°C)	36–38	36.2–37.5	37.5–39
Respiration rate at rest (breaths per minute)	60–80	40–70	80–150
Heart rate at rest (beats per minute)	300–460	250–400	250–400
Gestation (days)	Average 16 (Chinese hamster 21)	15–18	24–26 (up to 42 days with delayed implantation)
Litter size	4–8	4–12	2–6
Birth weight (g)	1–1.5	2–3	2.5–3.5
Weaning age (days)	20–24	21–28	21–30
Age at sexual maturity (weeks)			
Male	5–6	6–8	8–9
Female	6–8 (Chinese hamster 14)	8–12	9–10
Oestrus interval (days)	3–4	4	4–6
Lifespan (months)	18–24	24–36	36–60

lungs. Gerbils have three lobes to the left lung and four to the right (Williams, 1974).

Digestive system

Oral cavity

The incisors in both species are continuously erupting (open rooted), and both species have orange pigmentation of the enamel surfaces. The dental formula is

I1/1C0/0Pm0/0M3/3.

Hamsters are born with the incisors fully erupted and use them to grasp the nipples of the female enabling them to suck effectively.

The molars do grow continually for a limited part of the early life of the rodent, with multiple, short, narrow tooth roots (so-called brachydont). In addition, there appears to be no evidence of deciduous teeth (monophyodont). All species possess a diastema. The mandible is generally wider than the maxilla and the occlusal surfaces of the molars are flat. Hamsters have small cusps to the occlusal molar surfaces but gerbils do not.

The cheek pouches of the hamster are its most distinguishing feature. These are not present at birth, but rather develop during the second week of life from a solid cord of cells which disintegrate, creating the cavities. The entrances to the cheek pouches open into the diastema. Each cheek pouch extends caudal to the respective ear. They are lined with stratified squamous epithelium and have a reduced local immune system and lymphatic function, although they have a high incidence of mast cells. This can be a problem if the cheek pouch becomes infected.

Stomach

The stomach of the hamster has two separate areas. The oesophagus enters the proximal portion. This portion is non-glandular and has a bacterial population that allows limited microbial breakdown of food. It is sharply divided by a deep groove from the distal area of the stomach, which is glandular, with a redder lining composed of the acid- and pepsinogen-secreting cells that start the process of enzymatic digestion.

The gerbil has two areas to the stomach but they are less clearly demarcated, and the proximal portion does not support a significant microbial population.

Small intestine

The hamster's small intestine is extremely long, being three to four times its own body length. The gerbil has a similar layout to the mouse.

Large intestine

In the hamster the caecum is a sacculated and enlarged organ sitting in the ventral left portion of the abdomen at the ileocaecal junction. Its connection with the ileum is complicated by a series of four valves in the hamster. The hamster caecum has fine divisions within it, which may function to increase its surface area and aid fibre fermentation. It also has a semi-lunar valve separating the caecum into basal and apical portions. The gerbil has a similar layout to the mouse.

Liver

The liver in both species is divided into four main lobes (although two of the lobes are further partly divided into two). In both hamsters and gerbils, a gall bladder is present. A bile duct empties into the duodenum accompanied by the pancreatic ducts.

Pancreas

The pancreas is found adjacent to the descending duodenum. It has a similar structure and function to that seen in the rat and mouse. The hamster pancreas has three lobes (gastric, splenic and duodenal). The common bile duct merges with the three pancreatic ducts before emptying into the duodenum similar to many other rodents.

Urinary system

Kidney

The kidneys are similar to the rat and mouse kidney. The gerbil is very good at concentrating its urine, being a desert-dwelling species, and to do this it has a large number of nephrons (over 96% of the total) with long loops of Henle containing the countercurrent multiplier system for water reabsorption (Ichii *et al.*, 2006). In the hamster, the renal papilla is particularly long and protrudes from each kidney into its ureter.

Bladder

The bladder of gerbils and hamsters is essentially the same as that seen in rats and mice.

Cardiovascular system

Heart

The heart is similar in form to the rat and mouse heart.

Blood vessels for sampling

The hamster has very few accessible external vessels for blood sampling. This is principally due to its much reduced tail length, which provides the main vascular access in the rat and mouse. The skin covering the gerbil's tail can slough easily, making tail vein blood sampling potentially hazardous. However, the lateral tail veins have been used in research settings as with mice and rats. Other vessels used include the jugular veins and the femoral veins, both of which require the hamster or gerbil to be sedated or anaesthetised. Capillary samples may be taken from the orbital sinus as described in the rat and mouse.

Lymphatic system

Spleen

The structure and position of the spleen is much the same for both species as that seen in the rat.

Thymus

The thymus is again a prominent organ in the cranial chest and often persists in the adult. It provides the T-cell lymphocytes.

Lymph nodes

The presence of lymphatic tissue is the same as that seen in the mouse and rat.

Reproductive anatomy

Male

The male hamster has a smaller fat body attached to the testicle than has the rat. The testes are freely moveable between the abdominal cavity and the scrotal sacs. A small os penis is present in the penile structure. Accessory sex glands, from proximal to caudal, include paired ampullae, seminal vesicles, coagulating glands, a trilobed prostate, and paired bulbourethral glands.

The male gerbil is similar to the male rat and mouse. The main difference is the slightly smaller size of the testes in relation to the overall body size and the presence of a pigmented scrotum.

Female

The hamster uterus is bicornuate. It has two separate canals combining to a single cervix that then opens into a common vagina. The vagina is, as with the rat, not patent at birth. It opens after day 10 of life, rather than at puberty as in the rat.

The gerbil reproductive tract is similar to that of the mouse. The main difference is that while there is only one cervical opening into the vagina, the division between the left and right uterine lumens persists to within a few millimetres of this single cervical orifice.

The female hamster has four pairs (in the Djungarian hamster up to seven pairs) of mammary glands stretching in a continuous band from the axillary region to the inguinal and perianal region.

The female gerbil has four pairs of mammary glands. Two pairs are found in the axillary region and two pairs in the inguinal region.

Reproductive physiology

The female hamster is seasonally polyoestrus with cycling and fertility dropping off during the winter period. The reproductive cycle is short, lasting 4 days. The female hamster develops a creamy white vaginal discharge around the first day following oestrus. This may be mistaken for a pathological discharge as it has an odour. Ovulation is spontaneous and generally occurs overnight. Phantom pregnancy does occur in the hamster, postponing oestrus for 7–13 days. Gestation itself lasts for 15–18 days in the Syrian hamster, an average of 21 days in the Chinese hamster and an average of 16 days in the Russian hamster. Successful mating is followed by the presence of a copulatory plug of coagulated semen 24 hours later. Pregnancy can be confirmed by failure to produce the copious white discharge 5 days after mating, and an increase in weight at around day 10. There is no evidence of pelvic separation at parturition. There is reduced fertility in the female hamster after 1 year of life. Male Syrian hamsters need exposure to more than 12.5 hours daylight per day for breeding to occur.

Gerbils form a monogamous pair, that is they pair for life. The female gerbil is seasonally polyoestrus and a spontaneous ovulator. The oestrus cycle lasts for 4–6 days. Oestrus lasts for 24 hours and may occur within 14–20 hours of parturition. Gestation lasts an average of 26 days but may take up to 42 days if mating has occurred at the postpartum heat as when the female is still feeding the young, the fertilised ova will not implant, so prolonging the interval from mating to parturition.

Neonatology

The young hamster is altricial. The pale pink colour of the skin is replaced by some darker pigmentation after the first 2–3 days, with the eyes opening at 2 weeks of age. Weaning occurs around 3–4 weeks of age, with the female hamster becoming sexually mature at 6–8 weeks (up to 14 weeks for the Chinese hamster) and the male at 8–9 weeks.

The young gerbil is also altricial. The skin is a pale pink at birth but darkens by the end of the first week with the appearance of the first few hairs. The teeth erupt in the first few days of life. The eyes open at 2 weeks of age and the ears around days 4–5. Weaning occurs at 3–4 weeks of age. The female gerbil becomes sexually mature at 9–10 weeks of age when the vaginal opening becomes patent. The male gerbil becomes sexually mature at 8–9 weeks of age, with the testes descending into the scrotal sac at 5 weeks.

It is inadvisable to disturb the female hamster with her young as cannibalism can occur. However, a common protective action of the female is to place the young into her cheek pouches to move them, and this may look as if she is 'eating' the young. Gerbils are less prone to abandoning or abusing their young if disturbed.

The placenta of gerbils and hamsters is haemochorial in form, similar to other rodents.

Sexing

This may be performed from 4 weeks of age. In the immature gerbil and hamster, the differences are determined by anogenital distances as with the rat and mouse. In the sexually mature hamster, the male has a pointed outline to its rear, owing to the descended testes, whereas the female has a more rounded appearance. In both, it is relatively easy to determine the sex once mature if the individual is supported in a vertical position with the head uppermost. In this position, the testes will descend into the scrotal sacs where they are clearly visible.

Skin

Hamster and gerbil skin has no sweat glands. Gerbils, however, can tolerate wider temperature ranges, up to 29–30°C, although if the humidity increases above 50% they will rapidly suffer from heat exhaustion.

In hamsters, there is a pair of oval, raised scent glands situated on each flank cranial to the thigh region. In the mature adult, particularly the male, they may become darkly pigmented. The secretions of these glands may matt the sparsely covered fur, increasing their prominence. Male and female hamsters also have a glandular sac in the region of the umbilicus.

In gerbils, there is a large ventral sebaceous scent gland in the region of the umbilical scar that secretes a yellow sebaceous fluid and which is more prominent in males. This area is devoid of fur and is predisposed to the development of adenocarcinoma in adults. The tail of gerbils is fully furred, but has a series of fracture planes in the middle and caudal sections allowing a degloving injury if a gerbil is grasped by the tail. The soft tissue structure never regrows, and the denuded vertebrae will die off leaving a stump. Gerbils should therefore never be restrained by the end of the tail. Gerbils also produce a number of secretions from the Harderian gland (see next section) including lipids and pigments, some of which drain through the tear ducts to the nose, are mixed with saliva and are then transferred to the fur of the coat. If the gerbil does not have dry (<50% humidity), dusty conditions (e.g. a sand bath or fine shavings) to bathe in and help remove these secretions, the coat may become dull and matted.

Eyes

In hamsters, as with mice, a significant orbital venous sinus exists and has been used as a means of blood sample collection, using a fine lithium heparin-coated capillary tube under anaesthesia. Female Syrian hamsters secrete between 100 and 1000 times more porphyrins from the Harderian gland than males (Buzzell, 1996).

Haematology

The lifespan of the gerbil erythrocyte is short, even by rodent standards, lasting only 10 days. This is why so many gerbil red cells show degenerative basophilic speckling when stained with Romanowsky stains. Gerbil blood is often lipaemic, and this has been blamed on their high-fat (sunflower seed) diet; they are often used as a cholesterol model for humans. They are resistant to atherosclerosis but not hepatic lipidosis. In addition, the blood parameters vary depending on the sex: the male gerbil has a higher packed cell volume, and white blood cell and lymphocyte count than the female. Hamster haematology is similar to that seen in mice.

GUINEA PIG, CHINCHILLA AND DEGU

Biological average values for the guinea pig, chinchilla and degu

The average normal values for guinea pigs, chinchillas and degus are given in Table 1.5.

Table 1.5 Biological parameters for the guinea pig, chinchilla and degu.

Biological parameter	Guinea pig	Chinchilla	Degu
Weight (g)	600–1200	400–550	200–300
Rectal body temperature (°C)	37.2–39.5	37.8–39.2	36–37.9
Respiration rate at rest (breaths per minute)	60–140	50–60	60–100
Heart rate at rest (beats per minute)	100–180	120–160	240–300
Gestation length (days)	59–72 (average 63)	111 (average)	90–95
Litter size	1–6 (average 3)	1–5 (average 2)	4–10 (average 6)
Birth weight (g)	45–115	30–50	10–16
Weaning age (weeks)	2–4	6–8	4–5
Age at sexual maturity (months)			
Male	2–3	6–7	3–4
Female	1.5–2	8–9	3–4
Oestrus interval (days)	16	30–50	16–26
Lifespan (years)	3–8	6–10	5–9

Musculoskeletal system

Guinea pig

Skull

The skull is rodent shaped, with an elongated nose, low forehead and widely spaced eyes. There are moderately large tympanic bullae which house the middle ear and are clearly visible on radiographs. All hystricomorphs have a flared angular process to the mandible to which the large masseter muscles attach, with a large infraorbital foramen through which the medial masseter muscle passes. The mandible is wider than the maxilla.

Axial skeleton

The vertebral structure is the same as that seen in the rat and mouse, except the number of coccygeal vertebrae (four to six) is much reduced and they are less mobile. There are 13–14 pairs of ribs depending on the number of thoracic vertebrae; the last two are more cartilaginous than mineralised and the last three to four are not attached to the rest (floating). Guinea pigs also possess vestigial clavicles. The vertebral formula for the guinea pig is

$$C7, T13/14, L6, S2/3, Ca4-6$$

The pelvis of the female is joined at the pubis and ischium by a fibrocartilaginous suture line, allowing separation of the pelvis prior to and during parturition. If the female guinea pig has not had a litter by the time she has reached 1 year of age, this suture line mineralises and prevents future separation. Female guinea pigs not mated before 1 year should therefore not be mated for the rest of their life as dystocia problems are common.

Appendicular skeleton

The forelimbs and hindlimbs are relatively long in comparison to the rat and mouse, but the same bone formulas exist. The main difference is that the guinea pig has four digits on each forelimb and only three digits on each hindlimb. Like other hystricomorph rodents, the guinea pig has an unfused tibia and fibula.

Chinchilla

Skull

The bones of the skull are more domed than the guinea pig, although still distinctly rodent-like (see Figure 1.6). The chinchilla has very large tympanic bullae, larger than the guinea pig, which are clearly visible as coiled, snail-shell-like features on radiographs. The mandible is wider than the maxilla.

Axial skeleton

The vertebral structure is similar to that in the rat and mouse. Chinchillas are fine-boned and prone to fractures. The vertebral formula is C7, T13, L6, S2, Ca20–25 with 13 pairs of ribs.

Appendicular skeleton

The hindlimbs in particular have very long femurs and tibias. The chinchilla has the usual four digits on each forelimb, but, unlike the guinea pig, has five digits on each hindlimb as well, although digits 1 and 5 are rudimentary. Chinchillas have an obvious and long tail often held erect.

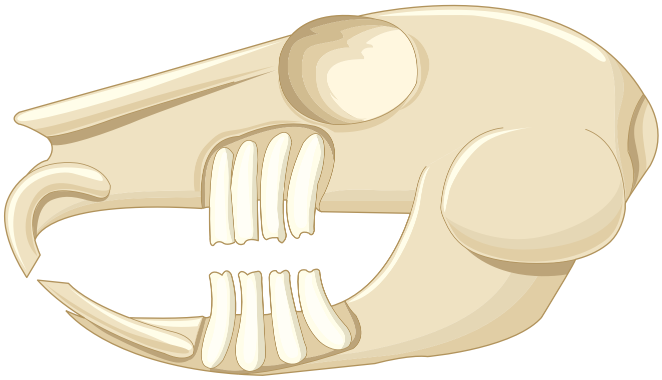

Figure 1.6 Lateral diagram of the skull of a normal chinchilla showing the relation of tooth roots to the orbit and jawbones. Note how close the roots of the third and fourth cheek teeth are to the inner aspect of the eye; hence, root elongation often causes watering of the eyes.

Degu

Skull

The bones of the skull are similar to those of the chinchilla and so more domed than the guinea pig. The tympanic bullae are more developed than guinea pigs but less developed than chinchillas. Other features (pronounced masseter muscles, flared masseter muscle attachments on the mandible) are also present. The mandible is wider than the maxilla.

Axial skeleton

The vertebral structure is similar to that seen in the chinchilla. Metabolic bone disease is relatively common, and there are reports of vertebral fractures and paresis/paralysis.

Appendicular skeleton

This is similar to the chinchilla, with elongated slender hindlimbs. The fibula and tibia are fused proximally.

Respiratory system

The lung structure of the guinea pig is similar to that seen in the rat and mouse. The left lung is divided into three lobes, and the right into four. Chinchillas follow a similar pattern. Degus have the same numbers of lobes, but in the left lung instead of a cranial/middle, caudal and accessory lobe they have a cranial, middle and caudal lobe.

Digestive system

Oral cavity

The dental formula for chinchillas, guinea pigs and degus is

I1/1C0/0Pm1/1M3/3.

In all three species, all of the teeth – incisors, premolars and molars (cheek teeth) – are elodont ('open rooted') and therefore continuously growing. This can lead to malocclusion, particularly in chinchillas and degus, if an inappropriate diet low in calcium, vitamin D_3 and fibre is fed. Degus have cheek teeth that in cross-section resemble the figure '8' (hence their scientific name *Octodon degus*). The incisors of the chinchilla are orange/yellow pigmented on their enamel surfaces, but those of the guinea pig are often white. In both cases, a diastema is present. The occlusal surface of the cheek teeth in guinea pigs is oblique as the mandible is wider than the maxilla, with the occlusal plane sloping from dorsolateral to ventromedial. In chinchillas and degus the occlusal surface of the cheek teeth is horizontal. In all species the occlusal surface of the cheek teeth has a folded, rough appearance due to alternating bands of cementum and dentin. Most texts describe rodents including guinea pigs as being monophyodont – they only develop one permanent set of teeth during their lifetime (having no deciduous teeth) (Hargaden and Singer, 2012; Lennox *et al.*, 2021). They are also often born with only the permanent incisor teeth fully erupted, the permanent cheek teeth erupting over the ensuing 1–6 weeks of life postpartum.

Hystricomorphs also have a palatal ostium creating an entrance through the soft palate, allowing communication of the oropharynx with the pharynx. It exists because the soft palate is actually connected with the base of the muscular tongue, the epiglottis achieving access to the nasopharynx through a hole (the palatal ostium) in the soft palate.

Stomach

The whole stomach of the guinea pig is covered with a glandular epithelium containing acid- and pepsinogen-secreting cells and is usually full of food material. It has a strong cardiac sphincter, making vomiting a rare and grave occurrence. The stomach of the chinchilla and degu is much the same. Stomach emptying time is around 2 hours in the guinea pig.

Small intestine

The small intestine of both species is relatively long and pink in colour, measuring anywhere up to 50–60 cm in the chinchilla and degu and more than 120 cm in the adult guinea pig.

Large intestine

The large intestine starts at the ileocaecal junction on the left side of the abdomen where the ileum enters the caecum. The caecum is a large sacculated organ, measuring 20 cm in length, and in the guinea pig it contains 60–70% of all the gut contents. It is attached to the dorsal abdomen and has a series of three smooth muscle bands running along its length known as taeniae coli. These produce the sacculations of the caecum known as haustra. In the chinchilla, the caecum is smaller, containing only 20–25% of gut contents, but it is more folded. The degu caecum has both taenia and haustra. The caecum itself forms a blind-ending sac at one end and empties into the colon near to the ileocaecal junction.

The colon is on average twice as long as the small intestine and is dark brown. In the chinchilla, the proximal section of the colon possesses taeniae and haustra, whereas in the guinea pig the whole of the colon is smooth surfaced. The degu proximal colon has taenia but no haustra. The latter half of the colon can be distinguished by the presence of faecal pellets in its lumen. The large intestine of the guinea pig has a complicated series of coils, which form a spiral of bowel on the right cranial ventral aspect of the abdomen. The chinchilla's colon is much more simply arranged, and not as long.

Hystricomorphs such as the guinea pig, chinchilla and degu all exhibit coprophagy.

Liver

The liver of the guinea pig has six lobes. There is also an obvious gall bladder, unlike the rat. The gall bladder empties through one bile duct into the small intestine. Just before it empties into the small intestine there is a small ampulla or swelling of the duct that has a sphincter proximally to prevent bile regurgitating up the bile duct towards the liver. The guinea pig liver does not possess the enzyme L-gluconolactone oxidase and therefore preformed vitamin C is required in the diet.

The chinchilla's liver has four lobes with a gall bladder present between the right and median lobes.

Pancreas

The pancreas has two limbs in the guinea pig and lies alongside the stomach and proximal duodenum. It empties via one duct into the mid-descending duodenum and performs the same functions as in other mammals.

Urinary system

Kidney

As with the hamster, the guinea pig has a relatively long renal papilla. Both kidneys in the guinea pig are surrounded by large amounts of fat, making them difficult to see at laparotomy; the chinchilla's kidneys have fewer fat deposits. The chinchilla and the degu originate from arid environments in the wild and appear to be able to produce highly concentrated urine. One study concluded that during the dry Chilean summers, wild degu urine osmolarity could be as high as 3137 ± 472 mosmol/kg, whereas urine produced during the wetter winter months was around 1123 ± 472 mosmol/kg (Bozinovic *et al*., 2003). Chinchilla urine commonly has a specific gravity in the region of 1.045 or greater (Hrapkiewicz and Medina, 2007).

Lower urinary tract

The urine of the guinea pig is often yellow and cloudy in nature. Like all herbivore urine, it is alkaline under normal conditions and may contain calcium carbonate or calcium oxalate crystals. In the female guinea pig, the urethra empties just caudal to the vagina, but without a urinary papilla, giving the false impression of a common urogenital opening.

In the female chinchilla, cloudy alkaline urine is common. The urethra of the bladder, however, opens through a separate orifice from the vagina. The urinary papilla is a large structure in the female chinchilla and may easily be confused with the male penis.

Cardiovascular system

Heart

In all three species, the thoracic cavity appears relatively small in comparison with the abdominal cavity; therefore, the heart appears relatively large in comparison with the lung field. Chinchillas have only a left coronary artery.

Blood vessels for sampling

The jugular veins are the vessels commonly used for blood sampling in all three species. Small doses of intravenous medications may be administered through the ear veins, which are clearly visible on the non-furred ears, or via the cephalic or saphenous veins, which occupy the same positions as in other species. Cephalic veins may be accessed for blood sampling and intravenous injections but are small, requiring 25 gauge or smaller-sized needles and catheters.

Lymphatic system

Spleen

The spleen of the guinea pig is a wide structure attached to the greater curvature of the stomach on the left side of the cranial abdomen.

The spleen of the chinchilla is a smaller strap-like organ attached again to the greater curvature of the stomach on the left side.

Thymus

In guinea pigs, the thymus is prominent in the cranial thorax in the immature stage, but there are often only remnants left in the adult. A similar situation exists in the chinchilla and degu.

Lymph nodes

The guinea pig is prone to *Streptococcus zooepidemicus* infections of the cervical lymph nodes, which run in a chain along the ventral aspect of the neck. Chinchillas, guinea pigs and degus have prominent mesenteric lymphoid deposits.

Reproductive anatomy

Male

Guinea pig

The male guinea pig is often referred to as a boar. Its testes are prominent and occupy the scrotal sacs on either side of the anus. Each testis has a large fat body projecting through the open inguinal canal into the abdomen. The vas deferens opens, with the accessory sex glands (vesicular glands, coagulating glands and ventral and dorsal prostate lobes), into the proximal urethra. The vesicular glands are the most prominent, curving cranially into the abdomen for 10 cm or more. The paired bulbourethral glands lie dorsal to the urethra just before it passes into the penis, which is Z-shaped, moving cranioventrally from the caudal brim of the pelvis and then caudoventrally so to point caudally at rest. The penis is a large structure by rodent standards and possesses a glans structure distally. There is an os penis which sits dorsal to the urethra when the penis is erect and pointing cranially. Ventral to the distal urethra is the intromittent sac that contains two invaginated spurs, which, when the penis is erect, project from the end of the glans as two slender spurs 4–5 mm in length. Their function is not fully known but they may aid in locking into similar grooves in the female reproductive system. The whole penis is contained in a prepuce, which possesses sebaceous glands, and is partly formed from a fold of perineal skin.

Chinchilla

There is no true scrotum. The tail of the epididymis sits lateral to the anus, while the testis occupies an inguinal position. A fat body projects from each testis into the abdominal cavity. The vas deferens opens into the urethra caudal to the bladder neck along with the accessory sex glands. These include the ventral and dorsal paired lobes of the prostate as well as the paired, frond-like vesicular glands. The urethra then passes caudally through the pelvis, becoming ensheathed in the ischiocavernosus muscles that control the movement of the penis and pelvic floor. The bulbourethral glands lie dorsal to the urethra in this area. The urethra then passes out of the pelvis and into the penis, which is tubular and blunt-ended and points caudally when relaxed. The penis forms a Z-like flexure, similar to the guinea pig, and contains a small approximately 1-cm long os penis in its most caudal portion. The glans has small backward-pointing spines on its surface.

Male chinchillas are often prone to fur rings. This is when a band of fine fur becomes wound around the penis inside the prepuce. This may constrict and so may cause ischaemic damage to the penis.

Degu

The male degu has no scrotum as the testes are intra-abdominal to inguinal in position with a wide inguinal canal. Sexual maturity can be inferred by the presence of two cornified spikes in the inside of an invagination of the skin of the glans penis. The penis has an os penis dorsal to the distal urethra. The accessory sex glands are similar to those of the chinchilla, and include a prostate, paired seminal vesicles, and bulbourethral glands.

Female

Guinea pig

The female guinea pig is often referred to as a sow. Its uterus is bicornuate. It has two uterine horns, a short uterine body and a single cervix. The ovaries are closely associated with the respective kidneys. The periuterine tissues and cornuate ligaments are sites for the same fat deposition that is seen in the female rabbit. The vagina opens just cranial to the urethral opening. A small clitoris sits just ventral to the urethral opening, and the two are enclosed in skin folds to create a Y-shaped slit. The entrance to the vagina is sealed by epithelial tissues at all times other than at oestrus and immediately prior to parturition. A perineal sac sits between the vagina and the anus and contains a large number of sebaceous glands that produce an oily fluid.

The female guinea pig has two mammary glands in the inguinal region (the male has two vestigial glands as well).

Chinchilla

The female chinchilla has a uterus like the rabbit. There are two uterine horns but no common uterine body. Instead two separate cervices open into the vagina. The entrance to the vagina is sealed at all times except during oestrus and just prior to parturition, although a faint transverse line can be seen in this area at other times. The urethra opens through a separate, cranially located, urinary papilla.

The female chinchilla has three pairs of mammary glands, two thoracic and one inguinal.

Degu

The uterus is bicornuate, similar to the guinea pig. The entrance to the vagina is sealed with a membrane except for a few days during oestrus and immediately prior to parturition. The urethra opens through a separate, more cranial, urinary papilla.

The female degu has four pairs of mammary glands.

Reproductive physiology

Guinea pig

The female guinea pig is non-seasonally polyoestrus. The cycle lasts for around 16 days, oestrus lasting for 6–12 hours, and ovulation is spontaneous. Immediately after mating (1–2 hours), a copulatory plug may be found in the cage. It is possible that this is necessary to prevent leakage of sperm back out of the reproductive tract, but it could also prevent another male from successfully mating the female. Gestation lasts on average 63 days, although it may take up to 67 days for small litters and 59 days for large ones. The average litter contains three young. Pregnancy may be detected by gentle palpation from 3 weeks. The entrance to the vagina is closed at all times other than immediately before parturition, and for 2–3 days around oestrus. There is a postpartum heat within 10 hours of parturition at which the female may be successfully re-mated.

In the last 2 days of gestation, hormones such as relaxin and progesterone allow the pelvic ligaments to separate the pubis and ischium by up to 2 cm, allowing the passage of the relatively large young. This occurs only if the female is less than 1 year of age or has had her first litter before 1 year. Nulliparous females more than 1 year of age have a fused pelvis, and dystocias are therefore common. Many female guinea pigs will breed through to 2 years of age.

The guinea pig placenta is haemochorial – the membranes of the placenta (chorion) are in contact with the blood of the mother. This allows for large amounts of immune system exchange between mother and fetus during gestation.

Chinchilla

The chinchilla is seasonally polyoestrus. The reproductive season stretches from November to May (in the northern hemisphere) and from May to November (in the southern hemisphere), and the cycle lasts on average 40 days with oestrus being 2–3 days in duration. The entrance to the vagina opens at oestrus, which lasts for 12–24 hours, and stays patent for 3–4 days. At this stage, the perineum may darken in colour, and clear mucus may be seen from the vaginal opening. It also opens 2–3 days prior to parturition and remains open for the commonly seen postpartum oestrus. Interestingly, male chinchillas in captivity can produce viable spermatozoa throughout the year.

Chinchillas are spontaneous ovulators. A copulatory plug is frequently found the day after a successful mating. Gestation lasts on average 111 days, with typically two kits being born. Pregnancy may be diagnosed by palpation from day 60. Female chinchillas may continue to breed up to 10 years of age.

The chinchilla placenta is haemochorial.

Degu

The degu is a spontaneous ovulator and in the wild seasonally polyoestrus (during the rainy season) but in captivity will often breed all year round. The oestrus cycle varies from 16 to 26 days (averaging 21) and, like the chinchilla, the vaginal opening is covered by a membrane at all times except at oestrus for 1–3 days and just prior to parturition. Gestation is typically 90–95 days with four to six young being born in primiparous females and 6–10 young thereafter. Female degus become noticeably less fecund after 4 years of age.

The degu placenta is haemochorial.

Neonatology

Guinea pigs, chinchillas and degus are precocial – they are born fully furred, with eyes and ears open, and often start to eat small amounts of solid food from day 1. Weaning generally occurs at 6 weeks in guinea pigs, 6–8 weeks in chinchillas and 4–5 weeks in degus. Sexual maturity occurs at 2–3 months in the guinea pig, 3–4 months in degus and 6–8 months in the chinchilla.

Sexing

Guinea pig

Sexing of male and female guinea pigs is relatively simple and may be performed from the first few weeks of life. The female anogenital area is oval in nature. The anus is closest to the tail base, and cranial to this is a Y-shaped slit housing the small clitoris and the entrance to the urinary and genital tracts. In the male, the distance between the anus and urogenital system is larger, and gentle pressure on either side of the prepuce will allow protrusion of an obvious penis.

Chinchilla

The female chinchilla has a large urinary papilla making identification difficult. The identification is made on the distance between the anus and the urinary papilla. The female's urinary papilla is close to the anus, and if examined closely it may be possible to observe the transverse slit which marks the sealed (when not in heat) entrance to the reproductive tract lying between the anus and urinary papilla. The male's prepuce, which resembles the female's urinary papilla, is much larger and more cranial, and the penis may be protruded in compliant individuals. See Figures 1.7 and 1.8 for comparison of female and male chinchillas.

In chinchillas, females are larger than males – the reverse of many other rodents. Female chinchillas also have three pairs of mammary glands, two thoracic pairs and one inguinal pair.

Degu

The female degu has a large urinary papilla that makes identification difficult as it can be mistaken for a phallus in very young animals, similar to the chinchilla. Caudal to this, the genital opening is covered with a membrane except during oestrus and immediately prior to parturition. Protrusion of the phallus in compliant males is possible and allows sex identification. The sexually mature male degu has two cornified spikes in the inverted sac of the glans penis that can easily be everted. These become apparent from 2.5 months of age, with all showing evidence at 3.5 months of age. The testes are inguinally located but can be easily retracted intra-abdominally.

Figure 1.7 External genitalia of a female chinchilla. Note the prominent urinary papilla at the top. Immediately below is the entrance to the reproductive tract and then the anus.

Figure 1.8 External genitalia of a male chinchilla. Note the prepuce towards the top and the greater distance from this to the anus with no evidence of an entrance between.

Skin

The fur patterns of guinea pigs differ significantly between breeds, with the Peruvian having the longest fur, Abyssinians having short fur in whorls and rosettes, Silky breeds having medium length soft fur and the English and American breeds having short smooth fur. The guinea pig has a prominent sebaceous gland on its back, cranial to the tail base which is more developed in the male. This secretes a yellow waxy material which frequently matts the fur in this area. There are additional glands emptying into the anal sacs in the folds of skin which enclose the anus and genitalia. These can produce a creamy white, strong-smelling discharge in the boar. Guinea pig fur is often relatively coarse in nature.

The fur colourations of chinchillas vary considerably. The 'wild-type' chinchilla fur colour was yellow-grey but captive breeding has selected predominantly for a blue-grey colour (Donnelly and Brown, 2004). Other colourations are now commonly seen in the pet trade including white, beige, ebony (all associated with dominant genes), sapphire and violet (associated with recessive genes). The coat of the chinchilla is renowned for its soft silky nature with a high density of hairs emerging from each pore (on average 50–60 soft wool hairs and a single longer guard hair). It responds badly to moisture, requiring dust baths for cleaning. In addition, the chinchilla may experience a feature known as 'fur slip'. This is when a section of fur drops out due to fright or stress, and the fur in this alopecic area may take several weeks to regrow. Breeding for a recessive trait of velvet, shorter fur is also common in the pet trade (Donnelly and Brown, 2004).

Significant vibrissae are present around the rostral upper lips in chinchillas, with less prominent vibrissae seen in guinea pigs, thought to be associated with the more nocturnal nature of the chinchilla.

In both chinchillas and guinea pigs, the ears are prominently furless, with the chinchilla in particular having the largest pinnae.

The guinea pig has a prominent subcutaneous fat pad over the scruff region of the neck, which makes large injections at this site painful.

The chinchilla has very small claws on each digit. In comparison, the guinea pig has prominent claws on every digit. Both have defined leathery pads at the ends of each digit and an area of thickened skin on the hindlimbs up to the hock joint with a tarsal pad to accommodate their more plantigrade stance.

Eyes

The eyes of the guinea pig are small in comparison to the size of its head. There is a prominent third eyelid tear gland which may prolapse. The chinchilla on the other hand has large prominent eyes, and a vertical slit-like pupil which allows the chinchilla to virtually close off all light reaching the retina. This reflects the more nocturnal nature of the chinchilla.

Haematology

The morphology of the red and white cells is similar to that seen in other rodents. There are predominantly more lymphocytes than neutrophils in the white cell count. In the guinea pig, an intracellular inclusion known as the Kurloff body may be seen in circulating monocytes, which are thus known as Kurloff cells. These are rare in juvenile and male guinea pigs, but common in adult females particularly during gestation, and they may play a role in the physiological immunity relationship between mother and fetus. Their origin is not clear but they are thought to come from the thymus or spleen.

CHIPMUNKS AND PRAIRIE DOGS

Biological average values for the chipmunk and prairie dog

The normal values for the basic biological parameters for the chipmunk and black-tailed prairie dog are given in Table 1.6.

Musculoskeletal system

The musculoskeletal system has many similarities to the rat as outlined above.

Skull

The skull is typically rodent-like in its long and flattened form.

Axial skeleton

The spinal vertebral layout is similar to the rat.

The vertebral formula of the chipmunk is

$$C7, T12-13, L6-7, S3, Ca26-31$$

The vertebral formula of the black-tailed prairie dog is

$$C7, T12, L7, S4, Ca12-18$$

Table 1.6 Biological parameters for the chipmunk and black-tailed prairie dog.

Biological parameter	Chipmunk	Black-tailed prairie dog
Weight (g)	55–150	500–2000 (males much larger than females)
Rectal body temperature (°C)	37.8–39.6 (when not hibernating)	38–39 (when not in torpor)
Respiration rate at rest (breaths per minute)	60–90	65–120
Heart rate at rest (beats per minute)	150–280 (drops to 3–6 during hibernation/torpor)	150–250
Gestation (days)	28–35	30–35 (average 34)
Litter size	2–10 (average 4)	2–10 (average 5)
Birth weight (g)	3–5	10–30
Weaning age (weeks)	5–7	5–7
Age at sexual maturity (months)		
Male	8–9	18–24
Female	9–12	18–24
Oestrus interval (days)	Average 14 (breeding season March–September in northern hemisphere)	Monoestrus (breeding season February–April in northern hemisphere)
Lifespan (years)	8–12 (may be shorter in captivity)	8–10

Appendicular skeleton

In the chipmunk each forelimb has four and each hindlimb five digits. The chipmunk's gait is a jumping sinuous movement, which makes them excellent climbers, with forelimbs and hindlimbs a similar length. The chipmunk body form is more elongated than that of rats or mice, and their long prehensile tail is used for balance and support. The chipmunk bone structure is lightweight and more bird-like than the heavier structure of the rat.

The prairie dog is a terrestrial rodent and has a body form that is heavier than the chipmunk family. It is however still identifiably squirrel-like in appearance. They have five digits on both fore and hind feet.

Respiratory system

In chipmunks the left lung is variably divided into two or three lobes and the right lung into four.

In the prairie dog the lungs are divided into four lobes on the right side with the left side being undivided. Their thoracic cavity is larger in relation to the abdomen than is the case in many other rodents.

Digestive system

Oral cavity

The incisors are open rooted or continuously growing, and malocclusions are not uncommon.

PART I: SMALL MAMMALS

The dental formula for Siberian chipmunks and prairie dogs is

$$I1/1C0/0Pm1-2/1M3/3.$$

They both have a diastema. The mouth is narrow, and the tongue fleshy and fixed firmly at the base, although the rostral tip is mobile. In both species there are small cheek pouches, communicating with the diastema of the oral cavity and extending back to the ear base. These are frequently sites for abscess formation if sharp seeds, such as unhusked oats, are fed.

Stomach
The stomach is of a simple glandular design. There is a strong cardiac sphincter which normally prevents regurgitation.

Small intestine
The small intestine is relatively long in both species. The duodenum receives a duct from the gall bladder just after the pyloric sphincter and one further on from the pancreas. In prairie dogs, other smaller openings of the pancreas may enter the duodenum in the descending limb.

Large intestine
In chipmunks the initial part of the large intestine at the ileocaecal junction has a small blind-ending caecum with some sacculations, or haustra.

In prairie dogs, the large intestine starts at the ampulla coli where a swelling and valve system exists. From this area the caecum extends across the ventral abdomen and is a significant organ reflecting the species' herbivorous (largely grass-based) natural diet. The ascending large intestine has taenial bands and haustra.

Liver
The liver has four main lobes in both species and possesses a gall bladder and common bile duct which joins the descending duodenum.

Pancreas
The pancreas is found along the descending duodenum and the edge of the stomach. In chipmunks it empties through one duct which empties into the proximal descending duodenum. In prairie dogs there also appear to be numerous smaller ducts in addition to the main one and these open directly into the duodenum.

Urinary system
Kidney
The kidneys are a typical bean shape in both species. Fat deposits are often found in this area during the late summer and early autumn. Each kidney has the usual ureter passing caudally to the urinary bladder.

Bladder
Both species' urine is usually alkaline in nature and may contain calcium crystals (calcium carbonate, calcium oxalate). However, chipmunks may also produce acidic urine due to their more omnivorous nature (they eat insects, eggs, etc.).

Cardiovascular system
Heart
The heart is similar to that seen in the rat and mouse.

Blood vessels for sampling
The jugular veins make the best vessels for blood sampling in both species. The ventral or lateral tail veins may be used in chipmunks but care should be exercised and the chipmunk should be sedated as the tail skin can deglove and slough relatively easily. Similarly, the cranial vena cava may be used in both species but this procedure should only be carried out under general anaesthesia. The saphenous and cephalic veins, although small, may be used in the larger prairie dog using a 23 or 25 gauge needle or catheter.

Lymphatic system
Spleen
The spleen is a small strap-like organ on the greater curvature of the stomach to the left side of the cranial abdomen in both species.

Thymus
The thymus is a prominent organ in the juvenile, and persists in the cranial thorax of the adult. It is described as bilobed in prairie dogs.

Reproductive anatomy
Male
In chipmunks the testes sit in a caudally placed scrotum, but only during the reproductive season. During the quiescent period, the testes are retracted into the abdomen. The scrotum and testes thus enlarge during the breeding season from January to September.

In prairie dogs, there is no true scrotum, the testes sitting more inguinally. The testes enlarge during the breeding season (February–April in the northern hemisphere).

Seminal vesicles, bulbourethral (Cowper's) glands and a prostate are reported as accessory sex glands in both species.

Female
Both species have a bicornuate uterus with a single cervix.

The female chipmunk has four pairs of mammary glands, two inguinal and two thoracic. The female prairie dog has four to six pairs of mammary glands.

Reproductive physiology
The chipmunk is seasonally polyoestrus, cycling between March and September. Chipmunks are spontaneous ovulators, with an oestrus cycle length of around 14 days. There is no evidence of a postpartum oestrus, and gestation length averages 31–32 days. Mammary development becomes prominent 24–48 hours prior to parturition. Reproductive success drops dramatically after 6–7 years of age in the female chipmunk.

The prairie dog is seasonally monoestrus, breeding once in the period February–April (in the northern hemisphere). Females will generally only breed in captivity in a colony situation as their social structure and behaviour is complex. The gestation length is around 30–35 days with an average of five young being born.

Neonatology
Chipmunk young are altricial and so are born blind, deaf and hairless. Fur starts to appear around 7–10 days of age, and the eyes open at 4 weeks. The age at weaning is 5–7 weeks. Sexual maturity is reached at 8 months in the male and 10 months in the female.